THE DEVELOPMENT OF SILVICULTURAL POLICIES FOR DIPTEROCARP FOREST IN SABAH

by

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A dissertation submitted in candidature
for the degree of Master of Science of
the Australian National University, Canberra

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DECLARATION

I hereby certify that this thesis submitted in canditure for the degree of Master of Science of the Australian National University, Canberra has not been submitted in substance for any degree and is not being currently submitted for any other degree.

The work is the result of partly my own investigations and partly my predecessors' in the field of ecology and silviculture in Sabah.

Candidate : ....

LIEW THAT CHIM

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THE DEVELOPMENT OF SILVICULTURAL POLICIES FOR DIPTEROCARP FOREST IN SABAH

SUMMARY

The principle objective of this thesis is the formulation of silvicultural policies for Dipterocarp forest in Sabah taking into consideration the ecology of the forest, prelogging silvicultural treatments, silvicultural methods, post-exploitation treatments and factors influencing the silvicultural decision.

As the ecological factor is one of the most important determinants of the silvicultural decision, an account of the Dipterocarp forest including its classification into Types is presented. The dynamic processes in the natural as well as disturbed Dipterocarp forest are discussed.

The principles of silvicultural methods practised rainforests are reviewed and examined. The important silvicultural systems i.e., even-aged or monocyclic and uneven-aged or polycyclic are discussed and evaluated. Forest plantation (not a natural system) which is a common alternative system for production of timber and cellulosic material in the tropics is also examined.

The effectiveness of linear sampling and important silvicultural treatments applicable to Sabah are examined and evaluated. Factors of other than biological nature, such as forest policy and management a objectives, harvesting system and logging damage, market for species, nature of logging and milling industries, economic etc., influencing silvicultural practice are presented and discussed.

It is concluded that a polycyclic system in the form of a Selection System is considered to be the most suitable silvicultural method for the management of the natural Dipterocarp forest in Sabah though difficulties may arise in the implementation of the system.

Abbreviations Used in Text

S.F.R.	:	Sabah Forest Record
A.R.R.B.	:	Annual Report of the Research Branch (Sabah Forest Department)
M.F.	:	The Malaysian Forester
R.P.	:	Research Plot
F.R.	:	Forest Reserve
Y.P.	:	Yield Plot
L.S.M.	:	Linear Sampling Milliacre
L.S.$\frac{1}{4}$	:	Linear Sampling Quarter-chain
L.S.$\frac{1}{2}$	:	Linear Sampling Half-chain
F.	:	Felling

PREFACE

Tropical rainforest is "Evergreen, hygrophilous in character, at least 30 m. high, but usually much taller, rich in thick-stemmed lianes and in woody as well as herbaceous epiphytes".

A.F.W. Schimper (1903, page 260)

Since the Tropical Rain forest is a climatic climax, it must, by definition, be in a state of equilibrium. When the trees die they are replaced by others of the same or different species ....

P.W. Richards (1957, page 40)

As long as man used moist tropical forests in a subsistence cultural system, at an intensity which did not exceed recuperative capacity, no problem of management arose.

Some people apparently feel that as a measure of efficiency in resource use financial return be the principal, if not the only valid criterion. The fact remains that efficiency is often deliberately reglegated in favour of other objectives. Any full evaluation of management systems for moist tropical forests should therefore not only take account of social values, but also assess them in relation to all social goals.

A Leslie (1977, Unasylva,
pages 6 and 9)

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CHAPTER 1

INTRODUCTION

1.1 Objective

The principal objective of this thesis is the formulation of silvicultural policies for Dipterocarp forests in Sabah taking into consideration the ecology of the forest, prelogging silvicultural treatments, silvicultural methods, post-exploitation treatments and factors influencing the silvicultural decision.

Since the appointment of an Ecologist in 1955, a voluminous amount of research work has been done pertaining to the ecology and silviculture of the Dipterocarp forests in Sabah. However, no definite silvicultural policies have been formulated, though pre-and post-exploitation treatments have been carried out to a certain extent to improve the growth and composition of forests in the permanent forest estates following exploitation. For the past 20 years silvicultural methods have been changed from the regeneration Improvement Felling System to the Malayan Uniform System, and now to the Minimum Girth Felling System or Selection System which is a modified Malayan Uniform System. All Standard silvicultural practices have been laid down in the Sabah Forest Record No. 8 (1971). Though silvicultural treatments have been implemented in patches in most of the Commercial Forest Reserves, there is no guarantee that the forests will be successfully regenerated under the natural regeneration process. This is because the Forest Department has no firm and legalised silvicultural policies embodied in current Forest Laws and Forest Policy ensuring successful regeneration of Dipterocarp Forests. For example, productive virgin Dipterocarp forests carrying 1500 Hoppus cu. ft. per acre are normally completely devastated leaving an inadequate distribution of pole-size trees and seedlings in the residual stands (Liew, 1974a). Current logging practice results in the opening of the forest canopy to such a degree that poison girdling in the form of liberation treatment is no longer required. The only logical treatment would be enrichment planting but the Department cannot afford to plant up hundreds of square miles of logged-over forest annually. On the other hand, the area of non-productive regenerating forests is increasing. It is therefore pertinent that silvicultural policies be formulated to ensure maintenance of the productivity of the Dipterocarp forest at a desirable level.

The ecological factor, which is one of the most important determinants of the silvicultural decision, is examined in some depth, as ecology is the basis of silvicultural pracitce. An account of the natural Dipterocarp forests and their regeneration is given in order to develop ecologically sound silvicultural practices, which in turn will contribute to the formulation of silvicultural policies.

The present Silvicultural methods may well be sound, but other methods may be more appropriate for the Dipterocarp forests. Therefore a range of silvicultural methods which are applicable to rainforests are explored in order to arrive at a system which is best suited to Sabah's conditions. Silvicultural treatments are examined and discussed in the thesis with reference to all available research data.

Attention must also be focussed on factors other than ecology in the formulation of silvicultural policies. The most important factors are "exploitation rate" which is related to political and socio-economic development, and logging damage, which are discussed in detail. The present cutting rate of more than 300 sq. miles per annum is three times higher than the allowable cut. In addition, all of the accessible commercial forests are comitted to immediate future logging, except the forest land licenced to the Sabah Foundation which is under sustained yield management. It is impossible to curtail the exploitation as timber is the only resource for raising State revenue and capital for agrobased industries and general development projects. The other factor is logging damage. To-day heavy logging equipment is used in timber extraction. The damage to the forest following logging often amounts 30% to 50% (Liew, 1974a). In some cases, patches of forests may be completely denuded of vegetation. The productivity of the forests will be directly affected if a natural regeneration system is employed. Under these constraints, what are the Silvicultural policies to be adopted? Chapter 8 outlines the ideal silvicultural policies. Among other things the thesis suggests that Silvicultural policies should aim at adopting a Selection System in which the cutting cycle is comparatively short, but within the capacity of the ecosystem. Conversion of nonproductive Dipterocarp forests into forest plantation may be carried out. Efforts should be directed to devise rules and regulations pertaining to timber extraction with a view to reducing or minimising logging damage. They should be made into laws and included in all Licence Agreements, Special Licences and Form I Lincenses.

With these measures taken, the continuity of timber production for local use and export may be maintained.

1.2 The Physical Environment

In this Section a brief account of geography, physiography, climate, geology and soil is given. It serves to provide a general background on the physical environment of Sabah.

1.2.1 Geography and Physiography

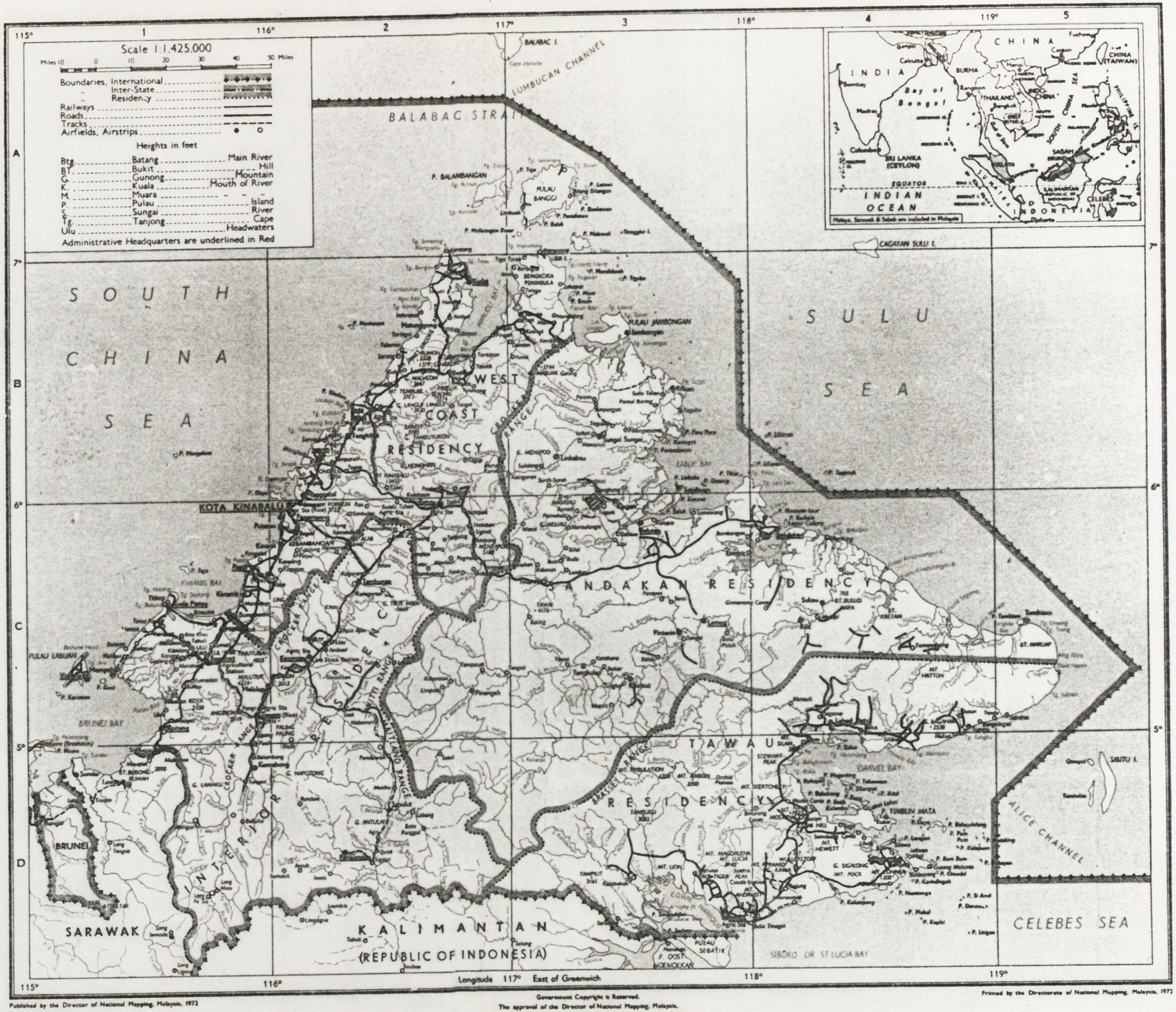
Sabah is situated at the northern tip of the island of Borneo. It lies between the Malayan peninsula, the Philippines and Indonesia (Figure 1.1). It occupies an area of 28,870 sq. miles (Webb *et. al* 1973).

The physiography of the State is dominated by the main mountain mass known as the Crocker Range (4000 feet a.s.l. to 6000 feet a.s.l.) extending from the southern end of Marudu Bay at the north and following the western coast line about 15 miles inland to the Sarawak border (Figure 1.1). This range has various spurs to the east, one of which culminates in the massif of Mount Kinabalu (13,455 feet a.s.l.), the highest mountain in South East Asia. Various rivers rising from the Crocker Range flow to the west coast but none of them are navigable.

The large rivers on the east coast are navigable. The Kinabatangan river, which drains the largest plain of the State is approximately 350 miles (563 km.) in total length. This river is navigable by shallow draft launches for over 100 miles (160 km.). This is the major waterway for floating timber. In recent years, more than 50 million cu. feet of timber per annum has been towed to the carrier via this waterway. The other important waterways for floating timber are Segama River, Labuk River, Sugut River, Kalabakan, Brantian and Umas-Umas. They are navigable by small craft for considerable distance.

Though on the east coast, the Brassey Range runs in a more or less north-east/south-west direction in the country behind Darvel Bay with various spurs, most of the

FIGURE 1.1 SABAH MAP



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Printed by the Directorate of National Mapping, Malaysia, 1972 area is accessible by roads or waterways. Hence, the natural vegetation on the east coast becomes the important asset producing more than 300 million Hoppus cu. feet in 1973. Timber resource is the lifeblood of Sabah (Liew, 1972).

1.2.2 Climate

The climate of Sabah is, in general, warm and wet, typical of many other regions of the world that support evergreen rainforests.

The temperatures rise from about 22°C at dawn to 31°C at midday. On exceptionally hot days, the midday temperatures may reach 34°C. The nights are mild and cool and the normal temperature is about 22°C. In the highlands of the West Coast the temperatures are considerably lower, and vary with altitude. For example, at the summit of Mt. Kinabalu, frost is by no means uncommon.

Temperatures in the forests are slightly lower than in the open at the same locality. Table 1.1 shows the diurnal variation of temperatures from sunrise to sunset, and the difference of temperatures in the forest and in the open at the Sepilok Forest Reserve, 15 miles away from Sandakan.

Average annual rainfall varies from 68 to 173 inches and is subject to coastal variation due to the monsoons (Fox, 1972). The West Monsoon is normally experienced from October to February, and the East Monsoon from May to August. These are normally the wet periods during the year.

Total annual rainfall varies considerably from year to year within one locality. Table 1.2 shows the extent of variation for some of the East Coast stations.

The distribution of rainfall within a year has often been considered to have a pronounced effect on physiological conditions of Dipterocarp trees. For example, a prolonged dry spell, say a period of 3 months, is thought to induce heavy flowering and fruiting of Dipterocarp trees. However, Burgess (1973) examined this subject in great detail and claims that other environmental factors such as temperature and microclimate effects play equally important roles in influencing flowering and fruiting of Dipterocarp trees. This will be further discussed in Chapter 4 under the regeneration of Dipterocarp forests.

Table 1.1 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 19		
Hours	Open	Forest	Difference	Open	Forest	Difference	Open	Forest	Dif
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

After Fox 1972

There is considerable diurnal variation in humidity. Humidity is highest at night, when the atmosphere is often saturated, and lowest at midday. Table 1.3 shows the extent of variation.

Table 1.2
Variation in total annual rainfall

Station	Rainfall in inches (year in Bracket)		
	Mean	Maximum	Minimum
Kalabakan (5 years)	96.3	104.4 (1956)	87.4 (1953)
Tawau (33 years)	71.6	99.9 (1952)	25.4 (1907)
Lahad Datu (23 years)	74.5	101.1 (1932)	52.8 (1951)
Sandakan (46 years)	123.9	173.2	58.4 (1914)
Lamag (29 years)	110.6	168.7 (1931)	179.4 (1951)
Beluran (27 years)	129.1	177.7 (1928)	92.4 (1931)

Table 1.3
Humidity and Sunshine data
at Sandakan Airodrome

Time / Month	Relative Humidity			Sunshine
	0800	1400	2000	Mean hours 1953 - 1963
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	39	5.6
December	93	77	88	5.1

Source: Department of Civil Aviation Records

From Table 1.3 it may be noted that sunshine averages 5 to 7 hours daily.

Variation in humidity at different heights in the forest has been studied by Palmer (1970). In his study, he found that diurnal ranges of 15 and 27 per cent at 0.8 and 32 m. respectively, were recorded during the wet period, and 27 and 33 per cent in the dry season.

1.2.3 Geology

The geology of Sabah is well documented. The country may be broadly divided into 5 regions (Wilford, 1967). Firstly the western half dominated by the Western Cordillera with inland plains and coastal lowlands. The formations are mainly hardstone mixed with other sedimentary rocks, The area dominated by the Crocker Range, is a geosynclinal flysch deposit of sandstone and shales. The Sapulat Formation has mudstone dominant with sandstone. The interior plains around Tambunan and Keningau are alluvial infillings.

The second region is the north-eastern portion of the country south of the Segama River. The area is generally undulating and less than 1000 ft. a.s.l. in altitude. However, ultra-basic instrusions and basalt of volcanic origin form mountains and hills. Ultra-basic hills are steep. The region is characteristised by dissected peneplains which have been periodically uplifted in the past. The peneplains are mainly of sandstone and shale formation.

The third region is the south-eastern mountainous segment of the country, excluding the Semporna Peninsula but including the highlands of Kuamut and Segama. The area has undergone periodic uplift with rejuvenation of drainage. The Brantian and Umas-Umas rivers have rapids in the upper reaches and wide alluvial filled lower courses. Similar geological features can be found elsewhere in this region.

The fourth region is the Dent Peninsula and the lower Segama River to Lahad Datu in the west. Volcanic activity in the Tertiary gave rise to andesite and dacite in the Bakapit region. The rocks east of Lahad Datu are of mixed volcanic and sedimentary origin.

The fifth region is in the Semporna Peninsula, west of Tawau, where an involved process of intrusive and volcanic activity has worked on the landscape (Paton, 1963). The area mainly consists of erosion surfaces within 100m. of sea level, but out of which rise hills of the more resistant rocks and upon which volcanic landforms have been superimposed.

(Addition to Section 1.2.3)

The sixth and the final region of the granite rocks forming the Mt Kinabalu which is the highest mountain in South East Asia. The peak is 13,455 feet above sea level. The vegetation is either montane or submontane which is of little importance to forestry. However, at the base of the mountain, the presence of copper is of economic importance.

group, covering Gunung Rara, Kalabakan, and Silabukan Forest Reserves.

(2) Red/yellow latosols and podsolics comprise 35 per-cent of the land surface. This group covers much of the north eastern Sabah, including Sugut and Paitan Forest Reserves, the Lokan Peneplain, Dent Peninsula and patches of lower Kinabatantan valleys. Red/yellow latosols are often intermingled with podsolic soils in places where rainfall is low, and the vegetation may be grassy or devoid of trees.

(3) Active riverine alluvial and organic soils; cover 9 per cent of the land surface. They are located in low-lying areas of the Kinabatangan and Segama rivers, and are subject to periodic flooding.

Few trees can be found growing on these soils.

(4) The other soil groups are lithosols and red/brown ferrasols, and red podsolic soils derived from fine grained alluvium. They are relatively unimportant.

1.3 The Brief History of Forestry and The Present Situation

The forest Department was formed in 1915. Exploitation of lowland Dipterocarp forests may be said to have begun in 1919 when the British Borneo Timber Company was granted exclusive rights to the timber of Sabah (then British North Borneo). Timber extraction was confined to heavy durable species such as Belian (Eusideroxylon sp.),*** Merbau (Intsia sp.) and Selangan Batu (Shorea Section of Shorea) all on a very small scale (Keith, 1935). The company was faced with severe competition to market the timber, as the high quality Siam teak almost dominated the market. In addition, shipping difficulty was experienced as there was a low level of trade going on between Sabah and outside world at that time.

By the 1950's, the timber trade had improved and the Administration, forseeing a rise in national aspiration and the apparent disadvantage of a timber monopoly, decided to buy out the monopoly rights previously sold to the British Borneo Timber Company (B.B.T.C.). The B.B.T.C. now known as Sabah Timber Company was awarded a special licence* area of 100 square miles at a cutting rate of 10 square miles per annum and in addition a concession area of 1000 square miles to be cut under sustained yield management at a rate of 10 square miles annually. Forest Reserves were constituted under Forest Enactment 1954 to be worked under sustained yield management. Areas were offered to interested parties. Special Licence and Licence Agreements** on similar terms as those for the Sabah Timber Company, were awarded to the Bombay Burma Timber Company Limited

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* Licence valid for a duration of 10 years.

** Valid for a duration of 21 years.

*** Authority for species are given in appendix 9 (latterly Wallace Bay Sdn. Bhd.) and Kennedy Bay Timber Company. North Borneo Timber Company and River Estates were granted concessions (Licence Agreements). Both North Borneo Timber Company and Sabah Timber Company are publicly owned and shares are purchasable on the open market. Other concessions (Licence Agreements) were awarded to locally owned Chinese Companies which had earlier worked as sub-licencees of B.B.T.C.. These were Messrs United Timber Company (Lai Fook Kim Brothers, and Teck Hing Lung), Chung Chao Loong Timber Co., Yeng Ho Hong, Shing Kee, Kwong Borneo Development Company, Ngui Ah Kui and Kwong Fui Loong. However, it needs to be emphasized that it was not easy to award timber concessions at that time as risks were considered high and the timber market was by no means steady. For example, a London based firm,Messrs Montaque L. Meyer Ltd.,which expressed an interest in obtaining concession rights subsequently declined the offer (Fox, 1971).

All the companies listed above, (with the exception of Special Licences), were allocated forest areas with permanent Production Forest Reserves. They were permitted to work an area annually equivalent to one hundredth part of the area reserved as their concession area. The total sum of annual areas to be worked equals one hundredth part of the toal area of the Production Forest Reserves. However, the actual rotation was supposed to be 80 years,as 20 per cent of forest areas were regarded as being non-commercial forest or too steep to be worked,or otherwise inaccessible. The management of commercial forests followed the established Forest Policies (1954), (see Chapter 7).

Between 1962 and 1970,though many Special Licences and other short term licences were issued, the Production

Forest Reserves were still managed on a sustained yield basis, as these licences were mainly allocated within timber land outside the Forest Reserves. The total annual cut on Forest Reserves during the period was in the vicinity of 30,000 hectares or 75,000 acres, (Table 1.4). This rate of exploitation was still reasonably within the limit of the allowable cut, and sustained yield management was not upset.

In 1970, there was a change in the management policy. Under this policy, all concessions under Licence Agreements, which normally may be renewed when they expire after a period of 21 years, could not be further renewed. 3,000 square miles of permanent productive forests were reallocated and licenced to the Sabah Foundation with an annual cut of 50 square miles. This partially accounts for the sudden rise of exploitation rate in 1971 (Table 1.4). From 1971 onwards, many timber licences (mainly short term licences) were awarded to private individuals to log Forest Reserves. By the end of 1971, sustained yield management seemed no longer possible. For example 51,850 hectares (128,000 acres) and 80,000 hectares (197,600 acres) were logged in 1971 and 1973 respectively. This rate of exploitation is approximately three times higher than the allowable cut. In addition, all accessible or semi-accessible Dipterocarp forests are committed to logging in the immediate future. However, it needs to be emphasized that the 3,000 square miles (1,920,000 acres) of forests allocated to the Sabah Foundation will be managed under sustained yield basis, cutting at an annual rate of 50 square miles. By 1984 it is envisaged that all the accessible commercial forests apart from those areas allocated to the Sabah Foundation will be logged. By then, timber industries in Sabah will be monopolised by the Sabah Foundation as it was monopolised by the British Borneo Timber Company in 1919.

Table 1.4

Trends of forest exploitation, 1960-1973

Year.	Forest Reserve exploited (hectares)	(acres)	Estimated State and alienated lands exploited (hectares)	(acres)
1960	11,906	29,400	11,100	27,000
1961	14,136	34,900	8,800	22,000
1962	11,441	28,300	9,000	25,000
1963	13,728	33,900	23,100	63,000
1964	8,716	21,500	20,500	56,000
1965	15,502	38,300	22,200	84,000
1966	21,540	53,200	30,700	78,000
1967	22,218	54,900	32,600	89,000
1968	22,886	56,600	34,000	93,000
1969	35,225	87,000	36,600	100,000
1970	27,048*	66,800	28,300*	78,000
1971	51,850*	128,000	25,300*	69,000
1972	65,000*	160,000	-	
1973	80,000*	198,000	-	

Source: Forest Department, Sabah: Annual reports

*Figures estimated.

Note: Commercial forest = 5,953,649 acres

Commercial forest under proposal = 29,519 acres.

It has always been the policy of the Forest Department to carry out post-logging silvicultural treatments of the forests. By 1973 approximately 66 per cent or 168,000 hectares of previously logged-over forest had received regeneration treatment, that is, elimination of undesirable or non-commercial species which would otherwise compete with the commercial trees. Other silvicultural treatments such as climber cutting and tree marking prior to logging are carried out on a large scale experimental basis. In recent years some steps have been taken to treat some of the older regenerating forests (e.g. 10 to 15 years after logging). Until recently, silvicultural operations have, in general, been implemented satisfactorily. It is envisaged that it is quite impossible to expand operations to deal with the greatly increased areas being logged, and it is likely that a greater proportion of the forest will remain untreated in the future. Though silvicultural treatments may be implemented, there is no guarantee that the increasing acreage of logged-over forest, which may form a huge proportion of the permanent forest, estate, will be successfully regenerated in the light of the current destructive logging practice. This could mean that the future productivity of the Dipterocarp forests will decline. Hence, formulation of concrete silvicultural policies for implementation in Dipterocarp forests is essential in order to ensure timber production in perpetuity.

CHAPTER 2

THE IMPORTANCE IN THE ECONOMY OF TIMBER AND TIMBER PRODUCTS DERIVED FROM THE DIPTEROCARP FORESTS

Sabah has vast tracts of forests covering an area of approximately 6,112,400 hectares. The country's vegetation may be described as a succession from the coast inland: coastal mangrove ——► lowland Dipterocarp forest ——► hill Dipterocarp forest ——► montane forest. The commercial forests stretch from sea level to a height of approximately 760 metres, covering an area of about 2,385,700 hectares, that is, almost half the forested area in Sabah. These forests provide the catalyst for the State's economic development. Currently, forest industries contribute about 50 per cent of Sabah's GNP, 55 per cent of its exports, 52 per cent of Government revenue and employ about 25 per cent of the labour force (Liew, 1972). As timber is a renewable asset it will continue to play an important role in the State's economy.

2.1 Forest Resources

Table 2.1 shows the acreages of different land categories, including various types of Forest Reserves constituted so far, for commercial, protection, domestic, recreational and research purposes.

From table 2.1, it may be noted that 32.58% of the total land of Sabah has been constituted as the commercial forest land for timber production, and a further area of 21,951 acres, or 0.12% of the total area, is being considered for the same purpose. However, at the time of writing up this thesis, another 1,500 square miles or 960,000 acres are further proposed as commercial reserves. Therefore, the size of the commercial forest reserves may eventually be 6,945,600 acres or 37.95% of the total land area.

Table 2.1

Area in acres by Land Category
(Figures in bracket are percentages of the total)

ESTABLISHED FOREST RESERVES		
Class I - Protection Forest	1,145,984	(6.27)
Class II - Commercial Forest	5,953,649	(32.58)
Class III - Domestic Forest	44,762	(0.25)
Class IV - Amenity Forest	46,853	(0.26)
Class V - Mangrove Forest	198,022	(1.08)
Total - Established Forest Reserves	7,389,270	(40.44)
PROPOSED FOREST RESERVES		
Class I - Protection Forest	686,428	(3.76)
Class II - Commercial Forest	21,951	(0.12)
Class III - Domestic Forest	4,136	(0.02)
Class IV - Amenity Forest	30,933	(0.17)
Total - Proposed Forest Reserves	743,448	(4.07)
TOTAL FOREST RESERVES	8,132,718	(44.51)
VIRGIN JUNGLE RESERVES	44,743	(0.24)
OTHER STATE LAND	8,387,541	(45.91)
ALIENATED LAND	1,533,222	(8.39)
NATIONAL PARK	173,101	(0.95)
GRAND TOTAL	18,271,325	(100.00)

After Webb et. al.,1973

The Domestic Forest Reserves are forests reserved for production of timber, for supplying timber and other forest products to be utilized by the local inhabitants only.

The Virgin Jungle Reserves are actually parts of Forest Reserves which have been designated as areas which are not to be logged or otherwise disturbed. They serve as gene pools in the evolution of plant species.

The Protection Forest Reserves are normally reserved for the maintenance of forest which is essential on climatic or physical grounds. In a strict sense, they are not supposed to be exploited or interferred in any way. However, in recent years portions of them have been, and are being logged. The main arguement is that protection forests may be developed for multiple use, e.g. logging in particular, provided that the side-effect of timber extraction will not include serious soil damage or instability of climatic conditions. No specific rules or regulations are imposed for timber extraction.

2.2 Forest Products

The major forest products are
(i) Round timber (log)
(ii) Sawn timber
(iii) Veneer and plywood
(iv) Mangrove wood chips

The minor forest products include:-
(i) Illipe nuts* - nuts produced by certain species of Shorea includes Shorea gysbertsiana Burck and Shorea pinanga Scheffer.
(ii) Bird's nests
(iii) Damar - a resin derived from the botanical family Dipterocarpaceae and used in varnish manufacture.
(iv) Rattan (mainly Calamus species)
(v) Fuelwood

2.2.1 Timber (Log)

The most important single forest product is timber, which is exported mainly as logs. The trend of production is shown in Table 2.2. Production has risen more than 6000 per cent since 1950. Between 1957 and 1966, production rose rapidly as the concession and special licencing system

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* Nuts produced by certain species of Shorea includes Shorea gysbertsiana Burck and Shorea pinanga Scheffer.

got underway, stimulated by increasing world demand for tropical hardwood during the period (see Section 1.3). Production from 1969 to 1972 had been static with an output of 6.2 to 6.9 million cu. metres* per annum. However, in 1973 production rose to approximately 11 million cubic metres and this output will be maintained for a number of years, or increased slightly, depending on the development of timber exploitation in remote areas.

In recent years approximately 95 per cent of the timber produced was exported in log form, and hence the trend in log export follows that of log production (Table 2.3). For example, in 1971, the production of about 6.9 million cubic metres of timber and the export of 6.5 million cubic metres in log form placed Sabah as one of the world's major tropical hardwood producers and suppliers. The remainder, about 5 per cent, served as raw material for sawmills or the local veneer and plywood industries (Liew, 1972).

The United Kingdom was once a major importer of Sabah's timber in the form of logs and sawn timber, and between 1945 and 1954, 10 to 20 per cent of timber products were exported to the United Kingdom. In 1971 more than 95 per cent went to four countries - Japan (64.9%); Korea (22.5%); Hong Kong (6.7%); and Australia (1.2%) (see Table 2.3). Japan is the principal market and has consistently taken in excess of 62 per cent of the total since 1960. In 1965 and 1966, Japan took approximately 77.3 per cent of Sabah's log exports, though since then the proportion has gradually decreased to approximately 65 per cent in 1971. The volume of timber exported to Japan has gradually risen, however, and now fluctuates around an annual level of 4.3 million cubic metres.** It may be difficult to raise exports to Japan above this level as there is strong competition for this market, in particular from Indonesia and the Philippines.

* 172 to 193 million Hoppus cu ft

** 120 million cu ft Hoppus

export of other processed timber: Sabah

Year	Production	Export			
	Log (cubic metre)	Log (cubic metre)	Sawn (cubic metre)	Veneer sheets (square metre)	Plywood (square metre)
1947-1951 (average)	168,426	95,368[a/]	-	-	-
1952-1956 (average)	464,185	337,751	26,762	-	-
1957-1961 (average)	1,689,437	1,414,660	27,041	b/	-
1962-1966 (average)	3,910,256	3,487,933	6,866	2,984,903	c/
1967	5,708,027	5,320,846	3,466	2,334,368	736,347
1968	5,907,985	5,795,800	4,014	3,453,390	1,021,469
1969	6,200,231	6,581,481	10,020	4,369,359	971,951
1970	6,559,782	6,149,296	11,902	4,805,642	1,589,229
1971	6,952,188	6,557,456	6,445	1,831,299	2,128,548

Source: Forest Department, Sabah: Annual reports.

a/ Including sawn timber.

b/ Production of veneer sheets started in 1960 with an average of 509,027 square metres between 1960/61.

c/ Plywood production started in 1966 with the production of 160,832 square metres in that year.

Note: Updated data for Tables 2.2 to 2.5 are presented as Appendix 10

Table 2.5 Exports of round logs from Sabah, by destination
(cubic metres and percentages)

estination	1961		1962-1966 (average)		1967		1968		1969		1970		1971	
	m^3	%	m^3	%	m^3	%	m^3	%	m^3	%	m^3	%	m^3	%
ustralia	61,843	2.7	89,605	2.6	110,805	2.0	117,165	2.0	102,791	1.7	104,016	1.6	81,063	1.2
hina	11,200	0.5	24,683	0.7	8,202	0.2	46,408	0.8	17,676	0.3	5,350	0.1	24,230	0.4
ong Kong	257,559	11.2	316,444	9.1	144,943	2.7	305,941	5.3	291,060	4.7	270,877	4.4	438,093	6.7
apan	1,799,514	78.4	2,655,111	76.1	4,079,274	76.7	4,044,509	69.7	4,293,084	69.0	4,089,683	66.2	4,268,553	64.9
orea, ep. of	909	-	202,831	5.8	635,844	11.9	1,052,102	18.1	1,118,753	18.0	1,356,731	22.0	1,475,981	22.5
nited ingdom	7,240	0.3	7,648	0.2	6,414	0.1	3,800	0.1	3,733	0.1	2,038	-	-	-
ll others	116,134	5.0	187,804	5.5	336,190	6.2	226,442	3.9	360,087	5.8	320,600	5.2	269,534	4.1

ource: Forest Department, Sabah.

Table 2.3 shows that timberexports to Korea and Hong Kong have increased gradually. Hong Kong has always been an important market for many years by taking a large proportion of low quality logs. Other countries, such as New Zealand, Canada, China, France, Germany, Singapore and Italy have regularly imported small quantities of round timber.

2.2.2 Veneer and Plywood

The most significant development in the wood processing industries in Sabah in the past decade has been the start of the manufacture of veneer and high-grade plywood in 1960 and 1966 respectively. Production of plywood and veneer shows a promising trend (Table 2.4), though the magnitude of this production is negligible compared to log production. At present, three plywood and veneer factories are in operation and another plywood factory is under construction. It is envisaged that these industries will form a vital sector in the State's economy.

The United States is Sabah's largest market for plywood taking, as in 1971, 75 per cent of the total export, or 1.35 million squares metres (14.5 m sq ft) (Table 2.4). The remainder goes to the United Kingdom, Australia and Hong Kong. Most of the veneer produced is exported to Australia and Japan.

2.2.3 Sawn Timber

The saw-milling industry is the oldest and the most widely established of the wood processing industries in the State. In spite of this, the industry has not advanced rapidly in recent years (Table 2.5). In 1962, 86 sawmills produced 53,974 cubic metres (1.9 million cu ft) of sawn timber and in 1971, 154 licenced sawmills produced 92,710 cubic metres (3.3 million cu ft) (Liew, 1972). However, a detailed survey showed that in 1970, 47 of the 139 licenced mills were not in operation.

Destination		1969		1970		1971	
		Sq. metre	Value (M$)	Sq. metre	Value (M$)	Sq. metre	Value (M$)
Australia	Plywood	-	-	18,208	18,772	118,094	126,348
	Veneer	3,043,193	865,766	1,631,581	649,407	901,269	406,391
Hong Kong	Plywood	125,271	160,692	110,168	215,930	32,664	97,544
	Veneer	-	-	-	-	-	-
Japan	Plywood	-	-	16,062	17,787	-	-
	Veneer	1,161,097	488,962	2,425,775	1,354,484	1,224,185	567,866
South Africa	Plywood	-	-	280,544	314,944	-	-
	Veneer	13,495	5,481	133,876	65,760	3,094	2,501
Thailand	Plywood	29,728	27,403	-	-	-	-
	Veneer	-	-	-	-	-	-
Sarawak	Plywood	-	-	-	-	-	-
	Veneer	-	-	31,994	11,896	-	-
India	Plywood	-	-	1,159	1,217	-	-
	Veneer	-	-	-	-	-	-
United Kingdom	Plywood	412,052	560,793	674,688	722,413	334,271	385,648
	Veneer	-	-	38,132	16,173	-	-
United States	Plywood	404,900	249,584	448,526	484,809	1,346,270	1,535,489
	Veneer	151,575	34,854	13,935	17,679	-	-

Source: Forest Department, Sabah.

Table 2.5 Sabah sawmill industry (Production and export)

Year	Number of sawmills	Logs intake (cubic metre)	Sawn timber produced (cubic metre)	Export (cubic metre)	Percentage exported
1962-1966 (average)	113	135,245 1,796	56,666	6,866	12.1
1967	136	141,068	57,085	3,466	6.1
1968	133	174,377	66,349	4,014	6.0
1969	140	152,309	64,164	10,020	15.6
1970	139	178,908	74,209	11,902	16.0
1971	154	206,043	92,710	6,445	7.0

Source: Forest Department, Sabah.

All sawmills are privately owned, many by individuals catering chiefly to immediate local demand. If the present structure of the industry continues, it is unlikely that production will increase substantially in the future. Development of efficient sawmills through amalgamation of the existing small mills into larger ones is difficult, and may be impossible under present circumstances because most of the mills do not have a steady source of logs. In the light of this, development of the sawmilling industry will depend on the establishment of sawmills by major timber producers. Highly mechanised mills, possibly including woodmoulding and prefabricating plants which could produce high-grade sawn timber and prefabricated buildings are being planned (Liew, 1973). However, it is unlikely that they will be established in the near future because it is anticipated that there may be difficulties in marketing the products. In addition, the demand for hardwood sawn logs from foreign countries has always been on the upward trend. Therefore the future outlook for sawmilling industries may not be bright.

2.3.4 Mangrove Wood Chips

A mill was established in November, 1971 by Bumiputras entrepreneurs together with the Kohjin Company Limited of Japan, to convert mangrove wood into chips for export. At maximum capacity, approximately 2,500 ha (6225 acres). of mangrove forests can be chipped per annum working at 3 shifts per day. However, in 1972, only 103,000 metric tons were chipped and exported, and about 2,500 acres of mangrove forests were exploited. This shows that the mill has not been run at maximum capacity. The main reasons for the setback have been difficulties in acquiring sufficient numbers of labourers to extract mangrove wood. The ideal number of labourers is about 1,500 men.

Towards the end of 1973, another wood chipping mill of similar size started operation. The trend of production is similar to that of the first factory.

While mangrove wood chip is a welcome industry, the resource is rather limited (see Table 2.1) and it is estimated that most of the coastal mangrove forests will be exploited within 20 years.

2.2.5 Minor Forest Products

Most of these are non-wood products. They are of little importance locally now, and it is envisaged that they will not play an important role in the State's economy in the foreseeable future.

2.3 Export and Import of Various Forest Products

The export of various products was discussed earlier. It is worthwhile to add that logs have accounted for 98 per cent of the total value of forest products exported in recent years (Table 2.6). In 1971, for example, the total value of exports of forest products was M$427 million of which M$419 million was derived from round logs. In 1973, the quantity of timber exported from Sabah exceeded 300 million Hoppus cubic feet or 11 million cubic metres valued at 800 million Malaysian dollars, the highest timber export figure achieved so far.

The various forest products imported into Sabah are shown in Table 2.7. It shows that M$8.01 million worth of forest products were imported in 1968 rising to M$11.27 million in 1971.

With the present value of forest exports at about M$800 million, and imports at about M$11 million, Sabah is a large net exporter of forest products.

Table 2.6 Value of exports of forests products: Sabah
(Thousand Malaysian dollars)

	1947-1951 (average)	1952-1956 (average)	1957-1961 (average)	1962-1966 (average)	1967	1968	1969	1970	1971
Logs	5,875a/	14,273	60,898	172,214	316,299	334,052	374,423	395,807	419,001
Sawn	-	2,155	3,603	878	528	596	936	1,031	445
Veneer sheets	-	-	b/	1,336	819	1,089	1,395	2,552	3,147c/
Plywood	-	-	-	-	936	1,419	998	1,814	2,145
Firewood	-	1,119	472	85	2	-	560	-	17
Charcoal	-	47	-	-	-	-	-	-	-
Damar	-	322	723	555	241	101	255	365	241
Bird's nest	-	139	179	164	134	162	207	214	308
Rattan	-	19	15	49	37	9	3	26	7
Illipe nuts	-	25	154	51	-	-	-	-	-
Cutch	-	2,330	1,428	d/	-	-	-	-	-
Other forests products	2,014e/	598	453	194	69	33	81	139	99
Total	7,889	21,027	67,925	175,526	319,065	337,461	378,858	402,201	427,229

Source: Forest Department, Sabah and Statistics Department, Sabah.

a/ Includes value of sawn timber.
b/ Veneer sheets production started in 1960, the average for 1960/61 was M$109,000.
c/ Including M$2,170,000 for veneer corestock.
d/ Cutch stopped production in 1962 with a value of M$25,395 in that year.
e/ This value represents all other forest products such as firewood, charcoal, rattan, etc., but excludes only the logs and sawn.

Table 2.7 Imports of wood and wood manufactures by Sabah.
(Million Malaysian dollars)

	1968		1969		1970		1971	
	M$ m.	% of total imports	M$ m.	% of total imports	M$ m.	% of total imports	M$ m.	% of total imports
Crude materials								
1. Wood, lumber and cork	2.74	0.8	1.99	0.5	2.62	0.5	2.51	0.4
2. Pulp and waste paper	0.17	0.1	0.22	0.1	0.18	0.1	0.21	-
Manufactured goods								
1. Wood and cork manufactures	1.11	0.3	1.95	0.4	1.96	0.4	3.01	0.5
2. Paper, paperboard and manufactures thereof	4.01	1.2	4.41	1.0	4.90	1.0	5.54	0.9

Source: Forest Department, Sabah.

2.4 Importance of Forest Industries in terms of Revenue, G.N.P., Investment and Employment

2.4.1 Government Revenue

The lowland Dipterocarp forests provide the State of Sabah with its major source of income. Table 2.8 gives details of Forest Department revenue and expenditure over the past 26 years.

Table 2.8 shows that the Forest Department is a self-financing department. It may be noted that in no year has a loss been occurred.

The amount of revenue collected shows a rapid rise since 1967. This is mainly due to a large increase in royalty rates in January 1967. In 1971, revenue collected was in excess of M$95 million, representing approximately 52% of the State's total earning.

Table 2.8

Forest Department Revenue and Expenditure from 1947 to 1973

Year	Forest Revenue M$	F.D. Expenditure M$	Surplus M$
1947-1951 (average)	373,300	255,140	118,160
1952-1956 (average)	1,705,250	799,560	906,690
1957-1961 (average)	5,296,820	1,462,630	3,834,190
1962-1966	16,497,290	2,515,870	13,921,420
1967	51,929,270	3,554,280	48,374,990
1968	67,617,570	4,748,180	62,869,390
1969	67,690,420	5,837,850	62,122,570
1970	79,748,640	8,015,950	71,732,690
1971	95,527,250	8,549,460	86,977,790
1972	78,000,000	-	-
1973	176,000,000	-	-

After Liew, 1973

Source: F.D. Annual Reports

2.4.2 GNP

During the 7-year period 1963-1970, the GNP of Sabah increased from M$389 to M$805 million (Table 2.9) at an annual rate of approximately 11 per cent. Forests and forest industries play an important and increasing role in the economy. In 1971, they provided about 55 per cent of the value of total exports and this proportion continues to rise. In 1970, they contributed 50 per cent of GNP. In 1973, .the contribution rose to M$799 million which may represent, at least, more than 70 per cent of the GNP. No data are readily available on the total value of forest products produced in Sabah. However, as local consumption probably accounts for 1 per cent or less of the total export value of forest products, the latter figure (FOB) has been used as the measure of the industry's contribution to GNP (Table 2.9).

Table 2.9

Contribution of forest products to GNP

r	Forest products[a/] M$ million	GNP M$ million	Value of forest products as percentage of GNP
3	152	389	39.1
4	151	418	36.1
5	188	488	38.5
6	262	562	46.6
7	319	661	48.3
8	337	696	48.4
9	379	796	47.6
0	402	805	50.0
1	427	-	-
2	409	-	-
3	799	-	-

a/ In all cases, the value of forest products consumed locally is not included since the magnitude is negligible.

Between 1964 and 1971, the contribution of forest industries increased at an annual average rate of 16 per cent. However, as indicated earlier, timber production, and therefore its contribution to GNP has probably reached its peak. Great emphasis is therefore being given to agricultural developments such as oil palm and cocoa. The future role of forest and forest industries will largely depend on their diversification into processed products.

2.4.3 Investment

Data on investment in forestry and forest-based industries are not readily available. However, the actual number of tractors, logging trucks, log loaders, road building equipment, launches, lighters, scows, locomotives etc. used in logging operations from 1966 to 1970 are tabulated in Table 2.10. The number of tractors used decreased from 641 in 1969 to 400* in 1970. On the other hand, logging trucks increased two-fold during the same period. A quick estimate indicates that approximately M$220 million worth of serviceable logging equipment and machinery was in use in logging operations in 1970. This amount excludes expenditures on the construction of roads, bridges and buildings, and investment in the repair of existing machinery and equipment during that year. The cost of road construction is very high, for example, the all weather road built by Wallace Bay. Sdn. Berhad may cost on average about $80,000 per mile.

As mentioned earlier, Sabah has 154 sawmills, 2 plywood and 2 veneer factories with a further two plywood factories under construction. The capital outlay for the recently established chipping plant was M$6 million. It is estimated that as at December 1973 a total sum of approximately M$45 million is invested in wood processing industries, excluding

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* This figure may be low due to the lack of response of the small contractors to the survey.

Table 2.10 Number of machines used in forest industry 1966-1970

Equipment	1966	1967	1968	1969	1970
Tractors					
Heavy	575	664	548	641	400
Light	145	173	150	153	142
Trucks					
Winch lorry	59	86	102	135	111
Logging	152	190	208	239	524
Trailer	62	90	66	72	111
Other	541	98	65	51	32
Log loader					
A-Frame	11	26	12	2	12
Mobile	41	40	40	32	33
Other[a/]	355	662	1055	758	510
Road building equipment					
Excavator	6	14	11	23	6
Grader	17	19	34	31	2
Dump lorry	87	115	103	133	77
Other	38	29	23	31	5
Logging arches	3	1	4	-	-
Launches					
Towing	224	259	207	226	206
Other	109	117	94	98	91
Lighters and scows	53	55	47	48	50
Locomotive	210	207	192	178	168

Source: Forest Department, Sabah.

[a/] Includes trolleys.

the cost of installation of advanced processing machines and investment in repairing existing machines.

2.4.4 Employment

Forestry and forest industries have employed more than twenty per cent of the total work force over the past two decades (Table 2.11). The number employed by forest industries has fluctuated over the period 1952 to 1971, peaking during the years 1962 to 1966, declining during the next few years and then increasing again in 1971. These changes may be attributed in part to the opening up of State and alienated lands (areas range from 10 hectares to 1,000 hectares), which were exploited by small inefficient contractors between 1962 to 1966, and to the acquisition of new labour-saving equipment which became available between 1967 and 1970. As at 30th September, 1971, 9,491 persons were engaged in forest and forest industries, excluding those employed by the Forest Department. It is expected that the number of persons employed will continue to rise because of the establishment of chipping plants and other wood processing industries mentioned earlier.

Table 2.11 Persons employed in forest industries[a]

Year	Total labour force (number)	Employed in forest industries (number)	Percentage of total
1952-1956 (average)	24,594	6,291	25.58
1957-1961 (average)	30,606	9,438	30.84
1962-1966 (average)	39,206	12,717	32.44
1967	39,662	12,573	31.70
1968	38,749	10,456	26.98
1969	37,458	8,734	23.32
1970	39,991	8,361	20.91
1971	40,502[b]	9,491[b]	23.43

Source: Forest Department, Sabah.

[a] Excluding those employed by Forest Department, Sabah Government.

[b] As at 30th September, 1971.

Chapter 3

THE DIPTEROCARP FORESTS IN SABAH

In this chapter, a vegetation classification scheme for Sabah, based on species and ecological principles is briefly reviewed. Geological history and world distribution of the Dipterocarps are outlined. A classification of Dipterocarp forests into types is presented, largely based on investigations made in the past. An account is given of these types with particular emphasis on their extent, commercial status and species composition. The classification attempts to take particular account of representative species of value.

Growth of large commercial trees, and the merchantable timber volume of various Dipterocarp forests are briefly presented. Harmful plants found within the ecosystem are also examined.

3.1 Classification of vegetation in Sabah

Forest is the natural vegetation cover throughout the State, with the exception of bare rocks at the summit of Mt. Kinabalu and some swamp. 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).

The first attempt at classifying vegetation on an ecological basis was made by Keith (1935). The basic division was between littoral and inland forests. The latter were subdivided into fresh-water swamp, Dipterocarp and hill forests. Later Keith (1947) went into more detail, following the terminology of Bartt-Davy (1936) and the outline of Symington (1943), to give the following classification:

Main (Climatic) Climax Formations

(i) Tropical Lowland Evergreen Rain Forest Formation (Lowland Dipterocarp Forest)

(ii) Tropical Lowland Evergreen Rain Forest Formation (Hill Dipterocarp Forest)

(iii) Tropical Lower-montane Evergreen Rain Forest Formation (Upper Dipterocarp Forest)

(iv) Tropical Alpine Elfin-woodland Formation (Mossy Forest)

Edaphic Climax Formations

(v) Tropical Mangrove Woodland Formation

(vi) Tropical Littoral Woodland Formation (Beach Forests)

(vii) Peat Swamp Forests

(viii) Tropical Riparian Woodland Formation (Riparian Fringe)

(ix) Heath forest

(x) Forests of Uncertain Ecological Status
(Source : F.D.A.R. 1947).

Of these Keith suggested that (i) was the dominant type spreading over a huge area on the East Coast but was practically non-existent on the West Coast. The Hill Dipterocarp Forest (Keith 1947) was characterised by the absence of Eusideroxylon zwageri (Belian), and scarcity of Dryobalanops lanceolata (Kapur Paji) which is one of the most abundant species found in type (i). Type (iii) was a transition between lowlands forests and the mossy forests present on the higher mountains at 750 - 1700 m. a.s.l., with Dipterocarps seldom found above 1000 m. a.s.l. and conifers higher. This forest he described as generally two storied with moss and lichens abundant at the higher elevations.

Fox's (1972) classification, which is a modified version of Keith's (1947), may be summarised as follows :

Scheme Climax Formations

(i) Lowland and Hill Dipterocarp Forests
0 to 6 - 900 m. a.s.l.

(ii) Lower Montane Forests 2-canopy (c.f. Robbins 1969)

(iii) Montane Forests 1-canopy (c.f. Robbins 1969)

Sub-Formations

(iv) Swamps
  a. Mangrove
  b. Peat Swamp
  c. Fresh Water Swamp
  d. Riparian

(v) Beach

(vi) Limestone

(vii) Heath (Kerangas of Bruing 1969)

Secondary Formations

(viii) Secondary Forest
(ix) Grasslands
(x) Plantations

An overall inventory of the State forests was carried out during 1970 - 1972 by the Canadian and Sabah Governments. The project involved an overall survey of the forest resources and included an aerial survey, physical forest inventory (i.e. sampling of the forests), and economic evaluation of the potentials of the State's forests. The classification of vegetation following the inventory may be summarised as follows :

Table 3.1 Forest type and area

Forest type	Area (Hectares)	Percentage of total land area
(i) Mangrove	365,500	4.94
(ii) Transitional Beach and Swamp Forests	203,256	2.76
(iii) Undisturbed high Forests	2,800,236	37.85
(iv) Montane Forest	771,874	10.43
(v) Other Forest (Immature and Disturbed)	1,399,024	18.91
	5,539,890	74.89

Source : Forest Inventory Report, 1973.

It is apparent that the scheme of classification adopted was aimed at delineating the economic importance of various major forest types. With this information forest management is facilitated.

For the past sixty years different types of Forest Reserves had been legally constituted by the Forest Department for recreation, production of timber, scientific research etc.. The types of Forest Reserves are summarised in Table 3.2.

Table 3.2 Types of Forest Reserve as at 1978

Type of Forest Reserve	See also Table 2.1 Area (Hectares)	Percentage of total land area
(i) Protection Forest	432,345	5.84
(ii) Commercial Forest	2,315,777	31.31
(iii) Domestic Forest	14,132	0.19
(iv) Amenity Forest	21,954	0.30
(v) Mangrove Forest	75,434	1.02
sub-total	2,859,642	38.66
Other State Forest (including Nation Parks)	2,769,277	37.43
Other Land (Alienated)	1,768,659	23.91
Grand Total	7,397,578	100

The Commercial Forest Reserves amounting to 2,315,777 hectares are the Lowland and Hill Dipterocarp Forests 0 to 6 - 900 metres a.s.l. according to Fox's scheme of classification of vegetation. In this dissertation, discussion on formulation of silvicultural policy will be focused on these Commercial Forest Reserve.

3.2 Geological History and World Distribution of the Dipterocarps

This topic has been comprehensively dealt with by Symington (1943). It is now known that Dipterocarps were fully developed during the Tertiary, 15 to 70 million years ago though it is very likely that they already occurred during the Cretaceous, 80 to 140 million years ago (Meijer and Wood, 1964).

Out of a total of about 500 species estimated by Symington (1943) for the family of Dipterocarpaceae, Borneo as a whole possesses, according to recent estimates, about 284 (276 in Symington's list), Malaya 168 and Sumatra 72. Dipterocarps have their greatest density of species per unit area in Borneo and Malaya, which are considered to be the theoretical centre of development, and from here numbers decline in all directions.

About 47 Dipterocarp species commonly found in Sabah also occur in Malaya, and 13 species in the Philippines. Approximately 100 species which occur in Malaya are absent in Sabah. On the other hand, approximately 100 species of which(84 Borneo endemics and 12 species occuring from Borneo to the Philippines and New Guinea or part of that area)are absent in Malaya (Meijer and Wood, 1964).

3.3 Forest Types within the Dipterocarp forests

The Dipterocarpaceae has been known to be the family of main commercial interest, dominating the lowland forest areas, for the past many decades. Only since 1947, however, have botanical studies progressed sufficiently to enable the majority of species to be described (A.R.R.B. 1963). To date 181 species of Dipterocarpaceae are presently known from Sabah (Cockburn, 1977), belonging to the following genera.

Genera	number of species
Anisoptera	4
Dipterocarpus	24
Dryobalanops	5
Cotylelobium	2
Hopea	27
Parashorea	4

Genera	number of species
Shorea	84
Upuna	0
Vatica	25

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

Section	Species
Anthoshorea	7
Richetia	12
Rubroshorea	45
Shorea	20

Symington (1943) produced a diagrammatic scheme 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 topgraphy. 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, 1964b) 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 export in post war years, and one or the other of which characterise much of the Lowland forest, are not known. However, it has been observed that distribution of the latter is wholly within the range of the former. Table 3.2 shows the broad ecological distribution, whereas Table 3.3 illustrates

Table 3.2

Broad Ecological Listribution

A Predominantly Lowland Species (80)

	150m	300m	600m	600m
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. verrusosus(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	(c) Coastal	(d) Ridges	(e) Heath
S. seminis(SB) S. pinanga(Ru) D. exalatus D. oblongifolius D. tempehes Dr. keithii	V. mangachapoi V. maritima C. melanoxylon H. nutans S. bracteolata(An) S. gratissima(An) S. guiso(SB)	H. beccariana H. wyatt-smithii A. costata D. acutangulus D. grandiflorus D. stellatus S. agami(An) S. beccariana(Ru) S. multiflora(Ri)	H. micrantha H. pentanervia A. marginata Dr. beccarii Dr. rappa S. kunstleri(Ru)(a) S. retusa(Ru) S. venulosa(Ru)(a)

(b) Swamp

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

B Hill and Mountain Species (42)

1. Mountains 600 m and higher

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

2. Mountains above 300 m

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

3. Ultrabasic

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

4. Hill Species

(a) Common

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

(b) Less Common

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

Notes 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 A - Anisoptera C - Cotylelobium

Table 3.3

Occurrence Dipterocarp species at Different altitudes

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	–
Selangan 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

the altitudinal distribution of Dipterocarp species (Data collected from a series of 17 one acre (0.4 Ha.) plots in the Gunung Rara Forest Reserve (R.P. 318).

Dipterocarp forest types

Lowlands

Type 1. Parashorea malaanonan Forest

Parashorea malaanonan is the most abundant emergent species in the Darval Bay area from the east (Silabukan Forest Reserve), through Lahad Datu to the Semporna peninsula (East Coast of Sabah). The Mostyn area near Kunak, 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). Other typical emergent species are *Shorea guiso* and *Hopea sangal* (small trees) with the Rubroshorea species such as *Shorea leprosula*, *S. parvifolia* and *S. leptoclados* also present, the latter locally abundant.

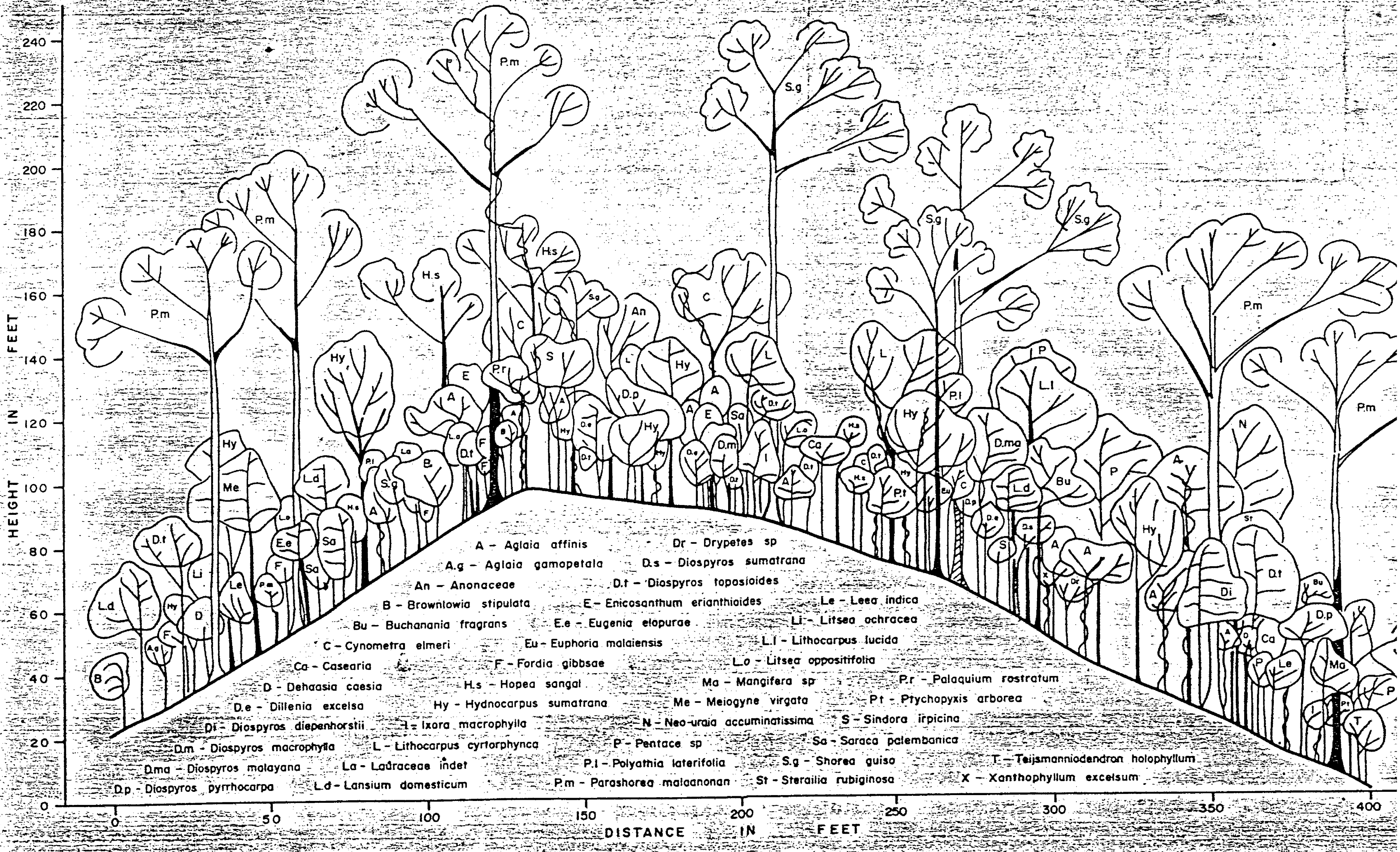
Figure 3.1 illustrates the profile characteristics of this Type. Individual large trees occur of 9 - 12 ft. girth (90 - 120 cm. diameter) and 160 ft. (50 m.) or more in height.

Parashorea malaanonan is locally gregarious on steep slopes of the Timbun Mata island (Liew and Samad, 1976) with *S. guiso*, *Cynometra elmeri*, *Pterocymbium tinctorum*, also with palms and lianas abundant (Figure 3.2). On less steep slopes, the predominant species is still *P. malaanonan* in association with the Rubroshorea species.

The *Parashorea malaanonan* type of Dipterocarp

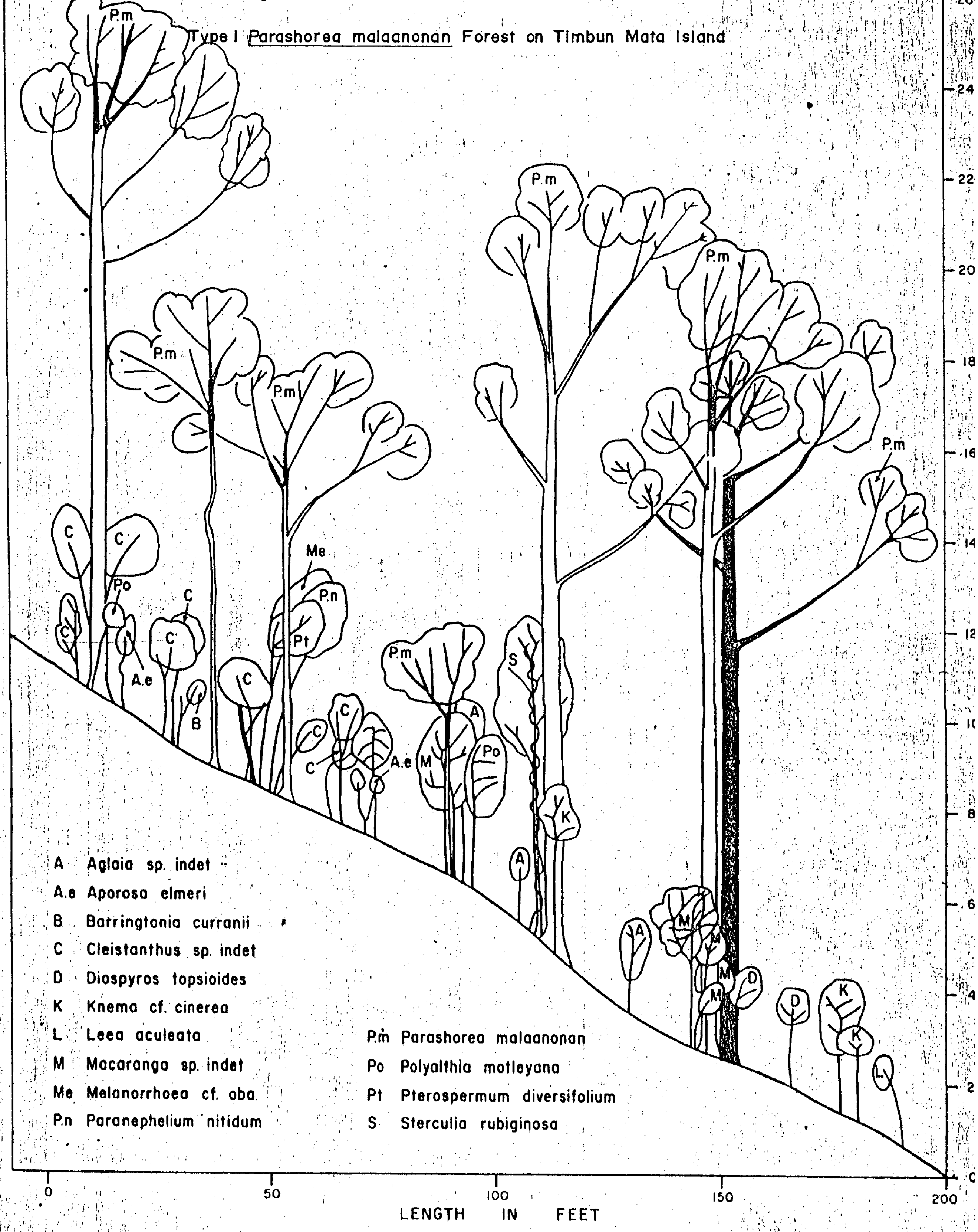
Figure 3·1 PROFILE PLOT, SILAM

Type I Parashorea malaanonan, Shorea guiso



FOREST DEPA

Figure 3·2 PROFILE DIAGRAM



Forest Department, Sabah.

forest is probably the most commercially valuable. The main areas of managed forest containing this type are parts of Silabukan F. R. Silam Extension, Ulu Segama F.R. and parts of Tingkayu F.R. The main occurrence is coastal, and is associated with comparatively rich soil and low rainfall.

Type 2. 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 the Sepilok and Segaliud-Lokan Forest Reserves.

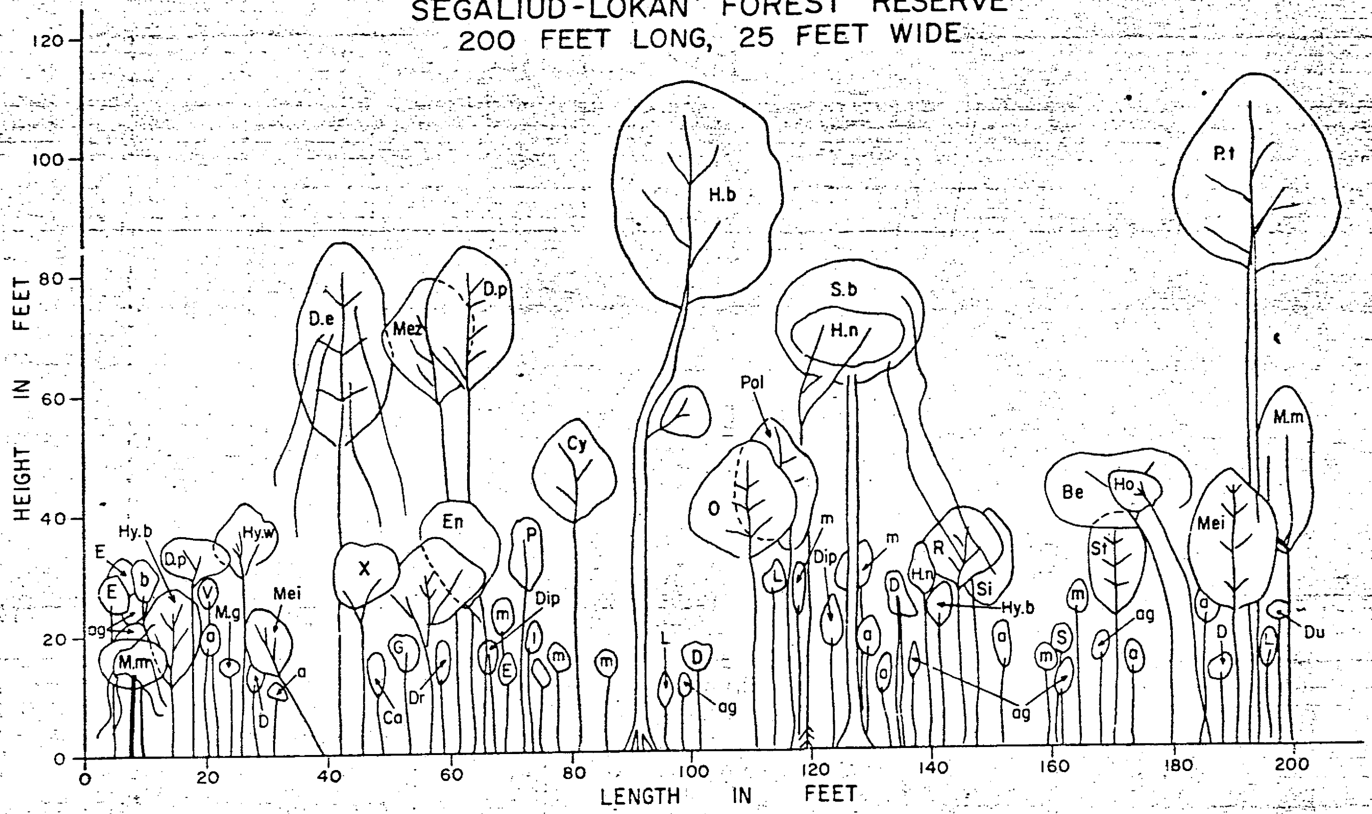
A forward enumeration covering 59 sq. miles (150 sq. Km.), made by the Sabah Timbers Company Limited, in the forest between the Lokan River and the Labuk Road, gave an average volume per acre of 1050 cu. ft. Generally the forest type has about 20 per cent Parashorea (of trees 6 ft. girth and larger, 58 cm. diam.), and though P. malaanonan is present, the main species is P. tomentella. Its principal associates are S. leptoclados, Dr. lanceolata and D. caudiferus. These four Dipterocarps generally account for 40 per cent or more of the larger trees. Fox (1967) carried out a detailed vegetation enumeration and no further elaboration is required. Figure 3.3 is the profile diagram illustrating the typical Parashorea tomentella / Eusideroxylon zwageri forest type in Segaliud-Lokan Forest Reserve.

In Sepilok F.R., Parashorea tomentella and Shorea leptoclados are most typical of the Type with abundant E. zwageri in main canopy below the emergents. They are on low-lying

FIGURE 3·3 TYPE 2

PROFILE DIAGRAM A

VIRGIN JUNGLE RESERVE, MILE 42
SEGALIUD-LOKAN FOREST RESERVE
200 FEET LONG, 25 FEET WIDE



a - Anonaceae indet
ag - Aglaia sp. indet
b - Baccaurea sp. indet
Be - Beilschmedia towaensis
Ca - Canarium sp. indet
Cy - Cynometra inaequifolia
D - Diospyros sp. indet
D.e - Diospyros elliptifolia
D.p - Diospyros perfida
Dip - Dipterocarpus caudiferus

Dr - Dryobalanops lanceolata
Du - Durio grandiflorus
E - Eugenia sp. indet
En - Enicosanthum erianthioides
G - Garcinia sp. indet
H.b - Hopea beccariana
H.n - Hopea nervosa
Ho - Horsfieldia wallichii
Hy.b - Hydnocarpus borneensis
Hy.w - Hydnocarpus woodii

I - Lithocarpus sp. indet
L - Litsea sp. indet
m - Mallotus indet
M.g - Mallotus griffithianus
M.m - Mallotus moritzianus
Mei - Meiogyne virgata
Mez - Mezzetia leptopoda
O - Orphea myriantha
P.t - Parashorea tomentella

Pol - Polyalthia obliqua
P - Pometia pinnata
R - Ryporosa hulletii
S - Sapotaceae indet.
Si - Sindora sp. indet
St - Stemoneurus dolichophyllus
S.b - Sympetalandra borneensis
V - Vitex sp. indet
X - Xanthophyllum affine

Forest Department, Sabah. 1971.

alluvial soils or soils derived from mudstone and shales. Figure 3.4 illustrates this forest in Sepilok, on a low mudstone hill rising from alluvium. Apart from *Eusideroxylon*, other genera of the main canopy include *Diospyros*, *Hydnocarpus*, *Chisocheton* and *Lithocarpus*. *Sympetalandra borneensis* occasionally reaches emergent status. Lianes are frequent and seral. Moisture loving species such as *Anthocephalus chinensis* and *Octomeles sumatrana* are found in lowlying areas which are often flooded. This would indicate that the forest would have been disturbed by man in the distant past.

Abundance of *Eusideroxylon zwageri* varies from place to place and is often scarce over wide areas. Normally, in most lowlying areas, *E. zwageri* is present.

Type 2 is of more importance in terms of the greater total land area in Forest Reserves than Type 1. As the soils, mainly sedimentary with some areas podozlic, are less rich, the areas of this type are likely to remain under forest management for production of timber for a longer period than those of Type 1. The main Forest Reserves of commercial importance containing Type 2 forests are Kretam, Sapagaya, Tenegang, Kuamut, Pinangah and Segaliud-Lokan, and the latter has been earmarked for agricultural development. The areas are characterised by comparatively high rainfall and gently undulating to moderately hilly land.

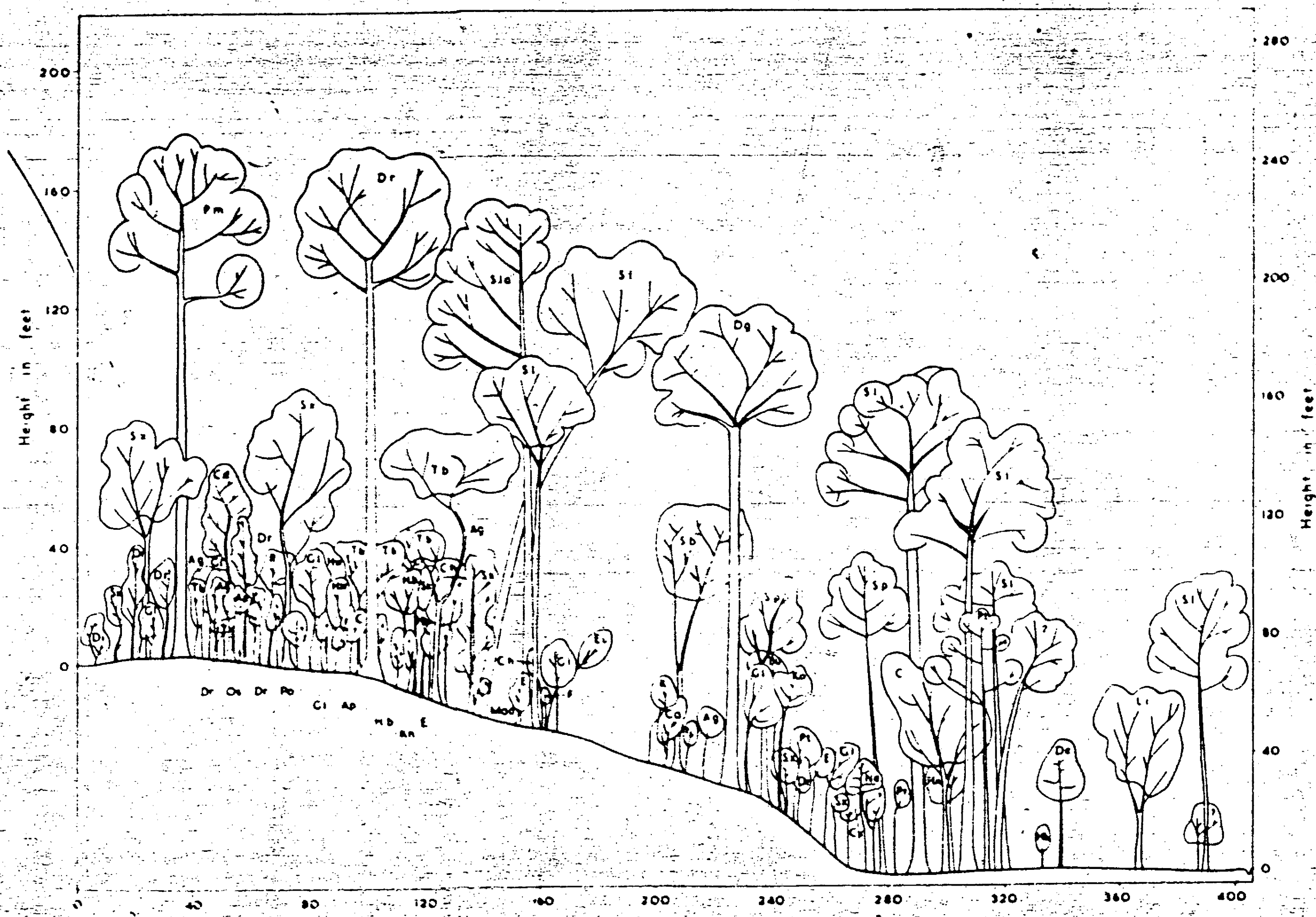
Type 3. Rubroshorea / Eusideroxylon zwageri Forest

This type is characterised by the presence of Rubroshorea species which form the majority of larger

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. argentifolia*

Figure 5.4 PROFILE DIAGRAM

Type 2 Parashorea tementella / Eusideroxylon zwageri Forest in Sepilok Forest Reserve



Legend for Sepilok Profile Plot 3

Sx	Shorea xanthophylla	Kp	[illegible] pinnatum	Ag	Aglaia polyantha	Eu	Euodia luna-ankenda
Sja	Shorea [illegible]	Hb	Hydnocarpus borneensis	Cd	Canarium denticulatum	F	Ficus gibbosa
Si	Shorea leptoclados	Bu	Buchanania sessifolia	C	Canarium odontophyllum	Dk	Diospyros spp
Sp	Shorea parvifolia	E	Eugenia spp	B	[illegible] acuminata	Ca	Canthium confertum
Pt	Parashorea tomentella	Cp	Cynometra [illegible]	Kn	Knema latifolia	Sb	Sympetalandra borneensis
Pm	Parashorea malaanonan	Ne	[illegible] acuminatissima	Hw	Hydnocarpus woodii	De	Dehaasia incrassata
Dr	Dryobalanops lanceolata	Di	Dillenia excelsa	Pa	Polyalthia glauca	Li	Lithocarpus conocarpus
Dg	Dipterocarpus gracilis	Tb	[illegible] [illegible]	O	Chisocheton [illegible]	Os	Ostodes pendulus
Hn	Hopea nervosa	Ae	Aporosa elmeri	Md	Madhuca sepilokensis	?	unidentified
Sr	Saraca [illegible]						

and others in the Tawau region.

Some 14 Rubroshorea species were represented by 3 or more stems and comprised 39 per cent of the trees of 6 ft. girth (58 cm. diam.) and over, in a set of 23 randomly placed 1 - ha. plots in about 500 ha. of forest of the Kerito 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. The common Rubroshorea species were *Shorea mecostopteryx*, *S. macrophylla*, *S. parvifolia* and *S. ovalis*. *Dr. lanceolata* was not represented and the genera *Parashorea* and *Dipterocarpus* were scarce.

Locally *Koompassia excelsa* is common on the basalt. Generally this species is abundant on lowlying alluvial areas.

In one study, RP.370(A) shows that this Type comprises productive forests. The results may be summarised as follows:

Compartment	Actual Outturn (cu. ft./acre)	Inventory Enumeration	SE %	Difference	Difference as a % of Enumeratio
17	1384	2874 ± 420	15	+ 1490	52
16	1695	2418 ± 268	11	+ 723	30
21	1543	1920 ± 258	13	+ 377	20
20	1426	1624 ± 204	13	+ 199	12

Actual outturn for this area achieved by the Wallace Bay Company Limited was 1519 cu. ft. per acre (135 cu. m. per ha.) and thus the enumeration over estimated production by 50 per cent, a figure often used to allow for defect, felling damage etc. (Francis, 1966).

Table 3.4 illustrates the floristic composition of this Type but unfortunately *E. zwageri* is scarce in these sample plots.

Table 3.4 Stand Table R.P. 256 10 - 1 acre (4 ha.) Mile 18.5 - 19.5 Luasong/Gunung Rara Road, Kalabakan Forest Reserve

Species	Number of Trees in Size Classes							
	Girth(ft.)	6	7	8	9	10	10+	Total
	Diam.(cm.)	58	68	78	87	97	97+	
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. symithiesii		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 markets have improved, higher yields have been taken from these forests, and though not as valuable as Type 1 they certainly compare favourably with the forests of Type 2.

Type 4. Rubroshorea/Dipterocarpus Forest

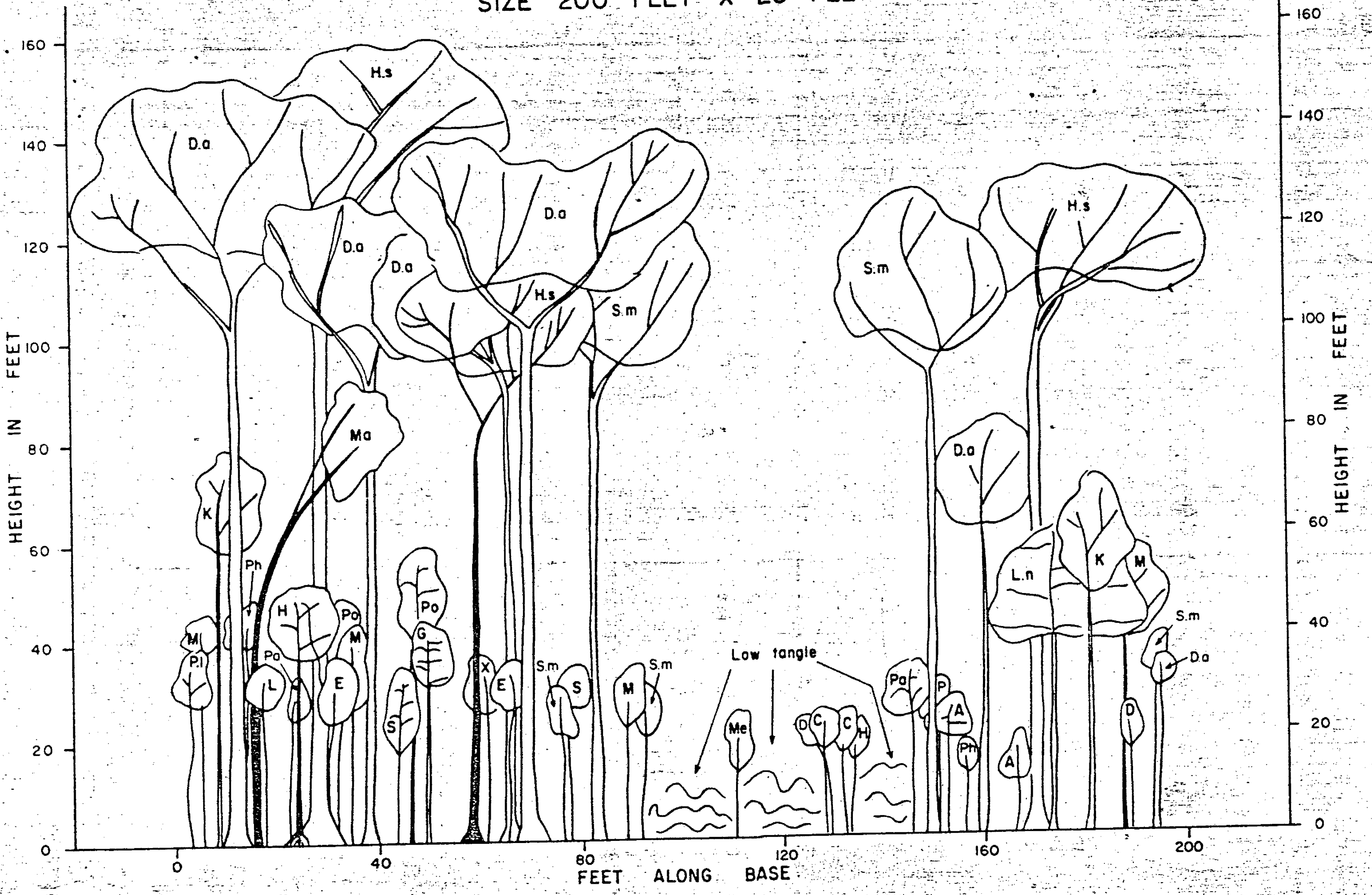
The forests described by Nicholson (in Paton, 1959) on the Grading family of soils were deficient in the otherwise common Rubroshorea S. *leptoclados*, and the genus *Parashorea*, though *P. smythiesii* was present. The whole of the coastal depositional platform of the Tawau/Semporna area is placed in this type (south of Sabah). This type is characterised by the presence of a number of *Dipterocarpus* species : *D. applanatus*, *D. acutangulus*, *D. pachyphylus*, *D. verrusosus*, *D. humeratus*, *D. grandiflorus*, *D. confertus*, *D. palembanicus* and *D. kerri*. Rubroshorea species present include *S. parvifolia*, *S. pauciflora*, *S. leprosula*, *S. olesosa* and *S. ovalis*. The soils are generally sandy latosols, with, in places,patches of the Kubota podsols which when not highly leached, carry the same type of forest.

A profile of the forest in such an area is illustrated in Figure 3.5 where *D. acutangulus* and *Heritiera simplicifolia* form the emergent canopy at 35 - 50 m.,while *S. multiflora* and smaller *D. acutangulus* trees form the main canopy at 30 - 37 m.

Unfortunately little remains of this forest type as the main belt has all been logged, and is destined for agricultural development despite the generally poor soils. Most of the forests of this type in the interior have been, or are being, destroyed by shifting cultivation. Restricted logging in hill areas, where types 2 or 3 occupy gentler slopes or valleys, may well extend logging into more of the type 4 areas. In the past such areas, e.g.,

FIGURE 3·5 TYPE 4

PROFILE PLOT
MILE 42, TAWAU/KALUMPANG ROAD
SIZE 200 FEET X 25 FEET



A	Aglaia cordata	H.s	Heritiera simplicifolia	Ma	Mangifera korthalsii	Ph	Phoebe macrophylla
C	Canarium odontophyllum	H	Hopea ferruginea	Me	Memecylon laevigatum	Po	Polyalthia sumatrana
D	Diospyros sp. indet	K	Koompassia malaccensis	Pa	Palaquium sp. indet	S.m	Shorea multiflora
D.a	Dipterocarpus acutangulus	L.n	Lithocarpus niewenheusii	P.l	Parinari laurina	S	Symplocos polyandra
E	Eugenia sp. indet	L	Litsea cf. firma	P	Pentace laxiflora	X	Xanthophyllum cf. affine

Serudong and Silimpopon, have been less attractive to logging interests, as the Dipterocarpus component often produces 'sinking' logs.

Type 5. *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 hill Dipterocarp Types which (i.e. Types 6 and 7). 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 1 and 5 in this area.

Table 3.5 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 hilly area, and of particular note are the absence of *Dipterocarpus* species other than *D. caudiferus* predominance of *S. leptoclados* and abundance of Richetia mainly *S. hopeifolia* and *S. faguetiana*.

At present the only important area of commercial managed forest of Type 5 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 2 and 3. However, the principal species components are important in regeneration consideration where *P. malaanonan*, *S. leptoclados* or *Dr. lanceolata* are abundant within the main commercial forests.

Table 3.5 Stand Table RP. 245/3 Silabukan F.R.
Parashorea malaanonan/Dryobalanops lanceolata
Forest Type

Species	Number of Trees in Size Classes							
	Girth(ft.)	6	7	8	9	10	10+	Tota
	Diam.(cm.)	58	68	78	87	97	97+	
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 10 acres/4Ha	15	11	14	17	10	8	75

Type 6. 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 preceding lowland types. Forests dominated by Dipterocarpus species, with Richetia abundantly representing the genus Shorea. Liew and Juin (1976) made a detailed vegetation study east of Sook Plain where the ten acre plots were established between 1200 ft. and 2400 ft. a.s.l.

For details, refer to Liew and Juin (1976).

The Selangan Batu Forests are of less commercial value, but recently a trunk road has been constructed linking the interior to the coast. It is therefore envisaged that this Type will be gradually exploited even though all Selangan Batu species are "sinkers."

Type 7. Dipterocarpus/Richia 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 podzolic sandy loams to sandy clay loams with depth. The Type is often associated with Heath forest on leached sandy soils on cuestas, ridges and steep slopes.

The general structure of the forest, has Dipterocarpaceae 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.

The forests are inherently less valuable as the larger trees are often hollow. The soil is unsuited to agriculture and any canopy opening accelerates erosion.

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 difference in growth rates between areas? Do the associated environmental factors of soil, topgraphy and rainfall influence the behaviour of principal species within the Type? 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.

3.4 Structure

Profile diagrams illustrating the structure of typical stands within the natural Dipterocarp forests have been given in Section 3.3. The natural stands of Dipterocarp forests are characterised by emergents (taller trees) 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 in Fig. 3.6. Individuals of small girth may reach the canopy, e.g. from 5 ft.g (R.P. 55, Type 1), and from 3 - 4 ft. g. in Segaliud-Lokan (Type 2) (Nicholson, 1962 a). Similarly, squat understorey trees may reach 6 ft. g. as some of the species e.g. Eusideroxylon zwageri have large girth boles. On average, trees of 7 ft. g. and larger reach the canopy in Segaliud-Lokan (Fox, 1967).

The emergent storey is often discontinuous in lowland areas (Figure 3.1) and on steep slopes, but on ridges and in some dense lowland areas, e.g. Type 4, it tends to be more or less continuous as the main storey.

The taller trees often reach 60 m. (Table 3.6) but occasional individuals, especially of Koompassia excelsa, may reach 80 m. Burgess (1961) described the structure of three profiles in detail. A generised height statement is that beneath the taller trees a poorly defined discontinuous storey from 18 to 34 m. stands over a well marked storey from 6 to 18 m. Ashton (1965) has suggested that layers are scarcely recogniseable but the most convenient description of the Dipterocarp forest as a whole is of a three layered forest (Robbins and Wyatt-Smith 1964). Considering the distribution of stem members in height classes (Figure 3.6 and Nicholson 1962 a), it certainly suggests the presence of definite layers even if they cannot be clearly seen on the ground.

Table 3.6 Height Measurement in R.P. 257

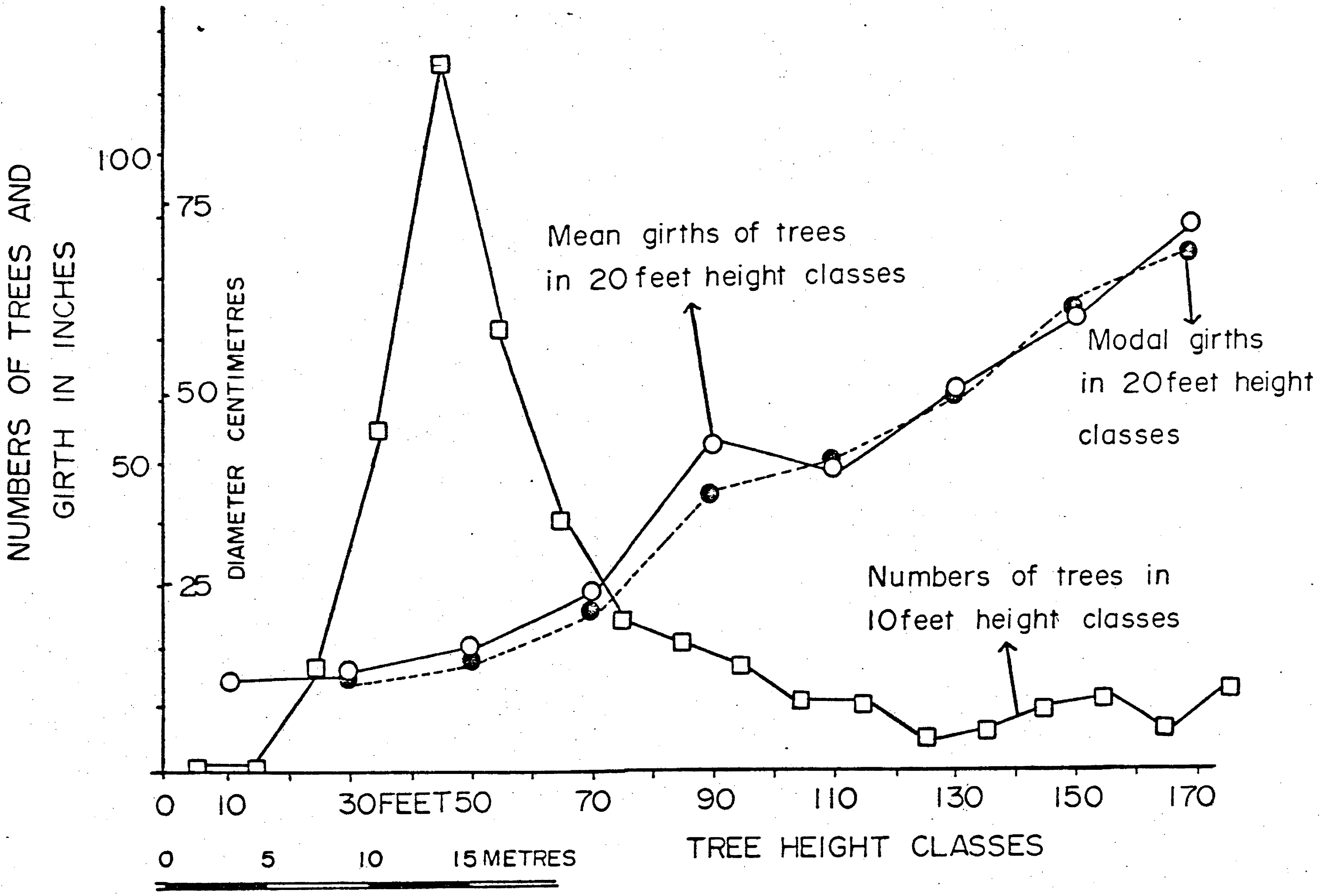
Species	Height in Metres				No. of trees greater than:		
	Girth(ft.)	6-9	10-13	14+ ft.	160	180	200
	Diam.(cm.)	60-96	97-116	116+ m.	50	55	60
Parashorea tomentella	Min	31	42	45	17	7	5
	Mean	43	52	58			
	Max	56	68	65			
Shorea leptoclados	Min	40	43	43	20	15	4
	Mean	49	52	58			
	Max	59	58	67			
Dryobalanops lanceolata	Min	29	44	43	10	7	3
	Mean	40	52	57			
	Max	46	64	65			
Dipterocarps caudiferus	Min	36	-	-	2	-	-
	Mean	45	51(1)	45(1)			
	Max	54	-	-			

Structure of regenerating stands, though basically likely to approximate the general form of natural stands,

FIGURE 3.6

NUMBERS OF TREES AND MEAN GIRTHS

BY HEIGHT CLASSES R.P. 18



may be even more dependent on the degree of destruction in the process of logging. However, with the current silvicultural treatment, e.g. poison-girdling, the stands tend to increase the representation of the common members of Dipterocarpaceae. This may eventually lead to a two layered stand consisting of a main canopy of preferred species over an under-storey of the same species but with different growth rates. The effects of competition may result in reassertion of the three layer tendency.

3.5 Growth (Large trees)

3.5.1 Undisturbed conditions

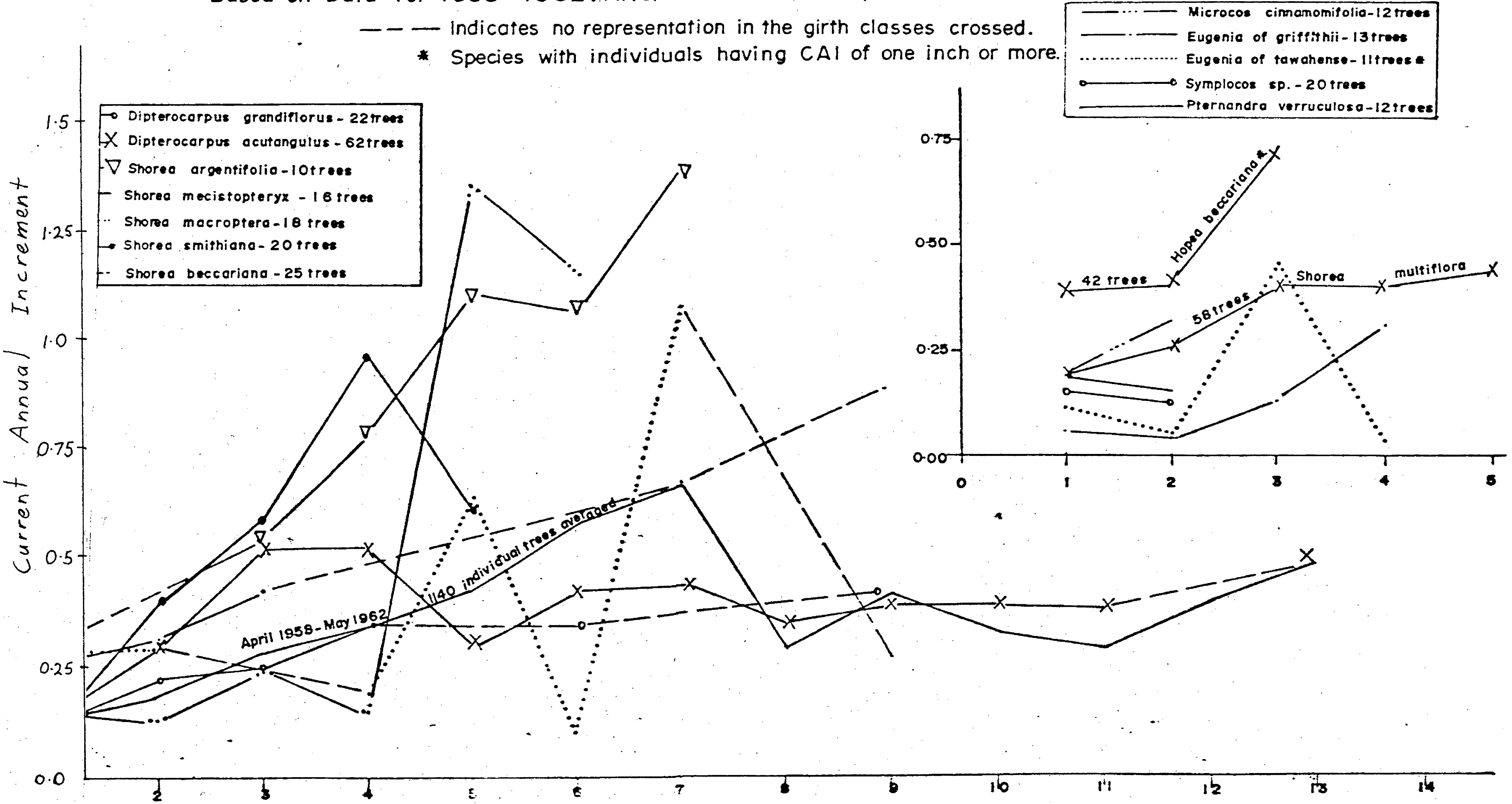
Sample plots in Sepilok F.R. give longest consistent measurement information on natural growth rates (Fox, 1972b). Growth rates for some common species in R.P. 17 (Sepilok F.R.) are illustrated in Figure 3.7. Nicholson (1963) discussed these with respect to probable ages of trees. The Rubroshorea species *Shorea argentfolia*, *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. girth (58 - 68 cm. diam.) is reflected in the graphs of these species.

Considerable variation in the growth rates of individuals of the same species and size at a given location is largely accounted for by differences in crown quality. Individuals with large crowns and relatively good increments occur in many species. There were a total of 35 species represented in RP17. Individuals of the four Rubroshorea species referred to above, and of 5 other Rubroshorea species had CAI girth increments of 1.0 in or greater, and individuals of a further 26 species had been growing at 0.5 in or better. Some of the smaller Dipterocarps trees with better crowns were more vigorous, and possibly younger than similar sized trees with poorer-formed crowns.

FIG 3·7

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.

Over a period of ten years the average growth rates of the more important species are summarised in Table 3.7.

Table 3.7 Growth rates of important species RP.17
Sepilok Forest Reserve (Virgin forest)
Type 6 forest
Measurement : 1958 - 1968

Species	Rate (girth) (CAI) inch.	number of individuals	Max size (ft.)
S. argentifolia	.76	8	8
S. smithiana	.44	17	6
S. mecistopteryx	.42	15	7
H. beccariana	.41	37	4
S. faguetiana	.39	7	11
D. acutangulus	.34	59	15
S. beccariana	.34	24	9
S. macroptera	.32	16	9
S. parvifolia	.28	5	5
S. multiflora	.27	53	5
S. glaucescens	.21	5	9
D. grandiflorus	.20	20	9
V. papuana	.19	4	3
S. virescens	.19	1	3
D. confertus	0.09	7	10
P. tomentella	0.05	1	8
P. malaanonan	0.01	1	12

Note : Max size = girth class of largest tree included.

The Table 3.7 indicates that the average growth rates of commercial species range from 0.76 inch to 0.01 inch (cai). Comparatively low rates for Parashorea, with only two trees considered, may reflect the fact that the trees may be defective because other Research Plots consistently show that Parashorea species are among the faster growing species.

For contrast, growth rates for R.P. 18 (Type 2 forest) are summarised in Table 3.8. Over a period of twelve years (1957 - 1969), nine trees, four of Shorea leptoclados, two of Parashorea tomentella and one Shorea waltonii, maintained average growth rates in excess of 1.0 inch of girth per annum.

Table 3.8 Growth rates of important species R.P.18
Sepilok Forest Reserve (Virgin forest)
Type 2 forest
Measurements : 1957 - 1969

Species	Rate (girth) (CAI) inch.	number of individuals	Max size (ft.)
S. waltonii	1.11	2	7
S. leptoclados	0.62	37	11
S. leprosula	0.51	2	7
S. parvifolia	0.48	7	8
P. tomentella	0.36	20	7
D. caudiferus	0.23	5	9
Dr. lanceolata	0.18	5	11
D. exalatus	0.15	5	4

Table 3.8 indicates that the average growth rates are faster than those of RP17. The presentation of the data in this form obscures the trend of increasing increment with size, i.e. there were more large sized trees in RP18 than in RP17. For the more abundant species reaching larger sizes the data clearly show that the Rubroshorea group in general, grow faster than other Dipterocarp species.

There are many other Research Plots which have been established in different virgin Dipterocarp forest types.

Records are kept in the Forest Research Centre.

3.5.2 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 3.8 (c) illustrates the growth of the best trees of commercial species in 0.5 chain squares (10m. x 10m. line sampling sub-plots - maximum stocking 40 trees per acre) 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 1). Increased increment occurred on measured stems in the smaller size classes following liberation.

In another study, R.P. 53 (20 acres or 8 ha.) in Segaliud-Lokan F.R. was logged over in 1962. Dipterocarp trees originally in the size range 1 - 5 ft. girth were measured during the period 1959 - 1971. Trees measured prior to logging (301) had average C.A.I. between 0.40 and 0.50 inch girth 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 inch and of 1.11 inch during 1963 - 1970, having grown on average, twice as fast in the seven years following felling as in the three years prior to felling.

Increments before and after felling for R.P. 53 are illustrated in Figure 3.9. Table 3.9 gives a summary of increments by size classes, showing clearly that increment of larger trees is unaffacted by intervention and that the

FIGURE 3·8 CURRENT ANNUAL INCREMENTS BY GIRTH CLASSES - NATURAL FOREST

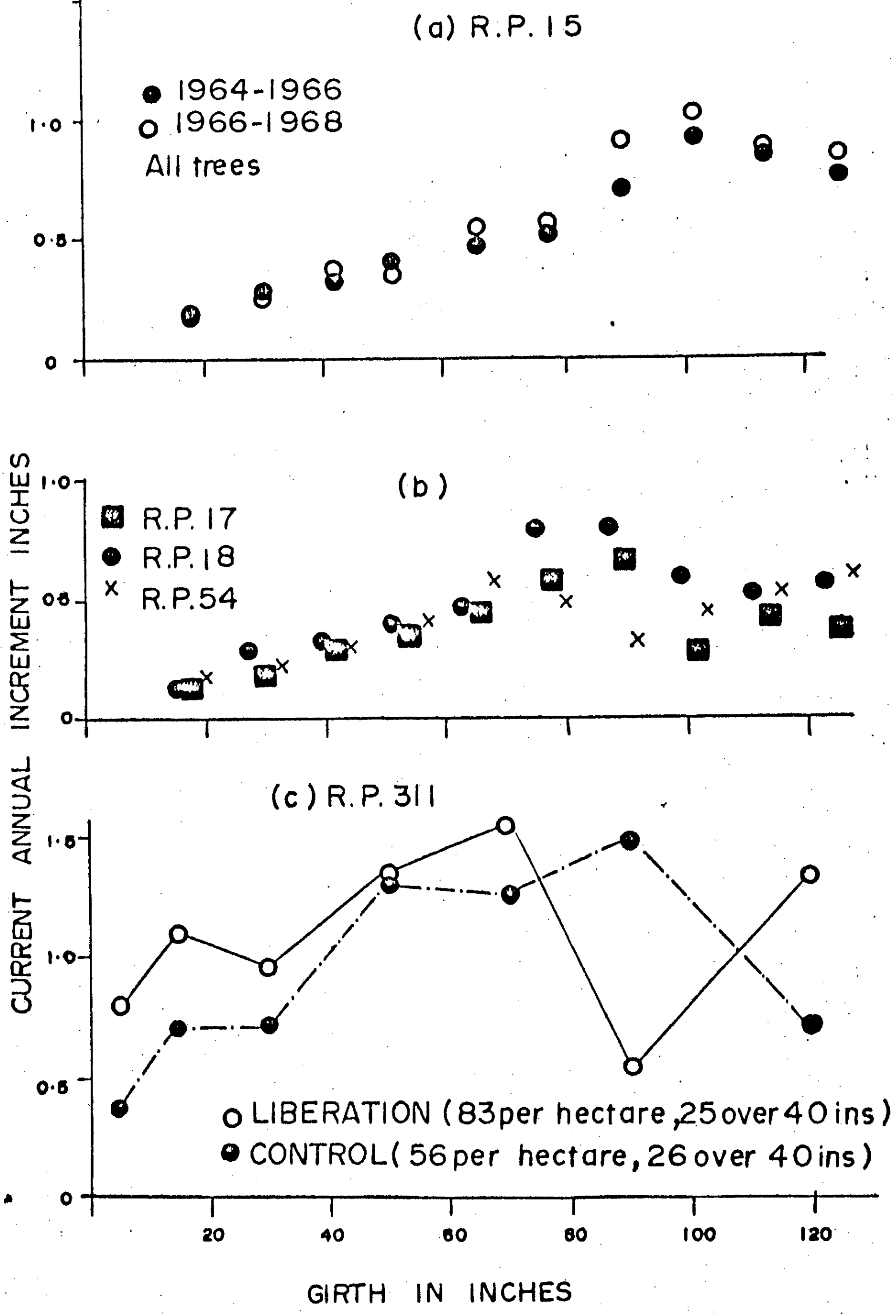
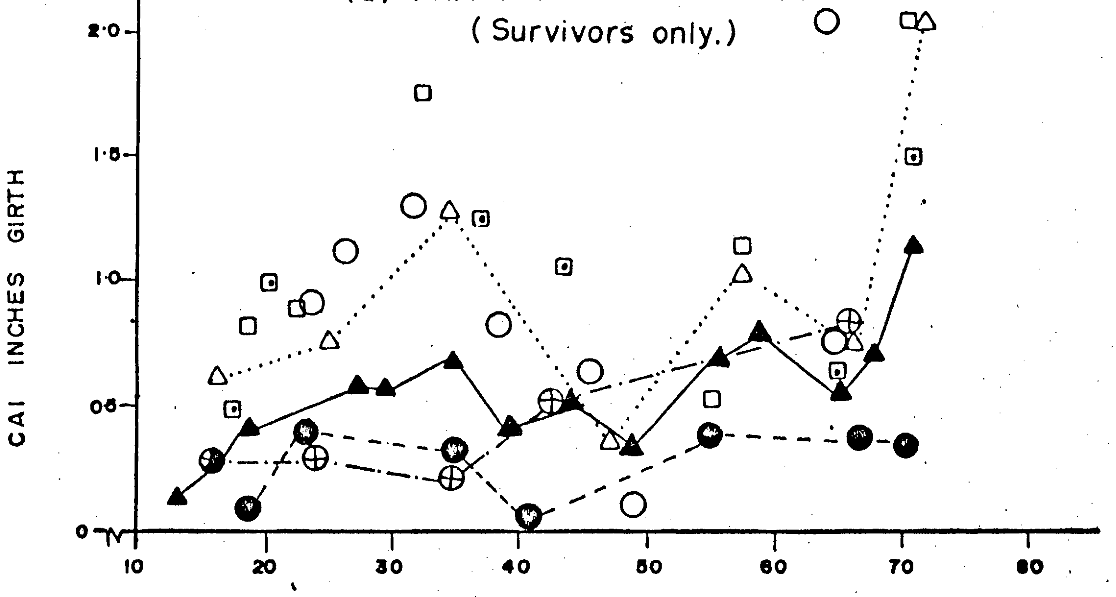
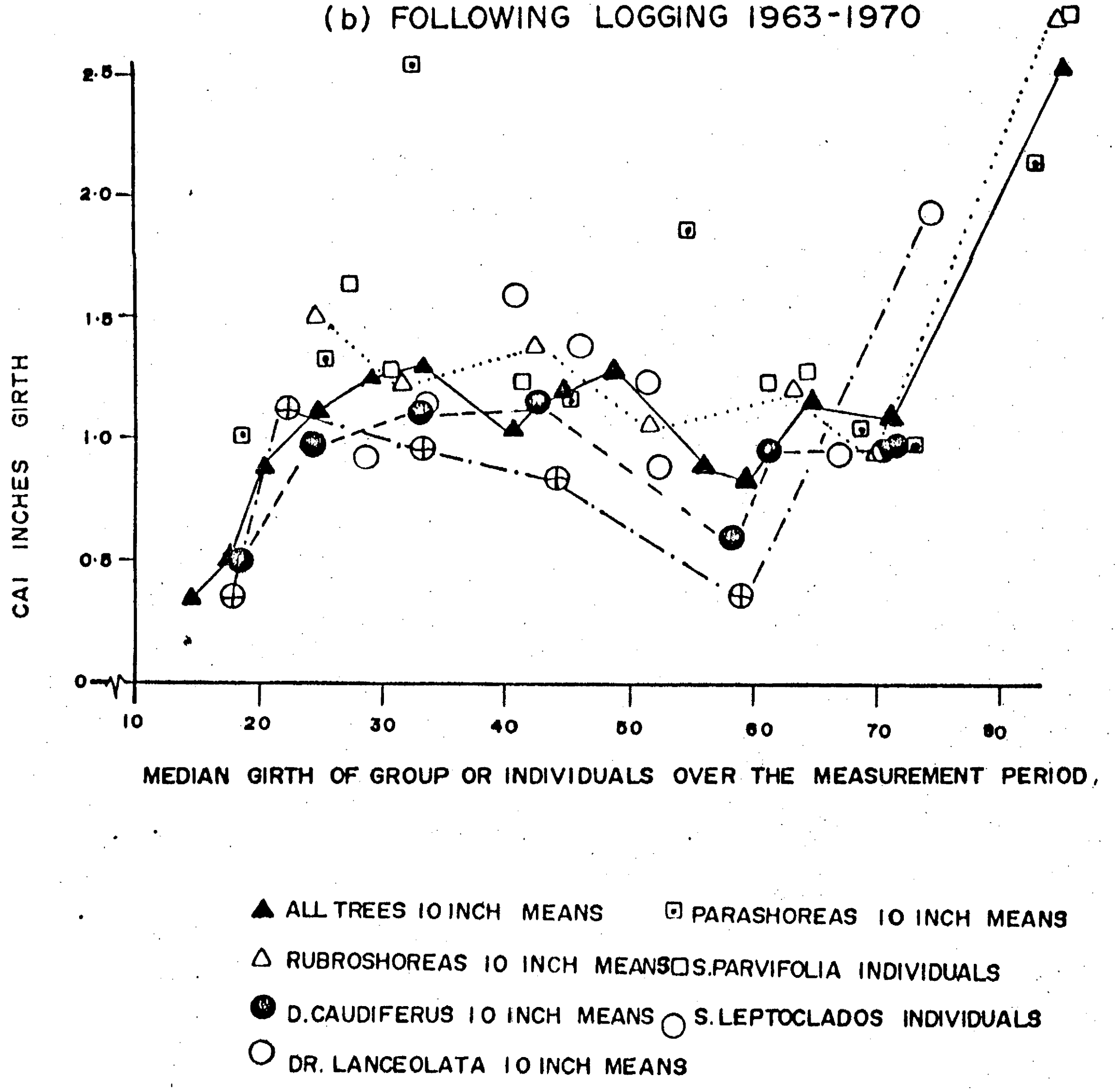


FIGURE 3·9 R.P.53 CURRENT ANNUAL INCREMENT AND MEDIAN GIRTHS

(a) PRIOR TO LOGGING 1959-1962
(Survivors only.)



(b) FOLLOWING LOGGING 1963-1970



greatest gains are for trees in the sizes 1 - 6 ft. girth.

Table 3.9 Average current annual increments by size classes for survivors to 1970. R.P.53 - Segaliud-Lokan F.R.

Girth Classes (inch)	Prior to Felling (1959 - 62)	After Felling (1963 - 70)	Percentag 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

Note : numbers in brackets are the trees in size class contributing to increment, at half way through the period.

Since 1966 more than 200 yield plots have been established in logged-over forests in different vegetation types with the objective of determining growth rate of commercial species. A report on the growth of the main commercial species in the Segaliud-Lokan F.R. based on yield plot data was analysed by Wong (1973). He concluded that for the best 20 trees per acre (50 trees/ha), their probable rotation ages (from seedling to 8 ft. girth) as calculated by the time passage method, range from 58 to 128 years (Table 3.10).

Table 3.10 Number of years required for important commercial species to grow from seedling to 8 ft. girth : Segaliud-Lokan F.R. (10 Yield plots, 2.5 acres per plot) Coupes 1957 and 1959. Best 20 trees per acre.

Species	No. of years to reach 8' girth
S. leptoclados	58
S. leprosula	61
P. tomentella	64
Dr. lanceolata	81
D. caudiferus	128
Chosen trees combined	65

Note : The forest received first silvicultural treatment, i.e. poison-girdling immediately after logging.

Table 3.10 clearly indicates that regenerating forests do not have uniform growth, in that different species display different growth rates.

3.6 Mortality in Natural Forest

Study on mortality in the natural forest requires long term observation, preferably of large trees. The present Research Plots have not been established long enough to provide this information. However, rates of mortality in R.P. 18 over the 12 year period 1957 - 1969 are summarised as follows:

Girth Class (ft.)	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number in 1957	225	70	38	35	17	19	11	4	3	0	3	2 5?	457
No. died 1957-69	60	19	14	5	5	1	0	1	0	0	0	1	105
Mortality percent	24	27	37	41	29	5	-	25	-	-	-	50	23

For trees of 5 ft. and larger the mortality percentage was 13.5 or a little over 1 percent per annum. Mortality was offset by ingrowth and there were 59 trees of 5 ft. and over in both 1957 and 1959. Clearly at any given time the changes taking place locally within the natural forest are adjusting overall stocking. 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 reflects the state of dynamic equilibrium.

3.7 Harmful Plants (Species) and Methods of Elimination

Harmful plants are defined as species which directly or indirectly impede the growth of economic species, pose as a menace accentuating logging damage in the course of logging, most likely have no commercial value at the present moment or even in the future, as a source of timber or cellulosic material. The most important ones are climbers, climbing bamboo and Ficus species (giant stranglers). All the other woody non-commercial tree species are not considered as harmful plants though may be eliminated by foresters in the management of their forest (see Chapter 7).

The presence of climbers lacing crowns and boles together accentuates damage to the forests during logging and they also impede the growth of commercial seedlings. In some cases, they may cause mechanical damage or deformity to young seedling and saplings.

<u>Table 3.11</u> RP. 370 Segaliud-Lokan F.R. Result of the Climber Study Plots
(6 Months After Treatment) - 1 acre per plot

Treatment	Lower ends alive	Alive with root	Alive with shoot	Alive with root and shoot	Dead	Upper ends alive	Alive with root	Alive with shoot	Alive with root and shoot	Dead	Total
1. Control-cutting (Plots 1 & 3)	16	-	35	3	1,159	23	108	2	41	1,039	1,213
2. Cut and poison lower end (Plots 6 - 8)	22	-	7	2	1,138	28	87	6	44	1,204	1,369
3. Cut and poison upper end (Plots 5 &7)	32	-	30	-	1,054	26	4	-	2	1,084	1,116
4. Cut out and poison upper and lower end (Plots 2 & 4)	4	-	13	-	1,132	4	15	1	1	1,128	1,149

T.C. LIEW, 1974

The author has carried out a number of studies on the abundance of climbers, at different localities in Sabah. The number of climbers of size 1" diameter and above ranges from 140 to 900 stems per acre (see Research Annual Reports, 1971, 1972, species, Phanera excelsa, Tetracra species, Zizyphus horsfieldii, Strychnos ignatii, Mesua species and Uncaria species.

Many foresters, including researchers, claim that climber cutting will induce colonisation of more climbers because of their reproductive capability by way of coppicing. R.P. 370 was established at the Segaliud-Lokan F.R. in 1973. The main object of this R.P. was to investigate the physiological response of climbers to various treatments. Treatments included cutting lower and upper ends of climbers, and poisoning. The results are summarised in Table 3.11. These show that under the control treatment (upper ends only cut), 1039 out of 1,213 stems of climbers were dead after a period of 6 months, compared with 1,084 out of the total of 1,116 stems in the cut and poison treatment No. 3. Thus treatments involving cutting and poisoning with sodium arsenite are marginally more effective methods of eliminating climbers. The results also indicate that treatments with sodium arsenite on lower ends of cuts inhibited coppicing more effectively. From a management viewpoint, cutting of climbers without poisoning is an adequate treatment.

Bamboos are rare or absent in wide areas of virgin forests in Sabah, except for the climbing bamboos (Dinochloa scandens). In virgin forests, climbing bamboos are present in forest gaps which are opened up by fallen trees, landslides and other agencies. They are particularly abundant in the following localities:

(a) wet low-lying areas - parts of Segaliud-Lokan

Forest Reserve; in the lower Kinabatangan F.R. and in Sapi, Sugut and Paitan F.R.

(b) in undulating forests from the Segama River northwards to the lower Kinabatangan River.

(c) in forest on ultrabasic hills.

After T.C. Liew (1973d)

The presence of climbing bamboo in logged-over forests often prevents the establishment of Dipterocarp seedlings at the early stage following exploitation. In one study Liew (1973e) demonstrates that climbing bamboo (Dinochloa species) can be effectively eliminated by cutting, but a combination of cutting and application of Dowpon or Dalapon at a concentration of 10% may be a more effective method of eradication.

Ficus species of the giant stranglers are classified as weed species. The reason for this is that most of these Ficus species are large trees and they often occupy considerable space. For example, Liew and Charington (1972) recorded a Ficus depressa tree having a crown diameter of 100 ft. and a total girth of 131 ft. This tree alone occupies 0.2 acre of forest. In addition, the tree species being strangled are mostly commercial Dipterocarp trees.

Apart from Ficus depressa, Ficus canlocarpa, Ficus benjamina and Ficus xylophylla are common in lowland Dipterocarp forest. In one study, Liew and Charington (1972) found that a $2\frac{1}{2}\%$ solution of 2,4,5-T in diesel oil was effective when applied as basal spray to unbroken bark for killing the giant Ficus.

CHAPTER 4

REGENERATION OF DIPTEROCARP FORESTS

4.1 Flowering and Fruiting

The flowering habits of rainforest plants growing under quite diverse microclimatic condition can be expected to be most varied. Some species, for example, belukars or pioneer species flower and fruit annually. However, the commercial Dipterocarp trees only flower gregariously at long and irregular intervals. In the Malay Peninsular, it has been observed that heavy flowering of most Dipterocarp trees occursat intervals of two to five years (Burgess, 1972). In Sabah, it has been observed that heavy flowering of Dipterocarp trees occurs at intervals of five to seven years (Nicholson 1958; Baur,1964b). For the past 25 years (1949 - 1973), only 4 heavy flowering years of Dipterocarp trees have been recorded. The years are 1955, 1961, 1967 and 1973 (Forest Department Record).

Wood (1956) gave a detailed account of various characteristics of the Dipterocarp flowering season in Sabah as observed in 1955. They are summarised as follows:

i) All montane species flowered much later than the lowland species. Several montane species flowered only throughout part of their range, and in several cases trees near the altitudinal limit of the species were found partly or wholly sterile e.g. Hopea species.

ii) Most species flowered abundantly throughout the crown and in some species the profusion was more striking than in others and depended on the size of the corollas.

iii) Despite the disparity in flowering times, in most of the genera the tendency was for the fruits of those that flowered late to develop faster than those that flowered earlier, except for a few species of Vatica.

iv) All trees of a species growing at a similar altitude flowered throughout Sabah within a period of a few weeks.

However, according to the recent investigation it has been observed that not all trees of a species growing at the same altitude and soil type will flower in a gregarious flowering year. In one investigation, 22 Dipterocarp trees of various species out of 39 (i.e. 56%) recorded flowering during the heavy flowering season in 1973 (Table 4.1). The same Table also shows that some trees of a species did not flower during that year, though they were growing in close proximity to flowering trees.

Table 4.1

Summary of 1973 observation of Phenological Trial in Kalabakan F.R. (RP. 324/B)

Species	Flowering	Total
Shorea leprosula	11	16
Shorea parvifolia	8	13
Shorea pauciflora	1	2
Shorea argentifolia	1	3
Hopea sangal	-	1
Hopea nervosa	-	1
Parashorea malaanonan	1	1
Parashorea tomentella	-	1
Shorea exanthophylla	-	1
	22	39

Percentage of flowering = 56%

N.B. The phenological trial was established in early 1971. None of the trees flowered in 1971 and 1972.

However, there are occasional Dipterocarp trees which flower and fruit in non-gregarious flowering years. According to past observations, a certain number of Parashorea and Dryobalanops species flower and fruit every year in virgin and logged-over forests (Cockburn, personal communication).

Little is known about the causes of gregarious flowering and fruiting of Dipterocarp trees though drought appears to be one prerequisite of heavy flowering (McClune, 1966; Poore, 1968). In Sabah, a severe drought occurred during the period between February and May in 1973, and there was heavy flowering of Dipterocarp trees immediately after this period. Similar phenomena were recorded for the past heavy flowering years. However, Burgess (1972) made a detailed study on the phenology of Dipterocarp trees. He found that there is no direct correlation of rainfall and flowering of Dipterocarp trees. There is, however, certain circumstantial evidence that flowering is not unrelated to water stress. For example, flowering of Dipterocarps occurs in a greater number of years in the dry zone of Kedah then in the rest of the Malaya Peninsula (Burgess, 1972). Also the forests of the Jelebu/Pilah appear to be better stocked with Dipterocarp regeneration then those areas of the Main Range to the north, and that part of Sembilan has a yearly pronounced dry season. Also, the dry area of Darvel Bay in Sabah, and especially the freely draining volcanic soils of the area carry dense stands of Dipterocarps. Burgess (1972) concluded that apart from water stress, other related environmental factors such as temperature, sunshine, and other microclimatic factors may be of equal importance in inducing gregarious flowering of Dipterocarps. In order to investigate the cause of flowering it is apparent that proper designed experiments under controlled conditions are necessary. At the same time, research into physiological changes within the trees prior to flowering and induction of flowering of Dipterocarps is of great importance to forest managers.

Dipterocarp trees normally flower from July or August and onwards during the flowering year, though there is variation exhibited by some species at the same or different localities. Table 4.2 shows the month of commencement of some species during 1972/1973 period. From the Table it may be seen that *Parashorea* commenced flowering in August whereas *Shorea* species only started to flower in December.

The flowers of Dipterocarp trees normally develop into mature fruit within a period of 6 months. *Parashorea* species require a period of 6 months to develop into mature fruits from the date they flower. (Table 4.2). Other species e.g. *Shorea leprosula*, *Shorea parvifolia* etc. require only half of this time period for the process.

Recently research work has been carried out by a Japanese researcher on the percentage of flowers that will eventually develop into mature fruits. It was found that approximately 5% of the flowers develop into viable mature fruits (Tamari, 1974). To date no work has been done on the absolute number of fruit that a Dipterocarp tree may produce when it is flowering.

Table 4.2

Summary of the observations of Phenological Trail at Beaufort Hill Forest Reserve (R.P. 374) (1972/1973)

Species	1972		1973	
Parashorea	Flowering Fruiting	August Sept-Dec.	Fruiting Fruit fall	January February
Shorea agami	Flowering Fruiting	August Sept-Oct.	Flowering Fruiting	Feb-March May-July
Shorea pauciflora	Flowering	Sept-Nov.	Fruiting	January
Shorea fallax	Flowering Fruiting	Sept-Oct. Nov.-Dec.	Fruiting -	January -
Shorea parvifolia	Flowering Fruiting	Oct. Nov.	- -	- -
Shorea macroptera	- -	- -	Flowering Fruiting	March-May June
Shorea oleosa	Flowering Fruiting	Oct. Nov.-Dec.	Fruiting -	January -
Shorea parvifolia	Flowering Fruiting	Oct. Nov.-Dec.	Fruiting -	January -

Several emergent Parashorea tomentella in the logged-over forest which flowered in 1970 in the Kinabatangan area were as small as 5 ft. girth (48 cm. diam.). Several 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 in 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 and 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 dependent on canopy position. This is of considerable importance for further seedling recruitment into regeneration stands. The data presented by Ng (1966) for planted stands suggest 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 inches per annum is achieved.

4.2 Seed Dissemination

Seeds of all Dipterocarp species are large in size and possess 2 to 5 wings depending on species. For example, the diameter of Parashorea tomentella seeds averages approximately 2 centimeters without wings (Table 4.4). The length of the wing of this species averages about 10 centimeters. The average weight per seed with wings is approximately 0.5 gram (Chai, 1973). The weight and length of wing of other species are well documented by Meijer and Wood (1964). Seeds are dispersed by wind or storm.

Table 4.4

Average Number per Kilogram and Size of *Parashorea tomentella*

	No./Kg.	Size (cm.)	Wing Span (cm.)
With Wings	195	12.86	
Without Wings	208	2.17	10.79

After Chai, 1973.

Though Dipterocarp seeds or fruits are in possession of wings they usually fall from the tree almost vertically and glide spirally down to land with the wings uppermost in the manner of a shuttlecock. That is why seedling density normally decreases rapidly away from the parent tree. However, lighter fruits may occasionally be distributed further by the gust winds which precede thunderstorms (Poore, 1968). Nicholson (1964) recorded that a good distribution of *Parashorea tomentella* fruits occurred up to 1.75 chains from the parent. A detailed study was carried out in 1967 to examine the patterns of distribution of Dipterocarp seedlings. Ten trees of various species which were fruiting at that time were chosen for the study. Around each parent tree on each of the north, south, east, west, north-east, south-west, north-west and south-east radii six milliacre plots were marked out at $\frac{1}{2}$, 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$ and 3 chains from the parent tree - i.e. 48 plots per tree. Similar patterns of distribution were obtained for all tree species investigated in this study (Table 4.5), that is, seedling density decreases with distance from the parents. For example, after a seedfall in 1967 the number of *Parashorea tomentella* seedlings recorded at half a chain from the parent tree was as high as 27,500 seedlings per acre, but only 1,875 seedlings per acre were found at the region three chains from the parent tree (Parent tree No. 3 - Table 3). However, mortality of seedlings was also greater in the immediate vicinity of the parent trees.

Table 4.5

Distribution of seedlings around the parent trees four years after seedfall.

Figures in parenthesis are the original number of seedlings developed immediately after seedfall.

Parent Trees	Distance in Chains						Per Acre
	½	1	1½	2	2½	3	
	No. of seedlings per acre						
. KPU	250 (11000)	250 (2625)	500 (625)	125 (125)	– (–)	– (–)	187 (2395
. UMB	2875 (9375)	5500 (18125)	4250 (16250)	3625 (16750)	3500 (5250)	875 (–)	3437 (1095
. UMB	2375 (27500)	5250 (25500)	1375 (12125)	500 (10375)	500 (6500)	250 (1875)	1708 (1397
. UMB	1250 (14125)	2250 (19500)	1125 (12125)	500 (5375)	2375 (16875)	375 (16875)	1312 (1308
. SKG	* –	375	125	–	–	–	83 –
. KPJ	125 (9125)	125 (5000)	– (750)	– (500)	– (–)	– (–)	42 (2562
. SP	125 (7750)	375 (1500)	– (–)	– (–)	– (–)	125 (–)	104 (1541
. SKP	250 (1750)	125 (1125)	125 (250)	375 (–)	250 (125)	– (–)	187 (542
. SBDH	625 (88750)	375 (80000)	375 (36250)	125 (10250)	125 (2125)	125 (1250)	292 (3643
0. SKG	7125 (74625)	2250 (51875)	375 (12375)	125 (8125)	125 (–)	– (–)	1667 (2450
Totals er acre	1500 (27111)	1687 (22806)	825 (10083)	537 (5722)	687 (2722)	162 (2222)	899 (1177

After Liew and Wong (1973).

* Data not available.

Note : KPU = Dipterocarpus caudiferus
UMB = Parashorea tomentella
SKG = Shorea gibbosa
KPJ = Dryobalanops lanceolata
SP = Shorea parvifolia
SKP = Shorea ovalis
SBDH = Shorea superba

Poore (1968) suggested that S. macroptera has the largest wings with respect to weight and could thus be carried furthest. The following length/weight ratios were determined from fruits collected in 1967 - 69 in Sabah:

Table 4.6

Ratio of length in centimetres over weight in grams

Species	Ratio
P. tomentella	1.9 - 2.9
P. malaanonan	3.8 - 4.5
S. argentifolia	7 - 10
S. leprosula	11.6
S. macroptera	7.5
S. parvifolia	15
S. pauciflora	1.5
S. beccariana	0.7
D. caudiferus	1.1
Dr. lanceolata	1.5 - 2
D. grandiflorus	0.4 - 0.6

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

For those species with ratios lower than 1 in the above list, it is expected that they tend to be gregariously distributed around the mother trees. Species with small wings and low overall weight, e.g. *S. parvifolia* and *S. leprosula* may be expected to be well distributed. However, according to Table 4.6 *S. parvifolia* did not exhibit this phenomenon. Therefore, it should be stressed that further information on the dynamics involved is needed.

4.3 Longivity and Germination of Seed

Dipterocarp seeds do not possess either physical or physiological dormancy. The viability period of the seeds is extremely short and normally it is less than 2 weeks. Within this period, they are subject to attack by insects such as weevils or eaten by wild pigs and other animals as all Dipterocarp seeds contain a high level of carbohydrates. As mentioned in the previous Section, seed fall usually occurs just before a heavy storm. As a result, the environmental conditions favour seed germination immediately after seed fall. It appears that moisture is the single most important requirement for germination. For example, Tang and Tamari (1973) demonstrated that germination of *Shorea curtisii* seeds may be prevented by reducing the moisture content of the seed, and the germination process can be reactivated by increasing the moisture content. In virgin forests, the light environment at ground level is extremely poor in terms of quality and quantity (Sunderland, 1974), but germination of seed is still possible. This indicates that light may not an essential condition to activate the germination process of Dipterocarp seeds. However, for the subsequent development of germinated seeds, light is an important factor (Nicholson, 1960).

In one study, Nicholson (1960) found that *P. tomentella* seedlings failed to develop from seed germinated in non-forest soil (R.P. 64; A.R.R.B. 1961). After a period of 8 months only 32 percent had leaves and the remainder were existing on the cotyledons. This may have been a mycorrhizal effect; Singh (1966) has demonstrated the presence of mycorrhiza on all species examined. Notwithstanding, there are many examples of successful germination and growth of both P. tomentella and Dr. lanceolata on exposed subsoil or road-stone 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). 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.

Under nursery conditions, Chai (1973) found that Parashorea tomentella seeds germinate two days after sowing (Table 4.7). The peak of germination period is found between 10-12 days after sowing. Germination continues to occur up to a period of 20 days. He also found that the germination capacity of Parashorea tomentella seeds is as high as 97 percent. In another study by the Research Branch, it was found that the germination capacity of Parashorea malaanonan, Shorea parvifolia and Shorea argentifolia was equally high under nursery conditions provided that the seeds collected were fresh . In addition all the species tested exhibited similar rates of germination.

Table 4.7

Rate of Germination of Parashorea tomentella

Days after Sowing	No. Germinated (average)
2	0.5
4	2.5
6	6.0
8	10.0
10	20.0
12	20.5
14	17.5
16	12.0
18	7.0
20	1.0

After Chai, 1973.

It has been mentioned earlier that the longevity of Dipterocarp seed is very short under natural conditions. Under Section 4.1, it has also been shown that Dipterocarp trees of all species do not flower or fruit regularly. Seed availability for research and artificial reaforestation is a major problem in the management of rainforests. The question is whether Dipterocarp seeds or fruits can be stored under artificial conditions in order to lengthen their viability. Barnard (1950) and Tang (1973) demonstrated that the viability of the seed can be increased to a period of 4 weeks if they are kept in sawdust or charcoal. Under such conditions, the moisture content of the seed is reduced. Therefore, by lowering moisture content of Dipterocarp seeds the longivity period can be slightly extended. It is, however, apparent that a thorough understanding of the physiology of Dipterocarp seeds is essential before a method can be found to store them successfully. Research into this field would be of great importance in forest management.

4.4 Seedling, Ecology and Physiology

This Section examines the abundance, recruitment, pattern of distribution with respect to parent trees, mortality and growth of Dipterocarp seedlings in virgin forests and their response to various degrees of opening of forest canopy.

4.4.1 Density in Virgin Forests

The density of Dipterocarp seedlings fluctuates within both virgin and logged-over forests. For example, a high seedling stocking may follow a heavy seedfall in a forest with a normally low density of Dipterocarp seedlings. Alternatively, the seedling density may be greatly reduced after floods in low-lying areas. Nicholson (1965) briefly cited the abundance of seedlings at two localities in Sandakan. Since his studies were made, considerable research data have been accumulated, showing that the abundance of seedlings in virgin forests varies greatly with forest types. It is lowest in lowlying forest (Sapagaya Forest Reserve) which is subject to floods, and the highest in sandstone ridge forest type and volcanic soil forest type (Table 4.8). Possible seedling abundance may be related to floristic richness of the forest. For example, it is possible that both the Sepilok F.R. (sandstone ridge type) and Madai F.R. (volcanic soil type) are the richest Dipterocarp forests floristically in Sabah. The abundance of seedlings in the typical undulating lowland Dipterocarp forests normally ranges from 10,000 to 20,000 per acre though different figures may have been quoted by other authors. Table 4.8 also shows that the Tawau Hills Forest Reserve is comparatively low in Dipterocarp seedlings. This is mainly attributed to the step topography and possibly the loose soil derived from andersite. All the forest types listed in Table 4.8 are characterised by the prevalence of members of Urat Matas (mainly <u>Parashorea tomentella</u> and <u>Parashorea malaanonan</u>), and in most types this group of species forms the most abundant seedling regeneration (Table 4.9). <u>Shorea leptoclados</u>

Table 4.8

The abundance of seedlings in various virgin forest types

Forest Reserve	Seedling per acre	Remarks
Sepilok RP. 17	30,000	On sandstone ridge
Sepilok RP. 28	35,000	"
Silabukan RP.200	19,350	Typical indulating forest Dip. lowland forest
Segaliud-Lokan RP.212	11,500	As above
Madai RP. 311/1	27,680	On volcanic soil
Madai RP. 311/2	35,880	As above
Tawau Hills RP.348/1	2,985	Steep or Hill forest Soil derived from andersite
Sapagaya RP. 243/1	1,313	Lowlying forest, subject to floods

(SMJ) is the most abundant single species recorded on the forest floor. This species is normally found in great abundance on well-drained soil of the lowland Dipterocarp forest in the East Coast of Sabah. The occurrence of Shorea pauciflora (OS) is rather localised and was only recorded in the volcanic soil forest type. This species is also present as scattered trees in other rich lowland Dipterocarp forests e.g. Kalabakan Forest Reserve. Both Shorea parvifolia (SP) and Shorea leprosula (STE) form another important group in the lowland Dipterocarp forest. The latter is normally found in flat land. Dryobalanops lanceolata (KPJ) also abounds. With the exception of Shorea pauciflora all the species referred to are important timber-export species (Liew et al. 1972).

Table 4.9

The most common Dipterocarp seedlings and their abundance at various localities

F.R.	Common Dipterocarps seedlings per acre									Remark
	UM	SMJ	SP	STE	KPJ	KPU	SB	OS	SKG	
Sila-bukan	4200	2050		1100	650	750	2590			Random plots
Seg-Lokan	1556	4722	722		722	1833	444			"
Seg-Lokan	2375	125	896	917	208	83	167		500	System Plots
Madai	18680	1920	5200	1640	160			80		"
Madai	6800	6280	16520	3800	80		200	2200		"
Tawau Hills	539	615	214	190	1244		11	127	13	Random Plots

Note: UM = _Parashorea_ species (mainly _P. tomentella_ and _P. malaanonan_)

SMJ = _Shorea leptoclados_

SP = _Shorea parvifolia_

STE = _Shorea leprosula_

KPJ = _Dryobalanops lanceolata_

KPU = _Dipterocarps caudiferus_

SB = _Shorea_ section of Shorea

OS= _Shorea pauciflora_

SKG = _Shorea gibbosa_

+ = Type 1 forest

++ = Type 1 forest

* = Type 2 forest

** = Type 5 forest

4.4.2 Mortality and Recruitment in Virgin Forests

Survival of seedlings in the regeneration pool in virgin forests in Sabah and West Malaysia has been comprehensively dealt with by Barnard (1956) Wyatt-Smith (1958) and Nicholson (1964, 1965). Survivals of seedlings recorded in Sabah are 87.9%, 59.5%, 51.4%, 42.7% for the first, second, third, fourth and fifth years respectively, disregarding recruitment occurred during that period (Nicholson, 1964). However, in the rich volcanic soil of the Madai Forest Reserve it was recently found that the survival percentage was as high as 96% after the first year.

During the investigation of seedling distribution patterns all seedlings found within 48 milliacre plots around each parent were pulled out at the time of plot establishment in 1967. Following a heavy seedfall in the same year, all recruited seedlings were recorded and marked accordingly. Subsequent assessments were carried at intervals of one year. At the end of the fourth year it was found that survival ranged from 0.8% to 16.9% of the original number of seedlings recruited and that survival percentage varies with species (Table 4.10). For example, survivals of the original recruitment of <u>Parashorea tomentella</u> seedlings were 41.95%, 24.48%, 22.74% and 16.90% for the first, second, third and fourth years respectively. Therefore, the seedlings may be extremely dense following a heavy seedfall but only a small percentage may survive and be added to the regeneration pool. Undoubtedly the mortality rate would have been higher still, if the original seedlings had not been pulled out when the plots were established, but had been left to compete with the new seedlings. The high mortality of seedlings is not a hazard in terms of regeneration as deaths occur firstly among seedlings in the competitive struggle.

From Table 4.10, it may also be noted that <u>Parashorea tomentella</u> (UMB) seedlings show the highest percentage of survival in the recruitment study. This may possibly account for its abundant distribution in the East Coast of Sabah.

Table 4.10

The survival percentage of seedlings after a heavy seedfall

Species	Species/acre (Mean)						
	UMB	KPU	SKG	KPJ	SP	SKP	SB
lot No.	T2,T3,T4	TI	T10	T6	T7	T8	T
/10/67	12,727	2,395	24,500	2,562	1,541	542	36,4
/7/68	5,339	104	3,666	146	542	417	2
from original No.	41.95	434	14.96	6.69	35.17	76.93	0.
/8/69	3,116	187	2,500	62	187	333	3
from original No.	24.48	7.80	10.20	2.41	12.13	61.43	0.
/7/70	2,895	208	2,000	83	208	292	4
from original No.	22.74	8.68	8.16	3.23	13.49	53.87	1.
/8/71	2,152	187	1,667	42	104	187	2
from original No.	16.90	7.80	6.80	1.63	6.74	0.80	0.

Note : KPU = *Dipterocarpus caudiferus*
UMB = *Parashorea tomentella*
SKG = *Shorea gibbosa*
KPJ = *Dryobalanops lanceolata*
SP = *Shorea parvifolia*
SKP = *Shorea ovalis*
SBDH = *Shorea superba*

From the records of various Research Plots, Dipterocarp seedlings can survive more than 10 years in virgin forests though light intensity reaching the forest floor ranges from 0.2 to 0.7% of full sunlight (Sunderland, 1974). Light quality is poor in terms of photosynthetically active radiation. Dipterocarp seedlings surviving in the regenerating pool for a long period can be attributed to high photochemical efficiency (Sunderland, 1974).

seedling regeneration plots in the first few years after logging (see Research Annual Report, 1964). The most detailed research study has been done in Silabukan F.R. on this subject (R.P. 200). Prior to logging, 20 randomised milliacre plots were established to assess the stocking of seedlings. Eight months after logging the stocking was reassessed. Subsequent reassessments were carried out at intervals of one year. From Table 4.16 it may be seen that some 14,000 seedlings were lost from one acre of forest during the period immediately prior to logging, and 8 months after logging. However, it is believed that a fair proportion of these seedlings was lost during logging. At the end of the 3rd year the survival was 13.7% of the original number of seedlings present on the forest floor. In spite of the high mortality, there is no apparent change in seedling composition before and after logging, suggesting that individuals of all important species can be perpetuated under logging, and that logging may have little effect on the relative species composition of the stands.

It may be of considerable interest to note that the density of seedlings of Dipterocarpus caudiferus and Dryobalanops lanceolata has become almost static since 1968 (Figure 4.1).

higher as some of the leaders of the plants were damaged mechanically.

The mean girth of the seedlings in 1971 (11 years after seedfall) was approximately 8.19 inches. Normally, in a 10 year old lowlying and poor regenerating forest at Segaliud-Lokan F.R. (i.e. same locality), the mean girth (40 best trees per acre) is about 12.0 inches. In contrast, in a nine year old undulating but richer logged-over forest of the same Forest Reserve the mean girth is about 14.8". This suggests that it may be better to emphasise management of the regenerating forest, rather than concentrate on planting trees in open areas.

Table 4.15

Growth of seedlings on open grassy land

Species	CAI in feet (Height)		Average ht. in feet 1971	Mean Girth in inches as at 1971
	1966 - 69	1969 - 71		
KPJ	0.8	3.1	18.4	5.9
UM	2.9	5.0	29.3	8.3
UMB	1.5	2.7	20.6	13.7
STE	2.7	4.8	33.7	15.5
KPU	0.6	2.4	23.8	7.9
SP	2.0	0.8	22.8	5.9
SMJ	1.4	6.0	32.5	10.1
Weighted Mean			21.3	8.2

(d) Seedling Regeneration in Logged-over Forests with Particular Reference to Mortality

Studies on seedling regeneration plots have been established to assess the density of seedlings in logged-over forests because it is extremely difficult to establish was established to study the mortality, growth and physiology of the seedlings in this open grassy area. At the time of establishment of the research plot the height of all seedlings ranged from 8 feet to 15 feet.

The following Table 4.14 shows the survival of these seedlings from 1966 till 1971.

Table 4.14

The survival of seedlings on open grassy land

Year	1966	1967	1968	1969	1970	1971
No. of Seedlings	138	126	126	123	123	117

Note : Seedlings came up after heavy seedfall in 1961.

Generally, it may be expected that mortality of Dipterocarp seedlings in an exposed environment may be high as they require shade for growth and development at the early stage (Nicholson, 1960). From Table 4.14 it can be noted that once seedlings have established themselves in open areas, they can tolerate exposed conditions. High mortality might have occurred between 1961 to 1965 prior to the establishment of the plot, in view of the recruitment study of Dipterocarp seedlings examined earlier.

The height growth of the seedlings is rather irregular (see Table 4.15). The table indicates that height growth of Dryobalanops lanceolata is much slower than Parashorea tomentella and Shorea leprosula. The height growth of Parashorea tomentella could have been

A second study was also initiated in 13 year old regenerating forest at Silabukan F.R. to examine growth of the latest recruited seedlings. It was found that height growth (CAI) of these seedlings was 2.4" which is equivalent to the growth of seedling present in the virgin forest (see Table 4.13). This suggests that late-recruited seedlings, ten years or so after logging, would never have a chance to grow into trees of commercial size during the next cutting cycle, unless forest gaps were opened in the course of forest treatment or there was mechanical damage to the overstorey. However, there would be little point in liberating any seedlings in the older regenerating forests which are already stocked with sufficient polesized trees.

Table 4.13

Growth of seedlings in a 13 year old regenerating forest at Silabukan Forest Reserve

No. of Seedlings	Mean Ht. in inches	No. of Seedlings	Mean Ht. in inches	CAI in inches
51	12.5	40	14.9	2.4

(c) Mortality and Growth in Open Area

Tractor paths or landings can be restocked with Dipterocarp seedlings a few years after logging if seed trees are present in the vicinity. A clear example can be seen around the old halting bungalow (at mile 6), Segaliud-Lokan Forest Reserve which is about 56 miles away from Sandakan. The area in question was bulldozed in 1957. After a heavy seedfall in 1961, Dipterocarp seedlings came up on the area. In 1966 a research plot

Table 4.12 clearly indicates that seedlings, which were already present on the forest floor, responded vigorously to heavy opening of forest canopy. Various species of seedlings attained the height increment (CAI) of 4' to 6' (Table 4.12). Therefore, the height growth of seedlings is very much greater under heavy opening of canopy, than that of seedlings in virgin forests treated with a light liberation only. It can also be noted that height growth gradually declined over time after logging. This may suggest that growth of seedlings may have been impeded by colonisation of various climbers and possibly belukars which normally swarm up soon after logging (Liew, 1974c).

Table 4.12

Growth of Dipterocarp seedlings with time after logging
(Both CAI and Mean height are in feet)

Species	1967-68	1968-69	1969-70	1970-71	Mea 1
1. KPJ	4.6	6.0	1.9	2.7	1
2. New recruit of KPJ	-	-	-	2.2	
3. SMJ	4.0	2.7	2.6	2.1	1
4. STI	4.5	2.7	1.3	2.5	1
5. UM	6.4	3.3	1.0	1.1	
6. *Keruing	-	3.9	2.3	2.2	1
7. *SKG	-	3.2	2.8	2.0	1
8. *SP	-	3.3	2.7	2.0	1
9. *STE	-	2.6	1.9	1.0	
10. *KPG	-	3.2	1.7	1.7	1
11. *SMIN	-	4.9	5.3	2.9	1
12. *SJG	-	2.1	4.7	1.9	1
13. *SME	-	3.3	4.2	2.2	1

* The seedlings were not included in the study at the time of the establishment of the plot.

contrast the height growth (CAI) of seedlings of similar size was 17.3" in the liberated block (Table 4.11). When compared with the seedling growth increments on the Madai Reserve, these increment data suggest that the larger the seedlings present on the forest floor, the greater the increment is likely to be, particularly after some liberation treatment is applied.

Table 4.11

Growth of seedlings at two different localities and treatments

Locality	Control Plot					Treated Plot			
	No. of Seedlings at 1st meas't	Mortality	% of survival	Mean ht. in ins.	CAI in ins.	No. of Seedlings at 1st meas't	Mortality	% of survival	Mean ht. ins.
Madai F.R.	692	24	96.53	11.9	1.3	897	53	95.21	13.5
Segaliud-Lokan F.R.	100	26	74.00	30.3	4.8	100	76	24.00	43.9

(b) Growth of Seedlings in Logged-over Forests

Two studies were established to examine growth of seedlings in logged-over forests. RP.254 was established in Coupe 1967, Kalabakan Forest Reserve. This experimental plot was established immediately after logging and the application of the normal 2nd Silvicultural treatment following logging. Most of the seedlings under study were natural regeneration plus some Kapur paji (Dryobalanops lanceolata) planted in the form of enrichment planting by use of wildings.

4.4.3 Growth of Dipterocarp Seedlings

(a) Growth in Virgin and Lightly Liberated Forest

It is a well known fact that seedlings of various species belonging to the family Dipterocarpaceae almost approach a state of dormancy in undisturbed virgin forest (Baur, 1964). In order to confirm this for Sabah forests, a detailed study of the height growth of seedlings in 1970 was carried out at the Madai Forest Reserve (RP. 311). It was found that 269 out of 668 seedlings measured were practically dormant i.e. there was no height increment over a period of one year. During the same period survival of seedlings was 96.53%. Apart from the dead and dormant seedlings the height increment (CAI) of the growing seedlings ranged from 1" to 3", though a limited number of them achieved as much as 5" growth. The average height increment (CAI) of all seedlings was 1.3" (Table 4.11) compared with 0.48" obtained by Nicholson (1965) for poor quality lowlying situations at the Segaliud-Lokan Forest Reserve. The relatively greater height growth of seedlings at the Madai Forest Reserve is mainly attributed to the rich volcanic soil of that forest. Therefore, it may be seen that the behaviour of seedlings in virgin rainforest varies with forest types or soil types, though other foresters or researchers who have little experience in the tropics may not accept this view.

There is some body of evidence that height growth of seedlings varies not only with forest types or soil types but also the actual size of seedlings present. In a detailed study carried out in a typical undulating forest at the Segaliud-Lokan Forest Reserve which is about 42 miles from Sandakan, the seedling height increment (CAI) was about 4.8" in a virgin forest block and the mean height of the seedlings under investigation was 30.3". In

FIGURE 4.1 THE RELATIONSHIP OF DENSITY OF SEEDLINGS AND TIME

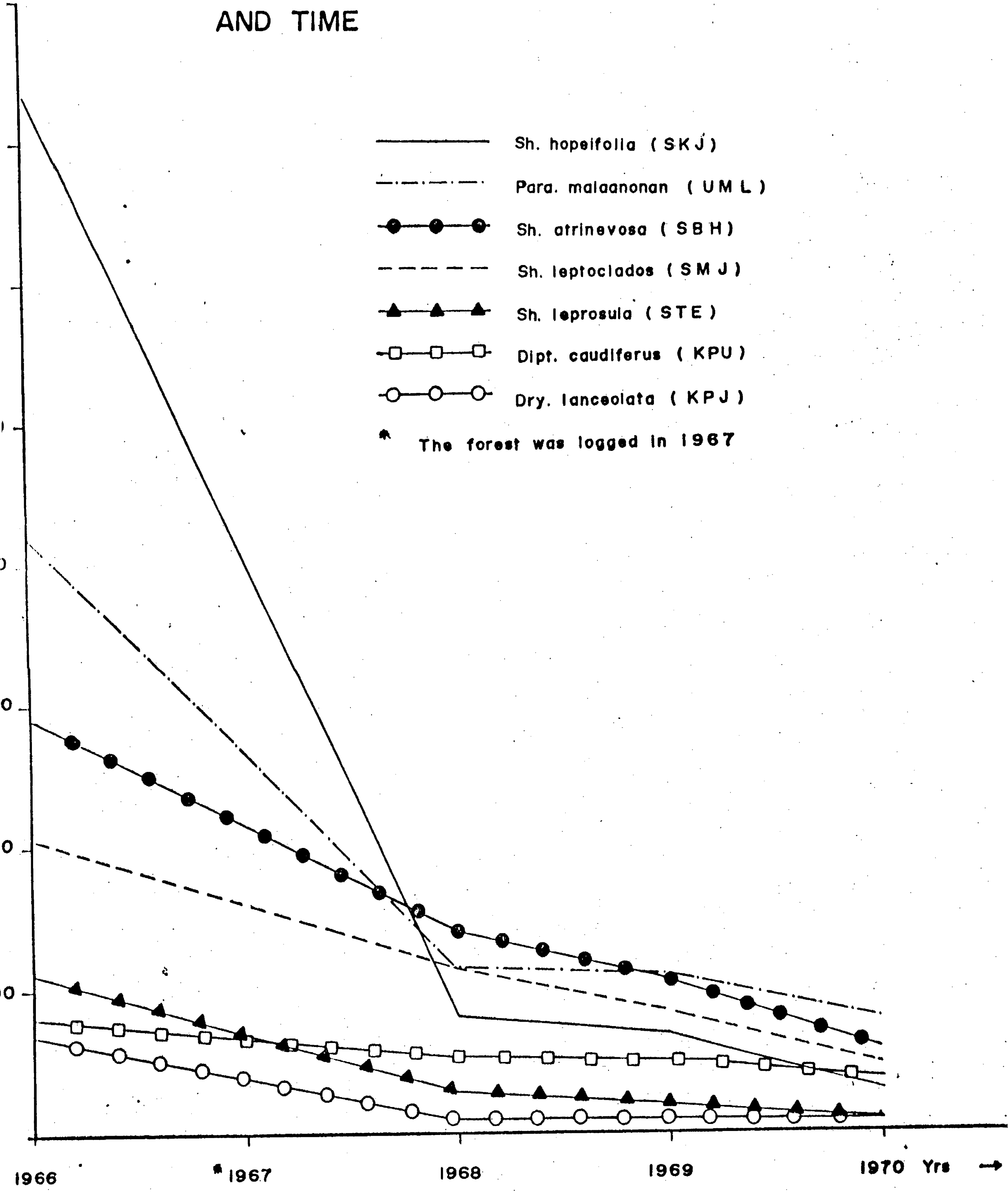


Table 4.16

Composition and abundance of seedlings before and after logging

Species	Before logging (No. per acre) (1966)	After logging (No. per acre)		
		1968	1969	1970
1. SKJ	7,450	850	750	250
2. UML	4,200	1,150	1,100	750
3. SBH	2,950	1,400	1,100	600
4. SMJ	2,050	1,150	900	450
5. STE	1,100	250	200	50
6. KPU	750	500	500	400
7. KPJ	650	50	50	50
	19,350	5,350	4,600	2,450

The relationship between density of seedlings and time period is also illustrated graphically (see Figure 4.1).

CHAPTER 5

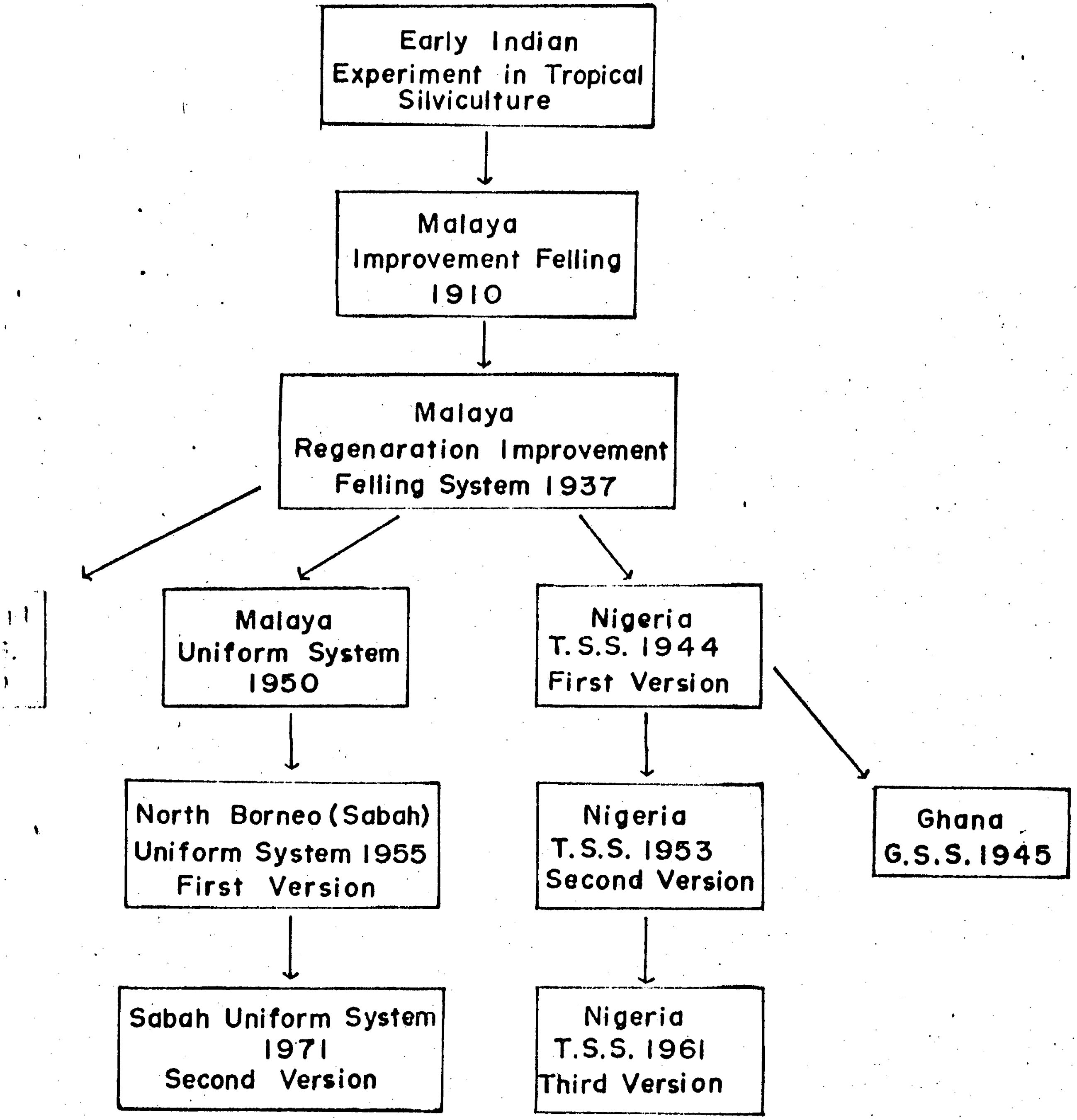
SILVICULTURAL METHODS IN RAINFORESTS

5.1 Introduction

Since the turn of the 20th Century, a considerable amount of research has been directed to developing sound silvicultural systems for exploitation of rainforests in various parts of the world. The main stream of the development of rainforest silviculture is shown schematically in Figure 5.1. From Figure 5.1, it may be seen that rainforest silvicultural systems were evolved from the early Indian experience in tropical silviculture. All the systems developed have one common management objective i.e. to regenerate evenaged or unevenaged stands of rainforests by natural regeneration systems with or without enrichment planting following exploitation. Different systems were evolved to suit local conditions as rainforests vary greatly in structure, species composition, patterns of species and size class distribution, abundance of regeneration on the forest floor etc. in different regions. For example, scarcity of intermediate size classes of commercial tree species and seedlings had led to the development of the Tropical Shelterwood System in Nigeria in 1944. Under this System, the forest was manipulated with the aim of inducing the establishment of a commercial crop before felling took place. On the other hand, the tropical Lowland Dipterocarp forests in Peninsular Malaya are stocked with abundant regeneration on the forest floor; the Malayan Uniform System was developed on this basis by Wyatt-Smith in 1950. However, it is now a well-known fact that this Malayan Uniform System cannot be applied to the hill forests because of scarcity of seedlings and prevailent members of Bertam, (a stemless palm) in the

Figure 5·1

Development of Silvicultural System in Rainforests



After Baur, 1962 with Modification

T.S.S.= Tropical Shelterwood System

hill forests. To date the Malaysian Foresters have yet to develop a silvicultural system for the management of the hill forests.

Though to date several recognised silvicultural systems have been developed, silvicultural treatments practised are remarkably similar. Basically there are two phases of treatments, viz., prelog and post-exploitation treatments. The main objective of prelog treatments is to refine the forest conditions with the aim at either improving the growth and stocking, or minimising logging damage. Such treatments include climber cutting, elimination of non-commercial trees etc. in various strata (Table 5.1). Post-exploitation treatments normally involve removal of non-commercial trees, climbers, bamboos and other harmful plants with the aim of creating a favourable environment (sufficient light in particular) for the growth of commercial species, as most tropical rainforest commercial species are light demanders. The types of treatment carried out after exploitation are summarised in Table 5.1. In short, though rainforests have been managed under different silvicultural systems, silvicultural prescriptions, particularly post-exploitation treatments, carried out in different parts of the world are similar. Prelog treatments may be omitted depending on management objectives and forest conditions, e.g., size class and species distributions, and the structure of the rainforest. Baur (1964b) outlined a comprehensive guideline for rainforest treatments (Table 5.2).

It must be emphasized that the concept of regenerating even-aged stands of rainforests was phasing out in the 1960's in Malaysia. This was largely attributable to the long rotation and repeated disappointments of the Malayan Uniform System

Squence of Operations in Typical Treatments for even-aged Regeneration

Year	Clear-cutting Malaya	Clear-felling Sabah* (1955 - 1970)	Pre-exploitation Shelterwood Nigeria	Post-exploitation Shelterwood Trinidad	Extended Shelterwood Andamans
Rotation	70 years	80 years	100 years	60 years	?
n - 5	(Ru) (1)	-	C, CC, Ru	-	Ru (9)
n - 3	(c) (2)	-	-	-	
n - 2	(CC) (3)	-	-	-	
n - 1	-	-	-	CC	CC
n	S, F, Ro, Ru (4)	F, S, Ro, CC	F	F	F, Ru
n + 1	-	-	-	Ru, Ro (P) (8)	L, C, CC
n + 2	(L) (5)	-	CC (L)	L	L, C, CC
n + 4	-	-	-	CC, L,	-
n + 5	S (CC, L, T, Ru) (6)	SCC, Ro. L.	-	CC, L, Ro	-
n + 6	-	-	-	T	T
n + 9	-	-	S (7)	-	-
n + 10 to 15	S (CC, L, T, Ru) (6)	Ro, L	-	-	-

After Baur, 1964a with modification.

Continued Table 5.1

Note : Ru = Understorey Removal
CC = Climber cutting
TM = Tree marking
Ro = Overstorey Removal
C = Understorey cleaning
F = Exploitation
P = Artificial Regeneration
L = Removal of impeders
T = Thinning
S = Diagnostic sampling

* Though Clear-felling was officially adopted in 1955, extensive treatments were only carried out from 1958 to 1970 in Sabah. However, towards the middle of 1960's management objective was to shifted to regenerate uneven-aged stands of forests though the change had not been officially adopted.

Table 5.2

Indicators for Rainforests Treatment

Situation	Action
(1) Forest not currently accessible for exploitation	(2)
(1x) Forest available for exploitation now or in near future	(3)
(2) No finance available for treatment	Reserve and protect
(2x) Finance available for treatment	Improvement treatment (e.g. Congo : uniformisation par le haut)
(3) Management for indirect benefits (e.g., watershed protection, recreation) paramount	Selection system (e.g., Puerto Rico)
(3x) Management for timber Production paramount	(4)
(4) Intermediate size classes plentiful; royalty rates make retention of these desirable	(5)
(4x) Intermediate size classes relatively scarce	(6)
(5) Severe opening of stand deleterious	Selection system (e.g., New South Wales)
(5x) Severe opening not deleterious	Group selection (e.g., North Queensland)

Situation	Action
(6) Desirable regeneration adequate in virgin forest, or occurs readily with exploitation	(7)
(6x). Regeneration not naturally adequate	(8)
(7) Regeneration capable of responding to sudden and complete increase in light and exposure	Clear-cutting (e.g., "Uniform System" of Malaya and Sabah, formerly known as North Borneo)
(7x) Regeneration needing partial shelter for some years	Post-exploitation Shelterwood (e.g., T.S.S. of Trinidad)
(8) Regeneration induced by canopy opening and cleaning	(9)
(8x) Regeneration not readily induced naturally	Artificial regeneration possibly combined with some other type of treatment (e.g., Reunion; North Queensland in part)
(9) Regeneration, once induced, responding to complete light and exposure	Pre-exploitation shelterwood (e.g. T.S.S. of Nigeria)
(9x) Regeneration after inducement still requiring shelter for some years	Extended Shelterwood (e.g., Andamans)

After Baur, 1964b.

in Peninsular Malaysia and the modified Malayan Uniform System in Sabah. Subsequently, a "bicyclic felling" system was proposed by the Forest Department for management of timber-complex concession forests in Peninsular Malaysia in 1974 (Tang, 1974) and was finally adopted in 1975. Under this system, an economic crop in twenty-five years is envisaged. Tang (1974) cast a great deal of doubt on the workability of the system in the light of the forest conditions and the short cutting cycle. Since 1971, considerable efforts have been made to retain intermediate size class trees in Sabah with the aim of producing an economic intermediate cut between rotations. Thus the modern trend of silvicultural development is to adopt a system which preferrably has a short cutting cycle in order to meet the requirements of politicians and decision-makers.

Though considerable efforts have been made by foresters in pursuing sound silvicultural systems for managing rainforests in different regions, Leslie (1977) pointed out that " Far too little is known about silvics and the silviculture of the different moist forest communities and thus appropriate silvicultural systems can be confidently prescribed for only a few limited areas." All that needs to be done is to find the appropriate variation of monocyclic or polycyclic management for the conditions applying in a specific forest. But almost universally, it seems that the search for appropriate methods is a particularly difficult and unrewarding task (Leslie, 1977). Thus, after a century or so of determined effort to mould the tropical moist forests into a managed natural state, the solution to the problem is apparently to be found in abandoning the natural forest. It has been therefore commonly accepted that the replacement of natural forests by plantation is a rational move toward making the future wood supply in tropical areas much less uncertain.

5.2 Pre-log Treatments

5.2.1 Review of the Development of Pre-log Treatments in Rainforest Silviculture

.In the previous Section brief mention was made of pre-exploitation treatments. Pre-log treatments were introduced as part and parcel of various silvicultural systems in the management of rainforests in some parts of the world, because it was found from past experience, that failure of rainforests to regenerate following exploitation was mainly attributable to paucity of commercial crop trees in various strata. Therefore the main objective of pre-exploitation treatment is to establish a reasonable tree crop by a series of intensive manipulations of the forest prior to logging. An early silvicultural system comprising pre-log treatment was Regeneration Improvement Felling (R.I.F.). This system was practised in Peninsular Malaysia and Sabah prior to the introduction of the Malayan Uniform System in 1950 (Baur, 1964a). The treatments involved were mainly removal of harmful plants and weed species which impeded or prevented establishment of commercial crop trees in various strata. In Sabah, the Sapagaya Forest Reserve was treated under the precriptions of Regeneration Improvement Felling System in 1947 (Forest Department Management Record). The treatments carried out were (a) Elimination of giant <u>Ficus</u> and weeds species e.g. <u>Eugenia</u> species, by poison girdling, and (b) Climber cutting prior to logging. The objective of the treatment was not to improve the stocking of the forest but rather to stimulate the growth of seedlings prior to felling.

In Nigeria, pre-exploitation under the Tropical Shelterwood System (T.S.S.) involved intensive treatments. The original sequence of operations was as follows:

Year	Operation
1	(a) Demarcation of compartment
	(b) Climber cutting and seedling assistance
	(c) Removal of middle storey canopy
2	(a) First Regeneration count and climber cutting
	(b) Second opening of canopy
3	First and second cleaning
4	(a) Third and fourth cleaning
	(b) Second Regeneration
5	Fifth cleaning or (Exploitation)
8, 12, 16 etc.	Pre-exploitation cleaning
n	Exploitation
$n + \frac{1}{2} + 10$	First post-exploitation cleaning
n + 3	Second post-exploitation cleaning
n + 8	Third post-exploitation cleaning
n + 13	Fourth post-exploitation cleaning

After Baur, 1964a

It can be clearly seen that the system requires a comprehensive forward planning which also incurs heavy expenditure in samplings and treatments. This may be the major drawback of the system because politicians and decision-makers of developing countries could hardly accept long-term pre-log planning of this nature for all forestry operations.

When the Malayan Uniform System was introduced in 1950, pre-log treatments were still practised in Peninsular Malaysia in the Northwest (Baur, 1964a). Between 1955 and 1969 pre-log treatments were not practised in Sabah. Since 1965, heavy equipment has been used in logging operations in Sabah, and damage to the forest has ranged from 30 to 50 percent of the land mass (Liew, 1974). To curtail this undesirable effect, climber cutting prior to logging was introduced in 1971 (S.F.R. No. 8). This followed studies by Fox (1968 a) who demonstrated that damage to pole-sized trees in particular might be halved in areas infested with climbers, provided that climbers were cut 1½ to 2 years ahead of felling. This treatment was also endorsed by Dawkins (1968a) who further recommended that pole-sized trees from 2 feet to 6 feet girth be painted with dazzling yellow paint on 3 sides of the trees. The main objective of these operations is to retain sufficient stems of pole-sized trees to yield an intermediate cut between rotations or cutting cycles.

5.2.2 Comments on Pre-log Treatments

The concept of establishing an economic pole crop of commercial species prior to logging through intensive manipulation of forest canopy and floor is feasible in rainforests, and the Nigerian Forestry Service has successfully regenerated several stands under the regeneration process prescribed in the previous Section (Baur, 1964a). However, in recent years heavy equipment e.g., crawler tractors and high tonnage logging trucks, have been introduced in harvesting rainforests. This results in considerable damage being done to the forests through movement of machinery in snigging and construction of roads. The pole crop raised from pre-log treatments may be lost in the course of logging. Therefore, pre-log treatment may only be useful in a pre-mechanised era or in countries where manpower is the main resource in the development of the nation, e.g. India (Berry, 1974). In Sabah, logging operations are highly mechanised, and damage to the forest amounts to 30-50% of residual stocking (Liew, 1974). Raising a pole crop prior to logging would be a waste of effort, time and expenditure.

Pre-log treatment requires intensive foreward planning (see Section 5.2.1). In most developing countries, South-east Asian countries in particular, timber is one of the main assets to generate income for economic growth. It is difficult to convince politicians and decision-makers to implement long-term planning projects connected with forestry matters. This may be partly due to great demand for hardwood, which tempts producing countries to clear the forests in a hurry and to exploit timber for short-term gain alone.

There are many other problems connected with the implementation of pre-log treatments. However, it must be emphasized that pre-log treatments are not to be abandoned altogether. Sabah is endowed with rich Dipterocarp forests carrying approximately 25 to 40 stems of pole-sized trees per hectare (see Section 5.3.1 cc) (ii). This pole crop may be partly saved provided pre-exploitation treatments, climber cutting and tree marking are being carried out two years ahead of logging (Fox, 1968a; Liew, 1973), though numerous problems are involved in the implementation. This will be discussed in details in later Sections.

5.3 Rainforest Silvicultural Systems

5.3.1 Selection System

(a) Selection System Practised in the Philippines

A selection system has been practised in Puerto Rico and in the Philippines. Under this system, the forest is selectively cut in order to retain its future productivity at the highest possible level: sufficient timber trees for subsequent selective cuts at short intervals are envisaged. The cutting cycle may be 5, 10, 15, 25 or 40 years depending on the amount and size class distribution of the pole crop in the forest. In a sense, timber exploitation is confined to selective removal of emergents, and the commercial trees of the upper forest canopy stratum are not to be damaged (as far as is possible) in the course of the timber extraction. The trees so retained are expected to grow into an exploitable diameter class within a short interval. At the same time, trees of the lower forest canopy stratum are expected to grow to form the upper forest canopy. The forests so managed are uneven-aged and uneven-sized but retaining the structure and composition of the virgin forests.

There are limitations to the applications of the system. For example, the system cannot be applied in Dipterocarp forests where intermediate size classes are few or even absent e.g., the hill Dipterocarp forests in Peninsular Malaysia. The system cannot be applied well if heavy equipment is used in the exploitation of rainforests. Thus the success of the system largely depends on the presence of pole-size trees in the forests and the method of logging.

A selection system was imposed in the Philippines in 1955 (Fox, 1967 b). The main objective in imposing this silvicultural method was that the Philippines Forestry Bureau realised the shortage of hardwood for export and local industries. By imposing a selection system, hardwood timber may be exploited at a slower rate. A recent publication by the Philippines Bureau of Forestry (1965) expounds in considerable detail the method of managing the Dipterocarp forests on a selection basis. Selective logging is defined on page 4 of the Handbook as "the removal of mature, overmature and defective trees in such a manner as to leave uninjured an adequate number and volume of healthy residual trees of the commercial species and other tree species necessary to assure a future crop of timber and forest cover for the conservation of soil and water". Under the system, 60 per cent of the number of healthy trees in the 20 to 70 centimetres diameter classes, are retained. If there are more trees in and over the 80 - centimetre class than below, 40% of all trees over 20 -centimetres are to be marked for retention. The system aims at exploiting 40 per cent of the stand. The Handbook covers details pertaining to

(a) How damage to the residual stand can be minimised
(b) Road and route construction
(c) Felling techniques
(d) Yarding method
(e) The responsibilities of logging company managers concerning the potential roles seen for them by the Bureau of Forestry in implementing the "Selective System".
(f) Three principal phases of the system are given in details:-
    (i) Tree marking
    (ii) Residual inventory
    (iii) Timber stand improvement
(g) Logging plans
(h) Method of recording data
(i) Penalty or fine to be imposed in damaging or injuring the pole crop.

From the foregoing it appears that the Selection System is one of the most difficult forms of silviculture to apply as all rules laid down must be strictly observed both by the private and the public sectors in order to make the system a success. For any departure from the prescribed rules, loggers may be fined accordingly.

The report by Alcarmen (1962) deals with an area of 141 acres within the concession area of Basilan Lumber Corporation. This area was said to have been cut over in 1929 using a diameter limit of 40 cms., and recut in 1959 using a diameter limit of 60 cms, which is a simple form of selective logging. He domenstrated that the second yield (in terms of volume) was not very different from the first and that the difference in numbers of stems cut indicates the relatively small proportion contributed to the outturn by the smaller sizes. Distribution of size classes of various species after the second cut was similar to that of the first.

From Alcarmen's paper it is obvious that considerable scope exists for a 30 year felling cycle. Its widespread success depends on the validity of his data; and the degree to which other forest areas approach the conditions of stocking and the methods of logging used. The system rests on the theory that sufficient medium sized trees can be retained during a harvest to contribute the bulk of the next crop. Seedling and sapling regeneration present on the ground and able to respond to the open conditions would form, initially, an understorey whose growth would provide the residuals for the second cut, and possibly, some of the second cut itself.

The foregoing paragraphs demonstrate that Dipterocarp forests can be regenerated and economic yield can be obtained at a cutting cycle of 30 years, provided an adequate diameter limit is imposed and logging damage is minimum. Dawkins (1958) commented that the system is impracticable and Fox (1967) cautioned that the success of the system has yet to be demonstrated if high lead or cable system is used in logging operations. Nicholson (1970) recommended that the cutting cycle for Dipterocarp forests should be standardised at 40 years, and the rotation at 80 years under the Selection System in the Philippines. These examples suggest that Dipterocarp forest is a renewable asset reflecting the stability of the Dipterocarp forest ecosystem following human disturbance. This provides incentive to forest managers to care for their Dipterocarp forests. Gomez-Pompa et al (1972) warns that rain-forests are on the verge of disappearance and therefore it would appear that a Selection System which maintains a high productivity of the forest should warrant further investigation and research.

Recently another form of Selection System has been developed in the Philippines. The deviation from the original system is that removal of timber is followed by planting of fast growing species on bare areas which are devoid of economic species (Fraser, 1974; Ryres, 1974 - Personal communications). Under this system, one to three trees per hectare are extracted. The trees to be extracted are not necessarily the largest or tallest trees. Trees to be removed are determined by size class distribution, from the actual distribution of timber trees in the forest following intensive inventory. In a simplified term it is a form of thinning. Immediately following timber harvest, roadside tractor paths and areas devoid of economic commercial species are planted with fast growing species, e.g., *Albizia falcataria*. The forest will be due for re-exploitation when the planted trees (*Albizia falcataria*) reach the exploitable size. During the extraction of the planted trees, one to three of Dipterocarp hardwood trees will be removed from the forest, which will be followed by the planting programme as before.

The process will then be repeated indefinitely. The interval between cutting cycles depends on the growth performance of the planted crop in growing commercial size. Normally a period of 5 to 7 years is required. This would mean that the cutting cycle is 5 to 7 years. Figure 5.2 shows the sequence of the operations diagrametically.

The objective of the latest developed Selection System is to further minimise the shortage of hardwood, and to ensure the perpetuity of hardwood supply. As the system involved little disturbance to the forest, it deserves a great deal of attention and further research from a conservation point of view.

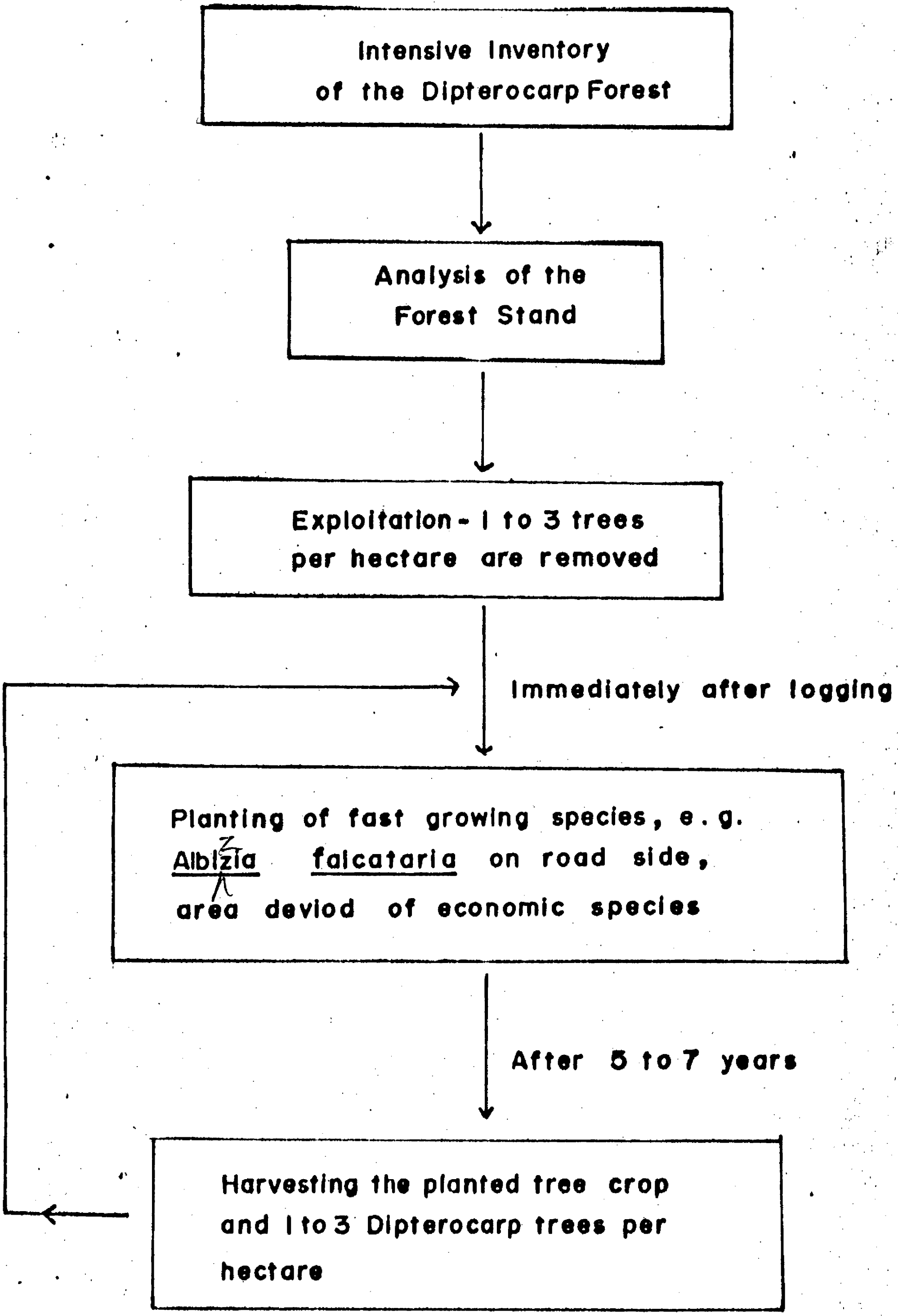
(b) Sabah's Approach (Selection System)

The current silvicultural system adopted for the management of the permanent forest estate of Dipterocarp forests in Sabah (S.F.R. No. 8) can be classified as a simple form of selective logging comparable to the system practised in the Philippines in 1929 (Section 5.3.1 (a)). It has been evolved, taking into account recent investigations.

As mentioned in Sections 5.2.1 and 5.2.2, increased mechanisation in logging operations in recent years has caused concern over the extent of logging damage to soil, seedlings and advance growth (Fox, 1968 a; Liew, 1974). Experiments involving pre-felling techniques to curtail such damage were undertaken (Nicholson, 1965) but the seedling stocking in the unfelled forest has not, thus far, been low enough to consider 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) Methods of stimulating growth of seedlings prior to logging

Figure 5·2

Sequence of Operations between Cutting Cycles in the Selection System
ıctised in the Philippines



ote : Reinventory of the Dipterocarp forest may be necessary between cycles. Roads and tractor paths are pre-laid prior to logging.

been tried (R.P. 60). In the latter experiment, girdling of understorey species gave no detectable improvement but cutting of climbers and woodystems smaller than 1 inch diamater achieved 130 milliacre plots per acre with seedlings of 5 - 10 ft. height, compared with 69 where no treatment was given.

In one study (R.P. 245), it has been demonstrated that larger seedlings are more prone to logging damage. Therefore treatments aimed at increasing seedling height are of questionable value. Destructive logging usually results in reduction of the absolute number of seedlings causing inadequate stocking of seedlings. 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 of pre-exploitation silviculture. A number of measures more specifically concerned with reduction of logging damage, (assessed with repect to the advance growth stems) include general marking of these trees with dazzling paints, climber cutting, and pre-laid tractor paths. All are considered to have some marked effect on the quantity of seedling regeneration.

The preceding paragraphs briefly summarise background to the silvicultural system currently enforced in Sabah. The system emphasizes (a) saving the abundant seedlings already present in the regeneration pool, and (b) retention of intermediate size class trees. The latter objective is aimed at yielding an economic intermediate cut between rotations. Under this system, all trees greater than 6 ft. girth are to be felled and removed. Intermediate size class trees from 1 to 6 ft. are to be retained as far as possible. Felling of defective trees greater than 6 ft. girth is optional. The sequence of operations is summarised as follows:

Table 5.3

Current sequence of silvicultural/ management operations in Sabah

Year	Operation
F-2	Allocation of coupe
F-2 to F-1	First Silvicultural Treatment - Tree Marking and Climber Cutting
F	Felling
F+0-1 month	Clearance Inspection
F+0-2 months	First Assessment of Regeneration L.S.M.
* F+3-6 months	Second Silvicultural Treatment - poison girdling with 2,4,5-T in diesoline
F or F+5 or F+10 years	Establishment of yield plots
F+5 years	Second Assessment of Regeneration L.S.$\frac{1}{4}$
F+5 years	Third Silvicultural Treatment - poison girdling. Treatments are prescribed according to the results of LS$\frac{1}{4}$. Should stocking be too low e.g., only 1/3 or less of the quadrats per acre is stocked with commercial poles or seedlings, enrichment planting may be carried out.
F+10-15 years	Third assessment of Regeneration
F+10-15 years	Forth Silvicultural Treatment - Liberation and refinement

Source : S.F.R. No. 8 1972.

* Note: Second Silvicultural treatment i.e., first poisoning-girdling with 2,4,5-T immediately after logging has been suspended since early 1977 because of excessive opening of forest canopy caused by logging. A study has been made by the silviculturist who was directed by the author to investigate the situation. The results indicate that logging is more than a silvicultural treatment.

The validity and practicability of this simple form of selective logging will be further examined in the following sub-section, and the effects and usefulness of the post-exploitation treatments will be evaluated in later Sections.

(c) Validity of Selective System Under Sabah Conditions

Whether a Selective System is workable under Sabah conditions will largely depend on (i) the effectiveness of climber cutting and tree marking prior to logging in minimising logging damage (ii)the abundance of intermediate size class trees, and (iii) the response of the advance growth so retained to the opening of the forest canopy.

(i) Effectiveness of climber cutting and tree marking in minimising logging damage

The abundance of climbers has been briefly discussed in Section 3.7. During felling, the crowns of large trees smashed through the trees of lower canopies giving rise to various categories of damage(e.g. bark, crown, both bark and crown damage) to the pole crop growing in the vicinity. 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 locality to locality 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 worthwile 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). Fox (1969) conducted another experiment (R.P. 245) with replicates at the Segaliud-Lokan and Kalabakan Forest Reserves. The results are summarised in Table 5.4.

Table 5.4

R.P. 245 Climber Cutting Experiment

(Plot of 1 ha., 2.5 acres)

	Segaliud-Lokan			Kalabakan		
	Nos. of Trees > 1 ft. girth per plot					
Category	Marked	No damage	Survival value	Marked	No. damage	Survival value
Treated						
Plot No 1	59	9	23	86	10	17
2	52	13	27	83	7	18
3	62	4	18	85	19	38
4	127	20	38	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						
Plot No 1	44	7	15	61	3	9
2	57	7	18	21	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

After Fox, 1972.

More stems were destroyed in treatment plots in both areas, but numbers free of damage after logging were slightly greater. The differences between the means for trees with no damage are not significant using the "t" test for difference with common variance (Dawkins, 1968 b), but is significant if the "t" ratio of the difference between pairs of plots is considered. In the latter case the overall difference is highly significant (P $\angle$ 0.1) for all pairs, whether taken as they come in Table 5.4, or 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 5.4 or of .10 if ranked.

The benefits due to climber cutting with respect 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.

All details connected with this field of study can be obtained from the Senior Research Officer, Forest Department, Sandakan, Sabah.

(ii) Abundance of intermediate size class trees

This topic was not been dealt with in Chapter 3 because it was felt that it is more conveniently included here, in order that a clearer perspective can be obtained. The abundance of intermediate size class trees (1' to 5' 11" girth) varies with forest types and from place to place. Normally the stocking of intermediate size class trees ranges from 15 to 25 trees per acre but it can be as low as 5 stems per acre on lowlying areas (Type 2). Tables 5.5 and 5.6 show the stocking of the pole crop (1' to 5' 11" G) of two Research Plots (20 acres per plot) at the Segaliud-Lokan Forest Reserve. It can be seen that the stocking of the pole crop averaged 17.8 stems per acre for Plot 1 -(Table 5.5), and 14.7 stems per acre for plot 2 (Table 5.6).

Table 5.7 shows the stocking of the pole crop at the Gunung Rara Forest Reserve (Type 3 Forest). It may be noted that the intermediate size trees averaged 25 stems per acre.

Generally taking the mean on a per acre basis, there are more than 10 pole-size trees per acre in most forest reserves. Thus it would appear that the forest conditions, particularly the abundance of pole-size trees can meet the requirements of the Selective System.

(iii) Response of Advance growth to the Opening of Forest Canopy

Upon opening of the forest canopy, pole-size trees can grow at twice the rate of trees in the undisturbed condition (Table 3.9). As considerable details have been presented in Section 3.5.2, the author feels that further elaboration is not necessary. It is however, imperative to examine the mortality rate of the advance growth following opening of the forest canopy, by logging.

Table 5.8 shows that during a period of 6 years (1969-1975) 16 trees died out of a total of 231, representing 6.93% mortality. This would mean that the percentage mortality per annum amounts to 1.16% which is very low. Though long-term data are not available, it is expected, should mortality be significant, it would have occurred soon after logging.

Table 5.5 RP. 135 Enumeration of Segaliud-Lokan F.R. (Type 2 Forest) prior to Logging

Commercial Species, Stems by Girth Classes (20 acres) Plot 1

GROUP	SPECIES	TIMBER	GIRTH CLASSES																				
			1	2	3	4	5	1–5	6	7	8	9	6–9	10	11	12	13	14	15	16+	10–16	6+	% 6+
	1 Parashorea tomentella	White	36	14	12	8	10	80	3	4	5	7	19	2	6		1		1		10	29	18.6
1	2 Parashorea malaanonan	Seraya	6	6	2	1	2	17				1	1								–	1	0.6
2	3 Shorea leptoclados	Majau	15	21	12	7	5	60	8	8	2	6	24	7	4	7	2	2	3	3	28	52	33.3
3	4 Dryobalanops lanceolata	Kapor	21	10	5	3	4	43	3	2	3	2	10	1	2	1	1				5	15	9.6
	5 Dipterocarpus caudiferus	Keruing	29	18	6	8	5	66	2	8		3	13	1							1	14	9.0
4	6 Dipterocarpus gracilis						1	1	1				1								–	1	0.6
	7 Shorea leprosula	Tembaga	8	6	3	3	6	26	3	4		1	8	1		1					2	10	6.4
	8 Shorea parvifolia	Punai	6	2	4			12	1	6	2	1	10								–	10	6.4
	9 Shorea waltonii	Kelabu	8	3	2	4	2	19					–	1		1	1	1			4	4	2.6
	10 Shorea almon	Kerukop	4			1		5					–					1			1	1	0.6
	11 Shorea macroptera	Melantai	1	2	1			4	1			1	2								–	2	1.3
	12 Shorea smithiana	Timbau				1						1	1		2						2	3	1.9
	13 Shorea pauciflora	Oba Suluk	1					1					–								–	–	–
5	Total Red Seraya 7 species	R.S.	28	13	10	9	8	68	5	10	2	4	21	2	2	2	1	2			9	30	19.2
	14 Shorea gibbosa	Yellow	3		1			4					–		1						1	1	0.6
6	15 Shorea hopeifolia	Seraya				1		1					–								–	–	–
7	16 Hopea sangal	Gangil	1	1		1	1	4		1	1		2								–	2	1.3
8	17 Shorea symingtonii	Melapi		1		1		2	1				1								–	1	0.6
9	18 Shorea superba	Selangan Batu	4	2	1		1	8	1			2	3	1	2		2				5	8	5.1
10	19 Vatica spp.	Resak	1					1					–								–	–	–
11	Non Dipterocarps (3 species)						1	1			1		1	1							1	2	1.3
	22 Totals		144	86	49	39	38	356	24	33	14	25	96	15	17	10	7	4	4	3	60	156	100
	Per acre		7.2	4.3	2.5	2.0	1.9	17.8	1.2	1.7	.7	1.3	4.8	.8	.9	.5	.4	0.2	.2	.2	3	7.8	

Table 5.6 RP. 135 Enumeration of Segaliud-Lokan (Type 2 Forest) Prior to Logging (20 acres) Plot 2

GROUP	SPECIES	TIMBER	GIRTH CLASSES																			
			1	2	3	4	5	1-5	6	7	8	9	5-9	10	11	12	13	14	15	16+	10-16+	6+	% 6+
1	1 Parashorea tomentella	White Seraya	35	13	17	13	9	87	6	6	2	4	18	5		2		1			8	26	17.6
	2 Parashorea malaanonan		2	2		2		7			1		1		1				1		2	3	2.0
2	3 Shorea leptoclados	Majau	13	11	11	10	5	50	3	2	9	4	18	4	5	5	2	2	2	1	21	39	26.4
3	4 Dryobalanops lanceolata	Kapor	8	3		2	2	15	3	2		1	6	1	1					1	3	9	6.1
4	5 Dipterocarpus caudiferus	Keruing	12	16	9	7		44	8	4	4	3	19								–	19	12.8
	6 Dipterocarpus gracilis												–	1							1	1	0.7
5	7 Shorea leprosula	Tembaga	3	6	2	2	7	20	1	2	2		5								–	5	3.4
	8 Shorea parvifolia	Punai	14		4	1	2	21	2		3	2	7	1	3	1					5	12	8.1
	9 Shorea waltonii	Kelabu	5	5		1		11	1	2	1		4		2	1			1		4	8	5.4
	10 Shorea almon	Kerukop	2					2	1	1			2								–	2	1.3
	11 Shorea macroptera	Melantai				1		1					–								–	–	–
	12 Shorea smithiana	Timbau		2			2	4				1	1								–	1	0.7
	13 Shorea pauciflora	Oba Suluk	2	1	1		1	5					–								–	–	–
	Total Red Seraya 7 species	R.S.	26	14	7	5	12	64	5	5	6	3	19	1	5	2	–	–	1		9	28	19
6	14 Shorea gibbosa	Yellow Seraya	5	1				6	1		1		2				1	1		1	3	5	3.4
	15 Shorea hopeifolia					1		1					–								–	–	–
7	16 Hopea sangal	Gagil	1				2	3					–								–	–	–
8	17 Shorea symingtonii	Melapi	1			1		2	1				1								–	1	0.7
9	19 Shorea superba	Selangan Batu	4	3	2	1	1	11			3	2	5	4	1						5	10	6.7
10	Non Dipterocarps (0.6 species)				1	1	1	3	1	1		3	5		2						2	7	4.7
	24 TOTALS		108	63	47	43	33	294	28	20	26	20	94	16	15	9	3	4	4	3	54	148	100
	Per acre		5.3	1.7	2.4	2.2	1.7	14.7	1.4	1.0	1.3	1.0	4.7	.8	.8	.5	.2	.2	.2	.2	2.7	7.4	

Gunung Rara F.R. (Type 3 Forest) Total area sampled - (10 acres per plot)

Plot No.	SIZE CLASS									
	1'+	2'+	3'+	4'+	5'+	1'-5'+	6'+	7'+	8'+	Total
1	108	73	40	26	26	273	16	20	59	368
2	69	44	23	20	22	178	12	18	42	250
3	68	52	20	26	17	183	18	28	31	260
4	94	57	37	39	19	246	13	18	41	318
5	166	98	58	32	23	377	18	24	61	480
Total	505	324	178	143	107	1257	77	108	234	1676
Per acre	10.10	6.48	3.56	2.86	2.14	25.14	1.54	2.16	4.68	33.52

Forest Department, 1977.

Table 5.8 Mortality of Dipterocarp species from 1969 to 1975 Segaliud-Lokan F.R. R.P. 135 (20 acres)

SPECIES	1969 Total Recorded	MORTALITY							
		1970	%	1974	Total 1969-74	% 1969-74	1975	Total 1969-75	% 1969-75
Parashorea tomentella	58	-	-	3	3	5.17	-	3	5.17
Shorea leptoclados	51	1	1.96	2	3	5.88	1	4	7.84
Dipterocarpus caudiferus	41	-	-	-	-	-	2	2	4.88
Dryobalanops lanceolata	32	1	3.13	3	4	12.50	1	5	15.63
Shorea leprosula	12	1	8.33	-	1	8.33	-	1	8.33
Shorea parvifolia	10	-	-	1	1	10	-	1	10
Shorea smithiana	9	-	-	-	-	-	-	-	-
Parashorea malaanonan	6	-	-	-	-	-	-	-	-
Shorea waltonii	5	-	-	-	-	-	-	-	-
Shorea macroptera	3	-	-	-	-	-	-	-	-
Shorea acuminatissima	2	-	-	-	-	-	-	-	-
Shorea gibbosa	1	-	-	-	-	-	-	-	-
Shorea argentifolia	1	-	-	-	-	-	-	-	-
Total	231	3	1.30	9	12	5.19	4	16	6.93

In the light of the preceding paragraphs pole-size trees retained in the logged-over forests could constitute a valuable crop for the subsequent cut.

(d) Problems encountered in the implementation of Climber cutting and tree marking prior to logging

The practicability of climber cutting and tree marking prior to logging as a silvicultural tool in Sabah has been comprehensively investigated by Liew (1973). Among other things, analysis of cost for the operations was presented. The fôrest condition of one square mile at the Umas-Umas Forest Reserve, which received the first silvicultural treatment, was examined before and after logging. The results show that the number of trees marked per unit area was far below the requirement level, while the percentage of undamaged trees of the total marked trees was found to be similar to the finding of Fox (1968a).

A number of problems has been and will be encountered in the implementation of the first silvicultural treatment. The more important ones are briefly discussed below:

(i) In the large scale experimental trial the average number of trees marked per unit area was well below the required level. Patches of forests carried no trees that could be marked for retention. This would seem to indicate that pole-sized trees are not uniformly distributed throughout the forest. The average number of trees per acre marked in one square mile of forest at Umas-Umas was only 5, which is too low (Liew 1973). The number of trees marked could have been increased appreciably if a wider spectrum of species used, and marking had not been confined to 8 to 10 per acre. It is recommended that all pole-sized trees be marked because it is difficult to mark the exact number of trees, e.g. 8 to 10 per acre in the forest in view of their distribution. This also indicates that constant supervision by Senior Officers is required to examine the forest composition and structure, and where necessary, vary or increase the number of species in the marking list. This problem may be overcome if an active Forest Manager undertakes the supervision.

(ii) Heavy logging equipment is now used in exploitation. The consequences of bad and destructive logging practices have been ignored. In addition, the Forest Department has little or no control over the actual logging. The loggers are permitted to do more or less anything they like in getting the wood out of the forest. This has often resulted in the depletion and elimination of valuable regeneration by creating an excessive number of landings and tractor paths. Hence, it is common to find as much as 40 - 50% of the forest without any stocking of regeneration due to the incidence of tractor paths (Fox, 1968b; Liew, 1974). No definite rules exist on timber extraction although licencees may be fined for avoidable damage to intermediate sized trees. But the term "avoidable damage" is not expressly defined and often little or no fines are imposed for careless logging. Thus loggers have not taken any precautions with respect to avoiding unnecessary damage to the forest. Any trees marked by the Forest Department may be up-rooted and destroyed by careless logging. Therefore, the first silvicultural treatment cannot be effectively implemented without co-operation from loggers. However, this silvicultural treatment may be effectively implemented if adequate rules and regulations are devised and imposed to overcome the present weakness with regard to logging damage.

(iii) Generally, most of the operations under licence agreement or special licence do not have sound advance planning in the exploitation of the licence areas. Very few licencees submit their coupe map two years ahead of logging as required, and while the Forest Department may allocate coupes for them, this has rarely, if ever, been practised. This may hamper the implementation of the first silvicultural treatment, although this difficulty can be easily overcome.

(iv) The implementation of any silvicultural practice, should be on a State wide basis as it would be unfair to impose certain rules in conjunction with first silvicultural treatment on specific licencees only. Logging activity is booming in almost all the accessible commercial forests today. It is estimated that the present cut in Forest Reserves is well over 300 square miles annually. If the first silvicultural treatment were to be implemented on a State wide basis, about 1.5 to 2 million Malaysian dollars would have to be spent. A margin of half a million dollars is allowed for inefficient silvicultural gangs and/or difficulties arising in the operation. In addition, approximately 100 trained foresters and 600 labourers would be required for the work. Although labour problems are now considered to be non-existent, the Government may not be prepared to spend this sum to implement the first silvicultural treatment.

Therefore, the main difficulties will be to obtain sufficient funds for the implementation and control of logging. In view of this, the first silvicultural treatment is only carried out in limitted areas.

(e) Concluding remarks

A selection System is one of the most difficult forms of silvicultural method to apply as it requires advance planning and the co-operation of the loggers. The concept of the Selective System is a sound one as its primary objective is to conserve the forest ecosystem in the original form as far as possible with the aim at producing timber in perpetuity to meet the increasing demand for tropical hardwood. Today it is a global concern to conserve rainforests in the light of their rapid disappearance.

The preceding subsections suggest that a Selective System could be applied to Dipterocarp forests in Sabah though problems other than biological viability may exist. The problems may be solved if a concrete management plan is laid down.

5.3.2. Tropical Shelterwood System (T.S.S.) and Regeneration Improvement Felling System (R.I.F.S.)

(a) T.S.S. with Particular Reference to Nigeria

The primary objective of Tropical Shelterwood System (T.S.S.) is to produce a more or less even-aged forest by establishing a pole crop of economic species before logging. The system was first introduced in the management of rainforest in Trinidad in 1939 (known as post-exploitation Tropical Shelterwood System) and later in Nigeria in 1944(known as pre-exploitation Tropical Shelterwood System) (Baur, 1964a). The system, based on Malayan experience in girdling and poisoning trees, together with a scanty background of experiment and experience in Nigeria, was devised in 1943 and applied on a large scale from 1944 onwards in Benin Province (Jones, 1950). When this system was introduced in Nigeria, a rotation of 100 years was adopted. The sequence of operations of the first version of T.S.S. adopted in Nigeria was as follows:

Year		Operation
1		Demarcation of compartment
1	(i)	Climber cutting and seedling assistance.
1 D.S.	(ii)	Removal of middle storey canopy.
2 R.S.	(iii)	1st regeneration count and climber cutting.
2 D.S.	(iv)	2nd opening of canopy.
3 R.S.	(v)	1st and 2nd cleanings.

Year		Operation
4 R.S.	(v)	3rd and 4th cleanings.
	(vi)	2nd regeneration count.
5 R.S.	(vi)	5th cleaning (or exploitation)
8, 12, 16 etc. R.S.	(vii)	Pre-exploitation cleanings
n	(viii)	Exploitation
n + ½ to 1 R.S.	(ix)	1st post-exploitation cleaning
n + 3	(ix)	2nd post-exploitation cleaning
n + 8	(ix)	3rd post-exploitation cleaning
n + 13	(ix)	4th post-exploitation cleaning

After Baur, 1964a

Note : D.S. = Dry Season   R.S. = Rainy Season

It was initially believed that climber cutting (operation i) had no value as a regeneration operation: the intention being chiefly to allow freedom of movement through the forest. Later it was found that climber cutting was actually the first stage in the opening of the forest canopy before logging, this gradual opening being the essential feature of T.S.S..

Canopy opening was, and still remains, "the most difficult and most critical of all the silvicultural operations" (Baur, 1962). The aim was to allow sufficient light to encourage development of seedlings, but insufficient to permit a lush tangle of weeds and vines to flourish, "but it soon became clear that, if enough light was let in to allow economic saplings to develop, weeds would grow too" (Lancaster, 1961). To cope with the weeds, several cleaning operations were prescribed.

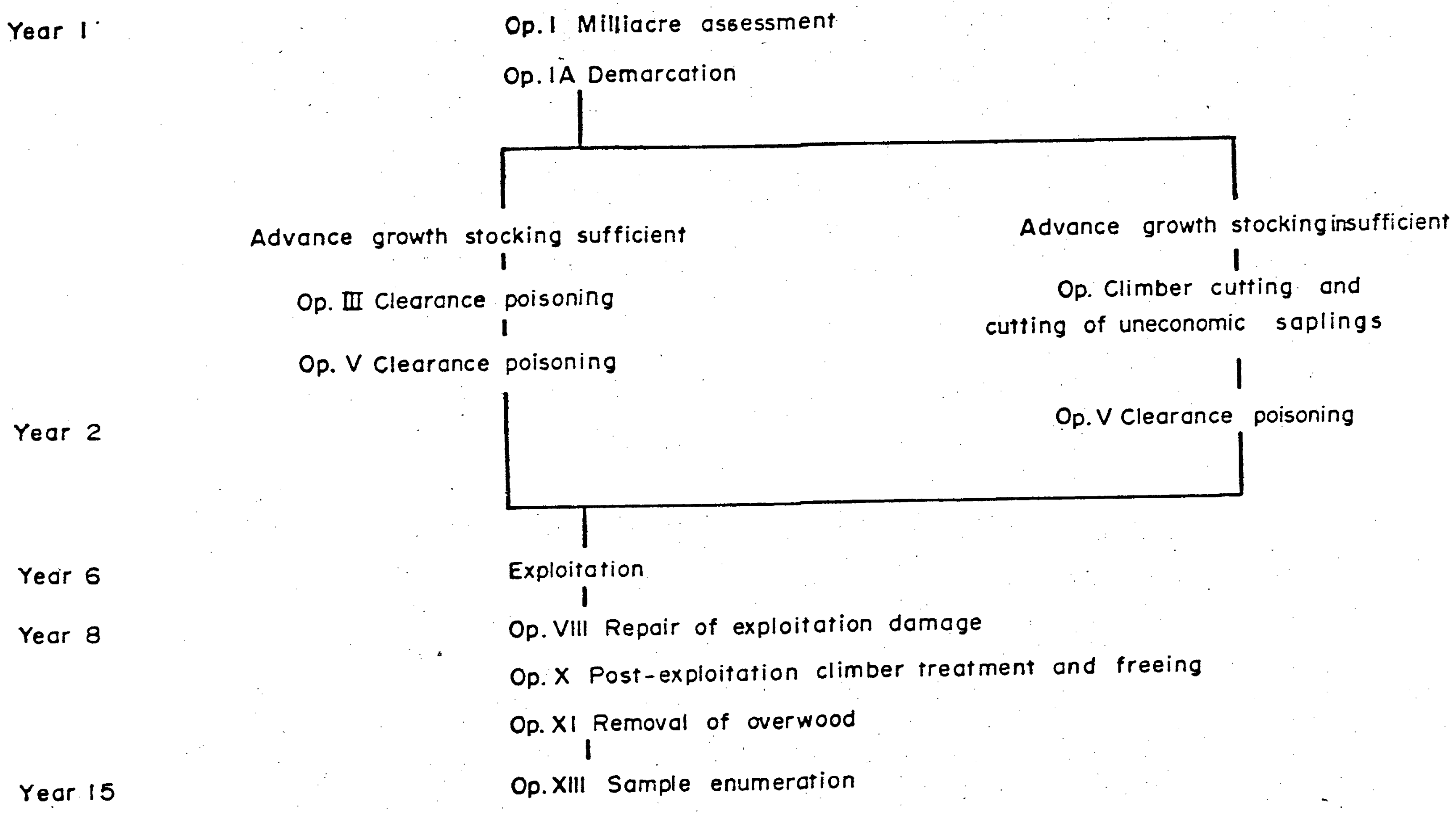
The logging operation normally commenced in year 6. Damage caused by felling was regarded as slight (Rosevear and

Lancaster, 1952). It was concluded that T.S.S. was moderately effective under selective logging, but could be put at risk by more intensive working, and that greater flexibility was needed to permit treatment to vary with individual stand condition.

The T.S.S. in Nigeria was revised in 1953, 1956 and 1961. Figure 5.3 illustrates the timetable of the operation in 1961.

Moore (1957) reported that a post-exploitation Shelterwood System was an economic method of silviculture in Trinidad because there was a favourable market for lesser-known species, the dominants need no longer be retained for the shelterwood since satisfactory regeneration can be obtained from a shelterwood of pole size trees; a shelterwood of pole-size trees is to be preferred since they will remain sound during the period of the felling cycle of 30 years, the cost of poisoning the shelterwood is reduced or eliminated, and dominant trees may be exploited during the formation of the shelterwood. The T.S.S. practised in Trinidad in 1957 embraced a much simpler sequence of pre-exploitation treatments, involving merely the cutting of vines two years ahead of felling. In fact the pre-log treatment was exactly the same as the current pre-exploitation practice in Sabah, though their post-exploitation treatments were very intensive during the first 5 years. Other treatments included enrichment planting carried in areas devoid of economic species, and elimination of weed species as well as vines. Under this system a cutting cycle of 30 years was envisaged (Moore, 1957) but Baur 1964 quoted the rotation as 60 years.

Figure 5·3 Timetable of Operations of T.S.S. Practised in Nigeria in 1961



Note : Op. = Operation

After Baur , 1962

(b) Regeneration Improvement Felling System (R.I.F.S.)

R.I.F.S. is one of the earliest silvicultural methods practised in Malaya. It was recorded as early as in 1910. In fact T.S.S. was evolved from the experience gained from R.I.F.S. in Malaya. As both silvicultural systems consist of a very intensive programme of pre-log treatments, and have almost similar management objectives it is considered that they should be discussed under one Section.

The original concept of R.I.F.S. practised in Malaya was designed to favour the development of *P. gatta* and any other valuable species through implementation of improvement operations prior to logging. Later, the Improvement Operations had the intention of removing the inferior species in several stages to promote the development of class 1 species before felling of these was permitted. According to Hodgson (1932) these operations had virtually ceased by 1932. The sequence of treatments laid down may be summarised as follows:

Year		Operation
n-1	P	Felling of unmarked class 2 poles under 8 inches D.B.H.
n	S1	First seeding felling of marked class 2 trees
n+2 or +3	C1	First cleaning (if necessary)
n+4	S2	Second seedling felling of marked class 2 trees
n+5	C2	Second cleaning
n+6	F	Final felling of marked class 1 trees (provided successful regeneration verified in (2)
n+7	C	Cleaning after final felling (if necessary).

Causens (1957, 1958) made detailed studies of regenerating forests treated with R.I.F.S. between 1916-1940, and he commented that "there can be no disputing the fact that the silvicultural aim of increasing the proportion of fast-growing Shorea species has been highly successful".

It was briefly mentioned in Section 5.2.1 that Regeneration Improvement Felling System was practised on a small scale with emphasis on production of harder woods which were often species shade tolerant in youth and difficult to regenerate. Among other treatments, climber cutting, girdling and felling of Ficus bound trees were carried out. 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 implemented, the forests had often been worked over earlier (Burgess, 1959) and were far from natural. However, it has been impossible to locate and examine any areas which definitely received early pre-exploitation treatments.

(c) Practicability of T.S.S. and R.I.F.S. in Sabah

The primary objective of T.S.S. and R.I.F.S. is concerned with improvement felling and cleanings prior to exploitation of the more important timber trees. This is done to secure an adequate supply of seedlings and small sapling regeneration, and to increase the value of the existing timber crop. Treatments often result in the development of excellent sapling regeneration which will be smashed if timber felling is permitted (Wyatt-Smith, 1961). As pointed out earlier, heavy equipment is used in logging operations. Raising a pole-crop is a waste of time, money and effort in the era of mechanisation, particularly in Sabah.

Sections 4.4.1 and 5.3.1 (c)(ii) emphasize that in Sabah an adequate number of seedlings are always present in the regenerating pool, and the pole crop usually amounts to 15 to 25 stems per acre. Thus pre-log treatments as prescribed in T.S.S. and R.I.F.S., with the aiming at increasing the stocking of seedlings and saplings, are not required in Sabah.

5.3.3 Malayan Uniform System (M.U.S. - Clear-cutting)

The Malayan Uniform System is perhaps one of the best known silvicultural methods devised for rainforest management. The primary objective of the system aims at achieving an even-aged regeneration by the way of clear cutting. It was introduced in Malaya in 1950 and later in Sabah in 1955 (Baur, 1964a). The success of the system depends six essentials:

1. Adequate stocking of seedlings of economic species at the time of exploitation.
2. Adequate stocking of seedlings of economic species after exploitation.
3. Economic species are capable of responding to sudden and almost complete opening of the forest canopy.
4. Complete removal of the upper strata of the canopy.
5. No tending until the regrowth has passed the ephemeral climbers.
6. Maintenance of adequate new canopy to prevent the redevelopment of climbers.

(a) Malayan Uniform System Practised in Peninsular Malaysia.

In order to establish the adequacy of the initial stocking regeneration, and subsequently to determine the need for, and nature of treatment in the developing regrowth, line sampling is carried out (transects of quadrats at regular intervals),with the quadrat size varied according to the stage of development of the new crop (Barnard, 1950). Wyatt-Smith (1961) stressed that linear sampling techniques form the most important tool in the Malayan Uniform System.

Where regeneration is adequately represented, felling should start as soon as possible, with all utilizable trees being exploited. If a market exists, pole fellings of small stems (under 12 inches D.B.H.), unsuitable as sawlogs, can precede or accompany the main logging operation. All mill trees to be felled are branded before-hand to ensure complete exploitation of the area in an orderly fashion. Relatively inaccessible or poor areas of the compartment should be marked first; and an area of good, accessible forest kept until the remainder has been satisfactorily logged, to serve as an inducement for satisfactory working. Felling should not extend over one area for more than 2 years.

Felling is followed as closely as practicable by the poison-girdling of all useless stems down to 2 inches D.B.H. However, Walton (1948) warned that treatments should aim at the improvement of all forest reserves rather than the conversion of a proportion of them to pure timber crop.

The sequence of operations for the Malayan Uniform System as originally prescribed is:

Year	Operation
n - $1\frac{1}{2}$ to n	Linear sampling of regeneration by miliacre quadrats (L.S.M) and enumeration of merchantable trees.

Year	Operation
n to n + 1	Exploitation, followed by poison-girdling down to 2 inches D.B.H.
+ 3 to n + 5	Linear sampling by ¼ chain square quadrats) followed by cleaning, climber cutting and poison girdling as required.
n + 10	Linear sampling (½ chain square or L.S.½) of new crop, followed by treatment as required, or passing as regenerated.
+ 20, n + 40 etc.	Sampling and thinning as required.

As mentioned earlier, diagnostic sampling plays an important ole in the Malayan Uniform System. The basic features of the inear Sampling Method (standardised by Wyatt-Smith 1960) may e summarised as follows:

1. The use of varying plot size depending on the average ize of the regeneration being sampled, viz. L.S.M. for seedlings ractised prior to logging; LS¼ (quarter-chain square) for 3 to years old regenerating forest; and LS½ (half-chain square) for 0 to 15 years old forests.

2. The selection of a stem of an economic species within he plot most likely to survive.

3. Recording of the size class and dominance class of he chosen stem; (in the first, pre-exploitation sampling, ominance is not recorded, but is replaced by an indication of he abundance of the selected species in the quadrat).

4. Recording the presence of any stems of a more desirable species, less well established within the plot.

5. Recording the presence of climbers, palms, etc. in the quadrat.

Over a period of years the M.U.S. had been modified and adjusted in the light of findings. However, the basic principle remains unchanged. For example, since the late 1960's pre-log treatments including diagnostic sampling have been deleted (Tang, 1974). The success of the M.U.S. will be examined in following sub-section.

(b) The Success and Practicability of the M.U.S. in Peninsular Malaysia

A short paper entitled "Malayan Silviculture in practice" was written by Strugnell (1954). He stated that the outline on Malaysn Silviculture by Barnard (1950) deals with lowland forests worked under ideal conditions, but in practice certain adjustments in treatments had been found necessary to cater for abnormalities. These abnormalities were mainly due either to incomplete exploitation because of lack of market, and owing to steep and hilly ground, or to restricted or prolonged interrupted felling because of security closures. Wyatt-Smith (1961) pointed out that the M.U.S. had not been very successful because of poor implementation, e.g. the staff were not always circulated with the instructions. He concluded that "there is little likelihood of the present system failing to achieve this (its objectives) in lowland forest rich in dipterocarps, though there is a depressing percentage of logged-over forest, which has failed (even with the present lengthy acceptable list of species) to reach the present adequacy standard of forty per cent (sixteen stems per acre) at ten or more years after completion of logging, and which in consequence will probably require enrichment planting if the area is to be retained as reproductive forest". This suggests that overall the M.U.S. has not fulfilled the management objectives satisfactorily.

Mok (1968) believes that the Manual of the Malayan Silviculture for Inland Forests by Wyatt-Smith is a monumental piece of work, the fruit of half a century of silvicultural research and observations which culminated in the evolution of the Malayan Uniform System. He stressed that although the M.U.S. has been successfully applied, it is sometimes over-looked that the system is intended for application to normal virgin forests, and more specifically, Dipterocarp forest where fast growing light hardwoods and principally Light Red Merantis (<u>Shorea</u> species) predominate. The system failed because its application had been extended to hill forest or forest where seedlings and pole crops are scarce or lacking for various reasons (Mok, 1968). There is nothing wrong with the system as it was devised to guide the regeneration up to the establishment stage, beyond which there is still a lot of silviculture to be done.

In 1970, there were 70,000 acres of logged forests in need of planting and about 600,000 acres of logged forests which had not received any silvicultural treatments in Peninsular Malaysia (Tang, 1974). About half the total acreage probably requires planting (Tang and wandle 1974). This suggests that the M.U.S. could be in a dying phase, though there is no official reference stating that implementation of the system is to cease.

The question is whether the M.U.S. is applicable to the hill forest? Could pre-log treatments improve stocking of seedlings in the hill forests? Should these treatments be able to fulfill the objectives, the past contributions of silvicultural principles remain valid.

Burgess (1973) outlined considerable details, for hill forests concerning the desirability of controlling the stemless palm bertam (Eugeissona tristis). According to him, this palm causes rapid supression of seedlings of most Dipterocarps due to a combination of shade and high competition for water in the surface layers of the soil. In addition, the felling of timber on top of bertam results in a dense mat of bertam fronds being pressed down on such seedlings which survive, resulting in their early death. After conducting a series of experiments, he concluded that bertam must be controlled before felling takes place, and it is desirable to do this, if possible, before a seeding of Dipterocarps, so that as little damage as possible to seedling regeneration is caused. The danger of reducing the relative humidity of the air near the ground to a point where Dipterocarp seed will not germinate can safely be disregarded. Though the original objective of raising an even-aged stand of rainforest is difficult because of its complexity, and variations growth rate, the basic principle to be adopted for rainforest management in Peninsular Malaysia remains unchanged. However, various treatments, including data collection in diagnostic samplings within the system, may have been altered to accommodate changing demands with respect to utilization and methods of logging.

(c) Malayan Uniform System Practised in Sabah

When the Malayan Uniform System was introduced in Malaya in 1950, Mr. Brown, a senior officer of the Forest Department Sabah (formerly known as North Borneo) was sent to Malaya to study the silvicultural techniques. In 1955, the modified Malayan Uniform System was officially adopted in Sabah but extensive implementation did not take place until 1958. However, it must be stressed that the emergence of the modified Malayan Uniform System was based on the silvicultural characteristics of the Dipterocarpaceae, which are listed below:

(1) The presence of seedlings of economic species in great abundance on the forest floor in virgin forests.

(2) The ability of these seedlings to remain alive for a period long enough to bridge the interval between seed years.

(3) The ability of these practically dormant seedlings to respond with vigour to any light increase due to opening up of the canopy.

After Nicholson (1958).

It must be pointed out that though these were the underlying factors, the technique for regeneration tending was not fully developed from these consideration alone, but rather by trial and error over a number of years.

The system practised in Sabah in 1958 consisted of relatively simple instructions which may be summarised as follows :

(A) Log all commercial trees greater than 6' girth
(B) L.S.M. to be carried out immediately after logging
(C) Girdle (after logging):
    (i) All non-commercial trees over two inches diameter

(ii) All commercial trees over two inches diameter that are crooked, damaged, hollow or otherwise defective.

(iii) All commercial trees over six feet girth.

(D) Only cut climbers on commercial trees

(E) Do not do any slashing of undergrowth

(F) The man who makes the girdle should also apply the poison

(G) Use 2 lbs. of arsenite to one gallon of water

(Forest Department Circular)

The reasons for the drastic treatments may be summarised as follows :

(a) The lower limit for girdling is set at two inches d.b.h. chiefly for economical reasons since the number of weed species below this size is often high; also the trees are becoming two small to girdle. Moreover it has been found that their presence does not unduly hamper the regeneration and does help reduce the competition from climbers.

(b) After girdling, only sound commercial trees should remain on the area. The six feet upper limit has been set since it is likely that trees larger than this will not be sound another rotation.

(c) As few climbers as possible should be cut, hence the restriction to those actually damaging future crop trees. This is because most tend to coppice profusely and make a denser tangle than previously existed. For a similar reason, if any slashing of small undergrowth is done, a dense coppice growth develops. In this case also many commercial seedlings may be cut.

It can be clearly seen that the early Malayan Uniform System practised in Sabah is aimed at regenerating an even-aged forest. It must be pointed out that the system also relies heavily on diagnostic sampling. The techniques pertaining to the linear sampling are presented in Appendix I.

The 1958's instructions continued to applied for a number of years though minor changes in treatments had been made from time to time. In 1962, a detailed circular was issued replacing the previous ones. The basic elements were the same, except for the following points;

(a) All commercial trees over 6 feet girth are <u>NOT</u> to be girdled regardless of their quality. In the previous circular, not only were poor-quality trees to be girdled, but also any remaining sound trees of economic species.

(b) All trees of non-commercial species over 6 inches diameter are to be girdled.

(c) Girdle all non-commerical trees over two inches diameter in dense islands of unlogged forests, where there is regeneration of commercial trees.

The basic feature of the change was the introduction of less drastic treatment. The change was necessary as logging damage was on the increase (Nicholson, 1965). It had also been detected that advance growth responded to liberation and logging. Emphasis was therefore placed on retaining advance growth and less marketable commercial species with the aim of obtaining an intermediate yield. However, no measures were taken to minimise logging damage. Nicholson (1965) stressed that this aspect of research certainly deserved attention.

(d) The Success and Practicability of the M.U.S. in Sabah

The results of the M.U.S. practised in Sabah were comprehensively reviewed by Nicholson (1965). He stated that natural regeneration of Dipterocarp forest is possible even after a drastic logging operation followed by girdling. However, the results were not so good as to merit complacency. Some foresters even predicted a gloomy future for the forests of Sabah because of the drawbacks of the M.U.S. Several senior officers including Dr. Meijer, were strongly against the system because of the poison-girdling operation, which in their opinion, might cause ecological imbalance, and would be a wastage of cellulosic material if utilization patterns changed with time.

Have any forests been successfully regenerated under the M.U.S.? Nicholson (1965) partially answered the question by presenting sets of data collected in five (5) year old regenerating forests at several localities (Table 5.9). Since the quadrat size used was quarter-chain square the maximum number of stocked plots was 160. From Table 5.9, it may be noted that the mean stocked plots ranged from 91 to 128 per acre out of 160 plots. The abundance of pole crop trees (1' to 2' girth) was variable, ranging from 1.3 to 26 stocked plots per acre. By the Malayan Standard, the forests could be considered as "successfully regenerated".

The stand of regenerating forest examined by Nicholson (1965) still exists today. It is now about 20 years old

Table 5.9

L.S.½ Linear Samplings

Means, Reliable Minimum Estimates and Error % for number of Stocked plots per acre

SIZE CLASS	Kalabakan			Kalabakan 1963									Kalumpang		
	1962			Part 1			Part 2			Part 3			1963		
	Mean	RME	ER	Mean	RME	ER	Mean	RME	ER	Mean	RME	ER	Mean	RME	ER
Less than 10' high	34.5	31.9	8	34.4	33.0	4	55.1	51.2	7	57.5	52.6	8	43.6	40.1	8
10' high to 6" girth	17.7	16.5	7	33.2	31.6	5	24.1	21.4	11	13.7	12.2	11	26.5	24.5	8
6" to 1' girth ...	24.6	23.3	6	28.9	27.5	5	13.7	12.3	10	7.2	5.9	19	18.7	17.0	9
1' to 2' girth ...	11.1	10.3	8	11.0	10.3	6	7.8	6.9	11	8.7	7.1	19	3.7	2.8	25
All sizes ...	91.5	89.0	3	110.9	107.6	3	106.8	102.1	4	91.8	87.4	5	96.1	91.5	5
Over 10' high ...	57.1	54.7	4	76.5	73.7	4	51.7	49.2	5	34.3	30.8	10	52.5	48.2	8
Over 6" girth ...	39.4	(36.6)	-	43.3	41.6	4	27.6	25.6	7	20.6	18.2	12	26.0	23.3	11
Over 1' girth ...	14.8	(13.4)	-	14.4	13.6	6	13.9	12.4	11	13.4	11.8	12	7.3	6.0	18
Over 2' girth ...	3.6	3.1	14	3.4	3.1	11	6.2	4.7	24	4.7	4.0	13	3.7	3.0	18

SIZE CLASS	Silabukan			Lungmanis			Silabukan 1964								
	1963			1964			Part 1			Part 2			Part 3		
	Mean	RME	ER	Mean	RME	ER	Mean	RME	ER	Mean	RME	ER	Mean	RME	ER
Less than 10' high	53.6	-	-	15.6	12.9	17	14.4	-	-	74.4	67.2	10	5.7	4.2	27
10' high to 6" girth	25.9	-	-	31.2	28.2	10	46.3	-	-	39.2	34.9	11	20.3	16.5	19
6" to 1' girth ...	13.1	-	-	60.2	56.8	6	17.8	-	-	13.2	11.4	14	10.2	6.6	35
1' to 2' girth ...	2.2	-	-	13.8	11.8	14	26.1	-	-	6.6	4.5	31	1.3	0.4	74
All sizes ...	99.7	-	-	128.3	122.6	5	110.5	-	-	135.4	131.2	3	39.7	35.8	10
Over 10' high ...	46.1	-	-	112.8	108.0	4	96.1	-	-	61.0	55.1	10	34.0	30.3	11
Over 6" girth ...	20.2	-	-	81.5	77.2	5	49.8	-	-	21.8	17.9	18	13.7	9.6	30
Over 1' girth ...	7.1	-	-	21.4	18.9	12	32.0	-	-	8.6	6.0	30	3.5	2.2	37
Over 2' girth ...	4.9	-	-	7.6	6.6	13	5.9	-	-	2.0	0.8	59	2.2	1.4	35

and well-stocked with Rubroshorea species. Indeed, it can be considered to be one of the best forests which has been successfully regenerated under the M.U.S. in Sabah. The success was mainly attributable to reasonably low intensity of logging damage and a relatively high percentage of Rubroshorea species present in the regenerating pool after logging.

Liew (1974a) cited several examples of successful regenerating stands treated under the M.U.S. According to Liew (1974a) LS$\frac{1}{2}$ survey was carried out in 1973 in the logged-over forests at the Segaliud-Lokan Forest Reserve. The compartment under study was logged in 1962. L.S.M. was carried out after logging followed by poison-girdling of weed trees. Immediately after logging approximately 450 milliacre plots (out of 1,000 plots) were stocked with commercial seedlings of various species. The results of the L.S.$\frac{1}{2}$ carried out in 1973 are summarised in Table 5.10. It may be noted that trees greater than 6" girth amount to approximately 25 trees per acre, and 75% of the half chain squares was stocked with commercial species. Trees greater than 12" girth constitute about 50 per cent of all chosen trees. From management point of view, the forest has successfully regenerated.

From a set of yield plots established in coupe No. 1959 in Segaliud-Lokan Forest Reserve, the regeneration greater than 12" girth constitutes more than 50 per cent of the chosen trees as at 1968 (Table 5.11). The assessment of the stand was made when it was about 9 years old. From the management point of view, the forest is considered as a successfully regenerating stand, as more than 90 per cent of the $\frac{1}{2}$ chain quadrats within the yield plots are stocked with large seedlings or pole-sized trees (Liew, 1974a). Therefore under certain circumstances,

Table 5.10 Distribution of Species by Size Class
Segaliud-Lokan F.R. Coupe 1962
Acreage Sampled 14.2 acres
LS½ Linear Sampling carried out in 1973

Species	Size Class									
	less than 10' ht.	10'ht-6"G	6"G-12"G	12"G-24"G	24"G-36"G	36"G-48"G	48"G-60"G	60"G+	Total	%
Shorea smithiana		7	11	8					26	5.83
Dipterocarpus crinitus		1							1	0.22
Shorea glaucescens			1						1	0.22
Shorea parvifolia	2		10	19	3		1	1	36	8.07
Shorea superba				1			1		2	0.45
Eusideroxylon zwageri	4	3	1		3	3	1		15	3.35
Parashorea tomentella	4	5	19	6	1		1	2	38	8.52
Shorea agami		1	2	2	1	1	1		8	1.79
Dipterocarpus gracilis			1						1	0.22
Dryobalanops lanceolata	12	20	26	10			2	5	75	16.82
Shorea leptoclados	1	3	6	31	11		1	1	54	12.11
Shorea leprosula	1	4	24	84	8		3	5	129	28.93
Shorea waltonii		3	1	2					6	1.35
Parashorea malaanonan	1	6	4						11	2.47
Dipterocarpus stellatus	1	3	5	1					10	2.24
Dipterocarpus caudiferus		7	6	1	1		1	1	17	3.81
Shorea acuminatissima		4	3	2	1	1			11	2.47
Sindora spp.			2						2	0.45
Shorea angustifolio							1		1	0.22
Shorea macroptera									2	0.45
Total	26	67	124	167	29	5	13	15	446	100
Per acre	1.83	4.72	8.73	11.76	2.04	0.35	0.92	1.06	31.41	

T.C. Liew, 1974

Table 5.11 Stand Table of Main Crop Trees of Chosen Species by Girth Classes

Segaliud-Lokan1969 Compartment 2nd Measurement as at 1968 (9 years old regenerating forest)

(Maximum 100 or 40 per acre)

Size of yield plot = 2.5 acres/plot

Plot \ Girth	1"+	6"+	12"+	18"+	24"+	30"+	36"+	42"+	30-42"+	Total
YP1	15	25	26	20	6	1	1	3	5	97
YP2	18	31	12	7	5	2	4	5	11	84
YP3	22	30	11	9	9	2	2	13	17	98
YP4	14	18	23	12	5	2	0	7	7	79
YP5	9	20	23	25	8	3	3	4	10	95
YP6	12	26	31	11	5	4	1	4	9	94
YP7	13	11	29	16	8	3	3	7	13	90
YP8	4	12	27	23	14	7	0	6	13	93
YP9	22	21	25	11	2	3	1	9	13	94
YP10	15	24	21	9	1	3	3	3	9	79
Total	144	218	228	143	63	30	18	59	10.7	903
Mean Per acre	5.76	8.72	9.12	5.72	2.52	1.20	0.72	2.36	4.28	36.12

T.C. Liew, 1974

forests can be successfully regenerated by the M.U.S.

Perhaps it is appropriate to point out that the rapid phasing out of the first version of the M.U.S. (1958) in Sabah was due to the drastic treatment, poison-girdling immediately after logging. Under this regime of treatment, all sound commercial trees greater than six feet girth left in the residual stand were girdled. In late 1950's and early 1960's, many valuable Dipterocarp species such as *Dipterocarpus* species, *Dryobalanops* species etc., with no overseas market, were not extracted by loggers. Hence all these sound commercial trees left in the residual stand were girdled. Pereira (1978, personal communication) confirmed that he had treated thousands of acres carrying a high volume of *Dryobalanops* species at Bakapit near Lahad Datu. Millions of cubic feet of timber were lost through girdling operation. Today, *Dryobalanops* species is considered to be the most valuable timber for construction because of its durability. Burgess (1978 - personal communication) confirmed that a great volume of valuable timber was lost through girdling in the past in Malaysia.

Under the M.U.S. it is necessary to classify species by their preferential value. This is a difficult task because the pattern of utilization changes with time. Species of little value in the overseas market today, may be of great demand tomorrow. As Dipterocarp forest is very complex, blanket rules for treating all forest types should be avoided as far as possible.

The revision of the M.U.S. (1962 circular) was a less radical approach, but it was found later that the modern logging operation was destructive, usually resulting in inadequate stocking of regeneration. The situation arose because of the break-through for tropical hardwood in the world market. The increasing demand for tropical hardwood had tempted the developing countries, such as Sabah, to extract everything that could be sold. Under this circumstance, silvicultural policy was shifted to the Selection System which.has been discussed in Section 5.3.1

The M.U.S. is not totally an unsound concept in both theory and practice. Where the composition of species is dominated by groups of fast growing species e.g., Rubroshorea and Parashorea an even-aged and even-sized forest can be regenerated through manipulation of the canopy. However, because of the long rotation involved and the drastic logging damage, the concept of this system could be out of place in Sabah. However, the research towards the understanding of the silvicultural characteristics of Dipterocarp forest has been the most outstanding contribution of the past investigations.

5.3.4 Planting

Tree plantation with the aim of replacing the Dipterocarp forest as an alternative method for producing cellulosic material is not a specific silvicultural system for rainforest management. However, the tree plantation has gained considerable popularity in tropical moist forest. Therefore, this form of artificial regeneration should be considered.

As pointed out in Section 5.1. the search for the appropriate methods for management of tropical moist forest has been considered as a difficult and unrewarding task. Baur (1964) shows most of the possible methods have been tried somewhere, and in the main have been found wanting. The tendency to abandon natural forest management is almost inevitable.

To a large degree economics gets the blame for this trend away from natural management systems in forestry. That natural management is very difficult is demonstrated in earlier Sections; to justify the effort is itself an economic judgement. But there are other factors : the natural tropical forest is too expensive in land requirements, too costly in its capital requirements, and too slow and uncertain in its response to treatment.

Since the break-through of tropical hardwood into the world market in 1962, the timber resources in South East Asian region are declining at a rapid rate (E CAFE report, 1973). As a result, this creates a global awareness of the importance of tree plantations in the tropics, with the view to abridging production and demand for timber to meet the world market. For example, 50,000 hectares of Pinus caribaea are planted annually in the tropics in recent years (I.U.F.R.O., 1977). Malaysia is no exception and has investigated the feasibility of forest plantation by establishing species and provenance trials since early 1950's. Extensive species trials were initiated in Sabah in 1958.

With the present exploitation rate of about 100,000 hectares per annum, the hardwood resource in Sabah is being depleted at a rapid rate. The Sabah Foundation which practices sustained yield management can continue to supply a certain amount of timber, cutting at a rate of 7770 hectares per annum. This quantity is insufficient, as timber and timber industries are the life-blood of Sabah from a socio-economic point of view (Liew et al, 1972). It has been programmed that when natural resources diminish, plantation forests can play an integral role in stepping up wood production because volume increment of tree plantation ranges from 20 to 40 m^3/ha/annum compared to 2 to 5 m^3/ha/annum of the Dipterocarp forest's (Tham and Liew, 1977).

(a) Growth Rate of Tree Plantation Species in Sabah

Various species have been tried in Sabah since 1922. To date, the Department has recorded several species which possess high potential for planting on a commercial scale. The suitable species are listed in Table 5.12.

Table 5.12

List of Suitable Species for Plantation in Sabah

Species	M A I m^3/ha/yr.	Age of Assessment	Possible end uses*
Acacia mangium	44	10	1,2,3,4
Albizia falcataria	44 - 50	8	2,4
Eucalyptus deglupta	25	8 - 10	1,2,4
Gmelina arborea	30	8 - 10	1,2,4
Pinus caribaea	20 - 30	15	1,2

* 1 - Sawlogs 2 - pulpwood
3 - Composite board 4 - plywood, veneer

After Tham and Liew, 1977.

With the exception of *Pinus caribaea*, the listed species flower and fruit regularly. Viable seeds of *Pinus caribaea* are only produced in very small quantities from trees growing in the highland. Importation of this seed is necessary for commercial plantation. Trials located in different soils and climatic conditions have been carried out for *Pinus caribaea*. Slee *et. al* (1976) reported that trees growing at different elevations show differences in growth and form.

The MAI of the listed species varies from 20 - 50 m^3/ha/annum (Table 5.12). The selection of species depends on sites and the products to be manufactured.

Other species such as *Pinus oocarpa*, *P. merkusii*, *Araucaria husteinii* and *A. cunninghamii* have shown satisfactory growth rate, but seeds are not readily available in large quantities for commercial planting.

(b) Biological and Management Problems

(i) Seed Supply

As far as conifer species are concerned, seed supply is the major contraint facing entrepreneurs wishing to establish large scale plantations. As mentioned in the preceding Section, *Pinus caribaea* trees planted in the tropics are only producing a small quantity of viable seed, despite the fact that the F.A.O. has spent a large sum investigating this problem from late 1960's to early 1970's in Peninsular Malaysia. The Department is now establishing a seed orchard of *P. caribaea* in the highland at varying elevations. The technical details of the orchard were designed by Dr. Nikles (Queensland Forest Department). The project is progressing well.

Though seeds of Pinus caribaea and other conifer species are available from Australia, Fiji and Central America, the price seems to be increasing all the time. For long-term planning, seed must be produced locally as this is the only way to improve the genetic characteristics of the trees through tree breeding and establishment of seed orchards.

For broad-leaved species, seed problems do not exist.

(ii) Weed Control

Past experience showed that weed control is a major cost in plantation establishment. Weed control usually represents more than 50 per cent of the total cost in a Pinus caribaea plantation during the period from planting to canopy closure (Tham and Liew, 1977). For a Pinus caribaea plantation at year 2 from establishment, the cost can be as high as M$1000.00 per acre of which 50 per cent is spent on weeding alone (J. Glyn - Chairman of the Sabah Softwood - personal communication).

(iii) Pests and Diseases

A common hazard to plantations of exotic species is attack by diseases and insects. Zeuzera coffeae, Alcidodes lucificatar, Amblypulta cocophaga larvae all bore holes into shoots and stems of Eucalyptus deglupta (Anon. 1972, Anon. 1973-1974). Termites such as Coprotermes curvignathus are a problem in living trees of Pinus caribaea and Araucaria species (Thapa and Shim, 1971). Gmelina arborea have been seen to be riddled by stem borers (Thapa, 1970). Acacia mangium seedlings are defoliated by Hypnomoces squamosus. Yoshii (1978) has detected that Cossidae larvae bore holes into stems of young Eucalyptus deglupta trees and Eurema blanda snelleni MOORE larvae defoliate Albizia falcataria trees in the Sabah Softwoods plantations. The latter species of larvae poses a management problem to the Albizia plantations.

The preceding paragraph illustrates some examples of pests and diseases that have been recorded in Sabah. Whether they would become major problems in large-scale plantations is difficult to foresee.

(iv) Long-term Biological Effects

Large scale plantations usually generate long-term biological and edaphic problems. For example, in the United Kingdom, planting of Pinus species has caused podzolization in soil (Burgess, 1974). Many problems now arise in Pinus radiata plantation in South Australia after the first rotation (L.J. Webb - personal communication). Also from past experiences, the introduction of monoculture systems whether of introduced or native species has often been followed by disastrous attacks by parasites which never become serious in the natural system (Burgess, 1974). Thus, the system of man-made forests is not as perfect as those of virgin and disturbed Dipterocarp forests (Liew and Khiong, 1974).

There are many other problems associated with tree plantations in the tropics, for example, high establishment cost, and the lack of knowledge pertaining to choice of species, function of the man-made system in the tropics etc..

(c) Present Trend of Tree Plantation Development

In 1966, the Sabah Forest Department started the first pilot plantation at Ulu Kukut with the objective of converting lalang (Imperata) grassland to a pine forest. With the experience from Ulu Kukut, the Department went on to establish two additional pilot plantations at Sook and Lungmanis in 1970. The former is also in grassland while the latter in the logged-over Lowland Dipterocarp forest.

In 1974, the Sabah Softwoods Sdn. Bhd. was formed. This is a joint venture of a private company and the Sabah Foundation. The government has alineated 150,000 acres (60,700 hectares) of logged-over forest (Type 3 forest) for planting fast growing species. To date more than 12,000 hectares have been planted with *Pinus caribaea*, *Eucalyptus deglupta*, *Albizzia falcataria* and *Gmelina arborea*.

In 1976, the Sabah Forestry Development Authority (SAFODA) was formed with the objectives of afforestation and re-afforestation in grassland as well as in regenerating forests. An annual planting target of 9,700 hectares is envisaged. Legislation has been passed to levy a sum of 15 cents on every hoppus cubic foot of timber extracted.

A Japanese company and an American firm have also established trial plantations of about 120 hectares, with the aim of embarking on large-scale planting at a later stage.

Though many problems are associated with tree plantations, there is growing evidence that man-made forests will gradually supercede the dynamic Dipterocarp forests as a system for production of wood and cellulosic material.

5.3.5 Concluding Remarks

Though a number of silvicultural systems has been evolved for tropical moist forest management, fundamentally, there are only two approaches viz., even-aged or monocyclic systems, and the uneven-aged or polycyclic systems which have been discussed in detail in preceding Sections. Ecologically, some forest types can be managed under one of these systems alone. However, problems such as destructive logging, utilization of species etc., complicate the already complex Dipterocarp ecosystem, which render considerable difficulties in regenerating the forests. Ideally, the system to be adopted should be based on the forest conditions and silvicultural characteristics of the Dipterocarp species. It should be within the capacity of the ecosystem.

From the foregoing Sections, Selective Systems (polycyclic or bicyclic), the modified Malayan Uniform System (Monocyclic or polycyclic), and other systems the emphasis on retaining advance growth, can be employed to manage Dipterocarp forest in Sabah. Artificial regeneration, i.e., the tree plantation, has been regarded by the Government as an alternative system for producing timber and cellulosic material in Sabah, in the light of the rapid depletion of the natural forest. The final choice of the system will depend on other economic and social factors, supply and demand for hardwood, and other factors which will be examined in Chapter 7.

5.4 Post-exploitation Treatments

Post-exploitation treatments are commonly carried out in rainforests with the aim at improving the stocking and growth rate of economic species. Treatments normally involve poison-girdling, climber cutting and enrichment planting. All these aspects particularly, their effectiveness will be examined in Chapter 6.

CHAPTER 6

EVALUATION ON THE EFFECTIVENESS OF LINEAR SAMPLINGS AND SILVICULTURAL TREATMENTS IN DIPTEROCARP FOREST WITH PARTICULAR REFERENCE TO SABAH

6.1 Introduction

In Chapter 5, it has been indicated that linear sampling is one of the most important tools in rainforest management, as silvicultural precriptions practised in Sabah are usually based on the results of L.S.M., LS$\frac{1}{4}$ and LS$\frac{1}{2}$. This sampling method has been popularly used by foresters in the tropics and therefore it is imperative that its effectiveness should be examined.

No matter which silvicultural system is to be adopted for management of the Dipterocarp forest in Sabah, pre-log and post-exploitation treatment may still be applied at different stages of development of the forest. It is therefore, of paramount importance to evaluate the effectiveness of the most important silvicultural treatments which are considered to be useful in managing the Dipterocarp forest in Sabah. The treatments to be discussed are of direct relevance to the silvicultural characteristics of the Dipterocarp forest.

6.2 Background of Linear Sampling

The characteristics of the populations of many tropical forests are unfavourable for sampling from a statistical point of view. The density of the merchantable or commercial timber trees and species, which are the object of the inventory, is often low, sometimes less than five trees per hectare, and frequently these species occur in irregular patches. Even if a large unit size is chosen, many units will still have zero values and, on the other hand a small number of units will occur with very high values.

The simplest and safest method of making an inventory of such a population is complete enumeration, which, however, is rarely done because of the many difficulties and the high cost (Loetsch *et al.*, 1973). Such complete enumerations have been occasionally carried out in Cambodia (Allouard, 1944), and of the chewing gum tree (Dyera lowii) in the peat swamp forest of Sarawak (Brünig, 1963). The only practical alternative in making an inventory of such difficult populations, is the application of sampling methods which are capable of producing, for the least possible cost, a tolerable estimate of the tree population (Loetsch *et al.*, 1973).

For practical reasons, most sampling designs in tropical forests employ strips as sampling units in spite of their susceptibility to bias, which in a difficult population may lead to serious errors. Inaccurate bearing and incorrect width of units, which occur even with the most careful execution of field work, lead to wrong information sampled area (Näslund 1939). It is difficult to maintain the correct width of a strips; for example; it becomes necessary to continually check right angle distance in order to decide on border-line trees. It is also difficult to check the width of the strips afterwards.

6.3 Evaluation of Linear Sampling of Regeneration Practised in Peninsular Malaysia And Sabah

Wyatt-Smith (1961) pointed out that the most important tool in the Malayan Uniform System is the linear sampling technique. This consists of a systematic sampling of the seedling regeneration (L.S.M.) of the classified species that are present at the time of felling or immediately after felling, and subsequently of the sapling regeneration (LS$\frac{1}{4}$ and LS$\frac{1}{2}$) and its development status during the regeneration period.

The original objective of linear sampling implemented in Peninsular Malaysia was to obtain information on the prospect for successful natural regeneration (L.S.M.) and to judge the success and condition of regeneration for tending precriptions (LS$\frac{1}{4}$ and LS$\frac{1}{2}$) and the probable composition of the future crop (LS$\frac{1}{2}$). Vicent (1961) criticised that L.S.M., a crude assessment of stocking and species composition, made at one instant of time, does not tell us much about the behaviour of regeneration and how it changes in quantity and quality with time. The standards for L.S.M. LS$\frac{1}{4}$ and LS$\frac{1}{2}$, for passing an area as regenerated, were fixed without intensive investigations (Vicent, 1961). Among other things, Vicent (1961) recommended that (a) L.S.M. should be omitted unless doubt exists on the adequacy of seedling stocking after an inspection designed to cover, sensibly, the total area of the compartment, and (b) if L.S.M. is done, it should be modified to take in advance-growth by running in full, LS$\frac{1}{2}$ with L.S.M. strips down the centre lines of the half chain squares. His suggestions have led to the development of Linear Regeneration Sampling one (LRS-1) which is currently in force in Peninsular Malaysia (Forestry Department, Peninsular Malaysia, 1974). The objectives of the LRS-1 may be briefly summarised as follows:

(i) If selected advance growth is adequate in terms of stocking and distribution, stand age can be advanced, and treatment prescribed accordingly.

(ii) If (i) above is not met with, but if selected seedlings are adequate in terms of stocking and distribution, appropriate treatment can be prescribed.

(iii) If neither (i) nor (ii) above is met with, but if selected advanced growth and seedlings are adequate in terms of total effective stocking and distribution, again, suitable treatment can be prescribed.

(iv) If none of the above is met with, artificial regeneration can be prescribed.

The LRS-1 is now carried out after logging. The field sheet designed covers considerable detail, both quantitative and qualitative aspects of data collection. Features such as presence of bamboo, bertam and other undesirable weeds are recorded. From the analysis of data, treatment requirement can be prescribed accordingly.

From a statistical point of view, the sampling method may be biassed, but the data so collected do provide sufficient information for management purposes.

The linear sampling method devised for use in Sabah is very much similar to that practised in Peninsular Malaysia. Following logging, L.S.M. is immediately carried out to determine the forest conditions, particularly the stocking of commercial seedlings, presence of impeders, climbing bamboo, climbers etc.. Treatments are then prescribed accordingly. However, logging intensity is high and damage to forest often amounts to 50 per cent of the land mass. Silvicultural treatment immediately following logging is no longer implemented. LS$\frac{1}{4}$ and LS$\frac{1}{2}$ are carried out only in 5 years old and 10 - 15 years old regenerating forests respectively. Treatments are prescribed according to the forest conditions. In short, in all cases linear sampling is used for purpose of understanding the forest conditions as well as the stocking of economic species at different stages of the regenerating forests. Apart from this, sampling is not of much scientific value. Field sheets and summary sheets of L.S.M., LS$\frac{1}{4}$ and LS$\frac{1}{2}$ used by the Forest Department, Sabah are included in this thesis (Appendices II to VII).

The author has carried out an investigation of linear sampling as a tool to predict the composition of the future Dipterocarp forest, at the Segaliud-Lokan Forest Reserve. The area was logged in 1962 and L.S.M. was run soon after felling. In 1972, the same area was resampled using LS$\frac{1}{2}$. It was found that the species composition was different from that of the L.S.M.'s. The Author had consulted Dr. Carron of the Forestry Department of the Australian National University, who explained that change in species composition is certainly a common feature in rainforests. The explanation is acceptable because at year 0 (felling), some of larger chosen seedlings were slow growing species. At year 10, Dipterocarp species of faster growth rate have out-grown the previous chosen trees. Hence the previous chosen trees could not be reselected as chosen trees at year 10. The actual data could not be presented here because the file was misplaced in the Record Room. Linear sampling, particularly L.S.M., cannot be used as a tool to predict the future crop. In the light of this, L.R.S.-1 practised in Peninsular Malaysia would be more useful, as pole crop and seedlings are sampled simultaneously by running L.S.M. and LS$\frac{1}{2}$ at the same time.

The preceding paragraph illustrates that linear sampling can hardly be used as a tool to predict the likely composition of the future crop though ample information can be gathered from it. But as a useful and simple sampling method, it should be used to determine the forest conditions for prescribing treatments at different stages of development. In order to study growth and dynamics of the Dipterocarp forest in a more detailed manner, yield plots (2.5 acres per plot) have been randomly established in a set of 10 in most of the annual coupes. This is the current practice to study longer term effects of logging in Sabah.

6.4 Prelog Treatment - Climber Cutting and Tree Marking prior to logging

The effectiveness of the pre-log treatment, climber cutting and tree marking prior to logging has been comprehensively dealt with in Chapter 5. The subject has been well documented (Fox, 1968a; Liew, 1973a). Though it is an effective treatment in minimising logging damage, its practical application has difficulties, among other things, it requires full co-operation of the loggers and comprehensive logging rules. This will be further examined in Chapter 7.

6.5 Poisoning-girdling Operation Immediately After F (Logging)

The silvicultural treatment, poison-girdling immediately after logging, had been practised in Sabah for more than two decades before it was finally suspended in 1977. This suspension is by no means indefinite as it is still subject to review from time to time.

The main objects of the treatment were,

(i) To ensure that seedlings where present have sufficient light for maximum development (but are not fully exposed), and to favour sound advance growth.

(ii) To remove species and defective stems where these will compete with regeneration if left.

(iii) Where seedlings are deficient to retain sufficient stems of commercial species to ensure eventual maximum stocking of regeneration.

(iv) To eliminate any climbers.

The question is whether poison-girdling of trees immediately after logging is an effective treatment. 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 the girdling increased the average crown status and overall stocking:

Table 6.1 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 1949
Stocked plots/acre (Max 160)				
Treated				
All plots	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 reduce seedling stocking. Of particular interest was the consistent level of stocking (some 60 to 75%) with good crown status recorded in the treated plots compared to about 25 per cent in untreated plots. This shows that poison-girdling is a useful treatment.

A large experiment started in 1957 (R.P. 33) compares girdling at 0, 2, 4, 6 and 8 years from felling with a control. The experiment was designed by the late G. A. McIntyre in 1956. Sampling of stocked plots on the LS$\frac{1}{4}$ principle at 5 years from felling gave the following:

Table 6.2 LS$\frac{1}{4}$ Stocking year five years from felling (F+5) R.P.33

Treatment	GO	G2	G4	NOG
Stocked plots/acre (Max 160)				
All	138	135	143	143
Over 6 inches girth				
All trees	63	57	44	44
Dominant or codominant trees	49	40	30	21
No climbers	12	14	12	15
Dom. or dodom., no climber	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 inches for year 2, and 6 inches 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 of the stocking.

Data for R.P. 33 was partly analysed by C.S.I.R.O., Australia with the assistance of the late G.A. McIntyre in late 1971. The results indicate that the best growth was achieved when poison-girdling was carried out at year F+2. According to McIntyre (1971), there are definite replicate (group block) effects in all years, and treatment effects in 1961, and 1969. LSD between adjusted means will not be greater than the average standard error Xt_{10df} or by 2.23 at 5% level. A comparison of means for 1957 and 1959 is given in Table 6.3.

Table 6.3 Treatment Means (Girth) as at 1957 and 1969
Forest Logged in 1957 R.P.33

Treatment No.	Name	Unadjusted Mean		Intrablock Adjusted		Interblock Adjusted	
		1957	1969	1957	1969	1957	1969
1	Control (No girdling	0.324	6.250	0.330	6.026	0.326	6.174
2	Poison girdling done immediately after logging	0.88	8.540	1.061	8.265	0.942	8.443
3	Poison girdling done two years after logging	0.516	12.46	0.580	13.893	0.537	12.826
4	Poison girdling done four years after logging	0.380	7.798	0.638	6.496	0.467	7.340
5	Poison girdling done 6 years after logging	1.002	8.120	0.548	8.828	0.849	8.369
6	Poison girdling done 8 years after logging	0.314	7.234	0.261	6.680	0.296	7.039
	Average STD error of difference			0.347	1.74	0.298	1.475
	Approx. VR. for treatments			1.327	5.798	1.640	5.060

G.A. McIntyre, 1971.

From Table 6.3, it is apparent that poison-girdling after felling is a useful silvicultural tool to improve growth in regenerating forest.

The data collected from R.P.33 in 1972 was further analysed (Table 6.4). The same trend of results can be seen.

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 difference 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, 1966) has in some cases, led to more residual stems being killed than necessary. But the rules, of a blanket nature, must be interpreted with some flexibility, as the amount of girdling to be done should be dictated by the residual population. Variation in treatment must take account of the increased intensity of felling.

As logging intensity increases, the difference in growth rates between treated and control plots becomes less and less significant. Table 6.5 illustrates effects of girdling in treated and control blocks of forest, logged by heavy equipment, in four Reserves. Girdling has had little effect on the girth of the post-logging stocking.

Table 6.4

R.P.33 Summary of Mean Girth (in inches) of the chosen trees by replications and treatments at the date of 1972

Treatment / Replication	Control untreated (Block 1)		Immediate treatment (Block 2)		Treatment at 2nd yrs. (Block 3)		Treatment at 4th yrs. (Block 4)		Treatment at 6th yrs. (Block 5)		Treatment at 8th yrs. (Block 6)		Weighted Mean
	Mean girth	No. of trees	Mean girth	No. of trees	Mean girth	No. of trees	Mean girth	No. of trees	Mean girth	No. of trees	Mean girth	No. of trees	
1	7.36	15	13.72	21	11.80	15	13.41	19	11.50	13	5.15	19	10.56
2	5.38	18	7.40	21	9.75	16	11.75	14	10.00	5	13.31	20	9.45
3	11.74	18	11.00	24	13.91	20	9.16	21	7.33	24	15.14	13	10.98
4	5.98	18	8.21	21	-	-	-	-	7.83	18	7.26	11	7.36
5	8.77	24	9.49	24	19.49	20	13.40	24	14.31	23	9.05	22	12.24
Weighted Mean	7.92		9.97		14.09		11.96		10.18		9.88		10.48

* Plots damaged.

Table 6.5 Average girths in RP.223

	Stocking Average (Max 160/acre)	Years from Felling	Girths (ins.) Average Girdled Plots	Control Plots
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

It can be concluded that poison-girdling immediately after felling is a useful silvicultural treatment to improve growth in particular in regenerating forests. However, its effects may decrease as logging intensity increases. No blanket rules for girdling should be imposed.

In any case if this treatment is to be implemented, it should be cautiously applied, as excessive opening of the forest canopy may cause mortality of seedlings (Liew and Wong, 1973). It points to the need for all silvicultural staff to have a clear understanding of the physiology of Dipterocarp seedlings. They should be able to judge whether poison-girdling is required under the present intensive logging conditions.

6.6 Liberation (Girdling, Climber cutting etc.) at F+5 and F+10 to F+15 Regenerating Forests

6.5.1 Liberation Treatment at F+5

The invasive climbers (e.g. Mesoneuron, Merremia, Phenera) established after felling lead to stem damage of the young Dipterocarps, as well as being competitors with them for light. An experiment (R.P.95) laid down in regeneration 5 years from felling in 1963 in Segaliud-Lokan Forest Reserve compares growth of regeneration following climber cutting, against a no-treatment control. An immediate and 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 larger trees. Increment continued to be put on at an increased rate in the treatment areas for 3 years from treatment, but after that the larger trees in control plots were growing at a slightly faster rate.

Table 6.6 summarises growth rates over the four years from treatment: for trees measured in the LS¼ sampling; mean girth and CA1 are shown for 160 trees/acre, and the best 40 and 25 trees.

Table 6.6 Summary of Measurements R.P. 95 Segaliud-Lokan Forest Reserve

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	1.08	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 sampled by LS¼ at the Kalabakan Forest Reserve by Nicholson (1965) were resampled during 1968-69. 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.

Liberation at F+5 is a useful treatment. Should treatment at F+10 be omitted because of high intensity of logging, liberation treatment at F+5 is certainly beneficial to the forests.

6.5.2 Liberation Treatment at F+10 to F+15

This treatment is usually carried after LS$\frac{1}{2}$. 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 Dipterocarps, (4) Retention of the best 160 Dipterocarps per acre. In treated plots, trees were either cut or girdled. After 5 years the position was as follows:

Table 6.7 Thinning Trial in R.P. 95 Segaliud-Lokan Forest Reserve

	- Treatment method -					
Treatment: -	Cutting		Girdling		Combined	
Trees/acre* -	80	40	80	40	80	40
	(Average C.A.I. ins. Girth)					
Treatment level (see text)						
1 (control)	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

*Chosen trees for measurement

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 the 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) the best response with girdling.

A large scale liberation experiment (R.P. 273) was also carried out in three regenerating forests (A) Segaliud-Lokan F.R. (Felled 1957) (B) Kalabakan F.R. (Felled 1956) and (C) Silabukan F.R. (Felled 1954). The objective of the study was to investigate 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.

In each block 2 plots received no treatment; one plot received a heavy treatment in which all trees of invading species, and of non-commercial species were eliminated (Treatment 2); and the fourth plot received a lighter treatment - elimination of non-commercial species only (Treatment 3). Treatment plots also received climber cutting. Chosen trees were subsequently remeasured to determine girth increments.

Soon after treatment it became apparent that indiscriminate girdling had resulted in damage to chosen trees through falling of branches and boles, particularly so in Silabukan Treatment 2, where the average girth 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 37 out of the 74 marked at the start survived one year. In other cases however, treatment resulted in higher average increment on the chosen trees (Table 6.8). CAl for control plots ranged from 1.14" to 1.85"; in the heavy treatment 2 CAl ranged from 1.29 to 2.81" for the same range of treatments.

Table 6.8 Mean girths and Average Increment (inches) RP.273

Replicate	A (Segaliud-)			B(Kalabakan)			C(Silabuka	
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	29.98	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	1.85	1.61	1.37	1.77
Stems/Plot (= 1 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	32.56	20.25	24.19	38.36	12.60	13.11
Av. C.A.I.	2.08	2.68	1.93	2.15	2.81	2.10	1.29	1.61
Stems /(= 1 ha)	79	47	25	79	48	25	57	39
Treatment 3								
Initial girth	21.44	21.16	33.88	16.26	12.89	24.29	14.71	11.50
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 (= 1 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).

Table 6.9 illustrates the comparative increments of two important species in R.P. 273B (at Kelabakan).

Table 6.9 Comparative Increments R.P.273B

Girth Class (Inches)	/10	10-19.9	20-29.9	30-39.9	40+
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)	3.35(3
T3	1.10(9)	1.30(20)	1.60(10)	2.40(4)	1.95(1
	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)	-

The figures suggest similar growth in control plots but Shorea parvifolia showed greater response to treatment, particularly in smaller sizes.

Table 6.10 summarises the response in increment of the three most important species in R.P. 273A (at Segaliud-Lokan).

6.10 Comparative Increment R.P. 273A

Girth Class (Inches)	/10	10-19.9	20-29.9	30-39.9	40+
		(Increment in inches)			
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(5
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

The foregoing account has demonstrated that silvicultural intervention in stands 10-15 years after felling can result in increased growth of the desirable species of such stands. As the major growth stimulus is to smaller size stems it is considered that this liberation treatment should result in an evening up of the stands : the larger sized trees, already in dominant or codominant positions vis-a-vis the invasive and understorey species, may be joined by additional recruits from the smaller categories.

As the stands develop after a release operation, it may be expected that growth increases will slacken off as competition sets in again. There may possibly be a case for further silvicultural treatment in older stands. However, this seems unlikely because large or dominant trees show little response to liberation.

6.7 Enrichment Planting

6.7.1 Introduction

The use of wilding (natural seedlings) as planting stock in early European forestry undoubtedly facilitated the stocking of bare ground and clear-felled areas. Köstler (1956) suggests that Beech and other hardwoods be pulled from wet spongy soil while conifers should be dug out. Drawbacks are the often poor root systems of wildings and the need to harden off plants from dense shade.

Flowering and fruiting of the Dipterocarp trees in Malaysia, Philippines etc. is both gregarious and irregular (Chapter 4). Dipterocarp fruits are difficult to handle even when abundant, as germination occurs immediately after fruitfall (Chapter 4). Wyatt-Smith (1959) suggests use of wildings for restocking poor areas in the vicinity of stocked areas, and for enrichment planting after the removal of economic species, under the Malayan Uniform System, when regeneration is gravely deficient or absent. The use of line planting as part of planned regeneration operations was initiated in Selangor in 1961 and in Perak in 1967, and by 1972, about 15,000 acres had been planted in these two states (Tang _et al_, 1974).

In Sabah and the Philippines bare landings, tractor paths and spar tree settings are rendered devoid of economic species. Such areas may be left alone, or replanted with Dipterocarp stock or with other fast growing species. A comprehensive programme has been planned to improve the growing stock level for increased timber yields in the Philippines (Reyes, 1977). Among other things, it involves enrichment planting with genetically improved fast growing species.

6.7.2 Recent Experiments in Sabah

The most inhospitable sites have been used with little tree growth of any kind present. Wildings of _Dryobalanops lanceolata_, _Shorea leptoclados_, _Parashorea tomentella_, _Shorea parvifolia_, _Dipterocarpus caudiferus_, _Shorea waltonii_ and _Shorea leprosula_ were planted immediately after collection in 1964. 153 plants were used. Two months later only 21 were alive. The only species of any interest was _Dipterocarpus caudiferus_ with 15 survivors, of which 12 survived of the 14 planted with heights less than 6". Of the wildings larger than 18" in height, only 4 out of 99 survived two months (Liew, 1971 C)

A number of subsequent trials involved standing the potted wildings for several weeks prior to planting. Most of these were failures due to one or more of the following causes:

(a) Subsequent erosion of planting site;

(b) Browsing by deer;
(c) Machinery disturbance; and
(d) death of plant probably connected with intense exposure to heat.

One trial which remains moderately successful deserves mention. This is at Malua F.R.. Four plots of 36 plants each were established in September - November, 1967. The results are summarised in Tables 6.11 and 6.12.

Table 6.11 Survival Percentage

	Survival Percentages		
	Year 1	Year 2	Year 3
Plot 1	86	75	72
Plot 2	98	89	75
Plot 3	72	61	55
Plot 4	72	42	33
Overall	82	67	59
Parashore tomentella	74	61	58
Dipterocarpus caudiferus	93	73	61
Dryobalanops lanceolata	91	82	74

Table 6.12 Average Height of Survivors (inches)

			Average Height of Survivors (inches)		
Species	No. Planted	Initial Height (ins.)	1 year (ins.)	2 years (ins.)	3 years (ins.)
Parashorea tomentella	64	14.8	30.5	53.7	86.6
Dipterocarpus caudiferus	44	13.6	17.2	26.6	48.3
Dryobalanops lanceolata	23	13.9	21.9	48.8	78.9
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	62.2
Plot 4	36	13.5	16.9	25.0	39.4

Table 6.12 demonstrates that once the wildings survived, satisfactory height growth could be attained from year 2 onwards.

A large scale enrichment planting using Dipterocarp wildings has been under investigation since 1974. Chai (1975) concluded that the establishment cost including overhead expenditure was M$257 per acre whereas the cost excluding overhead expenditure amounted to M$74 per acre. The percentage survival one year after planting was 42.5%. Tables 6.13 and 6.14 show some aspects of the results of the large scale enrichment planting trial.

Table 6.13 Survival and Growth in Height

	KPJ*	UMB+	Others	Total
No. planted in 1974	2626	881	9	3,516
No. as at 1975	1172	322	1	1,495
Survival %	44.63%	36.55%	11.1%	42.52%
Mean Height in 1974	8.2"	11.9"	9.2	
Mean Height in 1975	18.8"	19.7"	19.0"	
C.A.I.	10.6"	7.8"	9.8"	

* KPJ = *Dryobalanops lanceolata*
\+ UMB = *Parashorea tomentella*

After Chai (1975)

Table 6.14 Survival of Seedlings for different size classes

Size Class (height)	Total Planted	Dead	Survival
0" - 6"	92	40 (43.5%)	52 (56.5%)
7" - 12"	2311	1315 (56.9%)	996(43.1%)
13"+	1113	666 (59.8%)	447(40.2%)

After Chai (1975)

Though the results are not very encouraging, the possibility of restocking the forests is there. Perhaps, the high cost factor may be the main constraint preventing large scale establishment. Tang (1974) pointed out that the high failure rate was attributable to (a) the use of poor planting stock (b) lack or improper timing of post-planting treatments, (c) shortage of staff and funds, and (d) the lack of sound reforestation planning based on existing staff and financial capabilities. According to the author's observation, perhaps the single most critical factor was the shortage of professional or sub-professional staff who could devote their full time and energies to the reforestation projects. Most of the other factors stemmed directly or indirectly from this.

Owing to repeated disappointments of enrichment planting using Dipterocarp wildings, bare areas are now planted with fast growing boardleaved species, either exotic or indigenous in the Philippines (Reyes, 1977). A similar development has been started in Sabah on a small scale. The main species used are Albizia falcataria, Acacia mangium and Eucalyptus deglupta. The initial results have been promising.

As land now becomes a scarce commodity, it cannot be left unproductive. Enrichment planting using wildings or fast growing species raised from seed can be an effective, albeit somewhat expensive, method of rehabilitating forests containing inadequate or no natural regeneration. But, unless the necessary Manpower, at all levels, funds and priority can be committed to reforestation projects, it is unlikely that any significant success can be achieved.

CHAPTER 7

FACTORS AFFECTING SILVICULTURAL DECISION

7.1 Introduction

Silvicultural practice is not only influenced by biological factors such as species tolerance, regeneration, growth, structure of the forest etc. but also by the forest policy and management objectives, harvesting system, market for species (present and future), the nature of logging and milling industries, the role of timber in the economy of Sabah, productivities under different silvicultural systems and others. The author will only examine the most important factors which have direct relevance to Sabah conditions.

7.2 Forest Policy and Management Objectives

The present statement of Forest Policy, substantially in accordance with the recommendation of the Fifth Empire Forest Conference in 1947 was formulated and adopted in early 1948. The Policy was last modified in 1954 and no further changes have been made up to the present. Elements such as inventories, supply/demand forecasts have not been prepared and applied in the formulation of the Forest Policy (Liew, 1973c). The main features of the Forest Policy may be summarised as follows:

(a) To reserve permanently for the benefit of the present and future inhabitants of the country forest land sufficient :

(i) for the maintenance of the climate and physical condition of the country, the safeguarding of water supplies, and the prevention of damage to rivers and agricultural land by flooding and erosion;

(ii) for the supply in pepertuity at reasonable rates of all forms of forest produce required by the people for agricultural, domestic and industrial purposes.

(b) To manage the Forest Estate with the object of obtaining the highest revenue compatible with sustained yield, in so far as this is consistent with the two primary objects set out above.

(c) To provide the technically trained staff necessary for forest management and revenue collection, and for research into such problems as can be investigated locally.

(d) To support and co-operate in all appropriate schemes of regional forest research.

(e) To accept in principle that secarity of tenure and long-term planning are essential for the successful management of the Forest Estate.

(f) To foster by education and propaganda, a real understanding amongst the peoples of Sabah of the value of the forests to them and their descendants.

In order to fulfil the objectives of (a) and (b) of the Policy, it was assumed that indigenous forests would regenerate into high forest again after a period of 80 years with artificial aids, i.e. various silvicultural practices to enhance growth rate of timber trees. The forest was managed by area basis with a total annual cut of 1/100 of the total forest reserves. No particular methodology for social-cost/benefit analyses has been developed to aid policy-making in general and/or in forestry.

The main management objectives are thus to favour regeneration of valuable Dipterocarp species, to practise sustained yield management as well as to implement conservation. Therefore, silvicultural systems which are capable of regenerating the Dipterocarp forest in Sabah should be adopted. As discussed in Chapter 5, The Malayan Uniform System, Modified Malayan Uniform System or Selective System could be suitable, as these systems are quite compatible with the silvicultural characteristics of the Dipterocarp forest. Silvicultural treatments which could improve growth rates, stocking of regeneration and productivity of the Dipterocarp forest, could also be carried out.

The recent trend of exploitation rate indicates that it is the Government's policy to log huge forest areas in order to generate income, capital etc. for development of the State. The annual cutting rate was 80,000 hectares in 1973 (Table 1.4) and today (1978) it has risen to 120,000 hectares per annum. With the exception of the Sabah Foundation which practises sustained yield management, all other timber licences are of short-term nature (Section 1.3). Overcutting is the grave concern of the foresters because it has been estimated that by 1985 2/3 of the total forest estate would be turned into young regenerating forests.* Should regeneration be dependent on seedlings, the cutting cycle would be 65 to 80 years (Chapter 3). As it is not possible to curtail the present exploitation rate because of the government's policy, it would be therefore more beneficial and practical to adopt a system which possibly could retain the pole-crop. Under ideal conditions, growth of pole trees of 1' to 6' girth could amount to 1.5" to 3.0" girth (C.A.I.), particularly the Rubroshorea and

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* A more recent assessment suggests most of the lowland forest will be removed by 1985 leaving only 3.5 million acres of mainly hill forests.

Parashorea species (Chapter 5 and 6). Such a management system could generate an exploitable volume of commercial species within a period of 40 years or less, depending on species composition and forest type. Hence, a future shortage of tropical hardwood in Sabah may be abridged. Therefore,Selection System as practised in the Philippines and timber complexes in Peninsular Malaysia (Reyes, 1977; Cheah, 1977; Hamdan, 1977) would appear to be most suitable in Sabah in the light of the shrinking forest resource. In this case, a comprehensive set of logging rules and viable management units must be formulated and determined (see Hamdan, 1977).

It has been discussed in Chapter 5 that the tree plantation could be an alternative system to supplement timber production when natural resources have been depleted This aspect of forestry activity will be further examined in later Sections.

7.3 Environmental consideration

Chapter 1 points out that Sabah is a mountainous country with high rainfall. It has been projected that most the lowland Dipterocarp forest will be logged by 1985 leaving the 1.5 million hectares of mainly hill forest for future exploitation. Exploitation of the hill forest has already commenced at several localities in the interior.

Conservation of forests for "maintenance of the climate and physical condition of the country, the safeguarding of water supplies and prevention of damage to rivers ......etc." is embodied in the current Forest Policy. Foresters should seriously consider the environmental impacts of logging in the Dipterocarp forest, particularly the hill forest in Sabah. Tampering unwisely with the ecology of the rainforest will result in poor water quality, fluctuating water tables as well as flows (especially during monsoons), and erosion problems that will hinder access and diminish the productive capacity of the forest. For example, Liew (1974b) found that at least an amount of 2500 to 3800 cubic feet of top soil may be eroded and lost from the bare and steep slope in Tawau Hills F.R. within a period of 20 months from logging. He warned that logging in steep hills should be carried out with precautionary measures. Siltation already occurs in streams and rivers and flash floodings are more frequently observed in recent years. Therefore, it is desirable that the hill forest be logged only on condition that sustained yield management is obtainable with minimum environmental damage. The Malayan Uniform System or Modified Malayan Uniform System may be too drastic to be adopted. Perhaps a form of Selection Logging System would be most suitable for exploitation of Dipterocarp forest, particularly the hill forest. Griffin and Caprata (1977) stress that Selection System is the only practical silvicultural method for the hill Dipterocarp forest in Malaysia from sustained yield and conservation points of view.

7.4 Harvesting Systems and Logging damage

The harvesting phase of forest management popularly known as logging comprises three stages - (1) felling and bucking, (2) snigging and, (3) transportation. Stages (1) and (2) exert the most influence on forest management, particularly silvicultural policy, and can either make or break the cycle in the light of the highly mechanised and sophisticated harvesting systems used in Sabah. As an extraction process, logging can be destructive to the forest and the environment if wrongly prescribed and haphazardly applied. Since 1965 heavy logging equipment has been introduced for timber extraction. Coupled with the absence of adequate logging rules logging damage has been significant, usually amounting to 30-50 % the land surface (Liew, 1974a). The forest condition after logging is not ideal, as commercial seedlings are present in patches (Liew op. cit.). Therefore, the subsequent silvicultural option to improve the forest stand is either to carry out enrichment planting or establish tree plantations. Thus logging has an influence on silvicultural policy.

Logging in rainforest Dipterocarp forest is a particularly destructive process in view of size of the trees and crowns, distribution of commercial trees, and equipment used in extraction. Crawler tractors used in snigging logs from the forest to landings account for the most significant damage, amounting to 14 to 33% of the land surface (Table 7.1).

Table 7.1 Logging Damage at Segaliud-Lokan Forest Reserve R.P. 384 (1 acre per plot - randomly located prior to logging).

Plot No.	Tractor Path %	Water Logged %	Fallen trees %	Total non-productive area %
1	14.38	9.35	5.00	28.73
2	33.38	-	14.18	47.56
3	19.55	2.38	16.18	37.11
4	19.88	-	24.85	44.73
5	26.60	-	5.45	30.05

After Liew, 1974a

As logging in rainforests is always destructive, should it be continued unchecked, bearing in mind that the method of rehabilitating forests containing inadequate or no natural regeneration is expensive and difficult

(Tang, 1974; Liew and Keong, 1974; Chai, 1975). On the other hand, could logging damage be minimised? Chapters 5 and 6 point out that such damage can be minimised by climber cutting and tree marking operations prior to logging. Mordeno (1977) and Reyes (1977) conclude that the Selection System is the best suited silvicultural method because the only ways to minimise logging damage are (a) to restrict movement of tractors in snigging and (b) to extract a certain portion of the overwood according to the inventory data. The method has been found both economical and successful in the Philippines. The sequence of operations involves detailed inventory, tree marking, pre-located log landings, skid trails etc. (see Hamdan, 1977).

Could another type of machine of similar power be designed for snigging logs? The F.A.O. has been requested to investigate this. K.S.Kim (1978, personal communication) confirmed that though research is in progress, it is unlikely that there would be a great success at all. After all, the skidder has been found unsuitable in Sabah. In the light of this, it would be desirable to adopt a silvicultural system which involves less destruction.

7.5 Market for species - Export and local

The Dipterocarp forest of Sabah is composed of complex and heterogeneous species of timber (Chapter 3). In its natural state, the influence of the market is minimal since nature has its own way of producing the species of timber that are acceptable in the market. However, once the market develops a taste for a particular species or group of species, the influence of markets on forestry management, especially silvicultural treatments or policies, would be predominant (Lee, 1977). The current trend of the timber

Table 7.2
Exports of Timber by Species and Classes 1972
(Volume Quarter Girth measured)

Species	Logs and baulks Meter^3	Sawn meter^3 (Round equipment)	Total meter^3	Percentage of total exports
s A				
n	8,262	-	8,262	0.1
u	169	-	169	-
gan batu II	30,694	-	30,694	0.4
	39,125	-	39,125	0.5
B				
ng	857	-	857	-
uluk	3,228	-	3,228	-
eraya	3,430,605	10,264	3,440,869	44.7
Seraya	1,935,500	10,254	1,945,754	25.3
	5,370,190	20,518	5,390,708	70.0
s C				
	8,365	-	8,365	0.1
	999,702	1,338	1,001,040	13.0
ng	540,417	709	541,126	7.0
i	132,506	-	132,506	1.7
h	11,042	-	11,042	0.2
ir	7,361	-	7,361	0.1
gan	36	-	36	-
w seraya	540,210	6	540,216	7.0
	2,239,639	2,053	2,241,692	29.1
D				
ong	1,246	-	1,246	-
	1,246	-	1,246	-
E				
	1,196	-	1,196	-
	1,196	-	1,196	-
O.T.				
	14,859	-	14,859	0.2
ng	2,468	-	2,468)	
ong	1,837	-	1,837)	
	185	-	185)	0.2
g	168	-	168)	
ris	309	-	309)	
llaneous species	4,992	-	4,992)	
gan batu merah	2,348	-	2,348)	
	27,166	-	27,166	0.4
l total of all ses	7,678,562	22,571	7,701,133	100.00

market is towards marketing by end-use, and thus forest management principles and objectives must be geared to what the markets demand, rather than what the forest's standing stocks are. Future forest regimes must be managed according to the market requirements, through manipulation of the forest. The price of a particular species of timber in this instance could act as a stimulant, particularly if future crops of timber are looked upon as an investment outlet (Lee, 1977).

For the past decade, Red Seraya (Mainly Rubroshorea species) and White Seraya (Mainly *Parashorea tomentella* and *P. malaanonan*) consistently constituted about 70% of the total export volume. To illustrate this point, Table 7.2 shows exports of timber by species and classes for the year 1972. The high percentage of White Serayas and Red Serayas exported to overseas markets in recent years indicates that these species are in popular demand by importers. In fact they fetched the highest prices in overseas markets (Table 7.3).

Table 7.3 Average FOB Price (M$) of logs per Hoppus Cubic foot 1974 to 1978 February

Class	A	B*	C	D	E	O.T.**
Year	M$	M$	M$	M$	M$	M$
1974	2.93	3.56	3.13	1.98	1.09	3.11
1975	1.74	2.69	2.21	1.01	-	2.14
1976	2.38	4.02	3.56	3.94	2.32	3.09
1977	2.40	4.29	3.72	4.14	-	2.81
1978	2.08	3.91	3.42	-	-	2.53

Mainly Red Serayas and White Serayas

O.T. = Other Timber

Note : This Table should be read in conjunction with Table 7.2 and Appendix VIII as far as the species of different classes are concerned.

Clearly, Tables 7.2 and 7.3 indicate that the harvesting of logs is related to market needs. In this case, it particularly refers to overseas markets. In other words, forest management policies in the short run, should permit harvesting of logs that will sell in the market, and in the long term should plan the future forest crops to meet the needs of the market. It is clear that Red Serayas and White Serayas have been, and still are the popular species in the overseas markets. Therefore, every effort should be made to create favourable conditions for the growth of these species, in any silvicultural treatments which are required to be carried out. Among other things, these species are floaters which can be easily transported and stored either locally or in overseas countries in log ponds, and in their wood properties have proven to be versatile for all uses. It is unlikely that these species will be unsaleable in the future.

It is appropriate to point out that Class A timbers and a great number of Class C timbers are sinkers. Because of their high specific gravity, they pose considerable difficulties in transportation from the forest to carriers or processing complexes, as water transport is mainly used for transportation (Chapter 1). In addition, the buyers may not absorb a high percentage of sinkers because they have difficulties storing them in their countries, e.g. Japan. However, most of them are durable species and command a reasonably good market in the form of sawntimbers. Though their growth rates are slow (Chapters 3 and 5), they should be given equal preference, particularly Class A and Class C timbers, in all silvicultural treatments, in the light of their wide-spread distribution and abundance (Chapter 3). Lee (1977) warns that it is difficult to forecast the future taste for timber species, and it is advisable to treat the forest as a system, in all silvicultural operations, though special attention may be paid to the popular species.

7.6 Future Supply and Demand

This factor is closely related to the previous Section. The point is : what is the future market situation for tropical hardwood? Unless this is known, foresters and politicians may be reluctant to toil hard in regenerating their forest under a natural process. Natural regeneration usually takes longer to establish than a tree plantation. It is therefore imperative to examine the future supply of, and demand for tropical hardwood.

The supply of tropical logs is projected to increase steadily from 109 million cubic metres in 1973 to 149 million cubic metres in 1980, 215 million cubic metres in 1990 and 303 million cubic metres in the year 2000. The Asia-Pacific region would still remain the major producer of logs with an estimated volume of 93 million cubic metres in 1980, 130 million cubic metres in 1990 and 150 million cubic metres in 2000. Latin America will increase in importance by the year 2000 (Table 7.4).

The projected consumption by producer nations of logs in 1980 is estimated to be 66 million cubic metres; in 1990, it will be 117 million cubic metres and in the year 2000, it will be 185 million cubic metres. The balance of 79 million cubic metres (1980), 98 million cubic metres (1990) and 118 million cubic metres (2000) will be consumed by importing countries (Tables 7.4 and 7.5).

The important point to note is that the consumption trends for both producer nations and importer nations are on the increase. This is significant for it means that countries with tropical moist forests must manage their forests to meet increasing forecasted demand. Hence the Dipterocarp forest must be efficiently managed for tropical hardwood production.

Table 7.4
Projected Demand for Products of Tropical Hardwood Logs
(In log equivalent volumes)

Region	1973	1980	1990	2000
	---------- million m3 (r) ----------			
TROPICAL PRODUCING REGIONS	46.5	66	117	185
Asia-Pacific	24	30	48	70
Latin America	17	28	53	90
Africa	5.5	8	16	25
IMPORTING REGIONS	62.5	79	98	118
Japan	28.9	35	38	40
Europe	17.2	21	27	35
United States	7.2	10	15	20
Rest of the world	9.0	13	18	23
Total	109	145	215	303

Table 7.5
Suggested Supply of Tropical Hardwood Logs and their Products
(In log equivalent volumes)

Region	1973	1980	1990	2000
Asia-Pacific	72.5(48.5)	93(65)	130(82)	150(80)
Latin America	20 (3)	32(4)	60(7)	118(28)
Africa	16.5(11)	20(12)	25(9)	35(10)
Total Tropical producing regions	109(62.5)	149(79)	215(98)	303(118)

Unbracketed figures indicate log production; bracketed figures, exports of logs or their products.

Source: S.L. Pringle, 1976 - "Tropical moist forests in world demand, supply and trade" Unasylva Vol. 28 Page 116.

7.7 Fluctuation of Timber Price

Fluctuation of timber price has considerable effect on the volume of timber to be extracted per unit area from the forest. When timber price is at a low ebb, there is a tendency for loggers to harvest only the best standing trees, leaving a fairly high residual stand volume. Fluctuation of timber price is a common phenomenon, though it tends to stablise at the higher level (Table 7.3). For example, the average F.O.B. price for Class B logs in Sabah was M$2.69 per cubic foot in 1975 (Table 7.3). As a result, logging damage to the forest was not significant, particularly in those forest areas which were logged by inefficient contractors. On this basis, treatment regimes would be quite different from those in forest areas logged in 1973/1974 when the timber price was high. Therefore, silvicultural policies including treatments must be flexible.

Leaving a fairly high volume of timber in the forest stand has now led to another management problem. At the present time (1978), timber price is attractive, and there is a strong pressure from licensees to relog 1975 coupes. In some instances, relogging of 1975 or earlier coupes is taking place. Regenerating forests carrying 200 to 400 cubic feet per acre are opened up for relogging. However, the policy is such that regenerating forests having received silvicultural treatments are not permitted to be opened up for relogging. The Research Branch has been directed to investigate the effects of relogging of immature regenerating forest, but results are not available. It is anticipated that the stocking of regeneration will not be adequate, in the light of intervening in the forest at so short an interval. Adequate silvicultural treatments for these forests have yet to be formulated. According to the silvicultural characteristics of the Dipterocarp forest, relogging at 2 - 10 year intervals should not be carried out, but politicians think otherwise. Perhaps silvicultural treatments may be used as a management tool to prevent relogging, because silviculturally treated areas cannot be relogged.

7.8 Products - Current and Likely Future Changes

Chapters 5 and 6 show that rainforest silvicultural treatments mainly embrace elimination of undesirable species exerting competition on the commercial pole crop or seedlings. A sad example was cited in Chapter 5, i.e., a forest stand carrying a high volume of sound *Dryobalanops lanceolata* was poison-girdled following logging in late 1950's in Lahad Datu District. This species now commands a reasonable market price (just below the average F.O.B. price of Red and White Serayas). In Peninsular Malaysia, species like Nyatoh species (*Sapotaceae*), Sepetir (*Sindora* species), Merpauh (*Swintonia* species) and Durian (*Durio* species) were not popular about four years ago but are now very popular on the export market (Tang, 1974). A careful study of the history of the regeneration species list will show up many more such changes.

These changes are mainly attributable to forest products utilization research. Though it has not been very advanced it has had considerable impact on forest industries (Iyamabo, 1974). Properties of many lesser-known species have been investigated and documented, and these have led to better utilization of forest resources. In some areas e.g., Peninsular Malaysia and the Philippines, this increased utilization was aided by scarcity of wood of the prime species. But in the case of Sabah, timber extraction is still confined to the prime species.

Wood lamination for structural and decorating purposes has now been successfully demonstrated by research in some developing countries (Iyamabo, 1974). This will make a considerable impact on the complete utilization of wood in these countries, particularly as the large trees are becoming scarce.

It has now been found possible to utilize mixed tropical hardwood chips for pulping. Peh (1977) tested the pulping properties of 24 Dipterocarp species and he found that most species are suitable for paper-making. However, <u>Dryobalanops</u> species and <u>Dipterocarpus</u> species gave bulky paper. Phillips and Harries (1975) pointed out that commercial utilization of tropical hardwoods as a source of raw material for cellulose fibre has been seemingly slow in development. There are several reasons for this, not the least important of which has been concern about technical problems involved with pulping, as a mixture, the range of woods with such diverse properties as is characteristic of the tropical hardwood forest. However, Peh (1977) confirmed that reasonable paper has been made by mixing chips of 102 species of tropical hardwood. Species containing exudate or gum have been excluded.

Shimokawa (1977) has forecast that a great shortage of wood chips for pulp will occur in Japan in the future. Table 7.6 shows the trend and forecast of pulpwood supply in Japan.

Table 7.6 Trend and Forecast of Pulpwood supply in Japan (1000 M^3)

	1970	1975	1980	1985
Domestic	22605	16996	20000	20000
Imports	5285	11791	18600	22000
Total	27910	28787	38600	42000

After Eio Shimokawa, 1977.

According to Shimokawa (1977), utilization of mixed tropical hardwood, so-called "jungle wood", for pulping in Japan began in 1974; the wood chips were imported from New Guinea. Further utilization of this kind of wood chips is strongly desired from the viewpoint of securing a stable supply of raw materials.

Extraction of mangrove wood for chipping commenced in 1970 in Sabah. At the present moment, a company is negotiating with the government to set up a pulp and paper mill in Sabah using the "jungle wood" as a source of raw material in the initial phase. This suggests that the silvicultural regime should take this factor, particularly the changes in utilizing the tropical hardwood species, into consideration.

7.9 The Nature of logging and Milling Industries

Chapter 2 touches on the importance in the economy of timber and timber products derived from the Dipterocarp forest. It is stressed that only a handful of timber licensees (Licence Agreements and Special Licensees) are actually carrying out logging themselves. All the other licensees, including the Sabah Foundation whose licensed areas range from 50 to hundreds of thousands of acres are logged by logging firms or contractors on a contract basis. Timber rights are given to private individuals or firms who are not in the position to raise the capital to extract the timber themselves. There is no regulation that licensees must log the forest land themselves. Under such an arrangement, the logging firms or contractors are naturally trying to obtain as much profit as possible. Therefore, it is difficult for the Forest Department to control the loggers. That is why tree marking and climber cutting are so difficult to implement. It is unlikely that the present practice can be wiped out at all because (a) timber licensees are issued on a short-term basis, and (b) the investment commitment of the logging firms or contractors is considerable.

Chapter 1 points out that the Sabah Foundation had been awarded a forest land of 3000 square miles. The original proposed cutting rate was 30 square miles per annum. This is the only licensee practicing sustained yield management in Sabah. There is now a move to increase the annual coupe to 50 - 60 square miles. In a recent meeting, it has been agreed that the Foundation would undertake all silvicultural treatments including tree marking and climber cutting operations and any other effective treatments. There is no departure from the current silvicultural system, but a great deal of emphasis is placed on retaining the pole crop. The concept of undertaking silvicultural operations by the Foundation is a sound one, because the forest area has been permanently allocated to the Foundation, They must assume responsibility for managing the forest to produce timber in perpetuity. The role of the Forest Department is only at the advisory level. This is certainly a step in the right direction. However, the basic problem remains unsolved, as they still intend to engage inefficient contractors for logging. It is doubtful that their objective of retaining the pole crop can be achieved.

Realising the importance of tenure in forestry development, the government is now convinced that forest land in the interior must be awarded to logging firms which will be required to operate on a joint venture basis with the government. Apart from practising sustained yield management it will be compulsory for them to process timbers locally and implement all silvicultural treatments. The setup is similar to the two wood-based complexes established in Peninsular Malaysia. Two projects of this nature are now a firm proposal. In view of the huge capital investment, it is likely that silvicultural practices will be implemented satisfactory.

The nature of the milling industries has been comprehensively dealt with in Chapter 2. Generally, wood processing operations are very much neglected, so much so that sawmilling, veneer and plywood manufacturers are but insignificant in Sabah's Economy. It must be stressed that 95 per cent of log production is exported to overseas countries, and the main species commanding lucrative overseas markets have been discussed (Section 7.5). However, there are indications that more wood-based industries will be established as steps have been taken to restrict log export by imposing a quota system.

7.10 The Role of Timber in the Economy of Sabah

This topic has been discussed in Chapter 2. In short, timber in the form of logs is the life-blood of Sabah. Without it her economy will be paralysed as the forest industries contribute about 50 per cent of Sabah's GNP, 55 per cent of her exports, 50 per cent of Government revenue and employ about 25 per cent of the labour force. Since timber is a renewable asset, the Dipterocarp forest should be managed for production of timber in perpetuity. Wherever possible, high quality sawlogs or peelerlogs should be produced in order to sustain the economy of Sabah.

7.11 Productivities Under Different "Systems"

It was mentioned in Chapter 5 (5.3.5) that though a number of silvicultural systems has been evolved for tropical moist forest management, fundamentally, there are only two approaches viz., even-aged or monocyclic systems, and the uneven-aged or polycyclic systems. Ecologically, some forest types can be managed by one of these systems alone.

The silvicultural systems discussed in Chapter 5 are Selection System (polyclic), Tropical Shelterwood System (monocyclic), Regeneration Improvement Felling System (monocyclic) and the Malayan Uniform System (monocyclic). Some success had been recorded in different parts of world using one or more of the systems. The significant point is that some of the systems have been abandoned. For example, Nigeria abandoned the formal Tropical Shelterwood System (T.S.S.) in 1962, but the reasons had little to do with success <u>per se</u>. Lowe (1975) gives inter alia : independence, pressure for land, and change of emphasis to agri-silviculture as contributing to abandonment of the T.S.S.. Similarly the M.U.S. was abandoned in Peninsular Malaysia when it was discovered that the system was not suitable to the hill forest. Hence a "Bicyclic System" (polyclic) is now in force for the management of the timber complexes (Griffin and Caprata, 1977; Hamdan, 1977).

As all the systems have not been tried out in the Dipterocarp forest in Sabah, it is impossible to quantify the productivity of different "systems". Therefore, the productivity of different systems may be measured by the suitability of the systems, taking into consideration, the structure of the forest, silvicultural characteristics of the forests, expenditure involved in implementing the systems and the time scales of the regeneration cycles.

Chapter 2 points out that the Dipterocarp forest is generally characterised by abundant seedlings, and a reasonably high component of pole trees amounting 10 to 25 stems per

acre (Chapter 5). Upon opening of the canopy, growth of seedlings as well as the pole crop is stimulated. With these characteristics, it may be concluded that prelog treatments aiming at improving stocking of regeneration are not required. Therefore, the T.S.S. and R.I.F.S. may not be appropriate. It is unnecessary to spend money carrying out silvicultural treatments which are not required.
The Malayan Uniform System had once proved to be a suitable system, but the growth of Dipterocarp species exhibits different rates, and therefore an even-sized stand may be difficult to conceive. In addition, the original concept of this system was to regenerate an even-aged stand based on the stocking of seedlings in the regeneration pool. In this case, the time scale for stand development was considerable, 65-85 years or more depending on species composition (Chapter 3). Given the presence of the pole crop and its growth response to opening of the canopy, a form of Section System may be more suitable to the Dipterocarp forest of Sabah. Under this system, a cutting cycle of 40 years or shorter is envisaged in light of the growth studies (Chapter 5 and 6). As pointed out in Chapter 5 a short cutting cycle is very much in favour in the new era of forest management because of political and cost factors, and productivity. The system aims to make maximum use of the existing pole crop. These poles can be raised to a commercial crop, if refined treatments, such as, climber cutting and tree marking are being carried out ahead of felling, and controlled logging is exercised. Systems which seek to ignore the presence of the pole crop will inevitably be expensive in view of the time scales of regeneration cycles. The following is a general rule, probably of universal application : "The more that comes off (or more disturbance) the further back in the process of succession is the stand placed". As the selection system

emphasies removal of overwood by stages, with the aim of maintaining the productivity of the forest at the highest possible level, it appears to be most suitable for the Dipterocarp forest in Sabah. It follows the ecological basis for rainforest management, which has been commonly stressed (Baur, 1964; Fox, 1972; Whitmore, 1975) and is becoming more widely understood.

7.12 Economic Factor

Section 7.11 points out that the current silvicultural systems are either monocyclic or polycyclic. The relative merits of monocyclic and polycyclic systems were discussed in some details by Dawkins (1958) in one of the earliest applications of the terms to forest management. Although his agrument was developed largely in terms of the Ugandan situation, the principles can be and have been extrapolated to a pan-tropical level. From the point of view of economic analysis, the essential elements in the two systems relate to the cost, the yields and the time intervals between successive cuts (Leslie, 1977). In this respect, Vannière's (1975) discussion of the factors that influence levels of costs and returns in tropical silviculture in West Africa is particularly useful. In some discussions a great deal is made of the shorter felling cycles under polycyclic systems, compared with monocyclic systems. It was concluded that the difference is of no economic significance. However, the argument was based on growth of trees to a given size from seedlings under both systems. The potential of the pole crop had not been taken into consideration. After an exhaustive discussion Leslie, (1977) concluded that a firm verdict cannot be rendered in the case of monocyclic versus polycyclic, because economically they cannot be differentiated.

Natural regeneration is often considered to be uneconomic on two main accounts. The first is the low productivity per unit of land area and uncertainty of the system (Chapter 5). Experts show unbounded enthusiasm for plantations: "with high yielding crops grown on short rotations it becomes profitable to apply methods used in agriculture. .... forests in Indonesia managed on the Selection System rarely produce more than 1 m^3/ha/annum. Pure stands of high yielding species on the same site can produce 10 - 30 m^3/ha/annum. (Lundquist, 1964; Lowe, 1975)." The second charge is that silvicultural operations are costly in terms of return for expenditure. When the major species regenerate freely without particular attention (Walker, 1948), it is scarcely necessary to indulge in much intervention. Some of the more discredited systems involved a number of visits and substantial man days of effort - the Nigerian T.S.S. being the worst offender (Baur, 1964; Ogbe, 1968).

The main cost advantage of concentrated plantations is that of land. Where land is plentiful, pine or monospecific plantations are likely to be a luxury and to have only theoretical advantages over natural regeneration systems. Silvicultural treatment of forests represents a rare opportunity to convert labour into capital assets (Wadsworth, 1974). The cost of silvicultural treatments in Sabah was analysed by Liew (1971a; 1973b). As for climber cutting and tree marking operations, 1.00 to 1.27 mandays are required to treat an acre of forest. With the present salary scale, it amounts to M$13.00 to M$17.00 per acre. Poison-girdling treatments usually require 1 manday per acre amounting to M$13.00. For 3 treatments in one cutting cycle the total cost would not exceed M$50.00 per acre, compared to M$1000.00 in the case of a tree plantation (see Section 5.3.4). Though this small sum may still be considered expensive by planners, silvicultural treatment enables a given unit of money to be more widely spread in natural forest operations. It is not correct that natural forest intervention is always uneconomic. Earl (1973) has drawn attention to discrepancies between net discounted revenue per unit of land vis-a-vis per unit of money. A given sum of money may yield a greater total return if spent on more hectares for a lower average return per hectare.

Wood consuming industries prefer to use as few species as possible. The ideal is one type of wood that can be used for several purposes. Concentration on a few species makes the forester's work easier (Lundquist, 1964). Superior growth in plantations in Sabah is reported by Tham and Liew (1977). Despite apparent economic advantages of plantations, it has yet to be shown that the spectacular growth of conifers or other species can be continued indefinitely without detriment to the site (Dawkins, 1958). Similarly, reliable prescriptions to avoid serious biological problems with plantations are not available (Wadsworth, 1974).

There are conflicts as far as economy of land-use is concerned. This is because it is difficult to show that natural regeneration for production of timber is a more effective form of land-use than the alternatives. The difficulties arise, fundamentally, from the low rates of commercial increment typical of tropical forests, and the long rotations required for growing commercial crops. Almost inevitably, comparative analyses based on cash flows discounted at anything like realistic rates show the moist tropical forest unable to hold its own against any feasible alternative. Therefore, competition for land commonly exists between agriculture and forestry sectors. Most politicians are in favour of converting rich forests into agricultural land. This is a quote from the recent publication of the Daily Express, a local newspaper "The Sabah State Assembly today approved an amendment to the Sabah Foundation

Enactment 1966 giving the government the right to acquire 3000 square miles of the Foundations timber concessions, to be used for agriculture and other purposes after it had been logged. .... The income earned from one acre of timber is about M$1000 for every 60 years. On the other hand, agriculture would earn M$1,000 to M$2,000 per acre every year. For cocoa cultivation, an income of M$5,000 to M$6,000 could be earned per acre per year ....". This clearly indicates that a great deal of productive forest land will be converted into agricultural land in Sabah in the near future. Realising this situation, the Forest Department has practically stopped silvicultural treatments in all asscessible Forest Reserves with Class II soil (most suitable for agriculture). In some cases, regenerating forests of 5 to 10 years are either earmarked or being converted into agricultural land. Rapid agricultural development has made foresters think about very carefully whether silvicultural treatments should be implemented in areas which are now considered as semi-accessible.

Economics is therefore a significant factor affecting silvicultural decision.

7.13 Availability of Funds and Staff

Silvicultural treatments cannot be effectively implemented without sufficient funds and staff. Liew (1973a) estimated that a sum of M$1.5 million (probably about M$2.5 million now in view of the increase in basic wage and higher rate of exploitation) would be required to implement climber cutting and tree marking operations prior to logging on a State-wide basis. In the period 1975 - 1978, only a sum of M$1.5 million was approved annually by the government for silvicultural treatments. It is obvious enough that the approved sum cannot be used for one treatment only. In order to use the money wisely, productivity, forest structure, general forest conditions, and the future land-use probability of the area must be considered before any treatments can be prescribed and implemented.

The author has been working in the Research Branch for almost 9 years and from experience it is very difficult to obtain sufficient funds for silvicultural treatments. Therefore it is necessary to adopt a simple but flexible silvicultural policy whereby silvicultural treatments are only carried out as and when necessity arises.

A flexible silvicultural policy may be difficult to implement because of shortage of staff at professional and sub-professional levels. The Forest Department only has 15 professional staff including the researchers. However, the Forest School at Sepilok is conducting a 10-month course to train the junior staff. To date more than 100 staff have been trained. A good number of them has been assigned to implement silvicultural treatments, though shortages still exist. The gap will be narrowed in the future.

CHAPTER 8

RESOLUTION OF FACTORS AND CONCLUSION

8.1 Introduction

Leslie (1977) stated that "the basic assumption of tropical forestry, implicit though it may be, is that natural management is possible and desirable. All that needs to be done is to find the appropriate variation of monocyclic or polycyclic management for the conditions applying in a specific forest. But almost universally, it seems that the search for the appropriate methods is a particularly difficult and unrewarding task". Gomez-Pompa et. al. (1972) emphasized this in his reference to "the tropical rainforest: a nonrenewable resource". Adeyoju (1974) reviewed rainforest management systems and found that "by and large throughout the tropics these systems have been abandoned because of lack of success." The preceding quotes imply that management of natural rainforests is difficult and is being phased out rapidly because of repeated disappointments.

Chapter 3(3.2) points out that Dipterocarps were fully developed during the Tertiary, 15 to 70 million years ago. Their persistence indicates their adaptability in the ecosystem (Liew and Khiong, 1974). Dipterocarp forests have been recognised as one of the most perfect systems in terms of nutrient cycling and other biological functions (IBP report, 1974; Burgess, 1974). In theory, these stable and perfect systems can continue to exist provided human disturbance, (for example, logging) does not exceed their recuperative capacity. In practice, it has been demonstrated that the Dipterocarp forests of Sabah can, at least, be regenerated adequately (Chapters 3, 4, 5 and 6).

Several examples of successful regeneration were cited to illustrate this point. However, introduction of heavy logging equipment and intensive logging have posed a severe threat to the natural regeneration process in Sabah (Chapter 7). Nevertheless, as a generalisation, it can be said that sound ecological management of natural rainforests is conceivable, although scientists and foresters have sometimes considered this to be impossible, probably because of the long cutting cycles involved.

Formulation of a silvicultural policy for Sabah is difficult because determination of a silvicultural policy is affected not only by biological factors, but by many other management, industrial and economic factors as well (Chapters 3 - 7). Table 8.1 summarises some of the factors discussed earlier which influence silvicultural decisions.

TABLE 8.1 Factors influencing Silvicultural Policy

No.	Factors	Remarks
1.	Nature of Forest:	
	Dipterocarp forest types	Section 3.3
	Type 1: *Parashorea malaanonan* Forest	Page 43 - 46
	Type 2: *Parashorea tomentella*/ *Eusideroxylon zwageri* Forest	Page 46 - 48
	Type 3: Rubroshorea/ *Eusideroxylon zwageri* Forest	Page 48 - 52
	Type 4: Rubroshorea/ *Dipterocarpus* Forest	Page 52 - 54
	Type 5: *Parashorea malaanonan*/ *Dryobalanops lanceolata* Forest	Page 54 - 55
	Type 6: Selangan batu Forest	Page 55 - 56

The examples in Table 8.1 show that silvicultural decisions are affected by many factors. Therefore, a silvicultural policy must be a compromise between many competing and conflicting factors, and it may be necessary to review the policy where circumstances change.

Silvicultural options have been comprehensively discussed in Chapters 5 and 6. However, it is appropriate to re-examine the silvicultural options, taking particular consideration of those factors discussed in Chapter 7, notably prelogging treatment (8.2), silvicultural systems (8.3), and post-exploitation treatments (8.4).

8.2.1 Prelogging Treatments

It was shown in Chapter 5 that prelog treatments have been introduced to rainforest management in some parts of the world where it has been found from experience that rainforests failed to regenerate following exploitation. This has been attributed mainly to the paucity of commercial crop trees in the various strata of the forest. Thus the primary objective of prelog treatment has been to establish a reasonable seed-producing tree crop by a series of canopy manipulations before logging. For example, pre-exploitation treatments have been intensively carried out in Nigeria under the Tropical Shelterwood System (T.S.S.) (Baur, 1964). However, as far as Sabah is concerned, Chapter 4 shows that enough potential regeneration (seedlings and poles) is normally present in the Dipterocarp forests. Therefore, prelog treatment such as manipulation of the canopy with the aim of improving the commercial stocking need not be carried out. However, since the introduction of heavy logging equipment in 1965, damage resulting from logging ranges from 30 to 50 per cent of the land area (Liew, 1974a, Chapter 1 and 5). Fox (1968a), Dawkin (1968a) and Liew (1973) have demonstrated that damage to pole-sized trees in particular might be halved in areas infested with climbers provided that climbers are cut 1½ to 2 years ahead of felling. Thus climber cutting as well as tree marking can be an effective treatment to minimise logging damage. The main purpose of this treatment is to retain sufficient stems of pole-sized tress to yield an intermediate cut between rotations or cutting cycles.

It is now pertinent to examine whether prelog treatment, including climber cutting and tree marking, is appropriate to Sabah, from silvicultural, biological, political, economic and other points of view. As far as silviculture is concerned, such treatment undertaken $1\frac{1}{2}$ to 2 years ahead of felling can minimise logging damage to the ecosystem (Fox, 1968a; Dawkin, 1968, Liew, 1973b). As logging in Dipterocarp forests or rainforests in general is always destructive in view of the size of the trees, distribution of emergents and other factors, any treatment which can minimise damage to the ecosystem should be encouraged from the biological point of view. It has been mentioned earlier that the greater the damage to the ecosystem, the longer the successional period must be leading to re-establishment of commercial species.

Prelog treatment, such as climber cutting and tree marking requires intensive forward planning of forest operations. For example, in Sabah, it is required that the coupe proposal must be submitted to the Forest Department $2\frac{1}{2}$ to 3 years ahead of logging. Logging roads should be constructed at the same time. However, in most developing countries, and those of south-east Asia in particular, timber is one of the main assets that generate income for economic growth. It is difficult to convince politicians and decision-makers about the value of enforcing forward planning in forestry. This may be partly due to the great demand for hardwood, which tempts producing countries to forego good forest planning, and to destructively log the forests exploiting them for short-term gain alone.

In Section 7.2, it has been established that the main management objectives in Sabah are to encourage regeneration of valuable Dipterocarp species, to practise sustained yield management and to implement conservation. However, overcutting is the grave concern of foresters and it has been estimated that by 1985, two-thirds of the total forest estate will be heavily logged and exist only as regenerating forest. As it is not possible to curtail the current exploitation rate because of Government policy, it would be most beneficial and practical to adopt a system which could retain the pole-crop so that the cutting cycle can be shortened. Under ideal conditions girth increment of the pole-crop (trees 1' to 6' girth) could be 1.5" to 3.0" per annum (C.A.I.), particularly the Rubroshorea and Parashorea species (Chapters 5 and 6). By retaining the pole-crop, it is possible to generate an exploitable volume of commercial species within a period of 40 years (Chapter 7). Therefore, climber cutting and tree marking can be extremely useful operations which aim at reducing damage to pole-sized trees.

It has also been pointed out (Chapters 5, 7) that natural regeneration is often considered to be uneconomic on two accounts, firstly, low productivity per unit of land area and , secondly, duration and uncertainty of the system, particularly under monocyclic systems. Therefore, retention of pole-sized trees with the aim of shortening the cutting cycle would be an ideal compromise. In this case, climber cutting and tree marking could be economically feasible operations.

Despite the perceived positive values of pre-log treatment, this is not normally carried out. Only a small number of licensees in Sabah (Licence Agreements and Special Licence) are carrying out logging themselves. All the other licensees (including the Sabah Foundation) have licensed areas which are being logged on a contract basis. Under such arrangements, the logging firms or contractors are trying to obtain as much profit as possible. In the light of this, it is difficult for the department to control the loggers. For example, the coupe permit is submitted to the department only two months before logging. It would be difficult, if not impossible to alter the system. That is why climnber cutting and tree marking cannot be implemented on a state-wide basis.

Thus there are both advantages and serious problems in the implementation of prelog treatment. Climber cutting and tree marking are effective prelog treatments. Despite the problems the prelog treatment should not be abandoned altogether. Sabah is richly endowed with pole-sized trees per acre (see Section 5.3.1). A continuing effort should be made to ensure this pole-crop is at least partly retained, through pre-exploitation climber cutting and tree marking 2 years ahead of logging.

8.3 Silvicultural Systems

The relevant silvicultural systems for rainforests in Sabah have been comprehensively examined in Chapters 5 and 7. There are two broad approaches to silviculture: even-aged or monocyclic and uneven-aged or polycyclic systems. Within this framework many recognised silvicultural systems have been developed over a period of years. In the case of monocyclic systems, emphasis is placed on producing an even-aged stand, usually from seedlings. The original concepts and objectives of the Tropical Shelterwood System, Malaysian Uniform System and Regeneration Improvement Felling System were the production of even-aged stands of forests, hence they can be classified as "monocyclic systems". Selection or 'polycyclic' systems are usually designed to produce and maintain uneven-aged and uneven-sized forest stands. Under these systems, the retention of the seedling and commercial pole-crop components has high priority because they will provide the basis for subsequent forest cutting. Polycyclic systems may be appropriately applied in the Dipterocarp forest. However, before silvicultural systems are examined further; an outline of the characteristics of the Dipterocarp forest is given to help illustrate the way the ecological factor may be taken into account in making the silvicultural decision in this forest.

8.3.1 Characteristics of Dipterocarp Forests

The distribution, species and growth of the various Dipterocarp forests in Sabah is outlined in Chapter 3. Chapter 4 deals with regeneration of Dipterocarp forests. Other silvicultural characteristics of the Dipterocarp; forests are discussed in Chapters 5, 6 and 7. The main biological features may be summarised as follows:

(1) Though the Dipterocarp forest may be classified into various recognised types, their productivity, stand volume and structure, and the presence of harmful plants such as climbers, climbing bamboos etc. are similar within the different types (Sections 3.3, 3.4 and 3.7).

(2) Species distribution and association can be quite different from one type to another but Rubroshorea species (red serayas) and Parashorea species (white serayas) are usually dominant.

(3) Different species exhibit different growth rates. For example, Rubroshorea species, particularly Shorea leprosula, S. leptoclados, S. pavifolia and S. smithiana, and Parashorea species are much faster growing than Dipterocarpus species, Dryobalanops species and others (Sections 3.5, 6.6 etc.).

(4) Flowering and fruiting of Dipterocarps usually occurs at long intervals. There is a body of evidence suggesting that Dipterocarp trees are capable of fruiting when 4 to 6ft. girth (g.b.h.). Usually trees of the common emergent species do not flower until they are in the upper emergent canopy. Therefore, the phase of flowering activity for individuals is independent of age, and the size of a tree when flowering commences is dependent on canopy position (Section 4.1).

(5) Though Dipterocarp fruits have wings, they usually fall from the tree almost vertically and glide spirally down to land with the wings uppermost in the manner of a shuttlecock. A good distribution can usually be found within 2 ½ chains of the parent tree (Section 42.).

(6) The stocking of Dipterocarp seedlings in the typical lowland Dipterocarp forests normally ranges from 10,000 to 20,000 per acre in virgin forest, though the density may fluctuate between fruiting years (Section 4.1) and the gregarious nature of the species.

(7) Dipterocarp seedlings are usually dormant in virgin forest. Upon opening of the forest canopy they immediately respond to light, and favourable height growth is achieved (Section 4.4.3).

(8) The productive Dipterocarp forest usually contains 10 to 25 stems of pole-crop per acre. In the extreme case it may be as low as 5 stems/acre. (see 5.3.1 C ii).

(9) Upon opening of the forest canopy, the intermediate size trees (commercial) respond to light, and higher growth rates are recorded compared to the undisturbed state. Under ideal conditions, Rubroshorea species and Parashorea species can achieve increment of 1.5 to 3.0" (C.A.I.) (Section 3.5.2 and 5.3.1 C iii). Mortality is low after the opening of the canopy (see 5.3.1 C iii).

With these silvicultural characteristics, both monocyclic and polycyclic systems are applicable. A closer examination of the biological characteristics suggests that polycyclic systems should have advantages, particularly because of the abundance of intermediate size class trees. These are potential crop trees in subsequent cutting cycles. However, in developing a silvicultural policy it is important to examine critically a number of silvicultural systems.

8.3.2 Evaluation of the current selection system in Sabah

The current silvicultural system adopted for the management of the permanent forest estate of Dipterocarp forests in Sabah (S.F.R. No.8) can be classified as a simple form of the Selection System. It is comparable with the system practised in the Philippines in 1929 (Section 5.3.1(a)). The system emphasizes (a) saving the abundant seedlings already present in the regenerating pool, and (b) retention of an intermediate size class tree crop. The latter aims at yielding an economic intermediate cut between rotations. Under the system, all trees greater than 6 ft. girth are to be felled and removed. Intermediate size class trees from 1 to 6 ft. girth are to be retained as far as possible. Felling of defective trees greater than 6 ft girth is optional. The prescribed sequence of operations is summarised as follows:

TABLE 8.3 Curent Sequence of Silviculture/Management Operations in Sabah

YEAR	OPERATION
a. F-2	Allocation of Coupe
b. F-2 to F-1	First silvicultural treatment: Tree marking and climber cutting
c. F	Felling
d. F + 0-1 month	Clearance inspection
e. F + 0-2 months	L.S.M.
f. F + 0-6 months	Second silvicultural treatment: poison girdling with 2, 4,5-T in diesoline (mainly poisoning of defective and non-commercial trees)
g. F + 5 years	L.S. ¼
h. F + 5 years	Third silvicultural treatment: poison girdling. Treatments are prescribed in accordance with the

		conditions of the forests obtained from L.S. $^1/_4$ If 1/3 or less of quadrats are stocked with economic species, enrichment planting may be carried out.
i.	F + 10-15 years	L.S. $^1/_2$
j.	F + 10-15 years	Fouth silvicultural treatment: Liberation and refinement. Prescription in accordance with the results of L.S. $^1/_2$

Whether such a Selection System is appropriate in Sabah largely depends on (1) the abundance of intermediate size class trees in virgin forests (2) the implementation and effectiveness of climber cutting and tree marking to minimise logging damage, (3) the response of the advance growth, and (4) all the factors influencing the silvicultural decision as discussed in Chapter 7. While all these factors have been examined earlier, they are briefly reviewed here.

(a) Abundance of Intermediate Size Class Trees

The abundance of intermediate size class trees (1' to 5'11" girth) varies with forest types (Section 5.3.1(b)). Normally the stocking of intermediate size class trees ranges from 15 to 25 trees per acre but it can be as low as 5 trees per acre on low (space) lying areas.

On average, there are approximately 15 intermediate size class trees per acre in most forest types. If a selection approach is to be satisfactory there must be sufficient stems of intermediate size class trees in virgin forests before exploitation. In this case, there are more than enough pole-size trees in virgin forests in Sabah and thus Selection System can be considered as an appropriate system.

(b) Implementation of Climber Cutting and Tree Marking as a Silvicultural tool in minimising Damage to Pole-sized Trees

The virgin forests in Sabah are infested with climbers (Section 3.7). Climbers which lace the crowns and boles of trees accentuate logging damage; the cutting of large climbers before tree felling reduces that damage. Fox (1968a), Dawkins (1968a) and Liew (1973b) demonstrated that damage to pole-size trees could be reduced by 50 per cent provided climber cutting and tree marking had been carried out 1/2 to 2 years ahead of logging.

Unfortuntely, climber cutting and tree marking cannot be implemented as a State wide silviculture treatment. This is partly because the forests in Sabah are harvested mainly by contractors who may submit coupe proposals only two months ahead of felling, particularly the "Form 1 licences". It follows that climber cutting and tree marking should be implemented at least in forest areas worked by long-term licensees (such as the Sabah Foundation and under other similar licence agreements), and where special licences can apply. In other words, this treatment may be omitted in Form 1 licensed areas where forward planning is practically non-existent.

Where the number of intermediate size class trees is low, two silvicultural options might be considered: either no climber cutting and tree marking to be carried out, or the spectrum of commercial species to be increased so that more intermediate tree species can be marked (see Liew (1973b)). The latter can be achieved where an active forester undertakes the tree marking and supervision of operations.

Heavy logging equipment is widely used in logging in Sabah. Usually the consequences of poor or destructive logging have been ignored. No definite rules have been formulated for timber extraction though the licensees may be fined for avoidable damaging of the pole-size trees. The term "avoidable damage" has not been clearly defined and thus loggers have not taken precautions to avoid unnecessary damage to the forests. Trees marked by the Forest Department may be accidentally destroyed by careless loggers. Therefore, climber cutting and tree marking can only be implemented with the close co-operation of the loggers. In addition, the Forest Department urgently needs regulations for logging practices to overcome the posibility of logging damage.

The argument is that it should be possible to retain 8 to 10 intermediate size trees per acre after logging, and that a further economic cut can be obtained within 40 years. This would mean that the yield after 40 years could be at least 1200 cu ft per acre (based on a volume of approx. 150 cu ft per tree).

(c) Response of Advance Growth to the Opening of Forest Canopy

After opening of the forest canopy, pole-size trees can grow at twice the previous rate (Table 3.9; Section 3.5.2). In addition, the post-logging mortality rate of pole-size trees is as low as 1.16%

(Section 5.3.1 (c) (iii)). The intermediate size class trees retained would therefore constitute a valuable crop for the subsequent cut, and the Selection System could be a feasible method.

(d) Other Factors

(i) Forest Policy and Management Objectives

The basic objective of forest management in Sabah is to manage the Dipterocarp forests under substained yield for production of tropical hardwood. It has been assumed that indigenous forests will regenerate into high forests again after 80 years. However, the level of forest utilization in recent years suggests that it is Government policy to log huge forest areas annually in order to generate income, capital, etc. for development of the State. The annual cutting rate has been increased from 80,000 hectares (1973) to approximately 120,000 hectares. Overcutting is a risk when 65% of the virgin forests would be exploited by 1985 and the remaining forest area would not be sufficient for sustained yield management. Under those circumstances it would be beneficial to conserve some of the present growing stock to enable a second economic cut to be made within the full rotation period. A selection system which basically aims at a shorter cutting cycle by retaining the pole-crop would appear to be the most suitable means of achieving this.

(ii) Environmental Considerations

Conservation of forests for "maintenance of the climate and physical condition of the country, the safe-guarding of water supplies and prevention of damage to rivers..." is embodied in the current forest policy. It has been projected that most of the lowland Dipterocarp forests will be logged by 1985 leaving 3.5 million acres of mainly hill forests for future exploitation. Despite this high rate of utilization, it is essential that whenever logging is being carried out in lowland or hill Dipterocarp forests, minimum damage be done to the forest ecosystem. Where ecological stability of the rainforest is prejudiced by poor standards of logging, the result may be poor water quality, fluctuating water tables and water flows (especially during monsoons), and erosion (Section 7.3). For example, Liew (1974b) found that at least 2,500 to 3,800 cu ft of top soil were eroded and lost from the bare and steep slope in Tawau Hills F.R. within 20 months of logging.

The selection System aims at protecting the forests, particularly by minimising logging damage. In environmental terms, it is a desirable silvicultural method.

(iii) Harvest Systems and Logging Damage

Logging in rainforests and the Dipterocarp forest in particular, is a destructive process in view of the size of the trees and crowns, the distribution of the emergents (commercial trees), and the nature of the equipment used in extraction. It has been pointed out earlier that rehabilitating forests containing inadequate or no regeneration is expensive and difficult (Tang, 1974; Liew and Khiong, 1974; Chai, 1975). Therefore, it would be preferable to adopt a silvicultural system which involves less damage to the ecosystem (Mordeno 1977, Reyes 1977).

(iv) The Nature of Logging and Milling Industries

Previous reference has been made to the fact that only a dozen timber licensees (Licence Agreements and Special Licences) are actually carrying out logging themselves. Timber rights are given to individuals and firms. Many of these are not in the position to raise the capital to extract timber themselves. Logging is an expensive operation. Therefore, most of the licence areas are logged by logging firms or contractors on contract basis. This includes the Sabah Foundation, whose licensed areas range from 50 acres to one hundred thousand acres.

The Sabah Foundation has been given a 100-year licence agreement which is renewable. The licensed area of the Sabah Foundation should be soundly managed in the interest of the State. Adoption of the Selection System with shorter cutting cycles would certainly be a step forward because 1,920,000 acres have been allocated to the Sabah Foundation. This huge forest area should be able to produce exploitable timber on a shorter cutting cycle.

The Government currently favours only awarding forest land in the interior region to logging firms which are required to operate on a joint venture basis with the government. It is highly desirable that these areas be managed for sustained yield. Two projects of this nature have been approved. For these projects, it would certainly be beneficial if the Selection System could be adopted, for reasons discussed earlier.

In the past, milling industries have been neglected (Chapter 2). However, there are indications that more and more sawmills and plywood mills will be needed soon because of the export quota system (see Section 7.9). Milling industries require continuing supplies of tropical logs, and therefore the Selection System would be an advantage.

(vi) Economic Factors

The relative merits of monocyclic and polycyclic systems have been discussed in detail by Dawkins (1958). From the economic point of view, the essential elements in the two systems relate to the cost, the yield and the time intervals between successive cuts (Leslie, 1977). Venniere (1975) concluded that the difference is not economically significant. However, the argument was based on growth of a tree to a given size from seedlings under both systems. After an exhaustive discussion Leslie (1977) concluded that a firm verdict cannot be rendered in the case of monocyclic versus polycyclic because of the lack of knowledge on the silvics of most tropical forests. Therefore, economically a rainforest can be either managed under monocyclic or polycyclic systems. However, it must be added that a system which ignores the potential of the pole-crop would be expensive.

(vii) Funds and Staff

It has been shown that the Selection System is difficult to implement because it requires considerable forward planning and suitable treatments. However, the funds allocated to silvicultural treatments are small, amounting to $3 million annually. With this limitation, silvicultural treatments must be cautiously examined and implemented. The silvicultural treatments to be carried out must be of the best interest to the State.

There are few professional staff in Sabah (Section 7.13). They must be used well. A Selection System which requires considerable supervision may be difficult to implement. However, the number of students reading for the forestry degree has increased, and the problem of shortage of staff can be overcome in the future.

(viii) Concluding Remarks on the selection logging in Sabah

Today, it is a global concern to conserve rainforests as far as possible, especially in the light of their rapid disappearance. Rainforests are destroyed for agricultural development and urbanisation, but most of all they have been destroyed by destructive logging operations. The Selection System for managing the Dipterocarp forests in Sabah should therefore be considered seriously. The Selection System is one of the most difficult forms of silvicultural method to apply, it requires advance planning and co-operation of the loggers. By conserving the forest ecosystem in the original form as far as possible, it is aimed at producing timber in perpetuity to meet the increasing demand for tropical hardwood.

From the discussion, it can be concluded that the Selection System could be applied to the Dipterocarp forests in Sabah, though some problems other than biological ones may exist. The shortage of professional staff may be considered as the greatest problem. However, 10 students are now reading for the forestry degree at the Universiti Pertanian Malaysia. They will be graduating in the near future. Apart from this problem, other obstacles can be overcome if a management plan has been laid down.

8.3.3 Tropical Shelterwood System (T.S.S.) and Regeneration Improvement Felling System (R.I.F.S.) - their relevance to Sabah

(1) Tropical Shelterwood System

The primary purpose of the Tropical Shelterwood System (T.S.S.) is to produce a more or less even-aged forest by establishing a pole crop of economic species before logging. Thus T.S.S. is a monocyclic system. The system was first introduced in Trinidad in 1939 and later in Nigeria in 1944. Under this system the rainforest is cutover repeatedly, at short intervals, during a relatively short part of the rotation. The sequence of operations has been summarised (see Table 8.3).

TABLE 8.3 Sequence of Operations of T.S.S.

YEAR	OPERATION
1	Demarcation of the compartment
1	(i) Climber cutting and seedling assistance
1 D.S.	(ii) Removal of middle storey canopy
2 R.S.	(iii) Regeneration count and climber cutting

2 R.S.	(iv)	Opening of canopy
3 R.S.	(v)	Clearing
4 R.S.	(vi)	Clearing
	(vii)	Regeneration count
5 R.S.	(viii)	Clearing or exploitation
8, 12, 16, etc. R.S.	(ix)	Pre-exploitation clearing
n	(x)	Exploitation
n + ½ to 1 R.S.	(xi)	1st post-exploitation treatment
n + 3	(xii)	2nd post-exploitation treatment
n + 8	(xiii)	3rd post-exploitation treatment
n + 13	(xiv)	4th post-exploitation treatment

The Dipterocarp forests in Sabah have an average of 10,000 to 20,000 seedlings per acre, and in addition 10 to 15 pole size trees are present (see Chapter 4). Repeated treatment and logging over a period of 5 to 16 years to induce the development of a pole crop would clearly be unnecessary. Quite apart from this, it would not be politically acceptable to propose 5 to 16 years of treatments before final logging. Therefore T.S.S. can be considered as an unsuitable method under conditions pertaining in Sabah.

(2) Regeneration Improvement Felling System (R.I.F.S.)

The Regeneration Improvement Felling System is similar to that of T.S.S. The original object of this silvicultural method was to remove inferior species in several stages and promote the development of economic species before felling. However, the system was only used in the Malaysia Peninsular between 1910 and 1932.

The Regeneration Improvement Felling System was also practised in Sabah in the late 1940s. However, no record is available. R.I.F.S. will not be further discussed, because the method is similar to that of T.S.S.

Thus both T.S.S. and R.I.F.S. can be regarded as "obsolete" silvicultural methods. Both methods emphasize development of a pole-crop before logging. Even if the pole-crop is developed, the heavy equipment currently used in logging in Sabah could definitely destroy the pole-crop. The current emphasis in Sabah must be on saving the existing pole-crop abundant in the Dipterocarp forests. Both T.S.S. and R.I.F.S. are therefore not appropriate for Sabah.

8.3.4 Malayan Uniform System (M.U.S. - Clear-cutting)

The Malayan Uniform System is the best known silvicultural method devised for rainforest management. The primary object of the system is achieving an even-aged regeneration by clear cutting. It has been argued that rainforest can be regenerated following exploitation from seedlings of economic species present on the forest floor. The success of the system depends on the following essentials:

(i) Adequate stocking of seedlings of economic species before logging

(ii) Adequate stocking of seedlings of economic species after logging

(iii) Economic species which are capable of responding to the suddent and complete opening of the canopy

(iv) Complete removal of the upper strata of the canopy

(v) Tending only after the regrowth has passed the ephemeral climber

(vi) Maintenance of adequate new canopy to prevent redevelopment of climbers.

The sequence of operations of the Malayan Uniform System appears in Table 8.4.

TABLE 8.4 Sequence of Opeation of Malayan Uniform System

YEAR	OPERATION
n + $\frac{1}{2}$ to n	L.S.M. (regeneration) and enumeration of merchantable trees
n to n + 1	Exploitation Followed by poison girdling down to 2 inches D.B.H.
n + 3 to n + 5	L.S.$\frac{1}{4}$ Followed by clearing, climber cutting and poison girdling
n + 10	L.S. $\frac{1}{2}$ Followed by prescribed treatments
n + 20) n + 40)	Sampling and thinning as required

From the preceding discussion, it can be clearly seen that the M.U.S. depends purely on the seedlings for the development into high forests for the subsequent cut.

The Malayan Uniform System was also implemented in Sabah in 1958 with the following instructions:

- (i) All commercial trees greater than 6 ft girth to be logged
- (ii) L.S.M. (regeneration sampling) to be carried out after logging
- (iii) Poison girdle (after logging):
    - (a) All non-commercial trees over 2 inches diameter
    - (b) All commercial trees over 2 inches diameter that are crooked, damaged, hollow or otherwise defective
    - (c) All non-commrcial trees over 6ft girth (poison-girdling involves use of 2 lbs of arsenite to one gallon of water)
- (iv) Specifically, undergrowth is not slashed in treatment (Forest Department Circular, Sabah)

This silvicultural method was applied until there was a slight modification in 1962. No matter how it is modified, the system basically relies on the development of seedlings of economic species to form high forests again.

From the preceding outline, it can be seen that the Malayan Uniform System is aimed at developing an even-aged forest stand after logging. Therefore it is a monocyclic system. Mok (1968) postulted that the system failed because its application had been extended to hill forests or forests where seedlings or pole-trees are scarce or lacking. Wyatt-Smith (1961) pointed out that the Malayan Uniform System had not been successful because of poor implementation in some forests. He concluded that there is little likelihood of M.U.S. failing to achieve its objective in lowland forest rich in Dipterocarps, though there is a depressing percentage of logged-over forest, which has failed to reach the required standard of forty per cent stocking (sixteen stems per acre) at ten or more years after completion of logging. This is despite the inclusion of a substantial number of species in the commercially acceptible list. In other words, the Malayan Uniform System has not fulfilled its management objectives satisfactorily.

Liew (1974a) cited several examples of successful regenerating stands treated under the Malayan Uniform System in Sabah. For example, it has been found that a forest logged in 1962 was carrying more than 25 trees per acre when the forest was sampled in 1973 (see Table 5.10). From the management point of view, the forest has been successfully regenerated. There is no doubt that the Malayan Uniform System has been a useful silvicultural method. Hence it will be further examined in the context of Sabah conditions.

(i) Abundance of Seedlings of Economic Species

The Malayan Uniform System depends heavily on the population of seedlings of economic species before and after logging. In short the population of seedlings of economic species must be sufficient before logging. Table 4.8 points out that the population of seedlings of economic species ranges from 1,300 to 35,000 per acre. The normal forest type usually has more than 10,000 seedlings of economic species. In view of the high density of commercial seedlings, the Malayan Uniform System can be applied without doubt.

(ii) Growth of Seedlings of Economic species in Logged-over Forests

Table 4.2 clearly indicates that seedlings of economic species, which are already present on the forest floor, respond to the opening of the forest canopy. For example, the height increment (CAI) is in the order of 4' to 6' under heavy opening of the canopy whereas the height increment in virgin forests is negligible.

It would be appropriate to point out that the growth rate is different from one species to another at a later stage. For example, Table 4.15 points out tht *Shorea leprosula* has a CAI three times higher than that of *Dryobalanopos lanceotala*. This would mean that an even-aged forest stand can be raised but not even-sized because of different growth rates of economic species. This may not fulfill the original objective of the Malayan Uniform System. For further information refer to Chapter 4.

(iii) Mortality of Seedlings of Economic Species after Logging

This subject is discussed in Section 4.4.3(d). It can be generalised that approximately 80 per cent of the commercial seedlings may be lost during logging. The survivors can normally develop into poles and commercial trees in about 60 to 80 years depending on species and the forest conditions. It should be noted that individuals of all economically important species are nearly always present after logging.

In the light of the above, the Malayan Uniform System can be considered as a viable silvicultural option.

(iv) Removal of the Upper Canopy Strata

The Malayan Uniform System favours heavy treatment in order to provide favourable conditions for the growth of seedlings of economic species. For example, whether commercial or non-commercial, trees over a certain girth limit must be poison-girdled. This would mean that the structure of the rainforests would be destroyed under this silvicultural method. Heavy removal of the upper canopy strata would amount to loss of commercial trees which have not been extracted. The original concept of the Malayan Uniform System was to poison all tress down to 2" D.B.H. This would be far too drastic. For example, the pole-crop which occurs abundantly in Dipterocarp forests in Sabah would be poisoned. This would mean that it is a very wasteful operation; therefore the concept of the Malayan Uniform System cannot be accepted in total.

Poison girdling is a useful silvicultural technique but complete removal of the upper canopy strata including the pole-crop cannot be accepted in modern forestry management.

(v) Other Factors

(a) Forest Policy and Management Objectives

The current policy and management objective is to regenerate the logged-over Dipterocarp forests by natural regeneration. It has been stressed that over-cutting is the principle concern of the State. In view of this, it would be advantageous to regenerate the forests within the shortest time period. The Malayan Uniform System depends on seedlings of economic species for the regeneration, and it would take approximately 60 to 80 years for this regeneration to reach commercial log size. In contrast, under a polycyclic selection system the forests may be harvested again within 40 years. A polycyclic cutting system would certainly be preferable where maintenance of log supply to industry is an objective of management.

(b) Environmental Condition

Silvicultural operations which include total removal of upper canopy strata are environmentally drastic treatments. It has been pointed out earlier this may prejudice the ecological stability of the rainforest ecosystem and result in erosion, polluted water supplies, and very slow recovery of the ecosystem. The Malayan Uniform System would have been appropriate in lowland areas but would appear to be too drastic for the hill forests where erosion would be enhanced by heavy treatments.

(c) Logging Damage

Since heavy logging equipment has been introduced (mid 1960's), damage caused by logging has become the most critical problem in Sabah. It would be difficult to minimise this damage under the Malayan Uniform System which involves total removal of upper canopy strata and hence severe disturbance to the system as a whole. According to Kim (1978) it would be difficult to design a machine for logging in rainforests which does not cause heavy environmental disturbance. This means that logging damage will remain a major problem, and will be reduced only where some positive attempt is made to retain a part of the upper canopy.

In terms of environment, the Malayan Uniform System is not seen as a suitable silvicultural method for Sabah.

(d) The Nature of Logging and Milling Industries

Logging in Sabah is mainly undertaken by contracting firms. Contractors normally undertake little forward planning. As the Malayan Uniform System involves little or no forward planning in terms of the trees to be logged, it might be seen as a suitable silvicultural method.

On the other hand, the milling industries are expanding, and continuing tropical hardwood supplies must be available. On this score, a polycyclic system, for example, the Selection System would be an advantage, as the cutting cycle is shorter.

(e) The Role of Timber in the Economy of Sabah

The State of Sabah would most probably collapse without the current forest industries. Forest industries contribute approximately 50 per cent of Sabah's GNP, 55 per cent of her exports, 50 per cent of Government revenue and employ about 25 per cent of the workforce in the State.

Whenever possible, high quality sawlogs or peeler logs should be produced in order to sustain the contribution of the timber industry to the economy of the State. This would mean that the forest resource be renewable as fast as possible. On this basis the Malayan Uniform System is unsuitable because of the long cutting cycle.

(f) Economic Factors

It has been concluded earlier that monocyclic systems (for example M.U.S.) and polycyclic systems (for example Selection System) are economically similar. This system which ignores the potential of the pole-crop must be seen as less appropriate than one which conserves this component of the forest for short-term log supply.

(e) Availability of Funds and Staff

This subject has been comprehensively dealt with under the Selection System. However it must be added that the Malayan Uniform System requires almost the same strength of staff and funds for implementation.

(2) Concluding Remarks on the M.U.S.

The Malayan uniform System is one of the best known silvicultural methods. It has been practised in Sabah and the results have been satisfactory. However, due to the heavy logging equipment now used, the exploitation rate, and political, economic and other factors, the Malayan Uniform System would appear to be an unsuitable silvicultural method. Nevertheless, the concept of the Malayan Uniform System is still sound provided a longer cutting cycle is acceptable in modern management of rainforests. Considering the heavy manipultion of the upper canopy strata, the Malayan Uniform System would be out of place because some rainforest elements would be lost through such a process.

8.3.5 Forest Plantations

The role of the tree plantation as a silvicultural system has been discussed in Sections 5.3.4 and 7.12. Tree plantations would replace the Dipterocarp forest as an alternative method for production of cellulosic material. However the plantation cannot be recognized as a silvicultural system for "rainforest management".

The growth rates of several species, for example, *Acacia mangium*, *Albizia falcataria*, *Eucalyptus deglupta*, and *Pinus caribbaea* have been attractive in Sabah (see Table 5.12). However, biological problems have been recorded in Sabah. It is difficult to foresee whether they may or may not become major problems in a large scale plantation (see Section 5.3.4 (B) (iii). Burgess (1974) stated tht from past experience, the introduction of monoculture systems have often been followed by disastrous attacks by parasites which never become serious in the natural system. This has happened where the monoculture is of an introduced of native species. It has been pointed out that man-made forests are not as perfect as those of virgin and disturbed Dipterocarp forests (Liew and Khiong, 1974).

The Sabah Softwoods Sdn Bhd is currently developing 60,700 hectares of tree plantation in logged-over Dipterocarp forests. To date (1981) approximately 20,000 hectares have been planted. However, the yield of the tree plantation has been negligible (see 5.3.4 (c). The Sabah Forestry Development Authority (SAFODA) is mainly establishing tree plantations in grassland. To date (1981) approximately 12,000 hectares have been planted, mainly with *Acacia mangium*.

In Sabah, land is plentiful for the small population. Superior growth of plantations in Sabah has been reported by Tham and Liew (1977). Nevertheless, pine in monospecific plantations is likely to be a 'luxury' and to have no real advantages over natural regeneration systems.

Forest land which has been destroyed by shifting cultivation in Sabah may amount to 700,000 acres. These grasslands are currently afforested by the Sabah Forestry Development Authority. Apart from the Sabah Softwoods Sdn Bhd's planting programme, it is unlikely that further logged-over Dipterocarp forests will be developed into tree plantations. The important point to be kept in mind is that a high potential market has already been developed for the tropical hardwood. The management policy should be greared to producing tropical hardwood and maintaining that market.

Tree plantations will eventually play an important role in the State, but that timber should be produced through the afforestation of the grasslands.

8.3.6 Further Concluding Remarks on silvicultural systems

It hs been established that a polycyclic system will be most appropriate for the management of the Dipterocarp forests in Sabah - based on ecological, political, management, economic and environmental considerations. The most appropriate polycyclic system would be one focusing on retention of the pole component of the forests - even though this will be very difficult to apply in the light of the shortage of funds and staff. However, such problems would also apply to any other system. For the development of the

State which requires the survival of the forest industries, application of a Selection System as outlined would appear to be vital.

8.4 Post-exploitation Treatments (Including Sampling

No matter which silvicultural system is adopted, prelog and post-exploitation treatments are essential at different stages of development of the forests. Prelog treatments have now been discussed. However, before a comprehensive prescriptions can be formulated, it is necessary to consider post-exploitation operations within the logged-over forests. This subject has been examined in Chapter 6. The main features are reviewed here, so that in the formulation of the silviculture policy, firm guidelines covering sampling and post-logging treatments can be made.

8.4.1 Sampling of regeneration

Nasland (1939) cautioned that regeneration sampling along strip lines (linear sampling) is difficult to apply for several reasons (see Section 6.2). Wyatt-Smith stressed that the most important tool in the Malayan Uniform System is the Linear Sampling technique. The aims of linear sampling are to obtain information on the prospects for successful natural regeneration (L.S.M.), to judge the success and condition of regeneration as a basis for formulating tending prescriptions (LS 1/4 and LS 1/2), and to determine the probable composition of the future crop. Thus linear sampling should provide the following information at the time of sampling:

(1) Density of seedlings and poles of economic species

(2) Species composition and distribution

(3) Condition of the forests, e.g. whether the logged-over forests are infested with climbers, weeds, etc.

Where forest conditions are known, the prescription for treatments can be made accordingly. Linear sampling of regeneration is carried out immediately after logging (L.S.M.) 5 years after logging (LS 1/4) and 10 years after logging (LS 1/2).

From a statistical point of view, the sampling may be biassed but the data so collected will provide sufficient information for management purposes (Chapter 6). Linear samplings, such as L.S.M., LS 1/4 and LS 1/2 can be used, though in Malasya Peninsula LRS-1 and LSR are adopted. The techniques of LRS-1 and LSR are basically the same as those for LSM, LS 1/4 and LS 1/2 The sampling techniques devised for the Malayan Uniform System can therefore be adequately used in the management of Dipterocarp forests.

8.4.2 Poison Girdling Operation Immediately After Logging

Poison girdling has been a popular silvicultural technique in rainforest management. Poison girdling immediately after logging had been used in Sabah for more than two decades. This operation was finally suspended in 1977 (see Section 6.2). The main objects of the treatment are:

(i) To ensure that seedlings where present have sufficient light for maximum development (but are not fully exposed?) and to favour sound advance growth.

(ii) To remove species and defective stems where these will compete with regeneration.

(iii) Where seedlings are deficient, to retain sufficient stems of commercial species to ensure eventual maximum stocking of regeneration.

(iv) To eliminate climbers.

After lengthy discussion of data collected in the past, it has been concluded that poison girdling immediately after felling is a useful silvicultural treatment to improve growth, particularly in regenerating forests (see Section 6.5). However, its effects may decrease as logging intensity increases, according to the present trend of logging. In any case if this treatment is to be implemented, it should be cautiously applied. Excessive opening of the canopy may cause mortality of seedlings (Liew and Wong, 1973). All silvicultural staff need to have a clear understanding of the physiology of Dipterocarp seedlings. They should be able to judge whether poison girdling is required under the present logging conditions. However, light manipulation of the canopy is still favourable immediately after logging.

8.4.3 Liberation (Girdling, climber cutting etc.) at F + 5 and F + 10 to F + 15)

The main object of liberation treatments is to create favourable conditions for the growth of seedlings, poles and advance growth of economic species.

In the logged-over forests, seedlings of economic species may be bent and broken by dense climbers and the regeneration may not succeed at all (Section 6.6). Under these forest conditions liberation and climber cutting appear to be essential.

It has been concluded that silvicultural intervention in stands particularly 10-15 years from felling can result in increased growth of the desirable species of such stands. As the major growth stimulus is to smaller size stems, it is considered this liberation treatment should result in "evening up" the stands. The larger trees already in a dominant or codominant position over the invasive and understorey species, may be joined by additional recruits from the smaller categories (Section 6.6).

8.4.4 Enrichment Planting

Enrichment planting has been extensively tried in Sabah. It has been concluded that enrichment planting using wildings or seedlings raised from seed can be an effective albeit expensive method of rehabilitating forests containing inadequate regeneration. However, staff and funds must be available before any heavy commitment can take place (Section 6.7).

8.4.5 Factors influencing implementation of silvicultural treatments

The basic post-logging silvicultural treatments in rainforests are poison girdling at various stages to create favourable conditions for the growth and development of economic species, and enrichment planting. Both these treatments are effective when growth rates of the economic species are enhanced by the treatments. However, it is imperative to review ways in which implementation of the treatments are affected by the other factors. (Chapter 7).

(a) Forest Policy and Management Objectives

The main forest policy aim in Sabah is to regenerate the logged-over Dipterocarp forests for producing tropical hardwood. If economic species could grow at a faster rate, the period between cutting cycles can be shortened. Enrichment planting can improve the stocking where necessary. Both poison girdling and enrichment planting are useful silvicultural tools which will help achieve forest policy objectives.

(b) Environmental Considerations

Manipulation of the upper canopy stratum as in poison girdling may be harmful to the environment. If the treatment is not drastic, some manipulation of this stratum would not be harmful to the functioning and recovery of the ecosystem.

(c) Market for species: Current and Future (Export and Local)

Poison girdling involves removal of trees and thus some potential species for the future market may be eliminated. For example, the current low market timber species may command reasonable market prices in the future. Lee (1977) warns that it is difficult to forecast the demand for particular timber species. It is therefore advisable to treat the forest as a system in all silvicultural operations though special attention may be paid to the popular species. Red and white serayas are and have been popular species in the local and overseas markets. However, a great number of heavy hardwood species, e.g. *Dryobalanops*, *Dipterocarpus* species and others command good international mrkets, though they may be difficult to transport by waterways. Therefore, in the poison girdling operation, any tree species having a good form with reasonable growth rate and which can be grown to a size of 4' girth should not be girdled. In an overstocked stand, preference should be given to retention of known Dipterocarp species when removal of trees is involved.

As discussed in Section 7.6, the consumption trends for both producer nations and importer nations are increasing. This means that tropical moist forests must be managed efficiently to meet forecast increasing demand. Dipterocarp forests must be treated so that the logged-over forests can be regenerated at a faster rate in producing tropical hardwood. This will include poison girdling. However, Shimokawa (1977) forecasted that a great shortage of wood chips for pulp would occur in Japan in the future. There is a possibility that the lesser-known species may be removed for chipping instead of being poisoned.

(d) The Role of Timber in the Economy of Sabah

It has been demonstrated that timber is the back-bone of the economy of Sabah. Silvicultural treatments which can enhance the growth of economic species should be implemented because the regenerating forests can then be harvested at shorter intervals.

(e) Reharvesting of the Forest

Regenerating forests which have been silviculturally treated are normally not approved for re-logging before the regenerating forests attain maturity. Therefore, silvicultural treatments can be used as a tool to protect them against early re-logging. This is because silvicultural treatments are difficult to implement and they are expensive operations. On this basis, it is the government's policy that treated forests cannot be relogged.

(f) Economic Factors

Within Sabah 1.5 million acres of the Forest Reserve have been excised for agricultural development. Usually decision-makers would hesitate to excise any regenerating forests which have been intensively managed. From the political point of view, agricultural development is seen as being financially sounder than long-term forestry projects. However, silvicultural treatments can act as a barrier to prevent excision of the forest land. The more rainforest treated, the greater the case for retaining an adequate area for continuing wood protection.

8.4.6 Concluding Remarks on post-logging treatments

Various post-silvicultural treatments are effective silvicultural operations if the growth rate of the economic species are enhanced significantly. From non-biological points of view, (for example, management objectives, economic and other factors), these silvicultural treatments are beneficial if manpower and funds are readily available.

8.5 Synthesis of Silvicultural Management

It has been shown that Dipterocarp forests can be successfully managed to produce tropical hardwood; several examples have been cited to illustrate this point. However, introduction of heavy logging equipment has posed a severe threat to the forests, particularly the regeneration process in Sabah. Should there be any failure, the cause is a man-made one. The fault does not lie in the system itself. Dipterocarp forests have failed to regenerate only in areas where the level of destruction is beyond the recovery potential of the ecosystem.

The management objectives for Dipterocarp forests have to be carefully considered. The current overseas market price for Red serayas (Rubroshorea species) and White serayas (Parashorea species) is excellent indicating that a solid market has been developed for these timbers. The consumption trends of tropical hardwood for both producer nations and importer nations are increasing. This is significant for it means that countries with tropical moist forest must manage their forests to satisfy the forecast increasing demand. It has been consistently emphasised that the Dipterocarp forest is the economic back-bone of Sabah. It has generated employment (25% of the workforce), considerable revenue, and foreign exchange. Economic factors may be the main threat against hardwood timber from the Dipterocarp forest because of the long cutting cycles and relatively low grow rates of commercial species. Because of this, some of the potential forest areas which are highly suitable for agriculture, may be converted into agricultural land. Where the forest has been silviculturally treated, the case against excision may be stronger. Thus implementation of silvicultural treatments may be used as tool to prevent excision. Despite this pressure on forest land, the population of Sabah is low (about 750,000 people) and at least 37 to 40 per cent of the land surface will be maintained as Forest Reserves for the next 40 to 60 years. Tree plantations have become popular in the tropics generally, and this is already evident in Sabah (Section 5.3.4). The Sabah Softwoods Company Limited plan to establish 150,000 acres of tree plantations in a regenerating forest. The Sabah Forestry Development Authority plan to reafforest waste land, and nonproductive and destroyed forests at a planting rate of 2000 acres per month. Possibly, one or two more firms may invest in reafforestation. The ultimate acreage of tree plantations would not exceed 750,000 acres. Taking these forestry activities into consideration, there still would be 6.5 to 7 million acres of forest land for hardwood production. It is apparent that the Dipterocarp forest of Sabah should continue to be managed for production of tropical hardwood, despite threats against this management objective.

If a large area of Dipterocarp forest is to be managed for production of hardwood, the next logical question is "what is the most suitable dilvicultural system". There are basically only two approaches to silviculture i.e., even-aged or monocyclic and uneven-aged or polycyclic systems, though many recognised silvicultural systems have been developed. With monocyclic systems, there is more emphasis on raising an even-aged stand from seedlings. The original aims of the T.S.S., M.U.S. and R.I.F.S. were directed at producing such even-aged stands. Hence they can be classified as "monocyclic systems". Selection systems are usually aimed at maintaining uneven-aged, and uneven-sized, forest stands. Under these systems, maintenance and retention of the forest structure, particularly the commercial pole crop, has high priority because this will provide the basis for subsequent cutting. Hence a shorter cutting cycle is envisaged, as opposed to the long rotations under monocyclic systems. Venniere (1975) concluded tht there is no economic difference between monocyclic and polycyclic systems. However, any system which ignores the potential of the pole crop will inevitably be expensive because of the time taken for new regeneration to reach commercial log size, and the failue to provide for an intermediate log harvest within that time.

The silvicultural characteristics of the Dipterocarp forest suggests that both monocyclic and polycyclic systems are applicable. However it has been consistently argued that polycyclic systems would certainly be preferable. The abundance of intermediate size class trees could form the potential crops in the subsequent cutting system. Retention of the pole crop in polycyclic systems may not only yield economic cuts at shorter intervals, but in addition, the pole trees which are capable of producing seed may act as parents in strengthening the regeneration pool. Alternatively, monocyclic systems such as T.S.S., R.I.F.S. and M.U.S. may not be as satisfactory. The primary objective of monocyclic systems is to establish a pole crop and/or seedlings through intensive manipulation before exploitation. As the Dipterocarp forests of Sabah contain sufficient stems of poles and abundant seedlings, such systems are not necessary.

Whatever forest policy and management objectives might be formulated for Sabah, the trend in the exploitation indicates that it is the government's policy to log huge forest areas in order to generate income for the development of the State. The annual cutting rate was 80,000 hectares in 1973. By 1980, it has risen to

120,000 hectares per annum. It has been estimated that by 1985, 65% of the total forest estate could be turned into young regenerating forests. Should regeneration be dependent on seedlings (monocyclic systems), the cutting cycle would be 65 to 80 years. Under such circumstances the Selection System appears to be most suitable, because exploitation a commercial log volume could be generated within a period of 40 years or less depending on species composition and the forest type. This is possible because under ideal conditions growth of the pole crop of 1' to 6' girth could amount to 1.5" to 3.0" girth (C.A.I.) particularly, the Rubroshorea and Parashorea species.

When environmental factors are also taken into consideration for the Dipterocarp forest, particularly the hill forest, a form ofSelection System with minimum environmental damage would clearly be preferable.

Logging damage is by far the most critical factor affecting the choice of a silvicultural system in Sabah. Damage to the forest caused by logging may amount to 50% of the land surface (Table 7.1). On this basis, again, the Selection System would be the most suitable for Sabah.

While a review of economic, biological and other factors, points clearly to a polycyclic system of management, its implementation may be prejudised by the nature of the logging and milling industries and availability of funds and staff. All timber licences except that of the Sabah Foundation are of short-term nature. Most licencees are not carrying out logging themselves. Logging, with the exception of a handful of licences, is done by the logging firms or contractors on contract basis. Co-operation between loggers and the Forest Department is almost negligible. Shortage of staff at the professional and sub-professional levels is acute (Section 7.13). It is likely that the situation will improve as the University Pertanian Malaysia is conducting both forestry diploma and degree courses. A number of staff are now reading forestry in the University Pertanian Malaysia.

Despite these difficulties, a positive attempt might be made to implement a Selection System in Sabah. After all, logging is a lucrative business. In view of the favourable timber price, loggers should be made to comply with some simple logging rules.

Pre and post-logging treatments are a critical part of any Selection System and should be implemented wherever possible. All poles (1' to 5.9' girth) should be marked for retention, with a stocking where possible of 15 trees per acre. The spectrum of economic species may have to be broadened should there be difficulty in selecting and marking 15 acceptable pole size trees per acre.

A system placing emphasis on retention of pole size trees will require that the pole crop be counted after logging. Thus it will be essential to sample the growing stock immediately after logging. This will involve undertaking the L.S.M. and L.S. $^1/_2$ operations simultaneously (i.e. sampling seedlings and poles at the same time). This would be a major change from current practice.

Poison girdling immediately after logging is a useful silvicultural treatment. However, in the light of the logging intensity and the changing demand for species, this silvicultural practice might be suspended. However, this is not a blanket rule. Where a forest clearly requires poison girdling after logging, this silvicultural treatment should be carried out. Apart from poison girdling, elimination of climbers, climbing bamboo and Ficus species immediately after logging is desirable.

The sampling program L.S.$^1/_4$ at F+5 should be carried out. This may be followed by light liberation depending on forest conditions. While heavy girdling of trees should be avoided, climber cutting is desirable at these stages, climber cutting alone can in fact stimulate growth. This is not a standard practice in the current silvicultural code.

The sampling programs L.S. $^1/_2$ at F+10 to 15 should also be carried out. These may be followed by light liberation depending on the forest conditions. Non-commercial trees may be girdled only if they are competing with, or suppressing, the economic species.

While enrichment planting is expensive, this may be the only means of restocking the forests which have already been ecologically degraded. With the implementation of the Selection System the scale of planting may be reduced.

Finally blanket rules pertaining to treatments can be dangerous and should not be adopted. Silvicultural practices should be flexible, and determined according to the condition of the forest.

8.6 A Silvicultural Code for Sabah

A comprehensive silvicultural system for Sabah's Dipterocarp forests is now presented. This requires among other things forward planning and co-operation of the logging firms, in addition to the required silvicultural treatments. It is recommended that the following sequence of management be adopted:

Year	Operation
F-3 ½ to -2 ½	To obtain yield data, stocking in particular from the Inventory Report (1973) or carry out survey. This operation has been carried out in 3 concessions in Peninsular Malaysia and in the Philippines.
F-1 to - 2 ½	Climber cutting and Tree Marking. One seed tree of 8 feet girth and above to be marked with ST in every 5 acres. Trees greater than 6ft are to be marked with white paint - Trees to be felled and extracted. The list of preferable species may be increased so that at least 16 pole-sized trees per acre are marked.
F-½	Determintion of road alignment, tractor paths and landings. Tractor path and landing should be determined as far as possible. Use topographical map.
F+½	Felling L.S.M. and L.S. ½ to be run simultaneously. Elimination of climbers, climbing bamboo etc. If

	possible large landings and areas devoid of economic species are to be planted with fast growing species e.g. *Eucalyptus deglupta* and *Acacia mangium*. Dipterocarps should not be planted at this stage because of exposure.
F+5	L.S. ¼ survey. May be followed by light treatment e.g. climber cutting depending on the forest conditions. Poison-girdling of non-commercial trees should be avoided as far as possible. Should severe suppression and competition exist, some of the non-commercial trees may be girdled. Yield plots are to be established to study growth and dynamic changes in forest composition.
F+10 to 15	L.S. ½ survey. May be followed by light treatments e.g. climber cutting depending on the forest conditions. Poison-girdling of non-commercial trees should be avoided as far as possible. Should severe suppression and competition exist, some of the non-

	commercial trees may be girdled.
P+15 to 20	Planted trees e.g. *Acacia mangium* and . *deglupta* may be harvested as sawlogs.

The sequence is relatively simple compared to those currently being implemented in Peninsular Malaysia and in the Philippines. The most difficult part is the imposition of pre-located tractor paths at an acceptable frequency. This applies to the main tractor paths. From these main paths, side paths can be branched out to extract the logs in the vicinity. This is practical, as it is done in the Philippines. Liew and Samad (1976) demonstrated that the restriction of tractor movement because of the presence of physical barriers, i.e. rocks, has been responsible for the successful regeneration in Timbun Mata Island.

Seed tree retention is introduced in order to ensure the survival of an adequate component of valuable species. At present there may be a lack of seed trees in inadequately stocked regenerating forests.

Poison-girdling of trees is avoided in the prescription because timber exploitation is now extending inland, and utilization patterns are changing. However, when commercial trees are being impeded or suppressed, removal of some of the non-commercial trees may be carried out.

Restocking bare landings with fast growing species will not threaten the replacement of rainforest with plantations, as the operation is confined to main tractor paths and landings.

If planting is not carried out at F+ $^1/_2$ enrichment planting with indigenous species could be carried out at F+5 when the bare sites have been colonised by belukars (secondary species) (Liew, 1973).

With the introduction of pre-laid tractor paths and landings, logging damage could possibly be reduced to 20 per cent in the light of previous findings.

The list of commercial trees should be reviewed from time to time, according to the market development of species.

Millions of dollars have been spent on the forest inventory. It is high time that the data collected should be used in the management of the Dipterocarp forest.

8.4.3 Methods of Controlling Forest Operations

While it is not expected that the proposed silvicultural code can be implemented immediately at a State-wide level, a sound silvicultural program has to start somewhere in order that the present failures may be rectified. The concept of forest management with the implication of "hit and run" should be eliminated before it is too late. The following are the proposals:

(A) The Sabah Foundation area - 1,920,000 Acres

The proposed silvicultural code should be implemented in the Sabah Foundation area which has been permanently allocated and licensed to the Foundation. The annual coupe is 32,000 to 38,400 acres. The Foundation should assume responsibility for planning and implementing all the required treatments including linear samplings and forward planning. It has been accepted in a recent meeting that the Foundation will take up such a responsibility. To date (1981) there is a strong indication that the Foundation will implement silvicultural treatment in 1982.

It would also be preferable for the Foundation to carry out the logging operation itself, rather than engaging inefficient contractors to extract timber.

(B) Virgin Forest in the Interior Region (about 3,000,000 acres)

Logging activity is now expanding to the interior region. Severe destruction of these forests may lead to environmental deterioration. The proposed silvicultural code should be implemented in the interior region.

Most of the Dipterocarp forests in the interior region have been committed for logging but licences have not been issued. It is recommended that licences for logging be not issued unless owners are prepared to form a group or groups to ensure that viable management on a sustained basis is feasible. This proposal is aimed at smooth implementation of a full scale silvicultural program according to the proposed code. In this case, all operations including silvicultural treatments are to be implemented by the licencees. A move has already been made by the Forest Department to include such additional clauses in the future licences.

(C) Timber Licences under Licence Agreements

There are eight timber licences under licence agreements. The total annual coupes are about 48,000 acres. As all these licences will expire by 1984, it is recommended that the proposed silvicultural code be implemented, but operations such as prelaid tractor paths and landings may be omitted for the time being. Planting with fast growing species on landings may also be omitted depending on availability of funds. Other operations such as climber cutting, tree marking, linear samplings, LSM, LS $1/4$ and LS $1/2$ should be carried out. Poison-girdling of trees, at F+ $1/2$ should cease but elimination of climbers and climbing bamboos should be continued. Light liberation at F+5 in the form of climber cutting may be introduced. In F=10 to F=15 regenerating forests the proposed silvicultural code should be followed. In addition, seed trees should be retained. All treatments including samplings are to be implemented by the Forest Department.

Forest land which has been earmarked for agricultural development should not be treated at all.

(D) Short-term Licenses - Special Licences, Form I Licences and Form 11B Licences

For those forest areas which are already issued with timber licences, it is recommended that management of the forest should follow recommendation (C) above. Climber cutting and tree marking cannot be implemented for reasons discussed earlier. The Forest Department is responsible for implementing all treatments.

The proposals are in fact rational and by no means do they hamper the present logging industries.

8.4.4 Problem Areas

A brief comment is necessary on regenerating forests which are inadequately stocked with economic species, especially those forests logged after 1968. Recent samplings show that patches of regenerating forests can be poorly stocked with commercial poles or seedlings. This indicates that the future productivity of the forest will decline if nothing is done. Unfortunately seed trees in most areas are absent. The following are three options:

(A) To carry out enrichment plantings on a large scale basis.

(B) To leave the forests as they are. The commercial trees present may be managed for sawlog production.

(C) To convert the areas into tree plantations.

Option A is unlikely to be implemented to a full extent as enrichment planting is an expensive operation. To date (1981) a centralised station has been established with up-to-date infrastructure for enrichment planting at Silam. Approximately 25,000 acres are planted annually.

It is hoped that the timber market may change and more species may be used. It is a good source of cellulosic materials. Tham and Liew (1977) indicate that option (C) is a possibility. However, option (C) should be avoided as far as possible, for reasons given earlier.

8.4.5 Funds, Staff and Other Requirements

Within the Sabah Foundation area, some changes in treatment regimes have been suggested, but the volume of work to be done remains almost the same, or perhaps slightly higher. As far as funds and staff are concerned, the costs may be met by the Forest Department if the Foundation can not finance the treatment regimes.

Steps must be taken to legalise the management objective based on sustained yield management. This is to curtail the issuing of short-term timber licences. A timber licence can only be issued if sustained yield management within the licenced area can be practised.

A set of comprehensive logging rules should be devised and incorporated in the timber licence.

The government should determine and delineate sufficient forest land to be alienated for agricultural development for the next 50 years.

8.5 General Concluding Remarks

Many scientists have little confidence that moist tropical rainforests can be managed under the natural regeneration process. However, the author is confident that the Dipterocarp forest of Sabah can be regenerated under this process provided that human interference (logging) does not exceed its recuperative capacity.

It has been demonstrated that a multiplicity of factors, other than ecological or biological, influence silvicultural decision. After an exhaustive examintion of all the possible factors, it is recommended that a polycyclic system in the form of the Selection System could be the most suitable system for the Dipterocarp forest of Sabah. Three levels of the proposed silvicultural code are devised for implementation of different categories of licences because of the inherent-problems and constraints in timber industries

(Section 8.4.3). In all three levels of implementation, reasonable productivity of the forests could be maintained in view of seed tree retention and imposition of logging rules, particularly restriction of tractor movements.

Linear samplings, particularly L.S.M. cannot be used as a tool to forecast the future crop, but L.S.M., LS $\frac{1}{4}$ and LS $\frac{1}{2}$ are useful sampling methods for diagnosing the forest conditions at the time of sampling. For growth and dynamic studies of the forests, permanent yield plots should be established.

With the implementation of the full level of the proposed Silvicultural Code, a cutting cycle of 40 years or less depending on the forest composition is envisaged. Heavy mechanical equipment is used in timber extraction and it poses a distinct threat to satisfactory regeneration if it involves excessive damage to the forest. In the implementation of the proposed silvicultural code, special attention must be paid to cutting logging damage from 30 to 50%, to 20%. Wherever possible, pre-located main tractor paths and landings should be observed. A set of logging rules must be formulated, legislated and incorporated in the licences. Steps should preferable be taken to legalise the management objective based on sustained yield management. A timber licence cannot be issued if sustained yield management cannot be practised within the licenced area.

Species distribution and associations within the Dipterocarp forest can be quite different from one type to another but Rubroshorea species (Section of Shorea - Red serayas) and White serayas (Parashorea) are usually dominant. They also exhibit fastest growth rates of all Dipterocarp species. Special attention may be given to regenerate these species but silvicultural treatments must be carried out uniformly in the Dipterocarp forest as an entire system.

The replacement of natural forests by plantations has been generally considered as a rational move for producing timber in tropical areas. The Sabah government has nominated forest plantation as an alternative system for production of timber. The present development of commercial-scale tree plantations by two agencies will play an important role in stepping up timber production in Sabah. This applies particularly to the timber produced from the rehabilitation of the grasslands in the light of the shrinking natural forest resource.

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LINEAR SAMPLING

(a) L.S.M.

L.S.M. was originally designed for use before logging to determine whether sufficient regeneration was present to allow logging. It has not been so used in North Borneo since regeneration has always been sufficient (?) and it would be difficult to hold up the working of timber companies. However inspections should be made before logging whenever possible. If regeneration appears to be sparse then an L.S.M. should be made. If the figures support the inspection it may be necessary to mark seed trees for retention as the only possible means of ensuring eventual regeneration.

The L.S.M. can however give valuable information on the state of the regeneration after logging. Such a survey can conveniently be combined with the girdling guide rentises. Whenever staffing allows, this survey should be carried out. It will provide a basis for judging development and compositional change of the regeneration. If every guide rentise is sampled the sample will be 2%. A lower percentage sample e.g. every 4th guide rentis (.5%) would be acceptable if the 2% sample is not possible, especially if extensive areas are covered.

Procedure

The following points should be adhered to. They differ in some respects from the manual, but the latter should be consulted for general information and procedure.

(1) Sampling is to be done on one side of the rentis and the labourers should know this so that all slash is thrown out on the other side and so that rentis panchangs are put as close to this side as possible.

(2) One chosen tree is to be selected on each milliacre. The chosen tree should be without logging damage and be a recognised commercial Dipterocarp whenever possible. Other trees in L.S. list, such as Jelutong, Kembang, Sepetir etc. should only be selected if they are good trees and three or more size classes larger than a possible Dipterocarp seedling. e.g. a size class 4 kembang can be selected in preference to a size class 1 or 1A Urat Mata.

(3) Chosen trees are to be booked in the following size classes. The actual sizes can be used in the field sheets, if prefered.

Size Class	Height & Diameter	Height & Girth (Approx.)
1	0 - 1' high	0 - 1' high
1A	1'- 5'	1' - 5'
2	5' - 10'	5' - 10'
3	10' - 2" diam.	10' - 6" girth
4	2" - 4"	6" - 12"
5	4" - 8"	12" - 24"
6	8" - 12"	24" - 36"
7	12" - 16"	36" - 48"
8	16" - 20"	48" - 60"
9	20" - 24"	60" - 72"

(4) Dominance classes need not normally be recorded, since girdling will follow the L.S.M. and change the dominance of most chosen trees. In special cases, where for instance degree of logging damage is being assessed the dominance classes given for LS¼ should be used.

(5) Abundance of commercial seedlings should be recorded in the following three classes, and refers to all commercial seedlings, <u>not only</u> to the same species as the chosen tree.

1 = 1 commercial seedlings (s) or tree (s)
+ = 2-5 " " " "
++ = 6 or more " " " "

(6) Climbers and relic trees need not be recorded since these will be cut or girdled. Areas with generally bad climber infestation should be noted in the remarks column, against the respective chainages.

Summaries

It is advisable to make out the summary for each sample line separately. This will allow them to be kept up to date (this is most important) and will allow approximate statistical tests to be applied to the sampling data. the totals for stocking, size class distribution, and abundance should be presented as No. of plots per acre rather than as % of stocked plots since it is easier to assess the significance of numbers per acre than percentages. The specific composition however is best presented as percentages of stocked plots so that comparisons with other areas or with later surveys is possible. The figures are of course convertable at any time.

The steps in making out the summaries are as follows:-

(1) Rule up a double foolscap sheet with headings, Species, Number, % (to be left blank), Size class (subdivided into 10 classes), Abundance (3 columns).

(2) Run through the field sheets dotting in (or other notation) the three records for each chosen tree by species.

(3) Total the columns, giving the totals irrespective of species. These can then be converted to numbers of plots per acre simply by multiplying by

$$\frac{1000}{\text{Total No. of samples in line(s)}}$$

This fraction can of course be converted to a decimal number to simplify the arithmatic. It should be corrected to 3 figures after the decimal point. The figure for number per acre need be recorded only as the nearest whole number.

(4) The vacant column headed percentage can be filled in by multiplying the number of plots for each species by

$$\frac{100}{\text{No. of stocked plots in line (s)}}$$

which can again be corrected to a decimal number as above. An example of a line summary sheet is appended.

(5) When a number of lines have been summarised they can be put on one sheet as below (by monthly working areas, compartments or other groupings as may be decided).

Item	Linear Samples			
	1	2	etc	Weighted Mean *
1. Area (acres)	.110			
2. Plots/acre with chosen trees	682			
3. Size Distribution (Plots/acre)				
0 - 1'	182			
1' - 5'	327			
5' - 10'	100			
10' - 2"	36			
2" - 4"	9			
etc.	etc.			

ITEM	LINEAR SAMPLES			
	1	2	etc	Weighted Mean *
4. Abundance Plots/acre with:-				
1 seedling	100			
2-5 seedlings	173			
6 and over seedlings	409			
5. Species Distribution.				
% of stocked plots				
Urat mata	48.0			
etc.	etc			

* Since the areas for each line may differ, the column for the mean should be calculated by adding the actual totals from the line summary sheets and calculating the numbers per acre as before. This is easier than weighting the per acre figures. Similarly the mean % should be worked out using the actual total from all the lines for each species and calculating the % as before.

These grouped summaries together with a map should be sent to Headquarters for inclusion in the reserve records.

(b) L.S.¼

¼ chain linear sampling is to be done at about 5 years after logging. Its purpose is to record the development and condition of the regeneration. It is probable that when further experience has been gained in our regeneration techniques this sampling will be discarded in favour of the LS½ at about 10 years after logging. The only treatment which could be prescribed at this age would be a climber cutting. In most areas this could wait till 10 years, when some further weeding and thinning can be done at the same time.

Procedure

For the time being systematic and not random samples will be used. The former has real advantages in giving a better coverage if the survey is needed for map making, as well as having a slight advantage in ease of layout. Methods of inding approximate sampling errors from systematic samples have now been developed, which further reduces the need for ramdom samples.

The intensity of the sample taken should be decided for each individual survey, but as a rule lines should be 5 chains apart giving a 5% sample. Over extensive areas lines 10 chains apart (2½% sample) will give an adequate sample. The following are the important points to remember in ¼ chain linear sampling:

(1) The ¼ chain samples should straddle the rentis i.e. they are 25 links along the rentis and 12½ links on either side. Care is needed in avoiding commercial trees in cutting the rentis and also ensuring that the width of the sample strip is checked from time to time.

(2) One chosen tree is to be selected on each sample. The same restrictions on the type of tree as were given for L.S.M. apply for LS¼.

(3) Size classes are the same as those given for L.S.M.

(4) Dominance classes are as follows:-

D = Dominant i.e. Taller than surrounding trees and receiving full light.

CD = Co-dominant i.e. as tall or lower than surrounding trees but receiving full overhead light.

d = Dominated i.e. below the crowns of other trees or climbers.

(5) No record of abundance of regeneration need be made.

(6) It is important to record the incidence of climbers, bamboo and rotan, but remember that this means climbers, bamboo or rotan actually on the stem or in the crown of the tree. They can be recorded in one column headed "Climbers".

(7) Relics from the previous stand should only be recorded if in the sample, and should of course only be recorded in one sample if they happen to occur on the boundary between two samples. In this way the stocking of these trees can be assessed. Their effects in dominating the regeneration will be included in the dominance figures.

Summaries

As for L.S.M. the summaries should be made out line by line and be recorded in the same units as given for L.S.M. above i.e. Plots/acre and %'s. The summaries are made in the same way, except that no column for abundance is needed, but columns for dominance, climbers and relics are. The conversion factor to numbers per acre for each total is

$$\frac{160}{\text{Total number of sample in line(s)}}$$

Converted to a decimal and corrected to 3 places as for L.S.M. The conversion factor to %'s for each species is

$$\frac{100}{\text{No. of stocked plots in line(s)}}$$

converted to decimals as before. An example of a line summary sheet is appended.

When a compartment, month's work or other unit area has been sampled the summaries can be grouped as below:-

	Linear Sample NO.				
Item	1	2	3	etc	Weighted Mean *
1. Area (acre)	1.125				
2. Plots/acre with chosen trees	137				
3. Plots/acre with D or CD chosen trees	122				
4. Size Distribution (Plots per acre) by size classes	-				
5. Plots/acre with climbers	44				
6. Plots/acre with relics	2				
7. Species Distribution % of stocked plots (by species)	-				

* See note given for L.S.M. mean figures.

These grouped summaries, together with a map should be sent to Headquarters for inclusion in the reserve recorded.

S. 1

Appendix II

Field Sheet
Linear Sampling After Logging Before Girdling LSMALBG

Sheet No.

Location ....

.... Date .... Officer .... Line No. .... Bearing .... Chainage .... Acres ....

CHAIN No.				CHAIN No.			CHAIN No.			CHAIN No.			CHAIN No.		
Distance	Species	Size	Remarks	Species	Size	Remarks	Species	Size	Remarks	Species	Size	Remarks	Species	Size	Remarks
0-10L															
10- 20															
20- 30															
30- 40															
40- 50															
50- 60															
60- 70															
70- 80															
80- 90															
90-100															

CHAIN No.				CHAIN No.			CHAIN No.			CHAIN No.			CHAIN No.		
0-10L															
10- 20															
20- 30															
30- 40															
40- 50															
50- 60															
60- 70															
70- 80															
80- 90															
90-100															

NOTES

1. *Species*—use symbols

e.g. UMB, SMJ, STE.

2. *Size*

(1) 0-1ft. Ht.
(1A) 1-5ft. Ht.
(2) 5-10ft. Ht.
(3) 10ft. Ht.-6″ g.
(4) 6″-1ft. g.
(5) 1-2ft. g.
(6) 2-3ft. g.
(7) 3-4ft. g.
(8) 4-5ft. g.
(9) 5ft. g. +

3. *Remarks.*

If no seedling, then
(T)=Tractor damage.
(S)=Sungei.
(K)=Otherwise empty.

Relics-Commercial Species within 1 chain each side, over 6ft. g. give species and girth.

Appendix III

S. 2 [illegible]

SABAH, MALAYSIA

SUMMARY SHEET

Linear Sampling After Logging Before Girdling LSMALBG.

Location .... Date Field wk. .... Officer in Charge ....

Date of Summary .... Summary by ....

If any lines not 10 chains state length .... Total chainage on Summary =

.... Thus acreage is ....

Relic acreage is ....

Species No.		Line Numbers (10 ch. if not entered)									Totals	Per Acre	%
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
Total Preferred													
Total Desirable													
Total Acceptable													
Others													
All Recorded													
Size Class													
1													
1A													
2													
3													
4													
5													
6													
7													
8													
9													
Total													
Relics													
T													
S													
K													

S. 8

SABAH, MALAYSIA

Appendix IV

Field Sheet

Linear Sampling Quarter Chain Survey at F + 5

Sheet No……………

Location…… ………… ……………………………

……………………… ………… Date ………… ….. …… Officer ……………………………… Line No………… Bearing ……………………… Chainage ……………………

P.K. 12/00L-1/2957-77.

Col. Plot	Column 2 Species	Col. 3 Size	Col. 4 Light Score	Column 5 Climbers	Column 6 Impeders	Column 7 Relics	Column 8 Remarks
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Notes

1. *Species* — Use symbols e.g. UMB, SMJ, STE. If column 2 blank do not enter columns 3, 4, 5, 6.
2. *Size.*
   Use the following:
   (1) O′ to < 5′ height
   (2) 5′ to < 10′ height
   (3) 10′ height to < 6″ girth
   (4) 6″ to < 12″ girth
   (5) 1′ to < 2′ girth
   (6) 2′ to < 3′ girth
   (7) 3′ +
3. *Light Score.*
   Position — use 5 for emergent; 4 for upper canopy; 3 for lower canopy; 2 for upper understorey; 1 for lower understorey.
4. *Climbers* — if present on tree write YES.
5. *Impeders* threatening growth of chosen tree R = Bamboo; B = Belukars; C = Relic Commercial; N = Non-commercial species; D = Other regeneration from outside the plot
6. *Relics* any tree over 6 feet girth. Record species and girth of any relic within 1 chain each side of the sample rentis.

S. 9

Appendix V

Copy No.

SUMMARY SHEET

LINEAR SAMPLING QUARTER CHAIN SURVEY AT F + 5

Total chainage on summary .... (L)

Thus acreage is $\frac{L}{40}$ .... (A)

Relic acreage is (A) x 8 ....

Location ....

....

Date of Field Work ....

Date of Summary ....

Officer in Charge ....

Summary by ....

		Field Sheet 1							Field Sheet 2							Field Sheet 3							Field Sheet 4							TOTAL						
		Size Classes							*Size Classes*							*Size Classes*							*Size Classes*							*Size Classes*						
Category		1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Stocking	A																																			
All A with impeders	B																																			
All A with climbers	C																																			
Light Score 5	D																																			
Light Score 3, 4	E																																			
Light Score 1, 2	F																																			
No. of Relic Comms.	G																																			
No. of Relic N-Comms.	H																																			

		Field Sheet 5							Field Sheet 6							Field Sheet 7							Field Sheet 8							PER ACRE						
		Size Classes							*Size Classes*							*Size Classes*							*Size Classes*							*Size Classes*						
		1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Stocking	A																																			
All A with impeders	B																																			
All A with climbers	C																																			
Light Score 5	D																																			
Light Score 3, 4	E																																			
Light Score 1, 2	F																																			
No. of Relic Comms.	G																																			
No. of Relic N-Comms.	H																																			

Notes

← Put total entries for each category all sheet entries added in this box.

To get per acre values divide acreage into all these entries and put in box beneath.

Categories

Take No of entries from columns of field sheet.

A — No. of entries col. 1.

B — No. of plots with an entry in columns 5 or 6 except when col. 6 only, with D.

C = No. of entries col. 5.

D, E, F = entries from col. 4.

G, H = from col. 7 totals, all trees recorded.

Appendix Ⅵ

S. 3

SABAH, MALAYSIA

Sheet No.

Field Sheet
Linear Sampling Half Chain Survey at F + 10 LSHIO

Location ....

.... Date .... Officer .... Line No. .... Bearing .... Chainage . . Acres ....

SPC-0246

Col. 1 Plot	Column 2 Species	Col. 3 Size	Col. 4 Crown Score	Column 5 Climbers	Column 6 Impenders	Column 7 Relics	Column 8 Remarks
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
					TOTAL		

NOTES

1. *Species* — Use symbols e.g. UMB, SMJ, STE. If column 2 blank do not enter columns 3, 4, 5, 6.
2. *Size.*
   Use the following
   (2) Less than 10 feet height.
   (3) 10′ height—6″ girth.
   (4) 6″—1′ girth.
   (5) 1′—2′ girth.
   (6) 2′—3′ girth.
   (7) 3′—4′ girth.
   (8) 4′—5′ girth.
   (9) 5′ girth +.
3. *Crown Score.*
   Position — use 5 for emergent; 4 for upper canopy; 3 for lower canopy; 2 for upper understorey; 1 for lower understorey.
4. *Climbers*—if present on tree write YES, if heavy YES+.
5. *Impeders* threatening growth of chosen tree R = Bamboo; B = Belukars; C = Relic Commercial; N = Non-commercial species; D = Other regeneration from outside the plot.
6. *Relics* any tree over 6 feet girth. Record species and girth of any relic within 1 chain each side of the sample rentis.

S. 4

Appendix VII

LINE SUMMARY SHEET

Copy No.

LINEAR SAMPLING HALF CHAIN SURVEY AT F + 10 LSH 10

Location ....

Date of Field Work .. ..

Date of Summary ....,...........

Officer in Charge ....:.........................

Summary by ....

Total chainage on summary .... (L)

Thus acreage is $\frac{L}{20}$ .... (A)

Relic acreage is (A) × 4 .. ..

Category		FIELD SHEET 1				FIELD SHEET 2				FIELD SHEET 3				FIELD SHEET 4				TOTALS			
		Size Classes				*Size Classes*				*Size Classes*				*Size Classes*				*Size Classes*			
Stocking	A																				
All A with impeders	B																				
All A with climbers	C																				
All A with heavy climbers	D																				
Crown Score 5	E																				
Crown Score 3, 4	F																				
Crown Score 1, 2	G																				
No. of Relic Comms	H																				
No. of Relic N-Comms	I																				
	J																				

		FIELD SHEET 5				FIELD SHEET 6				FIELD SHEET 7				FIELD SHEET 8				PER ACRE			
Stocking	A																				
All A with impeders	B																				
All A with climbers	C																				
All A with heavy climbers	D																				
Crown Score 5	E																				
Crown Score 3, 4	F																				
Crown Score 1, 2	G																				
No. of Relic Comms	H																				
No. of Relic N-Comms	I																				
	J																				

Notes

← Put total entries for each category all sheet entries added in this box.

To get per acre values divide acreage into all these entries and put in box beneath.

Categories

Take No. of entries from columns of field sheet.

A=No. of entries col. 1.

B=No. of plots with an entry in columns 5 or 6 except when col. 6 only, with D.

C=No. of entries col. 5.

D=Col. 5 entries with YES + only.

E, F, G. entries from col. 4.

H, I from col. 7 totals, all trees recorded.

Size Classes. Inspect Field Sheets. May use e.g.

12 < 24"; 24" + < 6"; 6 < 12"

Appendix VIII

Standard trade name	Botanical name
	Class A
Belian	Eusideroxylon zwageri
Merbau	Intsia spp.
Selangan batu No. 1	Shorea laevis
	Shorea atrinervosa
	Shorea foxwarthyii
	Shorea seminis
	Shorea exelliptica
	Shorea isoptera
	Shorea maxwelliana
	Shorea leptoderma
	Shorea hypoleuca
	Shorea inappendiculata
	Shorea domatiosa
	Shorea biawak
Selangan batu No. 2	Shorea superba
	Shorea glaucescens
	Class B
Geriting	Lumnitzera littorae
Kembang	Heritiera spp.
Oba suluk	Shorea pauciflora
Red seraya	Shorea leptoclados
	Shorea parvifolia
	Shorea waltonii
	Shorea leprosula
	Shorea smithiana
	Shorea macroptera
	Shorea ovalis
	Shorea oleosa
	Shorea beccariana
	Shorea argentifolia
	Shorea almon
White seraya	Parashorea malaanonan
	Parashorea tomentella
	Parashorea smythiesii
	Parashorea parvifolia
	Class C
Standard trade name	Botanical name
Gagil	Hopea sengal
Kapur	Dryobalanops lanceolata

/Dryobalanops

	Dryobalanops beccarii
	Dryobalanops rappa
	Dryobalanops keithii
	Dryobalanops aromatica
Keruing	Dipterocarpus caudiferus
	Dipterocarpus acutangulus
	Dipterocarpus warburgii
	Dipterocarpus grandiflorus
	Dipterocarpus exalatus
	Dipterocarpus costulatus
	Dipterocarpus confertus
	Dipterocarpus applanatus
	Dipterocarpus hermeratus
	Dipterocarpus kerii
	Dipterocarpus lowii
	Dipterocarpus pachyphyllus
	Dipterocarpus temehes
	Dipterocarpus stellatus
	Dipterocarpus gracilis
Melapi	Shorea symingtonii
	Shorea virescens
	Shorea agami
	Shorea bracteolata
	Shorea lamellata
	Shorea gratissima
	Shorea ochracea
Nyatoh	Diploknema sebifera & Palaquium spp.
Sepetir	Sindora spp.
Serungan	Cratoxylum spp. (mainly c. arborescens)

Class C

Standard trade name	Botanical name
Yellow seraya	Shorea acuminatissima
	Shorea gibbosa
	Shorea hopeifolia
	Shorea kudatensis
	Class D
Jongkong	Stenostachys
	Class E
Ramin	Gonystylus bancanus

/Other Timber

Appendix IX Botanical Nomenclature
Common Species Quoted

Shorea	*smithiana*	Syminton
Shorea	*symingtonii*	Wood
Shorea	*superba*	Syminton
Shorea	*leprosula*	Miqi
Shorea	*gibbosa*	Brandis
Shorea	*acuminatissims*	Syminton
Shorea	*leptochados*	Syminton
Shorea	*parvifolia*	Dyer
Shorea	*pauciflora*	King
Shorea	*argentifolia*	Syminton
Shorea	*oleosa*	Meijer
Shorea	*ovalis*	Blanco
Shorea	*monticola*	Ashton
Shorea	*multiflora* (Burck)	Syminton
Shorea	*nebulosa*	Meijer
Shorea	*laevis*	Ridley
Shorea	*inappendiculata*	Bruck
Parashorea	*malaanonan*	Blanco
Parashorea	*tementella*	Meijer

Dryobalanops	*aromatica*	Gaertn
Dryobalanops	*lanceolata*	Bruck
Dipterocarpus	*candiferus*	Merr.
Dipterocarpus	*confertus*	van Slooten
Dipterocarpus	*acutangulus*	Vesque
Dipterocarpus	*grandiflorus*	Blanco
Dipterocarpus	*stellatus*	Vesque
Anisoptera	*costata*	Korth
Anisoptera	*marginata*	Korth
Cotylelobium	malayanum (Hook)	Pierre
Hopea	*nutans*	Ridl.
Hopea	*beccariana*	Bruck
Hopea	*wyattsmythii*	Wood
Hopea	*micrantha*	Hook.f.
Vatica	*papuana*	Dyer
Vatica	*bancana*	Scheffer
Vatica	*oblongifolia*	Hook.f.

TABLE 2.2 COMPARISON OF LOG PRODUCTION AND EXPORT WITH EXPORT OF OTHER PROCESSED TIMBER : SABAH

Year	Production	Export			
	Log (Hoppus cu ft)	Log (Hoppus cu ft)	Sawn (square ft)	Veneer sheets (square ft)	Plywood (square ft)
1974-1951 (average)	4,670,000	2,645,000	-	-	-
1952-1956 (average)	12,870,000	9,369,000	26,762	-	-
1957-1961 (average)	46,860,000	39,242,000	27,041	b/	-
1962-1966 (average)	108,470,000	96,755,000	6,866	32,228,000	c/
1967	158,340,000	147,600,000	3,466	25,118,000	7,923,000
1968	163,887,000	160,775,000	4,014	37,158,000	10,991,000
1969	171,994,000	182,157,000	10,020	47,014,000	10,458,000
1970	183,077,000	170,581,000	420,000	51,729,000	17,017,000
1971	192,853,000	181,900,000	227,000	22,912,000	19,713,000
1972	236,504,000	213,802,650	295,000	58,736,000	35,412,000
1973	307,956,000	281,352,293	444,000	54,991,000	38,267,000
1974	275,209,000	269,958,402	152,000	108,475,000	24,030,000
1975	252,923,000	249,376,501	333,000	59,168,000	50,149,000
1976	349,175,000	334,539,000	580,000	47,978,000	43,735,000
1977	330,552,000	342,189,000	1,261,000	31,159,000	34,196,000
1978	368,638,000	364,096,000	1,159,000	17,802,000	15,994,000
1979	300,701,000	286,577,000	2,722,000	91,195,000	32,909,000
1980	251,406,000	246,000,000	9,125,000	99,729,000	45,118,000

Year	Production	Export			
	Log (Hoppus cu ft)	Log (Hoppus cu ft)	Sawn (square ft)	Veneer sheets (square ft)	Plywood (square ft)
1974-1951 (average)	4,670,000	2,645,000	-	-	-
1952-1956 (average)	12,870,000	9,369,000	26,762	-	-
1957-1961 (average)	46,860,000	39,242,000	27,041	b/	-
1962-1966 (average)	108,470,000	96,755,000	6,866	32,228,000	c/
1967	158,340,000	147,600,000	3,466	25,118,000	7,923,000
1968	163,887,000	160,775,000	4,014	37,158,000	10,991,000
1969	171,994,000	182,157,000	10,020	47,014,000	10,458,000
1970	183,077,000	170,581,000	420,000	51,729,000	17,017,000
1971	192,853,000	181,900,000	227,000	22,912,000	19,713,000
1972	236,504,000	213,802,650	295,000	58,736,000	35,412,000
1973	307,956,000	281,352,293	444,000	54,991,000	38,267,000
1974	275,209,000	269,958,402	152,000	108,475,000	24,030,000
1975	252,923,000	249,376,501	333,000	59,168,000	50,149,000
1976	349,175,000	334,539,000	580,000	4[illegible],978,000	43,735,000
1977	330,552,000	342,189,000	1,261,000	33,159,000	34,196,000
1978	368,638,000	364,096,000	1,159,000	17,802,000	15,994,000
1979	300,701,000	286,577,000	2,722,000	91,195,000	32,909,000
1980	251,406,000	246,000,000	9,125,000	99,729,000	45,118,000

Source: Forest Department, Sabah: Annual reports

a/ Including sawn timber.

b/ Production of veneer sheets started in 1960 with an average of 509,027 square metres between 1960/61.

c/ Plywood production started in 1966 with the production of 160,832 square metres in that year.

[redacted]

TABLE 2.3 EXPORTS OF ROUND LOGS FROM SABAH, BY DESTINATION (Hoppus cu ft and Percentages)

Destination	1961		1962-1966 (average)		1967		1968		1969		1970		1971	
	ft^3	%	ft^3	%	ft^3	%	ft^3	%	ft^3	%	ft^3	%	ft^3	%
Australia	1,716,000	2.7	2,485,000	2.6	3,073,000	2.0	3,250,000	2.0	2,851,000	1.7	2,885,000	1.6	2,249,000	1.2
China	311,000	0.5	685,000	0.7	227,000	0.2	1,281,000	0.8	490,000	0.3	148,000	0.1	672,000	0.4
Hong Kong	7,145,000	11.2	8,778,000	9.1	4,021,000	2.7	8,474,000	5.3	8,074,000	4.7	7,514,000	4.4	12,153,000	6.7
Japan	49,919,000	78.4	73,653,000	76.1	113,159,000	76.7	112,195,000	68.7	119,090,000	69.0	113,448,000	66.2	118,409,000	64.9
Korea, Rep. of	25,000	-	5,627,000	5.8	17,638,000	11.9	29,185,000	18.1	31,034,000	18.0	37,636,000	22.0	40,943,000	22.5
United Kingdom	201,000	0.3	212,000	0.2	177,000	0.1	105,000	0.1	104,000	0.1	-	-	-	-
All others	3,221,000	5.0	5,209,000	5.5	9,325,000	6.2	6,281,000	3.9	9,989,000	5.8	8,893,000	5.2	7,477,000	4.1

Source: Forest Department, Sabah.

TABLE 2.4 PLYWOOD AND VENEER EXPORTS FROM SABAH BY DESTINATION

Destination		1969		1970		1971	
		sq. ft	Value (M$)	sq. ft	Value (M$)	sq. ft	Value (M$)
Australia	Plywood	-	-	196,000	18,772	1,271,000	126,348
	Veneer	32,745,000	865,766	17,559,000	649,407	9,698,000	406,391
Hong Kong	Plywood	1,348,000	160,692	1,185,000	215,930	351,000	97,544
	Veneer	-	-	-	-	-	-
Japan	Plywood	-	-	173,000	17,787	-	-
	Veneer	12,493,000	488,962	26,101,000	1,354,484	13,172,000	567,866
South Africa	Plywood	-	-	3,019,000	314,944	-	-
	Veneer	145,000	5,481	1,441,000	65,760	33,000	2,501
Thailand	Plywood	320,000	27,403	-	-	-	-
	Veneer	-	-	-	-	-	-
Sarawak	Plywood	-	-	-	-	-	-
	Veneer	-	-	344,000	11,896	-	-
India	Plywood	-	-	12,000	1,217	-	-
	Veneer	-	-	-	-	-	-
United Kingdom	Plywood	4,434,000	560,793	7,260,000	722,413	3,597,000	385,648
	Veneer	-	-	410,000	16,173	-	-
United States	Plywood	4,357,000	249,584	4,826,000	484,809	14,486,000	1,535,489
	Veneer	1,631,000	34,854	156,000	17,679	-	-

[redacted]

TABLE 2.5 SABAH SAWMILL INDUSTRY (PRODUCTION AND EXPORT)

Year	Number of sawmills	Logs intake (Hoppus cuft)	Sawn timber produced (cu ft)	Export (cu ft)	Percentage exported
1962-1966 (average)	113	3,175,000	2,000,000	242,000	12.1
1967	136	3,913,000	2,072,000	122,000	6.1
1968	133	4,837,000	2,343,000	141,734	6.0
1969	140	4,225,000	2,265,000	254,000	15.6
1970	139	4,962,000	2,695,000	421,000	16.0
1971	154	5,715,000	3,274,000	228,000	7.0

<u>Source</u>: - Forest Department, Sabah.