Regeneration of the forest after logging at Kintap, South Kalimantan, Indonesia

DRAFT

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by
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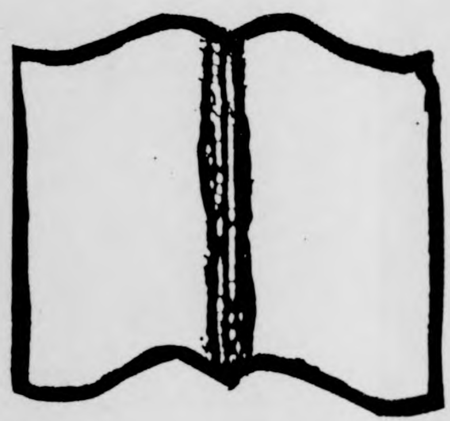

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Yusuf Jafarsidik

ABSTRACT

A study on the regeneration of the forest after logging was conducted in the Hutan Kintap concession, South Kalimantan, Indonesia. The study began in 1991, and nineteen 0.25 ha plots were set up in a total of six blocks. Block A was a newly logged forest and had five plots, and Blocks B - D were in forest which had been logged in 1979. Block B (five plots) had received no silvicultural treatment, Block C (five plots) and D (one plot) had been lightly thinned after felling and Block C received a further thinning treatment. Block E (one plot) had been heavily thinned, and Block F (2 plots) was an unlogged control. The study included observations on the condition of the forest in the plots, the growth rate of the remaining trees, seedlings and saplings, and the size of the soil seed banks and seed rain. It was completed in 1996.

The average annual precipitation in the study area was about 3000 mm, the average temperature recorded in Pelaihari (60 km from the study site) ranged between 26.4^0 C and 27.6^0 C, humidity between 76 % and 87 %, and irradiation between 35 % and 77 % sunshine hours (between 0800 and 1600). The topography was undulating with an altitude of 10 - 200 m above sea level. A soil survey revealed mainly ultisols but there were gleyed areas and some lithosols. Soil particles were dominated by clay with pH's ranging between 4.8 and 6.1, available-P between 0.1 and 5.9 μg g^{-1}, total P between 92 and 503 μg g^{-1}, and organic C, CEC and the sum of exchangeable cations all relatively high.

In all 19 plots the Dipterocarpaceae were the leading family in terms of number of individuals and basal area. There were at least 305 species of tree (≥ 10 cm dbh) included in 49 families. Growth rates in the plots varied among Blocks and among plots of the same Block, ranging from 0.31 to 0.57 m^2 ha^{-1}year^{-1} depending among other factors on the site condition and species composition. Liberation treatment in Block C resulted in a higher increment rate than in Blocks A and B, the difference however was not significant. Dipterocarps had the highest increment in the study area. Mortality within the study sites ranged from 1.15 to 2.70 % year^{-1}. The density of seedlings varied within the study sites, and averaged 47000 ha^{-1} to 121000 ha^{-1}. The mean height growth per Block was from 2.9 cm year^{-1} to 10.5 cm year^{-1}. Seedling mortality ranged from 16 to 37 % year^{-1}, and declined with height class. The density of saplings ranged from 6800 ha^{-1} to 7700 ha^{-1} and they had a diameter growth of 0.8 mm year^{-1} to 2.2 mm year^{-1}, and a height growth of 12.6 cm year^{-1} to 21.8 cm year^{-1}.

The size of seed banks varied greatly among plots, ranging from 73 m^{-2} to 1084 m^{-2}, and the number of identified species varied from 10 to 29 per plot. Pioneers contributed most to the seed banks both in numbers of species and individuals. Seed fall was 4534 (collected in traps with a total area of 57 m^2), with the peak occurring in February - March 1992 (45 %). The heavy seed rain in February - March 1992 followed a mast flowering and fruiting in November - December 1991. Dipterocarp seeds contributed 847 seeds (15 m^{-2}) from 12 species and 3 genera.

Given the condition of the logged-over forest of the study sites, the forest recovery will take up to 50 years. Sufficient seedlings and saplings and the productivity of the remaining stands as indicated by the seed fall during a mast fruiting ensure the regeneration of the forest after logging. Unfortunately the condition of the logged-over forests were very much worse outside the study area, and no predictions can be made of the recovery time or even if recovery will ever occur over most of the concessionary area.

ACKNOWLEGMENTS

I wish to thank the Agency for Forestry Research and Development (AFRD), the Office of Forest Research Development and Nature Conservation (FRDNC) Bogor, and the INDECO Supporting Office, for the permission for, and support of, my study. I owe much to the Finnish International Agency (FINNIDA) for support during the field work at Kintap, South Kalimantan, and funding for the completion of the study in joint efforts with the Ministry of Forestry, Indonesia.

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Finally I thank my wife Elly and all my sons and daughters for their patience, sacrifices, encouragement and support.

CONTENTS

CHAPTER 1 GENERAL INTRODUCTION

Background

The natural regeneration of forests has been widely studied in gaps which are recognized as an important part of the forest growth cycle (Whitmore 1978; Hartshorn 1978; Denslow 1980; Brokaw 1982; Brokaw 1985; Canham & Marks 1985). Tree population dynamics, species composition, and growth rates are dependent on the frequency and size of gaps (Brokaw 1985).

Logged forests may be regarded as a severely disturbed natural system, and through natural dynamic processes and with an appropriate management system sustainable forest production may be maintained (Swaine *et al.* 1987). Studies on the response of forest to logging are still inadequate in spite of the vast areas of logged forests which occur throughout the wet tropics.

The most favoured management system in Indonesia is the Indonesian Selective Cutting and Replanting System ("Tebang Pilih Tanam Indonesia") which is designed to have a 35-years cutting cycle. This requires that after logging, 25 mother trees ($\geq$ 35 cm) must be left per ha and no tree of less than 50 cm must be cut (Djamaludin 1991). The selective cutting creates gaps and forest patches of varying sizes, depending on the intensity of logging. A grouping of desired commercial trees (notably dipterocarps) will open larger gaps and cause heavy damage to the area.

Felling and mechanized log extraction are the two main factors damaging forests, soil water resources, and animal habitats during logging (Nicholson 1958; Fox 1969; Tinal & Palenewen 1978; Abdulhadi *et al* 1980; Ewel & Condo 1980; Kartawinata 1981). Felling damage includes that to bark or crowns or both, and fallen or broken stems, and may range up to 36% of the former total number of trees (≥ 14 cm dbh) (Nicholson 1958; Tinal & Palenewen 1978). Log extraction is more damaging than felling (Burgess 1971; Fox 1978). Mechanical log extraction opens up the forest floor by up to 40% (Nicholson 1979; Hutchinson 1980). The logging operation affects the soil physically and chemically and has a potential effect on soil micro-organisms (Ewel & Condo 1980). Erosion is one of the apparent effects of logging, especially on roads and skid trails (Burgess 1971; Ewel & Condo 1980; Kellman 1969; Liew 1974, Wyatt-Smith 1949). A cleared area in the logged forest may have slower decomposition and hence less mineralization of nutrients and organic inputs contributing to a lower cation exchange capacity (Ewel 1976; Ewel & Condo 1980).

In order to understand the damage to the forest caused by logging and the processes involved in its recovery several aspects must be studied. These include a quantification of the damage, growth of trees, seedlings and saplings, the mortality and recruitment of trees, the survivorship of seedlings and saplings, and the seed banks and the seed rain.

The natural growth rate of trees in the tropical rain forest differs among emergent, canopy and understory species, and within individuals of the same species at the same site (Whitmore, 1984 ; Swaine *et al* 1987a; Manokaran & Kochummen, 1987, Korning & Balslev 1994). Manokaran & Kochummen (1987) studied the growth rate of trees in primary lowland tropical rain forest in Peninsular Malaysia over 34 years. A higher growth rate was observed for some emergent trees than upper canopy species, and the latter had a higher growth rate than understory species. Similarly Korning & Balslev (1994) observed a higher growth rate of higher-layer tree species in primary rain forest in Amazonian Equador. The growth of trees in a successional stage (60-years old forest on abandoned agricultural land) was studied by Lang &

Knight (1983) on Barro Colorado Island, Panama, over 10 years. The study suggested that diameter growth was highly variable among species and among size classes. Small understory trees grew most slowly, mostly less than 1 mm $year^{-1}$ dbh, while individual canopy trees had a maximum growth rate of 15 mm $year^{-1}$. Growth at this site was very slow for most species with a 0 - 2% dbh increment over the first 10 years. Growth of dipterocarps in contrasting primary forest types, managed forest, logged-forest and plantations was studied by Primack *et al.* (1989). The results of the study suggested that the growth response of species and genera is site specific, and growth rates are distinctly increased by silvicultural treatment following logging. Studies on the advance growth of pole-size dipterocarps in Sabah (Nicholson 1965) indicated that the girth increment after logging was higher than before. The growth rate of residual stands (excluding damaged trees) in a heavily logged forest in East Kalimantan showed a significant increase (Miller, 1981). In the older logged-over forest competition may increase and reduce the growth rates. Primack *et al.* (1985) found that growth rates in the Moraceae increased in 1 and 2 years-old logged-over forest and declined 3 and 4 years after logging.

Tree mortality is related to the maximum age of species, relative density, size-class distribution and the occurrence of canopy gaps. There is a constant proportion of tree mortality in any age class over a time period, even though mortality is independent of tree age for trees $\geq$ 10 cm dbh. Annual mortality rate in tropical rain forest sites shows a narrow range of 1% - 2% (Swaine *et al.* 1987). In a successional stage, the mortality rate may be higher in the understory species followed by mid-canopy and canopy species (Lang & Knight, 1983).

Recruitment to pole size from seedlings and saplings occurs generally in gaps (Whitmore, 1978; Brokaw 1985). Canopy opening may also enhance the growth of light-demanding tree species. During a certain period of succession, mortality exceeds recruitment (Manokaran & Kochummen 1987; Lang & Knight 1983). This may be understood during a building phase (Whitmore 1984) when most short-lived pioneers could have died and been replaced by the growth of primary species. The equilibrium of the forest is achieved when the growth of some trees may cause the death of the others and the loss of trees is replaced by new recruits. In the steady state forest, mortality closely matches recruitment and there is an inverse relationship between mortality and growth rate (Swaine *et al.* 1987).

Regeneration after logging depends among other factors on the availability, pattern of growth, and survivorship of seedlings and saplings remaining on the forest floor or germinated from dispersed seeds and from seeds deposited in the soil seed bank.

Forest trees may be divided into: climax species (shade bearers) of which the seeds may germinate and establish in the shade, although they may respond with rapid growth when the forest canopy is opened, and pioneer species which germinate, establish and complete their life cycle in large gaps (Whitmore, 1984; Brokaw, 1985; Swaine & Whitmore, 1988). Regeneration after logging involves both species groups and to some extent simulates the regeneration in large natural gaps.

Growth of seedlings under the closed canopy of virgin forest is slow (Popma & Bongers, 1988; Turner, 1990) whereas in a logged-over forest seedling growth may be markedly higher. Nicholson (1958b) indicated that the large openings caused by heavy logging induced the growth of dipterocarp seedlings, with larger seedlings responding more than smaller ones, whereas about 40 % of seedlings in virgin forests were almost dormant. Growth of seedlings in the gaps increased with light intensity (Popma & Bongers, 1988; Whitmore, 1989; Turner, 1990). Light intensity in this case may correspond to the size of the gaps, the larger the gap the higher the intensity of light on the gap floor. Species composition in gaps, either from formerly suppressed seedlings and saplings or from germinating seeds, is determined by growth and mortality associated with gap-size variation, individual species density, and other factors such as shading from the earlier growing trees (inhibiting pioneer seedlings), root competition, and pattern of flowering and fruiting (frequently recruitment after mass fruiting is subject to rapid death, whereas species with infrequent fruiting generally have longer-lived seedlings) (Whitmore 1984; Whitmore 1987; Connell 1989). Survivorship varies between species (Liew & Wong 1973; Turner 1990), and larger seedlings show higher survivorship than smaller ones (Uhl *et al.* 1988; Turner 1990).

The soil seed bank in both primary and secondary forest is composed mainly of pioneers (Guevara & Gomez-Pompa 1972; Liew 1973; Hall & Swaine 1980; Hopkins & Graham 1983; Putz 1983; Whitmore 1983; Vazquez-Yanes & Orozco Segovia 1984) and plays a role in succession after disturbance. The seed bank responds quickly to gap formation and was shown to be much more important than seed rain in the first nine months after sucession at the Pasoh Forest Reserve, Malaysia (Putz & Appanah 1987). The seed bank in primary forests is less than in secondary forests because of the higher continuous input of seeds in the latter (Hopkins & Graham 1984). The species composition of a disturbed area in a forest may be predicted to some extent from the floristic composition of its seed bank (Liew 1973; Hopkins & Graham 1984).

Seeds or fruits of species with a gregarious occurrence in secondary forest are generally provided with an efficient mechanism of dispersal by wind or animals (particularly birds and bats). In the primary forest, seeds and fruits have but few special adaptations for wind dispersal (Richards 1966), and aerial movement is physically more obstructed (Ridley 1930, Sheldon & Burrows 1973, Willson & Crome 1989). Canopy or emergent tree species however, are exposed to wind (Richards 1966), which can act as a dispersal agent. The height of the release affects dispersal distance of winged seeds (Harper 1977, Lamont 1985, Sheldon & Burrows 1973). The Dipterocarpaceae usually have fruits which are dispersed by wind. The flowering of dipterocarps occurs at irregular intervals and at varying intensities (Ashton 1982). Gregarious flowering follows high average maximum temperatures and a sharp increase in irradiation or both (Wycherley 1973, Ng 1977), and many other families flower in a good dipterocarp year (Medway 1972, Ng 1977, Ashton 1982). Gregarious flowering following a sharp increase in daily sunshine occurred at Kepong, Malaysia, in March or April in certain years, and mast seeding occurred in August - September (Ng 1977). The section Mutica (Red Meranti group) have been observed to flower at different times but serially, reducing the chance of hybridisation and avoiding competition between pollinators (Whitmore 1984).

Kintap forest and the FINNIDA Tropical Forest Management Project

The logging concession at Kintap in South Kalimantan was available for a study of the forest regeneration characteristics.

Kintap forest is about 90 km south-east of Banjarmasin, the Provincial capital. It lies between 3°40' - 3°45' S and 115° - 115° 30' E, and has a rugged topography with the altitude up to 200 m above sea level. The Kintap forest has been logged since 1979 by the South Korean Hutan Kintap concessionaries, and has a total forest area of 125,000 ha. Within the concession a research project has been conducted since 1985 by the Reforestation and Tropical Forest Management Project (formerly the Mechanized Nursery and Plantation Project), a collaborative project between the Finnish International Development Agency (FINNIDA) and the Ministry of Forestry, Indonesia. Studies on the regeneration and plantation trials have been reported by

Hadengganan *et al* (1992), Adjers *et al* (1995a), Adjers *et al* (1995b), Kuusipalo *et al* (1996) and Tuomela *et al* (1996).

One of the FINNIDA projects had involved the setting up of four permanent 50 m x 100 m plots in 1985 with the following treatments: two unlogged and unmanaged plots, one intensively managed plot, and one lightly managed plot. The recording of these plots formed part of the work in this thesis.

It must be pointed out at this stage that during the course of the work it was found that the Kintap forest had been excessively and illegally exploited by the concessionaries. No unlogged forest was available for comparisons beyond the FINNIDA permanent plot which had been chosen by the concessionaries almost certainly because it was atypical with little commercial value. The logged forest studied was relatively lightly damaged compared with the rest of the concession because the concessionaries respected the presence of this project and my conclusions will unfortunately not apply to the bulk of the virtually destroyed concession.

The aims of this study

In view of the background information given in this general introduction and the likelihood that there will be many site-specific factors involved, a study was designed with the following aims:

(a) To provide a description of the physical environment in the Kintap area, including the soil

(b) To describe the tree composition in the 19 study sites in the five Blocks which have been subjected to different treatments.

(c) To assess the extent of the logging damage particularly in the newly-logged 50 m by 50 m plots.

(d) To monitor tree growth after logging.

(e) To monitor seedling and sapling growth after logging.

(f) To quantify the seed bank and seed rain in all the plots.

(g) To use the data obtained to address questions in tropical ecology and forestry.

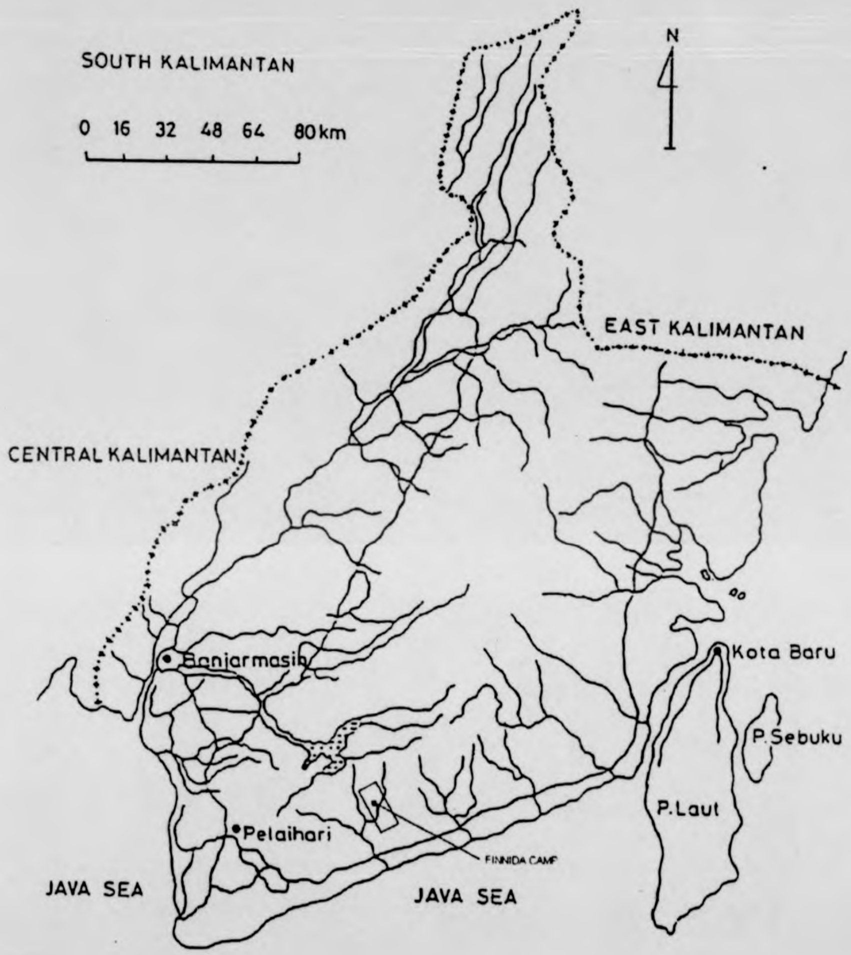


Figure 1.1 The Hutan Kintap concession. The study Block were located around The FINNIDA camp, with the nearest 2 km and the farthest 11 km.

CHAPTER 2. PHYSICAL ENVIRONMENT

CLIMATE

Precipitation

The rainfall station at the FINNIDA Camp ran from March 1991 until December 1993. Longer term stations are at Pelaihari , about 60 km to the west of the Kintap Camp and Jorong about 60 km to the south-west (Fig. 1.1). The FINNIDA Camp rainfall was higher than the rainfall recorded at Pelaihari and Jorong in the same years (Tables 2.1 and 2.2). The FINNIDA Camp recorded its highest monthly rainfall in June 1993 with 928.5 mm and 24 rain days and its lowest in September 1993 with 5.5 mm rainfall and 2 rain days. The driest months were August – October which may be regarded as dry season of the year at the FINNIDA Camp.

The average annual rain fall and rain days recorded at Pelaihari for 17 years from 1979 - 1995 was 2838 mm and 144 rain days, and at Jorong was 2696 mm and 124 rain days. The highest in Pelaihari was 3751 mm in 1981 and in Jorong 4645 mm in the same year (Table 2.2). The average monthly rainfall at Pelaihari ranged from 65 mm (August) to 447 mm (December), and at Jorong from 53 mm (August) to 394 mm (December). The highest monthly precipitation at Pelaihari during 1979 - 1995 occurred in November 1981 with 962 mm and at Jorong in April 1984 with 897 mm (Appendices 1 and 2). In some years at Pelaihari there were rainless months in August (1981, 1982, 1986, 1993), and September (1987, 1991), at Jorong in April (1986), June (1987), August (1979, 1987, 1991, 1993), September (1982, 1987, 1991, 1994), and October (1982, 1983, 1991) (Appendices 1 and 2). The wettest months were December and January (Table 1.3). August - September was always the driest period in Pelaihari and Jorong (Table 2.3 and Figure 2.2), however since the average rainfall in these months was always more than 60 mm, except in Jorong with an

Table 2.1 Precipitation (Pr) (mm) and number of rain days (Nrd) at the FINNIDA Camp Station, March 1991 - December 1993.

Month	Pr	Nrd	Month	Pr	Nrd
March 1991	81	3	January 1992	344.5	16
April	434.5	23	February	229	14
May	805.8	18	March	454	20
June	180.8	9	April	295	19
July	69.2	3	May	349	14
August	22	3	June	223.5	18
September	36.5	2	July	590	18
October	40	3	August	53.5	6
November	233	14	September	242.5	16
December	274	20	October	194	13
Total 1991 (March - December)	**2177**	**98**	November	-	-
			December	492	20
January 1993	374.5	16	**Total 1992** (excluding November)	3467	174
February	396	18			
March	553.5	21			
April	676.5	21			
May	495	18			
June	928.5	24			
July	269	11			
August	27	4			
September	5.5	2			
October	7.5	3			
November	93	16			
December	157	15			
Total 1993	**3983**	**169**			

average of 53 mm rainfall in August (Table 2.3), the climate cannot be considered to have a dry season (Bremen *et al.* 1990). The FINNIDA Camp however was wetter in 1991 – 1993, and more seasonal than Pelaihari and Jorong.

Table 2.2. Annual precipitation (Pr) and number of rain days (Nrd) at Pelaihari and Jorong stations, South Kalimantan, 1979 - 1995.

Year	Pelaihari		Jorong	
	Pr	Nrd	Pr	Nrd
1979	2633	125	2630	132
1980	2860	146	3297	138
1981	3751	113	4645	151
1982	2476	101	2529	94
1983	3519	140	3476	129
1984	3599	174	3171	152
1985	2949	119	2680	112
1986	1836	158	1898	98
1987	2648	130	2379	103
1988	3373	198	3494	114
1989	3617	176	2566	109
1990	1470	128	2089	123
1991	2196	133	2198	117
1992	3105	172	2164	145
1993	2245	151	2349	136
1994	2351	134	2124	111
1995	3626	155	2158	142
Average	2838	144	2696	124

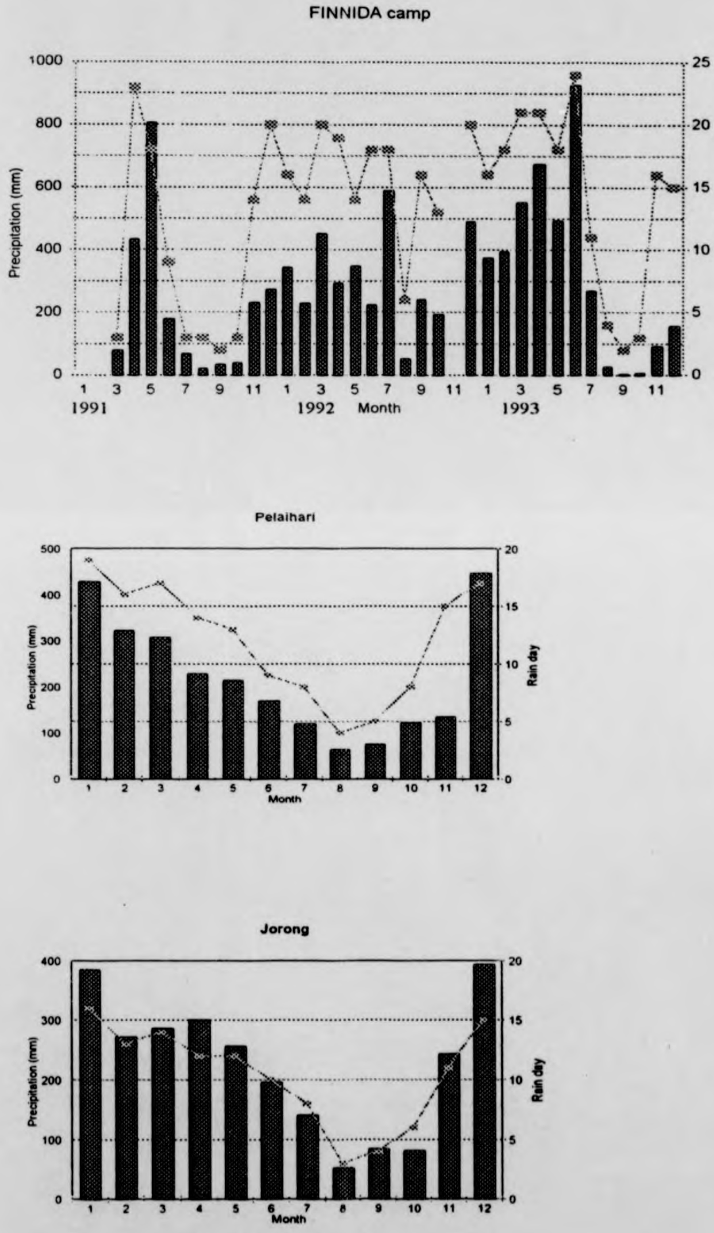


Figure 2.1 Mean monthly precipitation (mm) recorded at FINNIDA Camp (March 1991 - December 1993), Pelaihari and Jorong Stations (1979 - 1995), South Kalimantan.

Table 2.3. The average monthly precipitation (P) and number of rain days (Nrd) at Pelaihari and Jorong stations, South Kalimantan, 1979 - 1995

Month	Pelaihari		Jorong	
	P (mm)	NRD	P (mm)	NRD
January	428	19	386	16
February	323	16	272	13
March	307	17	286	14
April	229	14	301	12
May	215	13	257	12
June	171	9	197	10
July	120	8	141	8
August	65	4	53	3
September	76	5	84	4
October	122	8	82	6
November	336	15	243	11
December	447	17	394	15

Temperature

The temperature in Pelaihari was relatively constant throughout the year (Table 2.4, Fig.2.2). The daily average temperature ranged from 26.4° C (January) - 27.6° C (October), the average monthly maximum from 30.9° C (December, January) - 33.2° C (October), and the average highest maximum 33.6° C (January) - 34.9° C (October) (Table 1.4). The absolute maximum of 36.0° C occurred in October 1987 and in September and October 1991 (Appendix 3). The hottest months were always August, September and October.

Humidity

Humidity followed the pattern of rainfall (Fig. 2.3). The most humid months were December and January with average relative humidities of 86% and 87% respectively, and the driest months were August, September and October with 76% - 77% relative humidity (Table 2.4).

Table 2.4. Temperature and relative humidity recorded in Pelaihari, South Kalimantan, 1981 - 1995.

Month	Temperature (°C)			Humidity (%)
	Daily average	Average maximum	Average highest maximum	Average
January	26.4	30.9	33.6	87
February	26.5	31.5	33.8	85
March	26.6	31.6	34.1	86
April	26.8	32.2	34.5	86
May	26.9	31.8	34.0	85
June	26.7	31.6	33.6	83
July	26.6	31.3	33.5	82
August	27.2	32.0	34.0	76
September	27.4	32.6	34.4	76
October	27.6	33.2	34.9	77
November	26.9	32.1	34.6	83
December	26.5	30.9	33.8	86

Table 2.5. The average daily sunshine hours expressed as a percentage of the eight hours (0800 - 1600) recorded daily in Pelaihari, South Kalimantan, 1981 - 1995.

Month	Sunshine hours	%
January	2.8	35.2
February	3.4	42.6
March	3.2	40.1
April	3.7	46.3
May	4.0	49.9
June	4.0	50.6
July	4.8	60.3
August	6.2	76.9
September	5.4	66.9
October	5.0	62.4
November	3.4	42.7
December	2.9	36.7

The highest average humidity was 91% in January 1981 and 1984, and the lowest average was 68% in September (1993, 1994) and October 1994 (Appendix 5).

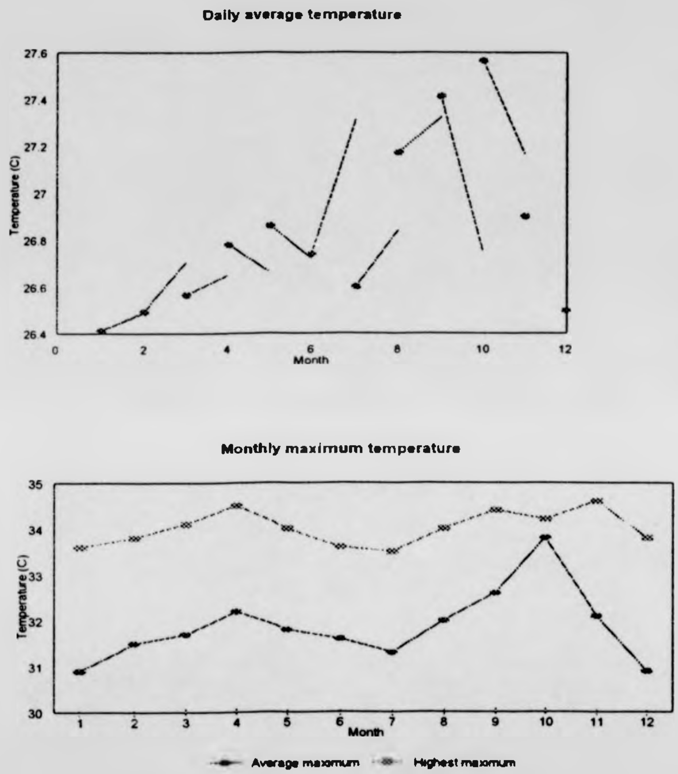


Figure 2.2 Average daily temperature and monthly maximum temperature recorded at Pelaihari, South Kalimantan, 1981 - 1995.

Solar radiation

Solar radiation for Pelaihari was measured using a Campbell-Stokes solarimeter with its paper was exposed to sunlight from 0800 - 1600 every day.

The brightest months were August and September, and the cloudiest months were December and January. The highest radiation occurred in August with 76.9% of the eight hours daily exposure and the least in January with 35.2% (Table 1.5).

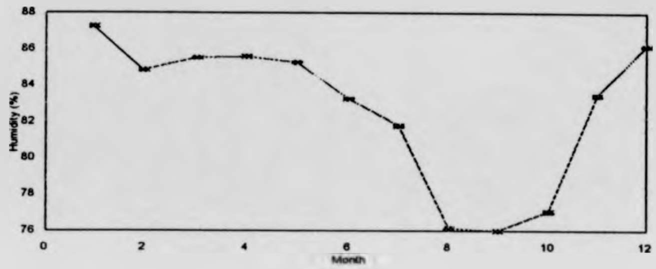


Figure 2.3 Monthly average humidity recorded at Pelaihari, South Kalimantan, 1981 - 1995

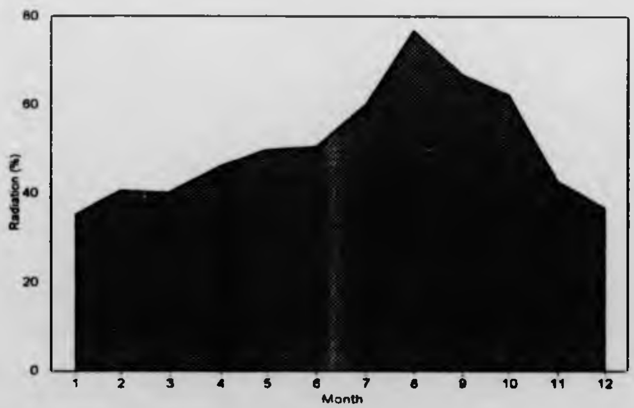


Figure 2.4 **The average daily sunshine (as a percentage of the hours exposed) recorded at Pelaihari, South Kalimantan, 1981 - 1995**

GEOLOGY

Kintap is included on the 1: 250,000 geological map of the Banjarmasin quadrangle I (3°00 - 4°15' and 114°00' - 115°30' E.) produced by the Agency for Geological Research and Development (1986) and is discussed by Sikumbang & Heryanto (1986). The geology of the study sites is included in the Tanjung Formation, and consists of Tertiary sedimentary rocks of quartz sandstones, siltstones, claystones and coal, and locally intercalated limestone. Quartz sandstone has a yellowish-white colour, and contains feldspar and mica flakes with silica cement. Claystone has a grey colour, shaly in some places, and occurs as an intercalation in the upper part of the Formation. Coal, black, lustrous and massive, is intercalated in the lower part. Conglomerate appears as the base, dominated by milky quartz and other rocks

SOIL

Soil survey

A soil survey was made in cooperation with Mr. Dian Lazuardi, a soil scientist from the Reforestation Technology Institute Banjarbaru; South Kalimantan. According to Peta Tematik (1986) the soil in the area of the study plots in the Kintap forest is of the red-yellow podzolic/lateritic type, which together with latosols and reddish brown lateritic soils is in the order Ultisol in the Soil Taxonomy System (Sanchez 1976). The Ultisols are dominant in South East Asia (Dent 1980). A great group of the Ultisols, Typic Paleudults are the major soils of the lowland dipterocarp forests in East Kalimantan (Ohta *et al.* 1992). Soil sub-types (Young 1976) which are found at Kintap include pedalfers, hydromorphic soils and lithosols. Pedalfers are leached soils with free or only slightly impeded drainage, hydromorphic soils have poor drainage and are dominated by mottling with dark grey colours; and lithosols are shallow or stony soils.

The present soil survey was aimed at identifying the soil heterogeneity in every plot. The results of the study are shown in table 1.6. Five soil groups were recognized:

Group I : Soil which lacked concretions, granules, mottles and nodules. The clay content was high and relatively homogenous throughout the profile. Soil layers were diffuse and the solum deep (>125 cm). This group had two units IA and IB based on the colour. The former group was reddish brown and occurred in plots 1, 2, 3, 4, 5 and 19; and the latter was dusky red and occurred in plot 19.

Group II : Soil profile with concretions, nodules and gravels which occurred > 30 cm depth. The group can be divided into two units : Group IIA, was not gleyed and mottled, and contained iron nodules and gravel. The soil was reddish brown to red. This unit occurred in plots 7, 8, 13, 14, 16, 17 and 18. Group IIB, was mottled and gleyed at 50 - 120 cm depth. It also contained nodules and gravel. The colour was red yellow or reddish brown. In the study plots it occurred in plot 6 on the higher slopes down to the lower slopes with a high water table.

Group III : Lithosols which occurred on rocky areas with a mean soil depth of about 10 cm, in plots 13 and 15.

Group IV : Soil with a high water table (up to 40 cm below the surface), gleyed, and included in the gleysol type. The soil occurred mostly scattered on lower sites in plots 6, 9 and 10.

Group V : Alluvial, showing an alteration of the unconsolidated accumulating materials, and occurring at the foot of the steep slopes and riversides. The soil was found in plots 11 and 12.

Table 2. 6. Soils on the nineteen 50 m x 50 m plots at Kintap.

Plot No.	Group	Soil type
1	I A	Ultisols
2	I A	Ultisols
3	I A	Ultisols
4	I A	Ultisols
5	I A	Ultisols
6	IIB. IV	Ultisols, Gleysols
7	IIA	Ultisols
8	I A. IIA	Ultisols
9	I A. IV	Ultisols, Gleysols
10	IV	Gleysols
11	I A. V	Ultisols, Alluvials
12	I A. V	Ultisols, Alluvial
13	IIA. III	Ultisols, Lithosol
14	I A. IIA	Ultisols
15	III	Lithosols
16	IIA	Ultisols
17	IIA	Ultisols
18	IIA	Ultisols
19	I A. IB	Ultisols

Soil chemistry and texture

Two surface (0 - 10 cm deep) samples were collected by a trowel from the centre of each subplot included in each soil group. The samples were analyzed by the staff in the Soil Laboratory of the Horticultural Research Institute, Banjarbaru, South Kalimantan, and the methods of analysis are given in Appendix 1.

Soil analytical data are given in Table 2.7 (individual values for the replicates are included in Appendix 8) and Figs 2.5 - 2.8. Most plots had high clay with the highest concentration

(80%) occurring in plot 19 in soils of group IA. Forest blocks A (plots 1 - 5) and F (plots 18 and 19) had generally higher clay than Block B. In Block C a high clay content occurred in plots 14 and 15. Relatively sandy soil occurred in plot 11 B (soil group V) where the samples had about 60% sand (Table 2.7). The soil pH ranged from 4.8 to 6.1. Block C had a higher pH than Blocks A,D,E, and F. The highest pH was in the soils with a high CEC, and high exchangeable Ca, Mg and K, found in plots 13 and 15 (Figs. 2.5, 2.6 and 2.7). Calcium was high in plots 13 and 15 which also had a relatively high percentage of organic carbon (Figs 2.6 and 2.7). The CEC generally followed the organic C content (Fig. 2.6). Available phosphorus was low, ranging from 0.1 to 6.0 $\mu g\ g^{-1}$, with the highest occurring in plot 6 of the podzolic type of group IIB and the lowest in plot 17. The highest total phosphorus was in plot 15 with 503 $\mu g\ g^{-1}$, this plot also had the highest CEC of 38.8 m-equivs/100 g (Figs 2.6 and 2.8). The CEC curve followed the pattern of pH and organic C curves (Figs 2.5, 2.6 and 2.7). The exchangeable cations were lower in Blocks A, D (plot 16) and E (plot 17) (Fig. 2.7). Among the blocks, Block C had the highest element concentrations, particularly in plots 13 and 15.

Table 2.7. Mean values (n=2) for soil texture and chemical properties in the Kintap study plots, South Kalimantan.

Plot no	Soil group	Texture			pH (H_2O)	C (%)	CEC (m-equivs/100g)	Exchangeable cations (m-equivs/100 g)				Available-P ($\mu g\ g^{-1}$)	Total- P ($\mu g\ g^{-1}$)
		Sand (%)	Silt (%)	Clay (%)				Ca	Mg	K	Na		
1	I A	9.5	17.3	73.2	4.9	3.9	19.10	0.52	0.34	0.19	0.23	2.5	292
2	I A	13.4	17.9	68.6	4.9	3.4	19.64	0.37	0.21	0.18	0.20	4.6	309
3	I A	22.8	21.0	56.2	4.9	3.6	13.77	0.37	0.21	0.15	0.17	1.8	266
4	I A	17.8	18.5	63.7	5.0	3.0	27.09	0.39	0.25	0.17	0.19	2.6	186
5	I A	22.6	19.8	57.6	5.0	3.2	15.01	0.23	0.12	0.14	0.15	1.9	293
6A	II B	40.9	17.9	41.2	5.1	2.9	12.89	1.52	1.11	0.28	0.32	5.9	206
B	IV	40.2	27.6	32.3	4.9	3.1	17.08	1.07	0.97	0.24	0.33	2.2	139
7	II A	29.9	38.4	35.8	5.0	3.6	15.84	2.48	0.57	0.38	0.48	2.9	77
8A	I A	15.5	24.8	59.7	4.9	3.9	16.79	1.03	0.70	0.34	0.42	2.2	244
B	II A	13.5	28.4	38.2	4.8	4.0	14.32	0.44	0.23	0.28	0.31	2.1	209
9A	I A	27.2	32.7	40.1	4.8	3.7	19.1	1.35	0.69	0.37	0.41	1.9	169
B	IV	48.4	27.2	24.5	4.9	3.3	14.45	2.13	0.58	0.20	0.25	2.1	92
10	IV	32.2	35.6	32.2	5.1	3.4	17.89	1.29	0.60	0.25	0.26	2.2	176
11A	I A	23.8	31.4	44.8	5.2	4.6	20.2	4.01	1.96	0.48	0.47	2.8	186
B	V	59.8	23.6	16.7	5.2	2.3	16.48	5.82	1.67	0.28	0.24	1.8	264
12A	I A	31.2	25.6	43.2	5.1	4.6	18.83	1.71	0.93	0.33	0.32	3.9	238
B	V	35.1	30.1	34.9	5.5	4.1	21.14	4.66	2.29	0.40	0.40	2.5	294
13A	II A	40	27.1	37.0	6.1	6.5	28.08	14.91	5.36	0.55	0.38	3.4	308
B	III	13.8	27.8	58.4	5.2	4.9	23.47	6.04	1.96	0.48	0.47	3.4	220
14A	I A	14.8	27.2	58.1	5.1	4.1	21.41	2.75	1.22	0.36	0.41	3.3	208
B	II A	25.8	28.5	45.8	5.4	3.7	18.21	4.16	1.94	0.38	0.34	2.6	236
15	III	18.4	21.5	60.2	6.0	7.1	38.28	12.46	4.52	0.55	0.38	2.1	503
16	II A	24.2	38.4	37.4	4.8	2.6	14.48	0.41	0.25	0.22	0.27	1.9	097
17	II A	14.7	29.2	56.0	4.9	3.6	17.22	0.44	0.40	0.28	0.27	0.1	201
18	II A	15.6	15.3	69.9	5.0	4.6	22.45	0.84	0.67	0.42	0.40	2.3	301
19A	I A	6.5	12.7	80.8	5.1	5.5	22.2	1.32	0.98	0.36	0.42	0.9	185
B	I B	13.9	27.3	58.9	4.9	4.5	23.21	1.54	0.68	0.37	0.33	2.5	246

The soil chemical properties in some locations in Kalimantan are shown in Table 1.8. The pH, organic C and CEC in Kintap were higher than in the other locations, however the available phosphorus was lower. The total phosphorus was the same as in the ITCI concession and Barito Ulu. The highest total phosphorus in Kintap occurred in plot 15, the rocky plot with the lithosol (Tables 2.6 and 2.7).

Table 2.8 Soil chemical properties in some locations in Kalimantan

Location (Reference)	pH (H_2O/KCl)	Organic C (%)	CEC(m-equivs 100 g^{-1})	Sum of exchangeable cations (m-equivs/100g)	Available-P ($\mu g\ g^{-1}$)	Total-P ($\mu g\ g^{-1}$)
The ITCI concession, East Kalimantan* (Bremen *et al.* 1990)	3.5 - 5.5 (H_2O)	1.43 - 6.14	7.52 - 18.89	0.56 - 10.15	1.5 - 36.4	50 - 340
Bukit Soeharto, East Kalimantan* (Ohta *et al.* 1992)	3.8 - 5.0 (H_2O)	1.43 - 4.5	5.99 - 19.99	0.70 - 1.66	50.9 - 80.2	3270 - 8890
Barito Ulu, Central Kalimantan** (Prajadinata 1996)						
50 years re-growth forest	3.0 - 3.2 (KCl)	-	8.27 - 10.71	0.54 - 0.74	-	30 - 40
Primary forest	3.1 - 3.3 (KCl)	-	9.42 - 9.96	0.46 - 0.52	-	
This study, Kintap, South Kalimantan**	4.8 - 6.1	2.3 -7.1	12.89 - 38.28	0.49 - 20.82	0.11 - 5.99	92 -503

Remarks: * A horizon surface samples (0 - 2) - (0 - 10) cm
** 0 - 10 cm surface samples

Total-P at Bukit Soeharto was higher than the other locations (Table 2.8). Ohta *et al.* (1992) found that soil total-P was correlated with the total-C at Bukit Soeharto. At Kintap total-P was also generally correlated with total-C with the highest values of both being in plot 15 (Figs. 2.6 and 2.8). The range in the sum of exchangeable bases at Kintap was wider than elsewhere and the highest exchangeable cation concentration at Kintap occurred in plots 13 and 15.

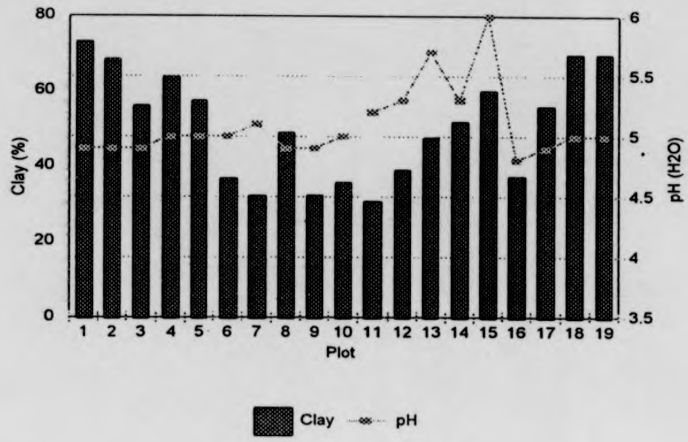


Figure 2.5 Clay and pH in the study plots. Kintap

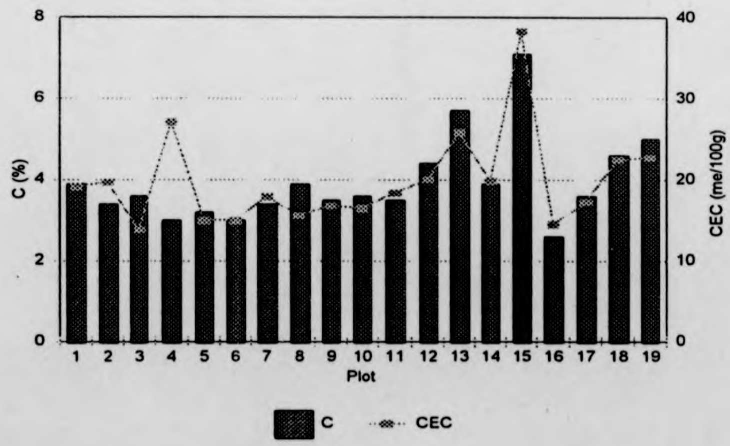


Figure 2.6 The cation exchange capacity (CEC) and the organic-C in the study plots. Kintap

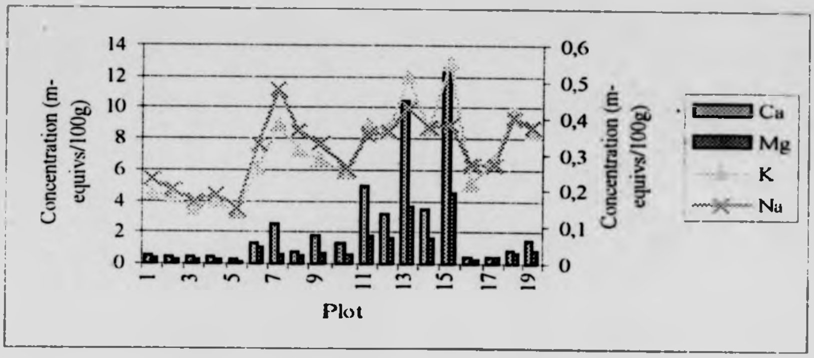


Figure 2.7 Exchangeable bases in the study plots, Kintap

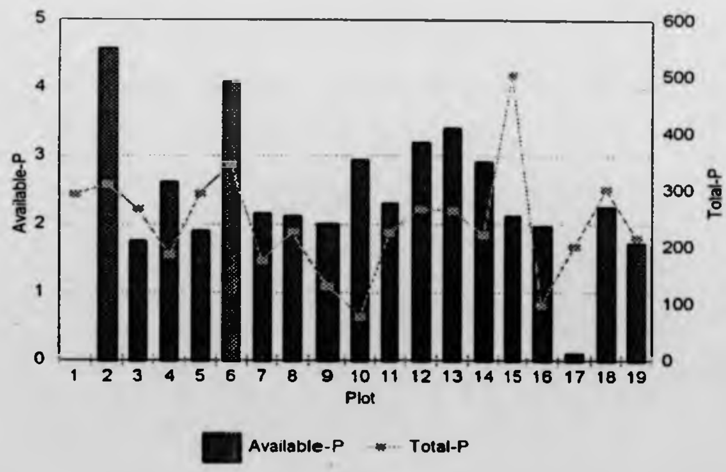


Figure 2.8 The available phosphorus ($\mu g\ g^{-1}$) and total phosphorus ($\mu g\ g^{-1}$) in the study plots, Kintap

CHAPTER 3 SELECTION, HISTORY AND FLORISTIC COMPOSITION OF THE STUDY SITES

INTRODUCTION

The main study plots

Areas of 500 m x 500 m were chosen in each of three Blocks A, B and C, which were selected from the Hutan Kintap concession (Figures 1.1 and 3.1). Block A was logged about 2 weeks before the plots were set up, Block B was logged in 1979 and had received no subsequent treatment, and Block C was logged in 1979 but had received silvicultural treatment (Table 3.1). The Blocks were notionally gridded into 100 50 m x 50 m plots Five of these plots were randomly selected within each Block, carefully positioned using a compass and measuring tapes, and marked with string. They were numbered as follows plots 1 - 5 were in Block A, 6 - 10 in Block B and 11 - 15 in Block C.

The subsidiary plots

Four Blocks of 50 m x 100 m each had been set up by FINNIDA in another area as a permanent study site in October 1985. The Blocks were part of the Timber Stand Improvement (TSI) programme. They were unreplicated and had the following treatments: (1) lightly thinned forest after logging in 1979 (Block D), (2) heavily thinned forest after logging in 1979 (Block E), and (3) primary forest control (Block F). Within each of these plots a new single 50 m x 50 m plot was located randomly along the longer axis of the original plot and marked out with string. The new 50 m x 50 m plots were numbered as follows: plot 16 (in Block D); plot 17 (in Block E); plots 18 and 19 (both in Block F). Brief details of the experimental treatments are given in Table 3.1.

PLOT DESCRIPTION

Plot establishment

All the plots (1-19) were gridded with string into twenty-five 10 m x10 m subplots. All trees (≥10 cm dbh) were enumerated, tagged with an aluminum nail and number label at 1.4 m, and their dbh usually measured at 1.3 m. Trees with large buttresses had their diameter measured at 30 cm above the junction of the buttress with the tree. Trees with two or more stems (which had branched below 1.3 m) greater than 10 cm dbh had the diameter of each measured separately but they only received one number label.

In each of the twenty-five subplots a quadrat of 1 m x 1 m was randomly located and within it, all seedlings (< 2m tall) were measured for height, given a permanent label, and identified. Five 5 m x 5 m quadrats were set up within each of the plots using a stratified random design and within these, all saplings (> 2 m high, <10 cm dbh) were measured for height and diameter (dbh), given a permanent label, and identified. All the 19 plots including subplots and quadrats were set up between 27 August and 25 September 1991.

Table 3.1 Forest Blocks and plot treatment in the Kintap study area.

Plot No	Forest block	Date	Treatment
1-5	A	August 1991	Set up in forest which had been heavily logged 15 days before. Plot 2 had previously been lightly logged in 1987 and had a few cut stumps of large trees.
6-10	B	September 1991	Heavily logged in1979 and subsequently (by local people) for ironwood (*Eusideroxylon zwageri*) before plot establishment.
11-15	C	September 1991	Less heavily logged for dipterocarps than forest Block B in 1979 but also had ironwood removal. In January 1991 all lianas were cut and individuals of *Macaranga* were killed by girdling in a trial by the Reforestation Technology Institute in cooperation with the FINNIDA. In March 1991 trees (<2cm diameter) and seedlings were cut by the concessionary.
16	D	September 1991	Logged for dipterocarps as forest Block C. No ironwood removal. In 1985 some large *Macaranga* were killed by girdling and all lianas cut.
17	E	September 1991	Logged for dipterocarps as forest Block C. No ironwood removal. In 1985 it received the same treatment as forest Block D. Since then all lianas have been cut and large *Macaranga* have been girdled at least twice a year.
18-19	F	September 1991	Not logged for dipterocarps but had recent ironwood removal.

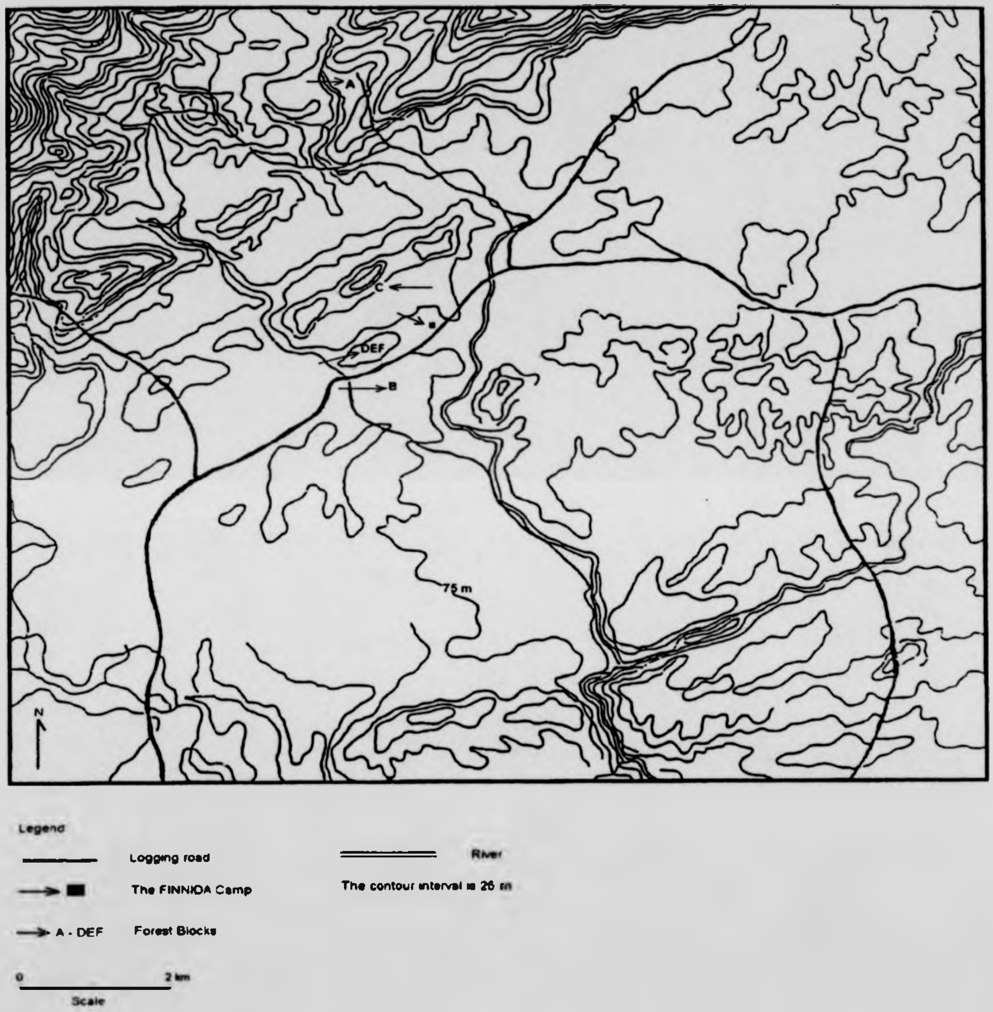


Figure 2.2 Topographic map of the study area.

Topography

The plots varied from flat to very steep sloping, with the altitude ranging from 20 m to about 200 m above sea level. Descriptions of each plot are given in Table 3.2.

Table 3.2. Topography of the 50 m x 50 m study plots at Kintap.

Plot No	Altitude (m)	Slope
1	125	Slightly sloping (< 10^0)
2	130	Slightly sloping
3	190	Partly flat and partly slightly sloping
4	145	Steep slope(>30°)
5	155	Mostly steep slopes and some slightly sloping
6	70	Mostly flat and some parts slightly sloping
7	90	Slightly sloping to steep slopes in the middle
8	20	Slightly sloping
9	25	Slightly sloping
10	20	Slightly sloping
11	35	Partly flat and partly slightly sloping up to 30°
12	25	Mostly flat with a creek running inside the plot, small part slightly sloping
13	45	Mostly steep with small flat area in the middle
14	40	Mostly flat with a creek running inside the plot
15	40	Steeply sloping some parts up to 60°
16	90	Slightly to steeply sloping
17	80	Mostly slightly sloping and with a small part steep sloping
18	80	Partly slightly sloping and partly steep
19	70	Mostly flat with a small part slightly sloping

Floristic composition

There were at least 305 tree species ($\geq$ 10 cm dbh) from 49 families in all 19 plots (4.75 ha). The total number of individuals was 2371, and 95 species were represented by one individual tree each. The highest number of individuals was for a dipterocarp *Shorea johorensis* with 132 trees (Table 3.3). The Dipterocarpaceae was represented by 21 species of 481 trees (Tables 3.3, 3.4 and 3.5). In all forest Blocks except Block A pioneer species occurred. The pioneers were represented by 17 species with a total of 172 trees. The most abundant pioneer species were *Macaranga hypoleuca* and *M. triloba* (Euphorbiaceae) (Table 3.3). The contribution of the 15 commonest families to the number of species, density and basal area in each Block is shown in Table 3.4. The Dipterocarpaceae had the highest basal area in every Block with a total of 31.9 m^2 (30.1% of the total) in all plots (Tables 3.4 and 3.5). The second highest contribution differed among Blocks. In Block A the second highest was the Anacardiaceae, in Blocks B, E and F the Flacourtiaceae and Blocks C and D the Euphorbiaceae.

The most frequent dipterocarps (present in all blocks) were *Hopea sangal*, *Shorea johorensis* and *S. parvistipulata* (Table 3.5). (*Shorea parvistipulata* was formerly identified as *Shorea fallax* in the study area. Both species are hardly distinguishable from non-fertile herbarium specimens, however since *S. fallax* has not been recognized in South Kalimantan (Ashton 1982), the species was identified as *S. parvistipulata*).

The numbers of species, density and basal area varied among plots and forest blocks. In forest Block A the number of species ranged from 47 to 56, and basal area from 4.8 m^2 to 8.4 m^2 per plot. The total basal area in the plots in this forest block was higher than in the others, but the number of species (131) was less than forest blocks B (163) and C (167) in 1.25 ha (Table 3.6).

Table 3.3 The tree species and their numbers of individuals in each Block, Kintap, South Kalimantan, 1991

Family	Species	Block						
		A	B	C	D	E	F	Total
Actinidiaceae	*Saurauia nudiflora DC.*			1				1
	Saurauia sp		1	1				2
Alangiaceae	*Alangium javanicum (Bl.) Wang*	1	2	2				5
	Alangium sp						1	1
Anacardiaceae	*Buchanania arborescens(Bl.) Bl*	1						1
	Buchanania sessilifolia Bl.	2	1				1	4
	Dracontomelon dao (Blanco) Merr. & Rolfe		1	5				6
	Gluta renghas L.	3	1					4
	Gluta wallichii (Hook. f.) Ding Hou	27	3		2	1		33
	Mangifera sp			1	1			2
	Melanochyla elmeri Merr.	1	1	1	1	2		6
	Melanochyla pulvinervis (Bl.) Ding Hou	14					1	15
	Melanochyla sp	2				1		3
	Parishia paucijuga Engl.	2						2
	Swintonia sp	2						2
Annonaceae	*Cananga odorata (Lamk.) Hk. F. & Thoms*			3				3
	Canarium littorale (Lamk.) Hk. f. & Thoms.		1		1			2
	Meiogyne montana			4				4
	Mitrephora sp		3	3				6
	Orophea sp	1	2	3				6
	Polyalthia celebica Miq.	6	2		1			9
	Polyalthia glauca Boerl.		2					2
	Polyalthia lateriflora King	1	6	1			1	9
	Polyalthia sp	1	2	12				15
	Polyalthia sumatrana King	7	2	1			1	11
	Saccopetalum horsfieldii Benn.			1				1
	Saccopetalum koalsii Kosterm.			1				1
	Sageraea lanceolata Miq	1		1				2
	Xylopia malayana Hk. f. et Th.	2	1	2				5
	Xylopia sp	1		1			1	3
Apocynaceae	*Alstonia angustiloba Miq.*						1	1
	Ervatamia macrocarpa Hassk.		1					1
	Kibatalia arborea G. Don						1	1
Bombacaceae	*Durio acutifolius (Mast.) Kosterm.*	3	19	2	2	1	4	31
Bombacaceae	*Durio dulcis Becc.*		2					2
	Durio excelsus Griff.				4	1	1	6
	Durio griffithii (Mast.) Bakh.	2	1					3
	Durio oxleyanus Griff.	1			1			2
Burseraceae	*Dacryodes costata (Benn.) Lam*	6	1					7
	Dacryodes macrocarpa (King) Lam		1					1
	Dacryodes rostrata (Bl.) Lam	19	10	4	7	1	6	47
	Dacryodes rugosa (Bl.) Lam	9	3	1			4	17
	Santiria griffithii (Hook. f.) Engl.		2					2
	Santiria laevigata Bl.			1				1
	Santiria tomentosa Bl.	1	1					2
	Trioma malaccense Hook. f.	1	2		2			5
Celastraceae	*Bhesa paniculata Arn.*			2				2
	Kookoona reflexa (Laws.) Ding Hou		2					2
	Lophopetalum javanicum (Zoll.) Turcz	5	1	2		1	1	10
	Lophopetalum multinervium Ridl.		2	1				3

	Lophopetalum sp	1	4	2		1		8
Cornaceae	*Mastixia cuspidata Bl.*	2						2
	Mastixia rostrata Bl.		1					1
	Mastixia trichotoma Bl.	8	1	5		2	1	17
Datiscaceae	*Octomeles sumatrana Miq.**			1				1
Dilleniaceae	*Dillenia borneensis Hoogl.*		1					1
	Dillenia excelsa (Jack) Gilg	4	4	4		1	1	14
	Dillenia grandiflora Wall. ex Hk. f.	2						2
Dipterocarpaceae	*Dipterocarpus caudiferus Merr.*			8				8
	Dipterocarpus gracilis Bl.	2	1					3
	Dipterocarpus hasseltii Bl.	4		3				7
	Dipterocarpus humeratus Sloot.	2						2
	Hopea dryobalanoides Miq.	5		1				6
	Hopea ferruginea Parijs			2				2
	Hopea sangal Korth	4	2	1		2		9
	Hopea tenuinervula Ashton	1						1
	Shorea faguetiana Heim				9	8	1	18
	Shorea hopeifolia (Heim) Sym.	56	2				1	59
	Shorea johorensis Fox.	29	33	15	7	43	5	132
	Shorea laevis Ridl.	11						11
	Shorea leprosula Miq.	1		4	5			10
	Shorea multiflora (Burck) Sym.	1						1
	Shorea ovalis (Korth.) Bl.	1		6	18	12	1	38
	Shorea parvifolia Dyer	12	7		16	17	2	54
	Shorea parvistipulata Heim	6	23	20	4	11	8	72
	Shorea polyandra Ashton	1	1	6				8
	Vatica rassak (Koerth.) Bl.	33			1		1	35
	Vatica umbonata (Hk. f.) Burck	2						2
	Vatica odorata (Griff.) Sym.	2						2
Ebenaceae	*Diospyros beccarii Heirn.*			1				1
	Diospyros borneensis Hiern.			1				1
	Diospyros buxifolia (Bl.) Hiern.	1		1				2
	Diospyros curraniopsis Bakh	3	10	9		1	5	28
	Diospyros densa Bakh.		1	3				4
	Diospyros macrophylla Bl.		3	4				7
	Diospyros andamica (Kurz.) Bakh.		1	4				5
	Diospyros paraoensis Bakh.			2			1	3
	Diospyros ulo Merr.		2					2
Elaeocarpaceae	*Elaeocarpus pierrei K. et V.*		1					1
Elaeocarpaceae	*Elaeocarpus sp*	1						1
	Elaeocarpus stipularis Bl.	2		2				4
Erythroxylaceae	*Erythroxylum cuneatum (Miq.) Kurz.*			1				1
Euphorbiaceae	*Antidesma ghaesembila Gaertn.*		2					2
	Aporusa lunata (Miq.) Kurz.	1						1
	Aporusa sp	3	11	6	3		7	30
	Baccaurea deflexa Muell. Arg.	4	1				1	6
	Baccaurea racemosa (Reinw.) Muell. Arg		1					1
	Baccaurea sp	1	12	8		1		22
	Blumeodendron kurzii (Hk. f.) J. J. Sm.			2				2
	Blumeodendron sp		1					1
	Bridelia glauca Bl.		1	1				2
	Claoxylon polot Merr.		1				1	2
	Chaetocarpus castanocarpus (Roxb.) Thw.			1				1
	Cleistanthus myrianthus (Hassk.) Kurz.	1	1				1	3
	*Croton argyratus Bl.**		1	2				3
	Croton sp			1				1
	Drypetes sp			1			1	2
	*Endospermum diadenum (Miq.) Airy Shaw**			2				2
	Euphorbiaceae sp1	1						1

	Euphorbiaceae sp4		1					1
	Euphorbiaceae sp5		1					1
	Euphorbiaceae sp9			1				1
	*Glochidion arborescens Bl.**		1					1
	Glochidion sp		3	4				7
	*Homalanthus populneus Pax.**		1					1
	*Macaranga conifera (Zoll.) Mell. Arg.**			2				2
	*Macaranga diepenhorstii Muell. Arg.**		1					1
	*Macaranga gigantea (Reich. f. & Zoll.) Muell. Arg.**		9	15	3			27
	*Macaranga hosei King ex Hk. f.**		4	9	8			21
	*Macaranga hypoleuca (Reich. f. & Zoll.) Muell. Arg.**		11	14	37			62
	*Macaranga sp**		9	3	3		4	19
	*Macaranga triloba (Bl.) Muell. Arg.**		24	24			2	50
	Mallotus blumeanus Muell. Arg.		1					1
	Mallotus echinatus Elm.	52	27		1		14	94
	*Mallotus paniculatus (Lam.) Muell. Arg.**		1					1
	Mallotus penangensis Muell. Arg.		10	2				12
	Mallotus sp	5	7	16		1		29
	Mallotus subpeltatus Muell. Arg.			16				16
	Neoscortechinia kingii (Hk. f.) Pax & Hoffm.	5		1				6
	Neotrewia cumingii Pax et Hoffm.		1					1
	Ostodes pendula A. Meeuwse	3			1			4
	Pimeleodendron amboinicum Hassk.						1	1
	Pipturus incanus Wedd.			2				2
	Podadenia sp	2	3		1			6
	Ptychopyxis costata Miq.		1					1
	Ptychopyxis sp			4				4
Fagaceae	*Lithocarpus blumeanus (Korth.) Rehd.*					1		1
	Lithocarpus leptogyne (Korth.) Soepadmo				1			1
	Quercus reflexa King	9	1	1	1			12
	Quercus sp	1	4	3	1		2	11
Flacourtiaceae	*Homalium foetidum (Roxb.) Benth.*			1				1
	Eleutherandra pescervi V. Sl.	1	1				1	3
	Hydnocarpus polypetalus (Sloot.) Sleum.	12	14	3		2	7	38
	Hydnocarpus sp	2		1	2	3	21	29
	Hydnocarpus sumatranus (Miq.) Koord.	18	4	13			2	37
	Hydnocarpus woodii Merr.	9	3	1	1		1	15
	Ryparosa kostermansii Sleum.	5	14	3	4	4	7	37
Guttiferae	*Calophyllum soulatri Burm.*	1						1
	Garcinia dioica Bl.		3	1				4
	Garcinia sp	1					1	2
	Kayea sp						2	2
Icacinaceae	*Stemonurus secundiflora Bl.*		1					1
	Urandra sp	4		1	1			6
Indet	*Unidentified 1*		1					1
	Unidentified 2			1				1
	Unidentified 3				2			2
	Unidentified 4			1				1
Lauraceae	*Alseodaphne ceratoxylon Kosterm.*	4	8	7	1	1	4	25
Lauraceae	*Alseodaphne insignis Gamble*						2	2
	Alseodaphne sp			3				3
	Alseodaphne umbelliflora Hk. f.	1	1	1				3
	Beilschmiedia sp			2			2	4
	Beilschmiedia wrightii Benth.			1				1
	Cryptocarya crassinervia Miq.	2		5				7
	Dehaasia caesia Bl.	7	4	5				16
	Endiandra rubescens Miq.	2		1				3
	Endiandra sp		3					3
	Eusideroxylon zwageri Teijsm. & Binn.		26	22		3	5	56

	Litsea pulva Villae			2				2
	Litsea roxburghii Hassk.			1				1
	Litsea sp	2	15	6			2	25
	Phoebe opaca Bl.	1						1
Lecythidaceae	*Barringtonia sp*	2	11	3	2	3	2	23
	Bertholletia excelsa H. et B.			1				1
	Planchonia valida (Bl.) Bl.			1				1
Leguminosae	*Abarema tjendana Kosterm.*		4					4
	Albizzia sp				1			1
	Crudia acuta de Wit	1	1	4				6
	Dialium procerum (Steen.) Stey		2	3				5
	Dialium sp		4					4
	Intsia sp	1						1
	Ormosia macrodisca Baker			1				1
	Ortholobium bubalinum Jack		2	1				4
	Parkia speciosa Hassk.		1	1				2
	Sindora bruggemanii de Wit			1				1
	Sindora leiocarpoa Backer ex de Wit						1	1
Linaceae	*Ctenolophon parvifolius Oliv.*			1				1
Loganiaceae	*Fagraea crenulata Maingay ex Clarke*	4						4
Melastomataceae	*Kibessia azurea DC.*		1					1
Melastomataceae	*Memecylon costatum Miq.*			1				1
	Memecylon glomeratum Bl.			1				1
	Memecylon laevigatum Bl.	6	1	1	1		2	11
	Memecylon sp	4	2					6
	Memecylon sumatrense Bakh.				2		1	3
	Pternandra coerulescens Jack	2	2	1			6	11
Meliaceae	*Aglaia argentea Bl.*			1				1
	Aglaia dookoo Griff.			1				1
	Aglaia eusideroxylon Koord. & Val.	1						1
	Aglaia ganggo Miq.		3	11				14
	Aglaia sp			4		4		8
	Aglaia tomentosa Teijs. & Binn.				1		1	2
	Aphanamixis sp			1				1
	Chisocheton divergens Bl.	2	1					3
	Dysoxylum acutangulum Miq			1				1
	Dysoxylum sp		2	1			1	4
	Melia sp	2	8	11			6	27
	Sandoricum borneense Miq.		4					4
Monimiaceae	*Kibara coriacea (Bl.) Tulasne*			1				1
Moraceae	*Artocarpus anisophyllus Miq.*		8	3	1		1	13
	Artocarpus dadah Miq.		1					1
	Artocarpus elasticus Reinw. ex Bl.		1	2			1	4
	Artocarpus heterophyllus Lamk.			2				2
	Artocarpus integer (Thunb.) Merr.	1	3	1				5
	Artocarpus kemando Miq.		1					1
	Artocarpus maingayi King					1	1	2
	Artocarpus nitidus Trec.		1	1				2
	Artocarpus rigidus Bl.			1				1
	Artocarpus sp	3	1	1			1	6
	Ficus sp		2	22				24
	Ficus variegata Bl.			3				3
Myristicaceae	*Myristica argentea Warb.*	2				1	1	4
	Myristica maxima Warb.		1	1				2
	Myristica sp	4	4	9				17
	Gymnacranthera forbesii (King) Warb.			2				2
	Horsfieldia irya (Gaertn.) Warb.		1	2				3
	Knema cinerea Warb.	1	1			1		3
	Knema latifolia Warb.		3		1		2	6

	Knema woodii Sinclair			1				1
Myrsinaceae	*Ardisia lamponga Miq.*		1					1
	Acmena acuminatissima A. P.DC.			1				1
Myrtaceae	*Eugenia glomerata K. et V.*		5	2				7
	Eugenia polycephala Miq.		2	2				4
	Eugenia sp1	8	1	1			6	16
	Eugenia sp10	1			1			2
	Eugenia sp11	3			1			4
	Eugenia sp2	1	3	3				7
	Eugenia sp3	2	3		1		2	8
	Eugenia sp4	5	9		1			15
	Eugenia sp5	8	3	5	2		6	24
	Eugenia sp6						2	2
	Eugenia sp7	9	6				1	16
	Eugenia sp8		1	1			1	3
	Eugenia sp9	2	2	5				9
	Eugenia striata K. et V.						1	1
Olacaceae	*Ochanostachys amentacea Mast.*	5	5	3		1	2	16
	Strombosia javanica Bl.		1					1
	Strombosia ceylanica Gardn.			2				2
Polygalaceae	*Xanthophyllum excelsum Miq*				1		1	2
Polygalaceae	*Xanthophyllum heteropleurum Chodat*	4	1		1	1		7
	Xanthophyllum sp		2	1				3
Proteaceae	*Helicia robusta (Roxb.) R. Br. ex Wall.*	2						2
	Helicia sp	8						8
Rosaceae	*Prunus arborea (Bl.) Kalkman*						1	1
	Pygeum parviflorum T. et B.		1					1
Rubiaceae	*Adina sp*	1						1
	Anthocephalus chinensis (Lamk.) A. Rich. ex Walp.		5	2				7
	Flectronia sp	1						1
	Gardenia forsteniana Miq		2					2
	Gardenia sp		3	3				6
	Ixora blumei Z. et M.	1	2					3
	Ixora sp	3	7	4				14
	Nauclea sp				1	1		2
	Nauclea calycina Merr.	1	4	1				6
	Petunga microcarpa DC			1				1
	Rubiac.sp1			1				1
	Timonius sp	1						1
	Tricalysia sp	1						1
Rutaceae	*Euodia alba Hook. f.**		1	2				3
	*Euodia speciosa Reich. f.**	3		1				4
Sabiaceae	*Meliosma nitida Bl.*			1			1	2
Sapindaceae	*Arythera littoralis Bl.*			3				3
	Euphoria sp	1					1	2
	Lansium domesticum Correa		1					1
	Nephelium mutabile Bl.		1	4		1	1	7
	Nephelium sp			1				1
	Pometia pinnata Forst.	1	6	4				11
	Spondias pinnata (L. F.) Kurz.			1				1
Sapotaceae	*Palaquium dasyphyllum (de Vriese) Pierre ex Dubard*		13	5				18
	Palaquium ferox Bl.	2						2
	Palaquium macrocarpum Burck		2	1				3
	Palaquium obovatum Engl.	1	2	5			3	13
	Palaquium obtusifolium Burck.	1						1
	Palaquium quercifolium (de Vriese) Burck		1		1	1		3
	Palaquium rostratum (Miq.) Burck	4	1				2	7
	Palaquium sp	1	10	24			5	40
	Payena acuminata (Bl.) Pierre		2	1			2	5

Saxifragaceae	*Polyosma sp*			1				1
Staphyleaceae	*Turpinia sphaerocarpa Hassk.*			1				1
Sterculiaceae	*Pterospermum javanicum Jungh.*	1	1					2
	Heritiera javanica (Bl.) Kosterm.	1			1			2
	Heritiera sp			1				1
	Scaphium macropodum J. Beum.		2					2
	Sterculia rubiginosa Vent.			1				1
Thymelaeaceae	*Aquilaria malaccensis Lamk*		1					1
	Gonystylus velutinus Airy Shaw		1				1	2
Tiliaceae	*Microcos florida Burr.*		2					2
	Pentace polyantha Hassk.						1	1
	Sloanea sp	8	7	1				16
Ulmaceae	*Gironniera nervosa Planch.*						4	4
	Gironniera subaequalis Planch	4	7	4				15
Verbenaceae	*Callicarpa pentandra Roxb.*		1	1				2
	Teysmanniodendron simplicifolium Merr.	1						1
	Vitex quinata F.N. Will.						1	1
Violaceae	*Rinorea bengalensis (Wall.) O.K.*	6						6
	Total	618	637	591	174	137	214	2371
	Number of species	131	163	167	52	35	82	

Remarks:

* - pioneer species

Table 3.4 The occurrence of the fifteen commonest families in each block in the Kintap study area, 1991.

Forest block	Dipterocarp.	Euphorb.	Anac.	Flacourt.	Laur.	Myrt.	Burserac.	Morac.	Bombac.	Eben.	Sapot.	Myrist.	Rubiac.	Annon.	Sapind.
A (1.25 ha)															
Number of species	17	12	9	6	7	9	5	2	3	2	5	3	7	7	2
Number of trees	174	79	53	47	19	39	36	4	6	4	9	7	9	20	2
Basal area (m^2)	11.50	1.57	6.63	0.90	1.61	3.07	0.93	0.39	0.41	0.04	0.46	0.23	0.42	0.36	0.05
B (1.25 ha)															
Number of species	7	27	6	5	6	10	8	8	3	5	7	5	5	8	3
Number of trees	69	147	10	35	57	35	21	18	22	17	31	11	20	20	8
Basal area (m^2)	5.35	3.44	1.42	4.51	3.70	1.07	0.85	2.23	0.95	1.43	0.59	0.18	1.21	0.47	0.29
C (1.25 ha)															
Number of species	10	21	4	6	11	7	2	9	1	8	4	5	6	13	4
Number of trees	66	136	8	22	51	19	6	36	2	25	37	15	12	31	12
Basal area (m^2)	5.78	3.11	0.64	0.68	1.71	0.44	0.19	0.70	0.22	1.34	0.62	1.72	0.34	0.93	1.45
D (0.25 ha)															
Number of species	7	8	3	3	1	5	3	1	3	-	1	1	1	1	-
Number of trees	60	57	4	7	1	6	10	1	7	-	1	1	1	1	-
Basal area (m^2)	2.06	0.97	0.33	0.19	0.26	0.57	0.49	0.01	0.48	-	0.03	0.03	0.02	0.01	-
E (0.25 ha)															
Number of species	6	2	3	3	2	-	1	1	2	1	1	2	1	-	1
Number of trees	93	2	4	9	4	-	1	1	2	1	1	2	1	-	1
Basal area (m^2)	4.24	0.03	0.07	0.19	0.12	-	0.01	0.03	0.04	0.06	0.13	0.11	0.04	-	0.01
F (0.50 ha)															
Number of species	6	9	2	6	5	7	2	4	2	2	4	2	-	3	2
Number of trees	19	32	2	39	15	19	10	4	5	6	12	3	-	3	2
Basal area (m^{21})	3.00	0.60	0.13	1.13	0.30	0.88	0.88	0.73	0.14	0.20	0.29	0.15	-	0.06	0.03
Total															
Number of species	21	44	12	7	15	14	9	12	5	9	9	8	12	16	6
Number of trees	481	453	81	159	147	118	84	64	44	53	91	39	43	75	25
Basal area (m^2)	31.9	9.9	9.1	4.2	6.4	6.1	3.3	2.4	2.2	3.1	2.1	2.4	2.0	2.1	1.8

The higher number of species in Blocks B and C was partly due to the occurrence of pioneers (particularly *Macaranga spp*) which were lacking in Block A (newly logged-forest). In the unlogged forest there were few pioneers, i.e. *Macaranga triloba* and *Macaranga sp* (Table 3.3). The presence of these pioneers in the unlogged forest may be due to the disturbance caused by ironwood *(Eusideroxylon zwageri)* removal or the fact that it was a relatively open patch, unlogged because it had no commercial value.

Table 3.5 The occurrence of dipterocarp species in the study area (total 4.75 ha) by block (blocks D, E and F were in the same site and were combined). Kintap, 1991.

No	Species	N	Basal area (m^2)	Block A	Block B	Block C	Block DEF
1	*Dipterocarpus caudiferus*	8	0.11	-	-	+	-
2	*D. gracilis*	3	0.11	+	+	-	-
3	*D. hasseltii*	7	0.88	+	-	+	-
4	*D. humeratus*	2	0.34	+	-	-	-
5	*Hopea dryobalanoides*	6	0.36	+	-	+	-
6	*H. ferruginea*	2	0.03	-	-	+	-
7	*H. sangal*	10	0.76	+	+	+	+
8	*H. tenuinervula*	1	0.01	+	-	-	-
9	*Shorea faguetiana*	18	2.04	-	-	-	+
10	*S. hopeifolia*	59	4.37	+	+	-	+
11	*S. johorensis*	131	5.96	+	+	+	+
12	*S. laevis*	11	0.55	+	-	-	-
13	*S. leprosula*	10	0.21	+	-	+	+
14	*S. multiflora*	1	0.01	+	-	-	-
15	*S. ovalis*	38	0.86	+	-	+	+
16	*S. parvifolia*	54	2.01	+	+	-	+
17	*S. parvistipulata*	72	10.39	+	+	+	+
18	*S. polyandra*	9	0.42	+	+	+	-
19	*Vatica odorata*	1	0.03	-	-	-	+
20	*V. rassak*	36	2.36	+	-	-	+
21	*V. umbonata*	2	0.08	+	-	-	-
	Total	481	31.87	17	7	10	10

The Shannon-Wiener diversity and equitability indices were calculated (Clifford & Stephenson 1975):

$$H = \log N - 1/N \sum_{i=1}^{S} n \log n$$

where N = grand total of the individuals, s = number of species, n = number of individuals of a given species.

The equitability $E = H/H_{max}$, where $H_{max} = \log S$.

Table 3.6 Number of species, density, basal area and diversity of trees ≥ 10 cm dbh in 19 50 m x 50 m plots, Kintap, South Kalimantan, 1991.

Block (with plot area in parentheses)	Plot	Number of species	N	Basal area (m^2)	Shannon-diversity index	Equitability
A (1.25 ha)	1	51	86	4.8	1.607	0.941
	2	46	140	5.7	1.418	0.853
	3	52	147	8.4	1.524	0.888
	4	56	113	6.3	1.625	0.930
	5	47	132	6.8	1.376	0.823
Total		**131**	**618**	**32.0 (25.6 m^2 ha^{-1})**		
B (1.25 ha)	6	53	115	3.9	1.164	0.936
	7	67	146	3.7	1.704	0.933
	8	63	142	6.6	1.646	0.915
	9	47	97	5.0	1.482	0.886
	10	68	137	5.6	1.720	0.938
Total		**163**	**637**	**24.9 (19.9 m^2 ha^{-1})**		
C (1.25 ha)	11	63	129	4.1	1.651	0.917
	12	67	117	5.9	1.712	0.938
	13	57	122	4.4	1.605	0.914
	14	46	117	4.5	1.455	0.875
	15	47	106	6.9	1.520	0.904
Total		**167**	**591**	**25.7 (20.6 m^2 ha^{-1})**		
D (0.25 ha)	16	52	174	6.0 (24.0 m^2 ha^{-1})	1.394	0.812
E (0.25 ha)	17	35	137	6.1 (24.4 m^2 ha^{-1})	1.156	0.749
F (0.50 ha)	18	54	110	5.2	1.625	0.938
	19	50	104	5.4	1.699	0.926
Total		**82**	**214**	**10.6 (21.2 m^2 ha^{-1})**		
Grand total		**305**	**2371**	**106 (22.3 m^2 ha^{-1})**		

The indices did not vary very much among plots. The highest diversity occurred in plot

10 and the least in plot 17 (Table 3.6).

Trees of ≥ 50 cm dbh were in higher number in Blocks A and F compared with forest Blocks B and C, but there were more trees in the 10 - 19.9 cm size class in Blocks B and C compared with Blocks A and F (Table 3.7, Fig. 3.3). For the data as a whole 3.5% of the trees had a dbh ≥ 50 cm.

Nineteen pioneer species occurred in all the study plots of Blocks B – E (Table 3.8). Block B had 15 pioneer species with 81 trees, which accounted for the basal area of 1.9 m^2 (7.6%).

Table 3.7 Number of trees ≥ 10 cm dbh by size class in the plots at Kintap, South Kalimantan, 1991

Block (with the plot area in parentheses)	Plot	dbh size-class (cm)				
		10 - 19.9	20 - 29.9	30 - 39.9	40 - 49.9	> 50
A (1.25 ha)	1	49	18	6	9	4
	2	100	21	6	5	8
	3	81	30	17	12	7
	4	71	18	11	5	8
	5	77	29	10	9	7
Total		**378 (61.2%)**	**116 (18.8%)**	**50 (8.1%)**	**40 (6.5%)**	**34 (5.5%)**
B (1.25 ha)	6	80	23	8	2	2
	7	117	20	7	2	-
	8	101	27	6	4	4
	9	63	18	4	8	4
	10	99	19	10	4	5
Total		**460 (72.2%)**	**107 (16.8%)**	**35 (5.5%)**	**20 (3.1%)**	**15 (2.4%)**
C (1.25 ha)	11	99	14	10	3	3
	12	83	15	12	4	3
	13	84	26	7	2	3
	14	94	12	5	1	5
	15	70	20	7	2	7
Total		**430 (72.8%)**	**87 (13.7%)**	**41 (6.4%)**	**12 (1.9%)**	**21 (3.3%)**
D (0.25 ha)	16	138	22	5	3	6
E (0.25 ha)	17	95	30	4	2	6
F (0.59 ha)	18	77	20	6	1	6
	19	69	16	6	5	8
Total		**379 (72.2%)**	**88 (16.8%)**	**21 (4.0%)**	**11 (2.1%)**	**26 (5.0%)**
Grand total		**1647 (60.3%)**	**398 (14.6%)**	**147 (5.4%)**	**83 (3.0%)**	**96 (3.5%)**

Block C had 13 species and 2.1 m^2 basal area (8.2%), and Blocks D and E together had 5 species with 0.9 m^2 basal area. Most of the pioneer basal area in Blocks B - E was contributed by *Macaranga hypoleuca* and *M. triloba*.

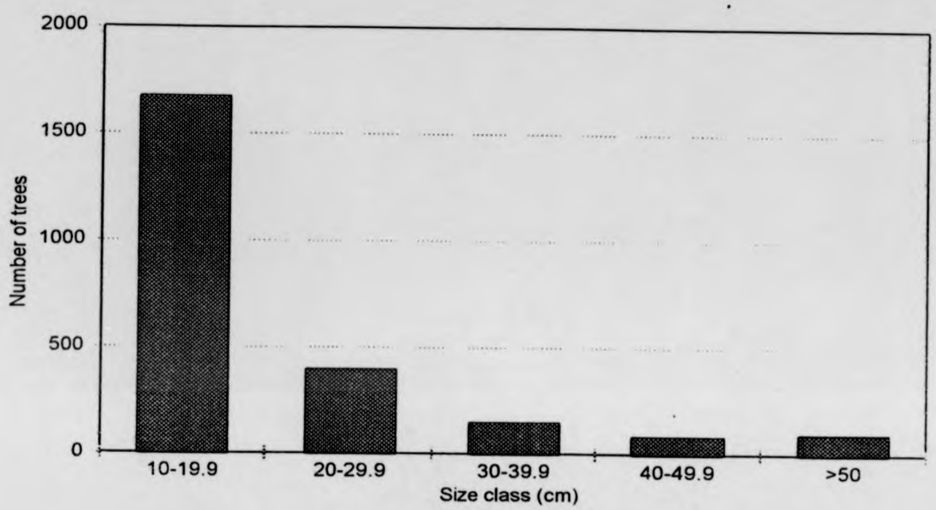


Figure 3.3 Number of trees by size-class in 19 0.25 ha plots in the logged-over forest, Kintap, South Kalimantan, 1991.

Table 3.8 The occurrence of pioneer species in the plots in Blocks B, C, D, and E, Kintap, South Kalimantan.

Block	No	Species	Density	Basal area (cm^2)
B	1	*Croton argyratus*	1	284
	2	*Euodia alba*	1	129
	3	*Geunsia pentandra*	1	97
	4	*Glochidion arborescens*	1	143
	5	*Glochidion sp*	3	2570
	6	*Macaranga diepenhorstii*	1	133
	7	*M. gigantea*	9	1915
	8	*M. hosei*	4	724
	9	*M. hypoleuca*	11	2573
	10	*Macaranga sp*	9	2335
	11	*M. triloba*	24	3694
	12	*Mallotus blumeanus*	1	125
	13	*M. paniculatus*	1	191
	14	*M. penangensis*	10	1470
	15	*Neonauclea calycina*	4	2259
		Total	**81**	**18642 (1.9 m^2)**
C	1	*Cananga ododrata*	3	672
	2	*Croton argyratus*	2	170
	3	*Euodia alba*	2	334
	4	*E. speciosa*	1	293
	5	*Geunsia pentandra*	1	356
	6	*Glochidion sp*	4	1626
	7	*Macaranga conifera*	2	217
	8	*M. gigantea*	15	2825
	9	*M. hypoleuca*	23	6201
	10	*Macaranga sp*	3	557
	11	*M. triloba*	24	4948
	12	*Mallotus penangensis*	2	246
	13	*M. subpeltatus*	16	2689
		Total	**98**	**21135 (2.1 m^2)**
D and E	1	*Macaranga gigantea*	3	590
	2	*M. hosei*	8	1010
	3	*M. hypoleuca*	37	6944
	4	*Macaranga sp*	7	755
	5	*M. triloba*	2	208
		Total	**57**	**9507 (0.9 m^2)**

Table 3.9 Shannon diversity and equitability by Block, Kintap, South Kalimantan

Block	Shannon-Wiener diversity index	Equitability
A	1.8021	0.8511
B	1.9627	0.8872
C	1.9800	0.8908
DEF	1.7194	0.8299

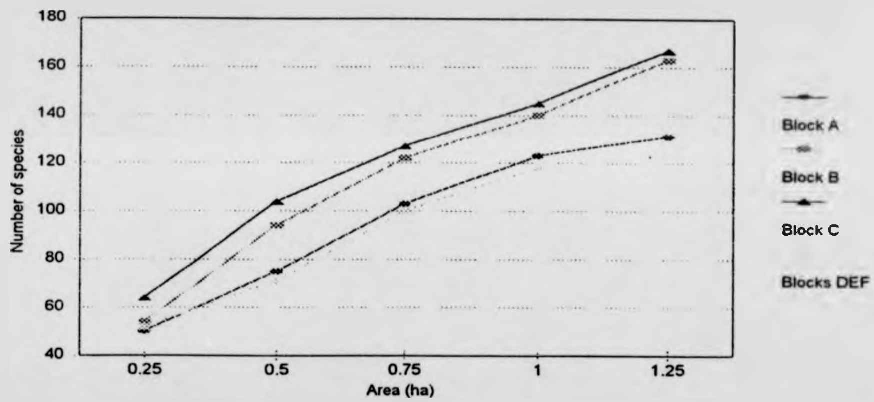


Figure 3.4 Species area curves of non-contiguous plots of 0.25 ha in each different forest block in the logged-over forest, Kintap, South Kalimantan

Species area-curves of non-contiguous (except the contiguous plots 18 and 19 of Block F) plots in Blocks A - DEF are shown in Fig. 3.4. The species-area curve followed the Shannon-Wiener diversity index and equitability by Block (Table 3.9) where the highest diversity and equitability occurred in Block C and the lowest in Blocks DEF. Higher curves in Blocks B and C may be partly due to the occurrence of pioneer species (Table 3.8). In Blocks DEF the pioneers occurred especially in plot 16, whereas in plot 17 most of the pioneers had been removed.

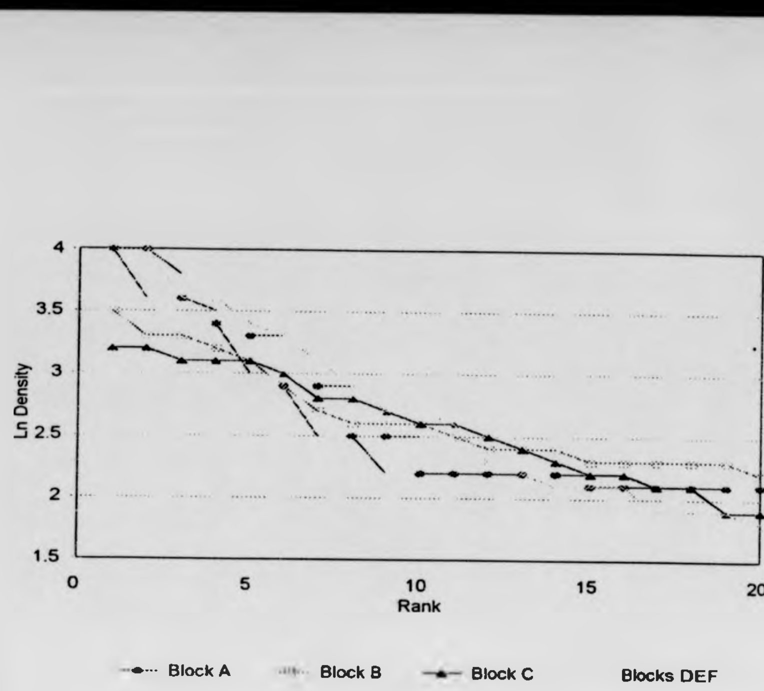


Figure 3.5 Rank abundance curve of the first twenty species in forest blocks A - DEF, Kintap

Rank-abundance for density of the first twenty species is shown in Figure 3.5. Blocks A and DEF had a higher density in the first rank than Blocks B and C, and the lowest density in the first rank was in Block C. The more horizontal curve of the rank abundance in Block C suggested more evenness of species diversity in this Block as was also indicated by a high diversity index and equitability. The higher density in the first rank in Blocks A, B and DEF was due to the density of dipterocarp species, i.e. the density of *Shorea hopeifolia* in Block A and *S. johorensis* in Blocks B and DEF, whereas in Block C the density in the first rank was for *Macaranga triloba*, the pioneer species (Table 3.10).

Table 3.10. Rank-abundance of species by Block, Kintap, South Kalimantan, 1991

Block	No	Species	Density	Rank-abundance
A	1	*Shorea hopeifolia*	56	4.0
	2	*Mallotus echinatus*	52	4.0
	3	*Vatica rasak*	35	3.6
	4	*Shorea johorensis*	29	3.4
	5	*Gluta wallchii*	27	3.3
	6	*Dacryodes rostrata*	19	2.9
	7	*Hydnocarpus sumatranus*	18	2.9
	8	*Melanochyla pulvimervis*	14	2.6
	9	*Hydnocarpus polypetalus*	12	2.5
	10	*Shorea parvifolia*	12	2.5
	11	*Shorea laevis*	11	2.4
	12	*Eugenia sp7*	9	2.2
	13	*Quercus reflexa*	9	2.2
	14	*Dacryodes rugosa*	9	2.2
	15	*Hydnocarpus woodii*	9	2.2
	16	*Eugenia sp5*	8	2.1
	17	*Eugenia sp1*	8	2.1
	18	*Sloanea sp*	8	2.1
	19	*Helicia sp*	8	2.1
	20	*Mastixia trichotoma*	8	2.1
B	1	*Shorea johorensis*	33	3.5
	2	*Mallotus echinatus*	27	3.3
	3	*Eusideroxylon zwageri*	26	3.3
	4	*Macaranga triloba*	24	3.2
	5	*Shorea parvistipulata*	23	3.1
	6	*Duno acutifolius*	19	2.9
	7	*Litsea sp*	15	2.7
	8	*Ryparosa kostermansii*	14	2.6
	9	*Hydnocarpus polypetalus*	14	2.6
	10	*Palaquium dasyphyllum*	13	2.6
	11	*Baccaurea sp*	12	2.5
	12	*Aporusa sp*	11	2.4
	13	*Barringtonia sp*	11	2.4
	14	*Macaranga hypoleuca*	11	2.4
	15	*Diospyros curraniopsis*	10	2.3
	16	*Dacryodes rostrata*	10	2.3
	17	*Palaquium sp*	10	2.3
	18	*Mallotus penangensis*	10	2.3
	19	*Eugenia sp4*	9	2.2
	20	*Macaranga gigantea*	9	2.2
C	1	*Macaranga triloba*	24	3.2
	2	*Palaquium sp*	24	3.2
	3	*Macaranga hypoleuca*	23	3.1

	4 *Eusideroxylon zwageri*	22	3.1
	5 *Ficus sp*	22	3.1
	6 *Shorea parvistipulata*	20	3.0
	7 *Mallotus sp*	16	2.8
	8 *Mallotus subpeltatus*	16	2.8
	9 *Macaranga gigantea*	15	2.7
	10 *Shorea johorensis*	14	2.6
	11 *Hydnocarpus sumatranus*	13	2.6
	12 *Polyalthia sp*	12	2.5
	13 *Aglaia sp*	11	2.4
	14 *Dysoxylum sp*	10	2.3
	15 *Diospyros curraniopsis*	9	2.2
	16 *Knema cinerea*	9	2.2
	17 *Baccaurea sp*	8	2.1
	18 *Dipterocarpus caudiferus*	8	2.1
	19 *Palaquium obovatum*	7	1.9
	20 *Shorea polyandra*	7	1.9
DEF	1 *Shorea johorensis*	55	4.0
	2 *Macaranga hypoleuca*	37	3.6
	3 *Shorea parvifolia*	35	3.6
	4 *Shorea ovalis*	31	3.4
	5 *Hydnocarpus sp*	26	3.3
	6 *Shorea parvistipulata*	23	3.1
	7 *Shorea faguetiana*	18	2.9
	8 *Ryparosa kostermansii*	15	2.7
	9 *Mallotus echinatus*	15	2.7
	10 *Dacaryodes rostrata*	14	2.6
	11 *Aporusa sp*	10	2.3
	12 *Hydnocarpus polypetalus*	9	2.2
	13 *Eusideroxylon zwageri*	8	2.1
	14 *Eugenia sp5*	8	2.1
	15 *Macaranga hosei*	8	2.1
	16 *Durio acutifolius*	7	1.9
	17 *Barringtonia sp*	7	1.9
	18 *Macaranga sp*	7	1.9
	19 *Aglaia sp*	6	1.8
	20 *Eugenia sp8*	6	1.8

CHAPTER 4 THE NEWLY LOGGED FOREST AT KINTAP

INTRODUCTION

The newly logged forest Block A (plots 1 – 5) is the farthest study area from the FINNIDA camp and ranges from 125 – 190 m compared with the other Blocks which range from 20 – 90 m (Table 3.2). The area was logged in August 1991, 15 days before the Block was set up.

This chapter is aimed at describing the situation of a newly logged forest with its soil disturbance, debris of boles and branches, cut stumps, canopy gaps, and trees uprooted, bulldozed, and killed or damaged by falling trees.

MATERIALS AND METHODS

The five 50 m x 50 m plots in the newly logged forest (Block A) were recorded in October 1991 for disturbance using the following criteria: (a) the percentage of area occupied by roads or other badly compressed soils caused by tractor tracks; (b) the area of bare, loose soil; (c) the area covered by large litter (debris of branches and logs ≥10cm); (d) the area of fine litter (other debris of leaves and branches < 10 cm diameter), (e) the area of open canopy (i.e. clear sky visible from 1.5 m above the ground); (f) uprooted, bulldozed trees; (g) trees killed by falling trees.

RESULTS

The extent of the logging damage to the primary forest can be seen in table 4.1. Skidding roads and other bare soils occupied 19.3% and large and fine litter occupied 16.9 % of the logged area. Stumps averaged three in 0.25 ha, which gives an indication of the rate of felling of the dipterocarps. Uprooted/bulldozed trees were found to average 14 in every 0.25 ha (56 ha^{-1}) with the dbh's ranging from 10 - 66 cm, but mostly in the 10 - 20 cm class. Trees killed by the falling trees were five in 0.25 ha (20 ha^{-1}) with the diameters ranging from 10 - 80 cm (mostly 10 - 19.9 cm), and they consisted of 13 different species in 1.25 ha. Bulldozed and killed trees altogether averaged 19 in 0.25 ha (76 ha^{-1}).

Individual numbers of trees of the residual stands in the newly logged forest ranged from 86 in plot 1 to 147 in plot 3 (Table 4.2). The total number of the individual trees was 618 in 1.25 ha or 494.4 ha^{-1}. Trees of diameter class 10 - 19.9 cm had the highest density with 61.2% and the trees of diameter 50 cm and above had the least with 5.7% (Table 4.2).

Table 4.1 Damage in the five newly logged (50 m x 50 m) plots in Block A, Kintap, October 1991.

Detail	Plot No					Means
	1	2	3	4	5	
1.Road (%)	18.7	10	10.4	10.8	18.8	13.7
2.Other bare soil (%)	8	2.2	1	10.2	6.6	5.6
3.Debris >10 cm (%)						
a. Boles	6	1.7	0.9	4.5	11.4	4.9
b. Branches	6.7	4.1	0.7	2.8	3.6	3.6
4. Other debris (%)	12.1	0.9	3.3	7.7	17.9	8.4
5.Cut stumps	5			3	6	2.8
6.Canopy gap (%)	23.4	7.2	1	13.8	32	15.5
7.Uprooted / bulldozed	16	5	7	15	25	13.6
8.Killed by felled trees	2	1	4	4	15	5.2

Table 4.2. Tree (> 10 cm dbh) density in each newly logged plot in Block A, Kintap.

Plot No	Dbh class (cm)					Total
	10-19.9	20-29.9	30-39.9	40-49.9	≥50	
1	49	18	6	9	4	86
2	100	21	6	5	8	140
3	81	30	17	12	7	147
4	71	18	11	5	8	113
5	77	29	10	8	8	132
Total	378 (61.2%)	116 (18.8%)	50 (8.1%)	39 (6.3%)	35 (5.7%)	618

DISCUSSION

The opening (road, other bare soils and soil covered with litter) of 36.2% of the forest floor (Table 4.1) resulting from the felling and extraction of an estimated 12 trees per ha in the newly logged area is within the 33 % and 40 % reported by Hutchinson (1980) and Nicholson (1979). Kartawinata (1974) noted that felling 19.5 trees per ha caused the damaged area (following log extraction) to be 0.39 ha (39 %). The damage to the soil caused by skidding was so severe that on many old skidding roads plants did not grow at all after 2 years, whereas on some others, shrubby species like *Eupatorium pallescens*, *Lantana camara* and many spiny climbers (mostly Rubiaceae) grew, particularly on the areas exposed to sunlight (pers. observation). The skidding roads that remained bare mostly occurred on slopes where erosion might have occurred.

Trees of smaller diameter generally suffered most from felling and log extraction (Abdulhadi *et al* 1980; Nicholson 1958; Tinal & Palenewen 1978). In this study the residual stands consisted of a mean of 494.4 trees per ha with 76 trees (13.3%) of 10 cm - 80 cm (mostly 10-20 cm) diameter killed. The numbers are lower than those reported by Tinal & Palenewen (1978) with 28.6 % of trees of 14 cm diameter and above (mostly 14 - 29.9 cm) fallen or broken. Kartawinata *et al.* (1978) and Abdulhadi *et al.* (1980) reported that a substantial area of the logged forest in East Kalimantan was covered by skidding roads, haul roads and log yards. Roads in Sabah (Malaysia) covered 14 - 17% of the logged area (Fox 1969; Nicholson 1958), and in the Philippines, 25-40 % (Serevo 1949). In this study, roads and other bare soils covered 19.3 % of the logged area, similar to those reported by Fox (1969) and Nicholson (1958).

Felling and extraction affect species diversity. Kartawinata (1980) recorded a number of tree species ($\geq$ 10 cm dbh) in the primary forest of 205 in 1.6 ha compared with 159 in 2 ha of the nearby logged-over forest in East Kalimantan. In the tropical rain forest many species are represented by only one individual tree each in tens of ha of forest area (Poore 1968; Ng 1983). The high rate of forest destruction which is now occurring is thus likely to cause the loss of species.

CHAPTER 5 GROWTH, MORTALITY AND RECRUITMENT OF TREES AT KINTAP.

INTRODUCTION

The study on tree growth after logging at Kintap is aimed at clarifying patterns of growth in the logged and unlogged Blocks. It may be expected that despite logging damage, the growth rate of trees in the newly logged forest will be accelerated because of reduced competition for light, nutrients or water. Mortality in the newly logged forest however, may also be higher due to the persistent effects of logging damage. Damage to the forest and its rate of recovery varies depending on the logging intensity. Estimated recovery times of the logged over forest in East Kalimantan have varied from 5 – 40 years (Miller 1981).

MATERIALS AND METHODS

In the newly logged forest (Block A) the diameter of trees was measured in November 1991 and February 1996 (over 51 months), and in the twelve-years old logged forest (Blocks B, C, D, E) and in the unlogged forest (Block F) in December 1991 and February 1996 (over 50 months). The measurements were made using a steel tape at 10 cm below the nail of the tag (1.4 m above the ground), but occasionally at 30 cm above a buttress or stilt root or other protrusion. Boles with lianas were measured with the meter tape inserted under the liana, or occasionally over the liana if it could not be prised from the bole. The bark was cleaned by hand before the measurement. A ladder was used to measure boles with high buttresses.

Tree species were grouped based on the Korning & Balslev (1994) classification and on their maximum height and diameter as recorded in Whitmore *et al.* (1989) and in the Flora Malesiana, i.e. canopy (maximum height > 30 m, maximum dbh > 70 cm), subcanopy (maximum height 20 - 30 m, maximum dbh 25 - 70 cm) and understory species (maximum height $\leq$ 20 m, maximum dbh $\leq$ 25 cm (30 cm). Mortality and recruitment were recorded during tree measurement. The annual mortality rate was estimated by the exponential rate measure (λ) derived from the differential equation: $dN/dt = -\lambda N$. The integral of the equation gives the standard exponential model

$$N_t = N_0 \, e^{-\lambda t} \quad \text{(Sheil \& May 1996)}$$

$\ln N_t = \ln N_0 + \ln (e^{-\lambda t})$

$e^{-\lambda t} = \exp(-\lambda t)$

$\ln N_t = \ln N_0 + \ln [\exp(-\lambda t)]$, since the exp and ln are inverse functions, then

$\ln N_t = \ln N_0 - \lambda t$

$\lambda = 1/t \, (\ln N_0 - \ln N_t)$

$\lambda = 1/t \, \ln (N_0/N_t)$

RESULTS

Block A (Newly logged-forest)

Basal area increment of trees varied among plots, ranging from 0.32 to 0.74 m^2, equivalent to a basal area increment of the surviving trees of 10.2% (plot 5) to 17.8% (plot 1). The difference in percentage increment among plots was significant ($p < 0.005$) (Table 5.1).

The growth rate was not simply related to size class and there was a tendency for lower growth rates to occur in the higher size-classes (Table 5.2). Mean dbh increment increased until the size class 30 – 39.9 cm with 0.56 cm $year^{-1}$ and declined afterwards. Size classes 60 - 69.9 cm and 70 - 79.9 cm were represented by only a few individuals and will be prone to sampling error.

Table 5.1 Density, basal area and increment of trees ≥ 10 cm dbh in the newly- logged-forest at Kintap.

Plot	Basal area (m^2 0.25 ha^{-1})	Density		Basal area of surviving trees (m^2 0.25 ha^{-1})		Increment	
	1991	1991	1996	1991	1996	(m^2 0.25 ha^{-1})	Percent (%)
1	4.75	86	67	4.16	4.90	0.74	17.8
2	5.80	140	126	5.33	6.01	0.68	12.8
3	8.37	147	141	6.75	7.37	0.62	9.2
4	6.31	113	95	5.22	5.54	0.32	6.1
5	6.84	132	122	6.37	7.02	0.65	10.2
Total	32.12	618	551	27.83	30.84	3.01	10.8

Table 5.2 Growth rate (cm $year^{-1}$) per diameter class in the newly logged forest (Block A) in the 51-month period (November 1991-February 1996)

Diameter class (cm)	N	Dbh increase (cm $year^{-1}$)			
		Mean	Minimum	Maximum	Median
10 - 19.9	313	0.34	0	2.75	0.20
20 - 29.9	95	0.39	0	2.60	0.25
30 - 39.9	43	0.56	0	1.75	0.46
40 - 49.9	30	0.52	0	2.61	0.33
50 - 59.9	16	0.32	0	1.00	0.18
60 - 69.9	2	0.23	0	0.46	0.23
70 - 79.9	4	0.38	0	1.51	0

The growth increment of the Dipterocarpaceae accounted for 48.2% of the total increment of 3.02 m^2. The second highest was Myrtaceae with 10% of the increment, followed by Anacardiaceae (7.3%) and Lauraceae (5.7%) (Table 5.3).

The dipterocarps were represented by 18 species in this Block with a total basal area of 10.56 m^2 in 1991, a high proportion of the total basal area of 32.1 m^2 even though many of them had been removed by the logging. All the dipterocarps were of canopy species with the mean dbh increment ranging from 0.20 cm $year^{-1}$ (*Hopea dryobalanoides*) to 1.22 cm $year^{-1}$ (*Shorea parvifolia*). *Shorea johorensis* was second to *S. parvifolia* with 1.05 cm $year^{-1}$ followed by *S. laevis* 0.40 and *Vatica rassak* 0.39 cm $year^{-1}$ (Table 5.5). *Shorea hopeifolia* had the highest density among the dipterocarps, followed by *Vatica rassak* and *Shorea johorensis*. The increment of *S. hopeifolia* however was relatively low with 0.31 cm $year^{-1}$. *Shorea johorensis* and *Shorea parvifolia* are included in the "red merantis" of Ashton (1982) and are commonly logged. The other "red merantis" in this Block were *Shorea leprosula* which had an increment of 0.72 cm $year^{-1}$, and *S. ovalis* with 0.23 cm $year^{-1}$

The proportion of dipterocarps and non dipterocarps for density, number of species, basal area of surviving trees and increment in each plot is given in Table 5.4. The proportion of basal area and its increment for dipterocarps and non dipterocarps is shown in figure 5.1. Plots 2 and 5 contributed the highest percentage increment of dipterocarps. Both of the plots had the densest dipterocarps. Some families were present in all plots including Dipterocarpaceae, Myrtaceae, Anacardiaceae, Flacourtiaceae, Guttiferae and Burseraceae. The dipterocarps grew fastest in plot 2 where they had an increment of 67.6% of the original basal area and least fast in plot 1 with 40.5%. Plot 2 included the relatively fast-growing dipterocarps *Shorea johorensis* (27 trees) and *S. parvifolia* (10 trees).

Canopy species had a mean dbh increment of 0.07 - 1.22 cm $year^{-1}$. The growth of canopy species had a higher general mean than the subcanopy species and the latter had a higher general mean than the understory species. Higher growth rate in the canopy species were well shown by the dipterocarps (Table 5.5). The canopy species of non-dipterocarps ranged from 0.07 - 0.82 cm $year^{-1}$, much lower than the dipterocarp dbh increment of 0.20 - 1.22. The highest was for *Quercus reflexa* (Fagaceae) with 0.82 cm $year^{-1}$, followed by *Hydnocarpus woodii* (Flacourtiaceae), *Lophopetalum javanicum* (Celastraceae) and *Mastixia trichotoma* (Cornaceae), each with 0.27 cm $year^{-1}$ (Table 5.5).

Table 5.3 Increment, density and the occurrence of 15 families in Block A, Kintap, South Kalimantan, plots 1 - 5.

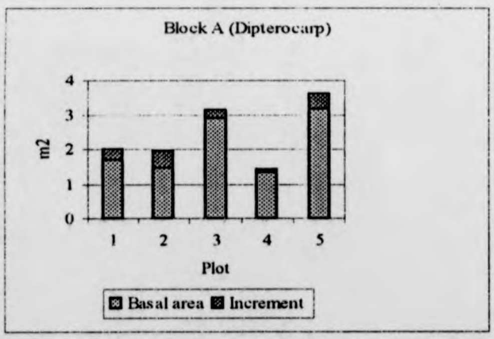
Family	Density (1996)	Increment (in 51 months)		Plot				
		m^2	(%)	1	2	3	4	5
Dipterocarpaceae	162	1.46	48.2	+	+	+	+	+
Myrtaceae	35	0.30	9.9	+	+	+	+	+
Anacardiaceae	42	0.22	7.2	+	+	+	+	+
Lauraceae	17	0.17	5.6	+	+	+	+	-
Flacourtiaceae	42	0.12	3.9	+	+	+	+	+
Euphorbiaceae	67	0.11	3.5	+	+	+	+	+
Fagaceae	10	0.09	2.9	+	+	+	-	-
Dilleniaceae	5	0.07	2.3	+	+	+	+	+
Bombacaceae	6	0.05	1.5	+	-	+	+	-
Burseraceae	33	0.04	1.4	+	+	+	+	+
Meliaceae	5	0.04	1.3	+	+	+	+	-
Sapotaceae	6	0.04	1.2	-	+	+	+	+
Cornaceae	9	0.03	0.9	+	-	+	+	+
Annonaceae	15	0.03	1.1	+	+	+	+	+
Myristicaceae	6	0.02	0.7	-	+	-	+	-
Total	460	3.02						

The dbh increment subcanopy species ranged from 0.15 - 0.77 cm $year^{-1}$, and those of the understorey species from 0.14 - 0.59 cm $year^{-1}$. Some understory species had higher mean diameter growth than subcanopy and subcanopy species had higher mean diameter growth than canopy species. However in general canopy species showed higher mean diameter growth than subcanopy and subcanopy had higher mean diameter growth than understory species (Table 5.5).

Table 5.4. Density, basal area (m^2 0.25 ha^{-1}), number of species and increment of dipterocarps and non-dipterocarps in Block A. Kintap, South Kalimantan, 1991-1996

Description		Plot 1		Plot 2		Plot 3		Plot 4		Plot 5	
		1991	1996	1991	1996	1991	1996	1991	1996	1991	1996
Number of species											
	D	5	5	6	6	8	7	7	6	8	8
	ND	47	38	41	32	44	44	49	46	40	38
Density											
	D	11	10	49	44	43	41	11	10	60	57
	ND	75	57	91	82	104	100	102	85	72	65
Basal area* (m^2)											
	D	1.69	1.99	1.47	1.93	2.90	3.13	1.34	1.43	3.16	3.60
	ND	2.47	2.91	3.86	4.08	3.85	4.24	3.88	4.11	3.21	3.43
Increment (m^2)											
	D		0.30 (40.5 %)		0.46 (67.6 %)		0.23 (37.1 %)		0.09 (28.1 %)		0.44 (66.7 %)
	ND		0.44 (59.5 %)		0.22 (32.4 %)		0.39 (62.9 %)		0.23 (71.9 %)		0.22 (33.3 %)

Remarks : D : Dipterocarps
ND: Non-dipterocarps
*: Basal area of surviving trees



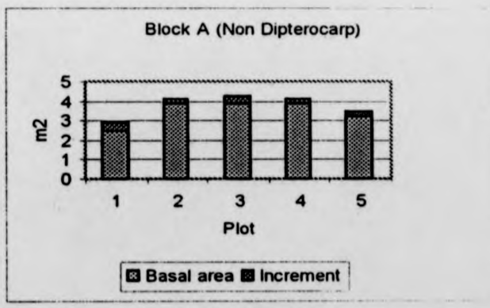


Figure 5.1 Basal area of the dipterocarp and non dipterocarp surviving trees and its increment in Block A

Table 5.5 Growth (cm year^{-1}) of trees (≥5 individuals) in Block A, Kintap, plots 1-5

Species (dipterocarps are asterisked)	N	Dbh increase			
		Mean	Minimum	Maximum	Median
Canopy					
Dacryodes costata	6	0.07	0	0.30	0.04
Dacryodes rostrata	17	0.15	0	0.43	0.10
Dacryodes rugosa	6	0.11	0	0.53	0.10
Gluta wallichii	20	0.29	0	1.23	0.14
*Hopea dryobalanoides**	5	0.20	0.08	0.38	0.20
Hydnocarpus woodii	8	0.27	0.03	0.62	0.28
Lophopetalum javanicum	5	0.27	0	0.58	0.21
Mastixia trichotoma	7	0.27	0.06	0.46	0.28
Melanochyla pulvinervis	10	0.23	0	0.72	0.17
Quercus reflexa	8	0.82	0.19	2.69	0.60
*Shorea hopeifolia**	53	0.31	0	0.94	0.25
*Shorea johorensis**	25	1.10	0.14	2.56	0.99
*Shorea laevis**	11	0.33	0	0.68	0.33
*Shorea parvifolia**	12	1.22	0.32	2.55	1.27
*Vatica rassak**	31	0.46	0	1.48	0.36
General mean		0.40			
Subcanopy					
Dehaasia caesia	6	0.43	0	1.35	0.32
Eugenia sp1	6	0.77	0.23	1.54	0.73
Eugenia sp5	6	0.58	0.09	1.16	0.61
Eugenia sp7	7	0.31	0.01	0.85	0.18
Hydnocarpus polypetalus	10	0.13	0.02	0.30	0.13
Hydnocarpus sumatranus	11	0.15	0	0.29	0.16
General mean		0.40			
Understorey					
Helicia sp	6	0.35	0.17	0.82	0.26
Mallotus echinatus	39	0.18	0.01	0.65	0.10
Memecylon laevigatum	6	0.14	0.02	0.38	0.12
Polyalthia sumatrana	5	0.34	0.09	0.67	0.33
Ryparosa kostermansii	5	0.59	0.10	1.72	0.24
General mean		0.32			

Block B (forest logged in 1979)

Many trees died in plots 7 and 10 between 1991 and 1996 and this may have been caused partly by the unusually strong wind on 25 January 1994. Most of plot 8 was burned by a farmer and several trees in plot 9 were illegally cut by local people

Total basal area increment for plots 6 - 10 was 2.38 m^2 (0.46 m^2 $ha^{-1}year^{-1}$), or 16.8% of the total basal area of surviving trees (Table 5.6). This was higher than the percentage increment in the newly logged forest of 10.8%. The basal area increment ranged from 0.33 - 0.60 m^2 with the highest percentage occurring in plots 8 and 9 with 22% and 19.3% respectively. The difference in the percentage increments between plots however was not significant. Growth rate was independent of diameter size classes as in Block A and ranged from 0.44 to 0.68 cm $year^{-1}$ (Table 5.7).

The highest family percentage increment was for the Dipterocarpaceae with 0.46 m^2 (19.5 %) in 50 months equivalent to 0.09 m^2 ha^{-1} $year^{-1}$. The increment was much lower than that of the dipterocarps in Block A (0.27 m^2 ha^{-1} $year^{-1}$).

Table 5.6 Density, basal area and increment of trees ≥ 10 cm dbh in Block B at Kintap, December 1991 - February 1996.

Plot	Basal area (m^2 0.25 ha^{-1})	Density		Basal area of surviving trees (m^2 0.25 ha^{-1})		Increment	
	1991	1991	1996	1991	1996	m^2	(%)
6	3.99	115	108	3.73	4.33	0.60	16.1
7	3.74	146	88	1.84	2.17	0.33	17.9
8	6.56	142	48	1.64	2.00	0.36	22.0
9	5.01	97	73	2.59	3.09	0.50	19.3
10	5.67	137	102	4.40	4.99	0.59	13.4
Total	24.97	637	420	14.20	16.58	2.38	16.8

Table 5.7 Growth rate (cm year^{-1}) per diameter class in the twelve-years old logged forest (Block B) in the 50-month period (December 1991- February 1996)

Diameter class (cm)	N	Dbh increment (cm year^{-1})			
		Mean	Minimum	Maximum	Median
10 - 19.9	284	0.49	0	2.65	0.31
20 - 29.9	62	0.56	0.01	1.97	0.45
30 - 39.9	19	0.44	0	1.05	0.46
40 - 49.9	12	0.68	0	1.58	0.71
50 - 59.9	-	-	-	-	-
60 - 69.9	5	0.48	0	0.84	0.52
70 - 79.9	1	0.46	-	-	-

The Dipterocarpaceae had only seven species of 68 trees in the study plots in Block B at the 1991 enumeration, with the total basal area of 1.98 m^2 This was much lower than the total dipterocarp basal area in Block A of 10.94 m^2. The Euphorbiaceae was second in the percentage increment with 15.3 %, followed by the Lauraceae and Ebenaceae with 11.0 % and 5.5 % respectively. The Euphorbiaceae had the highest density with 82 trees, followed by the Lauraceae (48), Dipterocarpaceae (35) and Myrtaceae (26) (Table 5.8). The families present in all the plots included the Dipterocarpaceae, Euphorbiaceae, Lauraceae, Myrtaceae, Moraceae, Sapotaceae, Flacourticaceae, Annonaceae and Ebenaceae.

Table 5.9 shows the proportion of dipterocarp and non dipterocarp trees for density, number of species and increment in each plot. The highest increment of the dipterocarps was for plot 9 with 34% followed by plot 8 with 22.2%. The increment may be related not only to the density. Plot 9 had the highest density and provided the highest dipterocarp increment, however plot 8 was less dense than plots 6 and 10 but had a greater increment. The higher increment in plot 8 may be related to more canopy opening resulting from burning and illegal cutting. The opening of plots 7 and 10 may have occurred too recently to have had a measurable effect on the girth increment

Table 5.8 Increment, density and the occurrence of the 15 commonest families in Block B, Kintap

Family	Increment		Density	Plot				
	m^2	%	1996	6	7	8	9	10
Dipterocarpaceae	0.46	19.5	35	+	+	+	+	+
Euphorbiaceae	0.36	15.3	82	+	+	+	+	+
Lauraceae	0.26	11.0	48	+	+	+	+	+
Flacourtiaceae	0.11	4.7	25	+	+	+	+	+
Leguminosae	0.10	4.2	10	-	+	+	+	+
Myrtaceae	0.09	3.8	26	+	+	+	+	+
Burseraceae	0.08	3.4	12	-	+	+	+	+
Moraceae	0.09	3.8	15	+	+	+	+	+
Sapotaceae	0.06	2.5	25	+	+	+	-	+
Bombacaceae	0.06	2.5	16	+	+	+	+	+
Annonaceae	0.05	2.1	13	+	+	+	-	-
Meliaceae	0.05	2.1	12	+	+	+	-	-
Ebenaceae	0.13	5.5	12	+	+	+	+	+
Rubiaceae	0.09	3.8	14	+	+	+	+	-
Sapindaceae	0.04	1.7	6	+	+	+	+	+
Subtotal	2.03	86.0	351					
Total	2.36							

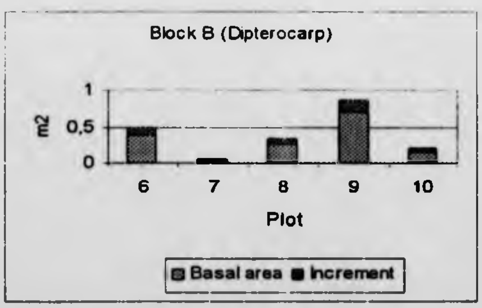
The growth rate of individual species is shown in Table 5.10. The "red meranti", *Shorea johorensis* had a mean dbh increase of 1.0 cm year^{-1} and *Shorea parvistipulata* 0.80 cm year^{-1}. These species were the remaining dipterocarp species having $\geq$ 5 individuals in Block B. The other surviving species were *Shorea parvifolia* (4), *S. hopeifolia* (1) and *Hopea sangal* (2).

Canopy species had a mean dbh increase from 0.10 cm year^{-1} (*Palaquium sp*) to 1.00 cm year^{-1} (*Shorea johorensis*), sub-canopy species from 0.11 cm year^{-1} (*Eugenia sp*) to 0.47 cm year^{-1} (*Aglaia sp*) and understory species from 0.12 (*Ixora sp*) to 0.73 cm year^{-1} (*Ryparosa kostermansii*) (Table 5.10). The range of the increment overlapped between canopy, sub-canopy and understorey species as in Block A. However the increment in general also showed canopy species had a higher increment than sub-canopy species

Table 5.9 Density, basal area (m^2), number of species and increment of dipterocarps and non-dipterocarps in Block B, Kintap, 1991-1996

Description		Plot 6		Plot 7		Plot 8		Plot 9		Plot 10	
		1991	1996	1991	1996	1991	1996	1991	1996	1991	1996
Number of species											
	D	2	2	3	2	4	3	3	3	3	2
	ND	51	50	62	38	53	29	44	35	65	53
Density											
	D	9	7	7	3	21	4	20	13	11	8
	ND	106	101	139	85	121	44	77	60	126	95
Basal area* (m^2)											
	D	0.38	0.49	0.04	0.06	0.26	0.34	0.71	0.88	0.14	0.21
	ND	3.35	3.84	1.80	2.11	1.38	1.66	1.88	2.21	4.26	4.78
Increment (m^2)											
	D		0.11 (18.3 %)		0.02 (6.1 %)		0.08 (22.2 %)		0.17 34.0 %)		0.07 (11.9 %)
	ND		0.49 (81.7 %)		0.31 (93.9 %)		0.28 (77.8 %)		0.33 (66.0 %)		0.52 (88.1 %)

Remarks : D : Dipterocarps
ND: Non dipterocarps
*: Basal area of surviving trees



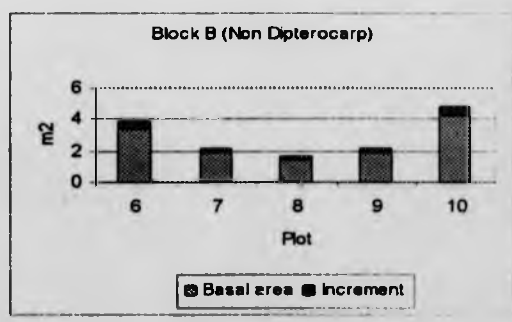


Figure 5.2 Basal area of the surviving dipterocarp and non dipterocarp trees and its increment in Block B.

Table 5.10 Growth rate of trees (≥ 5 individuals) in Block B at Kintap, plots 6 - 10.

Species (asterisked are dipterocarps)	N	Dbh increase (cm year⁻¹)			
		Mean	Min	Max	Med
Canopy					
Alseodaphne ceratoxylon	6	0.50	0.12	1.21	0.40
Dacryodes rostrata	7	0.28	0.09	0.41	0.23
Eusyderoxylon zwageri	23	0.41	0.06	1.06	0.31
Gironniera subaequaalis	6	0.35	0.07	0.78	0.28
Palaquium sp	5	0.10	0	0.20	0.06
*Shorea johorensis**	17	1.00	0.07	2.02	0.91
*Shorea parvistipulata**	11	0.80	0.33	1.42	0.72
General mean		**0.47**			
Subcanopy					
Aglaia sp	6	0.47	0.28	0.52	0.48
Diospyros currniopsis	5	0.35	0.00	0.68	0.42
Durio acutifulios	12	0.29	0.03	1.03	0.24
Eugenia sp4	3	0.11	0.00	0.22	0.09
Hydnocarpus polypetalus	8	0.26	0.05	0.66	0.14
Litsea sp	13	0.32	0.00	0.84	0.24
Palaquium dasyphyllum	11	0.29	0.02	0.80	0.24
General mean		**0.30**			
Understorey					
Baccaurea sp	5	0.32	0.12	0.51	0.35
Barringtonia sp	6	0.23	0.05	0.41	0.22
Ixora sp	6	0.12	0.00	0.43	0.06
Macaranga triloba	16	0.35	0.02	0.85	0.35
Mallotus echinatus	13	0.21	0	0.44	0.20
Mallotus sp	6	0.13	0.00	0.28	0.12
Ryparosa kostermansii	6	0.73	0.08	1.93	0.65
General mean		**0.29**			

* Dipterocarp species

and, the latter had a higher increment than the understorey species. High growth of the canopy species was contributed by *Shorea parvistipulata* and *S. johorensis*. A canopy non-dipterocarp species, *Alseodaphne ceratoxylon* had the highest dbh increase with 0.50 cm year^{-1}, followed by *Eusideroxylon zwageri* with 0.41 cm year^{-1}. The ironwood

Eusideroxylon zwageri was the commonest species in Block B, followed by *Shorea johorensis* and *Macaranga triloba* (Table 5.10).

Block F (unlogged forest)

The unlogged forest was represented by two contiguous 50 m x 50 m plots. Illegal cutting of one *Shorea johorensis* and one *S. parvifolia* had occurred in plot 19. The total growth increment of the two plots was 0.65 m^2, equal to the increment of 0.31 m^2 ha^{-1} $year^{-1}$ or 6.3 % of the total surviving trees' basal area (Table 5.11). The growth increment was less than in Block A of 10.8% and Block B of 16.8%.

Mean dbh increment by size class increased until the 30-39.9 cm class with 0.55 cm $year^{-1}$ (Table 5.12). Higher classes had too few individuals to be certain of other trends.

Table 5.11 Density, basal area and growth of trees in Block F, Kintap.

Plot	Density		Basal area (m^2)	Basal area of surviving trees (m^2 0.25 ha^{-1})		Increment	
	1991	1996	1991	1991	1996	(m^2)	Percent (%)
18	110	108	5.30	5.13	5.48	0.35	6.8
19	104	96	5.42	4.96	5.26	0.29	5.8
Total	**214**	**204**	**10.72**	**10.09**	**10.74**	**0.64**	**6.3**

The Dipterocarpaceae contributed an increment of 0.19 m^2, or 39.1% of the total. This was followed by the Euphorbiaceae with 12.7%, Flacourtiaceae 9.7% and Lauraceae 8.4% (Table 5.13). The Dipterocarpaceae also had the highest mean individual increment with 121.7 cm^2, followed by the Burseraceae (34.6 cm^2) and Lauraceae (27.9 cm^2).

Table 5.12 Growth rate (cm year^{-1}) for a range of diameter classes in Block F, Kintap

Diameter class (cm)	N	Dbh increment (cm year^{-1})			
		Mean	Minimum	Maximum	Median
10 - 19.9	122	0.23	0	0.94	0.19
20 - 29.9	29	0.33	0.03	0.94	0.24
30 - 39.9	12	0.56	0.06	1.34	0.49
40 - 49.9	3	0.35	0.02	0.73	0.30
50 - 59.9	3	0.53	0.20	1.01	0.38
60 - 69.9	4	0.37	0	0.64	0.42
70 - 79.9	1	0.32	-	-	-
80 - 89.9	1	0	-	-	-

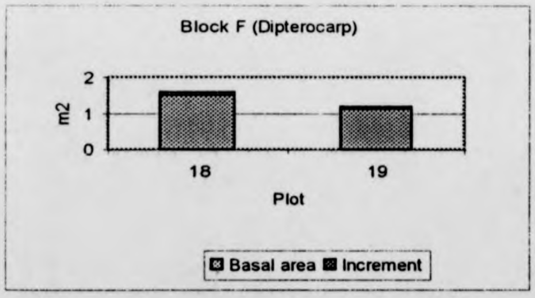
Table 5.13 Basal area increment of nine families (≥ 5 individuals) in the study plots in Block F, Kintap.

Family	N	Increment		Mean individual increment
		cm^2	%	cm^2
Dipterocarpaceae	16	1,947.4	39.1	121.7
Euphorbiaceae	31	634.1	12.7	20.5
Flacourtiaceae	37	485.0	9.7	13.1
Lauraceae	15	418.7	8.4	27.9
Burseraceae	10	345.9	6.9	34.6
Sapotaceae	12	315.7	6.3	26.3
Myrtaceae	17	313.2	6.3	18.4
Ebenaceae	6	141.4	2.8	23.6
Bombacaceae	5	103.8	2.1	20.8
Sub total	149	0.47 m^2		
Total (including other families)	204	0.57 m^2		

Table 5.14. Density, basal area (m^2), number of species and increment of dipterocarps and non-dipterocarps in Block F, Kintap.

Description	Plot 18		Plot 19		Total	
	1991	1996	1991	1996	1991	1996
Number of species						
D	4	4	5	5	6	6
ND	49	49	45	43	75	75
Density						
D	8	8	11	8	19	16
ND	102	100	93	88	195	188
Basal area* (m^2)						
D	1.51	1.59	1.13	1.19	2.64	2.78
ND	3.62	3.89	3.83	4.07	7.45	7.96
Increment (m^2)						
D		0.08 (22.9%)		0.06 (20%)		0.14 (21.5 %)
ND		0.27 (77.1%)		0.21 (80%)		0.51 (78.5 %)

Remarks : D : Dipterocarps
ND: Non dipterocarps
* : Surviving trees



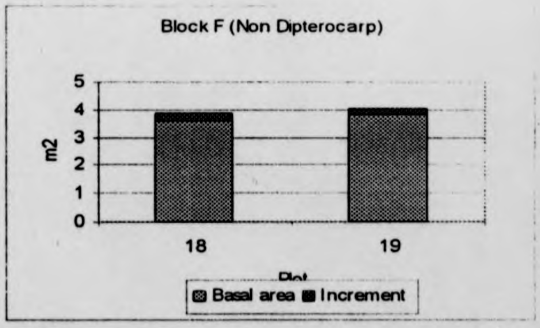


Figure 5.3 Basal area of the dipterocarp and non dipterocarp surviving trees and its increment in Block F.

Table 5.15 Growth rate of trees (≥ 5 individuals) in Block F, at Kintap, plots 18 and 19

Species*	N	Dbh increase (cm year⁻¹)			
		Mean	Min	Max	Med
		Canopy			
*Shorea parvistipulata**	6	0.65	0.08	1.07	0.68
Palaquium sp	5	0.13	0	0.30	0.15
Eusideroxylon zwageri	5	0.25	0	0.45	0.24
Dacryodes rostrata	6	0.24	0.04	0.48	0.23
General mean		**0.32**			
		Subcanopy			
Hydnocarpus sp	17	0.13	0.01	0.36	0.13
Diospyros curraniopsis	5	0.16	0.02	0.37	0.07
Eugenia sp5	5	0.26	0	0.19	0.25
Eugenia sp1	6	0.12	0	0.14	0.12
General mean		**0.17**			
		Understorey			
Aporusa sp	6	0.15	0.09	0.31	0.13
Mallotus echinatus	13	0.23	0.02	0.47	0.24
Ryparosa kostermansii	5	0.19	0.06	0.28	0.25
General mean		**0.19**			

*= dipterocarp species

The Dipterocarpaceae had 6 species in this Block with 16 surviving trees (Table 5.14). The density of the dipterocarps was less than in Block A (162 trees of 18 species) and Block B (35 trees of 7 species). The dipterocarp increment was low, was only 5.3% of the total surviving dipterocarp trees in 1991, lower than the total non dipterocarp rate of 6.8%. Figure 5.3 shows the proportion of dipterocarp and non dipterocarp basal area and its increment.

The overall growth rate of trees in the unlogged forests was low ranging from 0.04 (*Pternandra caerulescens)* to 0.45 cm year^{-1} (*Shorea parvistipulata*) (Table 5.15). Growth of canopy, subcanopy and understory species also overlapped as in Blocks A and B. However canopy species had the highest general mean diameter growth. General mean diameter growth of the understory was more or less the same as the subcanopy species (Table 5.15). The ironwood *Eusideroxylon zwageri* had a growth rate of 0.25 cm year^{-1}, lower than in Block B with 0.41 cm year^{-1}.

The effect of liberation treatment

The liberation treatment was made in Block C (plots 11 - 15) and in Block E (plot 17) (Table 3.1). The total basal area increment in Block C was 4.12 m^2, 20.4% of the total surviving tree basal area of 20.6 m^2 (Table 5.16). The percentage increment in Block C was higher than that in Block B (untreated 12 years old logged forest) of 16.8% but not significantly so (Table 5.6).

Table 5.16 Density, basal area, mortality and increment of trees ≥ 10 cm dbh in Blocks C, D and E, Kintap.

Block/ Plot	Basal area (m^2)	Density		Mortality		Basal area of surviving trees (m^2)		Increment	
	1991	1991	1996	Number	λ	1991	1996	(m^2)	(%)
Block C									
11	4.08	129	96	33	0.0709	3.19	3.99	0.80	25.1
12	5.95	117	108	9	0.0193	5.74	6.40	0.66	11.5
13	4.39	122	119	3	0.0059	4.36	5.54	1.17	26.8
14	4.48	117	111	6	0.0126	4.37	5.33	0.95	21.7
15	6.88	106	93	13	0.0314	2.50	3.04	0.54	21.6
	25.59	**591**	**527**	**31***	**0.0167***	**20.16**	**24.30**	**4.12**	**20.4**
Block D									
16	6.02	174	160	14	0.0201	5.77	6.83	1.06	18.4
Block E									
17	6.05	137	111	26	0.0505	4.62	5.66	1.04	22.5

Remarks: * excluding plot 11 which was partly damaged by windstorm.

Another liberation treatment in Block E (plot 17) resulted in a higher percentage increment (22.5%) than the untreated Block D (plot 16) of 18.4% (Table 5.16). The mean individual dbh increment in plot 17 was 2.77 cm, significantly higher (p 0.05) than in plot 16 of 2.07 cm.

Mortality and recruitment

Illegal cutting after logging occurred in Block B in plot 6 with 2 trees, plot 8 with 12, and plot 9 with 4 trees. No illegal cutting occurred in plots 7 and 10, however both these plots were seriously damaged by windstorms. There had been burning in plot 8 caused by a farmer, resulting in 94 trees ($\geq$ 10 cm dbh) dying in addition to the 12 trees illegally cut. The windstorm also had damaged plot 11 of Block C. Mortality in this Block therefore is studied in plots 12 to 15 (Table 5.16). The annual mortality varied among Blocks and among plots in the same Block. It also varied among size classes and among species groups. The annual mortality in Block A was 0.0270, with the highest in plot 1 (0.0587) followed by plot 4 (0.0408) and plot 2 (0.0247) (Table 5.17). Plot 1 was the most disturbed plot in this Block.

Mortality by size classes and species groups in Block A is given in Table 5.18. Mortality was highest in dbh size-class 10 - 19.9 cm (57.4 %), followed by size class 20 - 29 9 cm (22.1 %). Canopy species had the highest mortality followed by the understory (Table 5.18). The death of the canopy species mostly occurred in size class 10 - 19.9 cm, followed by size class 20 - 29.9 and 40 - 49.9. Dead trees in size classes 30 - 39.9 and above cm were all of canopy species.

In Block F (the unlogged forest) fewer trees died. There were only 2 dead trees in plot 18 and 8 trees (including 2 cut trees) in plot 19. Natural mortality in this Block accounted for 4.7 % of the total density in 1991, with a rate of 0.0115. This is much less than in Block A (the newly logged forest) of 0.0270.

Table 5.17 Mortality and recruitment from 1991 - 1996 in plots in Blocks A, B and F, Kintap

Block/Plot	N (1991)	Mortality				Recruitment			
		Number	Basal area (m^2)	%*	λ	Number	Basal area (m^2)	%**	
								Number	Basal area
Block A									
1	86	19	0.59	22.1	0.0587	17	0.24	25.4	4.90
2	140	14	0.47	10	0.0247	12	0.15	9.5	2.50
3	147	6	1.62	4.1	0.0098	4	0.03	2.9	0.40
4	113	18	1.09	15.9	0.0408	11	0.07	11.6	1.26
5	132	10	0.47	7.8	0.0185	11	0.10	9	1.42
Total	618	67	4.24	11	0.0270	55	0.59	10	1.9
Block B									
6	115	7	0.26			16	0.17	14.8	3.9
7	146	58	1.90			21	0.28	23.9	12.9
8	142	94	4.92			2	0.02	4.2	1.0
9	97	24	2.42			39	0.51	53.4	16.5
10	137	35	1.27			29	0.38	28.4	7.6
Total	637	218	10.77			107	1.36	25.5	8.2
Block F									
18	110	2	0.17	1.8	0.0044	-	-		-
19	104	8	0.42	7.7	0.0192	2	0.02	2.1	0.4
Total	214	10	0.59	4.7	0.0115	2	0.02	1.0	0.2

Remarks:

* Percent of individual numbers 1991

** Percent of individual numbers and basal area 1996

The mortality rate in Block C (excluding plot 11) ranged from 0.0059 (plot 13) to 0.0314 (plot 15) (Table 5.16). The annual mortality of this Block was 0.0167, lower than in Block A and slightly higher than in Block F.

Recruitment varied between sites and between plots within the same site. The plots in Block B had the highest recruitment, followed by Block A, with 25.5 % and 10 % of the total surviving individuals. These were much higher than in the plots in Block F with 2.1 % (Table 5.17). The difference however was not significant.

Table 5.18 Mortality by diameter size-classes and potential height categories (a canopy; b sub canopy; c understory species) in Block A, Kintap.

Size class (cm)	Plots					Total
	1	2	3	4	5	
10 - 19.9						
a	4	3		4	3	14
b	4	1	2	1	1	9
c	4	5		6	1	16
Subtotal						**39 (57.4 %)**
20 - 29.9						
a	3	1		1	2	7
b	1	1		2		4
c	2	1			1	4
Subtotal						**15 (22.1 %)**
30 - 39.9						
a		2				2
b						
c					1	1
Subtotal						**3 (4.4 %)**
40 - 49.9						
a	1		1	3	1	6
b						
c						
Subtotal						**6 (8.8 %)**
50 - 59.9						
a			1			1
b						
c						
Subtotal						**1 (1.5 %)**
60 - 69.9						
a			1	1		2
b						
c						
Subtotal						**2 (2.9 %)**
70 - 79.9						
a			2			2
b						
c						
Subtotal						**2 (2.9 %)**

There was a correlation between the number of trees dying and the number of recruits ($p<0.01$). Plot 18 of the unlogged forest had 0.17 m^2 basal area loss from two dead trees, however there was no recruitment, whereas plot 19 had 8 trees (including 2 cut trees) which died with a loss of 7.7 % of the basal area and had a recruitment of 2 trees (Table 5.17).

DISCUSSION

Growth increment per unit area in the newly logged forest Block A may depend on the intensity of logging as well as the composition of trees. Plot 1 had a wide canopy gap resulting from logging (Table 4.1) and this plot showed a higher growth increment, whereas the higher increment in plot 2 was due to the abundance of *Shorea johorensis* (Table 5.19), a relatively fast growing meranti with the mean dbh increment of 1.05 cm $year^{-1}$ and a maximum of 2.56 cm $year^{-1}$ (Table 5.5). Plot 5 had wider canopy gaps, however this plot consisted mainly of *Shorea hopeifolia* (Table 5.19) having a slow growth of 0.31 cm $year^{-1}$ An individual highest maximum growth (2.69 cm $year^{-1}$) in this block was shown by *Quercus reflexa* (Fagaceae). The mean diameter growth of this species was 0.82 cm $year^{-1}$ (Table 5.5).

Among blocks the percentage increment and the mean individual dbh increment of trees varied among the newly logged forest (Block A), the 12 years old logged forest (Block B) and the unlogged forest (Block F) (Table 5.20). The difference was significant ($p<0.05$), and was shown by Block B against Block F in Tukey's pairwise comparison. A higher percentage increment in Block B was due to the severe damage caused by the illegal cutting and burning, resulting in the least basal area of surviving trees of 11.4 m^2ha^{-1}, compared with 22.3 $m^2 ha^{-1}$ of Block A and 20.2 $m^2 ha^{-1}$ of Block F.

Table 5.19 Dipterocarp species and number of individual trees (≥ 10 cm dbh) in the newly-logged forest Block A, 1991

No	Species	Plot				
		1	2	3	4	5
1	*Dipterocarpus gracilis*	-	-	-	-	2
2	*D. hasseltii*	4	-	-	-	-
3	*D. humeratus*	-	1	-	1	-
4	*Hopea dryobalanoides*	-	-	4	1	-
5	*H. sangal*	-	3	-	1	-
6	*H. tenuinervula*	-	-	1	-	-
7	*Shorea hopeifolia*	-	-	22	3	31
8	*S. johorensis*	2	27	-	-	-
9	*S. laevis*	-	-	7	1	3
10	*S. leprosula*	-	-	-	-	1
11	*S. multiflora*	-	1	-	-	-
12	*S. ovalis*	-	-	-	-	1
13	*S. parvifolia*	2	10	-	-	-
14	*S. parvistipulata*	1	-	1	3	1
15	*S. polyandra*	-	-	1	-	-
16	*Vatica rassak*	-	7	6	1	19
17	*V. umbonata*	2	-	-	-	
18	*V. odorata*	-	-	1	-	1
	Total	11	49	43	11	59

Similar results by Miller (1981) indicated that annual diameter growth in heavily logged forest was significantly higher than in primary forest. In the logged-over forest, the canopy was more open and competition was less resulting in the acceleration of growth Growth in the unlogged forest (Block F) was similar to that observed by Lieberman *et al.* 1987) in Costa Rica and Korning & Balslev (1994) in Equador, however in the logged-over forest Blocks A and B the maximum dbh increments were higher. The average increment in virgin and logged-forest reported by Miller (1978) was higher than in this study (Table 5.20).

Liberation treatment resulted in higher increments in Blocks C and E (Table 5.16) possibly due to reduced competition. This is in accordance with the result of liberation thinning following logging reported by Primack *et al* (1989).

Table 5.20. The increment of trees in Blocks A , B and F at Kintap.

Block	N		Total increment		Basal area increment ($m^2ha^{-1}year^{-1}$)	Mean individual dbh increment (cm year^{-1})
	1991	1996	m^2	%		
Block A	618	551	3.01	10.8	057	0.31
Block B	637	420	2.38	16.8*	0.46	0.39
Block F	214	204	0.64	6.3	0.31	0.25

Remarks: * significant ($p<0.05$)

Table 5.21 Growth rates of trees in several tropical forest sites

	Site	Dbh increment (mm year^{-1})			
		Median	Maximum	Minimum	Mean
Lieberman *et al.* (1987)	La Selva Biological Station Costa Rica	0.35 - 13.41	0.95 - 14.6	0 - 7.5	
Korning & Balslev (1994)	Amazonian Equador	0.5 - 11.6	1.2 - 20.0	0 - 2.4	
Miller (1981)	ITCI concession, East Kalimantan, Indonesia Virgin forest				2.0 - 7.0
	Logged-forest (6 years after logging)				4.1 - 16.0
This study	Kintap, South Kalimantan				
Unlogged forest (Block F)		0.6 - 5.2	1.4 - 10.5	0 - 1.5	0.4 - 2.6
Newly logged forest (Block A)		0.2 - 9.3	2.9 - 26.9	0 - 4.1	0.3 - 10.6
Twelve year-old logged-over forest (Block B)		0 - 10.1	2.0 - 22.8	0 - 4.9	0.8 - 10.9

The different increment per unit size as shown in Blocks A, B and F might not only depend on the stand basal area but on other factors including site (Primack *et al* 1989) and species composition. The steeply sloping plot 4 in the newly logged forest (Table 3.2) had the least percentage increment (Table 5.1). Plot 5 was also steep but had 55 dipterocarp trees compared with plot 4 with 11 dipterocarps (Table 5.19).

Plot 2 had several individuals of *Shorea johorensis*, a relatively fast growing dipterocarp. The increment in this plot was relatively high (12.8%), second to the most disturbed plot 1 which had 17.8% (Table 5.1).

The growth rate of trees in Blocks A, B and F was independent of size class, however there was a tendency for slower growth to occur in the higher size class ($\geq$ 60 cm dbh) (Tables 5.2, 5.7 and 5.12). The Dipterocarpaceae showed the highest growth rate in every Block. Block A had no pioneer trees, unlike Blocks B and C. The second highest growth rate in Block A was by the Myrtaceae, and in Blocks B and C the Euphorbiaceae owing to the presence of fast growing pioneer *Macaranga* species in this family (Table 5.10).

Canopy species generally had a higher mean dbh increment than subcanopy species, and the latter had a higher mean increment than the understory species.

Mortality and recruitment varied among and within the sites studied. It seemed that a bigger basal area loss promoted more recruitment as indicated by a bigger loss of basal area in Block B (10.77 m^2) which resulted in more recruitment than in Block A having 4.24 m^2 basal area loss (Table 5.17). Mortality of the canopy species was higher than the subcanopy and understory species (Table 5.18).

In primary and old secondary forest, recruitment rate matches mortality (Swaine *et al.*, 1987). Studies on mortality and recruitment in the logged-over forests indicated higher mortality than recruitment. This is in accordance with Manokaran & Kochummen (1987) and Lang & Knight (1983) that in certain periods of succession mortality exceeds recruitment. High mortality in the newly logged forest reflects the medium-term effects of the logging damage.

The total surviving tree basal area in the logged-over forest ranged from about 21 - 25 $m^2\ ha^{-1}$, whereas the rate of basal area increment ranged from about 0.31 - 0.57 m^2

$ha^{-1}year^{-1}$. The least disturbed plot 3 of the newly logged forest had a total basal area of 8.4 m^2 (Table 5.1), equivalent to the basal area of 33.6 m^2 ha^{-1} which is close to Dawkins (1958, 1959) 'pan tropical average' basal area. It would take up to about 50 years for the logged-over forest to return to the general total basal area (trees $\geq$ 10 cm dbh) in the lowland rain forest of 36 m^2 ha^{-1}

CHAPTER 6 GROWTH AND SURVIVAL OF SEEDLINGS AND SAPLINGS IN THE LOGGED-OVER FOREST

INTRODUCTION

Growth response of seedlings and saplings following logging depends on canopy opening and on the species composition. An area dominated by dipterocarps and or pioneer seedlings and saplings may have higher growth rates in response to the canopy openings. The species groups (canopy, sub canopy and understory species) may respond differently to light intensity.

The study aimed to verify the pattern of growth and survival of seedlings and saplings in the forest plots logged in 1979 or 1991, and compared it with the unlogged forest patches.

MATERIALS AND METHODS

Seedling (< 2 m high) heights were measured in a 1 m x 1 m quadrat, randomly set up in every 10 m x 10 m subplot in each plot of 50 m x 50 m. Sapling heights (≥ 2 m height - < 10 cm diameter) were measured in every quadrat of 5 m x 5 m randomly set up in a randomly selected 10 m x 10 m subplot on every 10-m wide strip (arranged north-south) of the 50 m x 50 m plot (Table 3.1). The total area of seedling quadrats was 25 m^2 per plot, and that of sapling quadrats was 125 m^2 per plot. All seedlings and saplings were labelled. The enumeration of seedlings and saplings in the newly logged-forest Block A (plots 1 - 5) was done on 17 December 1991, 20 June 1992, and 11 December 1992 (total 12 months), and in the rest of the plots (plots 6 - 19) on 20 December 1991 and 18 September 1993 (total 20 months). Mortality was recorded at the same time as the measurements.

RESULTS

Seedlings

The numbers of individual seedlings in Block A (newly logged forest) varied between plots, the highest being in plot 3 with 260 seedlings and the least in plot 5 with 143 seedlings in the first enumeration (Table 6.1). The total number of seedlings in all five plots was 924 with the average of 185 per plot (in 25 m^2), equivalent to a density of 73,920 ha^{-1} The individual mean increase in height growth varied among plots, both in the first and second six months. The highest mean increase occurred in plot 1, followed by plot 5 and plot 4, and the least increase occurred in plot 2 (Table 6.1). The difference in the increment between plots tested by a one way ANOVA was highly significant (p 0.001), this was due to the large difference between plot 1 and the others.

Mortality in the newly logged forest varied among plots with the highest in plot 3 with 36.5 % in the first six months (Table 6.1). The difference in mortality among plots in the newly logged forest was significant ($p < 0.05$).

Table 6.1 Height increment (cm) and mortality (%) of seedlings in the newly logged forest (site A), December 1991 - December 1992 (12 months).

Plot	Mean increment			N			Mortality		
	First six months (June 1992)	Second six months (December 1992)	Overall	December 1991	June 1992	December 1992	June 1992	December 1992	Overall ($year^{-1}$)
1	13.1	12.6	25.1***	150	131	124	12.7	5.3	17.3
2	2.4	1.5	3.9	189	152	137	18.5	9.7	26.5
3	2.8	2.7	4.5	260	173	165	33.5	4.6	36.5*
4	4.2	4.3	8.4	182	155	151	14.8	2.6	17
5	4.9	6.9	11.3	143	104	100	27.2	3.8	30.1
General Mean	5.5	5.5	10.5	184.8	143	135.4	21.3	5.2	25.5

Remarks: * significant ($p<0.05$)
*** significant ($p<0.001$)

Numbers of individual seedlings in the first enumeration (December 1991) varied between Blocks with the average per plot ranging from 171 (Block C) to 303 (Block F) (Tables 6.1 and 6.2) equivalent to 68,240 to 121,200 ha^{-1}.

The mean height increment of seedlings varied among Blocks (Tables 6.1 and 6.2). Block A had the highest general mean increment of 10.5 cm $year^{-1}$, followed by Block C of 5.4 and Block F, 4.5 cm $year^{-1}$. Growth of seedlings in Block B was low, even lower than the growth in the unlogged Block F (Table 6.2). The difference of the increment among Blocks A, B, C and F however was not significant.

The liberation treatment in Block C resulted in a higher ($p < 0.001$) increment (5.4 cm $year^{-1}$) than the untreated Block B (2.9 cm $year^{-1}$). Plots 16 (Block D) and 17 (Block E) had been set up to determine the relative effects of intensive liberation (Block E) compared with light liberation treatment (Block D) (Table 3.1). There was no significant difference in the mean individual increment between the two plots (Table 6.2). The height increment and mortality with initial seedling height in Blocks A, B and F are shown in table 6.3. The increment generally increased with the initial height in every Block except in the unlogged-forest Block F where the increment declined at the height class 120 – 149.9 cm (Fig. 6.1).

The average annual mortality varied little among Blocks A, B, C and F, ranging from 23.9% (Block B) to 26.6% (Block C) (Table 6.1 and 6.2). Mortality was higher in Block E (22.2% $year^{-1}$) compared with Block D (16.3% $year^{-1}$).

Table 6.2 Height increment (cm) and mortality (%) of seedlings in sites B, C, D, E and F, December 1991 - September 1993 (20 months).

Block	Plot	Average first height (m)	Mean increment		N_1	N_2	Mortality	
			In 20 months	Year^{-1}			In 20 months	Year^{-1}
B	6	29.9	5.1	3.1	232	125	46.1	27.7
	7	29.9	4.3	2.6	271	155	42.8	25.7
	8	30.2	3.4	2	233	154	33.9	20.3
	9	33.1	6.1	3.7	215	121	43.7	26.2
	10	35.4	5.5	3.3	220	147	33.2	19.9
	Mean			**2.9**	**234.2**	**140.9**		**23.9**
C	11	18.7	10	6.0	348	133	61.8	37.1
	12	24.2	7.8	5.0	155	72	53.2	31.9
	13	25.7	10.1	6.1	147	93	36.5	21.9
	14	33.5	8.8	5.3	117	84	28.8	17.3
	15	28.5	7.6	4.6	86	50	41.9	25
	Mean			**5.4**	**170.6**	**86.4**		**26.6**
D	16	42.5	6.9	4.1	118	86	27.1	16.3
E	17	35	9.8	5.9	211	133	37.0	22.2
F	18	28.1	6.6	4	285	162	42.8	25.7
	19	26.3	4.9	4.9	321	188	41.4	24.8
	Mean			**4.5**	**303**	**175**		**25.3**

Table 6.3 Height increment (cm year^{-1}) and mortality (% year^{-1}) of seedlings by height class in site A, B and F

Height class (cm)	Block A				Block B				Block F			
	N_1	N_2	Increment	Mortality	N_1	N_2	Increment	Mortality	N_1	N_2	Increment	Mortality
≤ 5 - 29.9	563	344	7.4	38.9	795	395	2	30.2	435	214	4.3	30.5
30 - 59.9	204	184	11.8	9.8	196	154	3	12.8	116	89	4.7	14
60 - 89.9	67	62	10.3	7.5	92	75	4.3	11.1	33	27	10.3	10.9
90 - 119.9	44	44	12.6	0	49	43	5.6	7.3	15	13	7.9	8
120 - 149.9	28	28	18.8	0	17	16	7.6	3.5	6	6	21.7	0
150 - 179.9	11	10	19.8	9.1	13	11	5.9	9.2	1	1	5	0
≥ 180	7	7	22.8	0	9	8	4.7	6.7	-	-	-	-

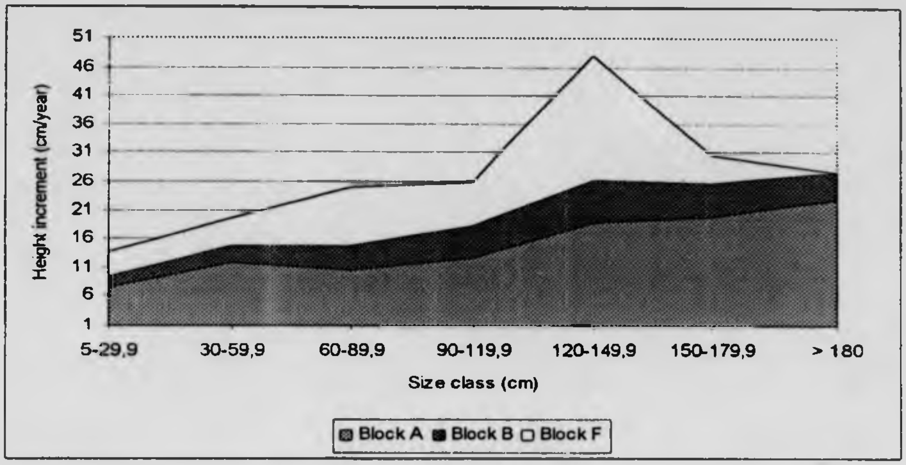


Figure 6.1 The initial height size classes (1991) of the seedlings and the height increment in Blocks A, B and F.

Increment and mortality of dipterocarps are compared with non-dipterocarps in Table 6.4. There were differences in the average annual increment of dipterocarps between Blocks A, B and F, with the highest increment in Block A. The difference in the average annual increment of dipterocarps was highly significant ($p<0.001$). The difference was shown between Block A and the other two Blocks, there was no difference in the dipterocarp seedling height increment between Block B and Block F, as indicated in the Tukey's test.

Canopy, subcanopy and understorey species might respond differently to canopy openings. Table 6.5 shows the increment and mortality of species in these categories by the Blocks A, B, and F. The species category was primarily based on the species grouping by Korning & Balslev (1994). The canopy, subcanopy and understory seedlings had the highest increment in Block A where the understory seedling species had a higher increment than the canopy and subcanopy seedlings. The understorey species had a much a higher increment in Block A than in B and F. The difference was highly significant ($p<0.001$) suggesting that seedlings of the understory species responded more to the canopy opening than under the shade in their earlier establishment.

The mortality of the three species categories differed little among the three Blocks (Table 6.5).

Table 6.4 Increment (cm $year^{-1}$) and mortality (% $year^{-1}$) of seedlings of dipterocarps and non dipterocarps in Blocks A, B and F

Block	Dipterocarps				Non dipterocarps			
	N_1	N_2	Increment	Mortality	N_1	N_2	Increment	Mortality
A	108	89	16.8***	17.6	816	590	8.9	27.7
B	249	130	3.0	28.7	922	572	2.8	37.9
F	200	100	3.9	30.0	411	254	4.7	38.2

Remarks: *** significant ($p < 0.001$)

Table 6.5 Increment (cm $year^{-1}$) and mortality (% $year^{-1}$) of seedlings of canopy, subcanopy and understorey species in sites A, B and F.

Block	Canopy				Sub canopy				Understory			
	N_1	N_2	Incr.	Mortl.	N_1	N_2	Incr	Mortl.	N_1	N_2	Incr	Mortl.
A	364	270	9.2	25.8	213	143	7.0	32.9	270	201	11.2***	25.6
B	397	232	3.1	25.0	381	230	2.2	23.8	230	147	3.0	21.7
F	281	144	4.5	29.3	162	86	4.8	28.1	108	71	4.6	20.6

Remarks: ***significant ($p < 0.001$)

The pattern of growth and mortality of the six commonest species is shown in Table 6.6. All the species grew faster in Block A than in Block B, and in Block F the species grew slightly faster than in Block B except *Hopea sangal* and *Xanthophyllum heteropleurum*. The dipterocarp species *Hopea sangal* and *Shorea parvistipulata* had a higher increment in Block A and showed no differences in the other Blocks. This indicates that both species grow faster under canopy openings. The six species included only one subcanopy species (*Hydnocarpus polypetalus*) and one understory species (*Polyalthia celebica*). The understory species *Polyalthia celebica* grew faster in Block A (3.6 cm year^{-1}) and in Block F (2.7 cm year^{-1}) compared with Block B (1.8 cm year^{-1}). Heavy mortality occurred in species with denser individuals (Table 6.6).

Table 6.6 Increment (cm year^{-1}) and mortality (% year^{-1}) of the six commonest seedling species (≥ 10 individuals) in Blocks A, B and F

Site	Species	N_1	N_2	Increment	Mortality
A	*Dacryodes rostrata*	67	29	5.8	56.7
	Hopea sangal	20	14	18.5	30
	Hydnocarpus polypetalus	14	11	7.0	21.4
	Polyalthia celebica	34	24	3.6	29.4
	Shorea parvistipulata	23	22	23.9	4.3
	Xanthophyllum heteropleurum	11	10	2.2	9.1
B	*Dacryodes rostrata*	12	8	1.9	20.0
	Hopea sangal	64	30	4.9	31.9
	Hydnocarpus polypetalus	14	14	2.9	0
	Polyalthia celebica	35	20	1.8	25.7
	Shorea parvistipulata	66	34	2.8	29.1
	Xanthophyllum heteropleurum	20	16	1.4	12
F	*Dacryodes rostrata*	23	9	2.5	36.5
	Hopea sangal	71	36	2.9	29.6
	Hydnocarpus polypetalus	25	15	3.6	24
	Polyalthia celebica	18	8	2.7	33.4
	Shorea parvistipulata	96	50	3.4	28.7
	Xanthophyllum heteropleurum	11	10	1.1	5.5

Saplings

The total number of individual saplings did not differ very much between Blocks A (7776 ha^{-1}), B (7632 ha^{-1}) and F (6840 ha^{-1}), however the number of individuals in Block C (2704 ha^{-1}) was much lower than in A, B and F (Table 6.7). The low number of saplings in Block C was due to the liberation treatment by the concessionary in 1991 (Table 3.1). Block D had 8640 saplings ha^{-1}.

The overall mean diameter increment was low in all blocks, ranging from 0.8 mm year^{-1} in Block F to 2.2 mm year^{-1} in Block C (Table 6.7). The difference in the diameter increment among Blocks A, B, C and F was not significant. There was a difference in the diameter increment among plots in Block A with the highest being in plot 1. The difference was significant ($p<0.001$). The average sapling height increment varied (but not significantly so) among Blocks, ranging from 12.6 cm $year^{-1}$ in Block A to 21.8 cm $year^{-1}$ in Block C (Table 6.7).

Table 6.7 Height (cm $year^{-1}$) and diameter (mm $year^{-1}$) increment, and mortality (% $year^{-1}$) of saplings in Blocks A - F.

Site	Plot	N_1	N_2	Mortality		Mean height increment	Mean diameter increment
A	1	66	66	0		10	1.9*
	2	209	207	0.9		18	0.6
	3	87	87	0		10	0.5
	4	74	74	0		10	1.1
	5	50	49	2.0		15	1.1
	Total	**486**	**483**	**0.62**	**Overall mean**	**12.6**	**1.0**
B	6	72	70	1.7		14	0.7
	7	88	86	1.5		21	0.8
	8	54	52	2.2		20	0.9
	9	146	140	2.5		20	1.1
	10	117	110	3.8		20	2.0
	Total	**477**	**458**	**2.39**	**Overall mean**	**19.0**	**1.1**
C	11	34	34	0		41	2.5
	12	34	33	1.7		20	1.3
	13	44	44	0		17	1.0
	14	42	39	4.3		17	2.9
	15	15	15	0		14	3.2
	Total	**169**	**165**	**1.42**	**Overall mean**	**21.8**	**2.2**
D	16	108	103	2.77		23	1.3
E	17	103	97	3.50		25	2.5
F	18	86	81	3.5		15	0.6
	19	85	83	1.4		18.6	0.9
	Total	**171**	**164**	**2.46**	**Overall mean**	**16.8**	**0.8**

Remarks: * significant ($p<0.001$)

The canopy opening resulting from the recent logging in Block A did not result in both greater mean height and diameter increment of saplings in this Block. Height increment in Block A was the lowest in all sites, and the diameter increment was only slightly higher than the diameter increment in Block F (unlogged forest) (Table 6.7).

The mean height increment in plot 17 (Block E) was similar to that in plot 16 (Block D) however the mean diameter increment in plot 17 of 2.5 mm year^{-1} was significantly ($p<0.001$) higher than in plot 16 of 1.3 mm year^{-1} (Table 6.7). The difference indicated a significant effect of the liberation treatment on sapling diameter increment in plot 17.

Mortality of saplings was ranked Block E > D > F B > A.

The number of dipterocarp saplings varied among Blocks with the highest in Block B (61 saplings) and the least in Block C (8 saplings) (Table 6.8). The low number of dipterocarp saplings in Block C indicated a faulty liberation treatment (from the concessionary's malpractice). Mean height and diameter increment of the dipterocarps did not differ significantly among Blocks. The diameter growth increment of dipterocarps in Blocks A and C was higher than non-dipterocarps, whereas in Blocks B, D, E and F it was lower (Table 6.8). Non dipterocarps in Block B consisted partly of pioneer tree species which showed higher growth than primary tree species (including dipterocarps) (Table 6.9). There were twelve pioneer tree species in Block B, mostly *Macaranga spp.*, with an average height increment ranging from 2 to 53 cm year^{-1} and a diameter increment from 0.3 mm year^{-1} (*Euodia aromatica*) to 6.1 mm year^{-1} (*Macaranga sp*) (Table 6.11). The mortality of the pioneers was low, with only one tree (out of 67) dying in 20 months (Table 6.9).

In Block B the average height increment of the pioneers (22 cm year^{-1}) (Table 6.9) was slightly lower than that of the dipterocarps (25 cm year^{-1}) (Table 6.8), but the average diameter increment of the pioneers of 2.7 mm year^{-1} was much higher than that of dipterocarps with 1.0 mm year^{-1}. The difference was significant ($p<0.001$). The height increment of the pioneer species did not differ much from the shade-bearing species in this site, whereas the mean diameter increment of the pioneers of 2.7 mm year^{-1} was significantly ($p<0.001$) higher than that of the shade-bearing species of 1.1 mm year^{-1} (Table 6.9).

Table 6.8 Growth increment of dipterocarp and non-dipterocarp saplings.

Block	Dipterocarps					Non-dipterocarps				
	N_1	N_2	Height increment (cm year^{-1})	Diameter increment (mm year^{-1})	Mortality (% year^{-1})	N_1	N_2	Height increment (cm year^{-1})	Diameter increment (mm year^{-1})	Mortality (% year^{-1})
A	30	29	21	1.3	3.33	456	454	13	0.9	0.44
B	61	60	25	1.0	1.02	416	398	18	1.4	2.58
C	8	8	22	2.4	0	161	157	22	2.0	1.49
D	29	29	29	1.1	0	79	74	22	1.3	3.8
E	27	27	29	2.2	0	76	70	23	2.6	4.7
F	10	10	17	0.3	0	161	154	17	0.8	2.61
	107	105	21.8	1.3	1.09	1196	1165	17.5	1.2	1.78

Table 6.9 Growth increment and mortality of pioneer and primary forest species in Block B

Species	N_1	N_2	Mean increment		Mortality (% year^{-1})
			Height (cm year^{-1})	Diameter (mm year^{-1})	
Pioneer species	67	66	22	2.7***	0.89
Shade-bearing species	410	392	18	1.1	2.63*

Remarks: ***significant ($p<0.001$)

The growth of the dipterocarp species in Block B is given in table 6.10. *Shorea johorensis* had the highest diameter increment of 1.6 mm year^{-1} followed by *S. parvifolia* with 1.3 mm year^{-1}. Both the species are relatively fast growing dipterocarps, included in *Shorea*-section Brachypterae (*Shorea* “Red Meranti” group) (Ashton, 1982).

In the unlogged forest (Block F) the height increment of the dipterocarps was the same as the non-dipterocarps, whereas the diameter increment of the dipterocarps was lower than the non-dipterocarps (Table 6.8). This implies that the diameter growth of the dipterocarp saplings in the virgin forest was very low.

Table 6.10 Growth increment and mortality of dipterocarps in Block B.

Species	N_1	N_2	Diameter increment (mm year^{-1})	Height increment (cm year^{-1})
Dipterocarpus hasseltii	2	2	1.1	10
Hopea sangal	10	10	0.7	37
Shorea fallax	23	23	0.7	14
Shorea johorensis	9	8	1.6	43
Shorea parvifolia	17	17	1.3	32

Pioneers in Block B had a higher average diameter (28.4 mm) and height (5.01 m) than dipterocarps at the first and second enumeration (Table 6.12).

The mortality of saplings was low in all sites. The percentage mortality in Block B (2.39% year^{-1}) did not differ very much from Block F (2.46% year^{-1}), both were much higher than in Block A (0.62 % year^{-1}) (Table 6.7). The difference in percentage mortality between Blocks A, B and F however was not significant. The average mortality of dipterocarps per Block (1.09 % year^{-1}) was not significantly lower than that of non-dipterocarps (1.78% year^{-1}) (Table 6.8). Pioneer tree saplings had less mortality than primary tree species in Block B with 0.89 % year^{-1} compared with 2.63 % year^{-1} (Table 6.9). The difference in mortality between the pioneer and the primary species in Block B was highly significant ($p<0.001$). The mortality in Block B (Table 6.7) was wholly of primary species, except in plot 10 where one pioneer sapling died.

Diameter increment increased with size class in sites A, B and F until the 40 mm class and then declined at the 60 mm class, whereas mortality occurred particularly for saplings in size class 40 - 59.9 mm and lower. None of the saplings in size class 60 - 79.9 mm and above died (Table 6.13).

Table 6.11 Growth increment and mortality of pioneer tree species in Block B

No	Species (family)	N_1	N_2	Increment		Mortality
				Height (cm year^{-1})	Diameter (mm year^{-1})	(% year^{-1})
1	*Cananga odorata* (Annonaceae)	1	1	20	0.5	0
2	*Euodia aromatica* (Rutaceae)	1	1	27	0.3	0
3	*Geunsia pentandra* (Verbenaceae)	1	1	33	0.8	0
4	*Glochidion sp* (Euphorbiaceae)	3	2	16	1.1	1
5	*Homalanthus populneus* (Euphorbiaceae)	2	2	2	1.5	0
6	*Macaranga conferta* (Euphorbiaceae)	3	3	13	1.1	0
7	*M. diepenhorstii* (Euphorbiaceae)	13	13	26	1.1	0
8	*M. gigantea* (Euphorbiaceae)	10	10	16	1.0	0
9	*M. hypoleuca* (Euphorbiaceae)	2	2	5	1.1	0
10	*Macaranga sp* (Euphorbiaceae)	2	2	53	6.1	0
11	*M. triloba* (Euphorbiaceae)	11	11	21	1.8	0
12	*Mallotus subpeltatus* (Euphorbiaceae)	18	18	35	5.8	0
	Total	67	66			

Table 6.12 Comparison of the average height and diameter between dipterocarps and pioneers in Block B in the first enumeration

Description	Dipterocarps		Pioneers	
	Height (m)	Diameter (mm)	Height (m)	Diameter (mm)
Mean	4.04	20.1	5.01	28.4
Minimum	2.03	5.7	2.04	5.8
Maximum	11.5	76.0	13.6	95.0
Median	3.76	17.1	4.62	22.8

Table 6.13. Diameter increment (mm $year^{-1}$) and mortality (% $year^{-1}$) of saplings by size-class in Blocks A, B and F.

Size-class (mm)	Block A				Block B				Block F			
	N_1	N_2	Incre-ment	Morta-lity	N_1	N_2	Incre-ment	Morta-lity	N_1	N_2	Incre-ment	Morta-lity
10 - 19.9	294	293	0.7	0.3	265	255	1.0	2.3	102	98	0.7	2.4
20 - 39.9	137	136	0.8	0.7	132	124	1.4	3.6	46	43	0.7	3.9
40 - 59.9	36	35	2.0	2.8	52	51	2.5	1.2	12	12	1.4	0
60 - 79.9	16	16	1.6	0	23	23	2.3	0	9	9	0.9	0
80 - 99.9	3	3	1.2	0	5	5	1.3	0	2	2	0.5	0

DISCUSSION

The seedling bank is important in forest regeneration after disturbance. The density of the seedling stock varies with forest type, soil and topography. In this study seedling density varied among Blocks and among plots of the same Block. The density of seedlings in the newly logged forest (Block A) for instance may to some extent be related to topography since the least density of seedlings occurred on steep slopes in plots 4 and 5 (Tables 3.1 and 6.1).

In Block A most seedlings could be derived from the existing seedlings before logging in August 1990, whereas in other logged-over Blocks seedlings may be derived mostly from the later recruits (seedlings germinated from the freshly dispersed seeds) after logging 12 years before.

The highest increment in plot 1 may be due to one or all of a lower density of trees ≥ 10 cm dbh (Table 5.1), relatively bigger canopy openings and relatively less disturbed plots (bare soil in this plot was not very compacted). Plot 2 was also lightly disturbed, but had more shade after regrowth following an earlier light logging in 1987 (Table 3.1).

The height increment of seedlings was ranked Block A > F > B (Table 6.14). The height increment in Block A could be due to the canopy opening after recent logging, particularly in plot 1. The lower increment in Block B than in Block F may due to a stage of forest

Table 6.14 Density, increment and mortality of seedlings in Blocks A - F.

Block	Density (ha^{-1}), 1991	Increment (cm $year^{-1}$)	Mortality (% $year^{-1}$)
A	73,920	10.5	25.5
B	93,680	2.9	23.9
C	68,240	5.4	26.6
D	47,200	4.1	16.3
E	84,400	5.9	22.2
F	121,200	4.5	25.3

development in this Block after the 1979 logging in which the forest floor was more shaded. The canopy opening resulting from the liberation treatment in Block C also caused a significantly higher increment than the untreated Block B. The seedling height increment increased with the initial height, in accordance with Nicholson (1958b).

The highest mortality in plot 3 of Block A may due to the least disturbance with the least canopy opening (Table 3.1), having shade and humidity similar to that in the virgin forest where the seedlings are vulnerable to pathogens (Connell 1989; Turner 1990). Mortality in all the plots was much higher in the first six months (average 21.3%) compared with the second six months (5.2%) (Table 6.1). This condition could be related to the humidity

December 1991 - July 1992 were wet while August - November 1992 had much less rainfall (Table 2.1, Fig. 2.2 and Appendices 2 and 6).

The mortality of seedlings among Blocks differed little. The least mortality in site D (16.3%) could be related to the relatively lower density of seedlings (Tables 6.2 and 6.14). Heavy mortality following the abundance of seedlings could be due to severe competition. Mortality declined with height class (Table 6.3) confirming Turner's (1990) suggestion that it was size dependent.

There may be variation among dipterocarp seedlings in their response to canopy opening (Baur, 1964; Liew & Wong, 1973). Certain seedling species like *Shorea multiflora* keep growing under the shade on the floor of virgin forest (Turner, 1990). In this study, the dipterocarp species *Hopea sangal* and *Shorea parvistipulata* had much higher increments than non-dipterocarps in the newly logged forest (Block A) (Table 6.6), whereas in Blocks B and F the two groups differed little. Both species may need light for their establishment since the canopy opening in Block A was more than in Blocks B and F.

The understorey species in this study showed more response to the canopy opening than the canopy and sub-canopy species. The understory species is an important stage for the pollinating insects to reach canopy-top trees during mass flowering.

Sapling stocking did not differ very much between Blocks except in Block C which had a liberation treatment. The stocking (excluding Block C) ranged from about 6,800 - 8,600 ha^{-1}. In plot 2 of the newly logged-forest Block A the number of saplings was 209 (16,700 ha^{-1}). The high number of the saplings in this plot may due to the regrowth after logging in this plot in 1987 (Table 3.1).

Dawkins (1958) found no increment of sapling growth after logging, whereas Nicholson (1965) noted the uncertainty of sapling (advance regeneration) growth. The uncertainty of sapling growth may due to the condition of the logged-over forest. In this study, saplings did respond to canopy openings caused by logging even though the growth was slow. Plot 1 in Block A had the widest canopy openings, and had the highest sapling diameter growth within the Block. It was also indicated by a higher diameter increment in the treated Block C, compared with the other Blocks (Table 6.7). The lower increment of saplings in the logged-over forest may be due to stronger competition with larger trees which respond better to the canopy openings.

The growth of the pioneer saplings was higher than that of dipterocarp saplings. Pioneer saplings were only present in the 12 years old logged-over forest, particularly in Block B, whereas pioneer seedlings were already scarce, indicating that the role of pioneers was diminishing at that age (Kuusipalo *et al*, 1996).

Low growth rates of saplings in the logged-over forest may indicate a different pattern of response to canopy openings from that in natural tree fall gaps. Competition of saplings with larger trees in the natural tree fall gaps may be less than in the logged-over forest resulting in vigorous gap growth of saplings formerly suppressed under the closed canopy.

CHAPTER 7 SOIL SEED BANKS

INTRODUCTION

This study is aimed at determining seed bank size and composition in different forest Blocks at Kintap. The recently logged-over and liberation-thinning Blocks were expected to have a bigger seed bank size than the unlogged forests owing to the new input when the canopy was open. It was also expected that the seed bank would consist largely of pioneer species which would be different from those occurring in mature forest.

MATERIALS AND METHODS

Sampling and shade house observations

Five soil samples of 30 cm by 30 cm and 5 cm deep were collected randomly in each of the 19 50 m x 50 m plots (Table 2.1) plus five samples randomly collected from a skidding road in plot 1. The sampling was done in all the plots on 23 - 31 January 1992 and all the samples were transferred to a shade house soon after collection. The shade house, situated in an open area beside the FINNIDA, camp was 8 m long, 6 m wide and 3 m high, constructed and covered with double layers of black shade cloth. The black shade cloth was neutral and maintained the balance between red and far red light. Far-red light inhibits the germination of secondary forest species, on the other hand red light promotes it (Vázquez-Yánes 1976, 1980). The intensity of light inside the shade house, measured by a camera (Nikon F 401 S), was 25% of the outside light.

In the shade house each soil sample was spread on a 23 cm x 33 cm tray containing 5 cm deep river sand. The river sand was taken from the bed of a c. 1 m deep stream about 50 m from the camp. The number of trays was 20 in five replicates plus five with river sand only, 105 trays in all. The trays were blocked (21 trays placed on each of 5 tables) inside the shade house. The trays were rerandomized on each table every two weeks. The samples were sprayed with river water as necessary to keep the soil moist. The seedlings which emerged were removed after 6 weeks and subsequently every week for 44 weeks. They were identifed in the Herbarium of the Forest Research Development and Nature Conservation Department, Bogor.

RESULTS

Size of seed bank

The size of seed bank ranged from 40 m^{-2} on the skidding road to 1084 m^{-2} in plot 15, and the density of seeds differed between plots within the same Block and between Blocks (Table 7.1). Block C had the highest average density of seeds with 616 m^{-2} and site A had the least density of 151 m^{-2}. The difference in the average seed density among Blocks A, B, C and F analysed by one-way ANOVA was highly significant ($p<0.001$). Block F (the unlogged forest) had an average of 280 m^{-2}, significantly higher than the average in Block A ($p<0.02$).

The number of seeds varied greatly among the plots, ranging from 33 (73 m^{-2}) in plot 5 (Block A) to 488 (1084 m^{-2}) in plot 15 (Block C) (Table 7.1). The peak of seedling numbers germinating occurred in week 14, and declined after that until week 28. In week 35 the numbers of seedlings germinating increased, and declined again until week 44 (Table 7.2 and Fig. 7.1).

Floristic composition

Species richness

Some species grew on the control (river sand) and were omitted from the results. The highest number of species was for plot 8 (Block B) with 29 species and the least was in plot 5 (Block A) with 11 species (Table 7.1). On the skidding road there were only 4 species from 18 seeds.

Table 7.1 The seed banks in the Kintap plots: number of species and density of viable seeds.

Block	Plot	Number of seeds		Number of species
		$0.45\ m^{-2}$	m^{-2}	
A (newly logged forest)	1	104	231	16
	2	118	262	19
	3	41	91	10
	4	43	96	13
	5	33	73	11
Average		67.8	151	
B (12 yr logged-forest)	6	152	338	25
	7	208	462	25
	8	146	324	29
	9	158	351	23
	10	197	438	22
Average		172.2	383	
C (12 yr logged-forest treated)	11	237	527	25
	12	230	511	28
	13	232	516	22
	14	200	444	28
	15	488	1084	23
Average		277.4	616	
D (12 yr logged-forest treated*)	16	88	195	20
E (12 yr logged-forest treated**)	17	140	311	21
F (unlogged-forest)	18	134	298	26
	19	118	262	17
Average		126	280	
Skidding road		18	40	4

Remarks: * lightly liberated
** intensively liberated

Table 7.2 Number of seedlings germinating from the seed bank after 7 - 44 weeks

No	Life form	Species	Week							Total
			7	14	21	28	35	42	44	
1	Grass	*Imperata cylindrica*		2	8	8	3			21
2	Grass	*Centotheca latifolia*	21	13	5	11	3			53
3	Forb	*Urena lobata*			2	2	3	4		11
4	Forb	*Pollia thyrdifolia*	1							1
5	Forb	*P. sozzogenensis*	41	15	16	2	17	8	1	119
6	Forb	*Halopegia blumei*		7	11	15	20	10	2	65
7	Forb	*Fimbristylis quinqueangularis*	1		2	3				6
8	Forb	*Drymaria cordata*		15	17	10	54	30	3	129
9	Forb	*Blumea balsamifera*		17	12	23	12	5	5	74
10	Liana	*Vitis adnata*			2	2	4			8
11	Liana	*Rubus sp*		2	6		1			9
12	Liana	*R. moluccanus*					1			1
13	Shrub	*Solanum torvum*		9	3	3	25	14	2	56
14	Shrub	*Ficus fistulosa*			2					2
15	Shrub	*Melastoma malabathricum*		68	215	104	276	163	14	840
16	Pioneer	*Trema orientalis*	10	33	11	19	16	5	2	96
17	Pioneer	*Ptychopixis costata*		12	2	2				16
18	Pioneer	*Parasponia parvifolia*		1	2	6				9
19	Pioneer	*Mallotus paniculatus*	5	30	3	2	1			41
20	Pioneer	*Macaranga triloba*	2							2
21	Pioneer	*Macaranga sp*	3							3
22	Pioneer	*Macaranga hosei*	5	1	2	8				16
23	Pioneer	*Homalanthus populneus*			10	8	1		1	20
24	Pioneer	*Glochidion sp*			1					1
25	Pioneer	*Glochidion kollmanianum*	129	65	23	17	12	3	5	254
26	Pioneer	*Ficus vasculosa*		2						2
27	Pioneer	*F. variegata*		15	28	39	20	7		109
28	Pioneer	*Ficus sp*		23	3	2	1			29
29	Pioneer	*F. melanocarpa*		1	1	2				4
30	Pioneer	*F. ampelas*		2	3	2	12	2		21
31	Pioneer	*Duabanga moluccana*		18	14	28	14	3		77
32	Pioneer	*Cananga odorata*		3		1	5			9
33	Pioneer	*Callicarpa cana*	259	346	2		1			608
34	Shade bearing	*Eugenia sp*		1	4	2	1			8
35	Shade bearing	*Buchanania sessilifolia*		8	22	5	3			38
36	Unidentified	*[68]*			1					1
37	Unidentified	*[67]*			9					9
38	Unidentified	*[66]*			1					1
39	Unidentified	*[65]*		1						1
40	Unidentified	*[64]*				1				1
41	Unidentified	*[63]*		1	65	4	2			72
42	Unidentified	*[60]*		2	1	1	1			5
43	Unidentified	*[55]*		1						1
44	Unidentified	*[53]*		18	39	1	1			59
45	Unidentified	*[49]*		6			1			7
46	Unidentified	*[47]*		8	7	4	1	1	2	23
47	Unidentified	*[43]*		56	13	29	18			116
48	Unidentified	*[26]*		2	4	1				7
49	Unidentified	*[22]*	3		5	1				9
50	Unidentified	*[19]*	3		2	7	3			15
	Total		483	748	622	378	544	273	37	3085
	Percentage of species present		26	68	80	70	62	26	20	

The number of species germinating showed a peak at week 21 with 40 species (Table 7.2). The number of species declined afterwards.

The treated Block C had the highest average number of seeds among Blocks, whereas Block A had a lower average number of seeds than Block F (the unlogged forest). Block E (plot 17), the intensively treated forest, had a higher number of seeds than the lightly treated Block D (plot 16) (Table 7.1).

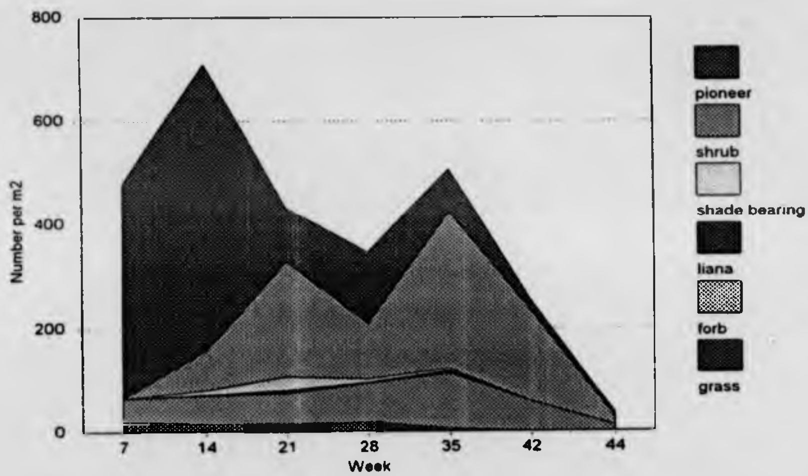


Figure 7.1 Number of seeds of different life forms germinated within weeks 7 - 44.

Composition

The most widespread species (occurring in 16 or more plots) included *Blumea balsamifera* (herb), *Callicarpa cana* (tree), *Duabanga moluccana* (tree), *Drymaria cordata* (herb), *Ficus variegata* (tree), *Glochidion kollmanianum* (tree), *Melastoma malabathricum* (shrub),

Table 7.3 Density, frequency and the Cover Value Index (CVI) of species presented as seed banks in all plots the CVI is calculated as the sum of relative density (RD) and relative frequency (RF) (Cox 1967)

No	Species	D	F	RD	RF	CVI
1	*Blumea balsamifera*	74	16	2.40	4.09	6.49
2	*Buchanania sessilifolia*	38	12	1.23	3.07	4.30
3	*Callicarpa cana*	608	16	19.71	4.09	23.80
4	*Cananga odorata*	9	5	0.29	1.28	1.57
5	*Centotheca latifolia*	53	14	1.72	4.58	5.30
6	*Drymaria cordata*	129	17	4.18	4.35	8.53
7	*Duabanga moluccana*	77	17	2.5	4.35	6.84
8	*Eugenia sp*	8	5	0.26	1.28	1.54
9	*F. fistulosa*	2	1	0.06	0.26	0.32
10	*F. melanocarpa*	4	4	0.13	1.02	1.15
11	*F. variegata*	109	16	3.53	4.09	7.63
12	*F. vasculosa*	2	2	0.06	0.51	0.58
13	*Ficus ampelas*	21	8	0.68	2.05	2.73
14	*Ficus sp*	29	8	0.94	2.05	2.99
15	*Fimbristylis quinqueangularis*	6	4	0.19	1.02	1.22
16	*Glochidion kollmanianum*	254	18	8.23	4.60	12.84
17	*Glochidion sp*	1	1	0.03	0.26	0.29
18	*Halopegia blumei*	65	16	2.11	4.09	6.20
19	*Homalanthus populneus*	20	10	0.65	2.56	3.21
20	*Imperata cylindrica*	21	10	0.68	2.56	3.24
21	*M. triloba*	2	1	0.06	0.26	0.32
22	*Macaranga hosei*	16	6	0.52	1.53	2.05
23	*Macaranga sp*	3	1	0.10	0.26	0.35
24	*Mallotus paniculatus*	41	13	1.33	3.32	4.65
25	*Melastoma malabathricum*	840	19	27.23	4.86	32.09
26	*P. thyrdifolia*	1	1	0.03	0.26	0.29
27	*Parasponia parvifolia*	9	2	0.29	0.51	0.80
28	*Pollia sozzogenensis*	119	18	3.86	4.60	8.46
29	*Ptychopyxis costata*	16	4	0.52	1.02	1.54
30	*Rubus moluccanus*	1	1	0.03	0.26	0.29
31	*Rubus sp*	9	4	0.29	1.02	1.31
32	*Solanum torvum*	56	15	1.82	3.84	5.65
33	*Trema orientalis*	96	17	3.11	4.35	7.46
34	*Unidentified [19]*	15	7	0.49	1.79	2.28
35	*Unidentified [20]*	7	3	0.23	0.77	0.99
36	*Unidentified [43]*	116	15	3.76	3.84	7.60
37	*Unidentified [47]*	23	11	0.75	2.81	3.56
38	*Unidentified [49]*	7	4	0.23	1.02	1.25
39	*Unidentified [53]*	59	12	1.91	3.07	4.98
40	*Unidentified [55]*	1	1	0.03	0.26	0.29
41	*Unidentified [60]*	5	3	0.16	0.77	0.93
42	*Unidentified [63]*	72	10	2.33	2.56	4.89
43	*Unidentified [64]*	1	1	0.03	0.26	0.29
44	*Unidentified [65]*	1	1	0.03	0.26	0.29
45	*Unidentified [66]*	1	1	0.03	0.26	0.29
46	*Unidentified [67]*	9	6	0.29	1.53	1.83
47	*Unidentified [68]*	1	1	0.03	0.26	0.29
48	*Unidentified[22]*	9	4	0.29	1.02	1.31
49	*Urena lobata*	11	6	0.36	1.53	1.89
50	*Vitis adnata*	8	3	0.26	0.77	1.03

Pollia sozzogenensis (herb) and *Trema orientalis* (tree) (Table 7.3). The highest density occurred for *Melastoma malabathrica* (840 seeds), followed by *Callicarpa cana* (608), *Glochidion kollmanianum* (254), *Drymaria cordata* (129), *Pollia sozzogenensis* (119) and *Ficus variegata* (109). Shade bearing species present in the seed bank were *Buchanania* *sessilifolia* and *Eugenia sp*. The former species had 38 seeds occurring in 12 plots, and the latter had eight seeds in 5 plots. *Imperata cylindrica*, the outstanding component of the degraded *Imperata* grassland, was present in 10 plots with 21 seeds, including plots 18 and 19 of the unlogged forest (Table 7.3 and Appendix 9).

Life form

The identified species were in seven life forms (Table 7.4). The pioneer trees contributed most to the viable seed bank with 1317 seeds (43 % of the total). This was followed by shrubs with 29.1 % and herbs with 13.3 %. *Callicarpa cana* (Verbenaceae) and *Glochidion*

Table 7.4 Density per life form and weeks of seedling germination

Life form	Week							Total
	7	14	21	28	35	42	44	
Grass	21	15	13	19	6	-	-	74
Forb	43	54	60	74	106	57	11	405
Liana	-	2	8	2	6	-	-	18
Shrub	-	77	220	107	301	177	-	898
Tree (pioneer)	413	552	105	136	83	20	8	1317
Tree (shade-bearing)	-	9	26	7	4	-	-	46
Unidentified	6	39	190	33	38	19	2	327

kollmannianum (Euphorbiaceae) made up most of the pioneers with a density of 608 and 254. Commercial secondary trees, *Trema orientalis* (Ulmaceae) and *Duabanga moluccana* (Sonneratiaceae) had also relatively high density and were frequent in the sites studied (Tables 7.2 and 7.3). *Melastoma malabathricum* (Melastomataceae) was the most important shrub and had 840 (93 %) of the total shrub seeds. Lianas consisted of three species with few seeds (Table 7.4). There were very few shade-bearing trees in the seed banks, i.e *Buchanania sessilifolia* and *Eugenia sp* which had 38 and 8 seeds respectively.

Table 7.5 Weeks of the initial and extended period of germination of trees and number of seeds by Block

No	Species	Week of first germination	Period of germination (weeks)	Number of seeds by Block					
				A	B	C	D	E	F
1	*Buchanania sessilifolia*	10	29	1	7	23	-	5	2
2	*Callicarpa cana*	7	17	21	87	436	3	10	51
3	*Cananga odorata*	10	34		4	4	1	-	-
4	*Duabanga moluccana*	12	42	10	19	39	1	6	2
5	*Eugenia sp*	9	32	1	1	3	-	3	-
6	*Ficus ampelas*	12	36	1	6	2	-	-	10
7	*F. melanocarpa*	12	28	-	1	1	-	-	2
8	*Ficus sp*	12	29	1	2	21	-	-	5
9	*F. variegata*	12	42	11	40	35	5	7	11
10	*F. vasculosa*	12	-		2	-	-	-	-
11	*Glochidion kollmanianum*	7	44	37	71	92	17	6	31
12	*Glochidion sp*	18				1	-	-	-
13	*Homalanthus populneus*	17	44	6	2	8	1	3	-
14	*Macaranga hosei*	7	26	-	4	9	2	-	-
15	*Macaranga sp*	7	-	-	3	-	-	-	-
16	*M. triloba*	7	-	-	-	2	-	-	-
17	*Mallotus paniculatus*	6	31	1	12	25	1	-	2
18	*Parasponia parvifolia*	11	25	-	9	-	-	-	-
19	*Ptychopyxis costata*	10	24	-	1	13	2	-	-
20	*Trema orientalis*	6	44	14	17	47	6	7	5
	Total			104 46 m^{2}	288 128 m^{2}	761 338 m^{2}	39 87 m^{2}	47 104 m^{2}	121 134 m^{2}

There were differences between tree species in their period of germination. In weeks 6 and 7 they included *Callicarpa cana*, *Glochidion kollmanianum*, *Macaranga hosei*, *Macaranga sp*, *M. triloba*, *Mallotus paniculatus* and *Trema orientalis*,. All *Ficus* seeds germinated in week 12, and the last to germinate were *Homalanthus populneus* (week 17) and *Glochidion sp* (week 17) (Table 7.5). Some species extended their germination until week 44, including *Glochidion kollmanianum*, *Homalanthus populneus*, and *Trema orientalis*. *Duabanga moluccana* germinated in week 12 and carried on until week 42. *Callicarpa cana* contributed most (46%) to the tree seed bank with 608 seeds (Appendix 9).

The tree seed bank was ranked Block C 338 m^{-2} > Block F 134 m^{-2} > Block B 128 m^{-2} (Table 7.5). The plots in Block A had the smallest tree seed bank with 46 m^{-2} (Table 7.5).

DISCUSSION

The density of seeds in the unlogged forest was 280 m^{-2} (Table 7.1). This was higher than the 131 m^{-2} in the mature forests of Pasoh Forest Reserve (Putz & Appanah 1987), but lower than the 592 m^{-2} in primary lowland forests in North Queensland (Hopkins & Graham 1984). The size of the seed bank in primary forests in Kalimantan was recorded as 627 m^{-2} by Santoso (1995) at Kuala Kayan and 175 m^{-2} by Prajadinata (1996) at Barito Ulu. The seed bank in Block A was lower than in the unlogged forest (Table 7.1) similar to the observations of Putz & Appanah (1987) and Abdulhadi & Lamb (1987). This may due to the timing of sampling. The timing of sampling in Block A (the newly logged-forest) was 4 months after logging, and it is likely that some seeds had already germinated and developed into seedlings reducing the size of the seed bank.

The contribution of the seed rain is likely to increase during succession, as was reported in a study on the re-growth on an abandoned farm in Australia where the peak seed bank occurred in the 20 years old re-growth (Abdulhadi & Lamb 1987). In the oldest re-growth the proportion of long-lived seeds may be higher than of short-lived seeds, and the seed bank size decreases as the short-lived seeds die, and the pioneer trees are out-competed by later succession species.

Seed bank size after disturbance may also depend on the timing of sampling. Within a month after disturbance many buried seeds may have germinated. Ng (1983) reported that 50% of seeds in the seed banks germinated within 6 weeks, resulting in a decrease of seed bank size. The rate of accession of freshly dispersed seeds into the seed pools may be related to the size of the disturbed area. Kramer (1926) and Brokaw (1980) found that the density of pioneer tree species increased with gap size. In Pasoh Forest Reserve the gaps caused by tree falls are generally small, hence the rate of accession of the freshly dispersed seeds into the gaps may be slow. Furthermore there is a scarcity of pioneer tree species near Pasoh and the number of seedlings germinated from the seed bank reaches up to seven times that from the newly dispersed seeds (Putz & Appanah 1987). Dirzo *et al.* (1992) reported that in young (1 - 2 years) large gaps (>400 m^2) the rate of closure was more than in small gaps due to the availability of light which allowed the surrounding vegetation to grow more rapidly. He found that both number of species and density of seed banks did not vary significantly with gap size and age. Unfortunately Dirzo *et al.* (1992) dealt with only one life form, the understory herb community.

The liberation treatment had a significant effect ($p<0.001$) on the size of the seed bank in Block C perhaps because the treatment allowed more freshly dispersed seeds to fall onto the ground. Similarly the intensively treated Block E (plot 17) had a higher number of seeds than the lightly treated Block D (plot 16). In terms of species diversity however there were no differences between the treated and untreated logged-over forests (Table 7.1).

Pioneer tree species had a higher proportion (43%) than any other life form. This was similar to most other tropical rain forests such as Panama 90% (Putz 1983), Nigeria 43% and 68% (Keay 1960) and Venezuela 90 - 96% (Uhl 1981). Liew (1973) reported that 61% of the soil seed bank consisted of pioneer tree species in Sabah, but a lower proportion (29%) occurred in Pasoh Forest Reserve (Putz & Apannah 1987). Hopkins & Graham (1984) reported that secondary or pioneer species accounted for 90% of the seed bank in all samples from Queensland rain forests.

The most frequent pioneer trees at Kintap were *Callicarpa cana*, *Duabanga moluccana*, *Ficus variegata*, *Glochidion kollmanianum* and *Trema orientalis*. *Duabanga moluccana* and *Trema orientalis* were present in the soil seed bank in Sabah and they took a similar time to germinate (Liew 1973). *Callicarpa cana* and *Trema orientalis* were among the commonest species occurring in the soil seed banks at Barito Ulu, Central Kalimantan (Prajadinata 1996). In the Kintap sample plots, *Macaranga* had only three species (*Macaranga hosei*, *M. triloba* and *Macaranga sp*), all with a low density in spite of their abundance as trees in the surrounding areas. There were at least seven species of *Macaranga* occurring in the Kintap area, including *M. conferta*, *M. diepenhorstii*, *M. gigantea*, *M. hosei*, *M. hypoleuca*, *Macaranga sp* and *M. triloba*. They were commonly found along the logging roads and logged areas along with other pioneers such as *Anthocephalus chinensis* and *Octomeles sumatrana* which were also absent in the seed banks in this study. *Anthocephalus chinensis* and *Macaranga hypoleuca* were in the seed bank in Sabah (Liew 1973).

The absence or scarcity of a number of pioneers in the seed banks, albeit their relative abundance at particular sites, was a common feature in the Australian forests studied by Hopkins & Graham (1983). This may be related to the seeds' longevity, and hence on the timing of sampling (Cheke *et al.* 1979). The pioneer seeds therefore may generally be divided into long-lived seeds that are present in the seed banks under the closed canopy of primary forests, and short-lived seeds of the pioneers capable of continuous input of fresh seeds in the re-growth.

Melastoma malabathricum was an important shrub species in this study and contributed 93% of all shrubs in the seed banks. This species was also dominant in most of the regrowth in shifting cultivation sites in Barito Ulu (Prajadinata 1996) and present at Pasoh Forest Reserve (Putz & Appanah 1987) and beneath lowland tropical rain forests North Queensland (Hopkins & Graham 1983).

CHAPTER 8 SEED RAIN OF DIPTEROCARPS AND SOME NON-DIPTEROCARPS

INTRODUCTION

Abundant dipterocarp seed fall follows mast flowering and fruiting which occur at irregular intervals, depending on the physiological readiness of the trees and the trigger of a sharp increase in temperature or irradiation. Some non-dipterocarps may follow the pattern of dipterocarp seed fall, and many non-dipterocarps may flower and fruit throughout the year to provide food to frugivorous animals. Dipterocarp species may have a different pattern of flowering and fruiting in a good seed year, particularly the time of first flowering and fruiting and then their duration of the flowering and fruiting time.

The study on seed rain at Kintap was aimed at determining its' monthly fluctuations in the logged-over and unlogged forest from February 1992 - March 1993 and was related to the composition of the dipterocarp trees occurring in the sites studied.

MATERIALS AND METHODS

Twelve seed traps of rectangular wooden trays 50 cm by 50 cm and 15 cm deep were put in every plot (50 m x 50 m), each randomly placed in alternate 10 m x 10 m subplots. A total of 228 traps were placed in the 19 plots in Blocks A – F on 1 – 8 January 1992. The traps had a fine 1 mm^2 mesh and had four legs of 15 cm at each corner. The first collection was made on 6 February 1992, and after that, every month for 14 months. The fruits and seeds were put in a plastic bag separately by species from each tray. Wet fruits and seeds were air-dried. The number of the seeds collected every month was recorded, and all those of dipterocarps and some of non-dipterocarps were identified.

RESULTS

A total of 4534 seeds (excluding that from a *Ficus* fruit which had seeds too numerous to count) was collected in the 14-month period. Most of the seeds and fruits were trapped in February - April 1992 with 3739 seeds (about 83% of the total). The peak occurred in March 1992 with 2055 seeds (45%) (Table 8.1 and Fig. 8.1). Seed fall per m^2 was ranked Block C > E > A > D >B > F (Table 8.1). Block C included plots 13 (633 seeds) and 14 (222 seeds) in March 1992 (Table 8.1). In plot 13 the seeds were mostly from only two different unidentified species (No. 045 , 312 seeds, and No. 173, 256 seeds), and in plot 14 mostly from two species (No. 173, 85 seeds, and No. 174, 128 seeds). The seeds from plots 13 and 14 were small with a diameter of 2 - 3 mm.

A high proportion of dipterocarp seeds occurred in March and April 1992 with 349 and 322 seeds respectively. In May 1992 there were only two dipterocarp seeds trapped, one of *Shorea parvifolia* and one of *S. leprosula* (Table 8.3 and Appendix 10). There were no dipterocarp seeds trapped afterwards until March 1993.

The number of seeds trapped varied among Blocks and between plots within the same Block, for both dipterocarps and non-dipterocarps. Block A had the highest number of dipterocarp seeds trapped with 236 in 15 m^2 (15.7 m^{-2}) (Table 8.2).

The total number of dipterocarp seeds trapped was 847 in 19 plots (14.9 m^{-2}), belonging to 12 species and 3 genera, including 8 species of *Shorea* (Table 8.3). These *Shorea* are included in section Richetioides (*Meranti-Damar Hitam*), i.e *Shorea faguetiana*, *S. hopeifolia* and *S. polyandra*, and sections Brachypterae, Mutica and Ovalis (*Red-Meranti*), i.e. *S. parvistipulata*, *S. johorensis*, *S. leprosula*, *S. ovalis* and *S. parvifolia*. *Shorea* *johorensis* had the highest number of seeds trapped with 240, followed by *S. parvistipulata* 163, *S. ovalis* 98 and *S. parvifolia* 80 seeds.

Table 8.1 Number of seeds trapped in plots 1-19 in 14 months, 6 February 1992 - 25 March 1993, Kintap, South Kalimantan.

Block	Plot	Month 2	3	4	5	6	7	8	9	10	11	12	1	2	3	Total
		1992											1993			
A	1	30	49	42	42	33	-	-	-	2	2	11	4	-	2	217
	2	66	60	23	1	7	2	-	4	3	5	7	2	-	3	183
	3	85	161	83	5	3	1	1	4	2	-	5	2	-	8	360
	4	50	65	60	7	9	-	-	4	4	6	1	-	3	-	209
	5	25	93	27	22	39	3	7	4	-	-	2	-	-	3	225
																1194 (79.6 m⁻²)
B	6	37	58	28	15	11	-	1	2	4	-	3	6	1	8	174
	7	25	99	44	6	9	-	1	-	1	-	5	9	2	-	201
	8	32	102	25	4	17	3	2	1	2	4	5	1	1	1	200
	9	27	53	34	4	10	-	1	4	2	18	7	-	1	3	164
	10	21	16	130	4	13	-	-	-	-	-	7	-	1	4	196
																935 (62.3 m⁻²)
C	11	3	50	36	-	-	-	-	5	2	-	1	1	1	-	99
	12	13	33	17	-	-	-	1	-	1	29	4	3	2	3	106
	13	67	633	81	-	3	-	-	2	1	56	-	20	-	9	872
	14	64	222	31	-	-	-	-	-	-	-	-	12	-	3	332
	15	101	49	42	-	11	-	-	12	1	-	9	2	-	13	241
																1650 (110 m⁻²)
D	16	31	100	49	5	15	1	1	1	-	-	2	-	4	-	**208 (69.3 m⁻²)**
E	17	83	122	72	1	27	-	3	-	-	1	1	-	-	1	**312 (104 m⁻²)**
F	18	11	41	47	2	2	2	-	2	1	2	3	-	1	4	116
	19	4	49	38	7	6	-	2	1	-	3	4	1	1	3	119
																235 (39.2 m⁻²)
Total		**775**	**2055**	**909**	**125**	**215**	**12**	**20**	**46**	**26**	**125**	**77**	**63**	**18**	**68**	**4534**

Table 8.2 Number of seeds of dipterocarps (D) and non-dipterocarps (ND) trapped in February - May 1992, Kintap, South Kalimantan (no more dipterocarp fruits trapped after this until March 1993).

Block	Plot No.	Month								Total	
		February		March		April		May			
		D	ND	D	ND	D	ND	D	ND	D	ND
A	1	20	10	11	38	13	29	-	42	44	119
	2	44	22	33	27	20	3	1	-	98	52
	3	3	82	3	158	5	78	-	5	11	323
	4	15	35	15	50	5	55	-	7	35	147
	5	4	21	30	63	14	13	-	22	48	119
Subtotal		86	170	92	336	57	178	1	76	236 (15.7 m^{-2})	760 (50.7 m^{-2})
B	6	5	32	4	54	4	24	-	15	13	125
	7	1	24	12	87	13	31	-	6	26	148
	8	-	32	4	98	2	23	-	4	6	157
	9	24	3	35	18	29	5	-	4	88	30
	10	-	21	-	16	3	127	1	3	4	167
Subtotal		30	112	55	273	51	210	1	32	137 (9.1 m^{-2})	627 (41.8 m^{-2})
C	11	-	3	16	34	12	24	-	-	28	61
	12	7	6	8	25	8	9	-	-	23	40
	13	-	67	20	613	22	59	-	-	42	739
	14	24	40	8	214	29	2	-	-	61	256
	15	-	101	-	49	1	41	-	-	1	191
Subtotal		31	217	52	935	72	135	-	-	155 (10.3 m^{-2})	1287 (85.8 m^{-2})
D	16	13	18	43	57	31	18	-	5	87 (29 m^{-2})	98 (32.7 m^{-2})
E	17	7	76	64	58	46	26	-	1	117 (39 m^{-2})	161 (53.7 m^{-2})
F	18	3	8	20	21	29	18	-	2	52	49
	19	4	-	23	26	36	2	-	7	63	35
Subtotal		7	8	43	47	65	20		9	115 (19.2 m^{-2})	84 (14 m^{-2})
Total		174	601	349	1706	322	587	2	123	847 (14.9 m^{-2})	3017 (52.9 m^{-2})

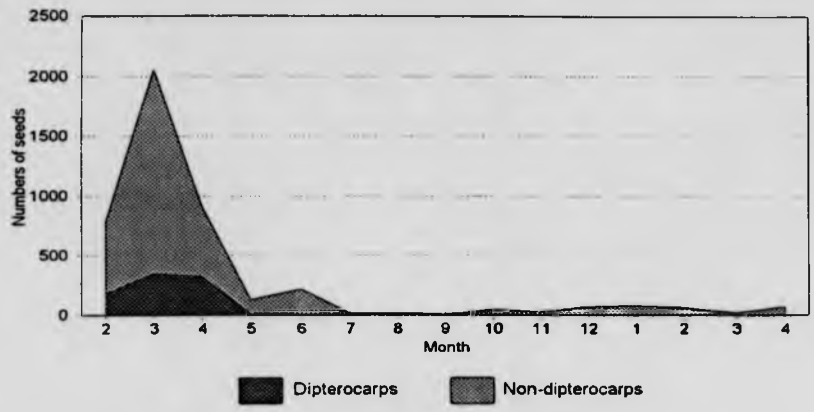


Figure 8.1 Numbers of dipterocarp and non-dipterocarp seeds trapped during Febrary 1992 - March 1993, Kintap, South Kalimantan.

There were differences in time and plots of seed abundance between species. *Shorea parvistipulata* had abundant seeds in April 1992, particularly in plots 9, 18 and 19, *S. johorensis* seeds were abundant in March 1992, mainly in plots 9 and 17, and *S. ovalis* in April 1992 in plots 12 and 17. *Shorea parvifolia* had a similar seed fall in February and March 1992, mainly in plots 2 and 16. *Hopea sangal* had seed fall trapped mostly in plot 2 with 68 seeds. The total fall of this species was 70 seeds, trapped in plots 2 and 10 in February - April 1992 (Table 8.3).

Most of the dipterocarp species had been trapped since February 1992. Some species were trapped in March 1992, including *Dipterocarpus humeratus*, *D. gracilis*, *Shorea ovalis* and *S. polyandra* (Table 8.3).

Some identified non-dipterocarp seeds trapped included *Durio acutifolius*, *Gluta wallichii*, *Quercus* and *Pentaspadon motleyi* (Table 8.3). *Pentaspadon motleyi* had the highest number of seeds trapped with 93 seeds, followed by *Gluta wallichii* (74 seeds) and *Quercus*

(29 seeds). Non-dipterocarp seeds were trapped particularly during February - April 1992, with a peak in March 1992.

Table 8.3 Number of seeds trapped by species of dipterocarps and non-dipterocarps, Kintap, South Kalimantan, February - May 1992

Species	February	March	April	May	Total
Dipterocarps					
Dipterocarpus gracilis	-	1		-	1
D. hasseltii	-	-	1	-	1
D. humeratus	-	1	1	-	2
Hopea sangal	31	21	18	-	70
Shorea faguetiana	-	29	21	-	50
S. parvistipulata	14	41	108	-	163
S. hopeifolia	6	13	8	-	27
S. johorensis	65	116	59	-	240
S. leprosula	26	33	12	1	72
S. ovalis	-	36	62	-	98
S. parvifolia	32	39	8	1	80
S. polyandra	-	19	24	-	43
Total	**174**	**349**	**322**	**2**	**847**
Non-dipterocarps					
Carallia brachiata	-	10	11	-	21
Durio acutifolius	5	1	-	-	6
Gluta wallichii	5	64	5	-	74
Quercus sp.	6	21	2	-	29
Lithocarpus blumeanus	1	2	1	-	4
Pentaspadon motleyi	13	67	13	-	93
Total	**30**	**165**	**32**	**-**	**227**
Palms					
Calamus caesius	1	1	-	-	2
C. manau	-	2	-	-	2
Total	**1**	**3**	**-**	**-**	**4**

DISCUSSION

The mast fruiting in Kintap occurred early in 1992 following a gregarious flowering in November - December 1991. A high average maximum temperature (up to 34.6^0 C) and a high average maximum irradiation (87 - 91 % of 8 hours exposure) had been recorded in

Pelaihari (about 60 km from the study site) in July - September 1991 (Figs. 8.2 and 8.3). The irradiation in the rest of the months in 1991 was 32 - 77% (Figs. 8.2 and 8.3; Appendices 3 and 7). Hence the flowering in November - December 1991 in Kintap which resulted in abundant seeds trapped in February - April 1992 followed a high average maximum temperature and irradiation in August - October 1991.

Figure 8.2 shows a sharp increase in the average maximum temperature from 32.1^{0} C in July to 33.6^{0} C and 34.6^{0} C in September and October 1991. Figure 8.3 shows a sharp increase in monthly average percentage irradiation from May to July 1991. A maximum intensity of irradiation for Kepong was measured as sunshine hours where the increase of 2.8 - 4.4 hours stimulated gregarious flowering (Ng 1977). The increase in the average percentage sunshine hours in the Tanah Laut district, South Kalimantan, from 47 % (3.8 hours) in May to 91 % (7.3 hours) in July 1991 (Fig. 8.3) should stimulate the gregarious flowering. In 1992 the increase of the average maximum sunshine hours from May to August was about 2.9 hours. This increase in the average monthly maximum irradiation however, did not stimulate gregarious flowering in early 1993, and similarly the increase in the average maximum temperature in July - October 1992 (Fig. 8.2) was likely to be insufficient to stimulate a gregarious flowering.

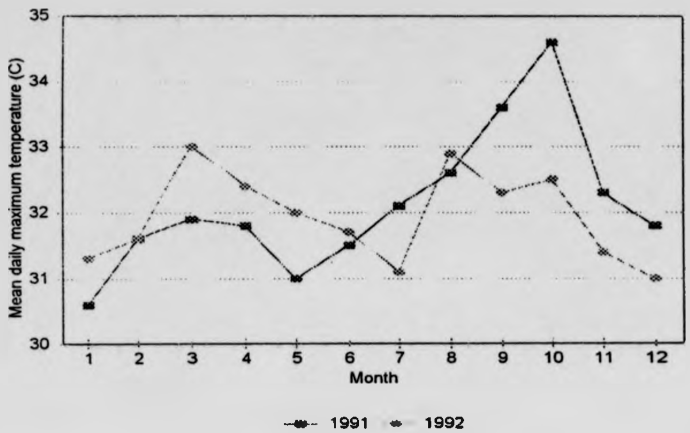


Figure 8.2 Monthly average daily maximum temperature recorded in Pelaihari, South Kalimantan, 1991 - 1992.

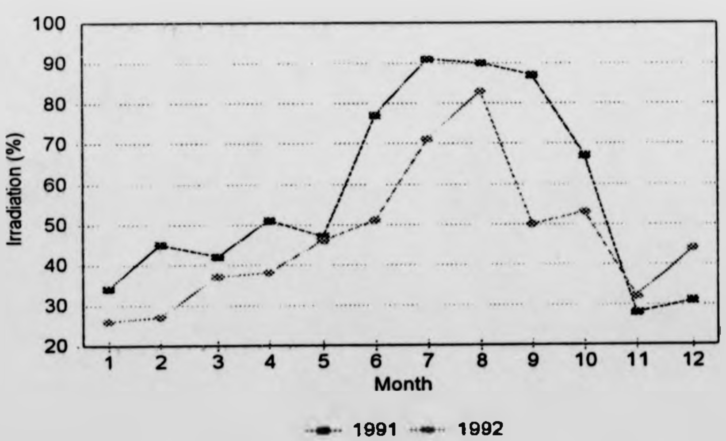


Figure 8.3 Monthly average maximum irradiation measured in Pelaihari, South Kalimantan, 1991 - 1992.

The germination percentage of woody species (including dipterocarps) was 69 - 77% at 10 - 14 weeks after seed fall (Ng 1980). If the percentage germination was similar at Kintap, there would be at least 10 seeds germinating from the average of 14.9 m^{-2}, which is equivalent to 100,000 ha^{-1}.

The number of dipterocarp seeds trapped varied between plots, ranging from 1 (plot 15) to 117 (plot 17) (Appendix 10). The variation between plots may reflect differences in density and species. Four species contributed most to the seed fall, i.e. *Shorea johorensis*, *S. parvistipulata*, *S. ovalis* and *S. parvifolia*. The former species had seed fall in 12 plots, and the second and the last in 11 plots out of the total 19 plots. The third species, *Shorea ovalis*, had seed fall in 5 plots but had more seeds (98 seeds) than *S. parvifolia* (80 seeds). *Shorea parvifolia* had the smallest seeds of the four and may have a greater seed dispersal distance.

The inventory of trees of ≥ 10 cm dbh in November 1991 showed 21 dipterocarp species in total: *Dipterocarpus* (4 species), *Hopea* (4 species), *Shorea* (10 species) and *Vatica* (3 species) (Table 8.4). The seed fall was of 12 species, mostly *Shorea* (8 species), and none of *Vatica*. *Hopea sangal* was the only species of the genus which provided seed fall, mainly in plot 2 (Appendix 10). It appears that even during a gregarious flowering many individual trees and some species may not flower.

The number of dipterocarp seeds trapped in February - May 1992 was 847 (only 2 seeds trapped in May 1992), an average of 14.9 m^{-2} (Table 8.1). This figure is quite high.

Table 8.4. Dipterocarp composition in 19 50 m x 50 m plots (=4.75 ha) Kintap, South Kalimantan, November 1991

No	Species	Diameter class (cm)						
		10 - 19	20 - 39	40 - 59	60 - 79	80 - 99	>100	N
1	*Dipterocarpus caudiferus*	8						8
2	*D. gracilis*	1	2					3
3	*D. hasseltii*	2	1	4				7
4	*D. humeratus*		1	1				2
5	*Hopea dryobalanoides*	3	2	1				6
6	*H. ferruginea*	2						2
7	*H. sangal*	5	2	2				9
8	*H. tenuinervula*	1						1
9	*S. hopeifolia*	25	21	12	1			59
10	*S. johorensis*	96	27	6	2		1	132
11	*S. laevis*	4	6	1				11
12	*S. leprosula*	9	1					10
13	*S. multiflora*	1						1
14	*S. ovalis*	34	4	1				39
15	*S. parvifolia*	36	16	1	1			54
16	*S. parvisipulata*	34	15	8	10	4	1	72
17	*S. polyandra*	5	2	1				8
18	*Shorea faguetiana*	8	5	3		2		18
19	*V. rassak*	16	17	1	2			36
20	*V. umbonata*	1	1					2
21	*Vatica odorata*	1						1
	Total	**292**	**123**	**42**	**16**	**6**	**2**	**481**

The highest number of seeds trapped in plot 17 may reflect that it had 29 trees of diameter ≥ 20 cm (Appendix 12). *Shorea johorensis* had 14 trees ≥ 20 cm dbh, and had 85 seeds out of the total of 117 dipterocarp seeds collected from this plot. In plot 2, *Shorea johorensis* had 27 trees, but only three were ≥ 20 cm dbh (Appendix 12), and this plot contributed only four seeds trapped in March 1992 (Appendix 10). Plot 15 had the least number of seeds trapped (1) and had 2 species of dipterocarp: *Dipterocarpus hasseltii* (one) and *Shorea polyandra* (three) all with a diameter < 20 cm dbh (Appendix 12). The single seed trapped was of *Dipterocarpus hasseltii* which may have fallen from outside the plot (Appendix 10).

In February - May 1992 there were 3017 non-dipterocarp seeds trapped (52.9 m^{-2}) (Table 8.2). This includes the seeds produced by species which flower throughout the year, but the highest proportion seems to be from the species which took part in the gregarious flowering. The identified non-dipterocarps had seed fall only until April 1992 with the peak in March 1992 (Table 8.3; Appendix 11), none of the species had seed fall after this until March 1993. This is similar to the dipterocarps and suggests that many non-dipterocarps have the same response as dipterocarps to an increase of temperature and irradiation.

CHAPTER 9 CONCLUDING REMARKS

The conclusions are made in the light of the aims of the thesis as set out in the Introduction.

(a) The physical environment at Kintap has been described and all relevant information collated. The rainfall at the FINNIDA camp was relatively high and reached 3980 mm in 1993. There was a pronounced dry and sunny season from August to October. Temperatures recorded at Pelahari (60 km west of Kintap) were relatively constant with daily averages from 26.4^0 C in January to 27.6^0 C in October. The average relative humidity ranged from 76% to 87%.The soil types at Kintap were mainly Ultisols and had a relatively high pH (4.8 – 6.0) among the investigated Blocks and were relatively rich in nutrients.

(b) There were at least 305 species of trees ($\geq$10 cm dbh) in the 4.75 ha of non-contiguous blocks in the study area. The Dipterocarpaceae were dominant overall with *Hopea sangal*, *Shorea johorensis*, and *S. parvistipulata* as the most frequent. The second most dominant family varied: Anacardiaceae in Block A, Flacourtiaceae in Blocks B, E, and F, and Euphorbiaceae in in Blocks C and D. In a total of 1.25 ha (five 50 m x 50 m plots in each Block) Block C had 167 species, Block B 163, and Block A 131 species. The higher numbers in Blocks B and C reflect the presence of pioneers. The most valuable non-dipterocarp, the ironwood, *Eusideroxylon zwageri* was codominant in Blocks B and C. The evidence from the Kintap plots suggests that even fairly heavy logging damage might not appreciably reduce tree species diversity at least within the confines of the present investigations.

(c) Logging activities caused much unharvested loss of mainly small trees and, in the most closely investigated Block A, ranged from 6 to 40 trees in each 0.25 ha plot killed by felled trees or uprooted by bulldozers. There is clearly much scope for research into minimal-impact logging procedures. The control unlogged Block F lacked commercial species initially and if experiments in rain forest silviculture are to be continued then close cooperation between the loggers and scientists will need to be maintained. Otherwise there will be the result, as at Kintap, that atypical economically worthless stands (such as Block F) are reserved as controls.

(d) The growth of the trees (basal area increment plus recruitment) in the remaining stands of the logged-over forest ranged from 0.64 m^2 ha^{-1} $year^{-1}$ (the unlogged-forest patches Block F) to 4.12 m^2 ha^{-1} $year^{-1}$ (the treated twelve years old logged-over forest Block C) (Table 9.1). The results indicate very slow growth of the unlogged forest and the accelerated growth of the treated logged-over forest. The liberation treatment in the 12-years old logged-over forest Block C however did not result in significant differences in tree growth compared with the untreated 12-years old logged-over forest Block B. It must be pointed out however that Block B had experienced illegal cutting, burning, and a violent storm, resulting in the thinning of most of the plots in this Block. The intensively liberated 12-years old logged-over forest Block E (plot17) had a significantly higher growth increment compared with the lightly treated Block D (plot16). The growth rates of trees in the unlogged-forests Block F (average 0.4 – 2.6 mm year^{-1}) was much lower compared with the newly logged-forests Block A (0.3 – 10.6 mm year^{-1}) and with the 12-years logged-forests Block B (0.8 – 10.9 mm year^{-1}).

The growth of the remaining stands depends to some extent on site characteristics like topography and on the composition of the trees. The Dipterocarpaceae showed the highest growth increment in the study areas (Tables 5.3, 5.8, 5.13). The highest growth rate of the dipterocarps was shown by *Shorea johorensis* (1.05 cm year^{-1}) and *S. parvifolia* (1.22 cm year^{-1}). In general canopy species grew faster than subcanopy species, and the latter generally grew faster than the understory species.

The soil properties may be related with the growth rate of trees and saplings. This was indicated by Block C where growth rate of trees and saplings was the highest (not significant) in all Blocks. Block B which had higher average exchangeable cations than Block A had also higher growth rate of saplings and trees than Block A.

Mortality and recruitment varied among and within the sites studied. Mortality rate was highest in the newly logged-forest compared with the 12-years old logged-over forest (Table 9.1). This indicates the short-term effects of the logging in which the damaged trees tended to die within the first few years. There was a correlation between the number of trees dying and the number of recruits ($p<0.01$). A bigger basal area loss may promote more recruitment. The bigger loss of basal area in Block B resulted in more recruitment than in Block A which had a lower basal area loss (Table 5.17).

(e) Seedling density ha^{-1} (dipterocarps in parentheses) ranged from 47000 (8600) in Block A to 121000 (40000) in Block F.The density of dipterocarp seedlings may be partly related to parent tree density, seed rain, and other factors. Block F had the highest tree density and had the highest seed rain and seedling numbers. However a higher dipterocarp seed rain in Block A did not result in a higher number of seedlings than in Block B. Other factors such a topography may control the density. The steeply sloping plots 4 and 5 in Block A had the least density of seedlings (Tables 3.1 and 6.1). The 12-years old logged forest Blocks B and C had the highest diversity of the pioneer tree seed bank possibly as a result of ironwood removal after the main logging activity.

The higher increment (10.5 cm $year^{-1}$) of seedlings in the newly-logged forest Block A may be related to the greater degree of canopy opening following the logging. The liberation treatment (removal of pioneer trees) in Block C was accompanied by a higher increment (5.4 cm $year^{-1}$) of both dipterocarp and non-dipterocarp seedlings compared with the untreated Block B (2.9 cm $year^{-1}$). Even the understory species showed a strong response to increased light (Table 6.5). The species with the highest density of seedlings showed the highest seedling mortality (Table 6.4). The sapling stock varied from 6800 ha^{-1} to 8600 ha^{-1}. Diameter growth ranged from 0.8 mm (Block F) to 2.2 mm year-1 in Block C. The growth may be partly related to canopy opening but the newly-logged Block

A did not have both higher diameter and height growth of saplings compared with the other Blocks.

Soil properties did not correlate with number and growth rate of seedlings. Block C had the highest average pH, exchangeable cations and available-P, however number and growth rate of seedlings were less than in Block A. Block B had higher average exchangeable cations than Block A but lower than Block C. This Block had a higher number but lower growth rate of seedlings than in Block C

(f) The highest average seed bank size occurred in Block C with 616 m^{-2} and the least in Block A with 151 m^{-2}. The unlogged-forest Block F had an average of 280 m^{-2}. There were at least 50 species (15 unidentified species) occurring in the seed banks in the Kintap study site. The highest number was for the shrub *Melastoma malabatricum* of 840 with 98 m^{-2}, the pioneer trees *Callicarpa cana* of 71 m^{-2}, and *Glochidion kollmanianum* of 30 m^{-2}. Shade bearing trees had very few seeds. The large seed bank in Block C may be resulted from the liberation thinning which allowed more freshly dispersed seeds to fall onto the ground. Block C has the most nutrient-rich soils but it is not certain how these might cause a larger seed bank.. Some pioneer species (*Anthocephalus chinensis*, *Octomeles sumatrana* and *Macaranga spp.*) which were frequently found along the logging road and logged area did not occur in the seed banks.

The seed rain observation occurred during a mast fruiting in early 1992. The number of seeds trapped from all plots from February 1992 – March 1993 was 4534 seeds. Most of the seeds were trapped in February – April 1992 with 3739 seeds (83%) with the peak in March 1992 of 2055 (45%). Dipterocarps contributed 847 seeds from 12 species, mostly *Shorea johorensis*, *S. parvistipulata*, *S. ovalis* and *S. parvifolia*. Some species had very scanty seed fall like *Dipterocarpus gracilis*, *D. hasseltii* and *D. humeratus*.

Even during a gregarious flowering many individual trees and some species may not flower. The mast fruiting occurring in February – April 1992 followed a gregarious flowering in November – December 1991 as a response to a high average maximum temperature and irradiation in August – October 1991.

Most of non-dipterocarps had the same response as dipterocarps to an increase in temperature and irradiation.

(g) The conclusions are drawn against the unfortunate backdrop that the Hutan Kintap concessionaries have largely destroyed most of the Kintap forest through excessive and illegal logging and even the sale of non-dipterocarps for local consumption. They have been able to disregard Government Forestry Regulations because of inadequate control by the provincial Forestry Officers in Banjarbaru, South Kalimantan

The plots studied in this thesis, and from which generalisations about management of the concession were to be made, were usually much less damaged than anything now left in the bulk of the concession. The concessionaries took care in the plots they knew were to be researched!

The conclusions from the plots may apply to varying extents to sites elsewhere but they are likely to be site-specific in view of the unusual combination of high rainfall and nutrient-rich soils at Kintap. Furthermore many of the Kintap treatments were unreplicated and some were damaged in such a way as to confound interpretations. There was good regeneration of trees including dipterocarps in nearly all the plots at Kintap and hence a reasonable expectation that if the forests were well managed then they would recover commercially within a time scale of 30-50 years. Sufficient seed stocks and seed fall during mast years would ensure the regeneration near mother trees. Where mother trees have been destroyed over wide areas as in the bulk of the concession then few seeds will be available for regeneration. In these circumstances some means of enrichment planting must be considered if any production is to be restored. This will inevitably result in a reduced biodiversity however. The mast fruiting might be predicted by monitoring rainfall, temperature and radiation and time since the last mast event. Preparations could then be made for seed collections for the establishment of dipterocarps. Enrichment planting seems the best strategy for most of the Kintap concession and is particularly suitable since most dipterocarps prefer partial shade to full full sunlight initially (Nicholson 1960, Revilla 1976, Mauricio 1987 and Adjers *et al.* 1995).

The conclusions are drawn against the unfortunate backdrop that the Hutan Kintap concessionaries have largely destroyed their forest through excessive and illegal logging and even the sale of non-dipterocarps for local consumption.

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Appendix 1. Procedures of the soil analysis in the Laboratory of the Horticultural Research Institute, Banjarbaru, South Kalimantan.

- pH was measured in a 1 : 2.5 mixture of soil and distilled water
- Cation exchange capacity (CEC) and exchangeable cations were measured on 5-g sub-samples which had been extracted at pH 7 with 1 M ammonium acetate solution; potassium and sodium were measured by flame photometry; calcium and magnesium by atomic absorption spectrophotometry (AAS); cation exchange capacity (CEC) was measured as follows: the extracted soil was washed with alcohol and then distilled with NaOH to release ammonium ions. The ammonium ions were captured in boric acid solution to be treated with sulphuric acid (Kjeldahl method).
- Available phosphorus was measured colorimetrically (using a spectrophotometer at 693 nm) after extracting 2 g of soil in 14 ml Bray I solution (Black *et al.* 1965).
- Total phosphorus was extracted from 2 g of soil with 10 ml 25% HCl solution and the phosphorus in the extract measured by colorimetry using a spectrophotometer at 693 nm.
- Organic carbon was measured by the Walkey-Black dichromate method on 0.5 g of soil (Hesse 1971).
- Texture was measured using the pipette method (Black *et al.* 1965). Ten-g subsamples were analysed from each plot to determine sand, clay and silt fractions.

Appendix 2. Precipitation (P) and number of rain days (Nrd) recorded at Pelaihari, South Kalimantan, 1979 - 1995

Year	P / Nrd	Month 1	2	3	4	5	6	7	8	9	10	11	12	Total
1979	P	467	179	251	108	334	155	135	189	134	107	156	418	2633
	Nrd	15	8	15	9	13	9	8	6	9	7	11	15	125
1980	P	480	389	232	440	61	205	19	34	5	68	450	477	2860
	Nrd	22	14	14	18	9	10	3	5	7	6	17	21	146
1981	P	490	292	138	350	270	121	140	0	241	135	962	612	3751
	Nrd	15	10	6	9	11	3	9	0	7	8	17	18	113
1982	P	770	320	308	310	135	188	7	0	6	23	68	341	2476
	Nrd	18	13	19	13	3	4	1	0	2	3	7	18	101
1983	P	407	320	269	258	188	93	192	54	23	180	880	655	3519
	Nrd	14	14	12	11	14	8	14	4	6	11	18	14	140
1984	P	454	261	655	402	241	132	213	33	227	133	154	694	3599
	Nrd	21	22	19	22	20	10	10	3	9	5	12	21	174
1985	P	521	489	425	144	173	112	100	120	25	98	365	377	2949
	Nrd	15	13	16	12	14	4	4	6	6	5	13	11	119
1986	P	312	179	276	120	106	100	142	0	22	206	179	194	1836
	Nrd	19	15	25	15	8	12	11	0	5	14	17	17	158
1987	P	470	303	362	161	400	147	64	6	0	29	217	489	2648
	Nrd	24	17	23	9	15	7	3	1	0	4	11	16	130
1988	P	398	396	438	105	109	100	160	314	331	229	243	550	3373
	Nrd	21	21	22	13	15	8	11	18	16	12	18	23	198
1989	P	533	429	330	213	263	145	241	35	104	231	450	643	3617
	Nrd	21	21	16	19	15	11	7	5	7	17	17	20	176
1990	P	198	309	204	160	268	27	62	14	3	40	185		1470
	Nrd	15	19	19	15	19	5	10	4	2	10	10		128
1991	P	508	255	173	231	257	67	3	38	0	45	245	374	2196
	Nrd	27	15	14	16	11	3	2	3	0	4	17	21	133
1992	P	206	433	334	307	247	169	217	26	83	276	282	525	3105
	Nrd	20	15	16	18	14	9	18	2	6	14	19	21	172
1993	P	352	332	221	192	198	160	37	0	2	130	168	453	2245
	Nrd	17	20	21	11	18	18	5	0	1	5	15	20	151
1994	P	267	281	310	157	135	698	82	40		12	143	226	2351
	Nrd	20	17	23	15	8	15	3	3		1	15	14	134
1995	P	446	325	288	235	267	290	226	198	81	137	565	568	3626
	Nrd	17	15	10	17	12	14	10	11	6	6	15	22	155
Average	P	**428**	**323**	**307**	**229**	**215**	**171**	**120**	**65**	**80**	**122**	**336**	**475**	**2871**
	Nrd	**19**	**16**	**17**	**14**	**13**	**9**	**8**	**4**	**6**	**8**	**15**	**18**	**146**

Appendix 3. Precipitation (P) and number of rain days (Nrd) recorded at Jorong, South Kalimantan, 1979 - 1995

Year	Month 1	2	3	4	5	6	7	8	9	10	11	12	Total
	P Nrd												
1979	312	180	249	185	177	297	172	0	168	59	291	540	2630
	18	15	13	13	10	20	6	0	4	4	14	15	132
1980	486	376	226	661	241	286	43	67	58	26	376	451	3297
	21	10	11	19	7	13	5	5	3	7	16	21	138
1981	593	187	273	497	600	89	183	26	417	235	847	698	4645
	19	10	12	20	13	4	15	2	11	6	19	20	151
1982	745	247	520	351	101	66	0	4	0	0	43	452	2529
	17	13	14	11	11	6	0	1	0	0	2	19	94
1983	675	456	434	240	455	250	250	12	149	0	112	434	3467
	21	14	13	10	18	11	11	2	4	0	13	12	129
1984	453	450	82	897	187	261	171	27	119	8	170	346	3171
	12	19	18	19	22	17	17	3	7	2	6	10	152
1985	175	256	349	317	398	307	115	27	35	213	233	255	2680
	7	4	14	15	13	9	12	6	2	6	12	12	112
1986	330	113	186	0	18	36	66	4	88	214	207	636	1898
	16	11	13	0	2	4	5	1	6	18	14	8	98
1987	319	231	302	78	426	0	44	0	0	86	212	681	2379
	22	12	17	3	18	0	3	0	0	4	8	16	103
1988	393	539	280	258	92	66	110	297	152	158	659	490	3494
	9	14	8	9	3	3	9	14	7	10	13	15	114
1989	410	204	216	255	202	385	95	92	43	144	253	267	2566
	10	9	15	7	7	15	5	6	3	7	13	12	109
1990	282	217	176	234	329	83	123	93	2	66	46	438	2089
	11	9	10	11	14	7	14	3	1	13	6	24	123
1991	373	220	461	333	423	42	40	0	0	0	164	142	2198
	23	11	18	17	12	3	2	0	0	0	12	19	117
1992	228	241	309	175	165	76	258	113	94	132	140	233	2164
	18	11	13	12	12	11	15	4	8	11	13	17	145
1993	332	299	205	197	209	455	127	0	5	12	175	333	2349
	18	20	17	18	15	16	7	0	2	1	8	14	136
1994	181	131	281	239	178	541	340	37	0	30	94	72	2124
	18	14	17	11	11	14	3	4	0	3	8	8	111
1995	270	273	309	208	175	114	265	102	97	11	108	226	2158
	19	18	18	13	10	13	12	3	4	2	13	17	142
Average	**386**	**272**	**286**	**301**	**257**	**197**	**141**	**53**	**84**	**82**	**243**	**394**	**2696**
	16	**13**	**14**	**12**	**12**	**10**	**8**	**3**	**4**	**6**	**11**	**15**	**124**

Apendix 4. The average maximum and highest maximum temperature at Pelaihari, South Kalimantan, 1981 - 1995

Year	Month 1	2	3	4	5	6	7	8	9	10	11	12
	Average maximum Highest maximum											
1981	30.3	30.9	31	32.7	32.4	32.5	31.5	32.7	31.9	32.7	31.9	30.6
	33.6	32.7	34	34.2	33.2	33.8	33.7	35.3	33.5	34.1	33.8	33.2
1982	30.3	30.2	30.9	31.4	31.5	31.5	31.4	32.4	33.5	33.9	34.1	32
	33.2	33.2	32.6	33.9	33.4	33.8	33.2	34.4	35.5	35.2	35.2	34
1983	31.4	33.1	32.8	33.6	31.9	31.2	30.7	31	32.6	32.4	31.4	31.2
	32.9	34.8	37.7	35.5	34.2	33.5	33	33.8	33.8	35	34.5	34.8
1984	30.6	32.2	31	31.4	30.9	30.5	29.9	31.3	31	32.2	31.4	30.4
	33.1	34.2	33.6	33.3	33.8	33	33	33.2	33.2	33.5	33.4	33
1985	31.7	32.1	31.3	31.4	31.7	31.6	32	31.7	32	32.4	31.9	30.9
	32.8	34.9	33.6	33.3	33.8	33.8	34	33.4	33.9	34.8	34	33.3
1986	30.6	31	30.9	31.8	31	31.5	31.6	32.3	33.6	32.3	31.7	31.8
	34.2	34.2	33.3	33.3	33.8	33.9	33.3	34	34.3	33.8	34.2	34
1987	30.3	31	32.3	32.7	31.2	31.8	31.7	32.1	33.8	34	32.2	31
	33.3	32.4	33.8	35.9	32.9	33.3	34	33.6	35.3	36	34.6	33.5
1988	30.3	31.3	32.4	33	32.7	31.9	31.2	30.7	31.8	33.5	31.2	30.1
	33.9	34.5	34.5	34.2	34	33.6	35	32.8	33.2	34.5	34.1	32.8
1989	30.7	30	30.8	31.4	31.5	30.9	30.9	31.5	31.6	31.7	31.4	30.7
	32.9	32	33.5	33.5	33	33	32.4	33.3	33.5	33	33	33.3
1990	30.6	32	31.5	32.7	31.8	31.7	31.1	32.2	33.2	33.8	33	30.4
	32.8	33.5	33.2	34.3	33.7	32.7	32.5	34	35	35.2	35	32.5
1991	30.6	31.6	31.9	31.8	31	31.5	32.1	32.6	33.6	34.6	32.3	31.8
	34	34.2	34	35	33.6	33.5	33.4	34.6	36	36	35	33.8
1992	31.3	31.6	33	32.4	32	31.7	31.1	32.9	32.3	32.5	31.4	31
	34	34.1	35.5	35.5	34.4	34	33.5	35	35	35.5	35.5	34.4
1993	31.3	31.3	31.5	31.6	31.7	32.5	31.9	34.1	34.1	34.3	32.7	30.7
	35.4	34	33.8	34.6	34.9	33.9	33.7	35.8	35	36.2	35	35
1994	31.2	32.5	31.5	32.3	32.5	30.7	31.2	32.1	32.3	34.2	33.8	30
	33.4	34.6	34.2	35.4	35.6	33.5	33.8	34.3	35.2	35.6	36	34.5
1995	31.6	31.6	32	32.3	33	32.3	31.4	30.5	32.2	33.1	31.6	30.4
	35.2	34	34.2	35	36	34.5	34.5	31.8	34	35.6	35.2	34.5
Average	**30.9**	**31.5**	**31.7**	**32.2**	**31.8**	**31.6**	**31.3**	**32.0**	**32.6**	**33.2**	**32.1**	**30.9**
	33.6	**33.8**	**34.1**	**34.5**	**34.0**	**33.6**	**33.5**	**34.0**	**34.4**	**34.9**	**34.6**	**33.8**

Appendix 5. The average daily temperature in Pelaihari, South Kalimantan, 1981 - 1995

Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1981	26.8	26.7	26.4	26.8	27.7	27.1	26.6	27.6	27.4	27.6	27.3	27
1982	26.6	26.4	26.6	26.6	26.8	26.5	26.6	27.1	27.5	28.2	27.5	26.9
1983	26.8	27.5	27.4	27.2	26.9	27.2	26.7	27.4	27.6	27	26.3	26.6
1984	25.8	26.1	25.9	25.8	25.7	26.1	26.1	26.8	25.9	26.8	26.5	26
1985	26.3	26.6	26.5	26.3	26.5	26.6	26.5	26.7	26.7	27	26.6	26.5
1986	26.6	26.3	26.1	26.7	27	26.4	26.2	27.4	27.6	26.9	26.7	26.7
1987	26.1	26.5	26.4	27.1	26.7	27.6	27.2	27.5	28.3	28.7	27.2	27
1988	26.5	26.6	26.9	27.2	27.3	27	26.4	26.2	26.6	27.1	26.9	26.1
1989	26	25.8	26.3	26.8	26.4	25.8	26.2	26.6	27.1	26.4	26.3	26
1990	26.2	26.6	26.7	27.4	26.8	27.1	26.4	27.2	28	28.1	27.7	26.2
1991	26.5	26.7	27	27.1	26.9	27.2	27.1	27.7	28.2	28.5	27	26.3
1992	26.4	26.4	26.9	27	26.7	26.6	26.6	27.3	26.7	27	26.4	26.1
1993	26.4	26.3	26.3	26.3	26.8	26.6	26.9	28	28.3	28.1	26.9	26.7
1994	26.8	26.4	26.2	26.8	27.4	26.4	26.9	27.4	27.8	28.5	27.6	26.5
1995	26.4	26.5	26.9	26.6	27.3	26.9	26.6	26.7	27.5	27.6	26.6	26.9
Average	**26.4**	**26.5**	**26.6**	**26.8**	**26.9**	**26.7**	**26.6**	**27.2**	**27.4**	**27.6**	**26.9**	**26.5**

Appendix 7. The average daily sunshine hours (%), 0800 - 1600, in pelaihari, South Kalimantan, 1981 - 1995

Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1981	57	50	61	62	70	75	60	82	54	61	42	37
1982	44	50	37	40	61	52	77	96	81	68	66	42
1983	44	-	52	64	40	40	59	80	62	53	46	47
1984	35	33	33	41	37	40	44	77	39	68	40	30
1985	45	43	46	34	40	58	58	63	49	59	45	39
1986	38	41	30	40	59	44	63	88	73	52	38	47
1987	18	46	55	59	62	68	83	84	91	81	53	54
1988	28	35	33	58	40	61	32	29	36	51	28	11
1989	29	30	44	44	45	20	3	71	60	37	48	29
1990	30	62	42	58	44	46	55	79	89	80	57	23
1991	34	45	42	51	47	77	91	90	87	67	28	31
1992	26	27	37	38	46	51	71	83	50	53	32	44
1993	37	38	31	33	40	39	75	91	91	74	45	31
1994	32	39	22	37	61	44	85	90	86	64	41	38
1995	31	30	37	36	56	44	48	50	56	68	32	48
Average	**35**	**41**	**40**	**46**	**50**	**51**	**60**	**77**	**67**	**62**	**43**	**37**

Appendix 6. The average humidity (%) at Pelaihari, South Kalimantan, 1981 - 1995

Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1981	91	83	86	87	88	81	87	79	82	83	85	87
1982	89	88	85	89	86	84	74	74	70	70	77	82
1983	87	85	86	84	86	87	83	77	77	82	87	87
1984	91	86	89	90	89	86	84	79	83	81	86	86
1985	90	84	85	86	87	84	84	82	80	79	85	85
1986	85	83	86	85	82	84	81	72	74	82	84	84
1987	87	85	82	82	87	78	77	71	69	70	85	86
1988	88	87	87	84	85	81	84	86	86	84	86	85
1989	88	88	88	85	86	89	84	78	81	86	88	89
1990	87	87	86	84	88	81	83	78	72	74	78	89
1991	88	87	86	87	87	82	75	72	67	69	80	89
1992	85	76	84	84	84	82	89	74	87	80	85	94
1993	84	85	85	87	84	81	79	69	68	70	83	84
1994	86	85	85	85	79	85	81	72	68	68	79	82
1995	83	84	83	85	81	84	82	79	76	78	84	84
Average	**87**	**85**	**86**	**86**	**85**	**83**	**82**	**76**	**76**	**77**	**83**	**86**

Appendix 8. Soil group and chemical properties in the Kintap Study plots, South Kalimantan

Plot No.	Soil group	Sample No.	Texture (%) Sand	Silt	Clay	pH H2O	% Org. C	CEC m-equivs/100 g	Exchangeable cations (me/100 g) Ca	Mg	K	Na	Av-P $\mu g\ g^{-1}$	Tot-P $\mu g\ g^{-1}$
1	IA	1	10.2	17	72.8	4.9	3.9	22.05	0.5	0.35	0.19	0.2	2.9	333
		2	8.7	17.7	73.6	4.9	3.9	16.1	0.54	0.32	0.18	0.25	2.2	251
2	IA	1	13.1	17.7	69.2	4.9	3.4	20.06	0.35	0.21	0.17	0.22	2.4	312
		2	13.8	18.2	68.1	4.9	3.4	20.06	0.35	0.21	0.18	0.19	6.8	306
3	IA	1	14	17.4	68.7	4.8	3.9	19.52	0.39	0.19	0.16	0.22	1.4	288
		2	31.6	24.7	43.8	5	3.2	8.01	0.33	0.23	0.13	0.14	2.2	243
4	IA	1	18.3	18.1	63.5	5	2.8	26.15	0.36	0.24	0.18	0.18	2.6	210
		2	17.3	18.6	63.9	5	3.3	28.02	0.42	0.26	0.16	0.21	2.6	162
5	IA	1	22.3	20.1	57.6	5	3.1	13.98	0.17	0.12	0.13	0.1	2.5	285
		2	22.9	19.5	57.6	5	3.2	16.03	0.29	0.12	0.15	0.2	1.3	300
6	IIB	1	38.3	17.7	44	5.1	2.9	13.32	1.42	0.92	0.26	0.31	4.76	272
		2	43.5	18.2	38.3	5.2	2.9	12.45	1.62	1.3	0.29	0.33	7.2	140
	IV	1	40.8	28	31.2	4.9	2.7	13.32	1.17	0.69	0.25	0.32	2.4	140
		2	39.5	27.2	33.2	4.9	3.5	20.83	0.96	1.25	0.22	0.33	2.03	138
7	IIA	1	30.9	37.1	32	5	3.8	16.7	2.67	0.26	0.38	0.48	3	70
		2	28.9	39.7	31.5	5	3.4	14.97	2.29	0.87	0.37	0.47	2.9	84
8	IA	1	15.8	25.8	58.4	4.9	4.1	15.9	1.03	0.73	0.36	0.41	2.1	245
		2	15.1	23.9	61	4.9	3.7	17.68	1.03	0.66	0.31	0.42	2.3	243
	IIA	1	13.3	27.8	58.9	4.6	4.1	10.59	0.41	0.24	0.28	0.31	2.3	210
		2	13.6	28.9	57.4	4.7	3.8	18.05	0.46	0.22	0.27	0.3	1.9	208
9	IA	1	26.1	38.4	35.5	4.8	3.8	19.39	1.39	0.76	0.41	0.46	1.5	163
		2	28.2	27.1	44.8	4.8	3.5	18.8	1.31	0.62	0.33	0.35	2.4	173
	IV	1	50.2	26.4	23.4	4.7	3.4	14.62	2.18	0.61	0.21	0.26	2.6	99
		2	46.6	27.9	25.5	4.9	3.2	14.27	2.08	0.55	0.18	0.24	1.6	85
10	IV	1	32.8	32.8	34.3	5.1	3.4	18.01	1.7	0.61	0.25	0.24	2.2	174
		2	31.5	38.4	30.1	5	3.4	17.76	0.87	0.59	0.24	0.28	2.2	177

11	IA	1	18	30.8	51.2	5.3	4.8	20.51	4.93	1.83	0.5	0.48	2.2	219
		2	29.5	32.1	38.4	5.1	4.5	19.89	3.08	2.09	0.45	0.45	3.4	153
	V	1	60.5	22.5	17	5.1	3.3	16.23	4.79	1.28	0.25	0.2	1.6	267
		2	59	24.7	16.3	5.3	1.3	16.72	6.85	2.06	0.3	0.28	2	261
12	IA	1	33.2	24.6	42.2	5.1	4.8	18.8	1.77	0.92	0.32	0.29	4.3	251
		2	29.1	26.7	44.2	5.1	4.5	18.89	1.64	0.94	0.34	0.34	3.6	224
	V	1	33.8	30.9	35.3	5.4	4.2	20.33	4.45	2.19	0.41	0.36	2.9	329
		2	36.3	29.3	34.4	5.5	4.1	21.95	4.87	2.38	0.39	0.43	2.1	259
13	IIA	1	36.6	26.8	36.7	5.9	6.8	28.55	15.81	5.6	0.63	0.43	4.8	317
		2	35.4	27.5	37.2	6.3	6.2	27.6	14.01	5.11	0.47	0.32	2	298
	III	1	12.9	28.9	58.1	5.2	5.1	23.18	6.14	2.05	0.48	0.5	3.4	226
		2	14.7	26.6	58.7	5.3	4.6	23.75	5.93	1.87	0.47	0.43	3.4	214
14	IA	1	15.3	27.1	57.6	5.2	4.2	23.6	3.11	1.24	0.34	0.37	4.1	249
		2	14.1	27.4	58.5	5.1	3.9	19.22	2.39	1.19	0.38	0.45	2.4	167
	IIA	1	24.5	27.6	47.9	5.2	3.7	18.27	3.47	1.34	0.45	0.34	3.1	149
		2	27	29.4	43.6	5.5	3.6	18.14	4.84	2.53	0.3	0.33	2	322
15	III	1	9.8	22.9	67.3	6.1	8	39.65	13.18	4.72	0.56	0.4	2.9	513
		2	26.9	20	53.1	5.9	6.3	36.9	11.73	4.32	0.54	0.36	1.37	492
16	IIA	1	28.6	42.4	29	4.8	2.8	14.87	0.39	0.25	0.21	0.23	1.9	77
		2	19.8	34.5	45.8	4.8	2.3	14.09	0.43	0.25	0.23	0.3	1.9	117
17	IIA	1	19.2	34.8	46.1	4.9	3.6	20.19	0.75	0.39	0.27	0.3	2.3	203
		2	10.3	23.7	66	4.9	3.7	14.3	0.12	0.41	0.29	0.24	1.9	199
18	IIA	1	16.2	15.5	68.3	5.1	4.6	23.37	0.84	0.59	0.41	0.4	2.4	324
		2	13.5	15.1	71.5	4.9	4.5	21.5	0.83	0.75	0.43	0.39	2.2	278
19	IA	1	6	15.9	78.1	5.1	5.7	22.48	1.34	0.97	0.36	0.43	0.9	240
		2	6.9	9.5	83.5	5.2	5.3	21.91	1.29	0.98	0.36	0.4	1	129
	IB	1	6.2	21.8	72.1	4.9	4.8	25.68	0.52	0.44	0.35	0.35	2.6	326
		2	21.5	32.7	45.7	5	4.2	20.74	2.56	0.91	0.38	0.31	2.4	165

Appendix 9. Composition, diversity and equitability of seed bank, Kintap, South Kalimantan, January 1992.

No	Species	Life form	Plot 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1	*Blumea balsamifera*	Fo	2	6	1			1	5	4	8	2	4	3	13	7	8	1	5	1	3		74
2	*Buchanania sessilifolia*	Sb		1				1	4			2	2	8	5	6	2		5	1	1		38
3	*Callicarpa cana*	Pi	15		3	3		22	19	14	10	22	5	29	39	12	351	3	10	8	43		608
4	*Cananga ododrata*	Pi							2	2				2			2	1					9
5	*Centotheca latifolia*	Gr				1	3	7	8	3	5		2	5	3	2	3	3		4	4		53
6	*Drymaria cordata*	Fo	1	17		2	1	13	10	5	5	17	20	12	3	7	7	1	2	2	4		129
7	*Duabanga moluccana*	Pi		2	5	1	2	4	5	4	5	1	6	7	15	5	6	1	6	2			77
8	*Eugenia sp*	Sb		1					1					2	1				3				8
9	*Ficus ampelas*	Pi					1	3		1	2			1		1				10		2	21
10	*Ficus fistulosa*	Sh							2														2
11	*Ficus melanocarpa*	Pi							1					1						1	1		4
12	*Ficus sp*	Pi		1				1			1		1	7		13				1	4		29
13	*Ficus variegata*	Pi	4	3			4	3	9	8	12	8	6	10	5	1	13	5	7	8	3		109
14	*Ficus vasculosa*	Pi						1		1													2
15	*Fimbristylis quinqueangularis*	Fo		2		1	1						2										6
16	*Glochidion kollmanianum*	Pi	10	6	9	8	4	23	10	7	19	12	26	23	13	17	13	17	6	14	17		254
17	*Glochidion sp*	Pi															1						1
18	*Halopegia blumei*	Fo	1	1	3	1		6	8	3	5	7	3	5		4	4		6	2	5	1	65
19	*Homalanthus populneus*	Pi	2	1		2	1			1		1	4	3	1			1	3				20
20	*Imperata cylindrica*	Gr			2			2		1		1			2	4	1		1	3	4		21
21	*Macaranga hosei*	Pi									4		2		1		6	2				1	16
22	*Macaranga sp*	Pi						3															3
23	*Macaranga triloba*	Pi														2							2
24	*Mallotus paniculatus*	Pi		1				3	1	6	1	1	1	1	18	2	3	1		2			41
25	*Melastoma malabatricum*	Sh	58	60	13	17	10	30	55	45	48	74	76	47	71	62	38	30	35	42	15	14	840
26	*Parasponia parvifolia*	Pi									1	8											9
27	*Pollia sozogenensis*	Fo	2	5	2	1	3	7	37	7	6	6	6	8	3	6	5	4	6	1	4		119
28	*Pollia thyrdifolia*	Fo						1															1
29	*Ptychopixis costata*	Pi								1						1	12	2					16
30	*Rubus moluccanus*	Li																		1			1

31	*Rubus sp*	Li								1	2		5							1			9
32	*Solanum torvum*	Sh	1			1		5	4	4	1	15	8	4	2	4	1	1	2	1	2		56
33	*Trema orientalis*	Pi	3	3	2	3	3	4	7	5	1		18	7	13	3	6	6	7	2	3		96
34	*Urena lobata*	Fo		3						1		1	3			1				2			11
35	*Vitis adnata*	Li											4			2			2				8
36	*Unidentified [19]*		1	2				3	2	4		1	1					1					15
37	*Unidentified [22]*		1		1									5	1				1				9
38	*Uidentified [26]*								2							4				1			7
39	*Unidentified [43]*		1	1				4	3	4	16	11	8	14	12	7	2	6	12	11	4		116
40	*Unidentified [47]*		1						1	3	1	2	2	5		3	2		1	1	1		23
41	*Unidentified [49]*							1		1				1		4							7
42	*Unidentified [53]*		1	2					5	3		3	22	5	2	5	1	1	6	3			59
43	*Unidentified [55]*									1													1
44	*Unidentified [60]*							1			3				1								5
45	*Unidentified [63]*					2			6	4		1		13	8	14	1		14	9			72
46	*Unidentified [64]*																	1					1
47	*Unidentified [65]*													1									1
48	*Unidentified [66]*										1												1
49	*Unidientified 67]*							3		2	1	1		1		1							9
50	*Unidentified [68]*								1														1
	N		**104**	**118**	**41**	**43**	**33**	**152**	**208**	**146**	**158**	**197**	**237**	**230**	**232**	**200**	**488**	**88**	**140**	**134**	**118**	**18**	**3085**
	Number of species		**16**	**19**	**10**	**13**	**11**	**25**	**25**	**29**	**23**	**22**	**25**	**28**	**22**	**28**	**23**	**20**	**21**	**26**	**17**	**4**	
	Shannon index		**0.71**	**0.82**	**0.85**	**0.87**	**0.92**	**1.16**	**1.11**	**1.19**	**1.07**	**0.98**	**1.08**	**1.22**	**1.03**	**1.17**	**0.57**	**0.98**	**1.15**	**1.1**	**0.96**	**0.33**	
	Equitability		**0.59**	**0.65**	**0.85**	**0.78**	**0.88**	**0.83**	**0.8**	**0.81**	**0.79**	**0.73**	**0.77**	**0.85**	**0.77**	**0.81**	**0.42**	**0.76**	**0.87**	**0.78**	**0.78**	**0.549**	

Remarks: Fo : Forb; Gr: grass; Li: Liana; Pi: Pioneer; Sb: shade bearing; Sh: shrub

Appendix 10 Dipterocarp seeds trapped by plot, Kintap, South Kalimantan, February - May 1992

No	Species	Plot 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
	(February 1992)																				
1	*D. hasseltii*																				
2	*D. humeratus*																				0
3	*Dipterocarpus gracilis*																				0
4	*Hopea sangal*		31																		31
5	*Shorea faguetiana*																				0
6	*S. hopeifolia*			1	5																6
7	*S. johorensis*				9	1	3	1		9			3		22		10	4		3	65
8	*S. leprosula*				1					15			3		2		3	1	1		26
9	*S. ovalis*																				0
10	*S. parvifolia*	11	13	2		3												2		1	32
11	*S. parvistipulata*	9					2						1						2		14
12	*S. polyandra*																				0
		20	**44**	**3**	**15**	**4**	**5**	**1**	**0**	**24**	**0**	**0**	**7**	**0**	**24**	**0**	**13**	**7**	**3**	**4**	**174**
																					3618
	(March 1992)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
1	*Dipterocarpus gracilis*					1															1
2	*D. hasseltii*																				
3	*D. humeratus*		1																		1
4	*Hopea sangal*		20	1																	21
5	*Shorea faguetiana*				2	11	2	1									10	3			29
6	*S. parvistipulata*	4				1	2		4	5							2	3	5	15	41
7	*S. hopeifolia*			2	1	10															13
8	*S. johorensis*	5	4		6	2				30			4		8			53		4	116
9	*S. leprosula*	2						11				16	3						1		33
10	*S. ovalis*													20			15	1			36
11	*S. parvifolia*		8		1	1							1				16	4	4	4	39
12	*S. polyandra*				5	4													10		19
		11	**33**	**3**	**15**	**30**	**4**	**12**	**4**	**35**	**0**	**16**	**8**	**20**	**8**	**0**	**43**	**64**	**20**	**23**	**349**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
(April 1992)																				
1 *Dipterocarpus gracilis*																				
2 *D. hasseltii*															1					1
3 *D. humeratus*		1																		1
4 *Hopea sangal*		17								1										18
5 *Shorea faguetiana*				3	1					2		1				9	2	3		21
6 *S. parvistipulata*	7	2						2	24			1		14		7		20	31	108
7 *S. hopeifolia*					5														3	8
8 *S. johorensis*				1		4			2			5		15		2	28		2	59
9 *S. leprosula*											12									12
10 *S. ovalis*							12		3				22			12	13			62
11 *S. parvifolia*	2						1					1				1	3			8
12 *S. polyandra*	4		5	1	8													6		24
	13	**20**	**5**	**5**	**14**	**4**	**13**	**2**	**29**	**3**	**12**	**8**	**22**	**29**	**1**	**31**	**46**	**29**	**36**	**322**
(May 1992)																				322
1 *Dipterocarpus gracilis*																				
2 *D. humeratus*																				
3 *Hopea sangal*																				
4 *Shorea faguetiana*																				
5 *S. parvistipulata*																				
6 *S. hopeifolia*																				
7 *S. johorensis*																				
8 *S. leprosula*										1										1
9 *S. ovalis*																				
10 *S. parvifolia*		1																		1
11 *S. polyandra*																				
		1								1										2
Total	**44**	**98**	**11**	**35**	**48**	**13**	**26**	**6**	**88**	**4**	**28**	**23**	**42**	**61**	**1**	**87**	**117**	**52**	**63**	**847**

Appendix 11. Non-dipterocarp seeds trapped by plot, Kintap, South Kalimantan, February - March 1992

No	Species	Plot 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
	February 1992																				
1	*Carallia brachiata*																				0
2	*Durio acutifolius*																	5			5
3	*Gluta wallichii*	1		2	2																5
4	*Quercus sp*																6				6
5	*Lithocarpus blumeanus*																	1			1
6	*Pentaspadon motleyi*						10									3					13
		1	**0**	**2**	**2**	**0**	**10**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**6**	**6**	**0**	**0**	**30**
	March 1992																				
1	*Carallia brachiata*			6	1	3															10
2	*Durio acutifolius*																	1			1
3	*Gluta wallichii*	8	9	14	24	6			1	1										1	64
4	*Quercus sp*																21				21
5	*Lithocarpus blumeanus*										1		1								2
6	*Pentaspadon motleyi*						31					4		25		7					67
		8	**9**	**20**	**25**	**9**	**31**	**0**	**1**	**1**	**1**	**4**	**1**	**25**	**0**	**7**	**21**	**1**	**0**	**1**	**165**
	April 1992																				
1	*Carallia brachiata*			6		5															11
2	*Durio acutifolius*																				0
3	*Gluta wallichii*	3	1		1																5
4	*Quercus sp*										1						1				2
5	*Lithocarpus blumeanus*										1										1
6	*Pentaspadon motleyi*						5					2		3		3					13
		3	**1**	**6**	**1**	**5**	**5**	**0**	**0**	**0**	**2**	**2**	**0**	**3**	**0**	**3**	**1**	**0**	**0**	**0**	**32**
	Total	**12**	**10**	**28**	**28**	**14**	**46**	**0**	**1**	**1**	**3**	**6**	**1**	**28**	**0**	**13**	**28**	**7**	**0**	**1**	**227**

Appendix 12. Dipterocarp trees by plot (@ 50m x 50m), Kintap, South Kalimantan, Nov. 1991

No	Species	Diameter class						N
		10 - 19	20 - 39	40 - 59	60 - 79	80 - 99	>100	
Plot 1								
1	*Dipterocarpus hasseltii*			4				**4**
2	*Shorea johorensis*			2				**2**
3	*S. parvifolia*		2					**2**
4	*S. parvistipulata*				1			**1**
5	*Vatica rassak*	**1**	**1**					**2**
		1	**3**	**6**	**1**	**0**	**0**	**11**
Plot 2								
1	*Dipterocarpus humeratus*			1				**1**
2	*Hopea sangal*		1	1				**2**
3	*Shorea johorensis*	24	3					**27**
4	*Shorea multiflora*	1						**1**
5	*Shorea parvifolia*	8	2					**10**
6	*Vatica rassak*	3	4					**7**
		36	**10**	**2**	**0**	**0**	**0**	**48**
Plot 3								
1	*Hopea dryobalanoides*	2	1	1				**4**
2	*Hopea tenuinervula*	1						**1**
3	*Shorea hopeifolia*	8	6	7	1			**22**
4	*Shorea laevis*	2	4	1				**7**
5	*Shorea parvistipulata*			1				**1**
6	*Shorea polyandra*			1				**1**
7	*Vatica rassak*	5	1					**6**
8	*Vatica umbonata*	1						**1**
		19	**12**	**11**	**1**	**0**	**0**	**43**
Plot 4								
1	*Dipterocarpus humeratus*		1					**1**
2	*Hopea dryobalanoides*	1						**1**
3	*Hopea sangal*			1				**1**
4	*Shorea hopeifolia*		2	1				**3**
5	*Shorea laevis*	1						**1**
6	*Shorea parvistipulata*	1	1		1			**3**
7	*Vatica rassak*		1					**1**
		3	**5**	**2**	**1**	**0**	**0**	**11**
Plot 5								
1	*Dipterocarpus gracilis*	1	1					**2**
2	*Hopea sangal*	1						**1**
3	*Shorea hopeifolia*	16	13	2				**31**
4	*Shorea laevis*	1	2					**3**
5	*Shorea leprosula*		1					**1**
6	*Shorea ovalis*	1						**1**
7	*Shorea parvistipulata*			1				**1**
8	*Vatica rassak*	7	10	1	1			**19**
9	*Vatica umbonata*		1					**1**
		27	**28**	**4**	**1**	**0**	**0**	**60**

Plot 6									
	1	*Shorea johorensis*	3	3	1				7
	2	*Shorea parvifolia*		2					2
			3	**5**	**1**	**0**	**0**	**0**	**9**
Plot 7									
	1	*Shorea johorensis*	4						4
	2	*Shorea parvifolia*	2						2
	3	*Shorea parvistipulata*		1					1
			6	**1**	**0**	**0**	**0**	**0**	**7**
Plot 8									
	1	*Shorea hopeifolia*			2				2
	2	*Shorea johorensis*	10	2					12
	3	*Shorea parvifolia*		1					1
	4	*Shorea parvistipulata*	4	1				1	6
			14	**4**	**2**	**0**	**0**	**1**	**21**
Plot 9									
	1	*Dipterocarpus gracilis*		1					1
	2	*Shorea johorensis*	1	1					2
	3	*Shorea parvifolia*		1		1			2
	4	*Shorea parvistipulata*	8	2	4	1	1		16
			9	**5**	**4**	**2**	**1**	**0**	**21**
Plot 10									
	1	*Hopea sangal*	1	1					2
	2	*Shorea johorensis*	7	1					8
	3	*Shorea polyandra*		1					1
			8	**3**	**0**	**0**	**0**	**0**	**11**
Plot 11									
	1	*Hopea dryobalanoides*		1					1
	2	*Hopea ferruginea*	2						2
	3	*Hopea sangal*	1						1
	4	*Shorea johorensis*	2						2
	5	*Shorea ovalis*		2					2
	6	*Shorea parvistipulata*	1	1					2
	7	*Shorea polyandra*	2						2
			8	**4**	**0**	**0**	**0**	**0**	**12**
Plot 12									
	1	*Shorea johorensis*	6	1		1		1	9
	2	*Shorea ovalis*	3						3
	3	*Shorea parvistipulata*				1			1
	4	*Shorea polyandra*		1					1
			9	**2**	**0**	**2**	**0**	**1**	**14**
Plot 13									
	1	*Shorea johorensis*	3		1				4
			3	**0**	**1**	**0**	**0**	**0**	**4**
Plot 14									
	1	*Dipterocarpus caudiferus*	8						8
	2	*Dipterocarpus hasseltii*	1	1					2

3 *Shorea leprosula*	4						4
4 *Shorea ovalis*	1						1
5 *Shorea parvistipulata*	9	3	2	1	2		17
	23	**4**	**2**	**1**	**2**	**0**	**32**
Plot 15							
1 *Dipterocarpus hasseltii*	1						1
2 *Shorea polyandra*	3						3
	4	**0**	**0**	**0**	**0**	**0**	**4**
Plot 16							
1 *Shorea faguetiana*	5	3	1				9
2 *Shorea johorensis*	7						7
3 *Shorea leprosula*	5						5
4 *Shorea ovalis*	18						18
5 *Shorea parvifolia*	13	3					16
6 *Shorea parvistipulata*		2		2			4
7 *Vatica odorata*	1						1
	49	**8**	**1**	**2**	**0**	**0**	**60**
Plot 17							
1 *Hopea sangal*	2						2
2 *Shorea faguetiana*	3	2	2		1		8
3 *Shorea johorensis*	29	14					43
4 *Shorea ovalis*	11	2					13
5 *Shorea parvifolia*	12	5					17
6 *Shorea parvistipulata*	8	1		1	1		11
	66	**24**	**2**	**1**	**2**	**0**	**94**
Plot 18							
1 *Shorea faguetiana*					1		1
2 *Shorea hopeifolia*	1						1
3 *Shorea johorensis*		1		1			2
4 *Shorea parvistipulata*	2	1		1			4
	3	**2**	**0**	**2**	**1**	**0**	**8**
Plot 19							
1 *Shorea johorensis*		1	2				3
2 *Shorea ovalis*			1				1
3 *Shorea parvifolia*	1		1				2
4 *Shorea parvistipulata*	1	2		1			4
5 *Vatica rassak*				1			1
	2	**3**	**4**	**2**	**0**	**0**	**11**
Sub total	**292**	**123**	**42**	**16**	**6**	**2**	
					Total		**481**