GROWTH AND SURVIVAL OF SEEDLINGS AND SAPLINGS IN THE LOGGED - OVER FOREST, KINTAP, SOUTH KALIMANTAN

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ABSTRACT

A study on demography, growth and survival of seedlings and saplings was conducted in the Hutan Kintap concension, South Kalimantan, Indonesia. The aim of the study was to monitor pattern of growth of seedlings and saplings among different types of logged - over forest, including the newly logged - forest, older logged - over forests (treated and untreated), and un-logged-forest patches. The study began in 1991, and nineteen of 0.25 ha plots were set up in a total of six blocks designated as consecutively A, B, C, D, E and F. Block A was a newly logged forest and had five plots, and Block B - D were in forest which had been logged in 1979. Block B (five plots) had received no silvicultural treatment, while Block C (five plots) and D (one plot) had been lightly thinned after felling and further Block C received a further thinning treatment. Block E (one plot) had been heavily thinned, and Block F (2 plots) was an un-logged control. The density of seedling varied within the study sites, and averaged from 47,000 ha⁻¹ to 121,000 ha⁻¹. The mean height increment of seedlings varied among block ranging from 2.9 cm year⁻¹ to 10.5 cm year⁻¹. Block A had the highest general mean increment of 10.5 cm year⁻¹, followed in decreasing order by Block C of 5.4 and Block F, 4.5 cm year⁻¹. Growth of seedling in Block B was low, even lower than the growth in the un-logged Block F. The difference of the increment among Block A, B, C and F however was not significant. The liberation treatment in Block C significantly resulted in a higher ($p < 0.01$) increment (5.4 cm year⁻¹) than that in the untreated Block B (2.9 cm year⁻¹). Seedling mortality ranged from 16 to 37 % year⁻¹, and declined with height class. The mortality of seedlings might be related among other factors to the humidity and density of seedlings per-unit area. The density of sapling ranged from 6,800 ha⁻¹ to 7,700 ha⁻¹ and they had diameter growth of 0.8 mm year⁻¹ to 2.2 mm year⁻¹, and height growth of 12.6 cm year⁻¹ to 21.8 cm year⁻¹. The difference in the diameter increment among block A, B, C and F was not significant. The average sapling height increment varied (but not significantly so) among Block, ranging from 12.6 cm year⁻¹ in Block A to 21.8 cm year⁻¹ in Block C. Mortality of sapling was relatively low in all block. Higher mortality in the un-logged forest Block F and in the untreated Block B might due to the low degree of canopy opening.

Keywords: seedling, growth, mortality, dipterocarp, pioneers, logged-over forest

I. INTRODUCTION

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 germinated, establish and complete their life cycle in large gaps (Whitmore, 1984; Brokaw, 1985; Swaine and 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 and Bongers, 1988; Turner, 1990) whereas in a logged-over forest seedling growth may be markedly higher.

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Nicholson (1958) 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 forest were almost dormant. Growth of seedlings in the gaps increased with light intensity (Popma and 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 gaps floor. Species composition in gaps, either from formerly suppressed seedling and sapling 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 generally have longer-lived seedling) (Whitmore, 1984 ; 1986; Connell, 1989). Survivorship varies between species (Liew and Wong, 1973; Turner, 1990).

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 under-story 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 to the un-logged forest patches.

II. MATERIALS AND METHODS

A. Study Area

Kintap forest is about 90 km South-East of Banjarmasin, the Provincial capital of South Kalimantan. 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.

This study set up 19 plots, divided into blocks A of the newly logged-over forest (logged in 1991, plots were set up 15 days after logging, designated as plot No.1 - 5), B of the twelve years old logged-over forest (logged in 1979, undergoing iron wood removal by local people, plot No. 6 - 10), C the same as block B but received liberation treatment in 1991 (all lianas were cut and trees of *Macaranga* were killed by girdling, plot No. 11 - 15), D (plot No. 16) same as C with liberation done in 1985 and no ironwood removal, E (plot No. 17) same as D but liberation was done at least twice a year after 1985 (intensive liberation) and F (plot No. 18 and 19) was not logged for dipterocarps but experienced ironwood removal.

B. Quadrata Setting and Enumeration

Seedling (<2 m high) heights were measured in a 1 m by 1 m quadrata, randomly set up in every 10 m x 10 m subplot in each plot of 50 m x 50 m. Sapling heights (= 2 m heights - < 10 cm diameter) were measured in every quadrata 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. The total area of seedling quadrata was 25 m² per plot, and that of sapling quadrata was 125 m² per plot. All seedlings and saplings were labeled.

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 plot (plots 6 - 19) on December 1991 and 18 September 1993 (total 20 months). Mortality was recorded at the same time as the measurements.

III. RESULTS

A. Seedlings

The numbers of individual seedling 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 1). The total number of seedlings in all five plot was 924 with the average of 185 per plot (in 25 m²), 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 in decreasing order by plot 5, plot 4, until the least in plot 2 (Table 1). The difference in the increment between plots tested by a one-way ANOVA was highly significant ($p < 0.01$), 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 1). The difference in mortality among plots in the newly logged forest was significant ($p < 0.05$).

Numbers of individual seedling in the first enumeration (December 1991) varied between blocks with the average per plot ranging from 171 (Block C) to 303 (Block F) (Table 1 and 2)

Table 1. Height increment (cm) and mortality (%) of seedlings in the newly logged forest (site A), December 1991 – December 1992 (12 months)

Plot	Mean height increment (cm)			Mortality					
				N			%		
	First six months (June 1992)	Second six months (December 1992)	Overall	Dec 1991	June 1992	Dec 1992	June 1992	Dec 1992	Overall (year ⁻¹)
1	13.1	12.6	25.7**	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	8.5	182	155	151	14.8	2.6	17
5	4.9	8.9	13.8	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

Remark: * significant ($p < 0.05$)

** highly significant ($p < 0.01$)

The mean height increment of seedlings varied among blocks (Tables 1 and 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 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 ($p < 0.01$) 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 to light

liberation treatment (Block D). There was no significant difference in the mean individual increment between the two plots (Table 2). The height increment and mortality with initial seedling height in Blocks A, B and F are shown in Table 3. The increment generally increased with the initial height in every block except that in the un-logged forest Block F where the increment declined at the height class 120 – 149.9 cm (Fig.1).

The average annual mortality varied little among Block A, B, C and F, ranging from 23.9% (Block B) to 26.6% (Block C) (Table 1 and 2). Mortality was higher in Block E (22.2% year⁻¹) compared to that in Block D (16.3 % year⁻¹).

Table 2. Height increment (cm) and mortality (%) of seedling in sites B, C, D, E and F, December 1991 – September 1993 (20 months).

Block	Plot	Height (cm)			Mortality			
		First average (cm)	Mean increment (%)		N ₁	N ₂	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 3. Height increment (cm year⁻¹) and mortality (% year⁻¹) of seedling by height class in site A, B and F

Height class (cm)	Block A				Block B				Block F			
	Mortality			Increment	Mortality			Increment	Mortality			Increment
	N ₁	N ₂	%		N ₁	N ₂	%		N ₁	N ₂	%	
<5 - 29.9	563	344	38.9	7.4	795	395	30.2	2	435	124	30.5	4.3
30 - 59.9	204	184	9.6	11.8	196	154	12.8	3	116	86	14	4.7
60 - 89.9	67	62	7.5	10.3	92	75	11.1	4.3	33	27	10.9	10.3
90 - 119.9	44	44	0	12.6	49	43	7.3	5.6	15	13	8	7.9
120 - 149.9	28	28	0	18.8	17	16	3.5	7.6	6	6	0	21.7
150 - 179.9	11	10	9.1	19.8	13	11	9.2	5.9	1	1	0	5
>180	7	7	0	22.8	9	8	6.7	4.7	-	-	-	-

Figure 1. Initial height size classes (1991) of the seedlings and their corresponding height increment in Blocks A, B and F.

Increment and mortality of dipterocarps are compared to non-dipterocarps in Table 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 ($p < 0.01$). 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 opening. Table 5 shows the increment and mortality of species in these categories by the Block A, B and F. The species category was primarily based on the species grouping by Koring and Balslev (1994). The canopy, subcanopy and understorey seedling had the highest increment in Block A where the understorey seedling species had a highest increment than the canopy and subcanopy seedling. The understorey species had a much higher increment in Block A than in B and F. The difference was highly significant ($p < 0.01$), suggesting that seedling of the understorey 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 5).

Table 4. Dipterocarp and non-dipterocarp increment (cm year^{-1}) and mortality ($\% \text{ year}^{-1}$) of seedling in Blocks A, B and F

	Block A				Block B				Block F			
	Mortality			Increment	Mortality			Increment	Mortality			Increment
	N ₁	N ₂	%		N ₁	N ₂	%		N ₁	N ₂	%	
Dipterocarp	108	89	17.6	16.8**	249	130	28.7	3.0	200	100	30.0	3.9
Non-dipterocarp	816	590	27.7	8.9	922	572	37.9	2.8	411	254	38.2	4.7

Remarks: ** highly significant ($p < 0.01$)

Table 5. Canopy, subcanopy and understorey species seedlings increment (cm year⁻¹) and mortality (% year⁻¹) in sites A, B and F.

	Block A				Block B				Block F			
	Mortality			Increment	Mortality			Increment	Mortality			Increment
	N ₁	N ₂	%		N ₁	N ₂	%		N ₁	N ₂	%	
Canopy	364	270	25.8	9.2	397	232	25.0	3.1	281	144	29.3	4.5
Sub-canopy	213	143	32.9	7.0	381	230	23.8	2.2	162	86	28.1	4.8
Understorey	270	201	25.6	11.2**	230	147	21.7	3.0	108	71	20.6	4.6

Remarks: ** highly significant ($p < 0.01$)

The pattern of growth and mortality of the six commonest species is shown in Table 6. All species grew slightly 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 difference in the other blocks. This indicates that both species grow faster under canopy openings. The six species included only one subcanopy species (*Hydnocarpus polyptalus*) and one understorey species (*Polyalthia celebica*). The understorey species *Polyalthia celebica* grew faster in Block A (3.6 cm year⁻¹) and in Block F (2.7 cm year⁻¹) compared to Block B (1.8 cm year⁻¹). High mortality occurred in species with denser individuals (Table 6).

Table 6. Increment (cm year⁻¹) and mortality (% year⁻¹) of the six commonest seedling species (= 10 individuals) in Block A, B and F

Site	Species	Increment	Mortality		
			N ₁	N ₂	%
A	<i>Dacryodes rostrata</i>	5.8	67	29	56.7
	<i>Hopea sangal</i>	18.5	20	14	30
	<i>Hydnocarpus polyptalus</i>	7.0	14	11	21.4
	<i>Polyalthia celebica</i>	3.6	34	24	29.4
	<i>Shorea parvistipulata</i>	23.9	23	22	4.3
	<i>Xanthophyllum heteropleurum</i>	2.2	11	10	9.1
B	<i>Dacryodes rostrata</i>	1.9	12	8	20.0
	<i>Hopea sangal</i>	4.9	64	30	31.9
	<i>Hydnocarpus polyptalus</i>	2.9	14	14	0
	<i>Polyalthia celebica</i>	1.8	35	20	25.7
	<i>Shorea parvistipulata</i>	2.8	66	34	29.1
	<i>Xanthophyllum heteropleurum</i>	1.4	20	16	12
F	<i>Dacryodes rostrata</i>	2.5	23	9	36.4
	<i>Hopea sangal</i>	2.9	71	36	29.6
	<i>Hydnocarpus polypt</i>	3.6	25	15	24
	<i>Polyalthia celebica</i>	2.7	18	8	33.4
	<i>Shorea parvistipulata</i>	3.4	96	50	28.7
	<i>Xanthophyllum heteropleurum</i>	1.1	11	10	5.5

B. Saplings

The total number of individual sapling did not differ very much between Blocks A (7,776 ha⁻¹), B (7,632 ha⁻¹) and F (6,840 ha⁻¹), however the number of individuals in Block C (2,704 ha⁻¹) was much lower than in A, B and F (Table 7). The low number of sapling in Block C was due to the liberation treatment by the concessionaires in 1991. 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 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 was in plot 1. The difference was significant ($p < 0.05$). 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 in Block C (Table 7).

Table 7. Height (cm year⁻¹) and diameter (mm year⁻¹) increment, and mortality (% year⁻¹) of saplings in Blocks A – F.

Site	Plot	Mortality				Mean increment	
		N ₁	N ₂	%		Height (cm year ⁻¹)	Diameter (mm year ⁻¹)
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	2.1		20	0.9
	9	146	140	2.5		20	1.1
	10	11	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		12	0.6
	19	85	83	1.4		18.6	0.9
	Total	171	164	2.46	Overall mean	16.8	0.8

Remarks: * significant ($p < 0.05$)

The canopy opening resulting from the recent logging in Blok A did not result in both greater mean height and diameter increment of sapling 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 (un-logged forest) (Table 7). Block D however the mean diameter increment in plot 17 of 2.5 mm year⁻¹ was significantly ($p < 0.05$) higher than in plot 16 of 1.3 mm year⁻¹ (Table 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 sapling varied among blocks with the highest in Block B (61 sapling) and the least in Block C (8 sapling) (Table 8). The low number of dipterocarp sapling in Block C indicated a faulty liberation treatment (from the concessionaires malpractice). Mean height and diameter increment of the dipterocarps did not differ significantly among blocks. The diameter growth increment of dipterocarps in Block A and C was higher than non-dipterocarps, whereas in Blocks B, D, E, and F it were lower (Table 8). Non dipterocarps in Block B consisted partly of pioneer tree species which showed higher growth than primary tree species (including dipterocarps) (Table 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 (*Enodia aromatica*) to 6.1 mm year⁻¹ (*Macaranga* sp). (Table 11). The mortality of the pioneers was low, with only one tree (out of 67) dying in 20 months (Table 9).

In Block B the average height increment of pioneer (22 cm year⁻¹) (Table 9) was slightly lower than of the dipterocarp (25 cm year⁻¹) (Table 8), but the average diameter increment of the pioneer of 2.7 mm year⁻¹ was much higher than that of dipterocarps with 1.0 mm year. The difference was significant ($p < 0.01$). 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 ($p < 0.01$) higher than of the shade-bearing species of 1.1 mm year⁻¹ (Table 9).

Table 8. Dipterocarp and non-dipterocarp sapling growth increment

Block	Dipterocarps					Non-dipterocarps				
	Mortality			Increment		Mortality			Increment	
	N ₁	N ₂	(% year ⁻¹)	Height (cm year ⁻¹)	Diameter (mm year ⁻¹)	N ₁	N ₂	(% year ⁻¹)	Height (cm year ⁻¹)	Diameter (mm year ⁻¹)
A	30	29	3.33	21	1.3	456	454	0.44	13	0.9
B	61	60	1.02	25	1	416	398	2.58	18	1.4
C	8	8	0	22	2.4	161	157	1.49	22	2
D	29	29	0	29	1.1	79	74	3.8	22	1.3
E	27	27	0	29	2.2	76	70	4.7	23	2.6
F	10	10	0	17	0.3	161	154	2.61	17	0.8
Average			1.09	21.8	1.3			1.78	17.5	1.2

Table 9. Growth increment and mortality of pioneer and primary forest species in Block B

Species	Mortality			Mean Increment	
	N ₁	N ₂	(% year ⁻¹)	Height (cm year ⁻¹)	Diameter (mm year ⁻¹)
Pioneer species	67	66	0.89	22	2.7**
Shadebearing species	410	392	2.63*	18	1.1

Remarks: * significant ($p < 0.05$)

** highly significant ($p < 0.01$)

The growth of the dipterocarp species in Block B is given in Table 10. *Shorea johorensis* had the highest diameter increment of 1.6 mm year⁻¹ followed by *Shorea 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 was on the contrary (Table 8). This implies that the diameter growth of the dipterocarp saplings in the virgin forest was very low.

Table 10. Growth increment of dipterocarps in Block B.

Species	Increment	
	Diameter (mm year ⁻¹)	Height (cm year ⁻¹)
<i>Dipterocarpus hasseltii</i>	1.1	10
<i>Hopea sangal</i>	0.7	37
<i>Shorea parvistipulata</i>	0.7	14
<i>Shorea johorensis</i>	1.6	43
<i>Shorea parvifolia</i>	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 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 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 8). Pioneer tree saplings had less mortality than primary tree species in Block B with 0.89% year⁻¹ compared to 2.63% year⁻¹ (Table 9).

Table 11. Growth increment and mortality of pioneer tree species in Block B

No	Species	Mortality			Mean Increment	
		N ₁	N ₂	(% year ⁻¹)	Height (cm year ⁻¹)	Diameter (mm year ⁻¹)
1	<i>Cananga odorata</i> (Annonaceae)	1	1	0	20	0.5
2	<i>Euodia aromatica</i> (Rutaceae)	1	1	0	27	0.3
3	<i>Gevunisia pentandra</i> (Verbenaceae)	1	1	0	33	0.8
4	<i>Glochidion</i> sp. (Euphorbiaceae)	3	2	1	16	1.1
5	<i>Homalanthus populneus</i> (Euphorbiaceae)	2	2	0	2	1.5
6	<i>Macaranga conferta</i> (Euphorbiaceae)	3	3	0	13	1.1
7	<i>Macaranga diepenhorstii</i> (Euphorbiaceae)	13	13	0	26	1.1
8	<i>Macaranga gigantea</i> (Euphorbiaceae)	10	10	0	16	1
9	<i>Macaranga hypoleuca</i> (Euphorbiaceae)	2	2	0	5	1.1
10	<i>Macaranga</i> sp. (Euphorbiaceae)	2	2	0	53	6.1
11	<i>Macaranga triloba</i> (Euphorbiaceae)	11	11	0	21	1.8
12	<i>Mallotus subpeltatus</i> (Euphorbiaceae)	18	18	0	35	5.8
	Total	67	66			

The difference in mortality between the pioneer and the primary species in Block B was highly significant ($p < 0.01$). The mortality in Block B (Table 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 13).

Table 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 13. Diameter increment (mm year⁻¹) and mortality (% year⁻¹) of saplings by size-class in Block A, B and F

Size class (mm)	Block A				Block B				Block F			
	Mortality			Increment	Mortality			Increment	Mortality			Increment
	N ₁	N ₂	%		N ₁	N ₂	%		N ₁	N ₂	%	
<10 - 19.9	294	293	0.3	0.7	265	255	2.3	1.0	102	98	2.4	0.7
20 - 39.9	137	136	0.7	0.8	132	124	3.6	1.4	46	43	3.9	0.7
40 - 59.9	36	35	2.8	2.0	52	51	1.2	2.5	12	12	0	1.4
60 - 79.9	16	16	0	1.6	23	23	0	2.3	9	9	0	0.9
80 - 99.9	3	3	0	1.2	5	5	0	1.3	2	2	0	0.5

IV. DISCUSSION

The seedling bank is important in forest regeneration after disturbance. The density of 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 slope in plot 5 (Table 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 (seedling 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, 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 re-growth following an earlier light logging in 1987.

The height increment of seedlings was ranked in Block A > F > B (Table 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 be due to a stage of forest development in this block after the 1979 logging in which the forest floor was more shaded.

Table 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

The canopy opening resulting from the liberation treatment in Block C also caused a significantly higher increment than the untreated Block B.

The highest in plot 3 of Block A may be due to the least disturbance with the least canopy opening, having shade and humidity similar to the virgin forest where the seedlings are vulnerable to pathogens (Connell, 1989; Turner, 1990). Mortality in all plots was much higher in the first six months (average 21.3%) compared to the second six months (5.2%) (Table 1). This condition could be related to the humidity. December 1991 – July 1992 were wet while August – November 1992 had much less rainfall (Appendices 1 and 2).

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 seedling (Tables 2 and 14). Heavy mortality following the abundance of seedlings could be due to severe competition. Mortality declined with height class (Table 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 and Wong, 1973). Certain seedling species like *Shorea multiflora* keeps growing under the shade on the floor of virgin forest (Turner, 1990). In this study, the dipterocarp species *Hopea sangal* and *Shorea pavistipulata* had much higher increments than non-dipterocarps in the newly logged forest (Block A) (Table 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 understorey species is an important stage for the pollinating insects to react canopy-top 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. In plot 2 of the newly logged-forest Block A the number of saplings was 209 (16,700 ha). The high number of the saplings of this plot may be due to the re-growth after logging in this plot in 1987.

Nicholson (1965) noted the uncertainty of sapling (advance regeneration) growth after logging. The uncertainty of sapling growth may be 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 C, compared to the other blocks (Table 7). The lower increment of saplings in the logged-over forest may be due to stronger competition with larger trees which

respond better to canopy openings.

The growth of the pioneer sapling was higher than that of dipterocarp sapling. Pioneer sapling 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 the age (Kuusipalo *et al.*, 1996).

Low growth rates of saplings in 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 that in the logged-over forest resulting in vigorous gap growth of saplings formerly suppressed under the closed canopy.

IV. CONCLUDING REMARKS

Seedling density ha^{-1} (dipterocarps in parentheses) ranged from 47,000 (8,600) in the newly-logged forests Block A to 121,000 (40,000) in Block F. Higher increment ($10.5 \text{ cm year}^{-1}$) 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 understorey species showed a strong response to increase light (Table 5). The species with the highest density showed the highest seedling mortality (Table 4).

The sapling stock varied from $6,800 \text{ ha}^{-1}$ to $8,600 \text{ ha}^{-1}$. diameter growth ranged from 0.8 mm (un-logged forest patch Block F) to 2.2 mm year^{-1} in the treated 12 years old logged-over forest Block C. The growth may be partly related to canopy opening.

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Appendix 1. Precipitation (P) and number of rain days (Nrd) recorded at Pelaihari, South Kalimantan, 1979 – 1995.

Year	Month												Total
	1 P Nrd	2	3	4	5	6	7	8	9	10	11	12	
1979	467	179	251	108	334	155	135	189	134	107	156	418	2633
	15	8	15	9	13	9	8	6	9	7	11	15	125
1980	480	389	232	440	61	205	19	34	5	68	450	477	2860
	22	14	14	18	9	10	3	5	7	6	17	21	146
1981	490	292	138	350	270	121	140	0	241	135	962	612	3751
	15	10	6	9	11	3	9	0	7	8	17	18	113
1982	770	320	308	310	135	188	7	0	6	23	68	341	2476
	18	13	19	13	3	4	1	0	2	3	7	18	101
1983	407	320	269	258	188	93	192	54	23	180	880	655	3519
	14	14	12	14	11	8	14	4	6	11	18	14	140
1984	454	261	655	402	241	132	213	33	227	133	154	694	3599
	21	22	19	22	20	10	10	3	9	5	12	21	174
1985	521	489	425	144	173	112	100	120	25	98	365	377	2949
	15	13	16	12	14	4	4	6	6	5	13	11	119
1986	321	179	276	120	106	100	142	0	22	206	179	194	1836
	19	15	25	15	8	12	11	0	5	14	17	17	158
1987	470	303	362	161	400	147	64	6	0	29	217	489	2648
	24	17	23	9	15	7	3	1	0	4	11	16	130
1988	398	396	438	105	109	100	160	314	331	229	243	550	3373
	21	21	22	13	15	8	11	18	16	12	18	23	198
1989	533	429	330	213	263	145	241	35	104	231	450	643	3617
	21	21	16	19	15	11	7	5	7	17	17	20	176
1990	198	309	204	160	268	27	62	14	3	40	185		1470
	15	19	19	15	19	5	10	4	2	10	10		128
1991	508	255	173	231	257	67	3	38	0	45	245	374	2196
	27	15	14	16	11	3	2	3	0	4	17	21	172
1992	206	433	334	307	247	169	217	26	83	276	282	525	3105
	20	15	16	18	14	9	18	2	6	14	19	21	172
1993	352	332	221	192	198	160	37	0	2	130	168	453	2245
	17	20	21	11	18	18	5	0	1	5	15	20	151
1994	267	281	310	157	135	698	82	40		12	143	226	2351
	20	17	23	15	8	15	3	3		1	15	14	134
1995	446	325	288	235	267	290	226	198	81	137	565	568	3626
	17	15	10	17	12	14	10	11	6	6	15	22	155
Average	428	323	307	229	215	171	120	65	80	122	336	475	2871
	19	16	17	14	13	9	8	4	6	8	15	18	146

Appendix 2. 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	8	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