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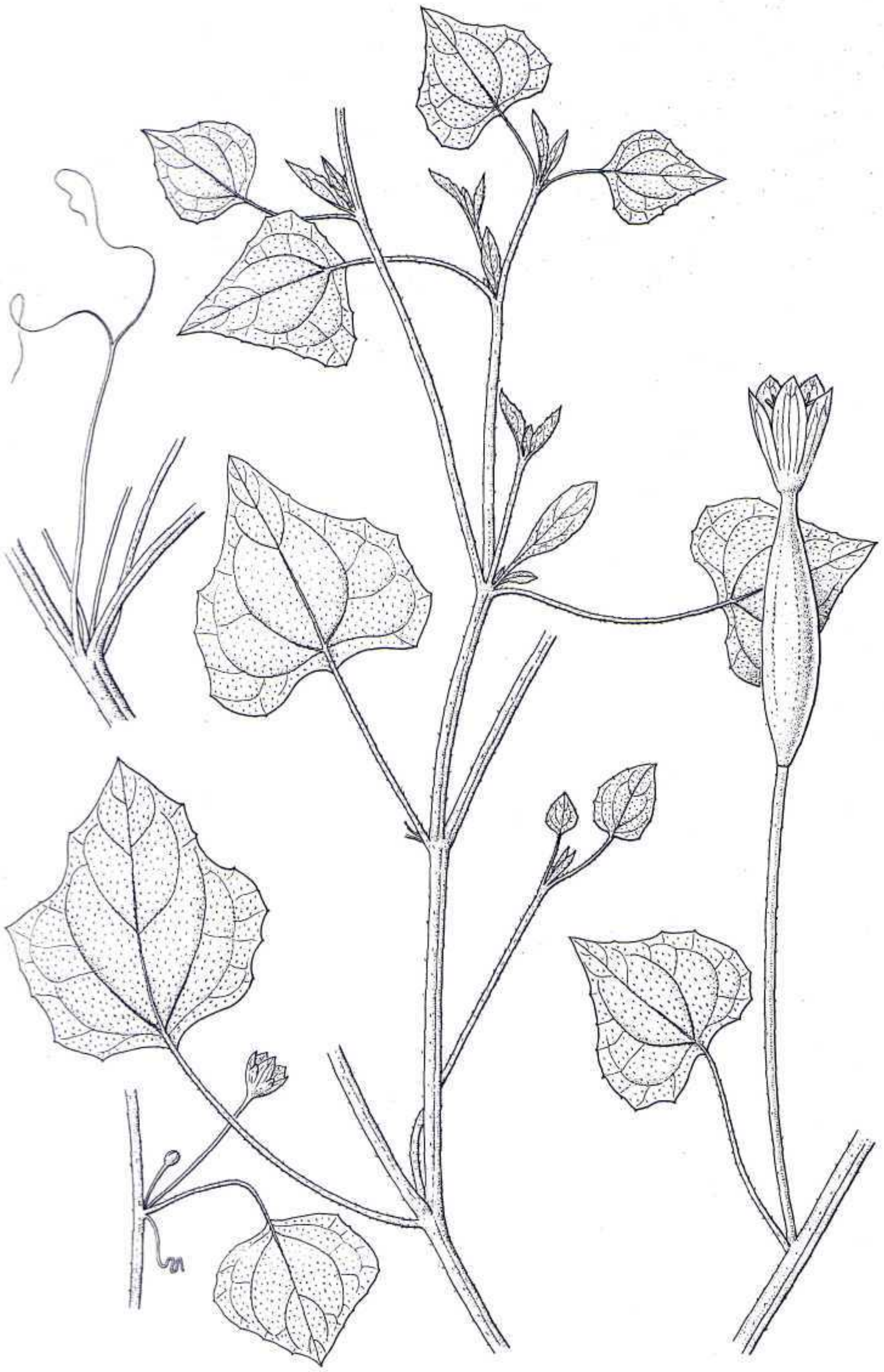

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RECOVERY OF A LOWLAND DIPTEROCARP FOREST TWENTY TWO YEARS AFTER SELECTIVE LOGGING AT SEKUNDUR, GUNUNG LEUSER NATIONAL PARK, NORTH SUMATRA, INDONESIA

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ABSTRACT
PRIATNA, D.; KARTAWINATA, K.; ABDULHADI, R. 2004. Recovery of a lowland dipterocarp forest twenty two years after selective logging at Sekundur, Gunung Leuser National Park, North Sumatra, Indonesia. *Reinwardtia* 12 (3): 237–255. — A permanent 2-ha plot of lowland forest selectively logged in 1978 at Sekundur, Gunung Leuser National Park, which is also a Biosphere Reserve and a World Heritage Site, North Sumatra, was established and investigated in 1982. It was re-examined in 2000, where remeasurement and reidentification of all trees with DBH ≥10 cm were made. The areas of gap, building and mature phases of the canopy were also measured and mapped. Within this plot, 133 species, 87 genera and 39 families were recorded, with the total number of trees of 1145 or density of 572.5/ha. *Euphorbiaceae* was the richest family with 18 species (13.5 % of the total) and total number of trees of 248 (21.7 % of the total or density of 124 trees/ha. The most important families were *Dipterocarpaceae* with IV (Importance Value) = 52.0, followed by *Euphorbiaceae* with IV = 51.8. The most prevalent species was *Shorea kunstleri* (*Dipterocarpaceae*) with IV =24.4, followed by *Macaranga diepenhorstii* (*Euphorbiaceae*) with IV = 12.4. They were the species with highest density, 34 trees/ha and 23.5 trees/ha, respectively. During the period of 18 years there has been no shift in the richest families, most important families and most important species. *Euphorbiaceae* was the richest family and *Dipterocarpaceae* was the most important family, with *Shorea kunstleri* as the most important species with highest importance value throughout the period. The number of species increased from 127 to 133 with increase in density by 36.8% , from 418.5 trees/ha to 572.5 trees/ha. The mortality was 25.57 % or 1.4 % per year. The diameter class distribution indicated that the forest recovery has not been complete. Trees were small, comprising 67.6 % with diameters of 10-20 cm and only two trees had diameters of 100 cm, *i.e. Melanochyla caesia* and *Lithocarpus urceolaris.* Based on the basal area of all species, the logged-over forest at Sekundur is estimated to reach the situation similar to undisturbed primary forest in 56 years after logging, but on the basis of basal area of *Dipterocarpaceae* such condition could be achieved in 172 years. The canopy has not fully recovered and the complete closure of gaps is estimated to take 53 years since the logging started. The canopy consisted of gap phase (24.6 %), building phase (19.7 %) and mature phase (55.7 %). During the period of 18 years the tree mortality was 25.57 % or the rate of 1.4 %/year. *Euphorbiaceae* experienced the highest mortality, particularly among the trees with diameters of 10-20 cm. Mortality decreased with the increase of diameters. During the same period 520 new trees of 16 species were recruited. The densities of 53 % of the species experienced changes of only one tree or no changes at all. Drastic increase in tree population occurred in light demanding species, such as *Baccaurea kunstleri*, *Endospermum diadenum*, *Mallotus penangensis*, *Sapium baccatum* and *Macaranga diepenhorstii* .

Key words: Forest recovery, selective logging, structure and composition, mortality, recruitment, canopy closure, Sumatra.

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ABSTRAK

PRIATNA, D.; KARTAWINATA, K; ABDULHADI, R. 2004. — Pemulihan hutan pamah dipterocarpaceae 22 tahun setelah tebang pilih di Sekundur, Taman Nasional Gunung Leuser, Sumatra Utara, Indonesia. *Reinwardtia* 12(3): 237–255. — Sebuah petak permanen seluas dua hektar dalam hutan pamah yang ditebang-pilih tahun 1978 dibuat dan ditelah pada tahun 1982 di Sekundur, Taman Nasional Gunung Leuser, Sumatera Utara. Petak tersebut diteliti ulang pada tahun 2000; semua pohon dengan diameter setinggi dada ≥10 cm, ditandai, diukur diameter dan tingginya dan diidentifikasi. Luas fase-fase rumpang, membangun dan matang dalam kanopi diukur dan dipetakan. Dalam petak ini tercatat 133 jenis, 87 marga dan 39 suku, dengan jumlah pohon sebanyak 1145 atau kerapatan 572.5 pohon/ha. *Euphorbiaceae* merupakan suku terkaya dengan 18 jenis (13.5 % dari semua jenis) dan jumlah pohon sebanyak 248 (21.7 % dari total) atau kerapatan 124 pohon/ha. Suku yang paling penting adalah *Dipterocarpaceae* (Nilai Penting, NP = 52.0), diikuti oleh *Euphorbiaceae* (NP = 51.8). Jenis yang paling menonjol adalah *Shorea kunstleri* (*Dipterocarpaceae*) dengan NP =24.4, diikuti oleh *Macaranga diepenhorstii* (*Euphorbiaceae*) dengan NP = 12.4, dan dua jenis ini mempunyai kerapatan tertinggi, masing-masing 34 pohon/ha and 23.5 pohon /ha. Selama 18 tahun tidak terdapat pergeseran suku-suku terkaya dan terpenting serta jenis-jenis terpenting. *Euphorbiaceae* merupakan suku terkaya dan *Dipterocarpaceae* suku terpenting, dengan *Shorea kunstleri* sebagai jenis terpenting selama 18 tahun ini. Jumlah jenis bertambah dari 127 menjadi 133 dengan peningkatan kerapatan sebanyak 36.8 %, yaitu dari 418.5 pohon/ha menjadi 572.5 pohon/ha. Mortalitas tercatat 25.57 % atau 1.4 % per tahun. Sebaran kelas diameter menunjukkan bahwa pemulihan hutan belum lengkap. Sebagian besar pohon-pohon berukuran kecil; 67.6 % termasuk kelas diameter 10-20 cm dan hanya dua pohon yang mempunyai diameter > 100 cm, yaitu *Melanochyla caesia* and *Lithocarpus urceolaris*. Berdasarkan luas bidang dasar semua jenis, hutan bekas pembalakan ini akan mencapai kondisi seperti hutan primer yang tidak terganggu dalam waktu 56 tahun setelah pembalakan, tetapi berdsarkan luas bidang dasar *Dipterocarpaceae* pemulihan ini memerlukan waktu 172 tahun. Kanopi hutan belum sepenuhnya pulih dan penutupan rumpang spenuhnya diperkirakan memerlukan waktu 53 tahun sejak hutan dibalak. Kanopi terdiri atas fase rumpang (24.6 %), fase membangun (19.7 %) dan fase matang (55.7 %). Selama 18 tahun mortalitas mencapai 25.57 % atau laju mortalitas 1.4 %/tahun dan tidak ada mortalitas dalam 44.1 % dari jenis. Penambahan pohon baru tercatat sebanyak 520 pohon yang termasuk16 jenis. Sebanyak 53 % dari semua jenis, kerapatannya mengalami perubahan hanya satu pohon atau sama sekali tidak mengalami perubahan. Jumlah pohon yang meningkat drastis terjadi pada jenis-jenis yang memerlukan cahaya, seperti *Baccaurea kunstleri*, *Endospermum diadenum, Mallotus penangensis*, *Sapium baccatum* and *Macaranga diepenhorstii*.

Kata kunci: Pemulihan hutan, pembalakan selektif, struktur dan komposisi, mortalitas, rekrutmen, penutupan kanopi, Sumatera.

INTRODUCTION

In view of continuous and rapid decrease of the tropical forest area, information on forest is badly needed (Wich *et al.* 1999). Research on the ecology of primary forests of Indonesia is still relatively meager, although at the same time ecological information has to be accumulated before the primary forest disappears (Abdulhadi *et al.* 1998). During the last three decades, various ecological research activities have been undertaken by various national and international institutions, but most of them have been short-term research projects on vegetation in Kalimantan and Sumatra (Kartawinata, 1990; Lamounier, 1997).

The success of conservation and management of tropical forests depends among others on a profound knowledge regarding forest dynamics (Hartshorn, 1990). To study forest dynamics, several permanent plots have been established in various localities, including at the Gunung-Gede Pangrango National Park, West Java; Kayan Mentarang National Park, Lempake and Wanariset Samboja in East Kalimantan; Gunung Palung National Park in West Kalimantan; Barito Ulu in Central Kalimantan; and the Gunung, Leuser National Park, North Sumatra (Budiman & Abdulhadi, 1995; Kartawinata 1990; Riswan, 1987).

Indonesia has extensive areas of logged-over forests and degraded lands arising from intensive exploitation of forest resources. In 2000 the logged-over forests covered about 23 million hectares or 55 % of the total logging concession area (Kartawinata *et al.* 2001*).* Selective logging operations led to the formation of canopy openings, resulting from tree felling, skid trails, haul roads and log-yards. The structure and composition of residual stands have been investigated by various authors *(e.g.* Abdulhadi *et al.* 1981; Bertault *et al.*, 1997; Cannon *et al.,* 1994*;* Haeruman 1978; Rosalina 1986; Sist *et al.,* 2003*;* Soemarna & Suyana 1979; Soemarno, 2001; Tinal & Palinewen 1978; see also some articles in Sist *et al*. 1997). The number of tree species in logged-over forests is usually lower than in primary forests (Kartawinata *et al.* 2001) and the tree mortality is higher (Cannon *et al.* 1994), which can be 2.1 % per year in logged over forests and 1.7 % in primary forests (Whitmore, 1984). Bare areas in the logged-over forests covered 14 to 50 % of the ground and were invaded by light-demanding, fast-growing and light-wood pioneer species (Abdulhadi *et al.* 1981; Fox 1969; Kartawinata *et al.,* 1983; Meijer, 1970; Nicholson, 1958; Riswan & Kartawinata, 1991; Tinal & Palinewen 1978). Should there be no additional disturbances, logged-over forests will return to compositional and structural characteristics similar to undisturbed primary forests in at least 150 years (Riswan *et al.* 1986; Riswan & Kartawinata, 1988, 1991).

Selective logging operations have left a mosaic of unlogged and logged areas. The unlogged primary forest areas are mainly on the less accessible or less productive areas, while the logged areas developed into secondary forest. There is a great spatial variation in term of degree of damages and consequent forest structure and species composition in the logged-over forest. This heterogeneity of habitat can support a diversity of species different from pre-logging conditions and is of value to conservation (Cannon *et al.* 1994).

In 1982 a study of a two-hectare plot of lowland forest selectively logged in 1978 was conducted at Sekundur, Gunung Leuser National Park, North Sumatra (Abdulhadi *et al.*, 1987). The present study was the re-invetigation of the same two-hectare plot carried out in 2000 to provide information on the recovery of selectively logged-over forests, with the objective of investigating the structural and compositional changes during the last 18 years since the previous study was conducted in 1982.

STUDY AREA AND METHOD

The study was carried out in a selectively logged lowland dipterocarp forest at 04°58'-04°59' N dan 98°04'-98°05' E, in Sekundur, within the Gunung Leuser National Park (GLNP) and Leuser Ecosystem Area in the Besitang Sub-district, Langkat District, North Sumatra, (Figure 1). In 1981 the GLNP was designated as a Biosphere Reserve and in July 2004, together with the Kerinci Seblat and Bukit Barisan Selatan National Park, it was inscribed in the World Heritage List as the Cluster Tropical Rainforest Heritage of Sumatra. The study area is located at 75-100 m above sea level within the 1978 logging block of the PT Raja Garuda Mas (Abdulhadi *et al*., 1987). The terrain ranges from undulating to somewhat hilly with gentle to steep slopes. The climate is very humid without dry months with the rainfall type A (Schmidt & Ferguson, 1951), and the annual rainfall is 3500 - 4000 mm (Leuser Management Unit, unpublished). Soil in the area is classified as 'tropudult' (USDA) or equivalent to Red Yellow Podsolic soil (Soepraptohardjo & Ismangun 1980). The parent material is acid tuff, sandstone and sand deposit. Solum is thick, red to yellow, with variable texture, firm to friable consistency, acidic, low nutrient content, slow to medium permeability, and easily erodable .

A permanent plot was subjectively established in a selectively logged-over forest in 1982 by Abdulhadi *et al.* (1987). The plot was two hectares (100 x 200 m) and was divided into subplots of 10 x 10 m. It covered the logging roads, skid trails, extracted area and undisturbed section of the logged forest. All trees with DBH ≥ 10 cm occurring within the subplots were recorded and numbered with metal tags at 160 cm above ground. The DBHs were measured at 130 cm above ground. For trees with tall buttresses measurements were made 20 cm above the upper ends of the buttresses. The gap, building and mature phases of the canopy (sensu Whitmore 1984) and a profile diagram were drawn.

In February-March 2000 and August-November 2000 the above two-hectare permanent plot was re-surveyed and all trees were re-numbered, re-marked and re- measured. The height of each tree within the plot was measured and its position was drawn on a graph paper with the scale of 1:200. The mosaic of the gap, building and mature phases of the canopy and a profile diagram of the forest were re-drawn on a 10 x 60 m plot. Voucher specimens were collected for identification at the Herbarium Bogoriense.

The density, frequency, and dominance as measured by basal area and their relative values as well as the Importance Values (Bray & Curtis, 1957) of each species were computed following the standard calculation described in detail in Mueller-Dombois and Ellenberg 1974. Calculation of the Family Importance Value follows the method used by Kartawinata *et al.* (2004). To show the diversity of tree species of the 1982 and 2000 results, Shannon-Winner Indices of Diversity and Evenness were calculated using the standard formulas (Magurran, 1988; Zar, 1996).

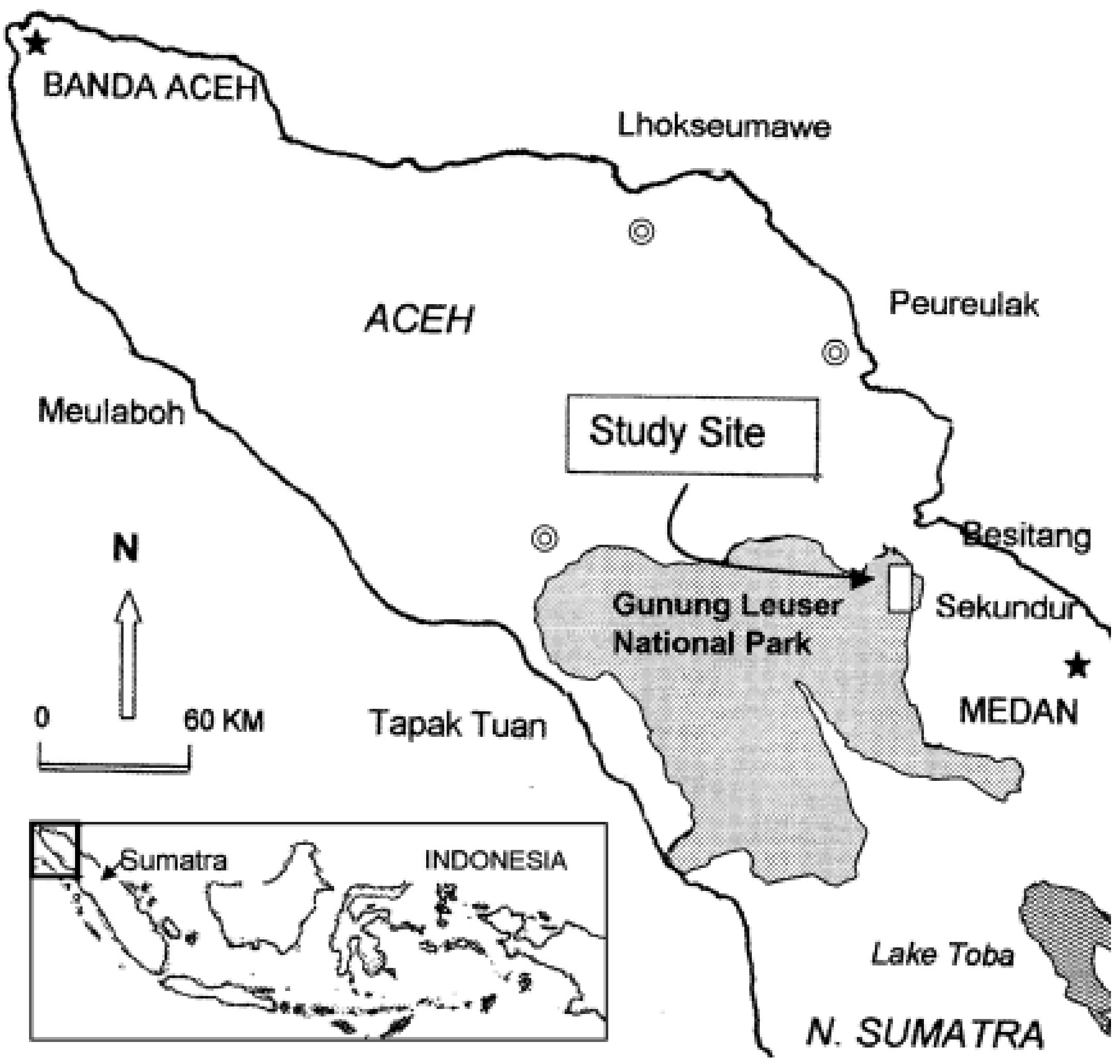

Figure 1. Map of the study area in a selectively logged lowland forest at Sekundur, GLNP, North Sumatera

The results of the present study were compared with the data of investigation of the same plot carried out in 1982 (unpublished data of Abdulhadi and Abdulhadi *et al.* 1987) and that in undisturbed primary forest at Ketambe (Abdulhadi *et al.* 1989). The estimate of floristic and structural recovery rate after logging was carried out by comparing the density, basal area and canopy coverage by applying the method used by Abdulhadi (1992).

RESULTS AND DISCUSSION

Composition

In the study of the 2-ha plot in year 2000, 133 species, 87 genera and 39 families of trees with DBH ≥ 10 cm (Table 1; see Appendix 1 for details) were recorded. Eighteen years earlier in 1982, 127 species, and 88 genera, 43 families were registered (Abdulhadi *et al.,* 1987). In the present study *Euphorbiaceae* was the richest family with 18 species (13.5% of the total), followed by Lauraceae with 10 species (7.5%), and *Anacardiaceae* and *Dipterocarpaceae* with 8 species (6%) each. Beside the richest in species, *Euphorbiaceae* had the highest number of genera (11) and number of trees (248). It is well known that, next to *Dipterocarpaceae, Euphorbiaceae* is in general the richest family in the primary and secondary lowland rain forests of Malesia (Abdulhadi *et al.* 1991; Kartawinata *et al.* 1981; Kartawinata, *et al.* 2004;Riswan, 1987). The success of *Euphorbiaceae* appeared to be closely related to its adaptive capability. It contains species preferring to grow on open places, such as gaps and they form the canopy of secondary forests (Riswan, 1982; Whitmore, 1984; Riswan, 1987; Manullang, 1998).

Table 1. Important families in the 2-ha plot of a selectively logged lowland forest at Sekundur in the Gunung Leuser National Park, North Sumatra in 1982 and 2000.

Family	Number of Species		% Number of species		Number of Genera		Number of trees (DBH ≥ 10 cm)		Family Importance Value	
	1982*	2000	1982*	2000	1982*	2000	1982*	2000	1982*	2000
Dipterocarpaceae	7	8	5.52	6.02	3	3	118	127	57.6	52.0
Euphorbiaceae	19	18	14.96	13.53	11	11	94	248	27.5	51.8
Lauraceae	10	10	7.87	7.52	5	5	71	96	21.1	21.0
Anacardiaceae	8	8	6.29	6.02	5	5	55	65	24.2	20.0
Myrtaceae	6	6	4.72	4.51	2	2	54	64	17.8	15.4
Sapotaceae	4	4	3.15	3.01	3	3	31	59	9.2	13.0
Flacourtiaceae	4	4	3.15	3.01	4	4	41	45	13.0	11.6
Annonaceae	7	4	5.52	3.01	6	4	33	38	12.5	10.0
Fagaceae	3	3	2.36	2.26	2	2	14	21	9.4	8.9
Tiliaceae	1	1	0.79	0.75	1	1	42	40	11.8	8.6
Moraceae	3	3	2.36	2.26	2	2	29	33	9.7	8.39
Other families	55	64	43.31	48.10	44	45	255	309	86.2	87.7
Total	127	133	100	100	88	87	837	1145	300	300

*) Abdulhadi (*unpublished data*)

The Importance Values of families differed from density, frequency and dominance (basal area). Seven families had FIV (Family Importance Values) >10, where Dipterocarpaceae had the highest FIV (52.0), followed by Euphorbiaceae with FIV of 51.8. These high values were contributed by *Shorea kunstleri* (Diptero-carpaceae) with IV (Importance Value) of 24.4 and *Macaranga diepenhorstii* (Euphorbiaceae) with IV of 12.4.

Ten most important species arranged in descending order of Importance Values (Figure 2) were *Shorea kunstleri*, *Mangifera gracilipes, Cinnamomum iners, Eugenia acutangula*, *Pentace polyantha*, *Cleistanthus bakonensis, Shorea pauciflora*, *Lophopetalum javanicum*, *Lithocarpus urceolaris* and *Mezzettia parviflora*. The total IVs of these species was 35.5 % of the total IVs of all species and *Shorea kunstleri* had the highest IV of 24.4 or 8.11 % of the total. Data recorded in 1982 (Abdulhadi *et al.* 1987) showed similar values, where the IVs of ten most important species was 38.8 %, and *S. kunstleri* had the highest IV of 29.8 or 9.9 % of the total; only one species, *Cleistanthus bakonensis*, was secondary species in this group. It should be noted, however, that *Macaranga diepenhorstii* with IV of 12.37, *Endospermum diadenum* with IV of 7.62 and *Sapium bacccatum* with IV of 7.36 should be considered important species in year 2000 whereas they had lower IVs in 1982. Figure 2 also shows the decrease of the IVs in 8 of the 10 most important species when IVs in

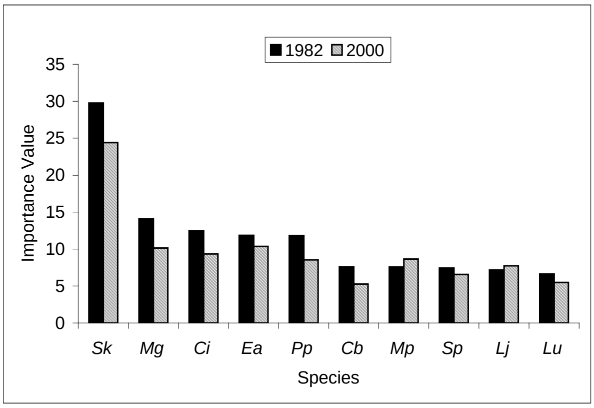

Fig. 2. Ten most important species recorded in 1982 (Abdulhadi, unpublished data) and 2000 in a 2-ha plot of a selectively logged lowland forest at Sekundur, GLNP, North Sumatra. *Sk= Shorea kunstleri; Mg= Mangifera gracilipes; Ci=Cinnamomum iners; Ea= Eugenia acutangula; Pp=Pentace polyantha; Cb=Cleistanthus bakonensis; Mp= Mezzettia parviflora; Sp= Shorea pauciflora; Lj= Lophopetalum javanicum; Lu= Lithocarpus urceolaris.*

1982 compared with those in 2000. The decrease were likely attributed to the death of trees, where, except for *Lophopetalum javanicum*, the mortality rates of these species were 4.76 –51.85 %. Meanwhile, the IVs of *Mezzettia parviflora* and *Lophopetalum javanicum* increased, which could be attributed to the high percentage of recruitment of 57.1 % for the former and 44.4 % for the latter.

Table 2 . Ten most important tree species based on density (trees/ha) in 2000 compared with the density in 1982 in the two-hectare plot of a lowland dipterocarp forest at Sekundur, Gunung Leuser National Park, North Sumatra.

Species	Family	Density (tree/ha)	
		Year 2000	Year 1982*
Macaranga diepenhorstii	Euphorbiaceae	34	*10*
Shorea kunstleri	Dipterocarpaceae	23.5	*25.5*
Eugenia acutangulum	Myrtaceae	22.5	*19*
Cinnamomum iners	Lauraceae	21	*21*
Pentace polyantha	Tiliaceae	20	*21*
Sapium baccatum	Euphorbiaceae	19	*1*
Mangifera gracilipes	Anacardiaceae	17	*15*
Mezzettia parviflora	Annonaceae	16.5	*10.5*
Endospermum diadenum	Euphorbiaceae	16	*3.5*
Litsea noronhae	Lauraceae	15	*0*

*) Abdulhadi (Unpublished data)

Table 3. The ten most important tree species based on basal area (m^2/ha) measured in 2000 and in 1982 in the two-hectare plot of a lowland dipterocarp forest at Sekundur, Gunung Leuser National Park, North Sumatra.

Species	Family	Basal Area (m^2/ha)		
		Year 1982*	Year 2000	Increase in 18 years
Shorea kunstleri	Dipterocarpaceae	3.89	4.48	0.59
Dipterocarpus grandiflorus	Dipterocarpaceae	0.91	1.25	0.34
Mangifera gracilipes	Anacardiaceae	1.46	1.21	(-0.25)
Lithocarpus urceolaris	Fagaceae.	1.1	1.16	0.06
Shorea pauciflora	Dipterocarpaceae	0.67	0.91	0.24
Macaranga diepenhorstii	Euphorbiaceae	0.1	0.84	0.74
Lophopetalum javanicum	Celastraceae	0.57	0.82	0.25
Shorea leprosula	Dipterocarpaceae	0.46	0.79	0.33
Shorea multiflora	Dipterocarpaceae	0.46	0.78	0.32
Mezzettia parviflora	Annonaceae	0.53	0.74	0.21
	Total	10.15	12.98	2.83

*) Abdulhadi (Unpublished data)

Twenty two years after logging, the ten most important tree species based on density in the two-hectare permanent plots are shown in Table 2. The density of these ten tree species constituted 35.7 % of the total density of all tree species. Note that in 2000, a secondary forest species, *Macaranga diepenhorstii,* was the leading species with the highest density of 34 trees/ha and represented 5.9 % of the total density. The second prevailing species was *Shorea kunstleri* with density of 23.5 trees/ha and made up of 4.1 % of the total. It was noted that *Macaranga diepenhorstii* filled up and grew in the gaps created by selective logging whilst *Shorea kunstleri* occupied the unlogged portion of the forest within the plot.

Density measurement undertaken in the same plot in 1982 (Abdulhadi, unpublished data) showed a similar pattern where the ten most important species made up 37.4 % of the total. During the period of 18 years, a drastic increase of density occurred in *Macaranga diepenhorsti* from 10 trees/ha in 1982 to 34 trees/ha in 2000, *Sapium baccatum* from 1 trees/ha to 19 trees/ha and *Litsea noronhae* from 0 to 15 trees/ha. *Litsea noronhae* should be registered as a new arrival. There was, however, a decrease in density of *Shorea kunstleri* during the period of 18 years. In 1982, *Shorea kunstleri* was the leading species with the highest density of 25.5 tree/ha or 12.2 % of the total, whereas in 2000 its density was 23.5 tree/ha. See also Table 4 for density figures of all species.

In term of basal area the ten most important tree species measured in 2000 (22 years after selective logging) in the two-hectare plot are presented in Table 3. The total basal area of the ten most important species amounted to 12.98 m^2/ha or 43.5 % of the total basal area of all species. *Shorea kunstleri* was the leading species with the basal area of 4.48 m^2/ha or 16.1 % of the total basal area for all species. The next important species was *Dipterocarpus grandiflorus* with the basal area of 1.25 m^2/ha or 4.5 % of the total for all species. The measurements in the same plot made in 1982 (Abdulhadi, unpublished data) showed comparable figures, where the total basal area of the ten most important species amounted to 10.15 m^2/ha or 47.2 % of the total for all species. Within the period of 18 years, with the exception of *Mangifera gracilipes*, the *basal* area increased ranging from 0.06 to 0.74 m^2/ha. Being a fast-growing secondary forest species, *Mangifera gracilipes* showed the highest increase (0.74 m^2/ha). The second highest increase was shown by Shorea *kunstleri* with the increase of 0.59 m^2/ha; it may be considered as a fast growing species, faster than *Shorea leprosula*, which is generally accepted as one of the fast growing dipterocarps. The basal area increase of the other dipterocarp species ranged from 0.24 to 0.34 m^2/ha.

Structure

The diameter class distribution of 837 trees recorded in 1982 and 1145 trees measured in 2000 (Figure 3) shows a shape almost like a short. inverted J, the shape of the curve typical for primary forest (Whitmore, 1984; Abdulhadi *et al.* 1991). It implies also that new growth is booming along just fine. In general the trees were small, consisting of 67.6 % with diameters of 10-20 cm and 17.0 % of diameters 21-30 cm. Only two trees (0.2 %) had diameters > 100 cm, *i.e., Melanochyla caesia* (*Anacardiaceae*) and *Lithocarpus urceolaris* (*Fagaceae*). It can be definitely inferred that the recovery process of the selectively logged forest here is still in progress The forest has not reached the conditions of an undisturbed primary forest 22 years after logging.

Within this 2-ha plot, *Euphorbiaceae* and *Dipterocarpaceae* had the highest number of trees, 248 (density = 124/ha) and 127 (density = 63.5 trees/ha) and were greater than in 1982 (Table 1). More than 85 % of the trees of Euphorbiaceae consisted of *Macaranga diepenhorstii*, *Sapium baccatum, Endospermum diadenum*, *Cleistanthus bakonensis*, *Mallotus penangensis* and *Baccaurea lanceolata*, which were pioneer species filling up gaps or growing on forest edges. In *Dipterocarpaceae* 73 % of the trees were composed of *Shorea kunstleri*, *S. multiflora* and *S. leprosula*., which are primary species that usually grow better in small gaps than in open sites or under closed canopy (Abdulhadi *et al.* 1987).

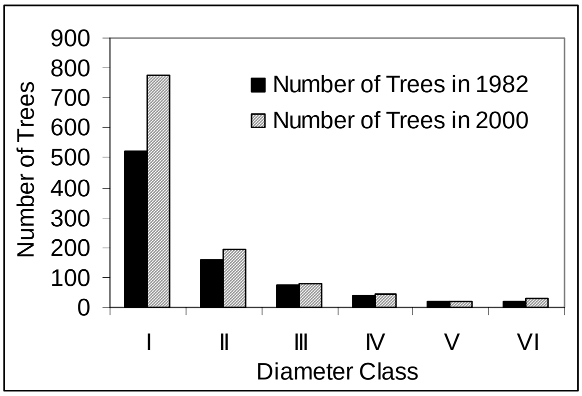

Figure 3. Diameter class distribution of trees with DBH ≥ 10 cm recorded in 1982 (Abdulhadi, unpublished data) and 2000 in a 2-ha plot of selectively logged forest at Sekundur, GLNP, North Sumatra. I = 10-20 cm; II = 21-30 cm; III = 31-40 cm; IV = 41-50 cm; V = 51-60 cm; VI = > 60 cm

In year 2000, 1145 trees with DBH ≥ 10 cm were recorded in the 2-ha plot, an ingrowth of 308 trees in 18 years. Forty species (31 % of the total) were each represented by a single tree, while 62 species (23 %) were each represented by 11 trees. *Macaranga diepenhorstii* and *Shorea kunstleri* were the most abundant species represented by 68 and 47 trees, respectively. *S. kunstleri* had the mean diameter greater than that of *M. diepenhorstii*. In the forest of Sekundur *M. diepenhorstii* regenerated well, especially in gaps and other open places

Table 3 shows that the total basal area of 1145 trees (572.5 tree/ha) in the plot was 55.36 m^2 (27.68 m^2/ha). Of these the Dipterocarpaceae contributed 127 trees with basal area of 16.49 m^2 (8.25 m^2/ha) In 1982, the same plot contained 837 trees with the total basal area of 42.87 m^2 (21.44 m^2/ha), including 118 trees of Dipterocarpaceae with basal area of 12.98 m^2 (6.49 m^2/ha). Table 3 shows also that there was an increase of basal area from 21.44 m^2/ha in 1982 to 27.68 m^2/ha 18 years later in 2000, implying that the rate of basal area increment was 0.35 m^2/year. Using this rate of increment and the total basal area of undisturbed primary forest at Ketambe of 40.90 m^2/ha (Abdulhadi *et al.* 1989), it can be estimated that the logged-over forest at Sekundur would reach the structure similar to the undisturbed primary forest in

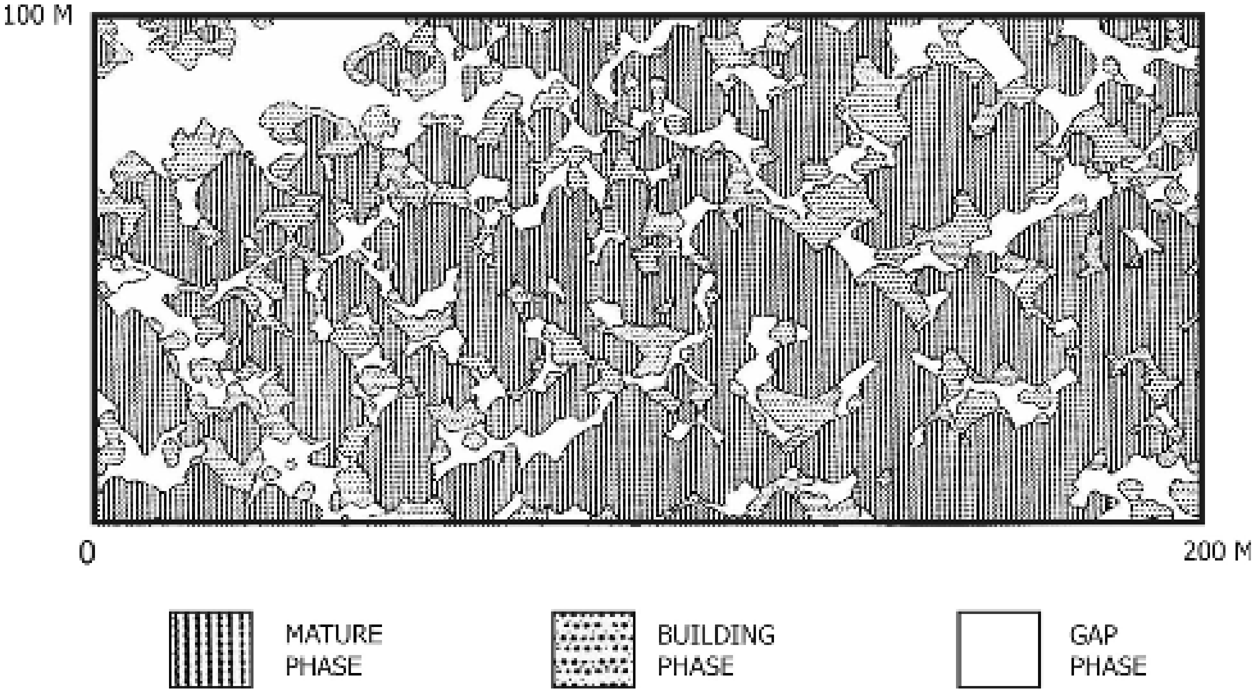

Figure 4. The gap, building and mature phases of the canopy of a 2-ha plot of selectively logged forest 22 years after logging at Sekundur, GNLP, North Sumatra. The mature phase consists of the unlogged forest left during the logging in 1978 and the mature phase developed from the building phase during 18 years since the observation made in 1982.

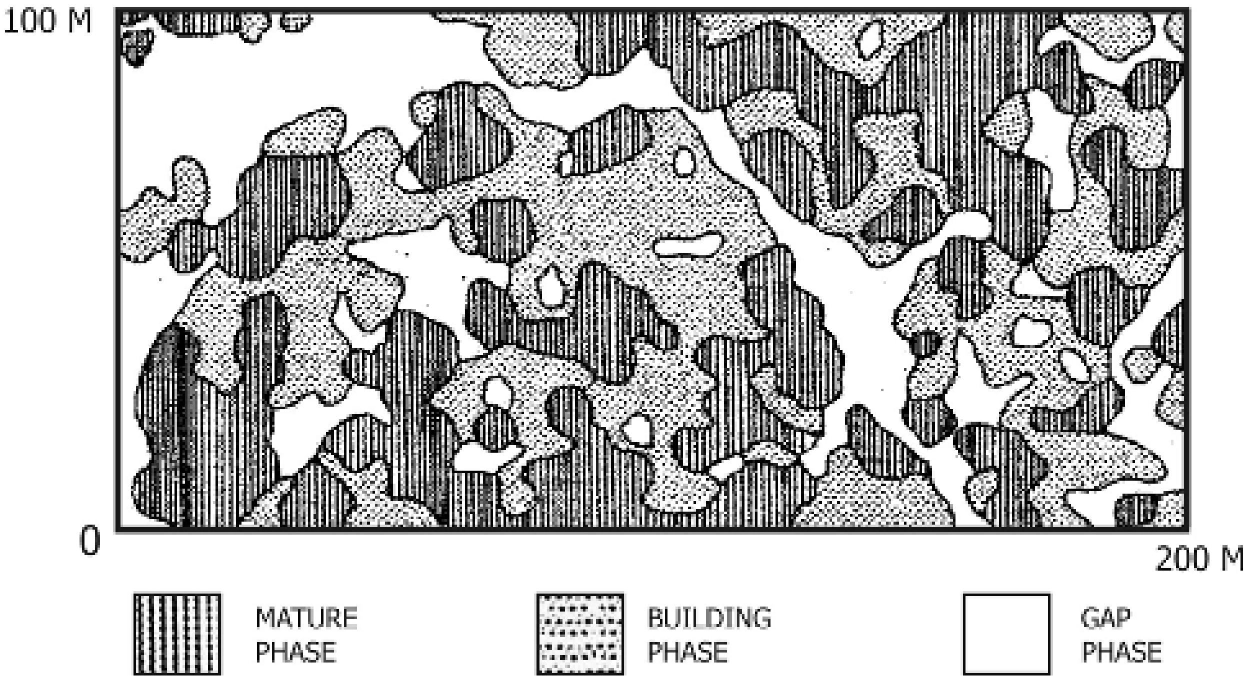

Figure 5. Gap, building and mature phases in the canopy of 2-ha logged-over lowland forest four years after logging at Sekundur, GLNP, North Sumatra (After Abdulhadi *et al.*1987). The mature phase consists of the unlogged forest left during the selective logging in 1978.

(40,90-27.68)/0.35 = 37.77 years from year 2000 or 33.77 + 18 = 55.77 years from 1982. If the basal area of *Dipterocarpaceae* was used as the basis of calculation it would take 154.39 years from the year 2000 or 154.39 + 18 = 172.39 years from the year 1982. This is based on the fact that in 18 years the basal area of *Dipterocarpaceae* in the logged-over forest increased from 6.49 m^2/ha in 1982 to 8.25 m^2/ha in 2000, thus giving the rate of basal area

Table 4. Basal area of trees with DBH ≥ 10 cm in a 2-ha plot of a selectively logged lowland forest four years (1982) and 22 years (2000) after logging at Sekundur and in an undisturbed lowland primary forest at Ketambe, GLNP, North Sumatra.

	Four years after logging (1982)*	Twenty two years after logging (2000)	Undisturbed primary forest**)
Number of trees/ha	418.5	572.5	538
Basal area (m^2/ha)	21.44	27.68	40.90
Number of trees of Dipterocarpaceae/ha	59	63.5	139
Basal area of Dipterocarpaceae (m^2/ha)	6.49	8.25	23.38

Source: *) Abdulhadi (unpublished data of 2 ha logged forest at Sekundur); **) Abdulhadi *et al.* (1989) from primary forest plot of 1.6 ha at Ketambe, TNGL, North Sumatra

Table 5. The area and percentage of the canopy phases in a 2-ha plot of a selectively logged lowland forest four years and 22 years after logging at Sekundur, GLNP, compared with an undisturbed lowland dipterocarp forest at Sungei Menyala, Peninsular Malaysia

Canopy phase	Four years after selective logging (1982)*		Twenty two years after selective logging (2000)		Primary forest **	
	Area (m^2)	% Area	Area (m^2)	% Area	Area (m^2)	% Area
Gap	6200	31.0	4920	24.6	2400	12.0
Building	6200	31.0	3940	19.7	6800	34.0
Mature	7600	38.0	11140	55.7	10800	54.0

*) The present 2-ha plot measured in 1982 (Abdulhadi *et al.*, 1987).
**) A primary lowland dipteroccarp forest at Sungei Menyala (Whitmore, 1984).

increment of 0.098 m2/year, while the basal area of Dipterocarpaceae in the undisturbed primary forest at Ketambe was 23.38 m^2/ha (Abdulhadi *et al.* 1989). Meanwhile the restoration of a selectively logged forest (Meijer 1970) and a small area of clear-cut forest (Riswan *et al.* 1986) to a forest similar to original undisturbed conditions would take more than 150 years. However, due to various habitat changes during the log extraction, such as loss of nutrients and soil soil compaction, the logged-over forest will probably never return to original conditions.

Gaps

Figure 4 shows the results of mapping the canopy in the two-ha plot carried out in the year 2000 or 22 years after selective logging, indicating the gap, building and mature phases . It should be noted that the mature phase consists of the unlogged forest left during the selective logging in 1978 and the mature phase developed from the building phase during 18 years since the observation made in 1982. It is evident that there were many small and big gaps forming scattered patches with a total area of 4920 m^2 (24.6%), while the building phase and mature phase covered 3940 m^2 (19.7%) and 11140 m^2 (55.7%), respectively (Table 4). Figure 5 shows the gap, building and mature phases of the canopy in 1982 with their areas shown in Table 3. The gap area amounted to 31 %, indicating the severe damage of the canopy that affected the further development of the forest. Comparing the above canopy situations revealed that as yet 22 years after logging the full recovery has not been achieved. Gaps in undisturbed lowland primary forests of Malesia are only 10 –17 % of the canopy coverage (Hopkins *et al.*, 1976; Partomihardjo *et al.*, 1987; Poore, 1968; Whitmore, 1984)

Table 5 shows also the closure of 20.6 % of gaps from 6200 m^2 to 4920 m^2 during the period of 18 years or a rate of closure of 1.14 % per year, while the mature phase increased by 46.6 % or a rate of 2.6 % per year. Trees that played a role in the closure of gaps were 34 % *Euphorbiaceae* (in particular *Baccaurea kunstleri* , *Cleistanthus bakonensis*, *Endospermum diadenum, Macaranga diepenhorstii, Mallotus penangensis* and *Sapium baccatum*), 9.5% *Dipterocarpaceae* (especially *Shorea kunstleri, S. pauciflora* and *S. multiflora*), 8.4 % *Lauraceae* (particularly *Cinnamomum inners* and *Litsea noronhae*), and 5 % *Anacardiaceae* (in particular *Mangifera gracilipes* and *Mangifera odorata*). Other species contributing to the gap closure included *Lophopetalum javanicum* (*Celastraceae*), *Archidendron bubalinum* (*Fabaceae*), *Artocarpus kemando* (Moraceae), *Ardisia lanceolata* (*Myrsinaceae*), *Eugenia acutangula* (*Myrtaceae*), *Pentace polyantha* (*Tiliaceae*), and *Teijsmanniodendron coriaceum* (*Verbenaceae*).

Considering the closure of gaps took place in 18 years from 6200 m^2 to 4920 m^2 or 71.11 m^2 per year and referring to the area of gaps of 2400 m^2 in an undisturbed forest of similar kind, it is predicted that the gap pattern in the logged-over forest at Sekundur would be restored to a condition similar to undisturbed forest in about 53 years after logging.

The gap phase of 6200 m^2 measured in 1982 had developed into building and mature phases of 4240 m^2 (68.4% of the total gap area in 1982), while the remaining 1960 m^2 (31.6%) by 2000 still remained in gaps whose ground surfaces were invaded luxuriantly by a creeping fern *Dicranopteris linearis* of 1-2 m thick. The largest area of such gaps occurred on the logging roads where the *D. linearis* cover was gradually thinning out as the tree crowns were getting wider.

While in general the total area of gaps decreased during the period of 18 years as indicated in Table 5, it was observed also that during the same period new gaps, resulted from broken crown and naturally fallen trees, were also formed totaling 2960 m^2 or 21.5 % giving the rate of formation of 1.2 % per year. This is slightly higher than 1.05 % recorded for East Kalimantan forest (Partomihardjo *et al.* 1987). The gap formation could be attributed to the Bohorok windstorm that regularly passed through the area.

Figure 4 shows one large and several small gaps that did not develop into building phase during the period of 18 years, totaling 1960 m^2 or 31.6% of the total area in1982. They were mainly logging roads and skidtrails with bare and compacted soils devoid of top layers.

Figures 6 show the profile diagrams of the logged-forest 22 years after logging. It is evident that the second layer with height of 10-20 m was already well occupied by young trees. It was apparently attributed to the growth of both undamaged and damaged trees and re-sprouting

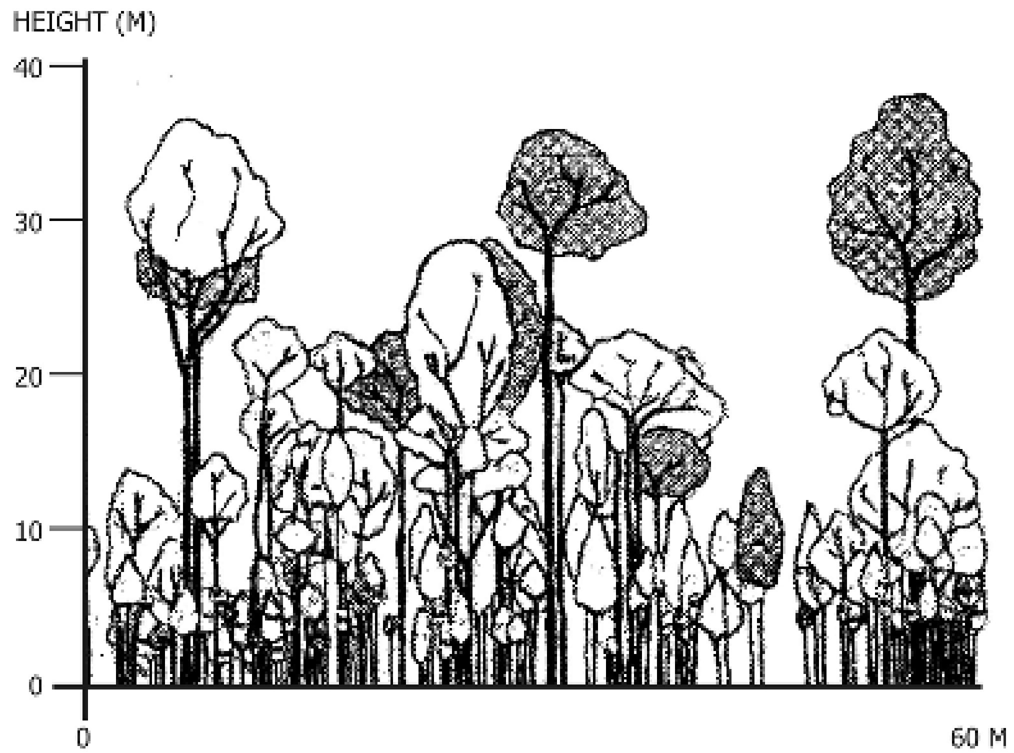

Figure 6. Profile diagram of a selectively logged lowland forest at Sekundur, GLNP, North Sumatra 22 years after logging. Shaded trees are species of Dipterocarpaceae, including *Diterocarpus grandiflorus* and *Shorea kunstleri* as the emergent reaching the height of about 40 m.

was responsible for the growth of damaged trees.

Soemarno (2001) found that in Sekundur forest recovery on logging roads were slower than on skidtrails, which in turn slower than on the areas of log extraction. In Sabah, Meijer (1970) noted that such areas were still discernible 40 years after logging. The slow recovery was perhaps due to heavy disturbance of soils, whose magnitude depend on the nature of soils, topography, logging intensity, technique of logging and the size and numbers of the equipment used (Kartawinata *et al.* 2001). The disappearance of top soils resulted in the loss of seed bank in the soil (Abdulhadi *et al.,* 1987). On compacted logging tracks the water infiltration rate is slow and could be seven times slower than that in the undisturbed soils (Abdulhadi *et al.* 1981), leading to an increase in surface runoff and subsequent erosion (Burgess 1971, Liew 1974). Growth of dipterocarp seedlings are hampered by drainage impediment resulted from soil compaction (Kartawinata *et al.*, 2001)

Changes in tree density and species richness

Between 1982 and 2000, the number of trees and the species richness increased (Table 6). In 1982 there were 837 trees recorded in 2-ha plot of which 214 trees could not be recovered in 2000. It indicates that during the period of 18 years the tree mortality was 25.57% or 1.4% per year, with the highest mortality occurred in the 10-20 cm diameter class, where 118 trees (14.10 %) died (Figure 7) . It was observed also that the mortality decreased as the diameter increased. Most of the 214 trees died between 1982 and 2000, were Euphorbiaceae (16.8 %), including *Cleistanthus bakonensis* and *Macaranga diepenhorstii,* followed by Tiliaceae (8.9 %), *i.e., Pentace polyantha*, while Anacardiaceae (*M. odorata*) and Dipterocarpaceae (*Shorea kunstleri*) lost only 8.9 %, respectively.

The mortality rate in the present study area was lower than that of the result of a long term investigation in undisturbed forest at Ketambe, which was only 2.3% per year (Wich *et al.* 1999). The high mortality at Ketambe was attributed among others to the high density of the strangling figs (Schaik, 1996), which was 8.5 trees/ha (Palombit, 1992). The mortality at Sekundur was comparable to the rate of 1-2 % generally recorded in tropical forests elsewhere (Swaine *et al*., 1987; Whitmore, 1984), although lower than the rate of 2.1 % per year occurring in secondary forests, where 40 % of the mortality taking place in trees with DBH of 19-24 cm (Whitmore, 1984).

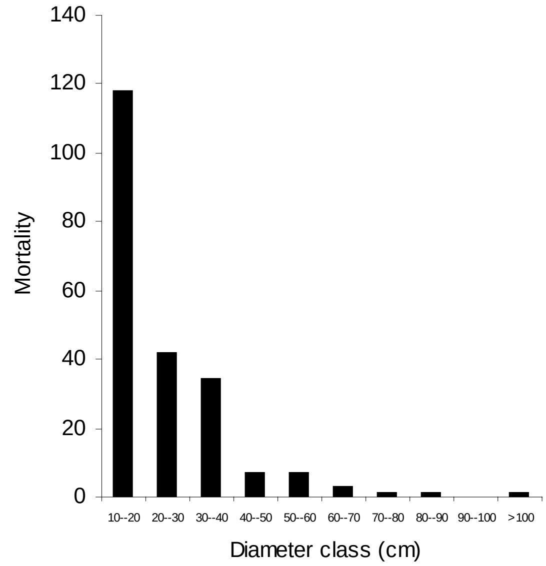

Figure 7. Mortality of trees by diameter classes between 1982 and 2000 in the 2-ha plot of selectively logged lowland forest at Sekundur, GLNP, North Sumatra.

Figure 8 shows that there was no mortality in 56 of 127 species recorded in 1982 (Class I). The remaining 71 species experienced mortality

Table 6. Changes in composition and density of trees with DBH ≥ 10 cm in the 2-ha plot of a selectively logged lowland forest between 1982 (Abdulhadi, unpublished) and 2000 at Sekundur, GLNP, North Sumatra.

	Four years after logging (1982)	Twenty two years after logging (2000)
Number of trees	837	1145
Number of species	127	133
Number of genera	88	87
Number of families	40	39
Species diversity index (H')	1.826	1.843
Species evenness index (E)	0.271	0.262

between 10 % and 100 % . Sixteen species had 100 % mortality (Class VII). Ten of them did not regenerate. Single trees that did not regenerate included *Alstonia* sp. (*Apocynaceae*), *Dillenia indica* (*Dilleniaceae*), *Macaranga triloba*, *Spathiostemon javensis* (*Euphorbiaceae)*, *Petunga* sp. (*Rubiaceae*), *Polyalthia sumatrana*, *Popowia hirta*, *Xylopia mucronata* (*Annonaceae*), *Scaphium macropodum* (*Sterculiaceae*), and *Scleropyrum cf. wallichianum* (*Santalaceae*).

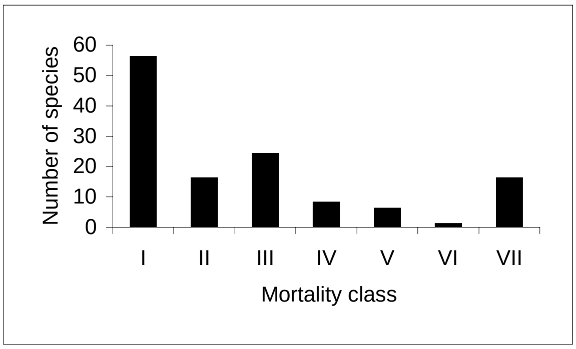

Fig. 8. Number of species and mortality class (I= 0.0%; II= 1.0-19.9 %; III= 20.0 -39.9 %; IV= 40.0-59.9 %; V= 60.0-79.9 %; VI= 80.0-99.9 %; VII= 100%) in the 2-ha plot of selectively logged lowland forest during the period of 18 years at Sekundur, GLNP, North Sumatra.

In 18 years, 520 new trees with DBH of 10-46 cm belonging to 101 species appeared in the 2-ha plot of the selectively logged forest. Among these new recruits, 16 species with a total of 17 trees were not recorded in 1982, indicating new appearance stimulated by logging. The 16 new species included the following: *Barringtonia macrostachya* (*Lecythidaceae*), *Canarium kipella* (*Burseraceae*), *Dysoxylum* sp3., *Dysoxylum* sp4. (*Meliaceae*), *Elattostachys* sp. (*Sapindaceae*), *Euodia robusta*, *Euodia* sp1. (*Rutaceae*), *Garcinia dioica* (*Clusiaceae*), *Leea* sp. (*Leeaceae*), *Myristica maxima* (*Myristicaceae*), *Rubiaceae* sp1. (*Rubiaceae*), *Shorea* sp2. (*Dipterocarpaceae*), *Sizygium racemosum* (*Myrtaceae*), *Trigonostemon serratus* (*Euphorbiaceae*), *Vitex gamosepala* (*Verbenaceae*) and *Xanthophyllum erhychum* (*Polygalaceae*). The number of species in secondary forests within the selectively logged forests is less than in primary forests.

Figure 9 shows the changes of number of trees in 127 species during the period of 18 years. It should be noted that 52.8 % of the species showed the change in density only by one tree or no change at all. The number of trees of eight species (*Ganua mottleyana* , *Mezzettia parviflora*, *Litsea noronhae*, *Baccaurea kunstleri*, *Mallotus penangensis*, *Endospermum diadenum*, *Sapium baccatum* and *Macaranga diepenhorstii*) changed from 12 to 48 trees. The number of trees of light-demanding species (*Baccaurea kunstleri*, *Mallotus penangensis Endospermum diadenum*, *Sapium baccatum* and *Macaranga diepenhorstii*) increased sharply. Most likely they were recruited from seeds stored in the soils under the canopy in response to the formation of gaps in the canopy.

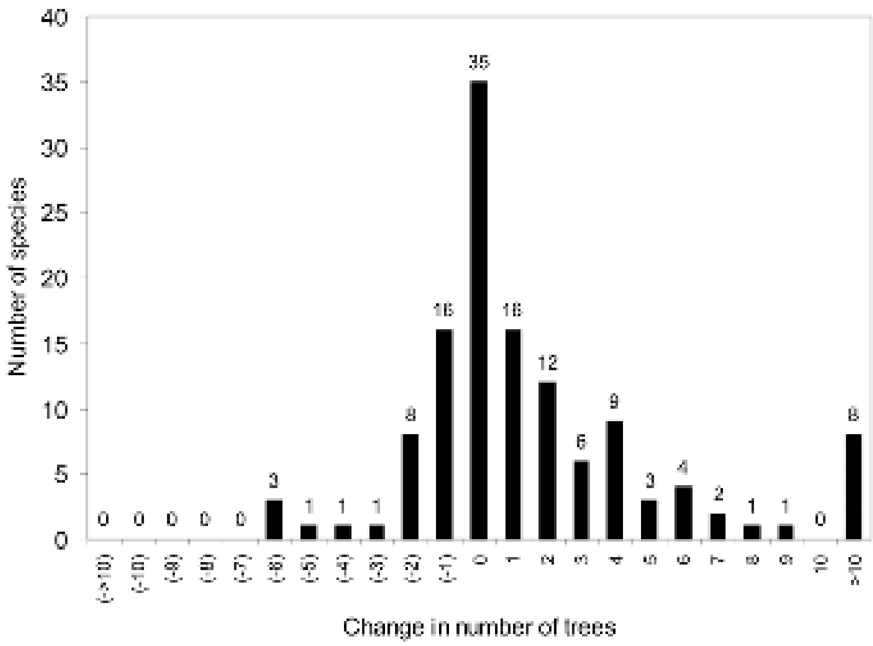

Figure 9. The change in number of trees during the 18 year period in 127 species occurring in a 2-ha plot of the selectively logged lowland forest at Sekundur, GLNP, North Sumatra.

CONCLUSION

During the period of 18 years there has been no shift in the richest families, most important families and most important species. *Euphorbiaceae* was the richest family and *Dipterocarpaceae* was the most important family. *Shorea kunstleri* was the most important species with highest importance values throughout the period. The number of species increased from 127 to 133 with increase in density by 36.8%. *Euphorbiaceae* experienced the highest mortality, particularly among the trees with smaller diameters. Mortality decreased with the increase of diameters. In 18 years the tree mortality rate was 1.4 % per year. The diameter class distribution indicated that the forest recovery has not been fully achieved. The canopy has not fully recovered and the complete closure of gaps is estimated to take 58 years since the logging started. Based on the basal area of all species, the logged-over forest at Sekundur is estimated to reach a situation similar to undisturbed primary forest in 56 years after logging, but on the basis of basal area of *Dipterocarpaceae* such condition could be achieved within 172 years. The construction of wide logging roads and skidtrails and heavy compaction of soils delayed the recovery of the logged-over forest.

The above facts have implications for the improvement of silvicultural system by adopting the reduced-impact logging technique in order to reduce the degree of destruction, hence increase the recovery rate and thus reduce the length of cutting cycle. Without additional disturbances the selectively logged forest will naturally develop into a more complex forest through succession. The recovery may be accelerated by rehabilitation measures while allowing natural succession to take place. In the Sekundur forest the objective of rehabilitation should be to achieve species diversity, hence the use of a wider set of species should be preferred.

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REFERENCES

ABDULHADI, R. 1992. Floristic changes in a sub-tropical rain forest succession. *Reinwardtia* 11: 13–23.

ABDULHADI, R.; SRIJANTO, A. & KARTA-WINATA. K. 1998. Composition, structure, and changes in a montane rain forest at the Cibodas Biosphere Reserve, West Java, Indonesia. Pp. 601-612 *in* DALLMEIER, F. & COMISKEY, J.A. (Eds.). 1998. *Forest biodiversity research, monitoring and modeling. Conceptual background and Old World case studies.* Man and the Biosphere Series Vol. 20, UNESCO, Paris.

ABDULHADI, R.; MIRMANTO, E. & KARTA-WINATA, K. 1987. A lowland dipterocarp forest in Sekundur, North Sumatra, Indonesia: Five years after mechanized logging. Pp. 255—273 *in* KOSTERMANS, A.J.G.H (Ed.). 1987. *Proceedings of the third-round table conference on dipterocarps,* UNESCO, Jakarta.

ABDULHADI, R.; MIRMANTO, E. & YUSUF, R. 1989. Struktur dan komposisi petak hutan Dipterocarpaceae di Ketambe, Taman Nasional Gunung Leuser. *Ekologi Indonesia* 1: 29-36.

ABDULHADI, R., KARTAWINATA, K. & SUKAR-DJO, S. 1981. Effects on mechanized logging in the lowland dipterocarp forest at Lempake, East Kalimantan. *Malaysian Forester* 44: 407–418.

ABDULHADI, R.; YUSUF, R. & KARTAWINATA, K. 1991. A riverine tropical rain forest in Ketambe, Gunung Leuser National Park, Sumatra, Indonesia. *In* SOERIANEGARA, I.; S.S. TJITROSOMO; R.C. UMALY & I. UMBOH (Eds.). 1991. *Proceedings of the fourth round-table conference on dipterocarps. BIOTROP Special Publication* No. 41: 247-255.

BERTAULT, J-G. & SIST, P. 1997. An experimental comparison of different harvesting intensities with reduced-impact and conventional logging in East Kalimantan, Indonesia. *Forest Ecology and Management* 94: 209-218.

BRAY, J.R. & CURTIS, J.T. 1957. An ordination of the upland forest communities of southern Wisconsin. *Ecological Monographs* 27: 325-349.

BUDIMAN, A. & ABDULHADI, R. 1995. Biodiversity and land degradation in Indonesia: Scientific and technological research promotion. Paper presented at the Brainstorming and High Level Workshop on Biodiversity and Land

Degradation of Third World Network of Scientific Organization. Trieste, Italy, 9-10 May 1995.

BURGESS, P.F. 1971. The effects of logging in hill dipterocarp forests. *Malayan Nature Journal* 24: 231-237

CANNON, C.H.; PEART, D.R.; LEIGHTON, M. & KARTAWINATA, K.1994. The structure of lowland rainforest after selective logging in West Kalimantan, Indonesia. *Forest Ecology and Management* 67: 49-68.

FOX, J.E.D. 1969. The soil damage factors in the present day logging in Sabah. *Sabah Society Journal* 5: 43-52.

HAERUMAN, H. 1978. Residual stand and its prospect for development in East Kalimantan. *In* SUPARTO, R.S. and seven others (Eds.), *Proceedings of the symposium on long term effects of logging in Southeast Asia.* BIOTROP Special Publication 3: 91-96.

HARTSHORN, G.S. 1990. An overview of geotropically forest dynamics. Pp. 585-598 *in* GENTRY, A.H. (Ed.). 1990. *Four neotropical rain forests*. Yale University Press, New Haven,.

HOPKINS, M.S.; KIKAWA, J.; GRAHAM, A.W.; TRACEY, J.G. & WEBB, L.J. 1976. *Towards a solution an ecological basis for the management of rain forest*: *The border ranges, a land use conflict in regional perspective*. Royal Society of Queensland, Queensland.

KARTAWINATA, K. 1989. Keanekaragaman flora dalam hutan pamah. Seminar regional aspek konservasi dalam pembangunan sumber daya hutan tropika humida di Kalimantan. Samarinda, 18-19 Oktober 1989.

KARTAWINATA, K. 1990. A review of natural vegetation studies in Malesia with special reference to Indonesia. Pp. 121-132 *in* Bass, P. *et al*. (Eds.). 1990. *The plant diversity of Malesia,* Kluwer Academic Publishers, Dordrecht,

KARTAWINATA, K., ABDULHADI, R. & PARTO-MIHARDJO, T. 1981. Composition and structure of a lowland dipterocarp forest at Wanariset, East Kalimantan. *Malaysian Forester* 44(2&3): 397–406.

KARTAWINATA, K; ADISOEMARTO, S.; RIS-WAN, S.; ABDULHADI, R.; NOERDJITO, W.A.; SOEDJITO, H; SUPRIATNA, J.; SUHARDJONO, Y.R. & WIRJOATMODJO, S. 1983. *Suksesi sekunder dan perubahan ekologi lainnya di hutan hujan tropik setelah perusakan oleh manusia di Kalimantan Timur.* Lembaga Biologi Nasional, Bogor & Panitia Program MAB Indonesia, Jakarta

KARTAWINATA, K.; RISWAN, S.; GINTINGS, A.N. & PUSPITOJATI, T. 2001. An overview of post-extraction secondary forests in Indonesia. *Journal of . Tropical Forest Science* 13(4): 621–638.

KARTAWINATA, K; AFRIASTINI, J.J.; HERIYANTO, M. & SAMSOEDIN, I. 2004. A tree species inventory in the Batang Gadis National Park, North Sumatra, Indonesia. *Reinwardtia* 12: 2004

LAMOUNIER, Y. 1997. *The vegetation and physiography of Sumatra*. Kluwer Academic Publishers, Dordrecht.

LIEW, T.C. 1974. A note on soil erosion study at Tawau hills forest reserve. *Malayan Nature Journal* 27: 20-26

MANULLANG, B.O. 1998. *Distribution patterns of Sumatran plants and primates.* Ph.D. Dissertation. University of California, Davis.

MAGURRAN, A.E. 1988. *Ecological diversity and its measurements*. Croom Helm Limited, London.

MEIJER, W. 1970. Regeneration of tropical lowland forest in Sabah, Malaysia, forty years after logging. *Malayan Forester* 32: 204–299.

MUELLER-DOMBOIS, D. & ELLENBERG, H. 1972. *Aims and methods of vegetation ecology.* John Wiley & Sons, New York.

NICHOLSON, D.A. 1958. Natural regeneration of logged tropical rain forest, North Borneo. *Malayan Forester* 21: 65-71.

PALOMBIT, R.A. 1992. *Pair bonds and monogamy in wild siamang* (Hylobates syndactylus) *and white-handed gibbon* (Hylobates lar) *in northern Sumatra*. Ph.D. Dissertation. University of California, Davis.

PARTOMIHARDJO, T.; YUSUF, R.; SUNARTI, S.; PURWANINGSIH; ABDULHADI, R. & KAR-TAWINATA, K. 1987. A preliminary note on gaps in a lowland dipterocarp forest in Wanariset, East Kalimantan. Pp. 241-253 *in* KOSTERMANS, A. J. G. H.(Ed.). 1987. *Pro-ceedings of the third-round table conference on dipterocarps,* UNESCO, Jakarta,

POORE, M.E.D. 1968. Studies in Malaysian rain forest: The forest on the Triassic sediments in Jengka Forest Reserve. *Journal of Ecology* 56: 143–196.

RISWAN, S. 1982. *Ecological studies of primary, secondary and experimentally cleared mix dipterocarp forest and kerangas forest in East Kalimantan*. Ph.D. Dissertation. University of Aberdeen, Aberdeen.

RISWAN, S. 1987. Structure and floristic composition of a mixed dipterocarp forest at Lempake, East Kalimantan. Pp. 435—457 *in* KOSTERMANS, A.J.G.H.(Ed.). 1987. *Proceedings of the third-round table conference on dipterocarps,* UNESCO, Jakarta.

RISWAN, S. & KARTAWINATA, K. 1988. A lowland dipterocarp forest 35 years after pepper plantation in East Kalimantan, Indonesia. *In* SOEMODIHARDJO, S. (Ed.). 1988. *Some ecological aspects of tropical forest of East*

Kalimantan: *A collection of research papers*. MAB Indonesia Contribution No. 48: 1-40.

RISWAN, S. & KARTAWINATA, K. 1991. Regeneration in a lowland dipterocarp forest in East Kalimantan, Indonesia. Pp. 295-301 *in* GOMEZ-POMPA, A., WHITMORE, T.C. & HADLEY, M. (Eds.). *Rain forest regeneration and management.* UNESCO, Paris.

RISWAN, S., KENTWORTHY, J.B. & KARTAWINATA, K. 1986. The estimation of temporal processes in tropical rain forest: A study of primary mixed dipterocarp forest in Indonesia. *Journal of Tropical Ecology* 1: 171-182.

ROSALINA, U. 1988. Natural regeneration of dipterocarp forest ; the secondary forest types. Pp. 129-138 *in* COTO, Z. (Ed.), *Forest Regeneration in Southeast Asia.* SEAMEO-BIOTROP, Bogor,

SCHAIK, C.P.VAN. 1996. Strangling figs: Their role in the forest. Pp. 112-120 *in* SCHAIK, C.P.VAN & SUPRIATNA, J. (Eds.), *Leuser*: *A Sumatran sanctuary,* YABSHI, Jakarta.

SCHMIDT, F.R. & FERGUSON, J.A. 1951. *Rainfall types based on wet and dry period ratios for Indonesia with Western New Guinea.* Verhandelingen 42, Djawatan Meteorologi dan Geofisika, Jakarta.

SIST, P.; SABOGAL, C & BYRON, Y. 1997. *Management of Secondary and Logged-over Forests in Indonesia; Selected Proceedings of an International Workshop, 17-19 November, 1997.* CIFOR, Bogor

SIST, P.; SHEIL,D.; KARTAWINATA, K. & PRIYADI, H. 2003. Reduced-impact logging in Indonesian Borneo: some results confirming the need for new silvicultural prescriptions. *Forest Ecology and Management* 179: 415-427.

SOEMARNA, K. & SUYANA, A. 1979. Inventarisasi potensi permudaan dan tegakan sisa penebangan di Kesatuan Pemangkuan Hutan Ketapang, Kalimantan Barat. *Lembaga Penelitian Hutan Laporan 309*.

SOEMARNO, S. 2001. *Struktur dan komposisi vegetasi pada petak tebang dan pola pemulihan tapak prasarana pasca pembalakan mekanis di Sekundur, Taman Nasional Gunung Leuser*. Tesis M.Si., Universitas Indonesia, Depok.

SOEPRAPTOHARDJO, M. & ISMANGUN 1980. Classification of red soils in indonesia by the Soil Research Institute. Pp. 15-23 *in* BUURMAN, P. (Ed.), *Red soils in Indonesia.* Bulletin No. 5, Soil Research Institute, Bogor.

SWAINE, M.D.; LIEBERMAN, D. & PUTZ, F.E.1987. The dynamics of tree populations in tropical forest: A review. *Journal of Tropical Ecology* 3: 359-366.

TINAL, U. & PALINEWEN, J. 1978. Mechanical logging damage after selective cutting in the lowland Dipterocarp forest at Beloro, East Kalimantan. In SUPARTO, R.S. and seven others (Eds.), *Proceedings of the Symposium on Long Term Effects of Logging in Southeast Asia.* BIOTROP Special Publication 3: 91-96

WHITMORE, T.C. 1984. *Tropical rain forest of the Far East,.* 2nd ed., Oxford University Press, Oxford.

WICH, S.A.; STEENBEEK, R.; STERCK, E.H.M.; PALOMBIT, R. A. & USMAN, S. 1999. Tree mortality and recruitment in an Indonesian rain forest. *Tropical Biodiversity* 6: 189–195.

ZAR, J.H. 1996. *Biostatistical analysis*. Prentice-Hall International Inc., New Jersey.

Appendix 1. Composition of tree species with DBH ≥ 10 cm in a two-hectare plot of selectively logged lowland forest at Sekundur, Gunung Leuser National Park, North Sumatra.

Family and Species	Basal area (m^2)	Density (trees/ha)	Frequency (%)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	Importance Value (%)
1	2	3	4	5	6	7	8
1. Anacardiaceae:	**4.70**	**32.50**	**0.29**	**5.677**	**5.734**	**8.487**	**19.899**
1 *Campnospermum auriculatum*	0.09	2.50	0.020	0.437	0.402	0.164	1.003
2 *Dracontomelon dao*	0.07	0.50	0.005	0.087	0.101	0.127	0.315
3 *Gluta renghas*	0.10	4.00	0.040	0.699	0.805	0.172	1.676
4 *Mangifera foetida*	0.04	1.50	0.015	0.262	0.302	0.070	0.634
5 *Mangifera gracilipes*	2.41	17.00	0.140	2.969	2.817	4.354	10.141
6 *Mangifera odorata*	0.42	4.50	0.040	0.786	0.805	0.764	2.355
7 *Mangifera* sp1.	0.14	2.00	0.020	0.349	0.402	0.250	1.001
8 *Melanochyla caesia*	1.43	0.50	0.005	0.087	0.101	2.585	2.773
2. Annonaceae:	**1.67**	**19.00**	**0.18**	**3.319**	**3.622**	**3.017**	**9.958**
9 *Cananga odorata*	0.05	1.00	0.010	0.175	0.201	0.088	0.464
10 *Goniothalamus giganteus*	0.01	0.50	0.005	0.087	0.101	0.021	0.209
11 *Mezzettia parviflora*	1.47	16.50	0.155	2.882	3.119	2.655	8.655
12 *Polyalthia lateriflora*	0.14	1.00	0.010	0.175	0.201	0.254	0.630
3. Apocynaceae:	**0.33**	**1.50**	**0.015**	**0.262**	**0.302**	**0.591**	**1.155**
13 *Dyera costulata*	0.33	1.5	0.015	0.262	0.302	0.591	1.155
4. Bombacaceae:	**0.71**	**12.50**	**0.120**	**2.183**	**2.414**	**1.284**	**5.882**
14 *Durio griffithii*	0.71	12.50	0.120	2.183	2.414	1.284	5.882
5. Burseraceae:	**0.66**	**9.00**	**0.090**	**1.572**	**1.811**	**1.201**	**4.583**
15 *Canarium caudatum*	0.56	5.00	0.050	0.873	1.006	1.007	2.886
16 *Canarium kipella*	0.02	0.50	0.005	0.087	0.101	0.028	0.216
17 *Dacryodes laxa*	0.03	0.50	0.005	0.087	0.101	0.053	0.241
18 *Dacryodes rostrata*	0.01	1.00	0.010	0.175	0.201	0.019	0.395
19 *Santiria oblongifolia*	0.05	2.00	0.020	0.349	0.402	0.094	0.846
6. Celastraceae:	**1.64**	**13.00**	**0.125**	**2.271**	**2.515**	**2.959**	**7.745**
20 *Lophopetalum javanicum*	1.64	13.00	0.125	2.271	2.515	2.959	7.745
7. Clusiaceae:	**0.87**	**8.50**	**0.085**	**1.485**	**1.710**	**1.571**	**4.766**
21 *Calophyllum saigonense*	0.38	2.00	0.020	0.349	0.402	0.680	1.432
22 *Calophyllum soulattri*	0.29	1.00	0.010	0.175	0.201	0.518	0.894
23 *Calophyllum venulosum*	0.11	3.50	0.035	0.611	0.704	0.194	1.510
24 *Garcinia celebica*	0.02	0.50	0.005	0.087	0.101	0.040	0.228
25 *Garcinia dioica*	0.01	0.50	0.005	0.087	0.101	0.014	0.202
26 *Garcinia havilandii*	0.07	1.00	0.010	0.175	0.201	0.125	0.501
8. Dipterocarpaceae:	**16.49**	**63.50**	**0.550**	**11.092**	**11.066**	**29.790**	**51.948**
27 *Dipterocarpus grandiflorus*	2.49	5.50	0.055	0.961	1.107	4.496	6.564
28 *Dipterocarpus rigidus*	0.07	1.50	0.015	0.262	0.302	0.118	0.682
29 *Hopea beccariana*	0.01	0.50	0.005	0.087	0.101	0.024	0.212
30 *Shorea kunstleri*	8.96	23.50	0.205	4.105	4.125	16.184	24.414
31 *Shorea leprosula*	1.57	10.50	0.090	1.834	1.811	2.843	6.488
32 *Shorea multiflora*	1.55	12.50	0.090	2.183	1.811	2.808	6.802
33 *Shorea pauciflora*	1.82	9.00	0.085	1.572	1.710	3.287	6.570
34 *Shorea* sp2.	0.02	0.50	0.005	0.087	0.101	0.030	0.218
9. Ebenaceae:	**0.30**	**9.00**	**0.090**	**1.572**	**1.811**	**0.550**	**3.933**
35 *Diospyros malabarica*	0.15	3.00	0.030	0.524	0.604	0.276	1.404
36 *Diospyros pychocarpa*	0.15	6.00	0.060	1.048	1.207	0.274	2.529
10. Euphorbiaceae:	**6.84**	**124.00**	**0.885**	**21.659**	**17.807**	**12.347**	**51.813**
37 *Aporusa antennifera*	0.03	1.00	0.010	0.175	0.201	0.058	0.434
38 *Aporusa nitida*	0.18	2.50	0.025	0.437	0.503	0.334	1.274
39 *Aporusa quadrilocularis*	0.03	1.50	0.015	0.262	0.302	0.049	0.613
40 *Baccaurea deflexa*	0.24	3.50	0.030	0.611	0.604	0.431	1.646
41 *Baccaurea kunstleri*	0.71	11.00	0.105	1.921	2.113	1.286	5.320

Appendix 1. continued.

Family and Species	Basal area (m²)	Density (trees/ha)	Frequency (%)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	Importance Value (%)
1	2	3	4	5	6	7	8
42 *Baccaurea lanceolata*	0.06	2.00	0.020	0.349	0.402	0.115	0.867
43 *Baccaurea* sp.	0.05	1.50	0.010	0.262	0.201	0.085	0.548
44 *Blumeodendron elatriospermum*	0.03	0.50	0.005	0.087	0.101	0.050	0.238
45 *Blumeodendron tokbraii*	0.20	1.00	0.010	0.175	0.201	0.362	0.738
46 *Bridelia glauca*	0.06	0.50	0.005	0.087	0.101	0.116	0.304
47 *Cleistanthus bakonensis*	0.45	14.00	0.100	2.445	2.012	0.820	5.278
48 *Drypetes longifolia*	0.46	3.00	0.030	0.524	0.604	0.835	1.962
49 *Endospermum diadenum*	1.28	16.00	0.125	2.795	2.515	2.312	7.622
50 *Macaranga diepenhorstii*	1.67	34.00	0.170	5.939	3.421	3.012	12.371
51 *Mallotus penangensis*	0.61	12.00	0.080	2.096	1.610	1.109	4.815
52 *Mallotus* sp1.	0.01	0.50	0.005	0.087	0.101	0.019	0.207
53 *Sapium baccatum*	0.73	19.00	0.135	3.319	2.716	1.327	7.362
54 *Triginostemon serratus*	0.01	0.50	0.005	0.087	0.101	0.026	0.214
11. Fabaceae:	**0.52**	**11.00**	**0.100**	**1.921**	**2.012**	**0.940**	**4.873**
55 *Parkia timoriana*	0.11	1.50	0.015	0.262	0.302	0.207	0.771
56 *Pithecellobium cf. bubalinum*	0.40	9.00	0.080	1.572	1.610	0.717	3.898
57 *Sindora leiocarpa*	0.01	0.50	0.005	0.087	0.101	0.016	0.204
12. Fagaceae:	**2.82**	**10.50**	**0.100**	**1.834**	**2.012**	**5.099**	**8.945**
58 *Lithocarpus urceolaris*	2.31	3.50	0.035	0.611	0.704	4.166	5.482
59 *Lithocarpus wrayii*	0.50	6.50	0.060	1.135	1.207	0.901	3.244
60 *Quercus argentata*	0.02	0.50	0.005	0.087	0.101	0.032	0.220
13. Flacourtiaceae:	**1.87**	**22.50**	**0.215**	**3.930**	**4.326**	**3.373**	**11.629**
61 *Hydnocarpus kunstleri*	0.61	2.50	0.025	0.437	0.503	1.106	2.045
62 *Osmelia maingayi*	0.38	5.00	0.050	0.873	1.006	0.682	2.562
63 *Pangium edule*	0.71	12.00	0.110	2.096	2.213	1.276	5.586
64 *Scolopia macrophylla*	0.17	3.00	0.030	0.524	0.604	0.309	1.436
14. Icacinaceae:	**0.16**	**3.00**	**0.03**	**0.524**	**0.604**	**0.282**	**1.409**
65 *Stemonurus secundiflorus*	0.16	3.00	0.030	0.524	0.604	0.282	1.409
15. Juglandaceae:	**0.14**	**0.50**	**0.005**	**0.087**	**0.101**	**0.252**	**0.440**
66 *Engelhardtia spicata* Blume	0.14	0.50	0.005	0.087	0.101	0.252	0.440
16. Lauraceae:	**2.66**	**48.00**	**0.390**	**8.384**	**7.847**	**4.799**	**21.030**
67 *Alseodaphne cf. elmeri*	0.15	2.00	0.020	0.349	0.402	0.268	1.019
68 *Alseodaphne crassifolia*	0.05	1.50	0.015	0.262	0.302	0.092	0.656
69 *Cinnamomum iners*	1.25	21.00	0.170	3.668	3.421	2.267	9.355
70 *Cinnamomum subterapterum*	0.02	0.50	0.005	0.087	0.101	0.037	0.225
71 *Cryptocarya crassinervia*	0.02	0.50	0.005	0.087	0.101	0.028	0.216
72 *Endiandra rubescens*	0.08	2.00	0.020	0.349	0.402	0.142	0.894
73 *Litsea glutinosa*	0.11	3.50	0.020	0.611	0.402	0.200	1.214
74 *Litsea noronhae*	0.92	15.00	0.115	2.620	2.314	1.653	6.587
75 *Litsea* sp1.	0.05	1.50	0.015	0.262	0.302	0.093	0.657
76 *Litsea* sp3.	0.01	0.50	0.005	0.087	0.101	0.019	0.207
17. Lecythidaceae:	**0.02**	**1.00**	**0.010**	**0.175**	**0.201**	**0.033**	**0.409**
77 *Barringtonia macrostachya*	0.01	0.50	0.005	0.087	0.101	0.016	0.204
78 *Barringtonia scortechinii*	0.01	0.50	0.005	0.087	0.101	0.017	0.205
18. Leeaceae:	**0.01**	**0.50**	**0.005**	**0.087**	**0.101**	**0.017**	**0.205**
79 *Leea* sp.	0.01	0.50	0.005	0.087	0.101	0.017	0.205
19. Melastomataceae:	**0.16**	**6.00**	**0.055**	**1.048**	**1.107**	**0.288**	**2.442**
80 *Pternandra caerulescens*	0.16	6.00	0.055	1.048	1.107	0.288	2.442
20. Meliaceae:	**1.47**	**14.50**	**0.140**	**2.533**	**2.817**	**2.648**	**7.998**
81 *Dysoxylum* sp1.	0.85	7.00	0.065	1.223	1.308	1.534	4.065
82 *Dysoxylum* sp2.	0.19	2.00	0.020	0.349	0.402	0.334	1.086

Appendix 1. continued.

Family and Species	Basal area (m²)	Density (trees/ha)	Frequency (%)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	Importance Value (%)
1	2	3	4	5	6	7	8
83 *Dysoxylum* sp3.	0.01	0.50	0.005	0.087	0.101	0.024	0.212
84 *Dysoxylum* sp4.	0.05	0.50	0.005	0.087	0.101	0.096	0.283
85 *Lansium domesticum*	0.12	2.50	0.025	0.437	0.503	0.211	1.151
86 *Sandoricum koetjape*	0.25	2.00	0.020	0.349	0.402	0.449	1.201
21. Moraceae:	**1.27**	**16.50**	**0.160**	**2.882**	**3.219**	**2.290**	**8.391**
87 *Artocarpus elasticus*	0.06	0.50	0.005	0.087	0.101	0.110	0.298
88 *Artocarpus kemando*	0.75	12.00	0.115	2.096	2.314	1.353	5.763
89 *Sloetia elongata*	0.46	4.00	0.040	0.699	0.805	0.827	2.331
22. Myristicaceae:	**1.39**	**11.50**	**0.105**	**2.009**	**2.113**	**2.508**	**6.629**
90 *Horsfieldia cf. subglobosa*	0.28	5.00	0.045	0.873	0.905	0.514	2.293
91 *Horsfieldia grandis*	0.21	3.00	0.030	0.524	0.604	0.374	1.502
92 *Horsfieldia macrocoma*	0.54	0.50	0.005	0.087	0.101	0.972	1.160
93 *Knema mandaharan*	0.35	2.50	0.020	0.437	0.402	0.631	1.470
94 *Myristica maxima*	0.01	0.50	0.005	0.087	0.101	0.017	0.205
23. Myrsinaceae:	**0.59**	**6.50**	**0.055**	**1.135**	**1.107**	**1.068**	**3.310**
95 *Ardisia fuliginosa*	0.01	0.50	0.005	0.087	0.101	0.015	0.203
96 *Ardisia lanceolata*	0.51	5.50	0.045	0.961	0.905	0.926	2.792
97 *Ardisia* sp1.	0.07	0.50	0.005	0.087	0.101	0.127	0.315
24. Myrtaceae:	**2.28**	**32.00**	**0.285**	**5.590**	**5.734**	**4.120**	**15.444**
98 *Eugenia acutangulum*	1.39	22.50	0.195	3.930	3.924	2.507	10.360
99 *Eugenia jamboloides*	0.38	4.50	0.040	0.786	0.805	0.691	2.282
100 *Eugenia polyantha*	0.02	0.50	0.005	0.087	0.101	0.030	0.218
101 *Eugenia* sp3.	0.04	0.50	0.005	0.087	0.101	0.069	0.257
102 *Syzygium laxiflorum*	0.07	1.50	0.015	0.262	0.302	0.128	0.691
103 *Syzygium racemosum*	0.38	2.50	0.025	0.437	0.503	0.694	1.634
25. Olacaceae:	**0.95**	**5.50**	**0.055**	**0.961**	**1.107**	**1.715**	**3.783**
104 *Strombosia javanica*	0.95	5.50	0.055	0.961	1.107	1.715	3.783
26. Podocarpaceae:	**0.013**	**0.50**	**0.005**	**0.087**	**0.101**	**0.023**	**0.211**
105 *Podocarpus* sp1.	0.013	0.50	0.005	0.087	0.101	0.023	0.211
27. Polygalaceae:	**0.29**	**5.50**	**0.050**	**0.961**	**1.006**	**0.528**	**2.495**
106 *Xanthophyllum affine*	0.27	5.00	0.045	0.873	0.905	0.494	2.273
107 *Xanthophyllum eurhychum*	0.02	0.50	0.005	0.087	0.101	0.034	0.222
28. Proteaceae:	**0.04**	**1.50**	**0.015**	**0.262**	**0.302**	**0.065**	**0.629**
108 *Helicia petiolaris*	0.04	1.50	0.015	0.262	0.302	0.065	0.629
29.Rhizophoraceae:	**0.03**	**1.50**	**0.015**	**0.262**	**0.302**	**0.047**	**0.611**
109 *Gynotroches axillaris*	0.03	1.50	0.015	0.262	0.302	0.047	0.611
30. Rosaceae:	**0.04**	**0.50**	**0.005**	**0.087**	**0.101**	**0.067**	**0.255**
110 *Parastemon urophyllus*	0.04	0.50	0.005	0.087	0.101	0.067	0.255
31. Rubiaceae:	**0.25**	**5.00**	**0.050**	**0.873**	**1.006**	**0.453**	**2.333**
111 *Neonauclea* sp.	0.03	1.00	0.010	0.175	0.201	0.051	0.427
112 *Plectroniella didyma*	0.13	2.00	0.020	0.349	0.402	0.226	0.978
113 *Randia macrophylla*	0.09	1.50	0.015	0.262	0.302	0.162	0.726
114 Rubiaceae spec1.	0.01	0.50	0.005	0.087	0.101	0.014	0.202
32. Rutaceae:	**0.15**	**3.00**	**0.030**	**0.524**	**0.604**	**0.273**	**1.400**
115 *Clausena engleri*	0.08	1.50	0.015	0.262	0.302	0.143	0.707
116 *Euodia robusta*	0.06	1.00	0.010	0.175	0.201	0.103	0.479
117 *Euodia* sp1.	0.01	0.50	0.005	0.087	0.101	0.027	0.215

Appendix 1. continued.

Family and Species	Basal area (m²)	Density (trees/ha)	Frequency (%)	Relative Density (%)	Relative Frequency (%)	Relative Basal Area (%)	Importance Value (%)
1	2	3	4	5	6	7	8
33. Sapindaceae:	**1.06**	**13.50**	**0.145**	**2.358**	**2.918**	**1.922**	**7.198**
118 *Elattostachys* sp.	0.01	0.50	0.005	0.087	0.101	0.018	0.206
119 *Lepisanthes alata*	0.16	1.50	0.015	0.262	0.302	0.297	0.861
120 *Nephelium lappaceum*	0.57	6.00	0.055	1.048	1.107	1.029	3.184
121 *Nephelium ramboutanake*	0.27	3.50	0.035	0.611	0.704	0.493	1.808
122 *Pometia pinnata*	0.05	2.00	0.035	0.349	0.704	0.085	1.139
34. Sapotaceae:	**1.32**	**29.50**	**0.270**	**5.153**	**5.433**	**2.382**	**12.968**
123 *Ganua mottleyana*	0.68	12.00	0.100	2.096	2.012	1.235	5.343
124 *Palaquium dasyphyllum*	0.04	1.00	0.010	0.175	0.201	0.070	0.445
125 *Palaquium sumatranum*	0.47	12.50	0.120	2.183	2.414	0.857	5.455
126 *Pouteria malaccensis*	0.12	4.00	0.040	0.699	0.805	0.221	1.725
35. Sterculiaceae:	**0.12**	**1.50**	**0.015**	**0.262**	**0.302**	**0.216**	**0.780**
127 *Sterculia cordata*	0.03	1.00	0.010	0.175	0.201	0.053	0.429
128 *Sterculia oblongata*	0.09	0.50	0.005	0.087	0.101	0.163	0.351
36. Symplocaceae:	**0.09**	**3.00**	**0.030**	**0.524**	**0.604**	**0.160**	**1.288**
129 *Symplocos fasciculata*	0.09	3.00	0.030	0.524	0.604	0.160	1.288
37. Tiliaceae:	**1.15**	**20.00**	**0.150**	**3.493**	**3.018**	**2.070**	**8.581**
130 *Pentace polyantha*	1.15	20.00	0.150	3.493	3.018	2.070	8.581
38. Ulmaceae:	**0.09**	**0.50**	**0.005**	**0.087**	**0.101**	**0.171**	**0.359**
131 *Gironniera subaequalis*	0.09	0.50	0.005	0.087	0.101	0.171	0.359
39.Verbenaceae:	**0.22**	**5.00**	**0.050**	**0.873**	**1.006**	**0.392**	**2.272**
132 *Teijsmannoidendron coriaceum*	0.21	4.50	0.045	0.786	0.905	0.373	2.064
133 *Vitex gamosepala*	0.01	0.50	0.005	0.087	0.101	0.020	0.208
TOTAL	**55.37**	**572.50**	**4.970**	**100.000**	**100.000**	**100.000**	**300.000**

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