Floristic composition, stand structure, and above-ground biomass of the tropical rain forests of Deramakot and Tangkulap Forest Reserve in Malaysia under different forest managements

Running title: Floristic composition and stand structure of Deramakot Forest Reserve

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Abstract Floristic composition, stand structure, and above-ground biomass of tropical lowland rain forests were examined to compare the effects of different forest managements, i.e., old-growth forest as control, the forest harvested by the reduced-impact logging (RIL), and the forest harvested by the conventional method in Deramakot and Tangkulap Forest Reserve, Malaysian Borneo. Species diversity was rich in the old-growth forest and the forest harvested by RIL where climax and important commercial-timber species of Dipterocarpaceae dominated, while low in the forest harvested by the conventional method where pioneer species of the genus *Macaranga* (Euphorbiaceae) dominated. Size structure showed that Dipterocarp trees regenerated well in the old-growth forest and the forest harvested by RIL. On the other hand, Dipterocarp trees did not regenerate well in the forest harvested by the conventional method and Euphorbiaceae trees demonstrated an evidence of regeneration. Basal area and above-ground biomass in the old-growth forest and the forest harvested by RIL were higher than those of the forest harvested by the conventional method. Floristic composition, stand structure, and above-ground biomass were not different between the old-growth forest and the forest harvested by RIL. However, the species composition and above-ground biomass of the forest harvested by the conventional method were different from those of the old-growth forest and the forest harvested by RIL due to high impacts of logging. Thus, RIL management could keep species diversity, forest structure, and biomass at a pre-harvest status.

Abstract for policy-makers

We conducted a comparative study of the effects of different logging methods on the floristic composition, structure and biomass of tropical rain forests in Deramakot and Tangkulap Forest Reserve, Malaysian Borneo. Logging methods that we compared were the reduced-impact logging and the conventional logging. We also added an old-growth forest as control where the sign of logging was minimal in our comparison. Logging can leave impacts primarily though two pathways: instant mechanical influences by the reduction of biomass and structure versus long-term influences by modifying species composition. The results of our analyses demonstrated that the structure (for instance basal area, the sum of stem cross-sectional areas), above-ground biomass and species composition of the forest harvested by RIL were closer to the old-growth forest than to the forest harvested by the conventional method. Moreover,

RIL was effective in reducing both the instant mechanical and the long-term influences of logging. This indicated that RIL was certainly effective for achieving sustainable forest management.

Keywords above-ground biomass, Deramakot Forest Reserve, reduced-impact logging, Sabah, selective logging, species diversity, Tangkulap Forest Reserve.

Introduction

Timber exploitation since the mid 1970s has been altering the primary lowland forests of Sabah, Malaysian Borneo (Sabah Forestry Department 1989). To reduce the logging impacts for sustainable forest utilization, reduced-impact logging (RIL), a low impact logging technique of timber harvesting, was introduced in Sabah from 1996. It is believed that RIL is an adequate method for the sustainable management of tropical forests, because RIL can reduce the damages to the forests compared to the conventional logging method. However, there are relatively limited data to justify the sustainability of RIL in terms of full recovery of species composition, diversity and biomass after a timber harvest (Pinard and Putz 1996; Bertault and Sist 1997; Sist and Nguyen-The 2002; Bischoff *et al.* 2005).

Can the secondary succession of the tropical forests after a RIL eventually demonstrate a climax phase comparable to the pre-harvest status? To answer this question, we compared the recovery processes of logged-over forests subjected to RIL and to a conventional method (high impact logging) in terms of floristic composition, species diversity and biomass.

Methods

The study site

The study site (5°22'N, 117°25' E, approximately 300 m asl) is located in a lowland forest of the Deramakot Forest Reserve (DFR) and Tangkulap Forest Reserve (TFR) in Sabah, Malaysian Borneo. Forests in DFR and TFR had been selectively logged in the 1970s. The logging intensity varied from site to site. Subsequently, these forests were logged again with RIL from the 1990s in DFR and by a conventional method in TFR. Thus, the forests in DFR and TFR can be divided into the following three types as (1) old-growth forests in DFR without any logging records after the 1970s logging, (2) forests in DFR logged with RIL after 1996 in addition to the conventional logging prior to 1996, and (3) forests in TFR logged with the conventional method.

Field measurements and data analysis

Eleven research plots of 0.2 ha (100 m x 20 m, or 50 m x 40 m) were established in DFR and TFR under different forest managements (Table 1). In DFR, four plots were set up in the old-growth forest which was not logged since 1970s and four plots in the forests logged by RIL after 1996 in May 2003. In TFR, two plots in the forest logged by the conventional method in May 2003 and one plot was added in March 2005. All plots were divided into contiguous twenty 10 x 10 m subplots. The location and altitude of the plots were measured by using a portable receiver of global positioning system (Garmin GPS III plus, USA). All living trees larger than 10.0 cm in trunk diameter at breast height at 1.3 m (DBH) were measured first in May 2003 and re-measured in March 2005. Dead trees were checked at the tree census in March 2005. Buttressed or stilt-rooted trees were measured for trunk diameter at above the protrusions as "DBH" but not at 1.3m above the ground. Multiple trunks were separately recorded for DBH. To identify species, we collected leaves for voucher specimens from the tree crown using a clipper and a catapult. Species identification was based on the leaf specimens and bark characters. Voucher specimens were stored at the laboratory of the Deramakot Forestry Office in DFR. Species diversity of each plot was calculated with Fisher's diversity index (Fisher *et al.* 1943). The index is calculated as:

$$S = \alpha \ln (1+N/\alpha) \quad (1)$$

where S is the number of species, N is the number

of individuals, and α is a constant known as Fisher's diversity index. UPGMA cluster analysis was used for classification of the eleven plots on the basis of family composition in basal area. Leaf area index (LAI) was measured at five plots using LAI-2000 Canopy Analyzer (LI-COR, USA) in June 2003. The five plots were ET, C54, DMG, 63B, and TK1 (see Table 1 for the abbreviation of the plot). LAI was estimated based on the measurements at four corners of each of ten 10-m x 10-m subplots for each plot. This was repeated three times in different parts of the plot, from which the mean LAI was calculated for each plot. Above-ground biomass (AGB, t ha^{-1}) was estimated from the allometric function obtained by Brown (1997) as:

$$Wt = \exp(-2.134+2.530 \ln DBH) \quad (2)$$

where Wt (kg) is the total weight of stem, branch and leaf. Change of AGB during tree censuses was calculated from the initial (May 2003) minus the final (March 2005) AGB.

Results

Species composition and diversity

The numbers of the observed families and species at the old growth and the RIL forests were higher than those of the forest harvested by the conventional method (analysis of variance, ANOVA, $F = 6.81$, $P < 0.05$ for observed family; $F = 7.14$, $P < 0.05$ for observed species; Figure 1). Species composition and diversity were not different between the old-growth forest and the forest harvested by RIL, but they were different between the forest harvested by RIL and the forest harvested by the conventional method (Figure 2, Table 2). Therefore, a most striking difference in species composition was found between the forest harvested by the conventional method and the rest (Figure 2). Further details of the observed species in the plots are listed in Appendix. The index of species richness of Fisher's α of the old growth forest and the forest harvested by RIL was higher than that of the forest harvested by the conventional method (ANOVA, $F = 13.1$, $P < 0.01$; Figure 1). The α of the old growth forest and the forest harvested by RIL was close to 100 while that of the forest harvested by the conventional method was approximately 20. The maximum value of α was 123.6 at the old growth forest at ETC and the minimum value was 18.7 at the forest harvested by the conventional method at TK3 (Table 3).

Stand structure and above-ground biomass

Stand structure was different between the forest harvested by RIL and the forest harvested by the conventional method (Figure 3). Stem density was not significantly different among the three categories of forest managements. However, maximum DBH and basal area were different between the forest harvested by RIL and the forest harvested by the conventional method (ANOVA, $F = 23.2$, $P < 0.001$ for maximum DBH; $F = 14.1$, $P < 0.01$ for basal area). DBH distribution in the forest harvested by RIL and the old growth forest showed an L-shaped pattern. DBH distribution of the forest harvested by the conventional method showed a lack of larger trees due to loggings (Figure 4). Dipterocarpaceae trees are of climax species in lowland forest, and this family is well-known as important commercial timer (Whitmore 1984). On the other hand, most of observed *Macaranga* (Euphorbiaceae) species were characterized as a gap-dependent species in regeneration (See details in Appendix, Slik *et al.* 2003). Their regeneration requires strong disturbance by large canopy opening with soil disturbance (Whitmore 1984). Thus, dominances of the Dipterocarpaceae and *Macaranga* can be used for forest condition as indicators for disturbance. According to the pattern of DBH distribution, Dipterocarpaceae trees were well regenerated both in the old growth forest and the forest harvested by RIL (Figure 5). On the other hand, Euphorbiaceae (the family of *Macaranga*) trees were well regenerated in the forest harvested by the conventional method (Figure 5). Old growth forest and the forest harvested by RIL were dominated by Dipterocarpaceae while the forest harvested by the conventional method was dominated by the genus *Macaranga* (Euphorbiaceae) (Figure 6).

Above-ground biomass (AGB) was also

different between the forest harvested by RIL and the forest harvested by the conventional method (ANOVA, $F = 21.4$, $P < 0.001$; Figure 3). AGB of old growth forest exceeded 500 t ha^{-1}. AGB of the forest harvested by RIL ranged from 455.4 to 322.7 t ha^{-1}. AGB of the forest harvested by the conventional method demonstrated a smallest value among the three forests (Figure 3). The old growth forest and the forest harvested by RIL showed a high gain and a low loss of AGB, while the forest harvested by the conventional method showed a low gain and a high loss of ABG. Thus, the net gain of AGB was high in the old growth forest and the forest harvested by RIL, and low in the forest harvested by the conventional method (Figure 7).

Discussion

Our results suggest that RIL is an efficient method to reduce logging impacts on species composition and diversity, and to keep AGB and minimize biomass loss compared with the conventional logging method. The size of canopy opening by loggings (i.e. creation of canopy gap) affected regeneration patterns and species composition elsewhere (Denslow, 1980; Pickett and White 1985). RIL operation regulates the amount of logged trees and their size (DBH), location, and transportation of harvested logs (Sabah Forestry Department and the Commission of the European Communities 2001). Consequently, RIL operation creates a smaller number of canopy gaps probably with a smaller mean size of canopy opening than the conventional logging (see Kitayama *et al.* in this volume). Shade-tolerant trees can regenerate under a darker light condition. Therefore, these trees could have been regenerated under small-sized canopy gaps in the forest harvested by RIL due to their physiological tolerance for reduced light. In contrast, the regeneration of shade-intolerant trees requires a sunnier condition (Turner 2001). Response to light condition associated with the difference in gap sizes caused a greater similarity of species composition and diversity between the old growth forest and the forest harvested by RIL, and facilitated the regeneration of dipterocarp trees in the forest harvested by RIL (Sist and Nguyen-The 2002; Bischoff *et al.* 2005).

Differences of forest managements were related to the differences in the disturbance regime and regeneration patterns. For example, bulldozers disturb topsoils by pulling out logged trees on the forest floor in the forest harvested by the conventional method (Pinard *et al.* 2000). From our study, the forest harvested by the conventional method was dominated by pioneer species such as the genus *Macaranga* of Euphorbiaceae. Euphorbiaceae trees are known to regenerate under large canopy gaps with disturbed soil conditions (Davies *et al.* 1998; Davies 2001). On the other hand, RIL operation is gentle to forest with minimum damage to soils (Sabah Forestry Department and the Commission of the European Communities 2001). Figure 8 shows an example of a RIL operation in Deramakot in 2004. The photograph indicates that the logged tree was extracted without damages to the surrounding trees. In contrast, an operation of the conventional method would have left a greater damage to the surrounding trees. Our analysis dealt with two to three decades of a secondary succession only, and whether the species composition and structure of the forest including shrubs and herbs (that we do not include in our current analysis) can fully recover to a pre-harvest condition is still not known. To confirm the sustainability of the biomass and floristic composition of tropical rain forests in DFR managed by RIL, long-term ecological monitoring is needed.

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Table 1. Description of the research plots. "RIL" indicates reduced-impact logging.

Plot name	(Abbreviation)	Plot size	Altitude (m)	Harvest methods
Old-growth unlogged since 1970's				
Ecological trail	(ECT)	100 m x 20 m	248	Primary forest
ET-antena	(ETA)	50 m x 40 m	248	Primary forest
ET-jauh	(ETJ)	50 m x 40 m	248	Unlogged since 1970's
C54	(C54)	50 m x 40 m	195	Unlogged since 1970's
RIL				
Mannan	(MAN)	100 m x 20 m	196	RIL 8 years after logging
Domingo	(DMG)	100 m x 20 m	200	RIL 8 years after logging
C63-bawah	(63B)	100 m x 20 m	195	RIL 3 years after logging
C63-atas	(63A)	100 m x 20 m	221	RIL 3 years after logging
Conventional method				
Tangkulap-1	(TK1)	100 m x 20 m	109	Conventional method
Tangkulap-2	(TK2)	50 m x 40 m	76	Conventional method
Tangkulap-3	(TK3)	100 m x 20 m	52	Conventional method

Table 2. Comparison of the floristic composition and diversity of the plots among different logging methods.

Plot	No. Family	No. Species	Fisher's α
Old-growth since 1970's			
ECT	27	66	123.6
ETA	20	48	75.9
ETJ	25	48	91.7
C54	20	42	102.2
RIL			
MAN	21	39	57.2
DMG	26	50	104.9
63B	29	62	83.4
63A	26	57	110.1
Conventional method			
TK1	13	27	23.1
TK2	18	27	36.1
TK3	18	32	18.7

Table 3. Comparison of the stand structure and above-ground biomass among different logging methods.

Plot	Density (0.2 ha^{-1})	Max DBH (cm)	Basal area (m^2 ha^{-1})	ABG (t ha^{-1})	LAI
Old-growth since 1970's					
ECT	151	106.4	39.3	521.7	6.37
ETA	144	129.1	40.6	482.4	–
ETJ	135	116.7	48.2	596.0	–
C54	102	102.9	38.5	483.0	5.70
RIL					
MAN	128	108.2	36.9	409.3	–
DMG	120	91.9	29.0	322.7	5.33
63B	154	113.7	38.0	455.4	4.57
63A	121	109.5	29.2	330.8	–
Conventional method					
TK1	126	61.4	21.9	203.4	4.99
TK2	84	72.5	25.5	265.3	–
TK3	85	55.3	11.3	96.2	–

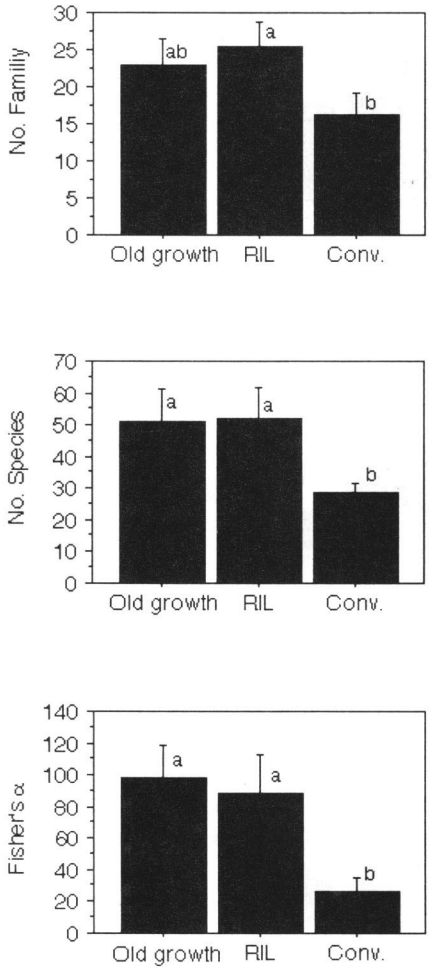

Figure 1. Differences of the number of families and species, and the diversity index of Fisher's α under different forest managements. Vertical bars show ± 1 SD. Means in a column followed by a different letter are significantly different according to the Bonferroni test at $P < 0.0167$. Old growth indicates the old growth forest without any logging records at least since 1970s, RIL indicates the forest logged by RIL after the 1970s, and Conv. indicates the forest logged persistently by the conventional method.

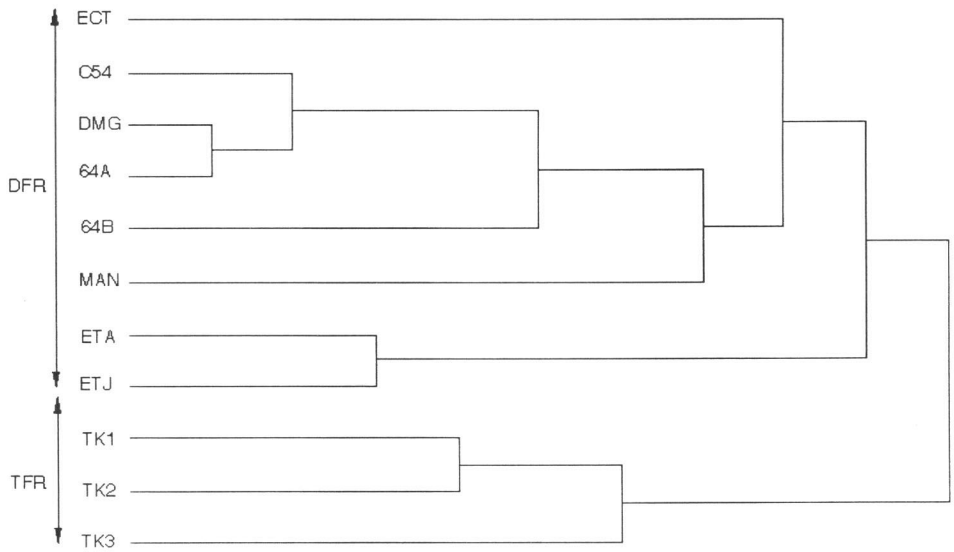

Figure 2. Dendrogram resulting from UPGMA cluster analyses to classify the eleven plots on the basis of family composition in basal area. The abbreviations in figure are the same as in Table 1.

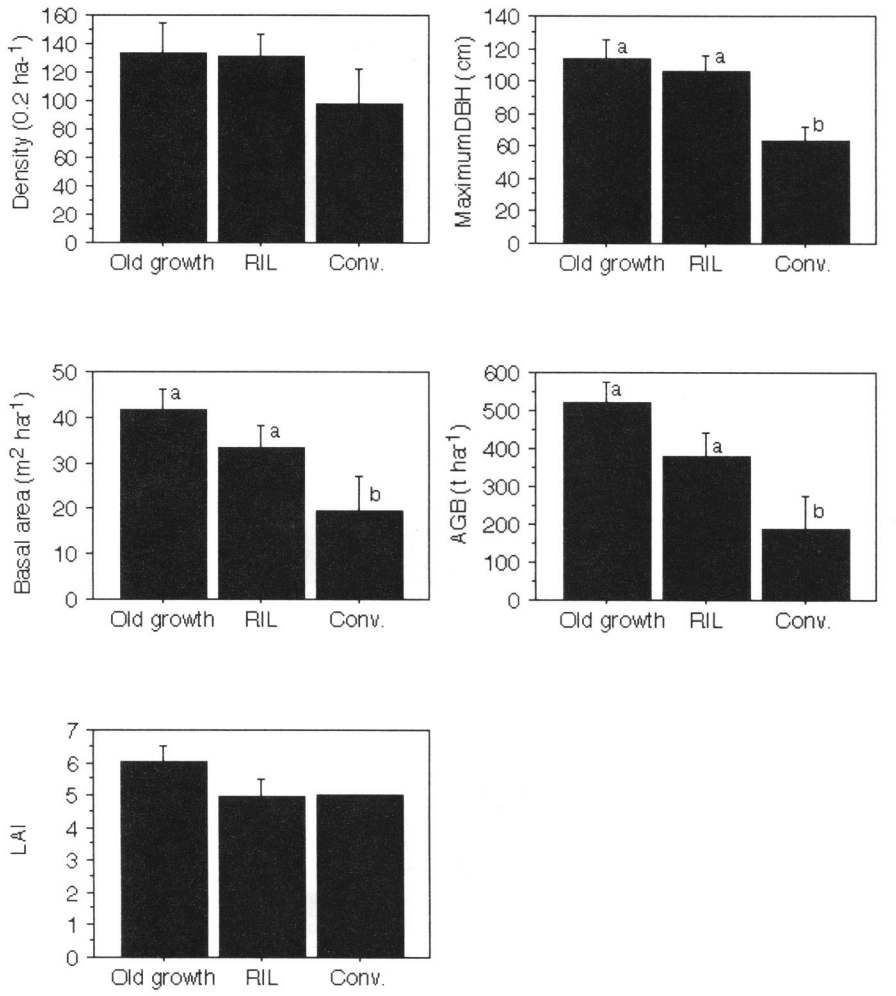

Figure 3. Differences of density, maximum DBH, basal area, AGB, and LAI among different forest managements. Vertical bars show ± 1 SD. Means in a column followed by a different letter are significantly different according to the Bonferroni test at $P < 0.0167$. The abbreviations of different forest managements in the figure are the same as in Figure 1.

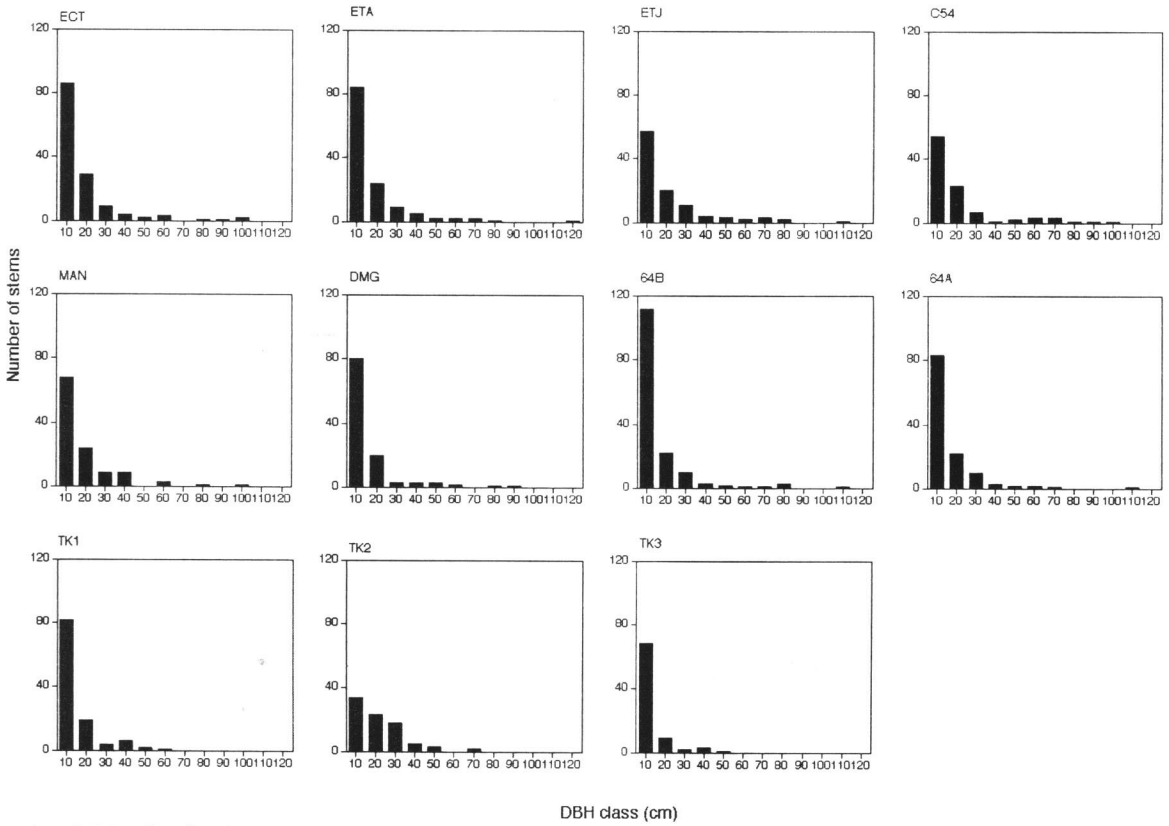

Figure 4. DBH distribution of the eleven research plots for stems larger than 10 cm DBH. The abbreviations in figure are the same as in Table 1.

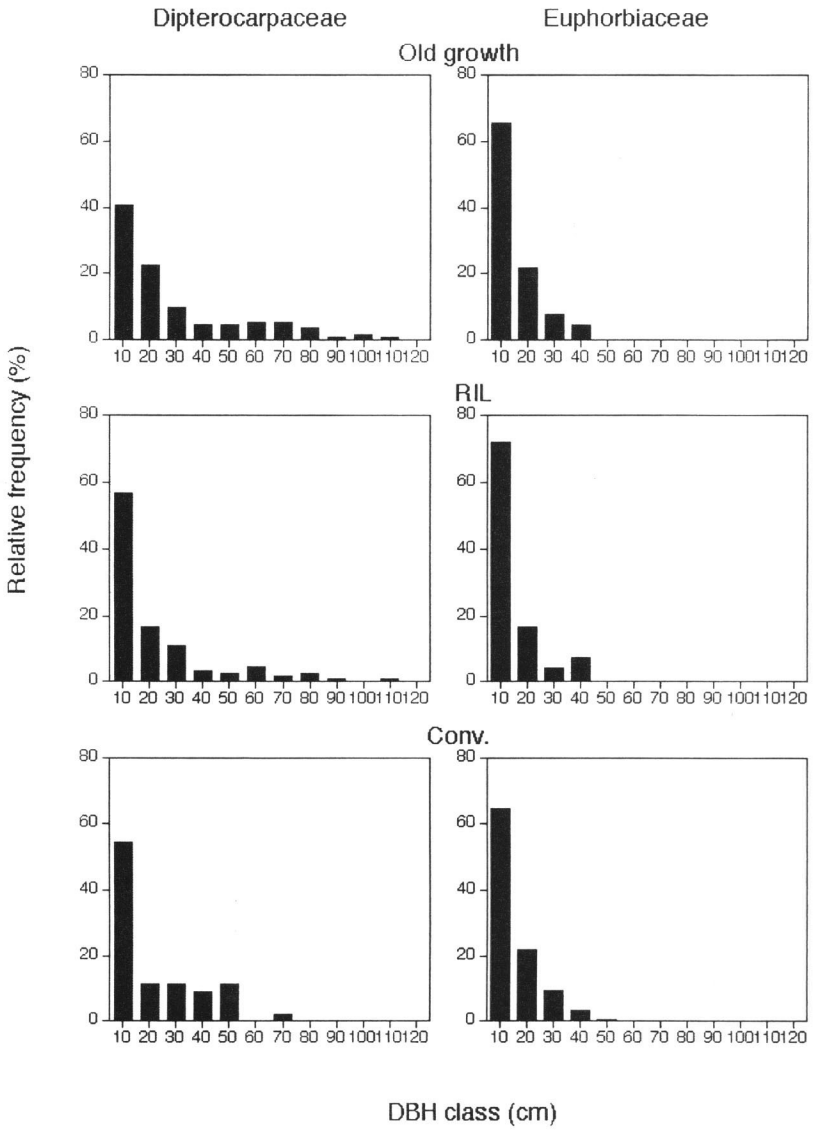

Figure 5. DBH distribution of Dipterocarpaceae and Euphorbiaceae by different forest management for stems larger than 10 cm DBH. The abbreviations of different forest managements in the figure are the same as in Figure 1.

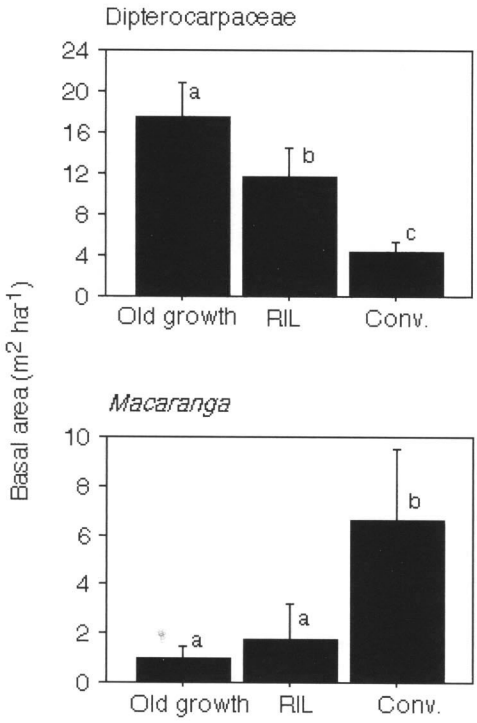

Figure 6. Basal area of Dipterocarpaceae and *Macaranga* of Euphorbiaceae by different logging methods. Vertical bars show ± 1 SD. Means in a column followed by a different letter are significantly different according to the Bonferroni test at $P < 0.0167$. The abbreviations of different forest managements in the figure are the same as in Figure 1.

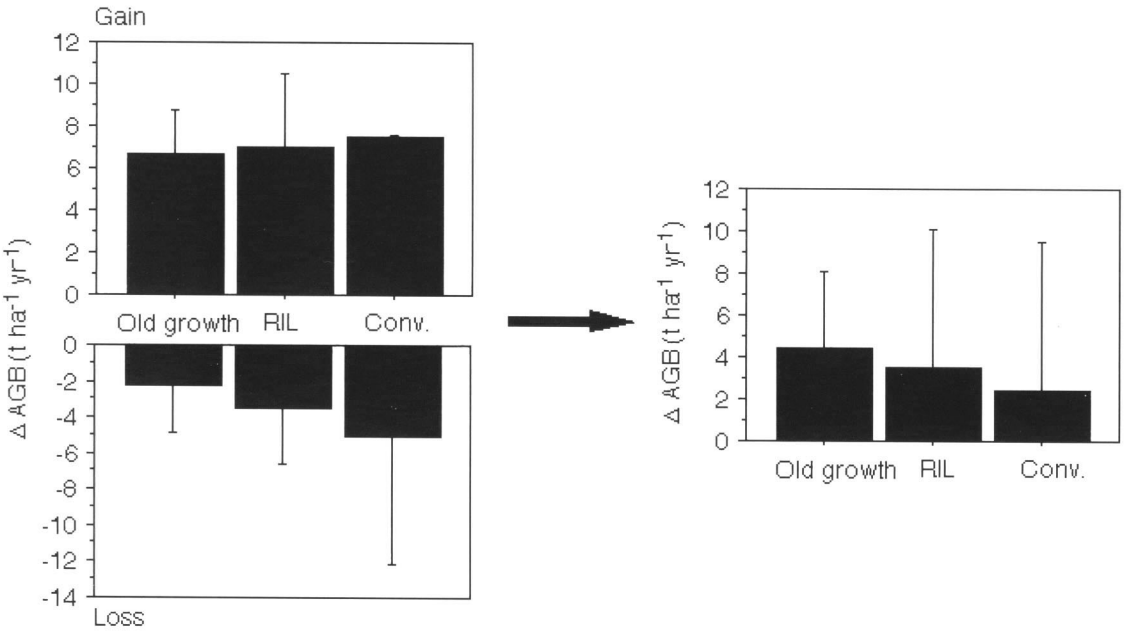

Figure 7. Changes of ABG by different forest management. Vertical bars show ± 1 SD. The abbreviations of different forest managements in the figure are the same as in Figure 1.

Figure 8. Example of a stump after logging by RIL. Note that logging operation was carried out without damage to the surrounding small trees.

Appendix 1. Species composition of the Ecological Trail (ECT) plot, showing the number of stems larger than 10cm DBH (N per 0.2ha), the relative basal area of stems larger than 10 cm DBH (RBA, %) and maximum DBH (Dmax, cm).

Family	Species	N	RBA	Dmax
Annonaceae	*Oncodostigma* sp.A	1	0.5	21.7
	Polyalthia sp.A	1	1.1	33.6
	Anno Indet sp.B	1	0.1	11.6
Apocynaceae	*Alstonia angustiloba*	1	0.9	29.2
Bombacaceae	*Durio acutifolius*	1	0.5	23.6
	Durio grandiflorus	1	0.1	10.9
	Neesia sp.A	1	0.1	10.2
Burseraceae	*Canarium hirtum*	2	1.0	31.2
	Canarium sp.A	2	4.4	65.4
	Dacryodes rostrata	2	0.4	15.1
Combretaceae	*Terminalia* sp.A	1	1.7	41.8
Dipterocarpaceae	*Dipterocarpus applanatus*	2	1.1	28.0
	Dipterocarpus stellatus	3	1.2	23.8
	Dryobalanops keithii	1	0.6	25.0
	Shorea fallax	2	7.0	64.6
	Shorea gibbosa	5	3.1	47.3
	Shorea macrophylla	2	7.3	85.9
	Shorea macroptera	9	5.1	46.3
	Shorea multiflora	1	0.1	13.3
	Shorea ovalis	1	0.4	18.7
	Shorea parvifolia	2	1.0	26.9
	Shorea parvistipulata	2	1.4	30.9
	Shorea pauciflora	2	11.3	106.4
	Shorea smithiana	1	0.1	13.0
	Vatica dulitensis	1	1.1	33.2
	Vatica sp.A	1	8.1	90.8
Ebenaceae	*Diospyros* sp.A	1	0.6	25.8
	Diospyros sp.B	1	0.6	24.4
	Diospyros sp.D	2	0.7	26.8
	Diospyros sp.E	1	0.2	15.4
Euphorbiaceae	*Baccaurea* sp.A	1	0.6	24.3
	Drypetes pendula	1	0.1	13.3
	Drypetes sp.B	1	0.2	14.0
	Drypetes sp.C	1	0.1	11.3
	Elateriospermum tapos	1	0.1	13.6
	Macaranga hypoleuca	1	1.4	37.1
	Mallotus penangensis	1	0.1	13.0
	Mallotus stipularis	2	0.4	15.1
Fagaceae	*Lithocarpus blumeanus*	1	0.9	29.4
	Lithocarpus sp.B	1	0.7	27.7
Flacourtiaceae	*Hydnocarpus* sp.A	2	0.6	20.9
	Ryparosa hulletii	1	0.2	17.3
Lauraceae	*Alseodaphne* sp.A	2	0.4	15.2
	Cryptocarya sp.B	1	0.1	13.7
	Dehaasia brachybotrys	1	0.1	10.5
	Endiandra sp.A	1	0.4	18.0
	Litsea sp.D	1	0.1	13.1
	Neolitsea sp.A	1	0.2	15.2
Lecythidaceae	*Barringtonia* sp.A	1	0.5	23.5
	Barringtonia sp.B	1	0.2	13.9
Leguminosae	*Crudia* sp.A	1	4.2	65.8
	Parkia sp.A	2	1.6	30.7
Melastomataceae	*Pternandra* sp.A	1	0.1	10.3
Meliaceae	*Aglaia shawiana*	1	0.1	10.8
	Aglaia sp.A	1	0.4	20.9
	Aglaia sp.D	1	0.1	11.7
	Aglaia sp.E	1	0.1	10.2
	Aglaia sp.G	1	0.1	13.8

	Aglaia sp.H	1	0.2	17.4
	Chisocheton sarawakanus	1	0.1	12.4
	Chisocheton sp.A	1	0.4	18.5
Moraceae	*Artocarpus odoratissimus*	1	0.2	17.5
	Artocarpus sp.A	1	0.1	12.3
Myristicaceae	*Gymnacranthera* sp.A	1	0.2	16.0
	Horsfieldia grandis	1	0.1	10.9
	Knema furfuracea	2	0.2	11.0
	Knema sp.B	1	1.0	32.0
Myrtaceae	*Syzygium* sp.A	3	1.5	27.0
	Syzygium sp.B	1	0.1	13.4
	Syzygium sp.D	2	0.6	21.8
Olacaceae	*Ochanostachys amentacea*	2	0.5	16.3
Oleaceae	*Chionanthus* sp.A	1	0.2	14.8
Rosaceae	*Prunus arborea*	1	2.6	52.1
Rubiaceae	*Porterandia* sp.A	1	0.2	15.3
Sapidaceae	*Lepisanthes* sp.A	1	0.1	11.6
	Nephelium lappaceum	1	0.2	14.9
	Nephelium uncinatum	2	0.7	21.1
	Pometia pinnata	1	1.9	43.2
Sapotaceae	*Madhuca kingiana*	1	0.1	12.0
	Madhuca malaccensis	2	0.2	12.3
	Palaquium sp.A	1	0.4	19.3
Sterculiaceae	*Heritiera elmerii*	1	0.4	18.5
	Heritiera simplicifolia	1	10.0	101.1
	Sterculia sp.A	1	0.4	18.5
Thymelaeaceae	*Gonystylus* sp.B	1	0.1	11.3
Tiliaceae	*Pentace borneensis*	2	0.2	12.7

Appendix 2. Species composition of the ET-Antena (ETA) plot. See Appendix 1 for abbreviations.

Family	Species	N	RBA	Dmax
Annonaceae	*Cyathocalyx* sp.A	1	0.6	23.4
	Polyalthia sumatrana	2	0.4	14.5
	Popowia sp.A	1	0.3	14.2
Burseraceae	*Dacryodes* sp.A	2	0.3	12.6
	Dacryodes sp.B	1	0.1	12.2
	Dacryodes sp.D	1	0.1	10.2
Chrysobalanaceae	*Maranthes* sp.A	1	1.3	34.1
Compositae	*Vernonia arborea*	1	0.6	22.9
Ctennolophonaceae	*Ctenolophon parvifolius*	1	4.3	62.3
Dipterocarpaceae	*Dipterocarpus gracilis*	6	17.7	74.1
	Dipterocarpus sp.A	1	0.1	11.2
	Dryobalanops lanceolata	2	1.1	28.2
	Shorea domatiosa	2	5.1	66.0
	Shorea exelliptica	1	18.6	129.3
	Shorea macroptera	2	0.7	23.9
	Shorea multiflora	3	6.2	70.4
	Shorea parvifolia	4	3.0	31.9
	Shorea pauciflora	1	0.1	10.9
	Shorea smithiana	1	0.1	12.0
	Shorea sp.B	1	0.6	22.0
	Vatica oblongifolia	1	0.9	27.2
	Vatica sp.A	2	0.4	15.1
Ebenaceae	*Diospyros* sp.B	1	0.7	24.5
	Diospyros sp.C	1	0.1	11.6
Euphorbiaceae	*Aporusa* sp.C	1	0.4	18.5
	Botryophora sp.A	1	0.9	28.0
	Drypetes sp.B	1	0.1	11.8
	Euph Indet sp.A	2	0.4	13.6
	Macaranga conifera	3	3.1	44.3
	Macaranga hypoleuca	2	1.7	28.5
	Mallotus penangensis	7	1.4	20.4
	Mallotus wrayi	1	0.1	13.8

	Neoscortechinia forbesii	1	0.3	16.9
Fagaceae	*Lithocarpus bullatus*	1	2.7	49.7
	Quercus sp.A	1	2.1	44.1
Flacourtiaceae	*Ryparosa hulletii*	1	0.1	11.0
Lauraceae	*Cryptocarya* sp.C	1	0.3	15.7
	Litsea oppositifolia	1	0.1	12.9
	Litsea sp.A	1	0.4	19.7
	Litsea sp.B	1	0.1	10.1
	Litsea sp.D	1	0.6	23.6
	Litsea sp.G	1	0.1	10.0
Lecythidaceae	*Barringtonia* sp.B	1	0.1	11.3
Leguminosae	*Sindora irpicina*	1	1.1	31.6
Meliaceae	*Aglaia* sp.F	1	0.3	17.5
	Chisocheton sarawakanus	1	0.4	19.5
	Walsura pinnata	1	0.1	10.8
Myristicaceae	*Gymnacranthera* sp.A	1	0.1	12.4
	Knema sp.A	1	0.6	22.5
	Knema sp.B	5	1.7	27.3
	Knema sp.C	1	0.9	26.5
	Myristica sp.A	1	0.1	11.3
	Myristica sp.B	1	2.7	49.2
Myrtaceae	*Syzygium* sp.A	3	0.6	16.1
	Syzygium sp.B	1	0.1	13.7
	Syzygium sp.E	1	0.7	26.3
	Syzygium sp.J	1	1.1	32.8
	Syzygium sp.K	1	0.1	13.2
Olaceae	*Ochanostachys amentacea*	1	0.3	17.0
Polygalaceae	*Xanthophyllum affine*	6	1.0	14.9
	Xanthophyllum heterophyllum	1	0.1	11.8
Proteaceae	*Helicia* sp.A	1	1.3	33.0
Sapindaceae	*Nephelium* sp.B	1	0.6	22.2
Sapotaceae	*Palaquium* sp.A	1	0.1	12.1
	Payena microphylla	1	1.6	38.0
Simaraoubaceae	*Irvingia malayana*	2	2.7	36.3
Symplocaeae	*Symplocos* sp.A	1	0.3	16.6
Theaceae	*Pyrenaria* sp.A	1	0.1	12.2
Thymelaeaceae	*Gonystylus* sp.B	1	0.4	20.1
Tiliaceae	*Brownlowia peltata*	1	0.1	12.6
	Pentace borneensis	5	1.6	25.0
Indet	Indet sp.C	1	0.1	10.2

Appendix 3. Species composition of the ET-Jauh (ETJ) plot. See Appendix 1 for abbreviations.

Family	Species	N	RBA	Dmax
Annonaceae	*Encosanthum* sp.A	2	0.2	11.6
	Polyalthia sumatrana	1	0.2	15.4
Bombacaceae	*Durio acutifolius*	2	0.2	12.7
	Durio oxyleanus	1	0.9	34.2
	Durio sp.C	1	0.4	23.0
	Neesia synandra	1	0.4	22.9
Burseraceae	*Dacryodes rostrata*	1	0.1	10.4
Celastraceae	*Lophopetalum beccarianum*	2	1.1	29.6
Chrysobalanaceae	*Kostermanthus* sp.A	1	1.0	35.8
	Kostermanthus sp.B	1	0.3	20.4
Cornaceae	*Mastixia cuspidata*	1	0.2	15.4
Dipterocarpaceae	*Dipterocarpus confertus*	1	10.9	116.7
	Parashorea malaanonan	1	0.1	12.4
	Parashorea tomentella	1	5.4	81.9
	Shorea domatiosa	5	18.2	84.9
	Shorea macroptera	1	0.7	30.1
	Shorea multiflora	4	2.7	51.8
	Shorea ovalis	1	4.0	70.4
	Shorea pauciflora	2	1.7	39.8
	Shorea pilosa	3	4.9	63.8

	Vatica dulitensis	1	0.2	14.6
	Vatica oblongifolia	1	0.4	23.4
	Vatica sp.A	4	4.9	50.2
Ebenaceae	*Diospyros elliptifolia*	1	0.3	18.2
	Diospyros sp.C	1	0.1	10.2
	Diospyros sp.F	1	0.1	10.8
Elaeocarpaceae	*Elaeocarpus* sp.A	1	0.5	24.7
Euphorbiaceae	*Aporusa* sp.A	1	0.2	15.8
	Baccaurea sp.A	6	2.7	23.2
	Baccaurea sp.B	2	3.0	45.3
	Baccaurea sp.D	1	0.1	10.1
	Drypetes pendula	1	0.2	16.2
	Drypetes sp.A	1	0.8	31.6
	Macaranga hypoleuca	3	1.9	29.6
	Macaranga pearsonii	1	1.0	35.8
	Mallotus penangensis	4	0.5	15.1
	Mallotus wrayi	1	0.1	11.1
	Neoscortechinia borneensis	1	0.4	21.8
	Neoscortechinia forbesii	1	0.3	18.0
Fagaceae	*Lithocarpus conocarpus*	1	0.3	19.3
	Lithocarpus sp.E	1	0.9	33.6
Flacourtiaceae	*Ryparosa* sp.A	2	1.4	33.8
Guttiferae	*Garcinia* sp.A	1	0.4	23.7
Lauraceae	*Alseodaphne* sp.A	2	1.2	36.4
	Beilschmiedia sp.A	1	2.1	51.7
Lecythidaceae	*Barringtonia* sp.A	1	0.9	34.1
	Barringtonia sp.B	2	0.5	18.0
Leguminosae	*Crudia* sp.A	1	0.2	16.3
	Cynometra sp.A	1	0.3	18.8
	Fordia sp.A	1	0.1	13.7
	Sindora irpicina	1	0.1	13.0
Melastomataceae	*Pternandra* sp.A	3	0.8	19.2
Meliaceae	*Aglaia shawiana*	1	0.1	10.2
	Aglaia sp.A	1	0.2	16.1
	Aglaia sp.H	1	0.2	16.3
Moraceae	*Artocarpus elasticus*	1	0.7	29.2
	Artocarpus tamaran	1	0.1	11.3
Myristicaceae	*Gymnacranthera* sp.A	2	0.2	11.8
	Horsfieldia grandis	1	0.2	15.4
	Knema sp.A	2	0.2	13.2
	Knema sp.D	2	0.2	12.4
	Myristica sp.B	3	2.6	42.1
	Myristica sp.C	2	0.9	31.2
Myrsinaceae	*Ardisia macrophylla*	1	0.1	10.1
Myrtaceae	*Syzygium* sp.A	2	1.1	35.0
	Syzygium sp.E	1	0.7	29.0
	Syzygium sp.G	1	0.2	17.8
Rubiaceae	*Porterandia* sp.A	1	0.3	18.4
	Rubiaceae Indet sp.A	1	7.3	95.7
Sapindaceae	*Nephelium ramboutan-ake*	1	0.3	18.9
Sapotaceae	*Madhuca kingiana*	1	0.3	18.0
	Madhuca sp.A	1	0.2	16.0
	Palaquium sp.B	1	0.2	17.3
Simaraoubaceae	*Eurycoma longifolia*	1	0.1	10.4
Sterculiaceae	*Scaphium macropodum*	1	0.6	27.8
Thymelaeaceae	*Gonystylus* sp.A	3	0.4	13.3
	Gonystylus sp.B	4	0.8	20.5
Tiliaceae	*Pentace borneensis*	3	0.6	18.4

Appendix 4. Species composition of the C54 (C54) plot. See Appendix 1 for abbreviations.

Family	Species	N	RBA	Dmax
Annonaceae	*Oncodostigma* sp.A	1	0.7	24.6
	Polyalthia sp.A	1	0.4	18.9
Burseraceae	*Dacryodes* sp.A	2	0.4	16.8
Celastraceae	*Lophopetalum beccarianum*	4	2.8	36.6
Combretaceae	*Terminalia* sp.A	1	5.0	67.9
Dipterocarpaceae	*Dipterocarpus applanatus*	2	1.5	36.3
	Dipterocarpus caudiferus	1	0.4	18.1
	Dipterocarpus pachyphyllus	1	11.9	104.2
	Parashorea malaanonan	4	3.5	38.9
	Shorea almon	2	1.8	29.3
	Shorea fallax	1	4.7	65.9
	Shorea macroptera	1	0.8	27.9
	Shorea mecistopteryx	1	0.8	27.1
	Shorea parvifolia	2	5.6	68.7
	Shorea parvistipulata	1	1.0	29.7
	Shorea pauciflora	1	0.8	27.3
	Shorea pilosa	6	14.5	80.8
	Shorea smithiana	1	0.1	10.3
	Vatica sarawakensis	1	0.1	11.7
Ebenaceae	*Diospyros* sp.A	1	2.2	45.0
	Diospyros sp.C	1	0.3	14.0
	Diospyros sp.F	1	0.1	10.6
Euphorbiaceae	*Aporusa acuminatissima*	1	0.6	23.5
	Drypetes sp.A	1	0.3	17.0
	Glochidion sp.A	1	0.1	10.0
	Macaranga bancana	1	0.1	12.0
	Macaranga conifera	1	0.4	19.1
	Macaranga gigantea	1	0.8	28.1
	Macaranga hypoleuca	2	3.1	38.9
	Mallotus penangensis	1	0.1	10.4
	Mallotus stipularis	1	0.1	11.1
	Mallotus wrayi	3	0.4	12.5
Fagaceae	*Lithocarpus blumeanus*	1	6.4	76.3
Flacourtiaceae	*Hydnocarpus* sp.A	1	0.4	19.0
Guttiferae	*Garcinia* sp.B	1	0.3	15.6
	Garcinia sp.D	2	1.1	27.8
Lauraceae	*Dehaasia* sp.A	1	0.1	11.2
	Litsea sp.G	1	0.3	17.5
Lecythidaceae	*Barringtonia* sp.A	1	0.3	14.2
	Barringtonia sp.B	2	1.8	29.5
Leguminosae	*Koompassia excelsa*	1	0.3	17.8
	Parkia sp.A	2	1.0	22.1
Meliaceae	*Aglaia shawiana*	1	0.1	11.2
	Chisocheton sarawakanus	2	0.8	23.6
	Chisocheton sp.B	1	0.7	24.1
	Pysoxylon sp.A	1	0.1	11.0
Moraceae	*Artocarpus* sp.A	1	0.1	11.5
	Artocarpus sp.C	1	0.4	17.9
	Artocarpus sp.D	1	0.1	10.7
	Ficus sp.A	1	0.1	10.8
Myristicaceae	*Horsfieldia grandis*	1	0.1	10.0
	Knema sp.B	2	1.1	24.9
	Knema sp.D	1	0.1	13.3
	Myristica sp.A	1	0.6	23.6
Myrsinaceae	*Ardisia* sp.A	1	0.4	19.9
Myrtaceae	*Syzygium* sp.C	1	0.6	22.8
Olacaceae	*Ochanostachys amentacea*	1	3.1	53.5
Oleaceae	*Chionanthus* sp.A	1	0.7	25.7
Rhizphoraceae	*Anisophyllea borneensis*	1	0.1	10.0
Rubiaceae	*Pleiocarpidia* sp.A	2	0.3	13.2
Rutaceae	*Maclurodendron* sp.A	1	0.6	21.6

Sapindaceae	*Nephelium cuspidatum*	1	0.1	13.7
	Nephelium ramboutan-ake	1	0.3	15.4
Sapotaceae	Sapotaceae Indet sp. A	1	1.3	33.8
Sterculiaceae	*Heritiera simplicifolia*	1	5.9	73.2
	Scaphium macropodum	1	0.4	18.7
Thymelaceae	*Aquilaria malaccensis*	1	3.5	56.5
Tiliaceae	*Brownlowia peltata*	2	0.3	12.3
Indet	Indet sp.	1	0.1	10.9

Appendix 5. Species composition of the Mannan (MAN) plot. See Appendix 1 for abbreviations

Family	Species	N	RBA	Dmax
Annonaceae	*Encosanthum* sp.A	1	0.3	16.5
	*Saigerae*a sp.A	3	0.6	15.9
	Xylopia sp.A	1	0.3	14.1
Apocynaceae	*Alstonia angustiloba*	1	0.5	19.0
Bombacaceae	*Durio grandiflorus*	1	0.2	10.9
Burseraceae	*Dacryodes rostrata*	1	0.2	10.6
	Santiria sp.C	1	0.3	17.8
Compositae	*Vernonia arborea*	1	0.3	13.9
Dipterocarpaceae	*Dipterocarpus kerrii*	8	18.3	68.0
	Shorea almon	1	0.8	25.0
	Shorea domatiosa	2	1.1	24.8
	Shorea macroptera	3	2.6	38.5
	Shorea mecistopteryx	1	0.3	16.1
	Shorea pauciflora	2	0.5	16.9
	Shorea sp.A	2	2.3	31.9
	Vatica dulitensis	3	3.1	32.9
Ebenaceae	*Diospyros elliptifolia*	1	0.5	18.3
Elaeocarpaceae	*Elaeocarpus* sp.B	1	0.6	22.9
Euphorbiaceae	*Baccaurea* sp.D	1	0.8	25.0
	Drypetes sp.A	1	0.5	18.4
	Macaranga bancana	1	0.2	10.2
	Macaranga conifera	1	0.6	23.2
	Macaranga gigantea	4	7.8	43.9
	Macaranga hypoleuca	5	8.3	44.9
	Macaranga sp.A	2	0.3	11.5
	Macaranga winkleri	1	0.2	13.8
	Mallotus griffithii	3	0.5	11.7
	Mallotus wrayi	1	0.2	10.3
Fagaceae	*Lithocarpus blumeanus*	1	2.3	42.5
	Lithocarpus bullatus	1	0.3	16.4
	Lithocarpus conocarpus	1	0.5	18.3
Guttiferae	*Mesua micrantha*	1	0.2	11.4
Icacinaceae	*Stemonurus* sp.A	1	0.2	10.9
Lauraceae	*Alseodaphne* sp.A	1	14.7	107.7
	Beilschmiedia sp.B	1	0.2	13.0
	Litsea sp.B	1	0.2	12.9
	Litsea sp.E	1	0.2	10.0
Leguminosae	*Entada rheedii*	1	0.6	21.8
Magnoliaceae	*Magnolia* sp.A	1	0.8	25.1
	Magnolia sp.B	1	0.8	24.9
Melastomataceae	*Pternandra* sp.A	1	0.5	20.0
Meliaceae	*Dysoxylum* sp.A	1	0.2	10.0
Myristicaceae	*Gymnacranthera* sp.A	3	0.6	14.6
	Myristica sp.B	3	1.5	20.9
	Myristica sp.C	1	0.6	23.6
Myrtaceae	*Syzygium* sp.F	1	1.0	27.9
Olacaceae	*Ochanostachys amentacea*	1	1.0	28.3
Rubiaceae	*Anthocephalus chinensis*	1	2.6	45.1
	Pleiocarpidia sp.A	1	0.2	10.4
	Psydrax sp.A	1	0.2	12.5
	Rubiaceae Indet sp.A	1	9.7	87.5
	Rubiaceae Indet sp.B	1	5.7	66.9

Sapindaceae	*Pometia pinnata*	1	0.5	20.1
Sterculiaceae	*Scaphium longipetiolatum*	1	0.2	10.1
	Sterculia sp.C	1	0.2	11.7
Tiliaceae	*Microcos* sp.B	1	0.2	10.2
	Pentace borneensis	1	0.2	10.6
	Pentace laxiflora	3	2.1	30.2
Indet	Indet sp.C	1	0.2	11.3

Appendix 6. Species composition of the Domingo (DMG) plot. See Appendix 1 for abbreviations.

Family	Species	N	RBA	Dmax
Annonaceae	*Polyalthia sumatrana*	1	0.4	16.4
	Annonaceae Indet sp.C	1	0.2	10.8
Bombacaceae	*Neesia synandra*	1	0.2	12.2
Burseraceae	*Canarium denticulatum*	1	0.4	17.4
	Dacryodes sp.B	1	3.7	49.2
	Dacryodes sp.D	1	0.2	11.2
	Santiria sp.B	1	0.8	22.9
Chrysobalanaceae	*Kostermanthus* sp.A	1	0.4	17.4
Combretaceae	*Terminalia* sp.A	1	0.4	16.5
Compositae	*Vernonia arborea*	1	1.4	29.8
Dipterocarpaceae	*Dipterocarpus confertus*	1	5.2	58.9
	Dipterocarpus humeratus	1	2.9	44.1
	Dipterocarpus kerrii	4	1.0	16.6
	Dipterocarpus sp.B	1	0.2	13.0
	Hopea beccariana	1	0.2	12.5
	Hopea nervosa	1	0.2	12.2
	Parashorea malaanonan	1	0.4	14.6
	Shorea beccariana	1	11.2	86.3
	Shorea gibbosa	3	1.2	18.9
	Shorea leprosula	1	1.4	30.8
	Shorea macroptera	5	14.9	68.8
	Shorea mecistopteryx	1	0.4	14.1
	Shorea parvistipulata	2	1.6	28.4
	Shorea pilosa	1	12.8	91.9
	Shorea sp.B	1	0.2	13.5
Ebenaceae	*Diospyros* sp.A	2	0.4	11.1
Euphorbiaceae	*Aporusa acuminatissima*	1	0.2	12.2
	Aporusa sp.A	1	0.2	11.8
	Aporusa sp.E	1	0.2	10.1
	Cleistanthus sp.B	1	0.2	13.3
	Drypetes pendula	2	1.4	22.9
	Macaranga conifera	2	1.0	18.3
	Macaranga pearsonii	1	1.7	33.6
	Mallotus penangensis	9	2.7	16.6
Fagaceae	*Castanopsis* sp.A	2	1.4	26.2
	Lithocarpus sp.D	1	0.4	14.9
Flacourtiaceae	*Casearia* sp.A	1	0.4	16.2
	Hydnocarpus sp.B	1	0.2	10.1
	Ryparosa sp.A	1	0.6	20.3
Guttiferae	*Garcinia* sp.A	1	0.2	12.6
	Garcinia sp.B	1	0.2	11.3
	Garcinia sp.C	1	0.2	12.5
Icacinaceae	*Stemonurus* sp.A	1	0.2	11.6
Lauraceae	*Beilschmiedia* sp.B	1	3.1	44.9
	Dehaasia brachybotrys	1	0.6	18.4
	Litsea sp.C	1	0.2	11.5
Lecythidaceae	*Barringtonia* sp.A	1	0.4	14.8
	Barringtonia sp.B	1	0.2	11.7
Leguminosae	*Cynometra* sp.A	1	0.4	14.6
	Dialium sp.A	1	0.2	13.1
Melastomataceae	*Pternandra* sp.A	1	1.2	26.9
Meliaceae	*Aglaia* sp.B	1	0.2	10.4
	Chisocheton sarawakanus	1	0.2	12.8

Myristicaceae	*Knema* sp.A	1	0.4	15.1
	Myristica sp.C	1	0.6	20.6
Myrtaceae	*Syzygium* sp.A	1	1.7	33.2
	Syzygium sp.F	1	5.4	59.2
	Syzygium sp.I	1	0.2	10.3
Rhizphoraceae	*Carallia brachiata*	1	0.2	11.8
Sapindaceae	*Dimocarpus* sp.A	1	1.2	28.2
	Nephelium ramboutan-ake	1	0.2	10.7
	Nephelium sp.A	1	0.2	11.7
Sapotaceae	*Madhuca malaccensis*	5	2.5	24.3
	Palaquium sp.A	1	0.4	16.8
Sterculiaceae	*Scaphium longipetiolatum*	1	1.2	27.5
	Scaphium macropodum	1	0.6	19.2
Symplocaceae	*Symplocos fasciculata*	1	0.4	14.9
Tiliaceae	*Pentace laxiflora*	7	3.1	25.9
Trigoniaceae	*Trigoniastrum hypoleucum*	2	1.6	23.2
Verbenaceae	*Teijsmanniodendron holophyllum*	1	0.4	15.9

Appendix 7. Species composition of the C63-Bawah (63B) plot. See Appendix 1 for abbreviations.

Family	Species	N	RBA	Dmax
Annonaceae	*Polyalthia* sp.A	1	0.1	10.3
	Polyalthia sumatrana	2	0.4	17.7
Bombacaceae	*Durio acutifolius*	1	0.4	19.8
Burseraceae	*Canarium denticulatum*	1	0.1	11.8
	Canarium sp.A	1	0.1	11.1
	Dacryodes sp.B	1	3.6	59.5
Celastraceae	*Lophopetalum beccarianum*	1	0.1	10.3
Chrysobalanaceae	*Licania splendens*	1	0.1	10.8
Crpteroniaceae	*Crypteronia griffithii*	1	0.1	10.6
Dipterocarpaceae	*Anisoptera gradistipula*	1	2.1	44.8
	Dipterocarpus acutangulus	1	0.3	14.8
	Dipterocarpus caudiferus	2	0.3	12.1
	Dipterocarpus confertus	1	7.7	86.7
	Dipterocarpus kerrii	2	0.9	27.3
	Parashorea malaanonan	3	1.8	34.0
	Shorea beccariana	1	1.8	41.8
	Shorea domatiosa	1	0.3	13.9
	Shorea exelliptica	1	0.8	27.7
	Shorea fallax	4	9.9	88.4
	Shorea gibbosa	1	0.5	23.4
	Shorea macroptera	7	5.9	70.7
	Shorea multiflora	3	0.8	20.8
	Shorea ovalis	1	1.6	38.8
	Shorea parvifolia	6	2.1	22.8
	Shorea parvistipulata	1	0.1	10.1
	Shorea smithiana	1	0.5	23.5
	Vatica sp.A	1	0.4	20.0
Ebenaceae	*Diospyros* sp.A	1	0.5	21.3
	Diospyros sp.C	1	0.1	10.3
Euphorbiaceae	*Aporusa grandistipulata*	3	0.8	20.2
	Baccaurea sp.A	1	0.1	12.2
	Baccaurea sp.B	1	1.6	39.3
	Baccaurea sp.D	2	0.7	20.5
	Chaetocarpus castanocarpus	1	0.9	30.5
	Drypetes pendula	1	0.4	19.2
	Glochidion sp.A	3	0.7	18.3
	Glochidion sp.B	4	1.3	22.3
	Macaranga bancana	1	0.1	12.3
	Macaranga conifera	2	0.7	22.4
	Macaranga gigantea	4	1.0	18.6
	Macaranga hypoleuca	10	2.6	20.2
	Macaranga pearsonii	1	0.4	20.5
	Mallotus penangensis	2	0.5	16.6

	Mallotus wrayi	1	0.1	10.5
Fagaceae	*Lithocarpus conocarpus*	2	0.5	15.7
	Lithocarpus sp.A	1	0.7	24.3
	Lithocarpus sp.C	1	0.1	12.4
Flacourtiaceae	*Hydnocarpus* sp.A	1	1.0	32.2
	Hydnocarpus sp.C	1	0.3	14.1
Guttiferae	*Calophyllum* sp.A	1	1.0	31.9
	Garcinia sp.D	1	0.3	14.3
Icacinaceae	*Stemonurus* sp.A	1	0.1	12.8
Lauraceae	*Alseodaphne* sp.A	1	0.1	10.8
	Litsea sp.C	1	0.1	11.1
	Litsea sp.D	1	2.1	44.6
	Litsea sp.F	1	0.4	20.5
	Nothaphoebe sp.A	1	3.8	60.3
Magnoliaceae	*Magnolia* sp.A	1	0.3	15.5
	Magnolia sp.B	1	0.3	14.3
Melastmotaceae	*Pternandra* sp.A	2	0.3	12.0
Meliaceae	*Chisocheton sarawakanus*	1	0.1	12.8
Moraceae	*Artocarpus* sp.A	1	0.1	13.8
	Ficus sp.B	1	3.3	56.0
Myristicaceae	*Knema* sp.A	2	0.3	12.4
	Knema sp.B	1	0.3	15.0
	Knema sp.C	1	0.1	13.8
	Myristica sp.	1	0.1	12.0
Myrtaceae	*Syzygium* sp.H	1	0.1	13.5
	Syzygium sp.L	1	0.1	10.4
Rubiaceae	*Pleiocarpidia* sp.A	2	1.6	32.7
	Rubi Indet sp.A	4	14.2	113.9
Rutaceae	*Melicope* sp.A	1	0.3	15.7
Sapindaceae	*Dimocarpus* sp.A	1	0.4	18.7
	Nephelium uncinatum	1	0.1	13.6
Sapotaceae	*Madhuca kingiana*	2	0.4	15.5
	Palaquium sp.A	1	0.1	12.0
	Palaquium sp.B	1	0.4	18.6
	Payena microphylla	1	0.3	15.0
Sterculiaceae	*Pterocymbium* sp.A	1	1.0	32.2
	Scaphium macropodum	1	7.6	86.0
	Sterculia sp.B	1	0.1	11.3
Theaceae	*Adinandra myroneura*	3	0.9	16.8
Tiliaceae	*Microcos* sp.A	1	0.8	26.9
	Microcos sp.B	1	0.4	18.2
	Pentace borneensis	1	0.1	11.0
Trigoniaceae	*Trigoniastrum hypoleucum*	1	0.1	11.1

Appendix 8. Species composition of the C63-Atas (63A) plot. See Appendix 1 for abbreviations.

Family	Species	N	RBA	Dmax
Annonaceae	*Xylopia* sp.A	1	0.5	19.6
Bombacaceae	*Durio* sp.B	2	0.7	15.6
	Neesia synandra	1	0.3	16.6
Burseraceae	*Dacryodes* sp.D	1	0.3	15.2
	Santiria sp.A	1	0.3	16.6
Celastraceae	*Lophopetalum beccarianum*	2	0.7	17.1
	Lophopetalum sp.A	5	5.9	46.8
Chrysobalanaceae	*Kostermanthus* sp.A	1	2.1	40.2
Dipterocarpaceae	*Dipterocarpus caudiferus*	1	0.3	17.5
	Dipterocarpus gracilis	1	3.8	54.7
	Dipterocarpus humeratus	1	6.3	69.3
	Dipterocarpus kerrii	1	0.2	11.2
	Dipterocarpus stellatus	1	0.2	11.9
	Dryobalanops lanceolata	1	0.2	12.3
	Parashorea malaanonan	2	2.6	36.8
	Shorea almon	1	0.2	12.6
	Shorea domatiosa	3	16.0	110.1
	Shorea fallax	1	1.0	26.7

	Shorea gibbosa	2	2.1	38.0
	Shorea leprosula	1	4.1	56.7
	Shorea macroptera	3	0.7	16.0
	Shorea mecistopteryx	6	2.5	22.1
	Shorea ovalis	2	6.4	63.0
	Shorea parvifolia	1	0.7	22.8
	Shorea pauciflora	6	8.6	77.5
	Shorea pilosa	1	1.5	33.5
	Shorea smithiana	1	0.2	13.8
	Vatica dulitensis	5	1.6	20.3
	Vatica sp.A	1	0.2	13.4
Ebenaceae	*Diospyros elliptifolia*	1	1.2	29.0
	Diospyros sp.E	1	0.2	10.5
	Diospyros sp.H	1	0.3	17.4
Euphorbiaceae	*Aporusa acuminatissima*	2	0.5	13.8
	Aporusa sp.D	1	0.2	10.1
	Baccaurea sp.A	1	0.2	11.2
	Baccaurea sp.B	1	0.2	11.6
	Drypetes pendula	1	0.5	19.8
	Macaranga conifera	1	2.1	41.2
	Mallotus penangensis	1	0.5	18.0
	Mallotus stipularis	1	0.5	20.1
	Mallotus wrayi	1	0.2	12.5
Fagaceae	*Castanopsis* sp.A	1	0.8	25.5
	Lithocarpus conocarpus	1	0.2	12.6
Flacourtiaceae	*Hydnocarpus* sp.A	3	2.1	31.4
Guttiferae	*Garcinia* sp.B	2	0.5	12.3
	Garcinia sp.D	1	0.5	20.8
Icacinaceae	*Stemonurus* sp.A	1	0.3	15.3
Lauraceae	*Alseodaphne* sp.B	1	0.5	20.6
	Cryptocarya sp.A	2	0.8	22.9
	Litsea sp.A	1	0.2	11.7
	Litsea sp.C	3	1.0	21.1
	Litsea sp.D	1	1.3	32.8
Lecythidaceae	*Barringtonia* sp.B	1	0.3	15.5
Leguminosae	*Archidendron* sp.A	1	0.5	20.4
	Fordia splendidussima	1	0.2	10.6
	Ormosia sp.A	1	0.2	11.3
Melastomataceae	*Pternandra* sp.A	1	0.5	18.1
Meliaceae	*Reinwardtiodendron* sp.A	1	0.2	10.4
	Walsura pinnata	1	0.2	12.2
	Walsura sp.A	1	1.0	26.8
Moraceae	*Artocarpus odoratissimus*	1	1.3	31.3
	Parartocarpus sp.A	1	0.8	26.4
Myristicaceae	*Gymnacranthera* sp.A	2	0.7	17.7
	Knema sp.A	1	0.3	14.0
	Knema sp.B	1	0.2	13.4
	Myristica sp.C	2	0.3	10.5
Myrtaceae	*Syzygium* sp.A	1	0.2	12.2
Olacaceae	*Ochanostachys amentacea*	2	2.5	36.4
Rhizphoraceae	*Carallia brachiata*	1	0.2	12.8
Rubiaceae	*Rothmannia* sp.A	1	0.3	17.2
Sapindaceae	*Dimocarpus* sp.A	1	0.7	21.3
	Pometia pinnata	1	0.2	11.6
Sapotaceae	*Palaquium* sp.A	1	0.2	12.4
	Palaquium sp.C	1	0.3	13.9
	Palaquium sp.D	1	0.5	19.7
	Payena microphylla	1	0.3	15.3
Sterculiaceae	*Sterculia* sp.B	1	1.6	35.7
	Sterculia sp.C	1	1.0	27.5
Tiliaceae	*Pentace laxiflora*	1	0.3	17.6
	Pentace sp.A	2	0.3	10.8
Verbenaceae	*Teijsmanniodendron holophyllum*	1	0.3	15.5

Appendix 9. Species composition of the Tangkulap-1 (TK1) plot. See Appendix 1 for abbreviations.

Family	Species	N	RBA	Dmax
Bombacaceae	*Durio* sp.A	1	0.2	12.9
Burseraceae	*Dacryodes* sp.D	1	0.2	10.7
Dipterocarpaceae	*Dipterocarpus caudiferus*	1	0.2	12.2
	Dipterocarpus pachyphyllus	1	6.0	56.6
	Dryobalanops beccarii	3	1.9	25.0
	Dryobalanops lanceolata	2	9.9	58.6
	Parashorea tomentella	3	1.2	16.8
	Shorea acuminatissima	1	0.5	16.4
	Shorea domatiosa	1	0.2	11.7
	Shorea gibbosa	3	3.6	36.8
	Shorea parvistipulata	1	1.0	23.7
Ebenaceae	*Diospyros* sp.I	1	0.2	10.3
Euphorbiaceae	*Aporusa* sp.B	2	0.5	13.6
	Glochidion sp.B	1	0.5	17.0
	Macaranga conifera	2	5.0	43.8
	Macaranga gigantea	2	0.5	13.5
	Macaranga hypoleuca	8	16.1	42.9
	Macaranga pearsonii	52	26.7	31.1
	Phychopyxis sp.A	1	1.4	26.6
Flacourtiaceae	*Hydnocarpus* sp.A	2	0.7	13.3
	Hydnocarpus sp.B	2	0.7	17.3
Lauraceae	*Eusideroxylon zwageri*	1	7.2	61.5
	Laur Indet sp.A	1	0.5	17.1
Leguminosae	*Archidendron* sp.A	1	0.2	12.7
	Fordia splendidussima	2	1.0	18.8
	Sindora irpicina	1	0.2	11.4
Magnoliaceae	*Magnolia* sp.B	1	0.2	10.4
Melastomataceae	*Pternandra* sp.A	1	0.2	10.3
Moraceae	*Artocarpus* sp.B	2	0.7	16.4
Myristicaceae	*Knema* sp.D	2	1.0	18.1
Myrtaceae	*Syzygium* sp.A	1	3.4	42.2
Rhamnaceae	*Alphitonia excelsa*	1	1.4	27.0
Sapindaceae	*Guioa* sp.A	1	0.2	11.4
Sapotaceae	*Madhuca* sp.A	1	1.7	29.1
	Palaquium sericeum	1	0.2	11.4
	Palaquium sp.A	1	3.1	40.8
Sterculiaceae	*Sterculia* sp.B	1	0.2	10.1
Verbenaceae	*Teijsmanniodendron holophyllum*	1	0.7	20.4
Indet	Indet sp.B	1	0.2	11.1

Appendix 10. Species composition of the Tangkulap-2 (TK2) plot. See Appendix 1 for abbreviations.

Family	Species	N	RBA	Dmax
Annonaceae	Anno Indet sp.A	1	0.2	12.4
Bombacaceae	*Durio acutifolius*	1	0.4	14.6
	Neesia synandra	1	0.6	20.8
Burseraceae	*Dacryodes* sp.A	1	0.4	15.7
	Dacryodes sp.B	1	1.5	31.8
Combretaceae	*Terminalia* sp.A	1	0.2	12.8
Dipterocarpaceae	*Dipterocarpus pachyphyllus*	1	1.5	31.4
	Dryobalanops beccarii	2	2.8	42.3
	Parashorea malaanonan	2	0.4	10.2
	Parashorea tomentella	1	4.2	53.7
	Shorea beccariana	2	0.7	18.0
	Shorea exelliptica	1	7.9	73.9
	Shorea macroptera	2	1.5	30.8
	Shorea ovalis	1	4.4	54.9
	Shorea sp.A	2	2.0	31.2
Ebenaceae	*Diospyros elliptifolia*	1	0.9	26.2
	Diospyros sp.G	1	0.2	10.4
Euphorbiaceae	*Aporusa acuminatissima*	1	0.2	12.1

	Croton argyratus	1	0.2	10.3
	Macaranga conifera	10	16.2	52.8
	Macaranga gigantea	4	7.7	42.4
	Macaranga hypoleuca	1	0.6	18.2
	Macaranga pearsonii	16	18.4	42.6
Fagaceae	*Lithocarpus conocarpus*	1	1.8	35.7
Flacourtiaceae	*Hydnocarpus* sp.	3	1.3	20.5
	Hydnocarpus sp.A	3	4.2	40.5
Lauraceae	*Eusideroxylon zwageri*	1	0.6	19.1
Leguminosae	*Peltophorum racemosum*	4	0.9	13.5
Melastomataceae	*Pternandra* sp.A	2	1.5	27.2
Meliaceae	*Aglaia* sp.A	1	0.2	10.9
Myristicaceae	*Knema* sp.A	1	0.2	13.0
	Myristica sp.C	1	0.9	26.0
Olacaceae	*Ochanostachys amentacea*	1	0.2	10.3
Polygalaceae	*Xanthophyllum* sp.A	1	0.2	11.6
Rubiaceae	*Timonius villamilii*	1	0.6	21.1
Sapindaceae	*Dimocarpus* sp.A	1	1.3	30.1
Sapotaceae	*Madhuca malaccensis*	1	0.7	22.4
	Palaquium beccarianum	1	0.9	25.3
	Payena microphylla	1	7.2	70.8
Sterculiaceae	*Sterculia cordata*	1	1.5	32.0
	Sterculia sp.B	1	0.4	17.0
Thymelaceae	*Gonystylus* sp.A	1	0.2	10.2
Tiliaceae	*Pentace laxiflora*	1	2.6	42.9

Appendix 11. Species composition of the Tangkulap-3 (TK3) plot. See Appendix 1 for abbreviations.

Family	Species	N	RBA	Dmax
Bombacaceae	*Durio* sp.C	1	0.9	16.9
Dilleniaceae	*Dillenia* sp. A	1	1.8	23.0
Dipterocarpaceae	*Dipterocarpus gracilis*	1	0.4	10.2
	Parashorea malaanonan	2	8.1	45.1
	Parashorea tomentella	3	2.2	21.1
	Shorea almon	2	1.3	15.1
	Shorea exelliptica	1	7.6	46.3
	Shorea pauciflora	3	15.7	55.3
	Vatica oblongifolia	2	3.1	23.8
Euphorbiaceae	*Macaranga conifera*	4	3.6	22.9
	Macaranga gigantea	7	7.6	32.7
	Macaranga hypoleuca	1	0.4	11.8
	Macaranga pearsonii	28	22.9	24.0
	Macaranga sp.B	2	2.2	18.2
	Euphorbiaceae Indet sp.B	3	1.8	13.3
Lauraceae	Lauraceae Indet sp.	1	1.3	19.3
Leguminosae	*Fordia* sp.A	1	0.4	11.3
Magnoliaceae	*Magnolia* sp.A	1	0.4	10.7
Moraceae	*Ficus* sp.C	3	0.9	10.4
Myristicaceae	*Knema* sp.B	1	0.9	15.0
Oleaceae	*Chionanthus* sp.B	1	0.4	12.2
	Chionanthus sp.C	1	0.4	13.6
Rubiaceae	*Pleiocarpidia* sp.B	1	0.4	12.4
Sapindaceae	*Nephelium lappaceum*	1	0.4	13.5
Sapotaceae	*Palaquium* sp.A	2	0.9	11.0
Sterculiaceae	*Scaphium longipetiolatum*	1	0.9	15.2
	Sterculia sp.D	1	0.9	17.0
Symplocaceae	*Symplocos fasciculata*	2	1.3	15.0
Thymelaeaceae	*Aquilaria malaccensis*	1	0.4	10.4
Tiliaceae	*Brownlowia peltata*	1	0.4	10.3
	Microcos laxiflora	1	6.7	43.0
Indet	Indet sp.D	1	1.3	20.9
	Indet sp.E	1	1.3	20.4