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The Dynamics of Species Composition Stand Structure and Above Ground Biomass of Undisturbed Forest in East Kalimantan

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ABSTRAK

Dinamika Komposisi Spesies Struktur Pohon dan Biomasa di Hutan Terganggu di Kalimantan Timur. Kajian dinamika komposisi spesies dan biomasanya dilakukan selama 4,3 tahun (Desember 2004 - April 2009) di hutan terganggu Kalimantan Timur. Untuk melakukan kajian di gunakan 6 plot permanen (100x100 m^2), yang berada di hutan penelitian Samboja. Semua pohon berdiameter > 10 cm dbh (diukur pada posisi 1,3 m diatas tanah). Pada Desember 2004, tercatat 2143 pohon tersebar di plot tersebut terdiri dari 39 famili, 82 genus dan 111 spesies. Pada pengamatan April 2009 tercatat 2466 pohon terdiri dari 40 famili, 86 genus dan 123 jenis. Sebagian besar spesies yang mendominasi adalah *Garcinia nervosa* dan *Trigonostemon laevigatus* tetapi setelah pengamatan pada tahun 2009, keduanya tidak lagi mendominasi. Selama kurun 4,3 tahun terjadi penambahan kepadatan 15,1%, basal area 12,9% dan biomasa 11,6%. Penambahan kepadatan tercatat meningkat dari 357 menjadi 411 pohon/ha. Basal area meningkat mulai dari 20,09 menjadi 22,67 m^2 ha^{-1}, sedangkan biomasa meningkat dari 286,3 menjadi 319,4 ton ha^{-1}.

Kata kunci: Komposisi, spesies, biomas, hutan terganggu

INTRODUCTION

Sustainable forest management is an important issue in Indonesia. Sound forest management cannot possibly be applied without an understanding of the basic ecology of the forests. One prerequisite for sustainable forest management is reliable information on stand dynamics and its characteristics since it is essential to know how the forest will grow and respond to natural conditions or occasional disturbances. However, little information is available regarding the dynamics of species composition, structural and productivity (biomass) changes of the tropical forests in Indonesia over time.

Most studies in Indonesia are based on surveys on compositional and structural patterns of certain sites or forests at one occasion (e.g. Kartawinata *et al*. 1981; Riswan 1987; Suselo & Riswan 1987; Sist & Saridan, 1998; Heriyanto 2001; Krisnawati 2003). Forest vegetations, however, are dynamic and changes occur continuously at individual and species population levels throughout time, even though the vegetation as a whole is expected to be stable, as a result of a balance between growth, recruitment and mortality. Several studies on forest dynamics in other tropical regions have been conducted (Lieberman *et al.*1985; Manokaran & Kochummen 1987; Swaine *et al.* 1987); however, a better understanding of the tropical forest dynamics particularly in Indonesian forests is still limited. Measurement of permanent sample plots at certain intervals and over a long period is therefore required for the understanding of the process in which the changes occur at individual, species and stand or community levels.

The objective of this study was to analyse the changes in species composition, stand structure, and above-ground biomass of the woody plants of an undisturbed forest of the Samboja Research Forest in East Kalimantan over a time (2004-2009). The main question was whether the forest vegetation in the site would maintain its species composition and structural characteristics over period of time. The results were expected to provide an insight into the temporal stability of forest vegetation in this site.

MATERIALS AND METHODS

This study was conducted in the 26.5 ha of 504 ha remaining Samboja Research Forest, 4.5 km from the starting point of Samboja-Semoi route (0°59' N latitude and 116.56° E longitude, Figure 1). This undisturbed natural forest was considered as a miniature of tropical rain forest in Kalimantan due to its high biodiversity (Gunawan *et al*. 2007). About 296 species of 54 families including species of Palmae have been reported to inhabit this forest (Yassir & Juliati 2003).

The site is located at the village of Sungai Merdeka, the Sub-District of Samboja, Kutai Kartanegara-East Kalimantan. The average annual precipitation in the site ranges from 1682 to 2314 mm with the number of rainy days of 72-154 days/ year. The temperature is about 26-28 ^{o}C with the minimum value in the day time of 23.3^{o}C and the maximum value in the night time of 32.7^{o}C and the humidity is 63 to 89% (Adinugroho *et al*. 2006; Atmoko 2007).

The altitudinal range of the area is from 40 to 150 m asl. The topography is relatively undulating and rolling with the slopes of around 10-40 % while some parts may reach 60% (Gunawan *et al*. 2007). The dominant soil type includes ultisol which is typically quite acidic and deficient in major nutrients, such as calcium and potassium. Geologically, the soil is mostly derived from tertiary sedimentary rocks.

The study was based on the results of the monitoring of six permanent sample plots (100m x 100 m square plot (1 ha) each, Figure 1 distributed over an area of 26.5 ha of Samboja Research Forest. All plots were first delineated on the ground to cover the range of topography of the site. Each plot was divided into 100 sub-plots of 10 x 10m to allow a better control of measurement. The plot installation and the first measurement were conducted in December 2004 and re-measured three times over 4.3 years. The re-measurements were done in May 2006, June 2008, and April 2009.

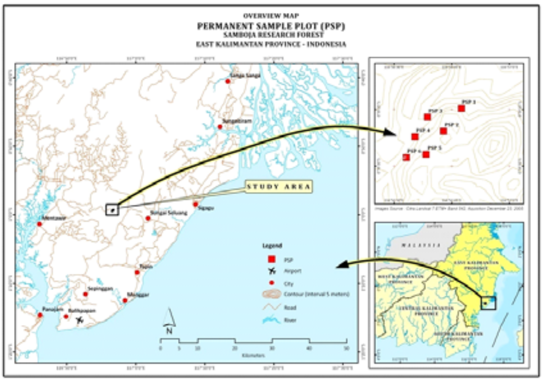

Figure 1. Location of research plots in Samboja Research Forest, East Kalimantan.

In each plot, all woody plants of at least 10 cm dbh (diameter at 1.3 m above ground) were marked, identified. The dbh of every target tree was measured at each measurement, and dead and newly recruited target trees were registered at each re-measurement time. Tree height was measured for all trees in the first and second measurements and for 50 trees with various dbh in the third and last measurements (i.e. 2 trees in each sub-plot). All trees in the plots were mapped, but no analysis was done at the individual level.

All tree specimens were collected and identified in the herbarium laboratory of the Samboja Forestry Research Institute. A list of species was compiled at each measurement. Shannon's diversity and Pielou's evenness indices were calculated for each occasion (Ludwig & Reynolds 1988). Stand density (number of trees), basal area, and above-ground biomass were also calculated at each occasion (Husch *et al*. 2003). The above-ground biomass was estimated using allometric equations developed by Yamakura *et al*. (1986) for undisturbed tropical lowland rain forests in Sebulu, East Kalimantan Province. The site of their study was considered to have similar characteristics with this study site in terms of forest type, topography, climate, soil type, and dominant family in the forests. Changes in the species composition, stand density, basal area, and above-ground biomass were analysed and then compared at each assessment.

RESULTS

Species composition

In December 2004, 2143 trees of e” 10 cm in diameter were measured in six permanent plots of the Samboja Research Forest. They consisted of 39 families, 82 genera and 111 species. The distribution in April 2009 (after 4.3 yr) was: 2466 trees, 40 families, 86 genera and 123 species. The list of species and families found in these plots for all measurement times was presented in Appendix 1.

Most species were found in both occasions, except for *Garcinia nervosa* and *Trigonostemon laevigatus* that did not occur in 2009, although these species might still be present below the diameter limit (10cm) used in this study. Fourteen new species were registered (i.e. *Actinodaphne malaccensis*, *Albizia minahasae*, *Diospyros confertifolia*, *Durio oxleanus*, *Knema conferta*, *Magnolia borneensis*, *Palaquium pseudorostratum*, *Palaquiun gutta*, *Parisia insignis*, *Porterandia anisophylla*, *Dillenia* sp., *Durio* sp., *Parashorea* sp., and *Shorea* sp1.), which contributed to 9.8% of a net addition of the total number of species found in the study site over the 4.3-yr period.

The species that disappeared from the plots occurred at low density in the study area (less than one tree per ha) and any cause of mortality might would eliminate them from the plots; however, their absence might be replaced by newly recruited trees due to ingrowth. These species might have also been represented in the study site as smaller individuals. The same state applied to the new species that entered the plots.

Stand Structure

In the first measurement (Dec. 2004), 16 species comprised about 80% of the stand basal area (*BA*) and 76% of the stand density (*N*) over 10 cm dbh (Table 1). All of these were categorized as commercial species. Of these species, half of them were from Dipterocarpaceae family which contributes to 44% of the stand density and 53% of the basal area. Most of them are fast growing and shade tolerant. The most abundant species was *Vatica odorata*, followed by *Shorea bracteolata* and *Shorea parvifolia*.

In general, the stand density increased by 15.1% from 357 trees per ha to 411 trees per ha over the 4.3 yr period (Table 1). Similarly, the basal area increased by 12.9% from 20.09 m^2 ha^{-1} to 22.67 m^2 ha^{-1}. The same trends applied to all individual plots ranging from 5.8 to 24.5% in density and from 9.8 to 17.7% in basal area. The positive changes in density found in this study probably due to more species and more recruited trees entered the plots. The number of trees that pass the minimum diameter limit was

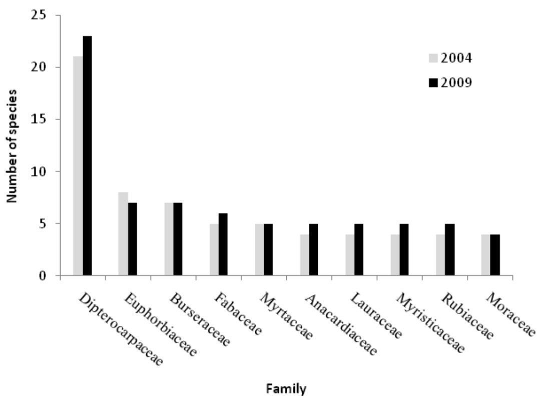

Figure 2. Ten dominant families based on species richness in the six plots.

Table 1. Changes in stand density (number of trees) and basal area of the six permanent plots in the Samboja Research Forest, East Kalimantan, between December 2004 and April 2009.

Species	Family	2004		2009		2004-2009		Change	
		N	*BA*	*N*	*BA*	*In.*	Mor.	N	BA
Shorea laevis	Dipt.	15.8	3.25	18.7	3.32	3.7	0.8	+	+
Shorea parvifolia	Dipt.	30.8	1.70	42.0	2.07	12.7	1.5	+	+
Vatica odorata	Dipt.	49.2	1.58	56.3	1.76	11.0	3.8	+	+
Eusideroxylon zwageri	Laur.	16.0	1.23	16.7	1.33	1.2	0.5	+	+
Shorea bracteolata	Dipt.	40.3	1.23	43.7	1.44	4.7	1.3	+	+
Syzygium sp.	Myrt.	27.3	1.04	33.5	1.24	7.3	1.2	+	+
Dipterocarpus	Dipt.	7.0	0.99	10.8	1.12	4.0	0.2	+	+
Sindora wallichii	Fab.	20.7	0.89	24.7	1.12	4.7	0.7	+	+
Koompassia	Fab.	7.5	0.73	7.0	0.80	-	0.5	-	+
Shorea lamellata	Dipt.	8.2	0.72	8.3	0.80	0.3	0.2	+	+
Dipterocarpus	Dipt.	4.5	0.71	5.8	0.78	1.5	0.2	+	+
Madhuca sericea	Sapot.	12.3	0.56	13.7	0.67	1.7	0.3	+	+
Diospyros borneensis	Eben.	14.7	0.45	16.7	0.55	2.2	0.2	+	+
Crypteronia griffithii	Crypt.	9.7	0.43	9.5	0.48	0.2	0.3	-	+
Shorea johorensis	Dipt.	0.8	0.39	0.7	0.38	-	0.2	-	-
Gonystylus velutinus	Thym.	8.7	0.33	8.3	0.37	0.7	1.0	-	+
Eugenia sp.	Myrt.	9.0	0.32	10.3	0.36	1.8	0.5	+	+
Diallium sp.	Caes.	1.3	0.28	1.3	0.30	-	-	+	+
Knema laterisia	Myrist.	8.5	0.25	8.7	0.29	0.5	0.3	+	+
Shorea smithiana	Dipt.	1.8	0.24	1.8	0.26	-	-	+	+
Tristaniopsis sp.	Myrt.	0.3	0.22	0.3	0.22	-	-	+	+
Shorea javanica	Dipt.	5.2	0.18	6.5	0.18	1.7	0.3	+	+
Hydnocarpus gracilis	Flac..	4.8	0.14	4.7	0.16	-	0.2	-	+
Gironniera nervosa	Ulm.	3.2	0.13	3.0	0.15	-	0.2	-	+
Hopea mengerawan	Dipt.	3.8	0.12	4.0	0.14	0.3	0.2	+	+
Remaining species		45.7	1.97	54.0	2.34	10.8	2.5	+	+
Total		357.2	20.09	411.0	22.67	70.8	17.0	+	+

Notes: N = number of trees per ha; BA = basal area (m^2 ha^{-1}); In = ingrowth (number of recruited trees per ha); Mor = number of dead trees per ha); + = increase; - = decrease.

about 71 trees per ha over 4.3 yr (or 16 trees ha^{-1} yr^{-1}), while the mortality was lower (about 17 trees per ha over 4.3 yr or 4 trees ha^{-1} yr^{-1}). The loss of basal area by death of some trees was lower than the gain by growth of surviving trees. Most of species showed a positive balance in basal area (Table 1).

Above-ground biomass

Four families (Dipterocarpaceae, Fabaceae, Myrtaceae, and Lauraceae) contained more than 80% of the above-ground biomass ($\geq$ 10cm dbh) in both 2004 and 2009 (Table 2). Of these, almost 75% of them were from Dipterocarpaceae family which comprised about 43% of the total above-ground biomass contained in the plots. The highest value in the amount of above-ground biomass belonged to *Shorea parvifolia*, followed by *Sindora wallichii* and *Shorea bracteolata*. These three species contributed to a net addition of 30% of total above-ground biomass.

Overall, the above-ground biomass of all species increased by 11.6% (33.1 tons ha^{-1}) over the 4.3 yr period, i.e. from 287.3 tons ha^{-1} in December 2004 to 319.4 tons ha^{-1} in April 2009 (Table 2). The same trends were also observed for each plot and for other occasions. The increase of each plot ranged from 7.4 to 13.8% tons ha^{-1}. The trend of increasing above-ground biomass may be attributed to the high rate of recruitment and growth of some species. However, the increase of above-ground biomass over the 4.3 yr was not significantly different. No significant change was found in the biomass with time. Most of families showed smaller change (less than 1 tons ha^{-1}) in the above-ground biomass during the 4.3 yr period (Table 2), suggesting that carbon uptake by these families was limited over the 4.3 yr period.

DISCUSSION

The Dipterocarpaceae family was the richest in species (more than 20 species found in both 2004 and 2009), followed by the families of Euphorbiaceae, Burseraceae, Fabaceae, and Myrtaceae (more than five species found in both occasions) (Figure 2). Most genera (80%) contained just one species; however, *Shorea* was the richest genus consisting of 13 species.

The indices of Shannon's diversity and Pielou's evenness were 3.34 and 0.71 in 2004, respectively; and 3.33 and 0.69 in 2009. Result of statistical *t*-test (Zar 2006) indicated that these values were not different ($P < 0.05$) meaning that the changes in species richness over the period of 4.3-yr did not cause any difference in the value of Shannon 's diversity index, which is little affected by rare species. Approximately 70% of the species found in the plots were rare

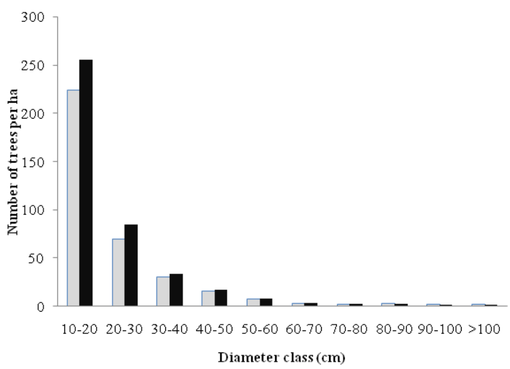

Figure 3. Diameter distribution of the six permanent plots in the Samboja Research Forest at the measurements of December 2004 and April 2009. (black=2009, white=2004).

Table 2. Changes in above-ground biomass (AGB) of the six permanent plots in the Samboja Research Forest, East Kalimantan, between December 2004 and April 2009.

Family	*AGB* (tons ha^{-1})		Increase	
	2004	2009	tons ha^{-1}	%
Dipterocarpaceae	175.2	189.5	14.3	43.30
Fabaceae	22.1	26.7	4.7	14.05
Myrtaceae	20.1	23.1	3.0	9.06
Lauraceae	18.0	19.5	1.5	4.52
Sapotaceae	7.7	9.6	1.8	5.51
Crypteroniaceae	5.7	6.3	0.7	2.09
Caesalpiniaceae	5.1	5.5	0.4	1.18
Ebenaceae	4.7	5.9	1.3	3.86
Thymelaeaceae	3.9	4.7	0.8	2.39
Myristicaceae	3.1	3.9	0.7	2.21
Euphorbiaceae	2.1	2.9	0.8	2.45
Anacardiaceae	1.9	2.3	0.4	1.21
Lecythidaceae	1.7	1.9	0.2	0.62
Ulmaceae	1.7	1.9	0.2	0.74
Moraceae	1.6	1.9	0.3	1.00
Flacourtiaceae	1.4	1.7	0.3	0.96
Burseraceae	1.3	1.5	0.2	0.72
Theaceae	1.2	1.4	0.2	0.64
Chrysobalanaceae	1.1	1.1	0.0	0.00
Meliaceae	1.1	1.4	0.2	0.74
Remaining families	5.9	6.2	0.3	0.89
Total	286.3	319.4	33.1	100.00

species (low density) with only less than one tree (dbh e” 10cm) per ha. However, this low density of the species is typically found in tropical rain forests (Whitmore, 1984). Although the majority of species have been found with a low density, the forest state in the study area can still be considered to be stable, as the value of Shannon’s diversity index is above 3.0 (Odum 1971). This result suggested that the vegetation of the study site maintains its original composition.

After the 4.3 yr period (April 2009), the same species still comprised 80% of the stand basal area but the ranking changed slightly (Table 1). *Shorea bracteolata* ranked fourth in basal area (higher than *Eusideroxylon zwageri*), since more recruited trees of this species entered the plots. However, in terms of stand density the ranking retained the same. A study conducted by Silva *et al.* (1995) in the logged-over area of the Tapajós Forest, Brazil, found a slight change in species ranking; but another study, conducted in the same site of the Brazilian Amazon (Carvalho 1992, cited in Silva *et al.* 1995), found no major changes in species ranking before and after logging.

Compared with other studies conducted in several other tropical forests, the change or the increase found in this study was greater which was probably due to an increase in the number of recruited trees and the fast growth of some species (particularly from Dipterocarpaceae family). Felfili (1995) reported a reduction of 2% in density over 5 cm dbh for a 6-yr period for a gallery forest located in the Central Brazil. Another study by Felfili *et al*. (2000) for a forest site in Brazil also showed a reduction (4.5%) in density over a 9-yr period. On the other hand, Silva *et al*. (1995) found an addition of 13% in density for a 11-yr period for a logged-over forest also located in Brazil. The increase in density was also reported by Carvalho (1992), cited in Silva *et al.* (1995), who found an addition of 1% for an Amazonian site over 8-yr period. Several other studies in Malaysian dipterocarp forest (Manokaran & Kochumen 1987) and in Ghana forest (Swaine *et al.* 1987) showed smaller variation in density over the study period than in this study (Table 1).

The addition (due to recruitment) and reduction (due to mortality) in the number of trees coupled with the growth of trees at a site would result in balance vegetation. Felfili (1995) noted that if there is a period of high mortality (when the density is reduced) and followed by another period of high recruitment (when new trees fill the gaps formed previously), the stand state can be said to reach the dynamic equilibrium, and therefore, maintaining the structure of the vegetation over time.

The diameter distribution of surviving trees for both occasions in December 2004 and April 2009 (Figure 3), showed a reversed-J shape which indicated a continuous ingrowth. The same trends applied to other diameter distributions for other years. For dead trees, numbers of mortality tend to decrease with increasing diameter. The diameter distributions showed that the number of trees at each diameter class generally increased over 4.3 yr period. However, the differences were not significant between the two occasions; the test statistic of the Kolmogorov-Smirnov two sample test (K-S) was 0.0062. The distributions between 2004 and other years (2006 and 2008) were also not significantly different (K-S of 2004-2006 = 0.0179; K-S of 2004-2008 = 0.0056). The same results were found by e.g. Swaine *et al.* (1987) for moist semi-deciduous forest in Kade, Ghana over a 14 yr period, Felfili *et al.* (2000) for savanna woodland in Brazilian Amazon over a 9 yr period.

CONCLUSION

Overall, number of species, stand density, basal area and above-ground biomass of woody plants of e”10 cm dbh increased over 4.3 yr (December 2004-April 2009). The changes in stand density and basal area in the Samboja Research Forest were greater than those found in several other tropical forests. These increases were probably due to more species entered the plots and more recruited trees passing the minimum diameter limit used in this study in addition to the fast growth of some species growing in the plots.

The increases in species richness and density, however, did not cause any significant differentiation in the diversity index and diameter distribution, respectively. This condition suggested that forest vegetation of the study site maintains its diversity composition and structural features over the period of study. Longer-term monitoring with regular measurements, however, is necessary to clarify these trends.

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REFERENCES

Adinugroho, WC., D. Setaiabudi, W. Gunawan, T. Atmoko, T & Noorcahyati. 2006. Potensi dan hambatan pengelolaan Kawasan Hutan dengan Tujuan Khusus (KHDTK) Penelitian Smaboja. *Prosiding Seminar Bersama Hasil-hasil Penelitia*n 3 UPT Badan Litbang Kehutanan Tahun 2006. (unpublished report).

Atmoko, T. 2007. Rintis Wartono Kadri, Pusat Keanekaragaman Hayati di KHDTK Samboja, Kalimantan Timur. *Wana Tropika* 2(4): 19-20.

Felfili, JM. 1995. Gorwth, recruitment and mortality in the Gama gallery forest in Central Barzil over a six-year period (1986-1991). *J. Tropic. Ecol.* 11: 67-83.

Felfili, JM., AV. Rezende, MC.Silva Júnior, & MA. Silva. 2000. Changes in the floristic composition of Cerrado sensu stricto in Brazil over a nine-year period. *J. Tropic Ecol.* 16 (4): 579-590.

Gunawan, W., CW. Adinugroho & Noorhidayah. 2007. Prospek pengembangan Rintis Wartono Kadri menjadi Unit Pendidikan Konservasi Alam dan Interpretasi Lingkungan (UPKA-ILS). Paper presented at the Seminar "Pemanfaatan Hasil Hutan Bukan Kayu dan Konservasi Biodiversitas Menuju Hutan Lestari". (unpublished report).

Heriyanto, NM. 2001. Komposisi dan penyebaran jenis tumbuhan di hutan bekas tebangan dan hutan primer, Maluku Tengah. *Bul. Pen. Hutan* 629: 31-42.

Husch, B., Beers, T.W., Kershaw, J.A. 2003. *Forest Mensuration* (4th edition). John Wiley & Sons, Inc.

Kartawinata, K., A. Rochadi & T. Partomihardjo. 1981. Composition and structure of a lowland dipterocarp forest at Wanariset, East Kalimantan (Indonesia). *Malayan Forester* 44: 397 – 406.

Krisnawati, H. 2003. Struktur tegakan dan komposisi jenis hutan alam bekas tebangan di Kalimantan Tengah. *Bul. Penelitian Hutan* 639: 1-19.

Lieberman, D., Lieberman, M., Peralta, R. and Hartshorn, G.S. 1985. Mortality patterns and stand turnover rates in a wet tropical forest in Costa Rica. *J. Ecol.* 73:915-924.

Ludwig, JA& JF. Reynolds. 1988. Statistical Ecology: A primer on methods and computing. John Wiley & Sons, New York. 337p.

Manokaran, N. &MN. Kochumen. 1987. Recruitment, growth and mortality of tree species in a lowland dipterocarp forest in Peninsular Malaysia. *J. Tropic.Ecol.* 3:315-330.

Odum, EP. 1971. Fundamentals of Ecology (3rd edition). W.B. Saunders, Coy, Philadelphia. 574p.

Riswan, S. 1987. Structure and floristic composition of mixed dipterocarp forest at Lempake, East Kalimantan. In: Kostermanns, A.J.G.H (Ed.). Proceedings of the 3rd International Round Table Conference on Dipterocarps. UNESCO, Jakarta, Indonesia. 435-457.

Silvia, JNM., JOP. de Carvalho, JDCA. de Lopes, BF. de Almeida, DHM. Costa LC. de Oliveira, JK. Vanclay & JP. Skovsgaard, J.P. 1995. Gorwth and yield of a tropical rain forest in the Brazilian Amazon 13 years after logging. *Forest Ecol. Manag.* 71: 267-274.

Sist, P. & A. Saridan. 1998. Description of the primary lowland forest of Berau. *In*: Bertault, J-G and Kadir, K. (Eds.). 1998. *Silvicultural research in a lowland mixed dipterocarp forest of East Kalimantan*. The Contribution of STREK project, CIRAD-forêt, FORDA, and PT. INHUTANI I. CIRAD-forêt Publication. 51-93.

Suselo, TB. & S. Riswan. 1987. Compositional and structural pattern of lowland mixed dipterocarp forest in the Kutai National Park, East Kalimantan. *In* Kostermanns, A.J.G.H (Ed.). *Proceedings of The Third International Round Table Conference on Dipterocarps.* UNESCO, Jakarta, Indonesia. 459 – 470.

Swaine, MD., JB. Hall, & IJ. Alexander. 1987. Tree populations dynamics at Kade, Ghana (1968-1982). *J. Trop. Ecol.* 3: 359-366.

Whitmore, TC. 1984. Tropical Rain Forest of the Far East (2nd edition). Clarendon Press, Oxford. 352p.

Yamakura, T., A. Hagihara, S. Sukardjo, & A. Ogawa. 1986. Above ground biomass of tropical rain forest stands in Indonesian Borneo. *Vegetatio* 68: 71-82.

Yassir, I. & N. Juliati. 2003. Prospek pengembangan Rintis Wartono Kadri sebagai arboretum di Wanariset Samboja. *Dipterokarpa* 7(1): 12-23.

Zar, JH., 2006. *Biostatistical Analysis*. Prentice Hall, New Jersey. 688p.

Appendix 1. List of species and families found in the six plots of Samboja Research Forest

Species	Family	Measurement time			
		2004	2006	2008	2009
-1	-2	-3	-4	-5	-6
Actinodaphne malaccensis	Lauraceae		√	√	√
Aglaia sp.	Meliaceae	√	√	√	√
Alangium javanicum	Alangiaceae	√	√	√	√
Albizia minahasae	Fabaceae			√	√
Alstonia scholaris	Apocynaceae	√	√	√	√
Anisoptera costata	Dipterocarpaceae	√	√	√	√
Anthocephalus chinencis	Rubiaceae	√	√	√	√
Aquilaria microcarpa	Thymelaeaceae	√	√	√	√
Archidendron microcarpum	Fabaceae	√	√	√	√
Artocarpus anisophyllus	Moraceae	√	√	√	√
Artocarpus dadah	Moraceae	√	√	√	√
Artocarpus niditus	Moraceae	√	√	√	√
Artocarpus sp.	Moraceae	√	√	√	√
Atuna racemosa	Chrysobalanaceae	√	√	√	√
Barringtonia macrostachya	Lecythidaceae	√	√	√	√
Beilschmiedia sp.	Lauraceae	√	√	√	√
Buerhavia paniculata	Lauraceae	√	√	√	√
Canarium littorale	Burseraceae	√	√	√	√
Canarium pilosum	Burseraceae	√	√	√	√
Chaetocarpus castanocarpus	Euphorbiaceae	√	√	√	√
Chionanthus sp.	Olaceae	√	√	√	√
Cotylelobium melanoxylon	Dipterocarpaceae	√	√	√	√
Cotylelobium sp.	Dipterocarpaceae	√	√	√	√
Cratoxylum sumatranum	Hypericaceae	√	√	√	√
Crypteronia griffithii	Crypteroniaceae	√	√	√	√
Dacryodes costata	Burseraceae	√	√	√	√
Dacryodes rubiginosa	Burseraceae	√	√	√	√
Dacryodes rugosa	Burseraceae	√	√	√	√
Diallium indum	Caesalpiniaceae	√	√	√	√
Diallium sp.	Caesalpiniaceae	√	√	√	√
Dillenia sp.	Dilleniaceae				√
Diospyros borneensis	Ebenaceae	√	√	√	√
Diospyros confertifolia	Ebenaceae		√	√	√
Dipterocarpus confertus	Dipterocarpaceae	√	√	√	√
Dipterocarpus cornutus	Dipterocarpaceae	√	√	√	√
Dipterocarpus sp.	Dipterocarpaceae	√	√	√	√
Dracontomelon mangiferum	Anacardiaceae	√	√	√	√
Drymicarpus luridus	Anacardiaceae	√	√	√	√
Dryobalanops sp.	Dipterocarpaceae	√	√	√	√
Drypetes crassipes	Euphorbiaceae	√	√	√	√

Appendix 1. Continued

Species	Family	Measurement time			
		2004	2006	2008	2009
-1	-2	-3	-4	-5	-6
Durio griffitii	Malvaceae	√	√	√	√
Durio oxleanus	Malvaceae		√	√	√
Durio sp.	Malvaceae		√	√	√
Dyera costulata	Apocynaceae	√	√	√	√
Dysoxylum sp.	Meliaceae	√	√	√	√
Endiandra kingiana	Lauraceae	√	√	√	√
Eugenia sp.	Myrtaceae	√	√	√	√
Eugenia stapfiana	Myrtaceae	√	√	√	√
Eusideroxylon zwageri	Lauraceae	√	√	√	√
Garcinia nervosa	Guttiferae	√	√	√	√
Gironniera nervosa	Ulmaceae	√	√	√	√
Gluta aptera	Anacardiaceae	√	√	√	√
Gluta speciosa	Anacardiaceae	√	√	√	√
Gonystylus velutinus	Thymelaeaceae	√	√	√	√
Gordonia borneensis	Theaceae	√	√	√	√
Hopea mengerawan	Dipterocarpaceae	√	√	√	√
Hydnocarpus gracilis	Flacourtiaceae	√	√	√	√
Kibatalia pillosa	Apocynaceae	√	√	√	√
Knema conferta	Myristicaceae			√	√
Knema laterisia	Myristicaceae	√	√	√	√
Knema sp.	Myristicaceae	√	√	√	√
Kokoona reflexa	Celastraceae	√	√	√	√
Koompassia malaccensis	Fabaceae	√	√	√	√
Lansium domesticum	Meliaceae	√	√	√	√
Licania splendens	Chrysobalanaceae	√	√	√	√
Lithocarpus sp.	Fagaceae	√	√	√	√
Macaranga hypoleuca	Euphorbiaceae	√	√	√	√
Macaranga lowii	Euphorbiaceae	√	√	√	√
Madhuca sericea	Sapotaceae	√	√	√	√
Madhuca pierrei	Sapotaceae	√	√	√	√
Magnolia borneensis	Magnoliaceae		√	√	√
Magnolia cassia	Magnoliaceae	√	√	√	√
Messua sp.	Guttiferae	√	√	√	√
Myristica iners	Myristicaceae	√	√	√	√
Myristica maxima	Myristicaceae	√	√	√	√
Neoscortechinia kingii	Euphorbiaceae	√	√	√	√
Nephelium sp.	Sapindaceae	√	√	√	√
Oncosperma horridum	Palmae	√	√	√	√
Palaquium pseudorostratum	Sapotaceae				√
Palaquiun gutta	Sapotaceae			√	√

Appendix 1. Continued

Species	Family	Measurement time			
		2004	2006	2008	2009
-1	-2	-3	-4	-5	-6
Parashorea sp.	Dipterocarpaceae				√
Parisia insignis	Anacardiaceae			√	√
Parkia speciosa	Fabaceae	√	√	√	√
Pellacalyx sp.	Rhizophoraceae	√	√	√	√
Pentace loxiflora	Tiliaceae	√	√	√	√
Pertusadina euricha	Rubiaceae	√	√	√	√
Pholidocarpus sp.	Palmae	√	√	√	√
Phychopyxis javanica	Euphorbiaceae	√	√	√	√
Pimelodendron griffitii	Euphorbiaceae	√	√	√	√
Pithecellobium rosulatum	Fabaceae	√	√	√	√
Polyalthia sp.	Annonaceae	√	√	√	√
Porterandia anisophylla	Rubiaceae		√	√	√
Prysmatomeris sp.	Rubiaceae	√	√	√	√
Pterospermum sp.	Sterculiaceae	√	√	√	√
Quercus sp.	Fagaceae	√	√	√	√
Rhodamnia cinerea	Myrtaceae	√	√	√	√
Sandaricum sp.	Meliaceae	√	√	√	√
Santiria griffithii	Burseraceae	√	√	√	√
Santiria oblongifolia	Burseraceae	√	√	√	√
Scaphium macroppodum	Malvaceae	√	√	√	√
Schima wallichii	Theaceae	√	√	√	√
Scorodocarpus borneensis	Olacaceae	√	√	√	√
Shorea bracteolata	Dipterocarpaceae	√	√	√	√
Shorea javanica	Dipterocarpaceae	√	√	√	√
Shorea johorensis	Dipterocarpaceae	√	√	√	√
Shorea laevis	Dipterocarpaceae	√	√	√	√
Shorea lamellata	Dipterocarpaceae	√	√	√	√
Shorea mujongensis	Dipterocarpaceae	√	√	√	√
Shorea ovalis	Dipterocarpaceae	√	√	√	√
Shorea parvifolia	Dipterocarpaceae	√	√	√	√
Shorea pauciflora	Dipterocarpaceae	√	√	√	√
Shorea smithiana	Dipterocarpaceae	√	√	√	√
Shorea sp1	Dipterocarpaceae				√
Shorea sp2.	Dipterocarpaceae	√	√	√	√
Shorea sp3	Dipterocarpaceae	√	√	√	√
Sindora wallichii	Fabaceae	√	√	√	√
Syzygium sp.	Myrtaceae	√	√	√	√
Tarenna rostata	Rubiaceae	√	√	√	√
Trigonostemon laevigatus	Euphorbiaceae	√	√		

Appendix 1. Continued

Species	Family	Measurement time			
		2004	2006	2008	2009
-1	-2	-3	-4	-5	-6
Tristaniopsis sp.	Myrtaceae	√	√	√	√
Vatica odorata	Dipterocarpaceae	√	√	√	√
Vitex sp.	Lamiaceae	√	√	√	√
Xanthophyllum griffithi	Polygalaceae	√	√	√	√
Xerospermum noronhianum	Sapindaceae	√	√	√	√
Xylopia sp.	Annonaceae	√	√	√	√
Unidentified species		√	√	√	√

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