

CHANGES IN THE SPECIES COMPOSITION, STAND STRUCTURE AND ABOVEGROUND BIOMASS OF A LOWLAND DIPTEROCARP FOREST IN SAMBOJA, EAST KALIMANTAN

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ABSTRACT

The dynamics of species composition, stand structure and aboveground biomass were studied over a 4.3-yr period (December 2004 – April 2009) in a lowland dipterocarp forest of Samboja, East Kalimantan. This study was conducted in six permanent sample plots (100 m x 100 m each) distributed over an area of 26.5 ha of Samboja Research Forest. All woody plants ≥ 10 cm dbh (diameter at 1.3 m aboveground) were identified. In December 2004, 2,143 trees were measured in the six plots, consisting of 39 families, 82 genera and 111 species. The condition in April 2009 (after 4.3 yr) was: 2,466 trees, 40 families, 86 genera and 123 species. Most species were found in both occasions. Fourteen new species were registered, which contributed to 9.8% of a net addition of the total number of species found in the six plots. Over the 4.3-yr period, there was also an increase of 15.1% in density, 12.9% in basal area, and 11.6% in aboveground biomass, respectively. The density increased from 357 to 411 trees per ha; the basal area increased from 20.09 to 22.67 m² ha⁻¹; and the aboveground biomass increased from 286.3 to 319.4 ton ha⁻¹. The family Dipterocarpaceae was the richest in species (more than 20 species found in both occasions), followed by Euphorbiaceae, Burseraceae, Fabaceae, and Anacardiaceae (more than five species). Most genera (80%) contained just one species, but *Shorea* with 13 species was the richest. Four families (Dipterocarpaceae, Fabaceae, Myrtaceae and Lauraceae) contained more than 80% of the aboveground biomass in both occasions (75% of them from Dipterocarpaceae family). The increases in species richness and density did not cause any significant differences in the diversity index and diameter distribution. This condition suggested that forest vegetation of the study site maintains its diversity composition and structural features over the period of study.

Keywords: stand dynamic, structure, biomass, permanent plots, tropical forest

I. 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

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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 and Riswan, 1987; Sist and Saridan, 1998; Heriyanto, 2001; Krisnawati, 2003). Forest vegetations, however, are dynamic and changes occur continuously at individual and species population levels throughout time, eventhough 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 (e.g. Lieberman *et al.*, 1985; Manokaran and 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 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 aboveground biomass of the woody plants of a lowland dipterocarp forest in the Samboja Research Forest, East Kalimantan, over a period of time (December 2004 - April 2009). The results were expected to provide an insight whether the forest vegetation in the study site would maintain its species composition and structural characteristics over the period of time.

II. MATERIALS AND METHODS

A. Site Description

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-Semai route (0°59' N latitude and 116.56° E longitude, Figure 1). This unlogged 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 and Juliati, 2003).

The site is located at the village of Sungai Merdeka, the Sub-District of Samboja, District of Kutai Kartanegara, East Kalimantan Province. The average annual precipitation in the site ranges from 1,682 to 2,314 mm with the number of rainy days of 72–154 days per year. The average temperature is about 26–28 °C with the minimum value in the day time of 23.3 °C and the maximum value in the night time of 32.7 °C. The humidity ranges from 63 to 89% (Adinugroho *et al.*, 2006; Atmoko, 2007).

The altitudinal range of the area is from 40 to 150 m above sea level. 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.

B. Methods

The study was based on the results of the monitoring of six permanent sample plots (100 m x 100 m square plot of 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 (quadrats) of 10 m x 10 m to allow a better control of measurement and monitoring. The plot establishment and the first measurement were conducted in December 2004 and then re-measured in May 2006, June 2008, and April 2009 (in total 4 measurements). However, only the first and fourth measurements covering a period of 4 years and 4 months (approximately 4.3 years) were reported in the present study.

In each plot, all woody plants of at least 10 cm dbh (diameter at 1.3 m aboveground) were marked, identified and measured. 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 by using a hagameter for all trees in the plots for the first and second measurements and 100 trees with various dbh (one

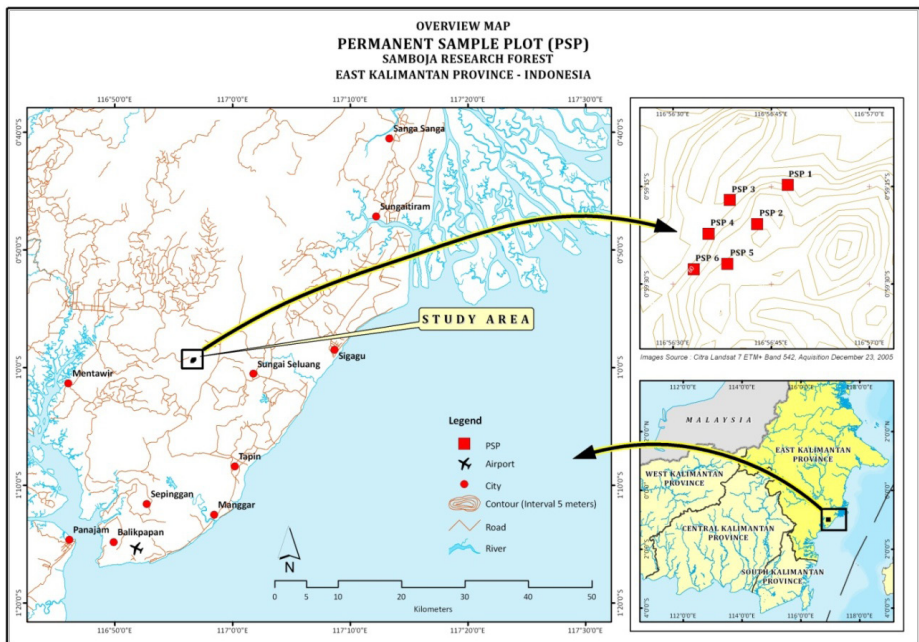


Figure 1. Location of the research plots in Samboja Research Forest, East Kalimantan

tree in each sub-plot) for the third and fourth measurements. 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 collection 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 (Magurran, 1988; Ludwig and Reynolds, 1988). Stand density (number of trees), basal area, and aboveground biomass were also calculated at each occasion (Husch *et al.* 2003). The aboveground 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 aboveground biomass were analysed and then compared at each assessment. The differences of diameter distribution between the two occasions were also tested using a Kolmogorov-Smirnov two sample test (Zarr, 2006).

III. RESULTS AND DISCUSSION

A. Species Composition

In December 2004 2,143 trees of ≥ 10 cm in diameter were measured in six permanent sample plots of the Samboja Research Forest. They consisted of 39 families, 82 genera and 111 species. The condition 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 both measurement times was presented in Appendix 1.

Most species were found in both occasions (2004 and 2009), except for *Garcinia nervosa* and *Trigonostemon laevigatus* that did not occur in 2009, although these species might still be present below the diameter limit (10 cm) used in this study. Fourteen new species were registered (i.e. *Actinodaphne malaccensis*, *Albizia minahasae*, *Diospyros confertifolia*, *Durio oxleyanus*, *Knema conferta*, *Magnolia borneensis*, *Palaquium pseudorostratum*, *Palaquium gutta*, *Parishia insignis*, *Porterandia anisophylla*, *Dillenia* sp., *Durio* sp. *Parashorea* sp., and *Shorea* sp.1), 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 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.

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 (Zarr, 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 species (low density) with only less than one tree (dbh \geq 10 cm) 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.

B. Stand Structure

In the first measurement (December 2004), 15 species comprised about 80% of the stand basal area (*BA*) and 77% of the stand density (*N*) over 10 cm dbh (Table 1). All of

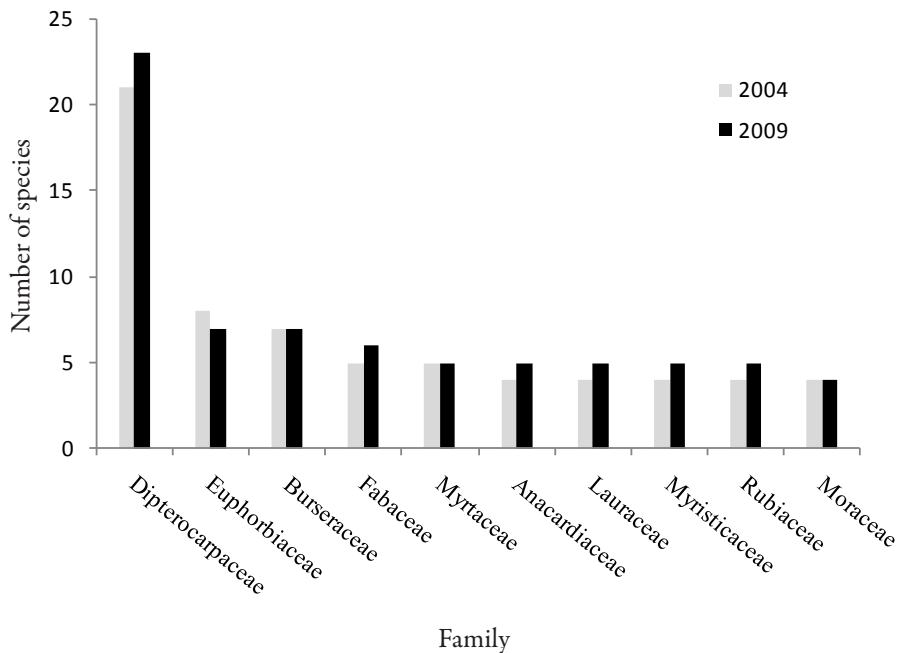


Figure 2. Ten dominant families based on species richness in the six plots over two observation periods.

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*.

After the 4.3 yr period, the same species still comprised 80% of the stand basal area but the ranking changed slightly (Table 1). *Shorea bracteolata* ranked fifth 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.

In general, the stand density in the study site increased by 15.1% from 357 trees per ha to 411 trees per ha over the 4.3 yr period. Similarly, the basal area increased by 12.9% from 20.09 m² ha⁻¹ to 22.67 m² 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 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).

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 and 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.

Table 1. Changes in stand density (N) and basal area (BA) of the six permanent plots in the Samboja Research Forest, East Kalimantan (December 2004-April 2009) listed based on basal area

Species	Family	2004		2009		2004-2009		Change	
		N	BA	N	BA	$In.$	$Mor.$	N	BA
<i>Shorea laevis</i>	Dipt.	15.8	3.25	18.7	3.32	3.7	0.8	+	+
<i>Shorea parvifolia</i>	Dipt.	30.8	1.70	42.0	2.07	12.7	1.5	+	+
<i>Vatica odorata</i>	Dipt.	49.2	1.58	56.3	1.76	11.0	3.8	+	+
<i>Syzygium</i> sp.	Myrt.	36.3	1.36	43.8	1.60	9.1	1.7	+	+
<i>Eusideroxylon zwageri</i>	Laur.	16.0	1.23	16.7	1.33	1.2	0.5	+	+
<i>Shorea bracteolata</i>	Dipt.	40.3	1.23	43.7	1.44	4.7	1.3	+	+
<i>Dipterocarpus cornutus</i>	Dipt.	7.0	0.99	10.8	1.12	4.0	0.2	+	+
<i>Sindora wallichii</i>	Fab.	20.7	0.89	24.7	1.12	4.7	0.7	+	+
<i>Koompassia malaccensis</i>	Fab.	7.5	0.73	7.0	0.80	0	0.5	-	+
<i>Shorea lamellata</i>	Dipt.	8.2	0.72	8.3	0.80	0.3	0.2	+	+
<i>Dipterocarpus confertus</i>	Dipt.	4.5	0.71	5.8	0.78	1.5	0.2	+	+
<i>Madhuca sericea</i>	Sapot.	12.3	0.56	13.7	0.67	1.7	0.3	+	+
<i>Diospyros borneensis</i>	Eben.	14.7	0.45	16.7	0.55	2.2	0.2	+	+
<i>Crypteronia griffithii</i>	Crypt.	9.7	0.43	9.5	0.48	0.2	0.3	-	+
<i>Shorea johorensis</i>	Dipt.	0.8	0.39	0.7	0.38	0	0.2	-	-
<i>Gonystylus velutinus</i>	Thym.	8.7	0.33	8.3	0.37	0.7	1.0	-	+
<i>Diallium</i> sp.	Caes.	1.3	0.28	1.3	0.30	0	0	+	+
<i>Knema laterisia</i>	Myrist.	8.5	0.25	8.7	0.29	0.5	0.3	+	+
<i>Shorea smithiana</i>	Dipt.	1.8	0.24	1.8	0.26	0	0	+	+
<i>Tristaniopsis</i> sp.	Myrt.	0.3	0.22	0.3	0.22	0	0	+	+
<i>Shorea javanica</i>	Dipt.	5.2	0.18	6.5	0.18	1.7	0.3	+	+
<i>Hydnocarpus gracilis</i>	Flac..	4.8	0.14	4.7	0.16	0	0.2	-	+
<i>Gironniera nervosa</i>	Ulm.	3.2	0.13	3.0	0.15	0	0.2	-	+
<i>Hopea mengerawan</i>	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

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 and Felfili *et al.* (2000) for savanna woodland in Brazilian Amazon over a 9 yr period.

C. Aboveground Biomass

Four families (Dipterocarpaceae, Fabaceae, Myrtaceae and Lauraceae) contained more than 80% of the aboveground biomass ($\geq 10\text{cm dbh}$) in both 2004 and 2009 (Table 2). Of these, almost 75% of them were from Dipterocarpaceae family which comprised about 43% of the total aboveground biomass contained in the plots. The

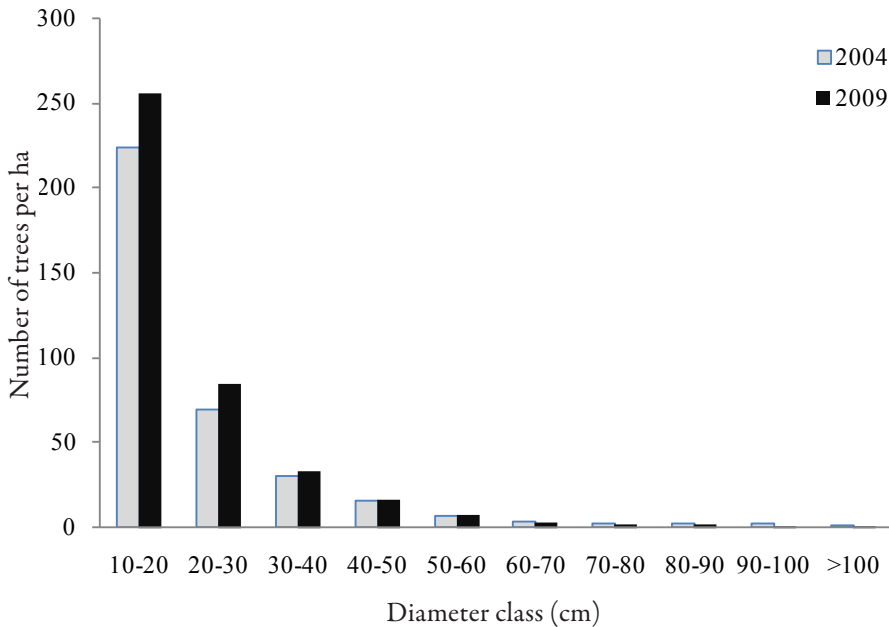


Figure 3. Diameter distribution of the six permanent plots in the Samboja Research Forest at the measurements of December 2004 and April 2009

highest value in the amount of aboveground biomass belonged to *Shorea parvifolia*, followed by *Sindora wallichii* and *Shorea bracteolata*. These three species contributed to a net addition of 30% of total aboveground biomass.

Table 2. Changes in aboveground biomass (*AGB*) of the six permanent plots in the Samboja Research Forest, East Kalimantan (December 2004–April 2009)

Family	<i>AGB</i> (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
Caesalpinaceae	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

Overall, the aboveground biomass of all species in the plots increased by 11.6% (33.1 tons ha⁻¹) over the 4.3 yr period, i.e. from 286.3 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 aboveground biomass increases may be attributed to the high rate of

recruitment and growth of some species. However, the increase of aboveground 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 aboveground biomass during the 4.3 yr period (Table 2), suggesting that carbon uptake by these families was limited over the 4.3 yr period.

IV. CONCLUSION

The number of species, stand density, basal area and aboveground biomass of the woody plants ≥ 10 cm dbh increased over 4.3 yr. 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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APPENDIX 1. List of species and families found in the six permanent plots of Samboja Research Forest (listed alphabetically)

No	Species	Family	Year of Measurement	
			2004	2009
(1)	(2)	(3)	(4)	(5)
1	<i>Actinodaphne malaccensis</i>	Lauraceae		√
2	<i>Aglaia</i> sp.	Meliaceae	√	√
3	<i>Alangium javanicum</i>	Alangiaceae	√	√
4	<i>Albizia minahasae</i>	Fabaceae		√
5	<i>Alstonia iwabigensis</i>	Apocynaceae	√	√
6	<i>Anisoptera costata</i>	Dipterocarpaceae	√	√
7	<i>Anthocephalus chinensis</i>	Rubiaceae	√	√
8	<i>Aquilaria microcarpa</i>	Thymelaeaceae	√	√
9	<i>Archidendron microcarpum</i>	Fabaceae	√	√
10	<i>Artocarpus anisophyllus</i>	Moraceae	√	√
11	<i>Artocarpus dadab</i>	Moraceae	√	√
12	<i>Artocarpus niditus</i>	Moraceae	√	√
13	<i>Artocarpus</i> sp.	Moraceae	√	√
14	<i>Atuna racemosa</i>	Chrysobalanaceae	√	√
15	<i>Barringtonia macrostachya</i>	Lecythidaceae	√	√
16	<i>Beilschmiedia</i> sp.	Lauraceae	√	√
17	<i>Buerhavia paniculata</i>	Lauraceae	√	√
18	<i>Canarium littorale</i>	Burseraceae	√	√
19	<i>Canarium pilosum</i>	Burseraceae	√	√
20	<i>Chaetocarpus castanocarpus</i>	Euphorbiaceae	√	√
21	<i>Chionanthus</i> sp.	Oleaceae	√	√
22	<i>Cotylelobium melanoxylon</i>	Dipterocarpaceae	√	√
23	<i>Cotylelobium</i> sp.	Dipterocarpaceae	√	√
24	<i>Cratoxylum sumatranum</i>	Hypericaceae	√	√
25	<i>Crypteronia griffithii</i>	Crypteroniaceae	√	√
26	<i>Dacryodes costata</i>	Burseraceae	√	√
27	<i>Dacryodes rubiginosa</i>	Burseraceae	√	√
28	<i>Dacryodes rugosa</i>	Burseraceae	√	√
29	<i>Diallium indum</i>	Caesalpiniaceae	√	√
30	<i>Diallium</i> sp.	Caesalpiniaceae	√	√
31	<i>Dillenia</i> sp.	Dilleniaceae		√

Appendix 1 (continued)

(1)	(2)	(3)	(4)	(5)
32	<i>Diospyros borneensis</i>	Ebenaceae	√	√
33	<i>Diospyros confertifolia</i>	Ebenaceae		√
34	<i>Dipterocarpus confertus</i>	Dipterocarpaceae	√	√
35	<i>Dipterocarpus cornutus</i>	Dipterocarpaceae	√	√
36	<i>Dipterocarpus</i> sp.	Dipterocarpaceae	√	√
37	<i>Dracontomelon dao</i>	Anacardiaceae	√	√
38	<i>Drymicarpus luridus</i>	Anacardiaceae	√	√
39	<i>Dryobalanops</i> sp.	Dipterocarpaceae	√	√
40	<i>Drypetes crassipes</i>	Euphorbiaceae	√	√
41	<i>Durio griffithii</i>	Malvaceae	√	√
42	<i>Durio oxleyanus</i>	Malvaceae		√
43	<i>Durio</i> sp.	Malvaceae		√
44	<i>Dyera costulata</i>	Apocynaceae	√	√
45	<i>Dysoxylum</i> sp.	Meliaceae	√	√
46	<i>Endiandra kingiana</i>	Lauraceae	√	√
47	<i>Eugenia stapfiana</i>	Myrtaceae	√	√
48	<i>Eusideroxylon zwageri</i>	Lauraceae	√	√
49	<i>Garcinia nervosa</i>	Guttiferae	√	
50	<i>Gironniera nervosa</i>	Ulmaceae	√	√
51	<i>Gluta aptera</i>	Anacardiaceae	√	√
52	<i>Gluta speciosa</i>	Anacardiaceae	√	√
53	<i>Gonystylus velutinus</i>	Thymelaeaceae	√	√
54	<i>Gordonia borneensis</i>	Theaceae	√	√
55	<i>Hopea mengerawan</i>	Dipterocarpaceae	√	√
56	<i>Hydnocarpus gracilis</i>	Flacourtiaceae	√	√
57	<i>Kibatalia pillosa</i>	Apocynaceae	√	√
58	<i>Knema conferta</i>	Myristicaceae		√
59	<i>Knema laterisia</i>	Myristicaceae	√	√
60	<i>Knema</i> sp.	Myristicaceae	√	√
61	<i>Kokoona reflexa</i>	Celastraceae	√	√
62	<i>Koompassia malaccensis</i>	Fabaceae	√	√
63	<i>Lansium domesticum</i>	Meliaceae	√	√
64	<i>Licania splendens</i>	Chrysobalanaceae	√	√
65	<i>Lithocarpus</i> sp.	Fagaceae	√	√

Appendix 1 (continued)

(1)	(2)	(3)	(4)	(5)
66	<i>Macaranga hypoleuca</i>	Euphorbiaceae	√	√
67	<i>Macaranga lowii</i>	Euphorbiaceae	√	√
68	<i>Madhuca sericea</i>	Sapotaceae	√	√
69	<i>Madhuca pierrei</i>	Sapotaceae	√	√
70	<i>Magnolia borneensis</i>	Magnoliaceae		√
71	<i>Magnolia lasia</i>	Magnoliaceae	√	√
72	<i>Messua</i> sp.	Guttiferae	√	√
73	<i>Myristica iners</i>	Myristicaceae	√	√
74	<i>Myristica maxima</i>	Myristicaceae	√	√
75	<i>Neoscortechinia kingii</i>	Euphorbiaceae	√	√
76	<i>Nephelium</i> sp.	Sapindaceae	√	√
77	<i>Oncosperma horridum</i>	Palmae	√	√
78	<i>Palaquium pseudorostratum</i>	Sapotaceae		√
79	<i>Palaquium gutta</i>	Sapotaceae		√
80	<i>Parashorea</i> sp.	Dipterocarpaceae		√
81	<i>Parisia insignis</i>	Anacardiaceae		√
82	<i>Parkia speciosa</i>	Fabaceae	√	√
83	<i>Pellacalyx</i> sp.	Rhizophoraceae	√	√
84	<i>Pentace laxiflora</i>	Tiliaceae	√	√
85	<i>Pertusadina euryncha</i>	Rubiaceae	√	√
86	<i>Pholidocarpus</i> sp.	Palmae	√	√
87	<i>Ptychopyxis javanica</i>	Euphorbiaceae	√	√
88	<i>Pimelodendron griffitii</i>	Euphorbiaceae	√	√
89	<i>Pithecellobium rosulatum</i>	Fabaceae	√	√
90	<i>Polyalthia</i> sp.	Annonaceae	√	√
91	<i>Porterandia anisophylla</i>	Rubiaceae		√
92	<i>Prysmatomeris</i> sp.	Rubiaceae	√	√
93	<i>Pterospermum</i> sp.	Sterculiaceae	√	√
94	<i>Quercus</i> sp.	Fagaceae	√	√
95	<i>Rhodammia cinerea</i>	Myrtaceae	√	√
96	<i>Sandaricum</i> sp.	Meliaceae	√	√
97	<i>Santiria griffithii</i>	Burseraceae	√	√
98	<i>Santiria oblongifolia</i>	Burseraceae	√	√
99	<i>Scaphium macropodum</i>	Malvaceae	√	√

Appendix 1 (continued)

(1)	(2)	(3)	(4)	(5)
100	<i>Schima wallichii</i>	Theaceae	√	√
101	<i>Scorodocarpus borneensis</i>	Olacaceae	√	√
102	<i>Shorea bracteolata</i>	Dipterocarpaceae	√	√
103	<i>Shorea javanica</i>	Dipterocarpaceae	√	√
104	<i>Shorea joborensis</i>	Dipterocarpaceae	√	√
105	<i>Shorea laevis</i>	Dipterocarpaceae	√	√
106	<i>Shorea lamellata</i>	Dipterocarpaceae	√	√
107	<i>Shorea mujongensis</i>	Dipterocarpaceae	√	√
108	<i>Shorea ovalis</i>	Dipterocarpaceae	√	√
109	<i>Shorea parvifolia</i>	Dipterocarpaceae	√	√
110	<i>Shorea pauciflora</i>	Dipterocarpaceae	√	√
111	<i>Shorea smithiana</i>	Dipterocarpaceae	√	√
112	<i>Shorea</i> sp.1	Dipterocarpaceae		√
113	<i>Shorea</i> sp.2	Dipterocarpaceae	√	√
114	<i>Shorea</i> sp.3	Dipterocarpaceae	√	√
115	<i>Sindora wallichii</i>	Fabaceae	√	√
116	<i>Syzygium</i> sp.	Myrtaceae	√	√
117	<i>Tarenna rostata</i>	Rubiaceae	√	√
118	<i>Trigonostemon laevigatus</i>	Euphorbiaceae	√	
119	<i>Tristaniopsis</i> sp.	Myrtaceae	√	√
120	<i>Vatica odorata</i>	Dipterocarpaceae	√	√
121	<i>Vitex</i> sp.	Lamiaceae	√	√
122	<i>Xanthophyllum griffithii</i>	Polygalaceae	√	√
123	<i>Xerospermum noronbianum</i>	Sapindaceae	√	√
124	<i>Xylopia</i> sp.	Annonaceae	√	√
125	Unidentified species		√	√
	Total species		111	123

Note: √ presence of the species in all six plots