

The ecological and economic values of a 50 years old secondary forest in East Kalimantan, Indonesia

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Abstract. Karmini, Karyati, Widiati KY. 2021. *The ecological and economic values of a 50 years old secondary forest in East Kalimantan, Indonesia. Biodiversitas 22: 4597-4607.* Secondary forests in the tropics are often ignored since they are assumed to have low ecological functions while on the other hand the economic values have been reduced. This study aimed to analyze the ecological and economic values of a 50-year secondary forest in East Kalimantan that experienced several various land-use changes. The ecological aspects analyzed were stand structure, floristic composition, and species diversity. Economic aspects include log prices, logging costs, profit margins, and stumpage values. A vegetation survey of woody trees with a diameter at breast height of more than 5 cm was carried out on ten plots measuring 20 m × 20 m each. A total of 437 trees belonging to 38 species, 30 genera, and 19 families were recorded with Moraceae and Euphorbiaceae were the most dominant families with Family Important Value (FIV) of 86.79. The three most dominant species were *Macaranga motleyana* (IVI of 50.95), *Artocarpus elasticus* (IVI of 34.41), and *Symplocos fasciculata* (IVI of 31.46). The trees in the study plot have a diversity index of 1.33, dominance index of 0.07, evenness index of 0.37, and species richness of 6.09. The average logging cost, logs price, lumber price, profit margin, and stumpage value at secondary forest were USD69.43 m⁻³, USD44.63 m⁻³, USD100.03 m⁻³, USD10.30 m⁻³, and USD28.73 ha⁻¹, respectively. The 50 years old secondary forests in East Kalimantan have biodiversity, especially trees that have economic value, therefore their existence needs to be preserved and their use is carried out by maintaining and increasing biodiversity.

Keywords: Abandoned land, diversity, fallow land, secondary forest, stumpage value

INTRODUCTION

Tropical forest management at a local level requires site-specific information about the region (Manyanda et al. 2021). It is needed information about the transformation process that occurs in the region. This information is important because according to Borges et al. (2021), historical variation of land use will affect the differences in biodiversity and biomass in urban forests and rural forests in the tropics. Furthermore, Naime et al. (2020) explained during the natural regeneration process in tropical secondary forests, there is a change in the magnitude of the trade-off and provision of ecosystem services. Other information that needed to be known relates to biophysical and social-economic variables. Biophysical and social variables are the basis for consideration in understanding the structure and biodiversity of tropical secondary forests (McClellan et al. 2018).

The result of Chen et al. (2020) study showed although tree size and regeneration in the secondary forest are smaller than in the primary forest, woody plant species, species richness, and proportion of young bamboo are generally higher (Chen et al. 2020). Secondary forest is undergoing succession to form tree canopy and palm species composition through the successful growth of seedlings, saplings, and young trees from mature forest species (Norden et al. 2009). Tree diversity of abandoned

land increased after 20 years, but remained 22% lower than natural forest (Nath et al. 2021). In another study, sixty percent of the total basal area and volume were contributed by fast-growing species dominant in secondary forests. In this secondary forest, trees aged 5, 10, and 20 years were categorized as an intermediate diversity, low dominance, and high evenness (Karyati et al. 2018).

Light competition and species characteristics greatly affect tree growth and survival which determine to stand architecture (Khamyong et al. 2018). The surrounding environment affects the plant community at the edge of the forest which typically has a low basal area, tree density, large-diameter trees, and AGB. The distribution of tree species is uniform, but not evenly distributed (Jana and Jusoh 2021). The valuation of tropical forests potential could be done with integration between some indicators of ecosystem services (such as provision, regulating, supporting, and cultural services) and the concept of total economic value (such as use-value, indirect use-value, and no-use value) (Matthew et al. 2019). A study found that the total economic value of forest ecosystem services is estimated at RM 13 billion (Nitanan et al. 2020). While the average value of stump on abandoned land after shifting cultivation and after traditional plantations are USD 83.05 ha⁻¹ and USD 51.56 ha⁻¹ respectively (Karmini et al. 2020a, Karmini et al. 2020b).

Many studies report the ecological aspects (Karyati et

al. 2013, 2018; Chen et al. 2020; Matsuo et al. 2021) and the economic aspects (Naime et al. 2020; Nitanan et al. 2020) of secondary forests separately. Several studies that simultaneously combine the ecological and economic aspects of several secondary forest types with different land-use histories have been reported (Matthew et al. 2019; Karmini et al. 2020a, 2020b). However, similar studies in 50-year-old secondary forest with several different land-use histories are rarely reported. The purpose of this study was to analyze the ecological and economic aspects of a 50-year secondary forest in East Kalimantan that experienced several various land-use changes.

MATERIALS AND METHODS

Study site

The study was conducted at a secondary forest aged 50 years old in Air Putih area, Samarinda Ulu Sub-district, Samarinda City, East Kalimantan Province, Indonesia. The research plot is located on the side of the Samarinda road to Kutai Kartanegara District at the coordinate point 117°6'29,7641"E; 0°26'56,5901"S (Figure 1 and 2). Based on interviews with the landowners, the history of land use of the studied site was forest clearing for shifting cultivation in 1969. The shifting cultivation activity was stopped due to a forest fire in 1983 which burned all the vegetation in the research plot. The next land use is the cultivation of rubber and local fruits. The land was then left until the research took place, although it was known that there was considerable coal potential in the location.

Procedures

The study was carried out from March to July 2021. Vegetation survey was conducted at ten plots, each measuring 20 m × 20 m. The measurements of diameter at breast height (DBH) and total tree height, and identification of tree species were performed to all woody trees with DBH ≥ 5 cm in the study plot.

Data analysis

Ecological analysis

The individual basal area (BA) and volume (V) were measured by using the following formula (Husch et al. 1982):

$$\text{Individuals BA} = \pi (\text{DBH}/2)^2 \cdot 10^{-4} \quad [1]$$

$$\text{Individuals V} = \frac{1}{4} \pi \times \text{DBH}^2 \cdot 10^{-4} \times H \times f \quad [2]$$

Where: DBH is the diameter at breast height (cm), 'H' is tree height (m), and 'f' is form factor.

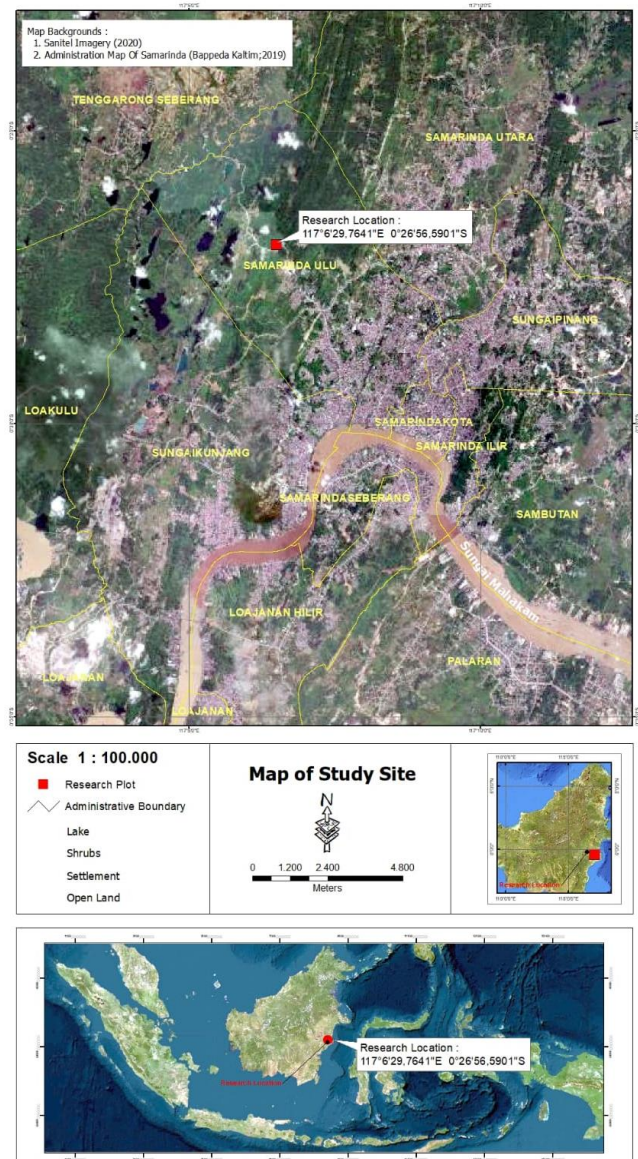


Figure 1. Map of study site in Air Putih area, Samarinda Ulu Sub-district, Samarinda City, East Kalimantan Province, Indonesia



Figure 2. Vegetation condition of a 50 years old secondary forest in East Kalimantan, Indonesia

The importance value index (IVI) was analyzed to determine the dominant species of community within the studied plots (Fachrul 2007):

RF = (Frequency of a species/Total of frequencies of all species) × 100 [3]

Rd = (The number of individuals of a species/Total number of individuals) × 100 [4]

RD = (Total basal area for a species/Total basal area for all species) × 100 [5]

IVI = RF + Rd + RD [6]

Where: RF is relative frequency, Rd is relative density, and RD is relative dominance.

The four diversity indices were used to describe the species diversity of standing trees in the studied plots. These diversity indices were Shannon-Wiener's diversity index (H'), Simpson's dominance index (D_s), Pielou's evenness index (J'), and Margalef's richness index (R) (Odum 2005):

$$H' = -\sum_{i=1}^s \left(\frac{n_i}{N} \right) \ln \left(\frac{n_i}{N} \right) \quad [7]$$

$$D_s = \sum_{i=1}^s \left(\frac{n_i}{N} \right)^2 \quad [8]$$

$$J' = \frac{H'}{\ln(S)} \quad [9]$$

$$R = \frac{(S-1)}{\ln n} \quad [10]$$

Where: n_i : number of individuals of the i -th species, N : total number of all the individuals in a unit area, and S : number of species in each plot.

Economic analysis

The estimation of the price of logs was carried out in several stages. The tree diameter data that has been collected will be analyzed and continued with the calculation of the number of logs produced from the felled trees. The cost of felling trees was USD69.43 m⁻³ at the study location at the time of the research. The data in Table 1 shows the number of logs that can be obtained from trees with a diameter of up to 75 cm and above. Based on the diameter class and the number of logs, it can be seen the equivalent merchantable height.

The reduction factor in the price of logs was determined based on the Diameter at Breast Height (DBH) size class and the data can be seen in Table 2. The high number of trees with DBH size class < 15 cm on study location was the background of Karmini et al. (2020b) determine the assumption that the price reduction factor for logs with a DBH size class < 15 cm is 0.60.

This study also set a profit ratio of 30% and profit margin was determined by the formula according to Dahalan (2011) as follows:

$$PM_{ij} = \sum_{i=1}^n \sum_{j=1}^k (P_{ij} \times PR) / (1 + PR) \quad [11]$$

Table 1. Merchantable tree heights in the studied site of secondary forest

Diameter class (cm)	Number of logs (5 m long)	Equivalent merchantable height (m)
< 15	0.5	2.5*
15-30	1	5
+30-60	2	10
+60-75	3	15
75 up	4	20

Note: Forestry Department of Peninsular Malaysia (FDPM) (1997) as cited by Dahalan (2011); Karmini et al. (2020a); *Karmini et al. (2020b)

Table 2. Reduction factor of logs price based on DBH class

DBH size class (cm)	Reduction factor
< 15	0.60*
15-29	0.45
30-44	0.30
45-49	0.15
50-54	0.025
≥ 55	0.00

Note: Karmini et al. (2020a); *Karmini et al. (2020b)

Where:

PM_{ij} : profit margin;

P_{ij} : logs price for each species at sawmill based on diameter class;

PR : profit ratio;

i : an index for each species ($i = 1, 2, 3, 4, \dots, n$);

j : an index for diameter class ($j = 1, 2, 3, 4, \dots, n$).

The exchange rate was USD1.00 equal to IDR14,403.70 at 22 August 2021. The following formula is used to evaluated stumpage values:

$$S_{ij} = \sum_{i=1}^n \sum_{j=1}^k V_{ij} (P_{ij} + C + PM) \quad [12]$$

Where:

S_{ij} : stumpage value for each species and diameter class (USD ha⁻¹);

V_{ij} : volume of timber for each species and diameter class (m³);

P_{ij} : logs price for each species at sawmill based on diameter class (USD m⁻³);

C : average logging cost (USD ha⁻¹);

PM_{ij} : profit margin (USD m⁻³);

i : an index for each species ($i = 1, 2, 3, 4, \dots, n$);

j : an index for diameter class ($j = 1, 2, 3, 4, \dots, n$).

RESULTS AND DISCUSSION

Ecological characteristics of 50-years secondary forest

Diameter at breast height (DBH) and height distributions

The diameter distribution is in the form of an inverted J curve with a high number of individuals in the low diameter class and a low number of individuals in the high

diameter class. A similar pattern of diameter distribution in various types of tropical secondary forest was also found in many studies (e.g., Feldpausch et al. 2007; Alvarez-Yépiz et al. 2008; Karmini et al. 2020a, 2020b). Eighty percent of the diameters of the trees belong to the DBH class of 5.0-15.0 cm (350 trees), followed by the DBH class of 15.1-25.0 cm (63 trees or 14%), DBH class of 25.1-35.0 cm (19 trees or 4%), and DBH class >35.0 cm (5 trees or 1%) (Figure 3).

Based on the height class, the trees belonged to class 0-5.0 m (108 trees or 25%), class 5.1-10.0 m (203 trees or 46%), and class 10.1-15.0 m (110 trees or 25%). A very small portion of higher trees with a total of 11 and 5 trees was included in the 15.1-20.0 m (3%) and >20.0 m (1%) as shown in Figure 4. The distribution of height class shows a slightly skewed toward positive pattern (Ohtsuka 2002). As early successional pioneer species began to disappear and long-lived pioneer species emerged (Norden et al. 2009), it was shown that intermediate-aged secondary forest between 30 and 50 years had lower structural complexity based on tree height and average stem diameter (Otuoma et al. 2014). The light-demanding pioneer species have also disappeared in 20-year-old secondary forests (Karyati et al. 2018). During the succession process there was a rapid increase in height and the stand size increased rapidly where the tree canopy was taller, thicker, and the canopy larger (Matsuo et al. 2021). Most late-successional species growing in old secondary forests can grow long enough to allow them to reach tree heights and average trunk DBH equal to or greater than trees in mature plantations (Otuoma et al. 2014).

Species richness, density, basal area, and volume

The vegetation survey of woody trees with a DBH of more than 5 cm in the 50 years secondary forest recorded 437 trees, 38 species, 30 genera, and 19 families. Table 3 presents the species, density, basal area, and volume of species in the study plot. The trees had DBH ranging from 5.1 to 56.3 cm with an average DBH of 11.5 cm. Meanwhile, the tree height ranged between 2.0 and 25.0 m with an average height of 8.50 m. The total basal area (BA) and volume of trees in the 50 years secondary forest were 15.36 m² ha⁻¹ and 122 m³ ha⁻¹, respectively. The smaller total BA (9.75 and 9.44 m² ha⁻¹) and volume (91.97 and 76.86 m³ ha⁻¹) were reported in abandoned land after shifting cultivation and traditional garden (Karmini et al. 2020a; 2020b). The three dominant species in terms of total BA and volume were *Artocarpus elasticus* (total BA=3.28 m² ha⁻¹ and volume=35.68 m³ ha⁻¹), *Mangifera motleyana* (total BA=2.88 m² ha⁻¹ and volume=19.77 m³ ha⁻¹), and *Symplocos fasciculata* (total BA=1.85 m² ha⁻¹ and volume=12.25 m³ ha⁻¹). These three tree species contributed more than 50% of the total basal area and volume. The other four species of *Vernonia arborea*, *Ficus septica*, *Talipariti simile*, and *Durio* sp. had a total volume of more than 3%.

The studied plots were dominated by fast-growing species such as *Artocarpus dadah*, *Artocarpus tamaran*, *Artocarpus elasticus*, *Macaranga gigantea*, *Artocarpus heterophyllus*, *Macaranga motleyana*, *Macaranga* sp., dan

Macaranga tanarius. In other studies, similar common fast growing species were also found, including *Macaranga* spp and *Artocarpus* spp. in 5 and 10 years old abandoned lands (Karyati et al. 2018), abandoned land after shifting cultivation (Karmini et al. 2020a), and abandoned land after traditional garden (Karmini et al. 2020b) as well as seedlings and saplings in 3, 5, 10, and 20 years of fallow lands (Karyati et al. 2013). *Hevea brasiliensis* and *Ceiba pentandra* are remnants of plantation crops grown at this location. Meanwhile, *Durio* sp. is a native plant of Kalimantan.

The three families of 19 families with the high basal area and volume at the study site were Moraceae, Euphorbiaceae, and Symplocaceae as shown in Table 4. The total basal area and volume of woody trees belonging to the three families is more than 70%. Other families that are also quite dominant are Malvaceae, Asteraceae, Fabaceae, and Phyllanthaceae. Total tree species belonging to Moraceae, Euphorbiaceae, and Symplocaceae were 7, 8, and 1 respectively. This shows the trees in these families play an important role in plant structure and composition at the study site. Three tree species belonged to Malvaceae and Phyllanthaceae. Meanwhile, Cannabaceae and Fabaceae had two tree species. The other 12 families are only consisting of 1 tree species. Another study found the family consisting of the highest number of species in secondary forest of uneven age is Moraceae, followed by Apocynaceae, Euphorbiaceae, Fabaceae, Rubiaceae, Sapindaceae, and Sterculiaceae (Aghimien et al. 2016).

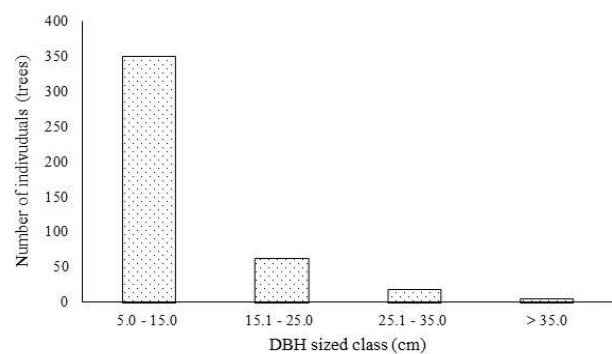


Figure 3. Distributions of diameter at breast height (DBH) of tree species in 0.4 ha of 50 years old secondary forest

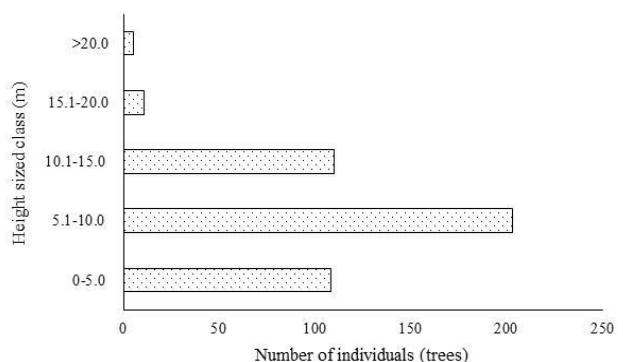


Figure 4. Distributions of height of tree species in 0.4 ha of 50 years old secondary forest

Table 3. Species richness, density, basal area, and volume of species (DBH of ≥ 5 cm) in the study plot

Species	N	Average of DBH (cm)	Average of height (m)	BA (m ² ha ⁻¹)		Volume (m ³ ha ⁻¹)	
				Total	%	Total	%
<i>Artocarpus elasticus</i>	27	21.9	13.2	3.28	21.33	35.68	29.23
<i>Macaranga motleyana</i>	103	11.2	9.3	2.88	18.76	19.77	16.20
<i>Symplocos fasciculata</i>	51	11.3	6.7	1.85	12.04	12.25	10.04
<i>Vernonia arborea</i>	8	21.0	13.4	0.83	5.40	8.48	6.95
<i>Ficus septica</i>	29	11.6	7.5	0.93	6.03	5.61	4.59
<i>Talipariti simile</i>	10	12.2	9.1	0.48	3.11	4.94	4.04
<i>Durio</i> sp.	1	38.2	25.0	0.29	1.86	4.65	3.81
<i>Archidendron pauciflorum</i>	10	15.2	9.2	0.52	3.37	3.34	2.73
<i>Bridelia stipularis</i>	18	11.1	8.7	0.48	3.13	3.22	2.64
<i>Derris caudatilimba</i>	16	10.3	9.0	0.41	2.70	2.98	2.44
<i>Macaranga gigantea</i>	9	14.1	8.9	0.41	2.66	2.74	2.24
<i>Artocarpus tamaran</i>	6	11.0	7.6	0.22	1.43	1.91	1.56
<i>Ficus uncinata</i>	34	7.1	7.0	0.37	2.38	1.75	1.43
<i>Nephelium lappaceum</i>	2	18.8	12.5	0.16	1.06	1.67	1.37
<i>Ecclinusa ramiflora</i>	8	11.1	11.5	0.20	1.31	1.58	1.30
<i>Glochidion obscurum</i>	1	27.0	15.5	0.14	0.94	1.45	1.19
<i>Macaranga tanarius</i>	12	8.5	7.6	0.20	1.31	1.36	1.11
<i>Hevea brasiliensis</i>	11	9.9	8.9	0.22	1.44	1.32	1.08
<i>Artocarpus dadah</i>	14	10.0	6.9	0.28	1.85	1.29	1.05
<i>Rhodamnia</i> sp.	6	12.3	9.7	0.19	1.22	1.20	0.98
<i>Vitex pinnata</i>	14	8.7	6.1	0.23	1.48	0.97	0.80
<i>Homalanthus populneus</i>	8	7.9	6.8	0.12	0.76	0.71	0.58
<i>Aleurites moluccanus</i>	3	10.9	8.7	0.08	0.55	0.47	0.39
<i>Macaranga</i> sp.	1	19.1	9.5	0.07	0.47	0.44	0.36
<i>Artocarpus heterophyllus</i>	5	9.7	4.6	0.10	0.65	0.37	0.30
<i>Mallotus paniculatus</i>	4	8.8	8.3	0.06	0.41	0.34	0.28
<i>Nauclea xanthoxylon</i>	2	13.2	5.5	0.07	0.45	0.25	0.21
<i>Litsea firma</i>	1	12.7	11.0	0.03	0.21	0.23	0.19
<i>Melicope lunu-ankenda</i>	3	8.2	8.0	0.04	0.27	0.22	0.18
<i>Garcinia intermedia</i>	2	8.6	9.0	0.03	0.19	0.18	0.14
<i>Ficus aurata</i>	3	7.7	5.3	0.04	0.25	0.17	0.14
<i>Baccaurea</i> sp.	3	7.1	7.0	0.03	0.20	0.16	0.13
<i>Ceiba pentandra</i>	7	6.3	2.9	0.06	0.36	0.10	0.09
<i>Cratoxylum arborescens</i>	1	10.8	6.0	0.02	0.15	0.09	0.07
<i>Giromiera celtidifolia</i>	1	8.3	10.0	0.01	0.09	0.09	0.07
<i>Alstonia scholaris</i>	1	8.6	6.0	0.01	0.09	0.06	0.05
<i>Dillenia excelsa</i>	1	6.4	5.0	0.01	0.05	0.03	0.02
<i>Trema orientalis</i>	1	5.1	3.5	0.01	0.03	0.01	0.01
Total	437.0	461.8	330.3	15.36	100.00	122.07	100.00
Average	11.5	12.2	8.7	0.40		3.21	
Minimum	1.0	5.1	2.9	0.01		0.01	
Maximum	103.0	38.2	25.0	3.28		35.68	

Note: N: number of individuals (trees), DBH: diameter at breast height, BA: basal area

Importance value index (IVI)

Most of the dominant tree species in terms of basal area and volume are also dominant species based on the importance value index (IVI). The IVI of tree in the studied site is shown in Table 5. The five most dominant species in terms of IVI were *Macaranga motleyana* (IVI of 50.95) followed by *Artocarpus elasticus* (IVI of 34.41), *Symplocos fasciculata* (IVI of 31.46), *Ficus septica* (IVI of 20.43), and *Ficus uncinata* (IVI of 15.33). The other three species of *Derris caudatilimba* (IVI of 12.40), *Bridelia stipularis* (IVI of 10.70), and *Archidendron pauciflorum* (IVI of 9.97) were also dominant in this site. Seven of 38 species recorded had an IVI of more than 10.00, 9 species had an IVI of 5.00-10.00 and the other 22 species have an IVI of less than 5.00.

Moraceae and Euphorbiaceae had the family important value (FIV) of 86.79 (Table 6). Tree species including

Moraceae are *Artocarpus dadah*, *Artocarpus elasticus*, *Artocarpus heterophyllus*, *Artocarpus tamaran*, *Ficus aurata*, *Ficus septica*, and *Ficus uncinata*. Meanwhile Euphorbiaceae consists of *Aleurites moluccanus*, *Hevea brasiliensis*, *Homalanthus populneus*, *Macaranga gigantea*, *Macaranga motleyana*, *Macaranga* sp., *Macaranga tanarius*, and *Mallotus paniculatus*. Similar results of prior studies also report that Moraceae and Euphorbiaceae are the important and dominant families in tropical lands (Danquah et al. 2011; Karyati et al. 2018; Karmini et al. 2020a; Karmini et al. 2020b). The floristic difference between forest fringes and the core of the forest is low tree diversity and distribution. The forest fringe plant community is dominated by Dipterocarpaceae and Euphorbiaceae (Jana and Jusoh 2021).

Table 4. Family, density, basal area, and volume of family (DBH of ≥ 5 cm) in the study plot

Family	N	Average of DBH (cm)	Average of height (m)	BA (m ² ha ⁻¹)		Volume (m ³ ha ⁻¹)	
				Total	%	Total	%
Moraceae	118	12.3	8.4	5.21	33.93	46.76	38.31
Euphorbiaceae	151	10.9	9.0	4.05	26.37	27.15	22.25
Symplocaceae	51	11.3	6.7	1.85	12.04	12.25	10.04
Malvaceae	18	11.3	7.6	0.82	5.34	9.70	7.94
Asteraceae	8	21.0	13.4	0.83	5.40	8.48	6.95
Fabaceae	26	12.2	9.1	0.93	6.07	6.32	5.18
Phyllanthaceae	22	11.3	8.7	0.66	4.27	4.83	3.96
Sapindaceae	2	18.8	12.5	0.16	1.06	1.67	1.37
Sapotaceae	8	11.1	11.5	0.20	1.31	1.58	1.30
Myrtaceae	6	12.3	9.7	0.19	1.22	1.20	0.98
Lamiaceae	14	8.7	6.1	0.23	1.48	0.97	0.80
Rubiaceae	2	13.2	5.5	0.07	0.45	0.25	0.21
Lauraceae	1	12.7	11.0	0.03	0.21	0.23	0.19
Rutaceae	3	8.2	8.0	0.04	0.27	0.22	0.18
Clusiaceae	2	8.6	9.0	0.03	0.19	0.18	0.14
Cannabaceae	2	6.7	6.8	0.02	0.12	0.10	0.08
Hypericaceae	1	10.8	6.0	0.02	0.15	0.09	0.07
Apocynaceae	1	8.6	6.0	0.01	0.09	0.06	0.05
Dilleniaceae	1	6.4	5.0	0.01	0.05	0.03	0.02
Total	437.0	216.2	159.8	15.36	100.00	122.07	100.00
Average	23.0	11.4	8.4	0.81		6.42	
Minimum	1.0	6.4	5.0	0.01		0.03	
Maximum	151.0	21.0	13.4	5.21		46.76	

Note: N: number of individuals (trees), DBH: diameter at breast height, BA: basal area.

Table 5. Importance value index (IVI) of trees (DBH of > 5 cm) in 0.4 hectare of the study plot

Species	Family	RF (%)	Rd (%)	RD (%)	IVI (%)
<i>Macaranga motleyana</i>	Euphorbiaceae	8.62	23.57	18.76	50.95
<i>Artocarpus elasticus</i>	Moraceae	6.90	6.18	21.33	34.41
<i>Symplocos fasciculata</i>	Symplocaceae	7.76	11.67	12.04	31.46
<i>Ficus septica</i>	Moraceae	7.76	6.64	6.03	20.43
<i>Ficus uncinata</i>	Moraceae	5.17	7.78	2.38	15.33
<i>Derris caudatilimba</i>	Fabaceae	6.03	3.66	2.70	12.40
<i>Bridelia stipularis</i>	Phyllanthaceae	3.45	4.12	3.13	10.70
<i>Archidendron pauciflorum</i>	Fabaceae	4.31	2.29	3.37	9.97
<i>Vernonia arborea</i>	Asteraceae	1.72	1.83	5.40	8.95
<i>Macaranga gigantea</i>	Euphorbiaceae	3.45	2.06	2.66	8.17
<i>Vitex pinnata</i>	Lamiaceae	3.45	3.20	1.48	8.13
<i>Talipariti simile</i>	Malvaceae	2.59	2.29	3.11	7.98
<i>Macaranga tanarius</i>	Euphorbiaceae	3.45	2.75	1.31	7.51
<i>Artocarpus dadah</i>	Moraceae	1.72	3.20	1.85	6.77
<i>Homalanthus populneus</i>	Euphorbiaceae	3.45	1.83	0.76	6.04
<i>Hevea brasiliensis</i>	Euphorbiaceae	1.72	2.52	1.44	5.68
<i>Ecclinusa ramiflora</i>	Sapotaceae	1.72	1.83	1.31	4.87
<i>Artocarpus tamaran</i>	Moraceae	1.72	1.37	1.43	4.53
<i>Rhodamnia</i> sp.	Myrtaceae	1.72	1.37	1.22	4.31
<i>Mallotus paniculatus</i>	Euphorbiaceae	2.59	0.92	0.41	3.91
<i>Melicope lunu-ankenda</i>	Rutaceae	2.59	0.69	0.27	3.54
<i>Nephelium lappaceum</i>	Sapindaceae	1.72	0.46	1.06	3.25
<i>Aleurites moluccanus</i>	Euphorbiaceae	1.72	0.69	0.55	2.96
<i>Durio</i> sp.	Malvaceae	0.86	0.23	1.86	2.96
<i>Ceiba pentandra</i>	Malvaceae	0.86	1.60	0.36	2.83
<i>Ficus aurata</i>	Moraceae	1.72	0.69	0.25	2.66
<i>Artocarpus heterophyllus</i>	Moraceae	0.86	1.14	0.65	2.66
<i>Baccaurea</i> sp.	Phyllanthaceae	1.72	0.69	0.20	2.61
<i>Glochidion obscurum</i>	Phyllanthaceae	0.86	0.23	0.94	2.03
<i>Nauclea xanthoxylon</i>	Rubiaceae	0.86	0.46	0.45	1.77
<i>Macaranga</i> sp.	Euphorbiaceae	0.86	0.23	0.47	1.56
<i>Garcinia intermedia</i>	Clusiaceae	0.86	0.46	0.19	1.51
<i>Litsea firma</i>	Lauraceae	0.86	0.23	0.21	1.30
<i>Cratoxylum arborescens</i>	Hypericaceae	0.86	0.23	0.15	1.24
<i>Alstonia scholaris</i>	Apocynaceae	0.86	0.23	0.09	1.19
<i>Gironniera celtidifolia</i>	Cannabaceae	0.86	0.23	0.09	1.18
<i>Dillenia excelsa</i>	Dilleniaceae	0.86	0.23	0.05	1.14
<i>Trema orientalis</i>	Cannabaceae	0.86	0.23	0.03	1.12
Total		100.00	100.00	100.00	300.00

Note: RF: relative frequency, Rd: relative density, RD: relative dominance, IVI: importance value index.

Table 6. Family Importance Value (FIV) of trees (DBH of > 5 cm) in 0.4 hectare of the study plot

Species	RF	Rd	RD	FIV
Moraceae	25.86	27.00	33.93	86.79
Euphorbiaceae	25.86	34.55	26.37	86.79
Symplocaceae	7.76	11.67	12.04	31.46
Fabaceae	10.34	5.95	6.07	22.36
Phyllanthaceae	6.03	5.03	4.27	15.34
Malvaceae	4.31	4.12	5.34	13.77
Asteraceae	1.72	1.83	5.40	8.95
Lamiaceae	3.45	3.20	1.48	8.13
Sapotaceae	1.72	1.83	1.31	4.87
Myrtaceae	1.72	1.37	1.22	4.31
Rutaceae	2.59	0.69	0.27	3.54
Sapindaceae	1.72	0.46	1.06	3.25
Cannabaceae	1.72	0.46	0.12	2.30
Rubiaceae	0.86	0.46	0.45	1.77
Clusiaceae	0.86	0.46	0.19	1.51
Lauraceae	0.86	0.23	0.21	1.30
Hypericaceae	0.86	0.23	0.15	1.24
Apocynaceae	0.86	0.23	0.09	1.19
Dilleniaceae	0.86	0.23	0.05	1.14
Total	100.00	100.00	100.00	300.00

Note: RF: relative frequency, Rd: relative density, RD: relative dominance, FIV: family importance value

Table 7. Diversity indices of trees with DBH of ≥ 5 cm in the study plot

Diversity indices	Value
Shannon-Wiener diversity index (H')	1.33
Simpson dominance index (D_s)	0.07
Pielou evenness index (J')	0.84
Margalef species richness (R)	6.09

Note: The values were calculated according to the 10 subplots sized 20 m \times 20 m each

Species diversity

The result of the analysis indicates that the secondary forest studied had an intermediate diversity index in terms of trees (DBH>5 cm) with H' 1.33 (Table 7). That is, the number of trees that grow in the research location is quite a lot. A high-growing species diversity represents a very complex community (Brower et al. 1990). The dominance index (D_s) of 0.07 in the study area included in the low criteria, indicates no dominant species in the area. The diversity index and dominance index are determined by the number of individuals of a species and the total number of individuals in an area. The 'high' evenness index category (J' value' 0.84) indicated that the trees growing in the plot were evenly distributed. The evenness of plant species is determined by the diversity of species and the number of species in the area. The species richness index of 6.09 indicates that many tree species grow in this research location. Plant species richness is calculated based on the number of species in an area (Krebs 2001), the number of individuals of a species, and the density of existing plants.

Species richness indicates the number of species in an area, while evenness is a relative measure of the abundance of different species that make up the wealth of an area (Supriatna 2018). The results showed that high diversity (H'), evenness (J'), and richness (R) tended to cause low dominance (D_s). Similar results were reported for the tree diversity index with DBH > 5 cm in plots with 5, 10, 20 years abandoned land (Karyati et al. 2018), abandoned land after shifting cultivation (Karmini et al. 2020a), and abandoned land after traditional gardening (Karmini et al. 2020b). In addition, due to the poor status of soil fertility in an area, a period of 50 years of abandoned land is not sufficient for lands to restore their vegetation conditions such as natural forests (Wasli et al. 2011). This is supported with the Brearley et al. (2004) study in Central Kalimantan Province, Indonesia that found Shannon-Wiener diversity index (H') at an old secondary forest and primary forest were 3.40 and 4.17, respectively, that meant species diversity indices at an old secondary forest was lower than at primary forest.

The economic value of 50 years secondary forest

Logging costs

In this study, the logging costs were the same for all tree species, i.e. USD69.43 m⁻³ (Table 8). The total logging costs of 38 species in this study location were USD3,526.20 ha⁻¹ or USD2,638.21 m⁻³ with an average of USD92.79 ha⁻¹ or USD69.43 m⁻³ for each species. The total logging costs in this study were higher than that of other previous studies (Karmini et al. 2020a; Karmini et al. 2020b). According to Karyati et al. (2021), the factors that influence logging costs include topography, tree dominance and species, density, tree diameter, log volume, felling productivity, loggers' experience, work, and remuneration systems, management competence, and other factors.

Prices of logs and lumber

The results of this study (Table 9) show that the total logs price of 38 species was USD1,696.03 m⁻³ with an average of USD44.63 m⁻³ species⁻¹. Meanwhile, the total lumber price of 38 tree species studied was USD3,801.11 m⁻³ with an average of USD100.03 m⁻³ species⁻¹. The lumber price of 10 tree species differed from one another while the lumber price of 28 other tree species was the same in the study location. A total of 13 tree species has the same logs price, which was USD20.83 m⁻³. There were three tree species (*Vernonia arborea*, *Macaranga* sp., and *Glochidion obscurum*) which had a log price of USD28.64 m⁻³. The total logs and lumber prices in this study was lower than the results of other previous studies (Karmini et al. 2020a, Karmini et al. 2020b). According to Karyati et al. (2021), the factors that determine the difference and the price of logs and lumber include tree species, tree diameter, wood quality, total tree individuals, harvesting cycle, supply, demand, use, price competition, substitute products, and other factors.

Table 8. Logging costs of trees in 0.4 ha of 50 years old secondary forest in East Kalimantan, Indonesia

Species	Family	Logging costs	
		USD m ⁻³	USD ha ⁻¹
<i>Artocarpus elasticus</i>	Moraceae	69.43	1,102.30
<i>Symplocos fasciculata</i>	Symplocaceae	69.43	498.68
<i>Macaranga motleyana</i>	Euphorbiaceae	69.43	434.37
<i>Vernonia arborea</i>	Asteraceae	69.43	283.25
<i>Ficus septica</i>	Moraceae	69.43	163.43
<i>Talipariti simile</i>	Malvaceae	69.43	152.20
<i>Archidendron pauciflorum</i>	Fabaceae	69.43	105.46
<i>Durio</i> sp.	Malvaceae	69.43	129.18
<i>Macaranga gigantea</i>	Euphorbiaceae	69.43	83.85
<i>Bridelia stipularis</i>	Phyllanthaceae	69.43	75.97
<i>Derris caudatilimba</i>	Fabaceae	69.43	68.82
<i>Artocarpus tamaran</i>	Moraceae	69.43	42.98
<i>Ficus uncinata</i>	Moraceae	69.43	41.25
<i>Nephelium lappaceum</i>	Sapindaceae	69.43	34.24
<i>Glochidion obscurum</i>	Phyllanthaceae	69.43	32.41
<i>Artocarpus dadah</i>	Moraceae	69.43	31.96
<i>Hevea brasiliensis</i>	Euphorbiaceae	69.43	30.78
<i>Macaranga tanarius</i>	Euphorbiaceae	69.43	30.53
<i>Rhodamnia</i> sp.	Myrtaceae	69.43	26.43
<i>Vitex pinnata</i>	Lamiaceae	69.43	25.59
<i>Ecclinusa ramiflora</i>	Sapotaceae	69.43	22.69
<i>Homalanthus populneus</i>	Euphorbiaceae	69.43	19.30
<i>Aleurites moluccanus</i>	Euphorbiaceae	69.43	16.31
<i>Macaranga</i> sp.	Euphorbiaceae	69.43	16.15
<i>Artocarpus heterophyllus</i>	Moraceae	69.43	11.32
<i>Nauclea xanthoxylon</i>	Rubiaceae	69.43	7.78
<i>Mallotus paniculatus</i>	Euphorbiaceae	69.43	7.09
<i>Ceiba pentandra</i>	Malvaceae	69.43	6.26
<i>Melicope lunu-ankenda</i>	Rutaceae	69.43	4.66
<i>Ficus aurata</i>	Moraceae	69.43	4.33
<i>Litsea firma</i>	Lauraceae	69.43	3.59
<i>Baccaurea</i> sp.	Phyllanthaceae	69.43	3.50
<i>Garcinia intermedia</i>	Clusiaceae	69.43	3.29
<i>Alstonia scholaris</i>	Apocynaceae	69.43	1.63
<i>Cratogeomys arborescens</i>	Hypericaceae	69.43	1.63
<i>Gironniera celtidifolia</i>	Cannabaceae	69.43	1.52
<i>Dillenia excelsa</i>	Dilleniaceae	69.43	0.90
<i>Trema orientalis</i>	Cannabaceae	69.43	0.57
		2,638.21	3,526.20
		69.43	92.79

Table 9. Prices of logs and lumber in 0.4 ha of 50 years old secondary forest in East Kalimantan, Indonesia

Species	Family	Logs price (USD m ⁻³)	Lumber price (USD m ⁻³)
<i>Alstonia scholaris</i>	Apocynaceae	333.25	833.12
<i>Durio</i> sp.	Malvaceae	206.54	295.06
<i>Cratogeomys arborescens</i>	Hypericaceae	97.20	242.99
<i>Artocarpus heterophyllus</i>	Moraceae	83.31	208.28
<i>Vitex pinnata</i>	Lamiaceae	63.87	159.68
<i>Artocarpus elasticus</i>	Moraceae	79.38	145.80
<i>Archidendron pauciflorum</i>	Fabaceae	65.96	138.85
<i>Nephelium lappaceum</i>	Sapindaceae	59.36	124.97
<i>Baccaurea</i> sp.	Phyllanthaceae	49.99	124.97
<i>Hevea brasiliensis</i>	Euphorbiaceae	28.72	69.43
<i>Vernonia arborea</i>	Asteraceae	28.64	52.07
<i>Macaranga</i> sp.	Euphorbiaceae	28.64	52.07
<i>Glochidion obscurum</i>	Phyllanthaceae	28.64	52.07
<i>Macaranga gigantea</i>	Euphorbiaceae	25.17	52.07
<i>Aleurites moluccanus</i>	Euphorbiaceae	23.43	52.07
<i>Talipariti simile</i>	Malvaceae	23.17	52.07
<i>Symplocos fasciculata</i>	Symplocaceae	23.13	52.07
<i>Bridelia stipularis</i>	Phyllanthaceae	22.56	52.07
<i>Ficus septica</i>	Moraceae	22.44	52.07
<i>Derris caudatilimba</i>	Fabaceae	22.29	52.07
<i>Artocarpus tamaran</i>	Moraceae	22.13	52.07
<i>Rhodamnia</i> sp.	Myrtaceae	22.13	52.07
<i>Macaranga motleyana</i>	Euphorbiaceae	22.04	52.07
<i>Homalanthus populneus</i>	Euphorbiaceae	21.80	52.07
<i>Macaranga tanarius</i>	Euphorbiaceae	21.48	52.07
<i>Ficus uncinata</i>	Moraceae	20.83	52.07
<i>Artocarpus dadah</i>	Moraceae	20.83	52.07
<i>Ecclinusa ramiflora</i>	Sapotaceae	20.83	52.07
<i>Ceiba pentandra</i>	Malvaceae	20.83	52.07
<i>Mallotus paniculatus</i>	Euphorbiaceae	20.83	52.07
<i>Ficus aurata</i>	Moraceae	20.83	52.07
<i>Melicope lunu-ankenda</i>	Rutaceae	20.83	52.07
<i>Nauclea xanthoxylon</i>	Rubiaceae	20.83	52.07
<i>Garcinia intermedia</i>	Clusiaceae	20.83	52.07
<i>Trema orientalis</i>	Cannabaceae	20.83	52.07
<i>Dillenia excelsa</i>	Dilleniaceae	20.83	52.07
<i>Gironniera celtidifolia</i>	Cannabaceae	20.83	52.07
<i>Litsea firma</i>	Lauraceae	20.83	52.07
		1,696.03	3,801.11
		44.63	100.03

Profit margin

The profit margin in this study was assumed based on the profits obtained from the sale of timber. The data in Table 10 shows the profit margins from the sale of lumber obtained from 38 tree species. The total profit margin from the lumber sale of 38 tree species was USD391.39 m⁻³ or USD978.48 ha⁻¹ with an average of USD10.30 m⁻³ or USD25.75 ha⁻¹ species⁻¹. The highest profit margin was obtained from the trade-in lumber of the *Alstonia scholaris* species. According to Karyati et al. (2021), the profit margin obtained from the trade-in logs and lumber is influenced by several factors, including the number of requests, the number of sales, the price of logs and lumber, tree diameter, production costs, pricing strategies, business management, and other factors.

Stumpage value

Economic assessment of the land can be done by assessing the stumpage growing on the land. The results of this study showed that the total stumpage value (consisting of 38 species) at the study site was USD1,091.76 ha⁻¹. The average stumpage value was USD28.73 ha⁻¹ species⁻¹. Figure 5 shows the stumpage value of each species at the study site. The stumpage value in this study was lower than the results of previous studies (Karmini et al. 2020a, Karmini et al. 2020b). The stumpage value is determined by the volume of timber for each species, the diameter of logs, the price of each species' logs at the sawmill, and the profit margin. Timber price is the dominant factor that determines the stumpage value. The more tree species that have a high selling value found on land, the higher the stumpage value. The results of this study can show that the stumpage at the study site has a very significant economic value.

Table 10. Profit margin assumed from the sale of timber from 0.4 ha of 50 years old secondary forest in East Kalimantan, Indonesia

Species	Family	Profit margin	
		USD m ⁻³	USD ha ⁻¹
<i>Alstonia scholaris</i>	Apocynaceae	76.90	192.26
<i>Durio</i> sp.	Malvaceae	47.66	119.16
<i>Cratogeomys arborescens</i>	Hypericaceae	22.43	56.08
<i>Artocarpus heterophyllus</i>	Moraceae	19.23	48.06
<i>Artocarpus elasticus</i>	Moraceae	18.32	45.79
<i>Archidendron pauciflorum</i>	Fabaceae	15.22	38.05
<i>Vitex pinnata</i>	Lamiaceae	14.74	36.85
<i>Nephelium lappaceum</i>	Sapindaceae	13.70	34.25
<i>Baccaurea</i> sp.	Phyllanthaceae	11.54	28.84
<i>Hevea brasiliensis</i>	Euphorbiaceae	6.63	16.57
<i>Vernonia arborea</i>	Asteraceae	6.61	16.52
<i>Macaranga</i> sp.	Euphorbiaceae	6.61	16.52
<i>Glochidion obscurum</i>	Phyllanthaceae	6.61	16.52
<i>Macaranga gigantea</i>	Euphorbiaceae	5.81	14.52
<i>Aleurites moluccanus</i>	Euphorbiaceae	5.41	13.52
<i>Talipariti simile</i>	Malvaceae	5.35	13.37
<i>Symplocos fasciculata</i>	Symplocaceae	5.34	13.34
<i>Bridelia stipularis</i>	Phyllanthaceae	5.21	13.02
<i>Ficus septica</i>	Moraceae	5.18	12.95
<i>Derris caudatilimba</i>	Fabaceae	5.14	12.86
<i>Rhodamnia</i> sp.	Myrtaceae	5.11	12.77
<i>Artocarpus tamaran</i>	Moraceae	5.11	12.77
<i>Macaranga motleyana</i>	Euphorbiaceae	5.09	12.72
<i>Homalanthus populneus</i>	Euphorbiaceae	5.03	12.58
<i>Macaranga tanarius</i>	Euphorbiaceae	4.96	12.39
<i>Ceiba pentandra</i>	Malvaceae	4.81	12.02
<i>Ficus aurata</i>	Moraceae	4.81	12.02
<i>Trema orientalis</i>	Cannabaceae	4.81	12.02
<i>Ficus uncinata</i>	Moraceae	4.81	12.02
<i>Artocarpus dadah</i>	Moraceae	4.81	12.02
<i>Dillenia excelsa</i>	Dilleniaceae	4.81	12.02
<i>Nauclea xanthoxylon</i>	Rubiaceae	4.81	12.02
<i>Ecclinusa ramiflora</i>	Sapotaceae	4.81	12.02
<i>Melicope lunu-ankenda</i>	Rutaceae	4.81	12.02
<i>Mallotus paniculatus</i>	Euphorbiaceae	4.81	12.02
<i>Garcinia intermedia</i>	Clusiaceae	4.81	12.02
<i>Gironniera celtidifolia</i>	Cannabaceae	4.81	12.02
<i>Litsea firma</i>	Lauraceae	4.81	12.02
		391.39	978.48
		10.30	25.75

East Kalimantan has a lot of 50 years old secondary forests that is rich in biodiversity. The 50 years old secondary forests in East Kalimantan have ecological and economic characteristics. As many as 14% of trees in the 50 years old secondary forests have diameters at breast height between 15.1-25.0 cm and most trees (40%) in there have height in class 5.1-10.0 m. The 50 years old secondary forest has approximately 437 trees, 38 species, 30 genera, and 19 families with the total basal area and volume are around 15.36 m² ha⁻¹ dan 122.07 m³ ha⁻¹. The most dominant families are Moraceae and Euphorbiaceae with an important value (FIV) of 86.79 and the three most dominant species were *Macaranga motleyana* (IVI of 50.95), *Artocarpus elasticus* (IVI of 34.41), and *Symplocos fasciculata* (IVI of 31.46). The trees in the 50 years old secondary forest have a diversity index of 1.33, the dominance index of 0.07, evenness index of 0.37, and

species richness of 6.09. The economic values of 50 years old secondary forest could be seen from total and average values of logging costs (USD2,638.21 m⁻³ and USD69.43 m⁻³), logs price (USD1,696.03 m⁻³ and USD44.63 m⁻³), lumber price (USD3,801.11 m⁻³ and USD100.03 m⁻³), profit margin (391.39 m⁻³ and 10.30 m⁻³), stumpage value (USD1,091.76 ha⁻¹ and USD28.73 ha⁻¹ species⁻¹). Because of its ecological and economic values, 50 years old secondary forest must be preserved so that its ecological and economic values will continue to increase. The use of 50 years old secondary forest can be done with give attention to maintain and increase biodiversity.

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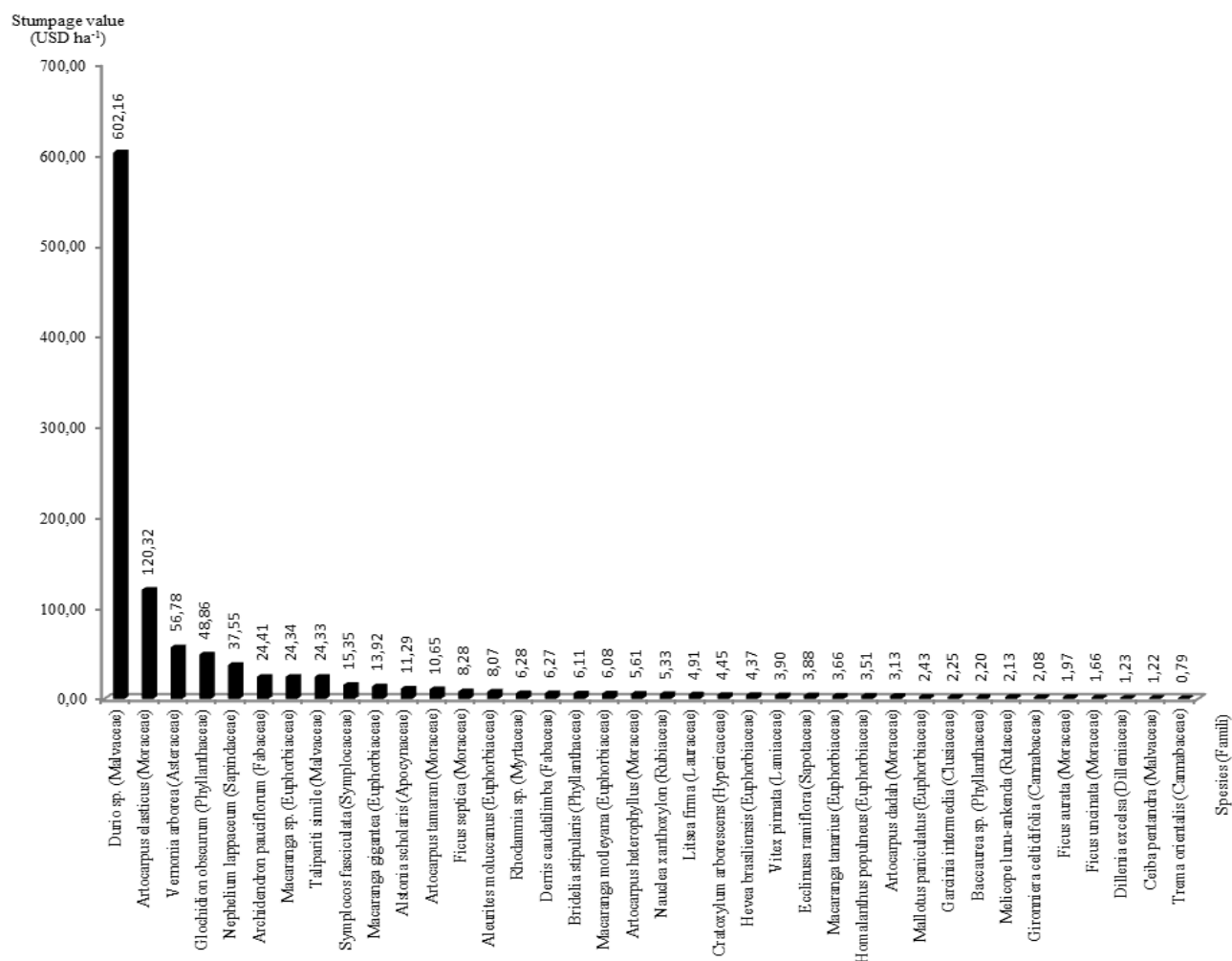


Figure 5. Stumpage value of trees in 0.4 ha of 50 years old secondary forest in East Kalimantan

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