The role of tropical abandoned land relative

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The role of tropical abandoned land relative to ecological and economic aspects

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Abstract: The floristic structure and composition of abandoned lands in the tropic have been observed to be changing dynamically during the succession process. This is mostly because they are not utilized maximally, therefore, there is a need to assess the economic and ecological impacts of this land abandonment in tropical areas. This study was conducted to determine the ecological aspects of stand structure, floristic composition, and species diversity and analyze the economic aspects of standing trees in tropical abandoned land. The vegetation containing woody trees with a diameter at breast height (DBH) of ≥ 5 cm were surveyed at six subplots sized 20 m × 20 m. The economic parameters were evaluated using data of log price, logging cost, profit margin, and stumpage value of standing trees in the study plot and a total of 126 trees including 26 species of 25 genera of 18 families were recorded. The most common species found were *Macaranga tanarius* with 50.60%, *Bridelia glauca* with 49.13%, and *Pterospermum javanicum* with 29.05% based on Importance Value Index (IVi). Moreover, the diversity, dominance, evenness, and richness indices were 1.23, 0.09, 0.87, and 5.17 respectively while the total log price at the abandoned land was 1,462.62 USD m^{-3} with an average value of 56.23 USD m^{-3}. The total and mean values of logging costs were 1,212.24 USD ha^{-1} and 46.62 USD ha^{-1}, respectively while the total profit margin of log selling was USD337.39 m^{-3} at maximum with an average of 12.98 USD m^{-3}. Furthermore, the average stumpage value was 83.05 USD ha^{-1} while the total was calculated to be 2,159.36 USD ha^{-1}. These findings showed the utilization of abandoned lands with respect to ecology and economic aspects has the ability to increase community welfare and support the implementation of developmental programs in the country.

Keywords: Abandoned land; diversity; economic; floristic structure; stumpage value

1. Introduction

The dynamics taking place at several scales determine plant diversity within regenerating fallows (Lawrence, 2004) exploited for agricultural purposes, mainly through shifting cultivation. This is observed to be a global phenomenon because two-thirds of the world's secondary forests were recorded to have been cultivated through the process in 1980 with 49% recorded annually in tropical Asia (Lanly, 1982). These forests are defined as the vegetation resulting from the clearing of natural high forest for shifting cultivation before abandonment (Abebrese, 2002; Johnson and Miyanishi, 2007; Keddy, 2007; Misra, 1992). They are characterized by the structure and extent of vegetative cover as well as their composition in terms of dominant and secondary species (Mittelman, 2001; Van Breugel et al., 2006). However, the principal types include the Swidden fallow secondary forests and some other gardens as reported by Chokkalingam et al. (2001).

According to Van Breugel et al. (2006), understanding the mechanisms of secondary forest succession requires the consideration of the time of abandonment as a compound factor to integrate the variables of plant community ecology - the total effective conditions determining the existence of the plants on the land (Tansley, 1993). Secondary forests are caused by human activity and fast-growing ecosystems whose species life cycles coincide with those of human land uses. In addition, they are also assets for the conservation of biodiversity in the tropics due to their many

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biotic characteristics such as the ability to improve soil and water quality as well as to conserve genetic material, nutrients, moisture, and/or soil organic matters (Brown and Lugo, 1990).

With the continuous depletion of primary forests, secondary forests have become increasingly important to maintain the larger habitat for biodiversity conservation (Mittelman, 2001). This is associated with their coverage of more than 600 million ha of the land area in the tropics which accounts for about 40% of the total forest area as well as the formation rates estimated at 9 million ha year^{-1} (Brown and Lugo, 1990). Moreover, FAO (1996) estimated the area of secondary forest in 1990 in Asia to be 87.5 million ha while the figures for Latin America and Africa were 165 and 90 million ha, respectively. These data and the awareness of the accelerated changes in the forest situations in countries like the Philippines, Indonesia, China, and Malaysia strongly suggest future goods and services obtained from tropical forests would increasingly be sourced from secondary or some other kinds of anthropogenically-induced forests such as the timber, environmental services, biodiversity conservation, and forest products for the rural poor (De Jong et al., 2001).

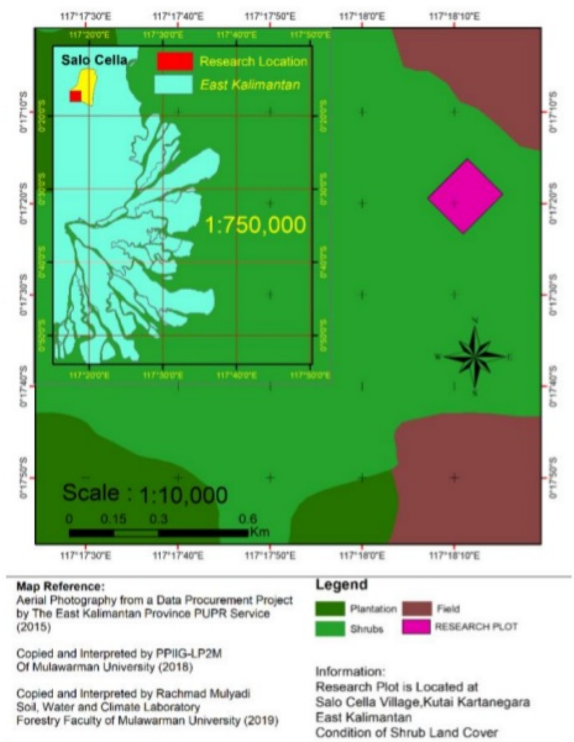

Figure 1. Map of the study site in Muara Badak Sub-district, Kutai Kartanegara District, East Kalimantan Province, Indonesia.

The total land area in Indonesia is estimated to be 190 million hectares and 2/3 of these are referred to as forest areas managed by the Ministry of Forestry while the remaining 1/3 is for business (HGU) and building (HGB). However, the National Land Agency (BPN) indicated 7.5 million hectares of land has the potential to be abandoned, both in and outside the forest areas, and several people have assumed these lands have no usefulness. However, they have certain ecological and economic benefits and several studies have been conducted on the ecological aspect such as the floristic composition and structure of the tropical secondary forest in Borneo Island as well as the less information provided on the ecological and economic aspects of tropical abandoned land in East Kalimantan. This study was, therefore, conducted to determine the ecological aspect such as stand structure, floristic composition, and species diversity as well as the economic aspect of standing trees such as log price, logging cost, profit margin, and stumpage value in an abandoned land. The findings are expected to be useful in conserving and managing tropical forest and environmental ecosystems.

2. Materials and methods

2.1. Study site

The study was conducted in Salo Cella Village, Muara Badak Sub-district, Kutai Kartanegara Districts, East Kalimantan Province, Indonesia with the geographic location of 0°17'18.7''S 117°18'08.2''E as shown in Figure 1. Salo Cella is one of 13 villages in Muara Badak located 10 km from the capital of Sub-district with a population of 49,361,000 most of which are farmers and an area of 939.09 km^2 dominated by lowland mixed dipterocarp forest. Moreover, the average monthly and amount of rainfall were recorded to be 92 mm^3 and 9 raindays in 2018 (Statistics Kutai Kartanegara Regency, 2019). The subdistrict is administratively bordered by Marang Kayu Sub-district, Anggana Sub-district Samarinda City, Makassar Strait, and Tenggarong Seberang Sub-district on the north, south, east, and west respectively. Furthermore, the sectors of Muara Badak with economic potentials are oil and gas, fishery, and plantation.

2.2 Data collection

The vegetation and economic surveys of the study site were conducted from March to August 2019 through the establishment of six subplots sized 20 m × 20 m. Moreover, all woody trees with DBH of ≥ 5 cm within the plot were enumerated and their species identified.

2.3 Data analysis

2.3.1 Ecological aspect

Individual basal area (BA) and volume (V) were determined using the following formulas (Husch et al. 1982):

$$\text{Individuals BA} = \pi\ (DBH/2)^2 . 10^{-4} \text{ .... } (1)$$

$$\text{Individuals V} = ¼\ \pi \times DBH^2 .\ 10^{-4} \times H \times f \text{ .... } (2)$$

where: DBH is the diameter at breast height (cm), ‘H’ is tree height (m), and ‘*f*’ is the form factor.

The dominant species within the plots were measured using the Importance Value Index (IVi) (Fachrul, 2007):

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

Rd = (The number of individual 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 species diversity for standing trees in the study site was described using four indices including 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):

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

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

$$J' = \frac{H'}{\ln(S)} \quad \text{.........} \quad (9)$$

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

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.

2.3.2 Economic aspect

The equivalent merchantable height, number of logs, and diameter class are presented in Table 1 while the reduction factors of log price based on the diameter class are shown in Table 2.

Table 1. Merchantable tree heights.

Diameter class (cm)	Number of logs (5 m long)	Equivalent merchantable height (m)
15 – 30	1	5
+30 – 60	2	10
+60 – 75	3	15
75 ke atas	4	20

Source: Forestry Department of Pinansular Malaysia (FDPM) (1997)

Table 2. Reduction cost of log price.

DBH size class (cm)	Reduction factor
15 – 29	0,450
30 – 44	0,300
45 – 49	0,150
50 – 54	0,025
55 and above	0,000

Source: Noor et al. (1992) and Hanum et al. (2001)

Logging cost was reported to be 480,000.00 IDR (Hikmat, 2005) while the profit ratio was 30% (Noor and Shahwahid, 1999). Therefore, the equation to calculate the profit margin (Noor and Shahwahid, 1999) is presented as follows:

$$PM_{ij} = \sum_{i=1}^{n} \sum_{j=1}^{k} (P_{ij} x PR)/(1+PR)$$

Where PM_{ij} = profit margin, P_{ij} = log price for each species at sawmill and diameter class, *PR* = profit ratio, *i* = an index for each species (i = 1, 2, 3, 4, ..., n), and *j* = an index for diameter class (i = 1, 2, 3, 4, ..., n).

Meanwhile, the stumpage values were calculated using the following equation:

$$S_{ij} = \sum_{i=1}^{n} \sum_{j=1}^{k} V_{ij}(P_{ij} + C_{ij} + PM)$$

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 (m^3), P_{ij} = log price for each species at sawmill and diameter class (USD m^{-3}), C_{ij} = average logging cost (USD ha^{-1}), PM_{ij} = profit margin (USD m^{-3}), *i* = an index for each species (i = 1, 2, 3, 4, ..., n), and *j* = an index for diameter class (i = 1, 2, 3, 4, ..., n). The exchange rate was 1 USD equal with 13,666 IDR at 21st January 2020.

3. Results and discussion

3.1. Ecological aspect

3.1.1 Diameter at Breast Height (DBH) and Height Distributions

There was a difference in the density of trees in the DBH classes as observed with the formation of L-shape characterized by the reduction in the total number of trees as the DBH increased as illustrated in Figure 2. There were 88 trees with the DBH size of 5.0-15.0 cm, followed by 22 trees (17%) with the DBH size of 15.1-25.0 cm, 14 trees (11%) with the DBH size of 25.1-35.0 cm, and 2 trees (2%) with the DBH size of more 35 cm. The abandoned land was also observed to be dominated by 70% of all trees having DBH $\geq$ 5 cm in the 5.0-15.0 cm class. Moreover, the tree diameter distribution formed a reverse-J-shape (Feldpausch et al., 2007; Álvarez-Yépiz et al., 2008) while the distribution of the classes of the height was skewed slightly positively (Ohtsuka, 1999) as shown in Figure 3 with approximately 58% of the trees included in the 5.1-10.0 m class. The overall composition was 18 trees (14%) of 0-5.0 m height, 73 trees (58%) of 5.1-10.0 m height, 19 trees (15%) of 10.1-15.0 height, 7 trees (6%) of 15.1-20.0 height, and 9 trees (7%) of more than 20.0 cm height.

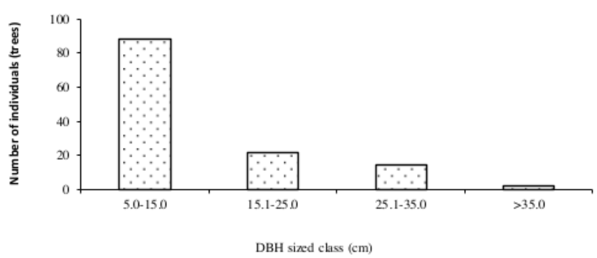

Figure 2. Distributions of diameter at breast height (DBH) in 0.24 ha of abandoned land.

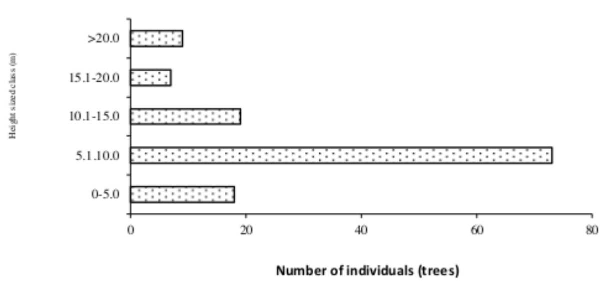

Figure 3. Distributions of height at different ages in 0.24 ha of abandoned land.

3.1.2 Density, basal area, and volume

The density, basal area, and volume of species at a DBH of > 5 cm are presented in Table 3. Twenty six species of 18 families were recorded in the study site. Three species such as *Bridelia glauca*, *Glochidion obscurum*, and *Baccaurea* sp. were included to Phyllanthaceae. Similarly, *Macaranga tanarius*, *Homalanthus* sp., and *Macaranga gigantea* were from Euphorbiaceae. The other 16 families had one species each. The density was found to be 126 trees in 0.24 hectare and the dominating species of trees based on the number of individuals include *Macaranga tanarius* with 38, *Bridelia* sp. with 20, *Homalanthus* sp. with 11, *Pterospermum javanicum* with 8, and *Ficus septica* with 5. The other species had number of individuals of $\leq$ 4 trees. The average of DBH and height of trees were 14.3 cm and 10.5 m, respectively. Regarding the basal area and volume per hectare, three dominant species were also observed and they include *Bridelia glauca* with 2.10 m^2 ha^{-1} and 23.24 m^3 ha^{-1}, *Pterospermum javanicum* with 1.64 m^2 ha^{-1} and 18.42 m^3 ha^{-1}, and *Ficus* sp. with 1.24 m^2 ha^{-1} and 11.74 m^3 ha^{-1} for basal area and volume respectively. This, therefore, means these three species covered more than 58 percent of the total volume while other six species including *Trema Orientalis*, *Trema Orientalis*, *Glochidion* sp., *Duabanga moluccana*, *Pometia pinnata*, and *Cananga odorata* had more than 3.70 m^3 ha^{-1}. The four species of *Nephelium* sp., *Nauclea* sp., *Artocarpus elasticus*, and *Homalanthus* sp. had relative high volume (> 1.07 m^3 ha^{-1}). While 13 other species had few basal area (0.02 to 0.15 m^2 ha^{-1}) and volume (0.07 to 0.83 m^3 ha^{-1}). *Macaranga gigantea*, *Vitex pubescens*, and *Dillenia suffruticosa* were three dominant species in terms of density, basal area and volume per hectare in the 5 and 10 year old after abandoned lands. In addition, *Macaranga hypoleuca* and *Macaranga caladifolia* were also common in the 10 year old of abandoned land, while *Macaranga trichocarpa* in the 5 year old of abandoned land (Karyati et al., 2018).

3.1.3 Importance value index (IVi)

The study site was dominated by light-demanding pioneer and fast-growing species in terms of IVi as presented in Table 4. However, the same four species observed to be predominant with total basal area and volume were also found for the IVi and they include *Macaranga tanarius* with 50.60%, *Bridelia glauca* with 49.13%, *Pterospermum javanicum* with 29.05%, and *Ficus septica* with 22.56%. The other three species discovered to be following the aforementioned were *Homalanthus* sp., *Trema orientalis*, and *Glochidion* sp. with 18.89, 16.10, and 11.53%, respectively. Three species of Euphorbiaceae were dominant in terms of the IVi. These three species such as *Macaranga tanarius*, *Homalanthus* sp., and *Macaranga gigantea* reached more than 72%. Similarly, Euphorbiaceae was include the ten most important family in the tropic as reported by Danquah et al. (2011) and Nizam et al. (2006). From 18 species recorded, there were 10 species with IVi of more than 5. The other 9 species reached IVi between 2 to 5. Furthermore, the seedling and saplings plants of *Ficus aurata* and *Macaranga* sp. were also common based on the Summed Dominance Ratio (SDR) in 3 and 5 years of fallow lands in Sarawak (Karyati et al., 2013). This is in line with the findings of Karyati et al. (2018) that trees species in lands abandoned for 5 and 10 years were dominated by *Macaranga* spp.

3.1.4 Species Diversity

The species diversity or heterogeneity (*H'* value) of the plot studied was categorized as 'intermediate' (Odum, 2005) according to the results presented in Table 5 while a low ecological dominance (D_s value) was also observed which means there were few or almost no species dominating the site. The high species diversity indicates a highly complex community (Brower et al., 1990). This was also supported by the high value of *J'* indicating all the species are evenly distributed in the community. These values may, however, be due to the high number of trees and the number of species. The species richness can be measured most simply by counting the number of species in an area (Krebs, 2001). Generally, the increasing diversity (*H'*), evenness (*J'*), and richness *(R)* caused a reduction in dominance (D_s) in accordance with the findings of a previous study that tree diversity declined while dominance increased linearly along a disturbance gradient (Sapkota et al., 2010). The typical of most tropical lowland forests are no single tree species with high frequency and dominance (Kartawinata et al., 1981).

Table 3. Density, basal area, and volume of species (DBH of > 5 cm) in the study site.

No.	Species	Family	Number of individuals	Average of DBH (cm)	Average of height (m)	Total of basal area (m^2 ha^{-1})	Total volume (m^3 ha^{-1})
1	*Bridelia glauca*	Phyllanthaceae	20	15.7	11.7	2.10	23.24
2	*Pterospermum javanicum*	Malvaceae	8	24.1	16.6	1.64	18.42
3	*Ficus septica*	Moraceae	5	23.5	11.0	1.24	11.74
4	*Trema Orientalis*	Cannabaceae	4	21.3	10.8	0.69	5.60
5	*Macaranga tanarius*	Euphorbiaceae	38	8.8	7.7	1.04	5.28
6	*Glochidion obscurum*	Phyllanthaceae	3	22.7	15.3	0.51	5.18
7	*Duabanga moluccana*	Lithraceae	1	29.0	22.0	0.28	3.94
8	*Pometia pinnata*	Sapindaceae	2	19.8	22.0	0.27	3.80
9	*Cananga odorata*	Annonaceae	2	17.5	13.5	0.27	3.72
10	*Nephelium* sp.	Sapindaceae	3	18.6	11.7	0.37	2.99
11	*Nauclea* sp.	Rubiaceae	2	13.4	14.0	0.13	1.39
12	*Artocarpus elasticus*	Moraceae	1	22.0	12.0	0.16	1.24
13	*Homalanthus* sp.	Euphorbiaceae	11	7.6	6.5	0.23	1.07
14	*Archidendron pauciflorum*	Fabaceae	1	16.1	15.0	0.08	0.83
15	Unknown species 1	Anacardiaceae	3	12.1	7.3	0.15	0.74
16	*Dillenia borneensis*	Dilleniaceae	2	11.6	9.5	0.10	0.65
17	*Diospyros* sp.	Ebenaceae	4	9.3	5.8	0.13	0.46
18	*Pternandra* sp.	Melastomataceae	2	11.8	7.0	0.09	0.41
19	*Macaranga gigantea*	Euphorbiaceae	1	11.2	9.0	0.04	0.24
20	*Fordia splendidissima*	Fabaceae	4	7.2	5.3	0.07	0.24
21	Unknown species 2	Anacardiaceae	1	12.3	6.0	0.05	0.19
22	*Eusideroxylon zwageri*	Lauraceae	3	5.7	8.0	0.03	0.16
23	*Vernonia arborea*	Asteraceae	1	9.5	6.0	0.03	0.12
24	*Syzygium* sp.	Myrtaceae	2	6.7	6.0	0.03	0.11
25	*Baccaurea* sp.	Phyllanthaceae	1	8.0	8.0	0.02	0.11
26	Unknown species 3	Unknown family	1	7.6	6.0	0.02	0.07
	Total		126,0	373.0	273.5	9.75	91.97
	Average		4,8	14.3	10.5	0.38	3.54
	Maximum		38.0	29.0	22.0	2.10	23.24
	Minimum		1.0	5.7	5.3	0.02	0.07

Note: DBH = diameter at breast height. The values were calculated based on vegetation surveyed in 0.24 hectare.

Table 4. Importance value index (IVi) of trees (DBH of > 5 cm) in 0.24 hectare of the study site.

No.	Species	Family	RF (%)	Rd (%)	RD (%)	IVi (%)
1	*Macaranga tanarius*	Euphorbiaceae	9.80	30.16	10.64	50.60
2	*Bridelia glauca*	Phyllanthaceae	11.76	15.87	21.50	49.13
3	*Pterospermum javanicum*	Malvaceae	5.88	6.35	16.82	29.05
4	*Ficus septica*	Moraceae	5.88	3.97	12.70	22.56
5	*Homalanthus* sp.	Euphorbiaceae	7.84	8.73	2.32	18.89
6	*Trema orientalis*	Cannabaceae	5.88	3.17	7.04	16.10
7	*Glochidion obscurum*	Phyllanthaceae	3.92	2.38	5.23	11.53
8	*Diospyros* sp.	Ebenaceae	3.92	3.17	1.35	8.45
9	*Cananga odorata*	Annonaceae	3.92	1.59	2.80	8.30
10	*Nephelium* sp.	Sapindaceae	1.96	2.38	3.82	8.17
11	Unknown species 1	Anacardiaceae	3.92	2.38	1.54	7.84
12	*Nauclea* sp.	Rubiaceae	3.92	1.59	1.29	6.80
13	*Eusideroxylon zwageri*	Lauraceae	3.92	2.38	0.34	6.64
14	*Pometia pinnata*	Sapindaceae	1.96	1.59	2.72	6.27
15	*Fordia splendidissima*	Fabaceae	1.96	3.17	0.71	5.85
16	*Syzygium* sp.	Myrtaceae	3.92	1.59	0.30	5.81
17	*Duabanga moluccana*	Lithraceae	1.96	0.79	2.82	5.58

No.	Species	Family	RF (%)	Rd (%)	RD (%)	IVi (%)
18	*Dillenia borneensis*	Dilleniaceae	1.96	1.59	0.99	4.54
19	*Pternandra* sp.	Melastomataceae	1.96	1.59	0.93	4.48
20	*Artocarpus elasticus*	Moraceae	1.96	0.79	1.62	4.38
21	*Archidendron pauciflorum*	Fabaceae	1.96	0.79	0.87	3.62
22	Unknown species 2	Anacardiaceae	1.96	0.79	0.51	3.26
23	*Macaranga gigantea*	Euphorbiaceae	1.96	0.79	0.42	3.18
24	*Vernonia arborea*	Asteraceae	1.96	0.79	0.30	3.06
25	*Baccaurea* sp.	Phyllanthaceae	1.96	0.79	0.21	2.97
26	Unknown species 3	Unknown family	1.96	0.79	0.19	2.95
	Jumlah		100.00	100.00	100.00	300.00

Note: RF= relative frequency, Rd=relative density, RD=relative dominance; IVi=importance value index.

Table 5. Diversity indices of trees with DBH of $\geq$ 5 cm in the study site.

No.	Diversity indices	Value
1	Shannon-Wiener diversity index (*H'*)	1.23
2	Simpson dominance index (D_s)	0.09
3	Pielou evenness index (*J'*)	0.87
4	Margalef species richness (*R*)	5.17

Note: The values were calculated according to the 6 subplots sized 20 m × 20 m each.

The study showed the floristic structure, composition, and diversity were related to the existence and importance of the abandoned land dominated by fast-growing species. Moreover, the species of tree on the site had 'intermediate diversity' (*H'*), 'low dominance' (*Ds*), and 'high evenness' (*J'*) and the same was found for seedling-sapling plants with DBH< 5 cm and tree plants with DBH>5 cm in 3, 5, 10, and 20 years after the lands have been fallowed (Karyati et al., 2013; Karyati et al., 2018). This, therefore, means abandoned land has important ecological roles. Furthermore, the information on the composition and diversity of plant regeneration at early stages of secondary succession on fallow lands is useful for biodiversity conservation and also provide social and economic values for future forest (Karyati et al., 2013). This shows it is necessary to understand the ecological and economic aspects of abandoned lands in order to manage and conserve them during successional periods in the tropic.

3.2 Economic aspect

3.2.1 Log price

The results showed the log prices for 10 species at the sawmill were different while Table 6 shows there were 525 stems ha^{-1} on the abandoned land. Moreover, the total and mean log price were 1,462.02 USD m^{-3} and 56.23 USD m^{-3}, respectively with the highest values obtained at *Eusideroxylon zwageri* of Lauraceae with 526.85 USD m^{-3}, *Diospyros* sp. of Ebenaceae with 263.43 USD m^{-3}, *Pometia zwageri* of Sapindaceae with 125.13 USD m^{-3}, and *Artocarpus odoratissimus* of Moraceae with 69.15 USD m^{-3}. Furthermore, most of the other 22 species had the same value or were under 65.86 USD m^{-3}.

Table 6. Number of stems at abandoned land and log price.

No.	Species	Family	Number (stems ha^{-1})	P_{ij} (USD m^{-3})
1	*Eusideroxylon zwageri*	Lauraceae	13	526.85
2	*Diospyros* sp.	Ebenaceae	17	263.43
3	*Pometia pinnata*	Sapindaceae	8	125.13
4	*Artocarpus odoratissimus*	Moraceae	4	69.15
5	*Archidendron pauciflorum*	Fabaceae	4	65.86
6	*Nephelium* sp.	Sapindaceae	13	59.27
7	*Pternandra* sp.	Melastomataceae	8	44.45
8	*Dillenia borneensis*	Dilleniaceae	8	16.46
9	*Macaranga tanarius*	Euphorbiaceae	158	16.46
10	*Trema orientalis*	Cannabaceae	17	16.46
11	*Syzygium* sp.	Myrtaceae	8	16.46
12	*Homalanthus* sp.	Euphorbiaceae	46	16.46
13	*Nauclea* sp.	Rubiaceae	8	16.46
14	*Glochidion obscurum*	Phyllanthaceae	13	16.46
15	*Fordia splendidissima*	Fabaceae	17	16.46
16	*Vernonia arborea*	Asteraceae	4	16.46
17	*Macaranga gigantea*	Euphorbiaceae	4	16.46
18	*Cananga odorata*	Annonaceae	8	16.46
19	*Duabanga moluccana*	Lithraceae	4	16.46
20	*Baccaurea* sp.	Phyllanthaceae	4	16.46
21	Unknown species 1	Anacardiaceae	13	16.46
22	Unknown species 2	Anacardiaceae	4	16.46
23	Unknown species 3	Unknown family	4	16.46
24	*Bridelia glauca*	Phyllanthaceae	83	16.19
25	*Pterospermum javanicum*	Malvaceae	33	15.09
26	*Ficus septica*	Moraceae	21	13.17
	Total		525	1,462.02
	Mean		20	56.23

Note: P_{ij} = log price for each species at sawmill and diameter class.

The log price depends on the species and diameter class of log such that trees with high timber quality and many sales in the market have higher log prices. However, a bigger diameter at breast height (DBH) led to a lower reduction factor and higher log price. This means it is easier to produce different kinds of products from the logs with big DBH and timber volume. Moreover, high community demand for logs of particular species usually increases their prices in the market in accordance with the laws of demand.

Trees with high log prices are in a small number on the abandoned land with an average of 20 stems ha^{-1} for each species. The *Eusideroxylon zwageri* (Lauraceae) had only 13 stems ha^{-1}, *Diospyros* sp. (Ebenaceae) with 17 stems ha^{-1} while *Pometia pinnata* (Sapindaceae) and *Artocarpus odoratissimus* (Moraceae) had 8 stems ha^{-1} and 4 stems ha^{-1}, respectively. This is, however, in line with the law of supply which states that a smaller supply of the commodity to the market leads to a higher price.

A different result was, however, observed with other species such as *Macaranga tanarius* (Euphorbiaceae) with a total number of 158 stems ha^{-1} and a log price of 16.46 USD m^{-3} and other families and species with low log prices. This means several factors determine the price of log in the market and they include tree diameter, timber quality, consumer taste, and others. According to Noor et al. (2007a), the market price is the first point of sale where the product is sold freely in the competitive market.

3.2.2 Logging cost

Logging cost was the same for each species of trees and was found to be USD35.12 m^{-3} including the costs for the chainsaw man, machine used, fuel, an6 depreciation. Table 7 shows the total and mean logging costs in the abandoned land were 1,212.24 USD ha^{-1} and 46.62 USD ha^{-1} respectively with the lowest being 0.72 USD ha^{-1} for 4 stems from *Anacardiaceae* family while the highest was 277.17 USD ha^{-1} for 21 stems from *Ficus septica* (Moraceae).

Table 7. Logging cost of trees.

No.	Species	Family	Number (stems ha^{-1})	C_{ij} (USD ha^{-1})
1	*Ficus septica*	Moraceae	21	277.17
2	*Bridelia glauca*	Phyllanthaceae	83	264.77
3	*Pterospermum javanicum*	Malvaceae	33	258.63
4	*Trema orientalis*	Cannabaceae	17	77.30
5	*Glochidion obscurum*	Phyllanthaceae	13	58.19
6	*Macaranga tanarius*	Euphorbiaceae	158	49.69
7	*Nephelium* sp.	Sapindaceae	13	39.72
8	*Duabanga moluccana*	Lithraceae	4	31.42
9	*Pometia pinnata*	Sapindaceae	8	30.31
10	*Cananga odorata*	Annonaceae	8	29.90
11	*Artocarpus odoratissimus*	Moraceae	4	18.08
12	*Nauclea* sp.	Rubiaceae	8	11.99
13	Unknown species 1	Anacardiaceae	13	11.55
14	*Diospyros* sp.	Ebenaceae	17	11.32
15	*Archidendron pauciflorum*	Fabaceae	4	9.68
16	*Dillenia borneensis*	Dilleniaceae	8	9.43
17	*Homalanthus* sp.	Euphorbiaceae	46	8.61
18	*Pternandra* sp.	Melastomataceae	8	3.46
19	*Fordia splendidissima*	Fabaceae	17	2.64
20	Unknown species 2	Anacardiaceae	4	1.80
21	*Macaranga gigantea*	Euphorbiaceae	4	1.57
22	*Eusideroxylon zwageri*	Lauraceae	13	1.26
23	*Vernonia arborea*	Asteraceae	4	1.13
24	*Syzygium* sp.	Myrtaceae	8	1.12
25	*Baccaurea* sp.	Phyllanthaceae	4	0.80
26	Unknown species 3	Unknown family	4	0.72
	Total		525	1,212.24
	Mean		20	46.62

Note: C_{ij} = logging cost of the tree.

Logging cost is, however, not determined by the number of trees cut but by the volume such that a higher estimation of log volume leads to a higher logging cost. Moreover, trees with high diameters were discovered to have more volume and vice versa, and those with small diameters were also found to have needed shorter logging time. Germain et. al. (2019) found two statistically significant variables influencing unit logging costs and they include volume per area harvested and the owner/operator experience such that an increase in these factors is expected to lower the per-unit logging costs, with experience variable having the least effect.

3.2.3 Profit margin

The total profit margin of selling logs was found to be 337.39 USD m^{-3} with an average of USD12.98 m^{-3}. The highest value of 121.58 USD m^{-3} was obtained from *Eusideroxylon zwageri* (Lauraceae) while the lowest was recorded to be 3.04 USD m^{-3} for *Ficus septica* (Moraceae) as shown in Table 8.

The factors determining the profit margin include the log price of each species at the sawmill and the class diameter such that the opportunity of the seller to make profit increases with a higher price and the log diameter.

Table 8. Profit margin.

No.	Species	Family	P_{ij} (USD m^{-3})	PM_{ij} (USD m^{-3})
1	*Eusideroxylon zwageri*	Lauraceae	526.85	121.58
2	*Diospyros* sp.	Ebenaceae	263.43	60.79
3	*Pometia pinnata*	Sapindaceae	125.13	28.88
4	*Artocarpus odoratissimus*	Moraceae	69.15	15.96
5	*Archidendron pauciflorum*	Fabaceae	65.86	15.20
6	*Nephelium* sp.	Sapindaceae	59.27	13.68
7	*Pternandra* sp.	Melastomataceae	44.45	10.26
8	*Dillenia borneensis*	Dilleniaceae	16.46	3.80
9	*Macaranga tanarius*	Euphorbiaceae	16.46	3.80
10	*Bridelia glauca*	Phyllanthaceae	16.19	3.74
11	*Trema orientalis*	Cannabaceae	16.46	3.80
12	*Syzygium* sp.	Myrtaceae	16.46	3.80
13	*Homalanthus* sp.	Euphorbiaceae	16.46	3.80
14	*Nauclea* sp.	Rubiaceae	16.46	3.80
15	*Glochidion obscurum*	Phyllanthaceae	16.46	3.80
16	*Fordia splendidissima*	Fabaceae	16.46	3.80
17	*Vernonia arborea*	Asteraceae	16.46	3.80
18	*Macaranga gigantea*	Euphorbiaceae	16.46	3.80
19	*Cananga odorata*	Annonaceae	16.46	3.80
20	*Duabanga moluccana*	Lithraceae	16.46	3.80
21	*Baccaurea* sp.	Phyllanthaceae	16.46	3.80
22	Unknown species 1	Anacardiaceae	16.46	3.80
23	Unknown species 2	Anacardiaceae	16.46	3.80
24	Unknown species 3	Unknown family	16.46	3.80
25	*Pterospermum javanicum*	Malvaceae	15.09	3.48
26	*Ficus septica*	Moraceae	13.17	3.04
	Total		1,462.02	337.39
	Mean		56.23	12.98

Note: P_{ij} = log price at sawmill and diameter class; PM_{ij} = profit margin.

3.2.4 Stumpage Value

The stumpage value was determined by the timber volume, log diameter, log price at the sawmill, and profit margin for each species and the total valued obtained was 2,159.36 USD ha^{-1}. However, Figure 4 shows eight species had economic values above the mean stumpage values on the abandoned land with the mean contribution found to be 83.05 USD ha^{-1} while 18 species of other trees had values under the mean stumpage values.

The studies conducted in other location found different stumpage economic values, for example, in Ayer Hitam Forest Reserve, Puchong, Selangor, it was estimated to be RM 34,278,980 for timber, RM 67,192 for medical plants, RM 773,090 for dependence of indigenous people, RM

865,770 for potential recreation benefits, and RM 2.39 billion for conservation value based on Malaysian adult population (Noor et. al. 2007b). Even though the values obtained in this study are lesser than the ones in Noor et. al. (2007b), it, however, shows abandoned land has many trees with potential economic values.

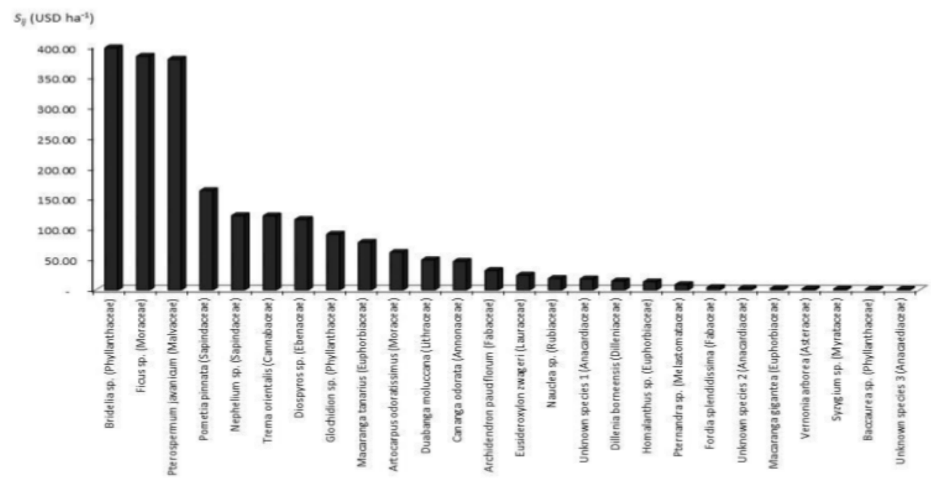

Figure 4. Stumpage values of trees at abandoned land.

4. Conclusions

This paper determined the abandoned lands in the tropics play important roles based on ecological and economic aspects. The ecological aspect was indicated by stand structure, floristic composition, and species diversity. The stand structure was dominated by trees with 5-10 cm DBH class and 5-10 m height class. The average basal area and volume of the trees with DBH of > 5 cm were recorded 0.38 m^2 ha^{-1} and 3.54 m^3 ha^{-1}. The presence of fast growing species indicated the early secondary successional process is still ongoing in the study site. The four most common species consisted mostly of light demanding pioneers, such as *Macaranga tanarius*, *Bridelia glauca*, *Pterospermum javanicum*, and *Ficus septica* in terms of IVi. The diversity indices of this abandoned land were categorized into intermediate diversity (*H*'), low dominance (*Ds*), and high evenness (*J*'). In addition, the tropical abandoned lands also have potential economic values for individuals and the community. The total of log price, logging cost, and profit margin at abandoned land were as much as 1,462.02 USD m^{-3}; 1,212.24 USD ha^{-1}, and 337.39 USD m^{-3}, respectively. Total stumpage value of this land was estimated as much as 2,159.36 USD ha^{-1}. Government – community cooperation need to be formulated so as to establish an appropriate method for sustainable land use. Therefore, basic information on ecological and economic aspects of abandoned lands are required for land management and conservation in the future.

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