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Agroforest diversity and ethnobotanical aspects in two villages of Berau, East Kalimantan, Indonesia

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Abstract. *Hartoyo APP, Supriyanto, Siregar IZ, Theilade I, Prasetyo LB. 2018. Agroforest diversity and ethnobotanical aspects in two villages of Berau, East Kalimantan, Indonesia. Biodiversitas 19: 387-398.* REDD+ aims to reduce emissions from deforestation and forest degradation, conservation, enhancement of forest carbon stocks, and sustainable forest management (SFM). An assessment of agroforest is important for REDD+ implementation in Indonesia. In this context, evaluation of the existing agroforests and their uses is an important issue. The objectives of this research were to characterize agroforest diversity with respect to habitat, regulation, production and information functions in Kampung Birang and Kampung Merabu, Berau, East Kalimantan. This research focused on two size classes of trees, namely medium trees (10≤dbh≤20 cm) and large trees (dbh>20 cm). Local community members were trained in plot establishment (60 plots, 50x50 m), tree diameter measurement, trees tagging, and herbarium collection. Local community members identified tree species by local names and listed the species uses. Results showed that agroforests as habitat obtained diversity indices (H') of moderate category for Kampung Birang and high category for Kampung Merabu. Otherwise, Margalef's index (D_{mg}) for the medium and large tree classes in Kampung Birang and Kampung Merabu were classified as high species richness category. This finding implies that enrichment planting using high economic value species is still necessary in Kampung Birang. Kampung Merabu was found to be more diverse than Kampung Birang, although soil quality in Kampung Birang was better than that in Kampung Merabu. Disturbances due to human activities that potentially impact agroforest stability were also pre-identified. The top ten tree species were classified based on importance value index (IVI) across both villages consisting of 80% shade intolerant and 20% semi-tolerant species. Agroforest showing production and information function as produces various edible fruits that are considered as key component for maintaining biodiversity sustainability and ecosystem functioning.

Keywords: REDD+, biodiversity, ethnobotanical, agroforestry, Kalimantan

INTRODUCTION

Tropical forests are important for production as well as for biodiversity conservation. Forests not only provide wood and non-wood products but also contribute to maintaining indigenous cultures (Kareiva 1994; Baird and Dearden 2003). Those various benefits of forests are usually framed in a single definition of ecosystem functions. Ecosystem functions are defined as the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly, and consequently are a subset of ecological processes and ecosystem structures (de Groot et al. 2002). Ecosystem functions are grouped into four main categories: regulation, habitat, production, and information (Dislich et al. 2017). However, these forests are under pressure from human activities (Mayaux et al. 2005; Kanninen et al. 2007). The tropical forest had the highest ratio of loss to gain (3.6 for >50% of tree cover), indicating the prevalence of deforestation dynamics with an estimated increase in loss of 2101 km^2/year (Hansen et al. 2013). Extensive clearing of Indonesian primary forests results in increased greenhouse gas emissions and biodiversity loss. Total Indonesian primary forest loss was over 6.02 Mha from 2000 to 2012 and increased on average by 47600 ha per year. By 2012, annual primary forest loss in Indonesia (0.84 Mha) was estimated to be higher than that in Brazil (0.46 Mha). The increasing loss of Indonesian primary forests has significant implications for climate change mitigation and biodiversity conservation efforts (Margono et al. 2014). Therefore, an assessment of environmental settings, biodiversity, and socio-economics are needed to fill requirements for Reducing Emissions from Deforestation and Forest Degradation (REDD+) implementation.

REDD+ aims to reduce emissions from deforestation and forest degradation, conservation, enhancement of forest carbon stocks, and sustainable forest management (SFM). It offers incentives for developing countries to reduce emissions from forested lands and invest in low-carbon pathways to sustainable development (UN-REDD 2017). According to the Cancun Agreement, REDD+ also requires biodiversity and social safeguards (United Nations Environment Programme 2010). Strengthening of SFM can be achieved through biodiversity conservation and involving local communities in biodiversity assessment, as well as considering socio-economic, and ecological aspects. Agroforestry is one of the ways to accommodate those aspects.

In the context of REDD+, agroforest and agroforestry have the potential to reduce deforestation and forest degradation directly and indirectly (Minang et al. 2014). Agroforestry is a dynamic landscape which can contribute to improving food security, livelihoods and delivery of ecosystem services (Nair 1989; Griggs et al. 2013). According to Shibu and Sougata (2012), organic coffee agroforestry practices decrease emissions of greenhouse gases and improve biodiversity compared to conventional coffee farming. Agroforestry practices consider both long-term investment in timber products and short-term investment in non-timber forest products. Some areas in Indonesia are well known for agroforestry practices, for example Damar agroforests in Krui, West Lampung, home garden (*pekarangan*) in Java, *tembawang* in West Kalimantan, *simpukng*, forest gardens and *umaq* in East Kalimantan (Foresta et al. 2000; Marjokorpi and Ruokolainen 2003; CIFOR 2004; Mulyoutami 2009; Kaswanto and Nakagoshi 2014; Matinahoru 2014; Hartoyo 2016; Filqisthi and Kaswanto 2017).

Sustainable agroforestry practices have been promoted by the government of Indonesia and implemented by communities including in Berau District, East Kalimantan. Local community participation is a promising way for maintaining the ecosystem functions. A continuous flow of timber and non-timber forest products may indirectly maintain and enhance agroforestry biodiversity. However, gaps in knowledge in site-specific agroforestry practices in relation to biodiversity status and ecosystem functions are still recognized that limit the formulation of sound strategies for conservation and sustainable utilization at a village level. The main objective of this research was to characterize agroforest diversity at village level and their associated functions such as habitat function (i.e., plant species richness), regulation function (i.e., soil fertility), production function (i.e., timber and non-timber), information function (i.e., ethnobotanical uses).

MATERIALS AND METHODS

Study sites

The study sites were located in Kampung Birang and Kampung Merabu in Berau District, East Kalimantan Province, Indonesia (Figure 1). The distance of Kampung Birang to nearest main city Berau is 11 km. Kampung Birang is the largest village in the Gunung Tabur Subdistrict with a total area of 302 km^2. The main livelihoods in the village are farming, gardening, labor in the mining industry, fishing, business, and government service. In addition, the community usually looks for valuable *gaharu* or agarwood, and hunt for wild animals in the forests. Kampung Merabu administratively belongs to Kelay Subdistrict, Berau District, East Kalimantan. The distance of this Subdistrict to Berau is about 300 km. This village has a total area of 221 km^2 (Statistic Agency of Berau 2015). The limestone caves are the source of livelihoods for young men who generate income as cave climbers and bird nest harvesters. The climate of Berau is tropical humid with a short dry period around August (Figure 2). The mean monthly rainfall remains above 100 mm throughout the year.

The plots were surveyed jointly by scientists and the local communities in October 2015. Then, establishment and assessment of the biodiversity in the plots were started in January to February 2016 and were carried out again in January 2017. Local communities (4-5 young and elder males per village) were trained for plot establishment, tree diameter measurement, tree species identification, tree tagging, and herbarium specimens collection. They were either owner of the agroforest or have shown willingness to participate. We trained only the males because most of them have higher roles to maintain the forest and the female usually stay at home or doing some works around their home.

Sampling plot

We used purposive sampling that was based on the following criteria: (i) area should represent agroforestry practices, (ii) owned and tended by the local community, and (iii) accessibility. The characteristic of agroforestry system is integration between two or more plantations and at least they consist of a perennial or woody species (Lundgren 1982). A total of 60 plots were surveyed in Kampung Birang and Kampung Merabu. Plots were square in shape (50m x 50m). This size was in accordance with Drescher et al. (2016) research in four landscapes in Jambi, Indonesia. Also, Huang et al. (2006) used plot size 50m x 50m because of resolution image is 20-30 meter. All trees above 10 cm dbh were measured and identified by local and scientific names. Trees were classified into two size classes based on the rule of Ministry of Forestry (2016), i.e., medium trees or called poles (10≤dbh≤20 cm) and large trees or called trees (dbh>20 cm).

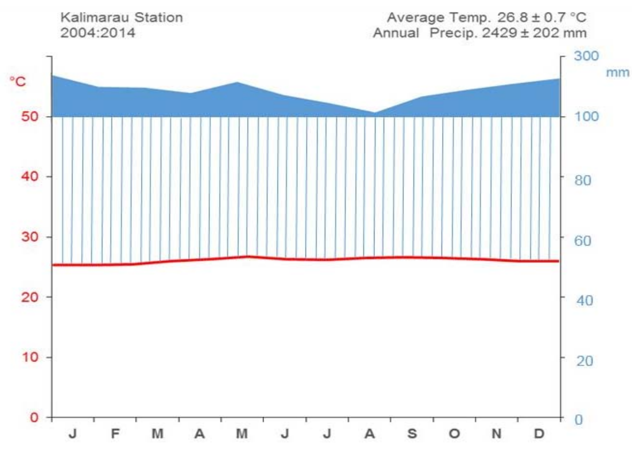


Figure 2. Average monthly temperature and rainfall at Kalimarau Airport, Berau (2004-2014), East Kalimantan, Indonesia (Hartoyo et al. 2016)

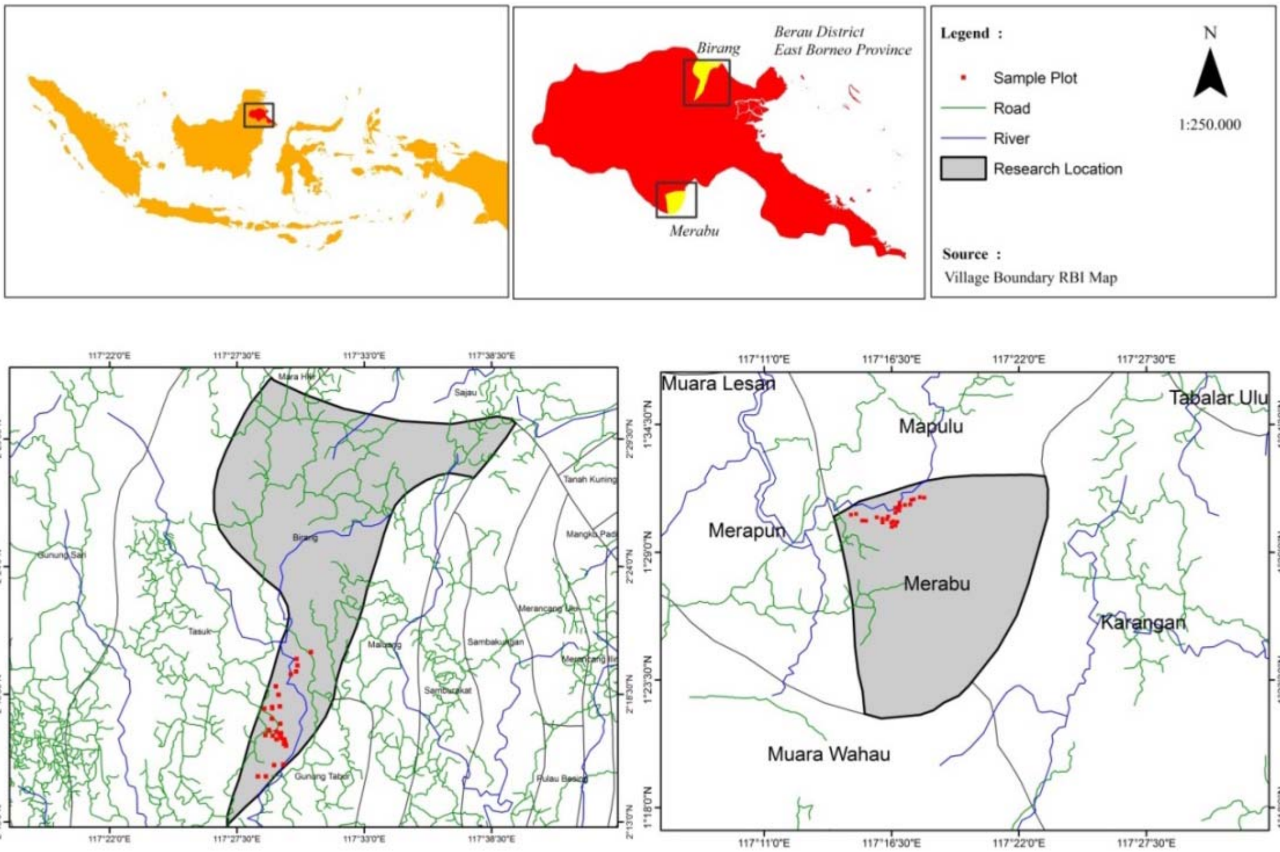


Figure 1. The location of two research sites in Kampung Birang and Kampung Merabu, Berau, East Kalimantan, Indonesia

Habitat Function: tree structure, species composition, and biodiversity assessment

We calculated the importance value index (IVI) for the tree species. IVI is obtained by adding up the value of relative density (RD), relative frequency (RF), and relative dominance (RDo) for each species (Curtis 1959 *in* Mueller-Dombois and Ellenberg 1974). Analysis of diversity index (H') was calculated by Shannon's formula (Magurran 1988). Evenness index indicates the level of individual evenness for every species (Pielou 1975 *in* Magurran 1988). Dominance index was used to understand the dominance of species in an area (Simpson 1949). Margalef's index (D_{mg}) was used as a simple measure of species richness (Margalef 1968). Based on the characteristic of trees growing under the shading, the tree species were classified into 3 types, the shade tolerant, semi-shade tolerant, and shade intolerant species. The species characteristics and uses were determined through field observation, interviews and validated using the database of Useful Tropical Plants which could be accessed at http://tropical.theferns.info/.

Regulation Function: soil analysis

We performed soil sampling at 6 plots in both villages. These plots represented high, medium, and low number individuals of trees. Soil sampling was categorized into 2 methods, the disturbed and undisturbed soil sampling, to obtain physical and chemical soil properties. Then, we analyzed the samples in service laboratory of SEAMEO BIOTROP (SL-SEAMEO BIOTROP) accredited by ISO/IEC 17025 for determining the various soil properties such as soil fertility (C, N, etc.), and soil physic (bulk density, the total of the pore, etc.).

Production and Information Functions: ethnobotanical aspects

These two essential function for human needs were assessed together for better understanding and the completeness of the information. The method for analyzing ethnobotanical aspects was conducted through field observation, interview with the local communities and validation based on the database of Useful Tropical Plants at http://tropical.theferns.info/.

RESULTS AND DISCUSSIONS

Tree stand structure and species composition

Agroforest function as important habitats for plant, animal and microbes will support the level of biological diversity. In this research, the habitat function was measured through tree stand structure and species composition, as well as biodiversity indices. In Kampung Birang, the total number of species and individuals recorded were 36 species (545 individuals) of medium trees and 34 species (572 individuals) of large trees. In Kampung Merabu, the total number of species and individuals recorded was 121 species (1689 individuals) of medium trees and 99 species (612 individuals) of large trees (Figure 3). The number of species richness and individuals across size classes in the Kampung Merabu were higher than that in Kampung Birang. The total of species in the medium tree class was higher than that in the large tree class both in Kampung Birang and Kampung Merabu. The number of species of medium and large trees in Kampung Merabu was higher than those in Kampung Birang (Figure 4.A). The number of individuals belonging to the medium tree class in Kampung Merabu was higher than that in Kampung Merabu. Meanwhile, the number of individuals belonging to the large tree class in Kampung Merabu was lower than that in Kampung Birang (Figure 4.B). Mean diameter of the medium and large trees in kampung Birang were higher than those in Kampung Merabu (Figure 4.C).

The agroforest structure reflected in relationships between class diameter and number of individuals in the Kampung Birang and Kampung Merabu resulted in reverse J-curve (Figure 5). The highest number of individuals were found in the diameter range 10-19.9 cm. The lowest number of individuals was found for diameter >50 cm. This relation is similar to that of the natural forest and unmanaged forest. De Jong (1997) said, the mature *tembawang,* a popular agroforestry practice in West Kalimantan, is a full-grown forest which has a structure that is similar to a mature natural forest and which hold considerable biodiversity. Additionally, Mulyoutami et al. (2009) explained that the structure of *simpukng* (forest garden) in East Kalimantan was almost similar to an unmanaged natural forest with high diversity and many useful species for food, fruit, fuelwood, timber, and honey.

Based on Table 1, the most frequent medium tree species that grew in Kampung Birang and Kampung Merabu were *Lansium parasitum* (langsat), *Nephelium lappaceum* (rambutan), *Mangifera indica* (ampelam/ mempalan/mangga). All of these species bear edible fruits. Table 2 showed that the large tree species which grew in both villages were *Nephelium lappaceum* (rambutan), *Vitex pinnata* (laban), *Artocarpus heterophyllus* (jackfruit). *N. lappaceum* and *A. heterophyllus* which had edible fruits. The timber of *Vitex pinnata* was used for construction and firewood.

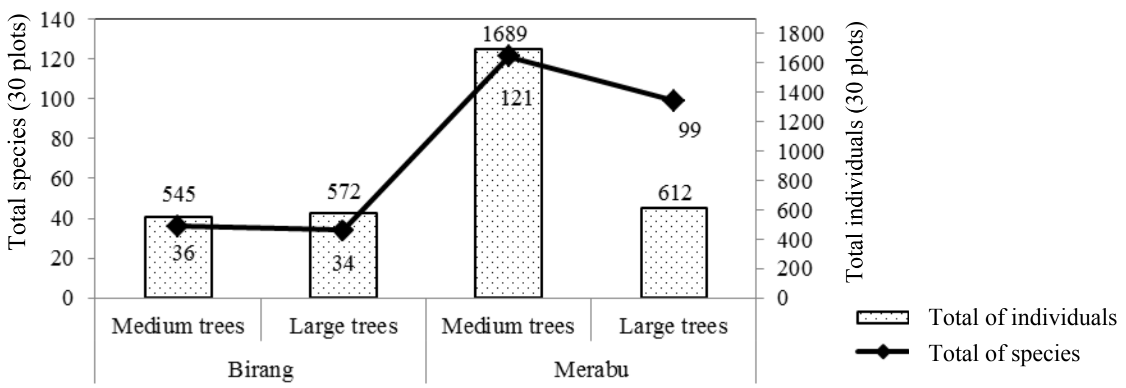
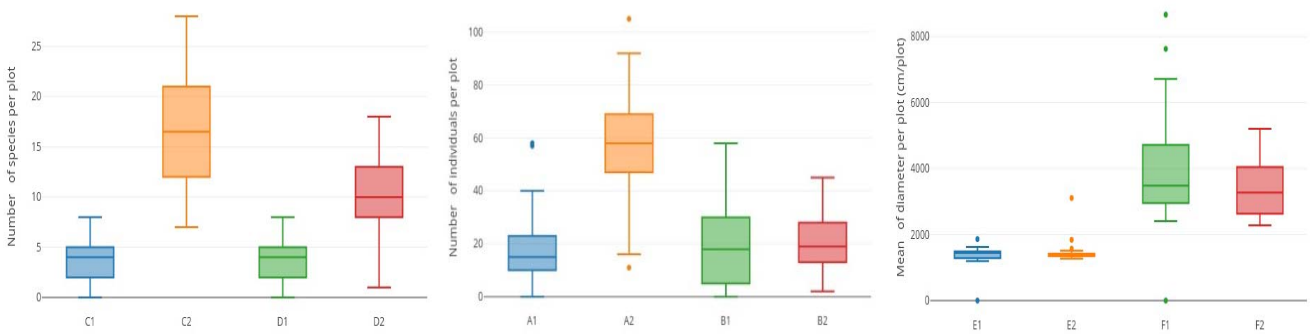


Figure 3. Total of individuals and species at the medium and large treeclasses in the Kampung Birang and Merabu of Berau, East Kalimantan, Indonesia



A B C

Figure 4. The number of species per plot (A), The number of individuals per plot (B), mean of diameter per plot (C) (A1, C1, E1= medium trees in Kampung Birang; A2, C2, E2= medium trees in kampung Merabu; B1, D1, F1= large trees in Kampung Birang; B2, D2, F2= large trees in Kampung Merabu)

Table 1 Top ten species with largest importance value index of medium trees both in Kampung Birang and Kampung Merabu of Berau, East Kalimantan, Indonesia

Species (in scientific name)	Species (in local name)	Kampung Birang				Kampung Merabu			
		RD (%)	RF (%)	Rdo (%)	IVI (%)	RD (%)	RF (%)	Rdo (%)	IVI (%)
Lansium parasitum (Osbeck) K.C. Sahni & Bennet	Langsat	46	19	47	112	2	3	2	7
Nephelium lappaceum L.	Rambutan	18	11	14	42	14	4	14	32
Durio zibethinus L.	Durian	5	10	5	19	-	-	-	-
Anthocephalus cadamba (Roxb.) Miq.	Kulimpayan	6	3	7	15	-	-	-	-
Parkia speciosa Hassk	Petai	3	5	4	13	-	-	-	-
Sandoricum koetjape (Burm .f.) Merr.	Simangar	2	4	2	8	-	-	-	-
Artocarpus integer (Thunb.) Merr.	Cempedak	2	4	2	8	-	-	-	-
Tectona grandis Linn. F.	Jati	2	2	3	7	-	-	-	-
Syzygium malaccense (L.) Merr. & L.M. Perry	Jambu lokal	1	4	2	7	-	-	-	-
Mangifera indica L.	Ampelam/ mempalan/ mangga	1	5	1	6	3	3	3	9
Vitex pinnata L.	Belangkan/leban	-	-	-	-	17	4	16	36
Theobroma cacao L.	Kakao	-	-	-	-	11	2	10	23
Artocarpus heterophyllus Lamk.	Jackfruit	-	-	-	-	3	3	4	11
Glochidion rubrum Blume	Berenai	-	-	-	-	3	3	4	10
Ficus septica Burm.f.	Berbocom	-	-	-	-	3	3	3	9
Mallotus mollissimus (Geiseler) Airy Shaw	Binang	-	-	-	-	3	2	3	8
Willughbeia coriacea Wall.	Karet	-	-	-	-	4	0	4	8

Based on the result of soil classification (Hardjowigeno 1995), soil condition in this research site was categorized as acid (pH 5.33 in Kampung Birang and pH 5.40 in Kampung Merabu). The organic matter content was high in Kampung Birang (3.07) and very low in Kampung Merabu (1.50). Soil organic matter could maintain the population dynamics of beneficial microorganism and improves biological nitrogen fixation in soil. It contributes to the cycling of nutrient and other ecosystem functions, and all soil functions contribute to ecosystem services (Raj et al. 2015). Nitrogen (N) and phosphorus (P) are major essential nutrients which are required to support the plant growth. N in Kampung Birang was moderate (0.39) whereas in Kampung Merabu it was classified as low (0.19). P was very high in Kampung Birang (16.30) and was found to be moderate in Kampung Merabu (8.17). C/N values for both Kampung Birang and Kampung Merabu were categorized as low. This result indicates that the decomposition rate in both villages was high. Soil texture in Kampung Birang was silty clay whereas it was clayey in Kampung Merabu (Table 5 and 6). Kampung Merabu was more diverse in term of plant diversity than Kampung Birang, although results of soil analysis showed that soil in Kampung Birang was better than soil in Kampung Merabu

However, harmful human activities that could disturb the agroforest stability were pre-identified. There were indications of human disturbances such as mining activities, oil and natural gas exploration, and also illegal logging. The disturbances to the forests in Kampung Birang were higher than those in Kampung Merabu. This is mainly due to the closer distance of Kampung Birang to the city was making it more accessible than Kampung Merabu. Additionally, some mining companies and an oil and gas company occupied an area of Kampung Birang. These agroforests were converted to the non-forest. The local communities in Kampung Birang cut down canopy trees which disturbed langsat (*L. parasiticum)* growth. This practice is done because of the high economic value of langsat fruit in Kampung Birang. Kampung Merabu was further away from the nearest city and difficult to access. In addition, the local communities in Kampung Merabu were more aware of the importance of forest functions to their livelihood. In addition, forests in Kampung Merabu were in a more preserved condition due to limited market access for harvested fruits that were only consumed locally. In the 1990s, the local communities planted some fruit species along the river and around the villages. They called the tree gardens *umaq*. They harvested fruits in the *umaq* but did no maintenance due to their lack of knowledge of silviculture treatment.

Tree structure and composition in Kampung Birang

Importance value index (IVI) is the sum result of RD, RF, and Rdo. This index shows the role of a species in a particular community or research site. *Langsat parasitum* (langsat) belongs to Meliaceae family dominated at medium and large tree classes in Kampung Birang as shown from its importance value index of 112% at the medium tree and 102% at the large tree class. The capability of langsat to occupy almost all of the research sites showed that this species had high adaptability. The abundance of Langsat was resulted from the local communities who cultivate the fruit as a commercial product with superior traits, serving as one of the highest incomes for them. The communities have 2 types of langsat, namely langsat roko and langsat telur. The local communities usually differentiate between the types based on the tree diameter, leaf size, and fruit size and taste.

Morphologically, langsat roko has bigger tree diameter, wider leaves, thicker rind, sweeter fruit, more resistant to rot, and less easy to fall than langsat telur. Langsat is also empirically used to treat malaria by people of Dayak Seberuang in West Kalimantan and other ethnic groups in Kalimantan, Indonesia as well as Sabah, Malaysia (Yapp 2002; Takoy et al. 2013). Langsat roko is more expensive than langsat telur. The price of langsat roko is about Rp 25 000-Rp 35 000 per kg, while the price of langsat telur is about Rp 5 000-Rp 8 500 per kg. Kampung Birang is known as a langsat supplier in the East Kalimantan. Upon identifying local species in the plots in Kampung Birang, we found other fruit trees of *Durio kutejensis* (elai), and *Durio okleyanus* Griff. (karatungan) (Figure 6).

Tree structure and composition in Kampung Merabu

Vitex pinnata (belangkan/leban) belonging to Lamiaceae family dominated the medium tree class found in Kampung Merabu. *V. pinnata* showed an IVI of 36 %. We found this species resided at the riverside. It is used as firewood by the community. *V. pinnata* belongs to pioneer species. Therefore, this species was more dominant than other species. According to Useful Tropical Plants Database (2014), *V. pinnata* is an evergreen and a pioneer tree in planting schemes to reclaim land infested with Imperata grass and it is one of the recommended species to plant along roadsides. It is also one of the recommended trees in its native range for shade tree. *V. pinnata* (Belangkan/leban) is generally found in an open area, secondary forest, and on riversides (Lemmens et al. 1995). *Artocarpus elasticus* (terap) belonging to Moraceae family, dominated the large tree group found in Kampung Merabu. *A. elasticus* exhibited an IVI of 26%. The local communities consume its fruits. Similar to *V. pinnata*, We found that some of this species grew along the riverside.

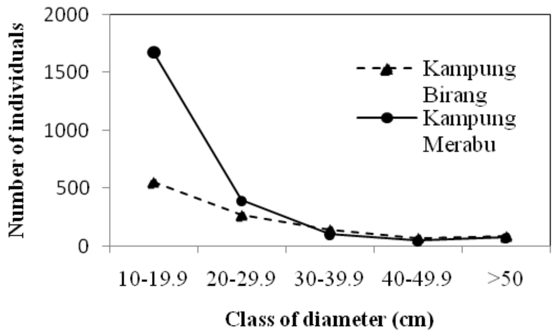


Figure 5. The relationship between class diameter and number of individuals in the Kampung Birang and Kampung Merabu of Berau, East Kalimantan, Indonesia

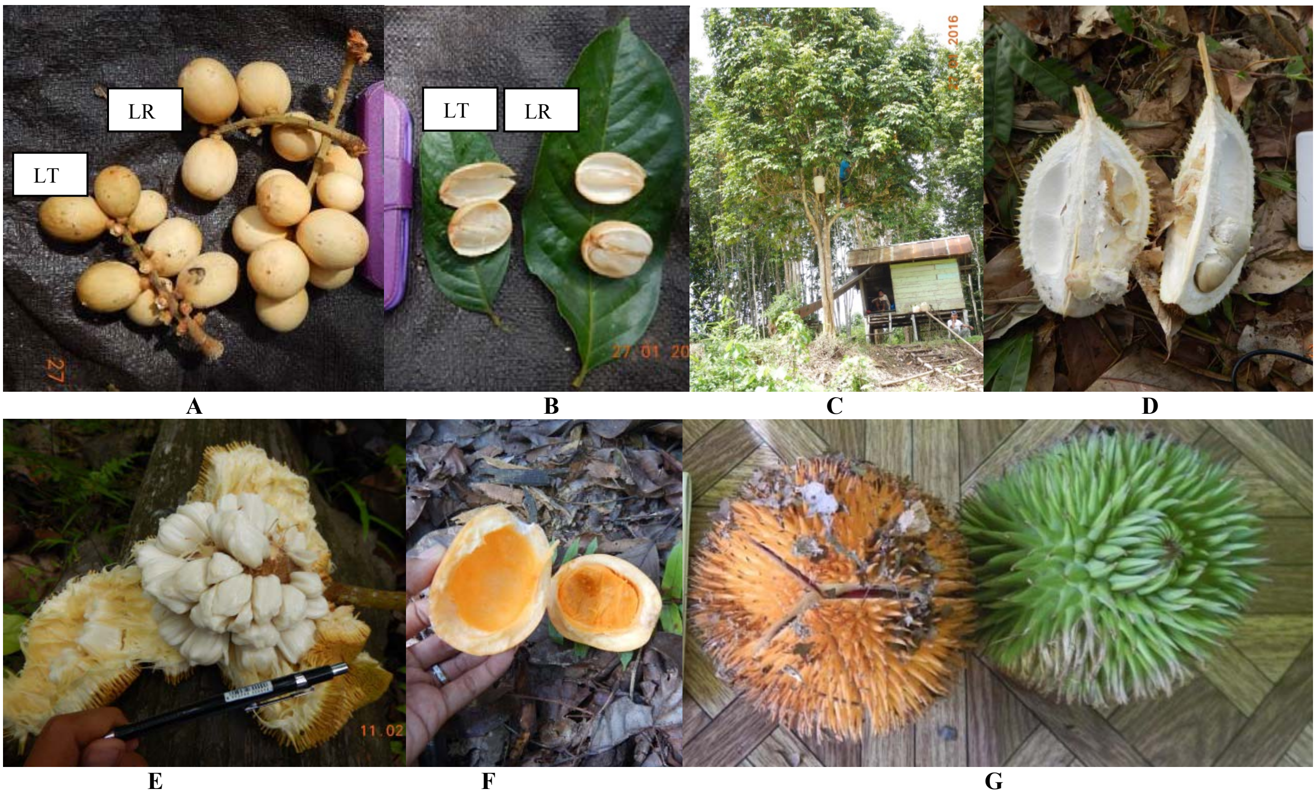


Figure 6. The difference between langsat telur (LT, *left*) and langsat roko (LR, *right*) (A,B), langsat tree (C), *Durio okleyanus* Griff. (karatungan) (D), *Artocarpus odoratissimus* Blanco (kameng) (E), *Willughbeia coriacea* Wall (karet) (F), and *Durio dulcis* Becc. (tebelak) (G)

De Jong (1997) reported that there was a rubber garden located adjacent to *tembawang*, a popular agroforestry practice. However, it was common practice to plant fruit trees in the rubber garden. In Kampung Merabu, there is an area to plant rubber where every family obtained 2 ha land to cultivate the plant. The communities obtained the rubber seedlings from the government. The communities also planted fruit species alongside the rubber trees. However, the fruit plantations were still too young, so we did not observe the fruit trees. The other fruits found in kampung Merabu were *Durio dulcis* Becc. (tebelak), *Artocarpus odoratissimus* Blanco (kameng), and *Willughbeia coriacea* Wall (karet).

Biodiversity indices

Based on Magurran's (1988) diversity index (H') category, 2<H'<3 was categorized as moderate and H'>3 as high diversity. H' index in Kampung Birang for medium and large tree were 2.1 and 2.0, respectively. H' index in Kampung Merabu for medium and large tree classes were 3.5 and 3.7, respectively. Thus, according to the H' index, Kampung Birang had a moderate diversity, while Kampung had a high diversity. Odum (1971) categorized that a stable forest is defined by H'≥3.0 and not stable forest by H'< 3.0. Therefore, forests in Kampung Birang is categorized as not stable whereas those in Kampung Merabu as stable forests. The values of dominance index (C) at the medium and large tree classes in Kampung Birang were 0.2 and 0.3, and in Kampung Merabu were 0.1 and 0.05, respectively. These diversity levels showed that the dominance of species was not found both in Kampung Birang and Kampung Merabu. Values of Evenness index (E) for the medium and large tree classes in Kampung Birang were 0.6 and in Kampung Merabu were 0.7 and 0.8, respectively. The differences of E index is due to the differences of H' in both locations. According to Magurran (1988), 0.3<E<0.6 indicates a moderate evenness and E>0.6 a high evenness. E index for both medium and large tree classes in Kampung Birang were 0.6 (moderate). E index for the medium and large tree classes in kampung Merabu were 0.7 and 0.8 (high). The values of Margalef index ($D_{mg)}$ shows species richness as one of habitat function indicator. D_{mg} for the medium and large tree classes in Kampung Birang were 5.6 and 5.2, respectively. D_{mg} index for the medium and large tree classes in Kampung Merabu were 16.1 and 15.3, respectively (Table 3). Therefore, both villages belonged to high species richness category. However, enrichment planting using high economic value species such as *L. parasitum* (langsat), *Artocarpus heterophyllus* (jackfruit), *Durio zibethinus* (durian), *Durio kutejensis* (elai/kelay), *Durio dulcis* (lahung), and *Parkia speciosa* (petai) in Kampung Birang is still needed to optimize the production function.

The characteristics and uses of agroforestry species

As a habitat function, study on trees species grown under shading is very important due to silviculture treatment and management, especially in multi-layers canopy such as in agroforestry practices. On the one hand, shade-intolerant species require full sunlight to survive and thus, grow well by opening the canopy through logging. On the other hand, tolerant species which require shading will not survive and eventually die. The top ten tree species with the largest importance value index (IVI) across both villages were 80% shade-intolerant species and 20% semi-tolerant species (Figure 7). The dominant medium and large tree species in Kampung Birang were *L. parasitum* (langsat). Langsat is a shade-semi-tolerant species so in the growth level its canopy will cover the canopy of other species. As a consequence, only semi and shade-tolerant species will survive under langsat. The dominant medium tree species in Kampung Merabu was *V. pinnata* (belangkan/leban). It is a shade-intolerant, pioneer species and used mainly for construction and firewood. The dominant large tree species in Kampung Merabu was *A. elasticus* (terap). It is a semi-tolerant species and has edible fruits. In the growth phase level, both *V. pinnata* and *A. elasticus* will cover the other species. Therefore, in the decision management, to enrich the species we need the planting of shade-semi-tolerant and/or shade-tolerant species.

Study on the forest function, particularly for production and information function revealed that most of the species belonging to the top ten species with the highest importance value index for both medium and large tree classes in Kampung Birang and Kampung Merabu have edible fruits. The other species were used for building material, medicines, fodder, and firewood (Table 4). In agroforestry practices, the products are not only timber but also non-timber products. In this case, the fruit was the main non-timber product in both villages. In relation to REDD+ mechanism and implementation, agroforestry practices should be managed sustainably by conserving targeted species groups and their utilization. The local communities in Kampung Birang maintain the tree species because of their economic value or production function, demonstrating the role of a non-timber product indirectly securing the ecosystem. In addition, sense of belonging to the communities has emerged due to this high people-forest dependency. Summary of ecological and ethnobotanical attributes in agroforestry practices can be shown in Table 7.

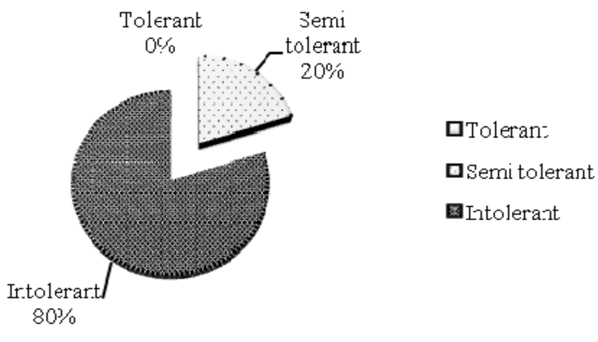


Figure 7. Percentage of species characteristics in agroforestry practices

Table 2. Top ten species with largest importance value index of large trees both in Kampung Birang and Kampung Merabu of Berau, East Kalimantan, Indonesia

Species (in scientific name)	Species (in local name)	Kampung Birang				Kampung Merabu			
		RD (%)	RF (%)	Rdo (%)	IVI (%)	RD (%)	RF (%)	Rdo (%)	IVI (%)
Lansium parasitum (Osbeck) K.C. Sahni & Bennet	Langsat	53	20	29	102	-	-	-	-
Durio zibethinus L.	Durian	11	18	16	45	-	-	-	-
Tectona grandis Linn. F.	Jati	9	2	4	15	-	-	-	-
Durio kutejensis (Hassk.) Becc.	Elai/ Kelay	11	18	16	14	-	-	-	-
Nephelium lappaceum L.	Rambutan	2	4	6	13	12	6	4	21
Durio dulcis Becc.	Lahung	1	3	7	12	-	-	-	-
Vitex pinnata L.	Laban	4	3	4	11	10	5	6	21
Ceiba pentandra (L.) Gaertn.	Kapuk/Randu	1	3	7	10	-	-	-	-
Artocarpus heterophyllus Lamk.	Jackfruit	1	6	1	8	6	4	4	13
Lansium domesticum Correa	Duku	0	1	6	8	-	-	-	-
Artocarpus elasticus Reinw. Ex Blume	Terap	-	-	-	-	3	5	18	26
Kleinhovia hospita L.	Temangar	-	-	-	-	9	2	10	21
Octomeles sumatrana Miq.	Benuang/Binuang	-	-	-	-	4	1	11	16
Mangifera indica L.	Mempalan/Mangga	-	-	-	-	5	5	4	14
Litsea costalis var.nidularis (Gamble) Ng	Mali	-	-	-	-	4	2	4	9
Dimocarpus longan Lour.	Dupar/mata kucing	-	-	-	-	3	3	2	8
Lannea coromandelica (Houtt.) Merr.	Ajaran	-	-	-	-	2	3	3	8

Table 3 Biodiversity index of medium and large trees both in Kampung Birang and Kampung Merabu of Berau, East Kalimantan, Indonesia

The level of tree growth	Kampung Birang				Kampung Merabu			
	H'	C	E	D_{mg}	H'	C	E	D_{mg}
Medium trees	1.1	0.2	0.3	5.6	1.7	0.04	0.4	16.1
Large trees	1.1	0.2	0.3	5.2	1.7	0.04	0.4	15.3

Table 5. Soil physical properties of Kampung Birang and Kampung Merabu of Berau, East Kalimantan, Indonesia (Hardjowigeno 1995)

Locations	Deep (cm)	Bulk Density g/cc	Total of pore space % (Volume)	The water content at pF 1.00	2.00	2.54	4.20	Drainage pore Fast	Slow	Water available %	Permeability cm/hour
				% (Volume)				(%Vol)			
KB6	-	0.98	63.02	62.07	60.67	56.20	43.46	2.35	4.47	12.74	16.35
KB10	-	1.41	46.79	46.26	45.86	40.13	24.97	0.93	5.73	15.16	1.08
KB17	-	1.19	55.09	53.17	52.92	48.55	38.13	2.17	4.37	10.42	12.43
Average	-	1.19	54.97 (m)	53.83	53.15	48.29	35.52	1.82	4.86	12.77	9.95 (rf)
KM 5	-	1.37	48.30	47.83	47.44	41.88	33.25	0.86	5.56	8.63	0.72
KM 21	-	1.26	52.45	51.11	50.41	47.03	35.48	2.04	3.38	11.55	8.41
KM 29	-	1.29	51.32	50.35	48.78	45.09	34.66	2.54	3.69	10.43	11.12
Average	-	1.31	50.69 (m)	49.76	48.88	44.67	34.46	1.81	4.21	10.20	6.75 (rf)

Note: m = moderate, rf = rather fast

Table 4. The characteristics and uses of agroforestry species both in Kampung Birang and Kampung Merabu of Berau, East Kalimantan, Indonesia (species with the highest importance value index)

Local name	Species	Durability classes	Strength class	Tolerant/ intolerant	Uses
Langsat	*Lansium parasitum* (Osbeck) K.C. Sahni & Bennet	III[e]	II[e]	Semi-tolerant	The fruit is edible; the twig can be used for firewood; the bark can be used as malaria medicine
Rambutan	*Nephelium lappaceum* L.	III[d,g]	I-II[d,g]	Intolerant	The fruit is edible; the green fruit is said to be astringent, stomatchi c, and anthelmintic [c]; the young shoots can be used as a green color [c]; a red dye can be obtained from the leaves and fruit [c]
Durian	*Durio zibethinus L.*	IV-V[a]	II-III[a]	Intolerant	The fruit is edible; the fruit is used as an aphrodisiac [c]; it is used in interior construction [c]
Kulimpayan	*Anthocephalus cadamba* (Roxb.) Miq.	V[a]	III-IV[a]	Intolerant	The stem can be used for building construction (wall), floor.
Petai	*Parkia speciosa* Hassk	V[e]	III-IV[b]	Intolerant	The fruit is edible; the wood is used for light construction, furniture, pulp and paper, wood energy [b]
Simangar	*Sandoricum koetjape* (Burm .f.) Merr.	V[f]	III-IV[h]	Intolerant	The fruit is edible; the powdered bark is an effective treatment for ringworms and contains triterpenes with anti-cancer activity [c]
Cempedak	*Artocarpus integer* (Thunb.) Merr.	II[d]	III-IV[a]	Semi-tolerant	The fruit is edible; vinir in bare core [b], light construction [b]
Jati*	*Tectona grandis* Linn. F.	I-II[a]	II[a]	Intolerant	The stem can be used for building construction (wall), floor; a red dye obtained from boiling the wood shavings of the tree has been used to color Easter eggs [c]; it is vermifuge, promotes digestion, effective in relieving bilious headaches and toothaches [c]
Jambu	*Syzygium malaccense* (L.) Merr. & L.M. Perry	-	II[b]	Intolerant	The fruit is edible; the wood is used for light and heavy construction [b], furniture[b], firewood [b], pulp and paper [b]
Ampelam/ mempalan/ mango	*Mangifera indica* L.	V[e]	III[b]	Intolerant	The fruit is edible; the wood is used for furniture[b], vinir[b], pulp[b]
Elai/ kelay	*Durio kutejensis* (Hassk.) Becc.	IV-V[a]	II-III[a]	Intolerant	The fruit is edible; the relatively durable wood is used in interior construction and for making furniture[c]
Lahung	*Durio dulcis* Becc.	IV-V[a]	II-III[a]	Intolerant	The fruit is edible; the relatively durable wood is used in interior construction and for making furniture[c]
Laban/leban/belangkan	*Vitex pinnata* L.	II-III[a]	II-III[a]	Intolerant	For firewood; a decoction of the bark is used to treat stomachache[c]; the timber is used for construction[c]; charcoal[c]
Kapuk/randu*	*Ceiba pentandra* (L.) Gaertn.	IV-V[g]	IV-V[g]	Intolerant	The wood can be used for making a box and decoration; tender leaves, buds, and fruit are mucilaginous and are eaten like okra[c]; it is an astringent, diuretic herb that lower fevers, relaxes spasms and controls bleeding[c]
Jackfruit	*Artocarpus heterophyllus* Lamk.	II-III[e]	III-IV[a]	Semi-tolerant	The fruit is edible; vinir in bare core[b], light construction[b]
Duku	*Lansium domesticum* Correa	III[e]	II[e]	Semi-tolerant	The fruit is edible; the dried pericarp is used in the treatment of diarrhoea and intestinal spasms, amalria and other fevers[c]
Kakao*	*Theobroma cacao* L.	-	-	Tolerant	The fruit is edible; it is a bitter, stimulant, diuretic herb that stimulates the nervous system, lowers blood pressure and dilates the coronary arteries[c]
Berenai	*Glochidion rubrum* Blume	-	-	Intolerant	The fruit is eaten by bird; the macerated leaves are used in the treatment of haemorrhoids[c]; the wood is used for timber[c]; the mixture of root and leaves can be used to cure dysentery and diarrhoea[c]
Berbocom	*Ficus septica* Burm.f.	V[f,h]	IV[h]	Intolerant	The fruit is eaten by mouse deer, pig, deer; the latex is used to cure certain varieties of herpes and wounds caused by poisonous fish[c]

Binang	*Mallotus mollissimus* (Geiseler) Airy Shaw	-	-	Intolerant	The stem can be used as a construction; the bark can be used as a toy
Karet	*Willughbeia coriacea* Wall.	-	-	Intolerant	The fruit is edible; The sap can be used to make baseball ball; the latex is used medicinally[c]
Terap	*Artocarpus elasticus* Reinw. Ex Blume	II-III[e]	III-IV[a]	Semi-tolerant	The fruit is edible; vinir in bare core[b], light construction[b]
Temangar	*Kleinhovia hospita* L.	-	-	Intolerant	The bark can be used as a rope; the wood can be used for firewood; the crushed leaves are used to treat skin diseases and headache[c]; the energy value of the wood is about 19 000 kJ/kg[c]
Benuang/ binuang	*Octomeles sumatrana* Miq.	V[f]	IV-V[a]	Intolerant	The stem can be used for building construction (wall), floor; young leaves are cooked and eaten as a vegetable[c]; a leaf extract is used to cure stomachache[c]
Mali	*Litsea costalis* var.*nidularis* (Gamble) Ng	III-V[a]	II-IV[a]	Intolerant	The fruit is edible; vinir in bare core[b], light construction[b]
Dupar/ mata kucing	*Dimocarpus longan* Lour.	-	-	Intolerant	For firewood; fruit is edible; it is used for construction[c]
Ajaran	*Lannea coromandelica* (Houtt.) Merr.	V[h]	III-IV[h]	Intolerant	The fruit is edible; the fruit is eaten by fish; the bark and the leaves are used as a medicine[c]; A soluble resin is used for calico printing and protecting nets[c]

Note: *) Introduced species;[a)] Anon (2010); [b)] ITTO (2009); [c)] Useful Tropical Plants (2014); [d)] Abdurrohim (2007); [e)] FORDA Ciamis (2009); [f)] Muslich and Sumarni (2010); [g)] Wahyudi et al. (2007); [h)] Seng (1990)

Table 6. Soil chemical properties of Kampung Birang and Merabu of Berau, East Kalimantan, Indonesia (Hardjowigeno 1995)

Locations	***pH (1 : 1) SNI 03-6787-2002**		***C Org**	***N Total**	**C/N Ratio**	***P_2O_5 available**	**Exchangeable cation and cation exchange capacity (SL-MU-TT-07 c (Buffer Extract NH_4OAc 1,0 N pH 7,0)**						**Base saturation**	**Al-H_{dd} SL-MU-TT-09 (Extract KCl 1N)**		**Texture SL-MU-TT-10 (Pipet)**		
			SNI 13-4720-1998 (Walkey & Black)	**SNI 13-4721-1998 (Kjeldahl)**		**SL-MU-TT-05 (Bray I/II)**	***Ca**	***Mg**	***K**	***Na**	**Total**	**KTK**		**Al^{3+}**	**H^+**	**Sand (50µ-2mm)**	**Silt (2µ-50µ)**	**Clay (0.2µ-2µ)**
	H_2O	**$CaCl_2$**	**%**	**%**		**ppm**	**cmol/kg**						**%**	**me/100g**	**me/100g**	**%**	**%**	**%**
KB6	6.1	5.9	2.81	0.36	8	14.0	1.10	4.52	1.01	0.16	6.79	25.26	26.87	0.00	0.23	15.6	45.0	39.4
KB10	5.6	5.2	3.57	0.47	8	19.2	17.21	7.05	1.74	0.24	26.24	32.66	80.34	0.00	0.15	6.1	41.3	52.6
KB17	4.3	3.9	2.84	0.35	8	15.7	2.02	2.17	1.30	0.22	5.71	25.56	22.34	9.65	0.93	22.2	39.0	38.8
Average	**5.33 (a)**	**5.00**	**3.07 (h)**	**0.39 (m)**	**8 (l)**	**16.30 (vh)**	**6.78**	**4.58**	**1.35**	**0.21**	**12.91**	**27.83 (h)**	**43.18**	**3.22**	**0.44**	**14.63**	**41.77**	**43.60**
KM 5	5.5	4.8	2.15	0.26	8	5.7	10.93	5.34	0.66	0.21	17.13	20.88	82.02	0.00	0.39	4.7	37.1	58.2
KM 21	5.1	4.2	1.30	0.16	8	6.7	1.10	1.15	0.52	0.15	2.92	7.68	38.08	1.88	0.07	36.6	32.6	30.8
KM 29	5.6	5.0	1.05	0.14	8	12.1	2.80	1.16	0.16	0.13	4.25	7.23	58.75	0.00	0.20	37.0	28.3	34.7
Average	**5.40 (a)**	**4.67**	**1.50 (vl)**	**0.19 (l)**	**8 (l)**	**8.17 (m)**	**4.94**	**2.55**	**0.45**	**0.16**	**8.10**	**11.93 (l)**	**59.62**	**0.63**	**0.22**	**26.10**	**32.67**	**41.23**

Note: a = acid, h = high, vl= very low, m = moderate, l = low, vf = very high

Table 7 Summary of ecological and ethnobotanical attributes in agroforestry practices

Attributes	Kampung Birang	Kampung Merabu
Environment		
Climate Type	Tropical humid	Tropical humid
Soil Properties	pH: acid Organic matter: high N: moderate P: very high Texture: silty clay	pH: acid Organic matter: very low N: low P: moderate Texture: clay
Biodiversity and ecosystem services		
Stand Structure	Reverse J-curve on class diameter and number of individuals 36 species (546 individuals) at medium tress 34 species (572 individuals) at large trees	Reverse J-curve on class diameter and number of individuals 121 species (1 693 individuals) at medium trees 99 species (612 individuals) at large trees
Composition	The highest IVI at medium and large trees were *L. parasitum* (langsat)	The highest IVI at medium tree was *V. pinnata* (belangkan/leban) The highest IVI at large tree was *A. elasticus* (terap)
Indices	H': low C: no dominant species E: moderate D_{mg}: high	H': low C: no dominant species E: moderate D_{mg}: high
Ethnobotany		
Uses (the top ten species with the highest importance value index at)	Edible fruits:*L. parasitum* (langsat), *N. Lappaceum* (rambutan), *D. zibethinus* (durian), *P. speciosa* (petai), *S. Koetjape* (simangar), *A. integer* (cempedak), *S. malaccense* (jambu), *M. indica* (ampelam/mango), *D. kutejensis* (elai/kelay), *D. dulcis* (lahung), *A. heterophyllus* (jackfruit), and *L. domesticum* (duku)	Edible fruits: *N. lappaceum* (rambutan), *T. cacao* (kakao), *A. heterophyllus* (jackfruit), *M. indica* (mempalan/mango), *W. coriacea* (karet), *L. parasitum* (langsat), *A. elasticus* (terap), *L. costalis* (mali), *D. longan* (dupar/mata kucing), *L. coromandelica* (ajaran).
	Building material: *D. zibethinus* (durian),*A. cadamba* (kulimpayan), *P. speciosa* (petai), *A. integer* (cempedak), *T. grandis* (jati), *S. malaccense* (jambu), *D. kutejensis* (elai/kelay), *D. dulcis* (lahung), *V. pinnata* (laban), and *A. heterophyllus* (jackfruit)	Material building: material building such as *V. pinnata* (belangkan/leban), *A. heterophyllus* (jackfruit), *M. indica* (mempalan/mango), *M. mollissimus* (binang), *A. elasticus* (terap), *K. hospita* (temangar), and *L. costalis* (mali)
	Energy (firewood): *L. parasitum*(langsat), and *V. pinnata* (laban), and *S. malaccense* (jambu).	Energy (firewood) were *V. pinnata* (belangkan/leban), *L. parasitum* (langsat), *K. hospita* (temangar), and *D. longan* (dupar/mata kucing).

In conclusion, the diversity indices (H') was moderate in Kampung Birang and classified as high in Kampung Merabu was generally, although species richness indices (D_{mg}) for both medium and large tree classes in both sites were categorized as high. Kampung Merabu has higher tree diversity than Kampung Birang, although soil quality analysis indicates that Kampung Birang had better fertility than Kampung Merabu. The top ten tree species with the largest importance value index (IVI) across both villages were classified as shade intolerant species (80%), while the remaining 20% as shade-semi-tolerant species. Most of the species were edible fruit implying the significance of agroforestry to produce not only timber but also non-timber forest products. The role of non-timber products is well-recognized and could be considered as the key component for conservation and sustainable use of plant biodiversity.

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