Plant diversity in logged over forest in Mahakam Ulu, East Kalimantan, Indonesia

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Abstract. *Setiawan AW, Tjiu A, Meididit A, Iswinanto, Ginanjar A, Atut Y, Agusti R. 2021. Plant diversity in logged over forest in Mahakam Ulu, East Kalimantan, Indonesia. Biodiversitas 22: 4829-4838.* A study of flora was conducted in the Ratah Timber concession area. The objectives of this study were to calculate the Importance Value Index (IVI) and identify species diversity in Mahakam Ulu, East Kalimantan. A survey was carried out in 128 plots within 13 transects placed purposively. Vegetation sampling was conducted using line-transect and a quadrat method. As many as 530 species belonging to 79 families were found. Of these species, 420 species were found in observation plots with 374 of the species being trees. The most dominant tree species were *Endertia spectabilis, Shorea pinanga* and *Shorea leprosula* with IVI of 10.24%, 8.25%, and 6.96%, respectively. In total, 114 species or 21.5% are endemic species of Borneo. The Shannon-Wiener diversity index at tree level was 5.51 and at seedling level was 4.95. The highest Similarity Index was found between transects 23 and 21, meanwhile the lowest was between transects 05 and 15. This study found 61 species that are classified on the International Union for Conservation of Nature (IUCN) Red List (2020-1) as critically endangered (16), endangered (11), and vulnerable (34) species.

Keywords: Borneo, diversity, endemic, flora

INTRODUCTION

Borneo is a source of biodiversity colonization in South East Asia (de Bruyn et al. 2014). Despite the absence of volcanoes, Borneo has a lot of substrate variations which are important in biodiversity evolution (de Bruyn et al. 2014; Yu et al. 2021). Borneo was considered by several studies as the center of diversification for multiple taxa (Nauheimer et al. 2012; Webb and Ree 2012) including the genus *Artocarpus*, making it an evolutionary biodiversity hotspot (Williams et al. 2017). Southeast Asian forests can be characterized by the ubiquity of Dipterocarpaceae (Aoyagi et al. 2012; Heckenhauer et al. 2018; Raes et al. 2014). The number of dipterocarps is the highest in Borneo Island (about 267 species) or Kalimantan (about 200 species) (Ashton 1982; Purwaningsih 2004). Occupying the Sunda Shelf in the Indo-Australian Archipelago and Southeast Asia region, Borneo sits astride the Equator (Husson et al. 2019). The island has a high degree of regional and local flora endemism (Lohman et al. 2011; von Rintelen et al. 2017; Wong 2011).

The basic forests ecology has to be understood in order to establish a sound forest management (Krisnawati et al. 2011). The lack of data suitable for conservation action priority setting often hampers conservation efforts targeting plant diversity (Darbyshire et al. 2017). Administratively, the island of Borneo is owned by three countries, namely Indonesia, Brunei Darussalam and Malaysia. Kalimantan Angiospermae diversity is second only to Java, although the area of Borneo is larger than that of Java (Retnowati et al. 2019). The fact that numerous collaborative research loci of Indonesian flora were mostly in Java Island is among the reasons why the number of species in Java Island is higher than that in Borneo. The estimate of collection density in Borneo is much less than Java at a ratio of 35:199 collections per 100 km^2 (Middleton et al. 2019). As a biodiversity hotspot, Borneo urgently needs effective conservation actions (Voigt et al. 2021). Basic biodiversity research that includes botanical explorations is one crucial activity that will help accelerate the planning and formulation of conservation plans in Borneo (Hairah et al. 2017; Sabran et al. 2014). One of the studies on botanical biodiversity is vegetation analysis. In Borneo, vegetation analysis for lowland trees in the whole island was conducted by Slik et al. (2003). However, the research was limited and did not include the Mahakam Ulu area in the sample. For this reason, the study of the unique lowland forests in Mahakam Ulu needs to be conducted. Therefore, the objectives of this study are to calculate the IVI and identify species diversity in Mahakam Ulu Forest. WWF Indonesia-Mahakam Kayan Project has conducted research in the Ratah Timber concession area. It is expected that the findings of this research will enrich the existing knowledge about forest formation type and provide a better

understanding of its ecological values.

MATERIALS AND METHODS

Study area

A vegetation survey in the forest area of Ratah Timber concession was conducted from March 18 to April 7, 2020.

The survey was carried out in 13 transects placed purposively, expected that they could represent the whole concession area and every forest coverage. (Figure 1 and Figure 2). The composition of forest vegetation in the study area is mixed dipterocarp forest. This forest type normally grows and develops in dryland habitats, in areas with undulating topography like hills or mountains.
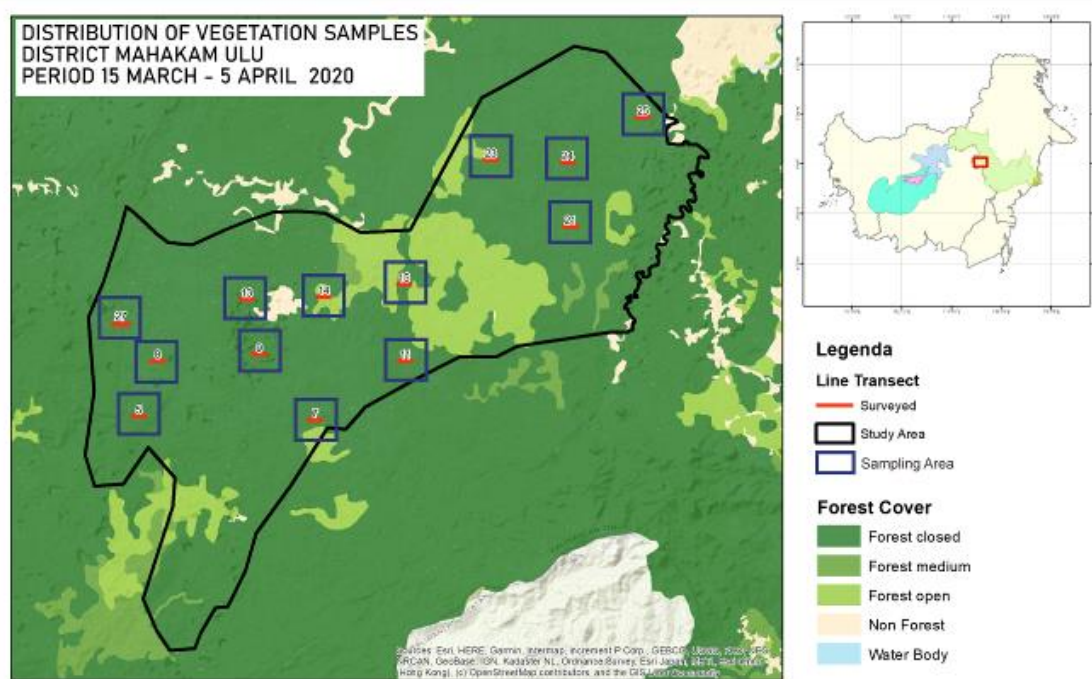

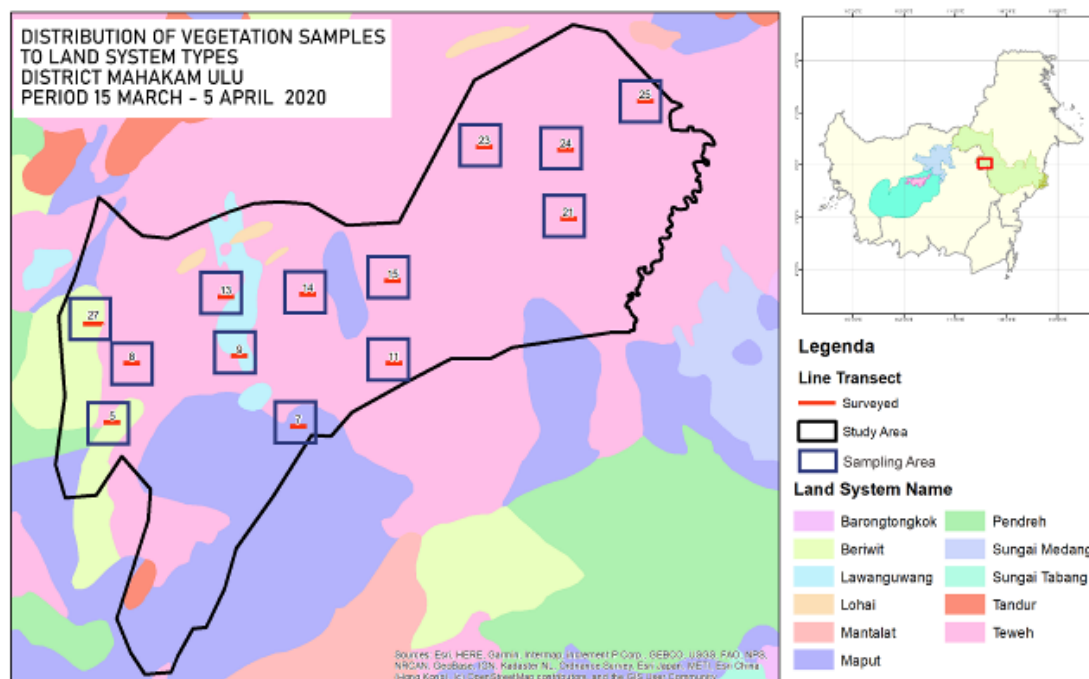**Figure 1.** Plot samplings distribution map (blue square)

Figure 2. Land system type distribution map (number with blue square)

Procedure

Transects and plots

Transect lines were 1 kilometer (km) long, comprising ten 20 x 20 m vegetation plots, separated 100m from each other. Objects observed were trees with a diameter at breast height (DBH / 1.3m above ground) of 10 cm or more. Seedling sub-plots, on the other hand, were 2 x 2 m, placed to record seedling species and their number in each observation plot. (Figure 3). Seedling is a category of the woody plant (especially trees) growing to ≤ 1.5 meters in height (Mansur 2011). Seedlings are recorded when they have 3-7 leaves and have fully extended outward or blossom to make it easier to distinguish the name of each species (Handayani et al. 2017).

The ecosystem type of the study site was determined by Kartawinata (2013) and described as field conditions. Specimen taxonomy identity was defined by local experts and published in the literature including the Flora Malesiana Series (1995-2012). Data literature/basics in networks like Plants of the World Online (Pelser et al. 2011; POWO 2019); Asian plant (Slik 2009) and Plant List (2019). Voucher specimens (including unidentified specimens) were stored in the herbarium of Wanariset Samboja for future reference. The global conservation status of all species collected in the field has been determined using the IUCN Red List (2020) and endemic tree species of Borneo (Sidiyasa 2015).

Data analysis

This study used a descriptive approach. Qualitative data analysis was conducted to determine ecosystem type and list all species in the ecosystem. Quantitative data analysis was carried out to study plant diversity, and parameters such as frequency, density, and important value index (IVI) of species were used. Parameters below were determined by Mueller-Dumbois and Ellenberg (1974).

Density (D, tree/m$_2$) = Number of individuals per species-area sampled

Relative Density (R_D) = $\dfrac{\text{Density of a species x 100}}{\text{Total density of all species}}$

Frequency (F) = $\dfrac{\text{Number of plots in which species exist}}{\text{Total number of plots sampled}}$

Relative Frequency (RF) =
$\dfrac{\text{Frequency value for a species x 100}}{\text{Total frequency for all species}}$

Relative Dominance (R_{Do}) =
$\dfrac{\text{Total dominance of a species x 100}}{\text{Total dominance of all species}}$

Importance Value Index (IVI) = $R_D + RF + R_{Do}$.

To further assess the species diversity, Shannon Diversity index (H') was computed as follows (Krebs 1989):

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

Where: n is the proportion (n/N) of individuals of one particular species found and N is the total number of individuals found, Σ is the sum of the calculations, and **s** is the number of species.

Community Similarity Index

Similarity Index (S) which points out at community similarity level between locations using Sørensen (Odum 1993) formulation:

ISs = 2 c / (a + b)
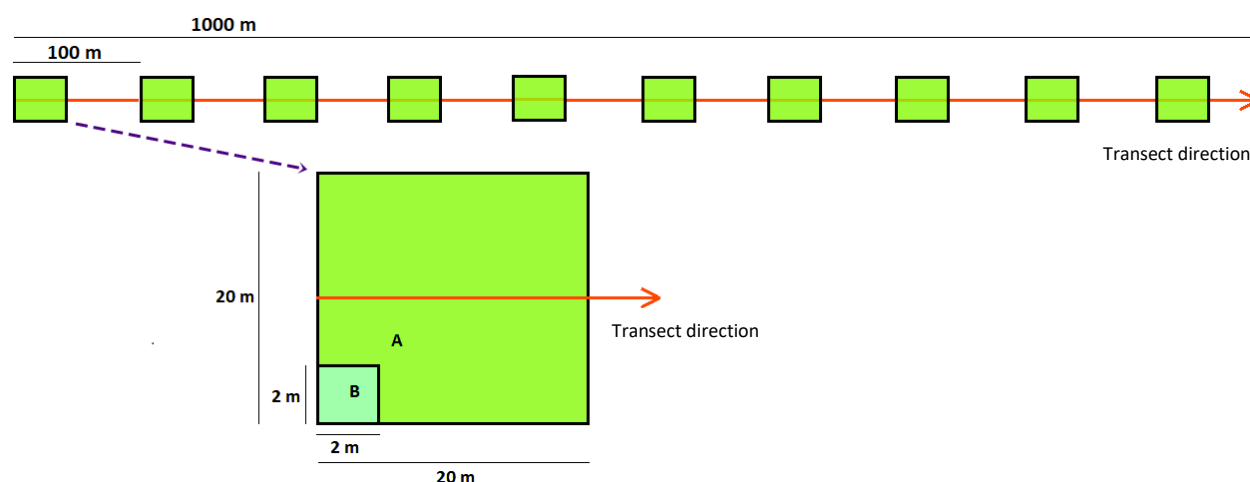
Where:
ISs : Community commonality
c : Individuals of particular species in the study plot
a : the number of species in study plot a
b : the number of species in study plot b

Figure 3. The design of vegetation transects and observation plots. Tree plot (A) with a size of 20 x 20 m^2 and seedling plot (B) with a size of 2x2 m^2

RESULTS AND DISCUSSION

Description of ecosystem and field condition

The topography of Ratah Timber concession, located in the lowland with an altitude of 50-300 meters above sea level, varies from flat, undulating hills to low cliffs. Based on its soil types and positions, the area being studied is made up of three ecosystems. They are Riparian, Dryland and Heath Forest. Field conditions are described below:

Riparian: A transitional area between water and land. The soil in the area contains water throughout the year, while flooding sometimes strikes as a result of fluctuations in river water discharge. Riparian ecosystem is common to the Ratah Timber Concession area, with good-condition forests along the bank of rivers of various sizes. Alluvial deposits cover a wide area in the eastern side of the concession, possibly resulting from Mahakam river sedimentation thousands of years ago. The alluvial deposits appear dark purple-black in color which is widely exposed during the soil excavation on the side of the concession road (a). Dryland: Evenly distributed throughout the concession, having a gentle topography, undulating to small hills with Red-Yellow Podzolic mineral soil conditions. Dryland is less likely to be inundated although flooding sometimes occurs due to river fluctuations. Located in the middle of the concession area, this dryland is obvious with hilly to cliffs and waterfalls topography. The composition of the rocks in the central area of the concession also differs from that in the eastern side which is made up of sedimentary and sandy rocks. The rock type in the center of the concession is basalt, an extrusive igneous rock originating from volcanic clots. Basalt rocks have a dark or pitch-black color which is clearly visible on the riverbed or cliffs in the center of the concession (b). Heath (Kerangas): Heath or Kerangas ecosystem is mainly characterized by the white sand substrate that makes it easily recognizable. Kerangas can also appear in higher land like hills/mountains. Unlike kerangas in a coastal area which is commonly flat with no rocks, chunks and sandy rock cliffs are often found in kerangas in higher areas. This condition is known as the sandstone ecosystem or sandy-rock ecosystem. In Ratah Timber Concession, kerangas or sandstone ecosystem is commonly found in the western side of the concession (c).

Table 1 below is the summary of the information in each observation transect, followed by a brief description of the field condition of each transect and the annual work plan (AWP).

Diversity of plant species

Despite the fact that some plants are not in great shape due to logging, Ratah Timber forest area has a pocket habitat that is considered important for plant diversity. The entire landscape of the Ratah Timber concession is remarkably diverse in plant species, as evidenced by the recorded 530 species with 79 families, inside and outside the plots. As many as 420 species were recorded within observation plots with 374 trees from 1588 individuals and 241 seedlings from 941 individuals. Overall, the family Dipterocarpaceae has the most common species (67 species), of which 35 species belong to *Shorea* (Figure 4).

Based on Figures 4 and 5, it is known that the number of species is not always directly proportional to the number of stems in the plot. The family Dipterocarpaceae had the most common species, with a total of 416 trees and 308 seedlings being recorded. The family Malvaceae, on the other hand, ranked second with 77 trees and 43 seedlings. In general, the average number of the tree is higher than that of seedlings, except for the families Euphorbiaceae and Rubiaceae. Arecaceae family, however, totaled 0 because rattan and palm were only included in the inventory but not counted in the plot.

Threatened, protected and endemic species

Direct observation of the sampling (13 transects and 128 observation plots) recorded 154 species classified as rare, endangered and endemic to Borneo (RTE). Table 2 summarizes the number of species based on the criteria of IUCN Red List, Appendix CITES, Distribution status of Borneo Endemic and national regulation.

Table 1. Summary of observation transect information

Transect ID	Field conditions	Rock formation
WR-23	Disturbed Primary Forest, AWP 2018	Teweh
WR-24	Primary Forest	Teweh
WR-14	Disturbed Primary Forest, AWP 2016	Teweh
WR-25	Disturbed Primary Forest, AWP 2019	Teweh
WR-21	Disturbed Primary Forest, AWP 2009	Teweh
WR-15	Disturbed Primary Forest, AWP 2007	Teweh
WR-11	Disturbed Primary Forest, AWP 2013 & 2017	Teweh
WR-09	Disturbed Primary Forest, AWP 1996-1993	Lawanguwang
WR-07	Disturbed Primary Forest, AWP 1996-1993	Maput
WR-13	Disturbed Primary Forest, AWP 1996-1993	Lawanguwang
WR-05	Primary Forest	Lohai
WR-08	Disturbed Primary Forest, AWP 2000	Teweh
WR-27	Disturbed Primary Forest, AWP 2000	Lohai

Note: WR: WWF-Ratah Timber Transect; AWP: Annual Work Plan for logging activities
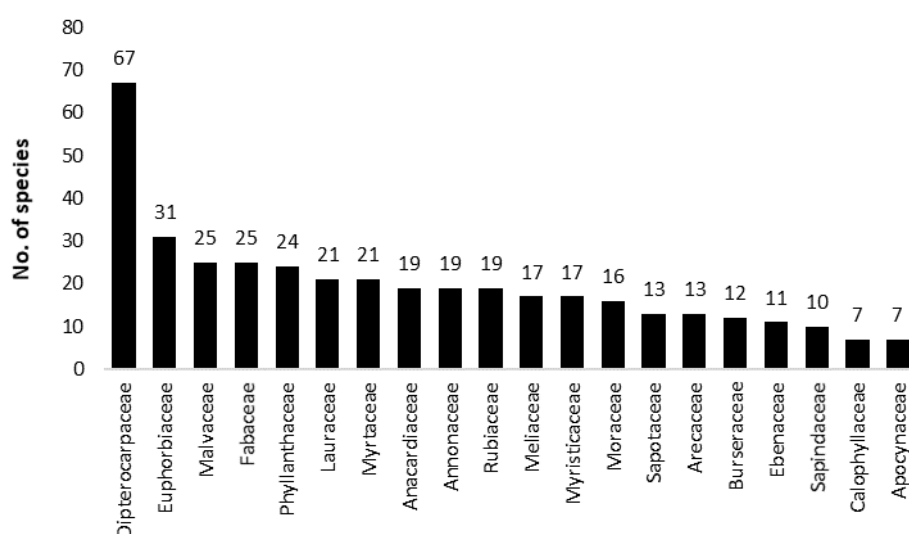
Figure 4. 20 families with the most recorded species
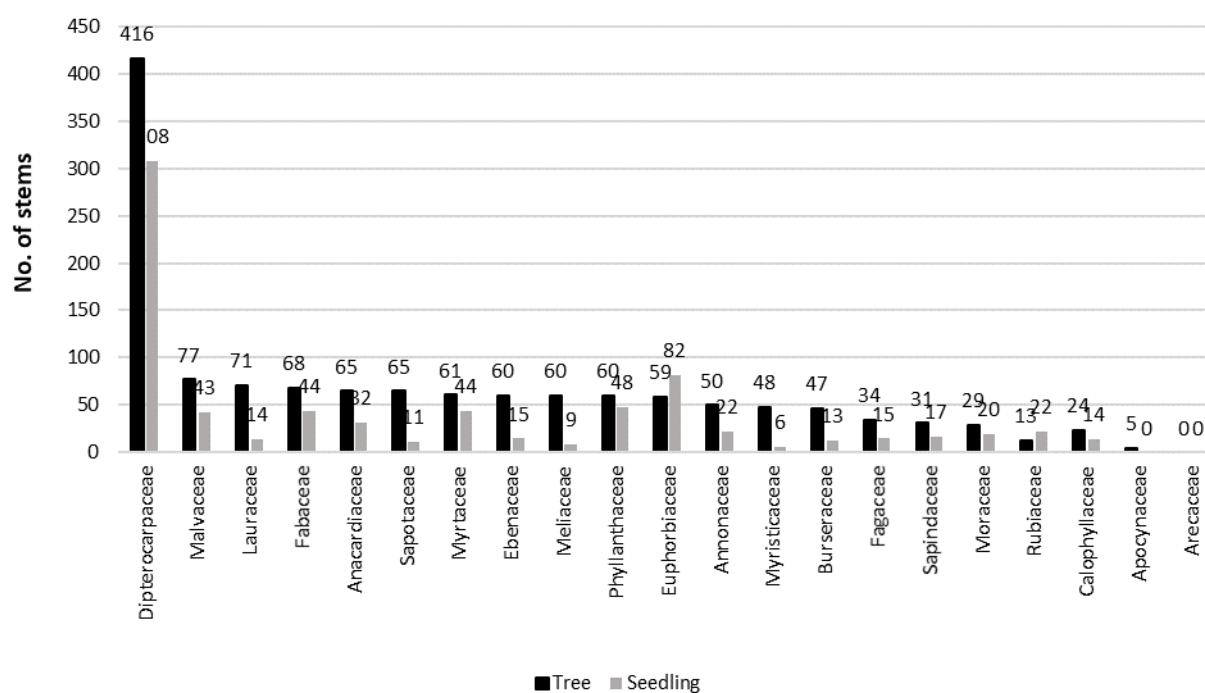
Figure 5. The proportion of stem number from 20 families with the most recorded species

Table 2. Summary of the number of RTE species found in agropolitan areas

Status	Number of species	Explanation
IUCN Red List	61	16 Critically Endangered, 11 Endangered, 34 Vulnerable
CITES	8	Appendix II
Endemic	114	Exist in Borneo Only
National Protection	0	Minister of Forestry Regulation 106/2018

Notes: CITES Appendix II: lists of species that are not necessarily threatened now but that may become so unless trade is closely controlled. National Protection: Minister of Environment and Forestry Regulation (PermenLHK) No. P.20/MenLHK/Setjen/Kum.1/6/2018 in conjunction with PermenLHK P.92/MenLHK/Setjen/Kum.1/8/ 2018 in conjunction with Permen LHK P.106/MenLHK/Setjen/Kum.1/12/2018 on protected plants and animals species

Tabel 3. Top 10 species with the highest Importance Value (IVI) at tree category

Rank	Species	R_D (%)	RF (%)	R_{Do} (%)	IVI (%)
1	*Endertia spectabilis*	2.0781	1.6320	6.5341	10.2442
2	*Shorea pinanga*	2.6448	2.3739	3.2293	8.2480
3	*Shorea leprosula*	1.7632	1.6320	3.5714	6.9667
4	*Shorea faguetiana*	1.3224	0.9644	3.4875	5.7743
5	*Eusideroxylon zwageri*	1.3854	1.2611	2.7557	5.4022
6	*Shorea parvifolia*	1.3854	1.1869	2.3773	4.9496
7	*Shorea macroptera*	0.8816	0.8902	2.5969	4.3687
8	*Shorea ovalis*	0.9446	0.8902	2.5158	4.3506
9	*Vatica oblongifolia*	1.3224	1.1869	0.8077	3.3170
10	*Parashorea melaanonan*	0.7557	0.8160	1.4287	3.0004

Note: R_D: Relative Density, RF: Relative Frequency, R_{Do}: Relative Dominancy, IVI: Importance Value Index

Out of 61 species classified as threatened according to IUCN Red List, the Dipterocarpaceae family or the *Shorea* dominates the list with 16 species being classified as critically endangered(CR). Meanwhile, of 8 species are listed in CITES Appendix II, 5 are ramin species (*Gonystylus* spp.) and 3 are tropical pitcher plants (*Nepenthes* spp.). Moreover, a large number of Borneo endemic species were identified, and 114 species are only found in Borneo Island, including 21.5% of 530 total plant species that were found. As to their status in national-scale protection, none of these species are listed in the Forestry Ministerial Regulation No. 106/2018. Two species, however, are included in the national priority tree species conservation strategy for 2019-2029, i.e., *Durio oxyleanus* and *Shorea pinanga*. Both are in Priority III, a widely distributed endemic species facing a high level of threat (Hamidi et al. 2019).

Plot data analysis

Sampling representation using 13 transects was done, with every transect having ten observation plots except transect WR-05 (8 plots only). There were a total of 128 plots in the sample. Landscape analysis shows that trees in the study area were relatively in good condition because logging was conducted selectively and Reduce Impact Logging (RIL) was applied, minimizing damage in the forest to the lowest possible level.

Importance Value Index (IVI)

In the 5.12 ha-sample plots, 1,588 individual trees with a diameter of at least 10 cm were recorded, consisting of 374 species. Of all trees recorded, 99.20 % of species could be identified while the other 0.80 % tree species could be identified only to genus level. Mlaha or Buan (*Endertia spectabilis*) possessed the highest IVI and ranked first, followed by Tengkawang Pinang (*S. pinanga*), Meranti Merah (*Shorea leprosula*), Meranti (*Shorea faguetiana*) and Ulin (*Eusideroxylon zwageri*) in the top five. Mlaha is not logged due to its low timber quality, while Tengkawang Pinang and Ulin are not logged for they are protected under the government regulations despite the fact that Ulin has been excluded from the list of protected plants issued in the latest regulation. It explains why these three large species had a significant number of individuals and were almost evenly distributed within the concession. The top ten trees were dominated by climax species without pioneer species domination. Some pioneer species found in the transects were Nasi-nasi (*Callicarpa pentandra*), Jabon (*Neolamarckia cadamba*), Terentang (*Campnosperma auriculatum*), Mahang (*Macaranga pearsoni*) and Medang (*Litsea grandis*) but were less dominant in the transects. The following is a summary of the ranking of the top 10 IVI at the species level (Table 3).

In the seedling category, a total of 941 individuals from 241 species were recorded from a total 512 m² area. Of this number, 99.60 % of seedling species could be identified, while 0.40 % could be identified only to genus level. The species' IVI showed that dipterocarps clearly dominated the top five as two Meranti species (*S. leprosula* and *S. pinanga*) ranked first and second, followed by two Kapur species (*Dryobalanops lanceolata* and *D. oblongifolia*) at the third and fifth places. This fact suggests that Ratah Timber forest has good potential for regeneration and shows promise as a mixed Dipterocarp lowland forest in the future. The following is a summary of the top 10 species according to their IVI at the seedling level (Table 4).

Tabel 5. Index Similarity of all research transects

Transect	23	24	14	25	21	15	11	9	7	13	5	8	27
23 (AWP 2018)	1												
24 (Primary Forest)	0.35	1											
14 (AWP 2016)	0.38	0.36	1										
25 (AWP 2019)	0.28	0.29	0.32	1									
21 (AWP 2009)	0.41	0.31	0.28	0.25	1								
15 (AWP 2007)	0.32	0.31	0.28	0.19	0.36	1							
11 (AWP 2013 & 2017)	0.34	0.36	0.23	0.18	0.32	0.31	1						
9 (AWP 1996-1993)	0.27	0.15	0.24	0.17	0.20	0.23	0.26	1					
7 (AWP 1996-1993)	0.34	0.25	0.22	0.17	0.26	0.25	0.25	0.32	1				
13 (AWP 1996-1993)	0.29	0.31	0.34	0.24	0.27	0.34	0.30	0.35	0.37	1			
5 (Primary Forest)	0.21	0.25	0.24	0.17	0.19	0.13	0.18	0.21	0.34	0.29	1		
8 (AWP 2000)	0.36	0.22	0.23	0.14	0.28	0.37	0.31	0.32	0.36	0.32	0.21	1	
27 (AWP 2000)	0.33	0.30	0.24	0.24	0.36	0.36	0.29	0.26	0.27	0.35	0.22	0.35	1

Note: Green color, the highest similarity value between plots. Blue color, the lowest similarity value between plots

Table 4. Top 10 species with the highest Importance Value (IVI) in seedling category

Ranking	Species	Individual	R$_D$ (%)	RF (%)	IV (%)
1	*Shorea leprosula*	38	4.0383	3.7702	7.8085
2	*Shorea pinanga*	34	3.6132	2.6930	6.3062
3	*Dryobalanops lanceolata*	33	3.5069	1.6158	5.1227
4	*Leea amabilis*	21	2.2317	1.9749	4.2065
5	*Dryobalanops oblongifolia*	29	3.0818	0.7181	3.8000
6	*Swintonia acuta*	21	2.2317	1.0772	3.3089
7	*Syzygium lineatum*	15	1.5940	1.6158	3.2098
8	*Vatica oblongifolia*	13	1.3815	1.7953	3.1768
9	*Mallotus minimifructus*	15	1.5940	1.2567	2.8508
10	*Pternandra coerulescens*	13	1.3815	1.4363	2.8178

Note: RD: Relative Density, RF: Relative Frequency, IV: Importance Value

Diversity index

The Shannon Weiner diversity index was 5.51 at the tree level and 4.95 at the seedling level. If seeds are found in large quantities, a parent tree will usually be found nearby. For example, *D. lanceolata* seedlings look like green expanses under the mother tree in several plots. When the survey was conducted, a lot of dipterocarps were fruiting and numerous seedlings grew simultaneously some of them are transect WR 05.

Similarity Index

Similarity Index is used to see similarities between communities and analyze the similarity statistically to determine the importance of forest type and disturbance. The community similarity index for both tree and seedling categories showed that transect 23 and transect 21 displayed the highest similarity value. The species composition was similar within the same forest type and/or with respective degrees of disturbance. Transect 23 is AWP 2018 and Transect 21 is AWP 2009. Both transects are at Teweh rock formation. Community similarity index was the lowest between transect 05 (hilly primary forest with sandstone community) and transect 15, a secondary forest where tree logging occurred in 2007 and pioneer trees spread evenly all over the transects. Transect 05 stands on Lohai rock formation while transect 15 is on Teweh rock formation.

Similarity Index among vegetation transects demonstrates a strong variation on local scales. Various land formations and soil types have an impact on the plants community level in the study area. Structure, species composition and distribution of vegetation are greatly affected by soil (Kartawinata 2013). Borneo as part of central Sundaland is covered by sandy soils (Silk et al. 2011), resulting in vegetation types such as heath forest and peat and kerapah swamp forests (Raes et al. 2014). The formation of the rocks shows that the majority of plots are in Teweh land system, while other observation transects are located in Mentalat, Lohai, Lawanguwang, and Maput land systems (Table 1, Table 2, Figure 2). The Teweh land system occupies a hilly plain landform, covering 95% of the sloping area and 5% of the peak, made up of sedimentary rocks. These rocks consist of sandstone and shale (RePPProT 1987). Igneous and metamorphic rocks

have rock-forming minerals that contain most of the nutrients required by higher plants to grow and develop (Harley and Gilkes 2000). According to Widyasari et al. (2005), Mentalat land system has low N, P, K concentrations but high aluminum saturation, while Teweh land system has low N and K levels but high aluminum saturation. The nutrient content is a determining factor in the remarkably different species compositions between transect 05 and transect 15 based on the map in Figure 2 and the similarity index in Table 5. Transect 05 was built upon a sandstone ecosystem, and no logging has ever been conducted here due to its limited wood potential. In transect 05, there were not only epiphytes growing on low branches but also *Nepenthes*. These are the characteristics of the forest with low nutrients. In transect 15, commercial tree species were logged and then abandoned, allowing a succession process to occur. Documentation of dipterocarp in dryland lowland forest and sandstone forest being studied can be seen in Figure 6.

Geological history may be an external factor, in addition to physical barriers, that hinder dispersal or biotic interactions (Bruchmann and Hobohm 2014). Forest dynamics along the secondary forest to primary forest logged from 1993 to 2019 also contribute to the floristic composition. Some pioneer species such as *C. auriculatum* are very small to affect beta diversity because these pioneer species have a narrow habitat range and abundance. Pioneer species are ubiquitous and normally grow on diverse habitats, yet potentially reduce diversity (Yano et al. 2021). *Macaranga* spp. is tolerant species that can grow in barren soil such as the main road that has been cleared (Aoyagi et al. 2013; Yano et al. 2021). According to Aoyagi et al. (2013), not many dipterocarp species are able to live under the shade of *Macaranga* spp. because the decomposition process of N and P elements is too fast. Increase in *Macaranga* spp. patches can lead to forest floor degradation and prolonged primary forest damage. In Ratah Timber, pure *Macaranga* spp. patches were never found in the transects. The number of species per unit number of stems (species richness) was higher in the RIL than in conventional logging forest and the community composition of the RIL forest was more similar with primary forest than conventional logging (Imai et al. 2012). The RIL process in Ratah Timber concession allows young

dipterocarp and non-dipterocarp plants to keep growing and regeneration of dipterocarp trees to take place at the site. Logging of certain species of trees with sufficient rotation time will minimize the damage of the forests and give time for the pioneers and the seedlings to compete and regrow into undamaged forests.

Landform also affects species composition in a community. In this research, tree species like Keruing (*Dipterocarpus verucosus),* Merawan (*Hopea dryobalanoides*) and Meranti/Tengkawang (*Shorea beccariana*) were generally found in mountain ridges while *Shorea parvifolia*, *S. leprosula*, *S. faguetiana* dan *S. Pinanga* grow in a rather sloping area.

Mahakam River and its deltas were formed in the early Miocene, when Australia collided with the eastern boundary of Sundaland (de Bruyn et al. 2014). Generally, rivers in Ratah Timber Concession display a dendritic pattern. It means that when the rain pours all over the river flow area, and flood peak will be so high that it will inundate the whole area around the river basin, especially in the downstream area. This floodplain was found at the beginning of transect 09 on the Nyaribungan River. At the beginning of transect 09, a lot of tree species with knee roots, breathing roots and taproots were found, and such roots are parts of plant's adaptation to their habitat. The plot was dominated by white sapped trees from Euphorbiaceae family (*Blumeodendron kurzii, Blumeodendron tokbrai, Elateriospermum tapos*), Sapotaceae (*Payena lucida, Madhuca costulata, Palaquium beccarianum, Palaquium sericeum*), and Apocynaceae (*Dyera costulata, Alstonia angustiloba*). A species with buttressed roots belonging to Anacardiaceae family (*Swintonia acuta*) was also found. Plants adapt to their habitat and occupy the niches to play their role in that certain habitat. This process has occurred for a really long time and has formed the structures and compositions of today's vegetation. In the wet area of the transects, wild palms like *Pinanga albescens* and *Pinanga auriculata* were also found. Although not included in the calculation analysis, the presence of *Pinanga* is an important record of biodiversity. Indonesia's palm diversity is the highest in the world, and 53% of the plants are endemic (Widyatmoko 2018). Genus *Pinanga* Blume spreads from the Himalayas and South China to New Guinea; however, the greatest diversity in the wet areas is found in Sunda Shelf (Agusti et al. 2019). Forty species of *Pinanga* grow in Borneo (Govaerts et al. 2018).
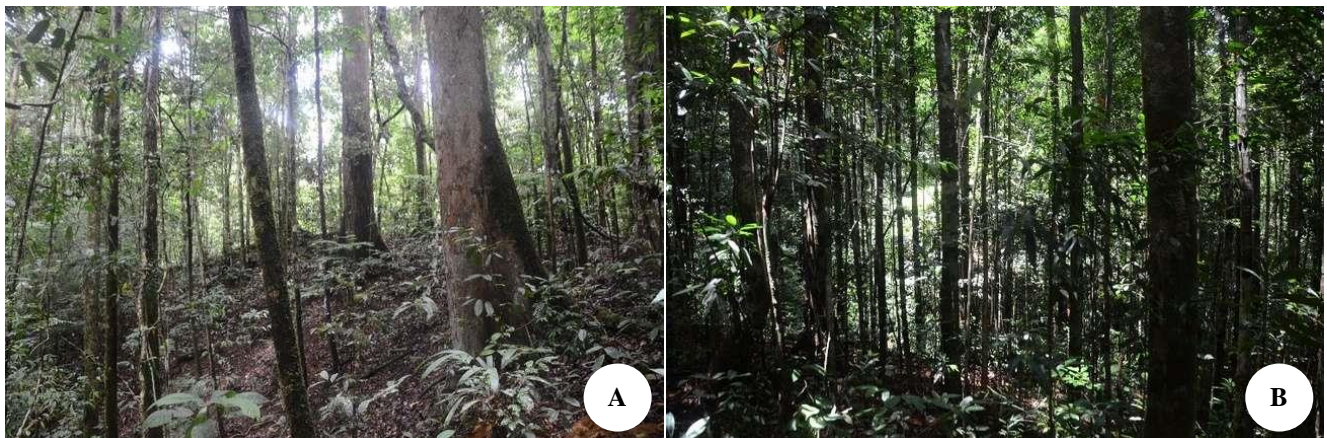
Figure 6. A. Condition of lowland forest, B. Heath forest in Ratah Timber Concession

Figure 6. Root systems in the swampy area on the plot observations. A. Stilt roots, B. Pencil roots

Borneo is home to 65 vascular plants genera from 25 families considered endemic to Borneo (Neo et al. 2020). Mlaha's findings reinforce that Borneo is unique as a biodiversity hotspot. Mlaha or Buan tree in local name (*E. spectabilis*) is special because it is *monotypic*, meaning there is only single species in the genus, and thus far the only known genera and species of the endemic tree of Borneo grows in two areas, East Borneo and South Borneo (Neo et al. 2020).

Diversity is high when the dominance of a species over the plot/study area is low, with an importance value of the vegetation being less than 10 for both trees and seedlings. Hilly lands and several cuts by rivers are the uniqueness of Mahakam Ulu study area. Individual and species population levels are dynamic and they have changed continuously throughout time (Krisnawati et al. 2011). The diversity of seedlings was less valuable in primary forests due to factors like predation and competition (Aoyagi et al. 2013).

Borneo is a large island with great physiography and environmental heterogeneity that can promote the availability of many niche spaces, facilitating possible speciation and providing more area for species to persist during historical global climatic fluctuations (Stein et al. 2014). The result of this research is just a small part of a bigger unsolved mystery in Borneo forests, besides the discovery of medicinal substances and other resources that can provide ecological values to support human well-being in the future. Forest in Ratah Timber Concession area has to be conserved to produce sustainable benefits for all living organisms in the future.

Ratah Timber concession generally covers a forest area with various conditions ranging from bushes to untouched primary forest. Located in the lowland and dominated by Dipterocarpaceae species, the forest is also called as Lowland Mixed Dipterocarp forest. The diversity of plant species in the area can be categorized as very high with 530 plant species being recorded both inside and outside the observation plots. The high level of plant diversity is caused by a combination of several important factors such as types of ecosystem, land cover, topography, altitude, soil and rock types, rainfall, humidity, location and threats to forests. A total of 154 species of all listed species are classified as rare, threatened and endemic, while 16 species are classified as Critically Endangered. Mlaha or Bulan in a tree in local terms (*E. spectabilis*) is the most dominant tree species based on the analysis of IVI. Meanwhile, the most dominant species in the seedling category was Meranti Merah (*S. leprosula*).

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