BUKTI-BUKTI PROSES REVIEW (PENULIS KORESPONDENSI)

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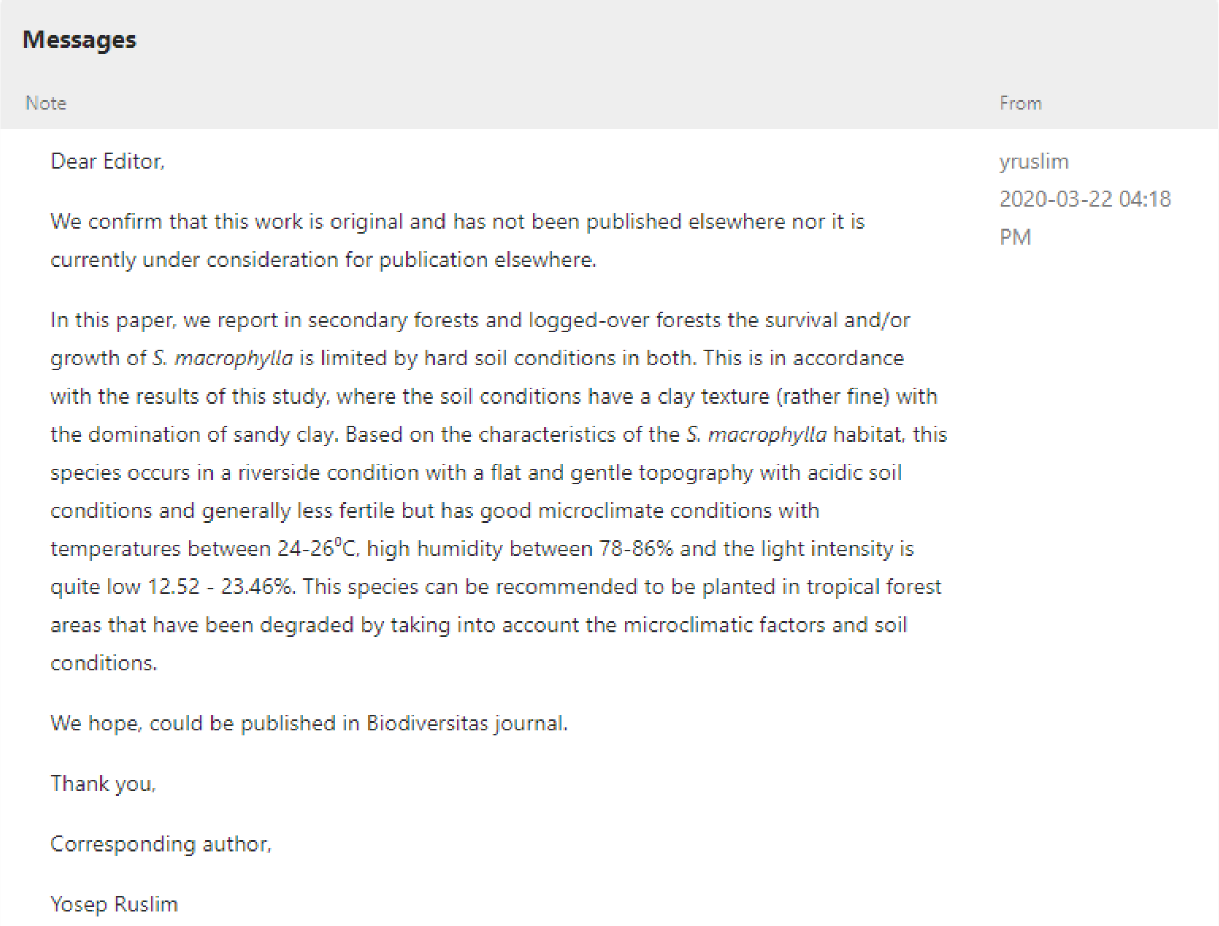
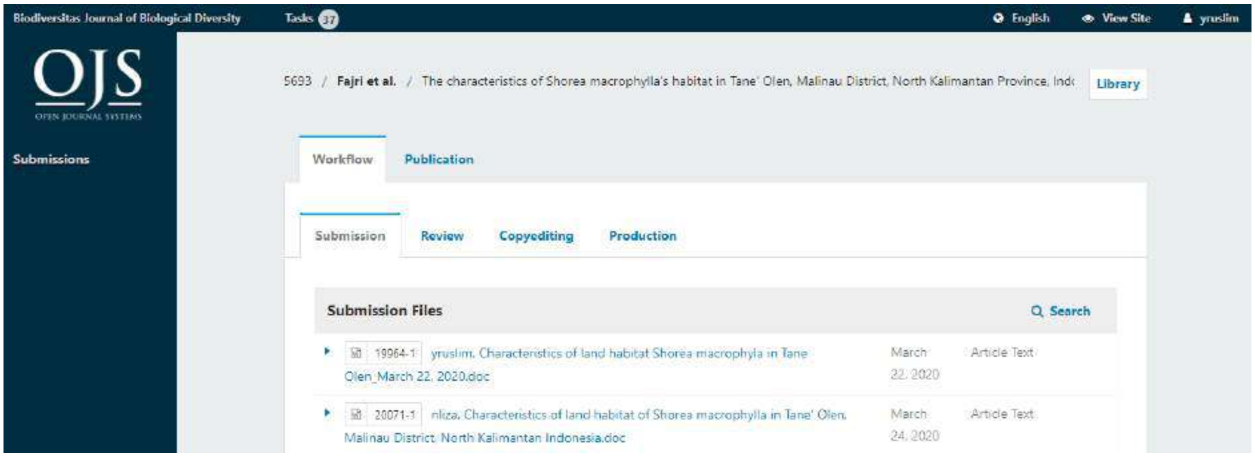


Messages

Note	From
Dear Editor, We confirm that this work is original and has not been published elsewhere nor it is currently under consideration for publication elsewhere. In this paper, we report in secondary forests and logged-over forests the survival and/or growth of *S. macrophylla* is limited by hard soil conditions in both. This is in accordance with the results of this study, where the soil conditions have a clay texture (rather fine) with the domination of sandy clay. Based on the characteristics of the *S. macrophylla* habitat, this species occurs in a riverside condition with a flat and gentle topography with acidic soil conditions and generally less fertile but has good microclimate conditions with temperatures between 24-26^{0}C, high humidity between 78-86% and the light intensity is quite low 12.52 - 23.46%. This species can be recommended to be planted in tropical forest areas that have been degraded by taking into account the microclimatic factors and soil conditions. We hope, could be published in Biodiversitas journal. Thank you, Corresponding author, Yosep Ruslim	yruslim 2020-03-22 04:18 PM



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Submission Files

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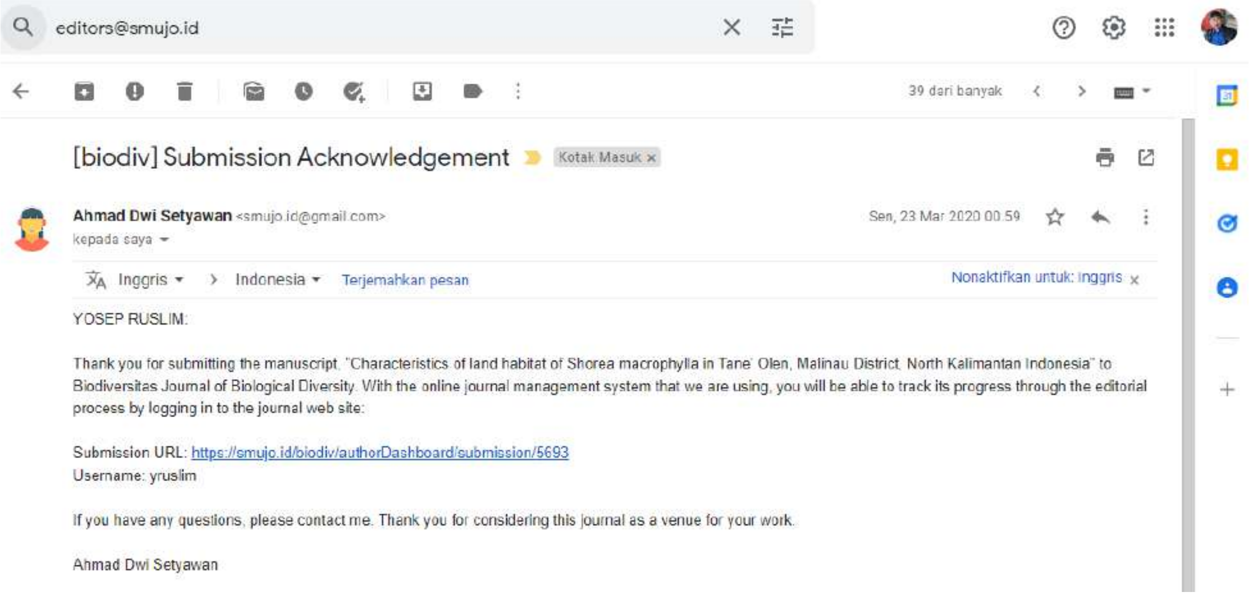

[biodiv] Submission Acknowledgement

Ahmad Dwi Setyawan <smujo.id@gmail.com>

Sen, 23 Mar 2020 00.59

YOSEP RUSLIM:

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Ahmad Dwi Setyawan

Characteristics of land habitat of *Shorea macrophylla* in Tane' Olen, Malinau District, North Kalimantan Indonesia

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Abstract. *Shorea macrophylla* is one of plant species in Tane' Olen forest area. This study aimed at analyzing the physical, chemical, topographical and microclimate condition as the habitat of S. macrophylla plant. Purposive sampling was applied as the methodology to identify soil condition while Pipet method was used to analyze the physical properties of the soil. Furthermore, the electrode method, ammonium Acetate pH 7 method, KCl 1 N method, Kjeldahl, Walkley N Black method, calculation method, Bray I method, and Barium chloride method were employed to analyze the chemical characteristics of soil and *S. macrophylla* abudance used INP analysis. The result of this research : The soil conditions in studi area were as follows: 1. The physical properties of the soil: a. bulk density values 0.60-1.31 gram cm^{3-1}, soil porosity value 50.51%-77.35%, water content 34.66%-5.37%, soil texture dominated by clay, loam and dusty clay; 2. The chemical condition of the soil: pH 3.6-4.8, the value of N 0.05%-0.19%, organic C content 1.40%-3.65%, P content value 0.41-2.3 mg 100 gr^{-1}, the content of potassium (K) 58.68-232.55 mg 100 gr^{-1}, Cation Exchange Capacity/CEC 5.35-10.81 meg 100gr^{-1}; 3. Topographic conditions flat – upper steep. Microclimate conditions: a. Temperature 24-26,5°C; b. Humidity 76-84%; c. Light intensity 350-750 Lm. INP $\geq$ 10% are *S. macrophylla*, *Madhuca spectabilis*, *Myristica villosa* Warb, *Scorodocarpus borneensis*, *Eugenia* spp, *Palaquium* spp, *Macaranga triloba*, *Syzygium inophyllum* and *Shorea* sp. Positive association between *S. macropylla* and *S. borneensis*, *Eugenia* spp, *Palaquium* spp and *M. triloba* and negative associations between *S. macropylla* with *M. spectabilis*, *M. villosa* Warb, *S. inophyllum* and *Shorea* sp.

Keywords: Habitat, land characteristics, *S. macrophylla*

Running title: Characteristics of land habitat of *Shorea macrophylla*

INTRODUCTION

Shorea macrophylla is one of the fastest growing climax tree species of the genera Shorea (Perumal et al. 2017). This species is very valuable for local communities as a source of wood and fruit (Randi et al. 2019). Community in West Kalimantan named *S. macrophylla* a *tengkawang tungkul* tree, and this species has been cultivated by the Dayak and Malay community (Fajri and Fernandes 2015). The distribution of *S. macrophylla* is generally clustered, can grow in tropical rain forests with A type rainfall, grows on latosol soils at altitudes up to 500 m asl, acidic pH (4.6-4.9) and quite good CEC (16.25-19.40) (Istomo and Hidayati 2010). This species is often found in sedimentary soils and spreads randomly and evenly on the banks of rivers or areas that have sloping or flat topography, rarely on hills, distribute in Sarawak, Sabah, Brunei and Kalimantan (Randi et al. 2019; Utomo et al. 2018; Perumal et al. 2017).

The use of this tree species includes: wood used for timber, veneer and plywood, besides, it can also be used for buildings, shipping wood, musical instruments, furniture or packing crates (Istomo and Hidayati 2010). The fruit locally known as *tengkawang tungkul* (Illipe nut) tree is used as raw material for cosmetics industries such as soap and brown fat substitution material and vegetable fat raw material (Maharani et al. 2016).

The existence of tengkawang in its natural habitat is now starting to diminish and is hard to find (Istomo and Hidayati 2010). As one of the prima donna woods of tropical forests, this species is starting to be difficult to find in the market because exploitation of this species is very high in line with the increasing demand for wood and forest conversion to other uses (Rikando et al. 2019).

Tane' Olen is a customary forest area having a high environmental value and is preserved by the people of Setulang Village (Hutauruk et al. 2018a), where forest management uses the wisdom of local communities and sustainable forest management (Fahrianoor et al. 2013; Kettle 2010), so that forest sustainability is maintained (Hutauruk et al. 2018). Forests are not only a place to live but can also be used as a source of food, medicine, economic, social, cultural and spiritual functions (Merang et al. 2020; Matthew et al. 2018; Quedraogo et al. 2014).

In relation with that matter, this study aims to obtain data and information regarding the characteristics of *S. macrophylla* habitat land in the context of developing these species. It is hoped that the results of this study will benefit users in an effort to conserve this species, especially on degraded lands in Indonesia.

MATERIALS AND METHODS

Studi Area

Study was carried out in Tane’ Olen forest area, Setulang village, Malinau district, North Kalimantan Utara (3°25’0.86” N and 116°25’52.59” E). Location map is presented in Figure 1.

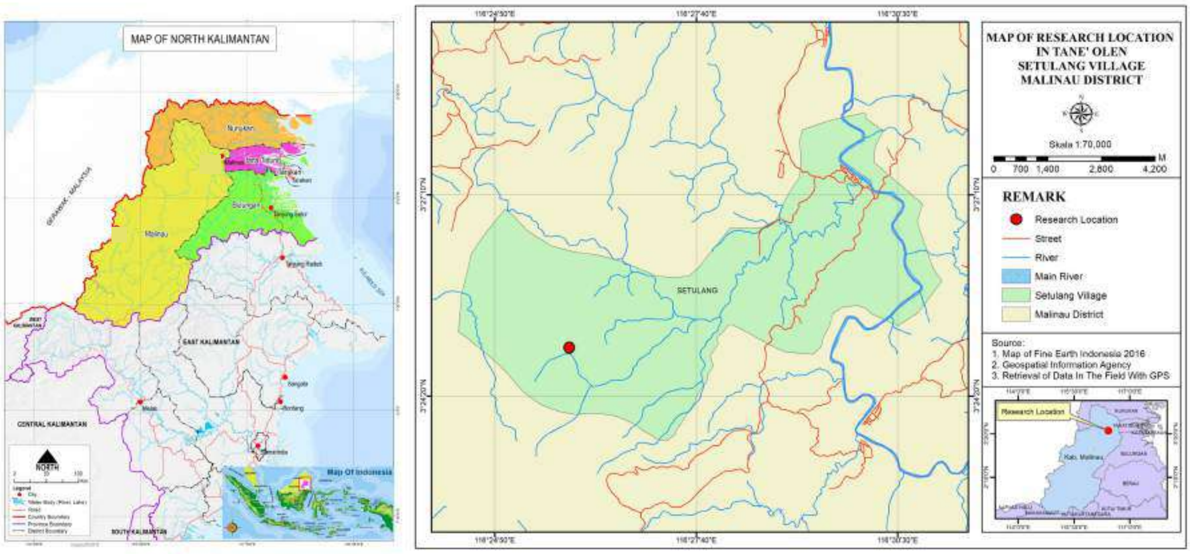


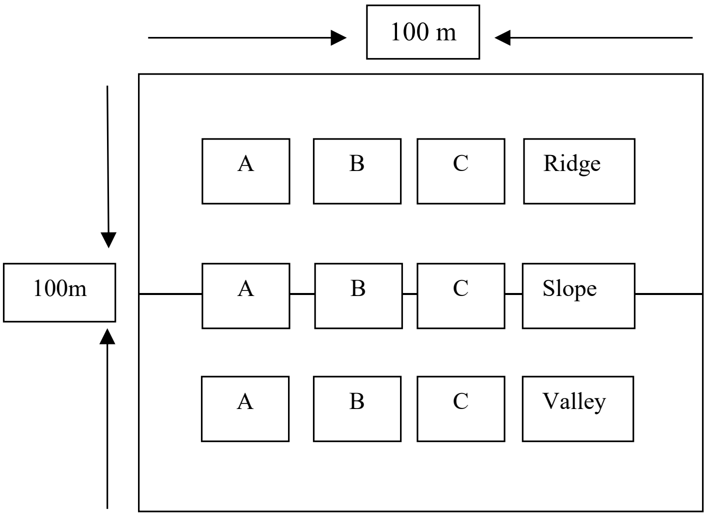
Figure 1. Location of the research in Tane’ Olen (●)

Research procedure

The 1 hectare research was conducted using the Purposive Sampling method. The plot is made in a square shape with a side length of 100 meters (Sari and Maharani, 2016). In the plot, soil sampling data is taken. Soil sampling using a purposive sampling technique with 3 sampling points in an area of 1 hectare. These 3 points were taken at locations on hills, backs and valleys respectively, so they were considered to represent the conditions of the study site. Micro climate data collection in the form of: temperature, humidity, light intensity conducted at the same location (design of soil and micro climate data collection can be seen in Figure 2). Collection og vegetation data is limited to the level of big trees (DBH ≥ 20.0 cm). Each plot is divided into 25 subplots (20 m x 20 m). In each subplot, all tree level species (20m x 20m) were identified and DBH recorded (Widiyatno et al. 2017). Plot making and field data collection activities, can be seen in Figure 2, while plot design can be seen in Figures 3 and 4.

Figure 2. A. Exploration, B. Make a research plot, C. Tree inventory, D. Soil sample collection, E and F. Microclimate data collection

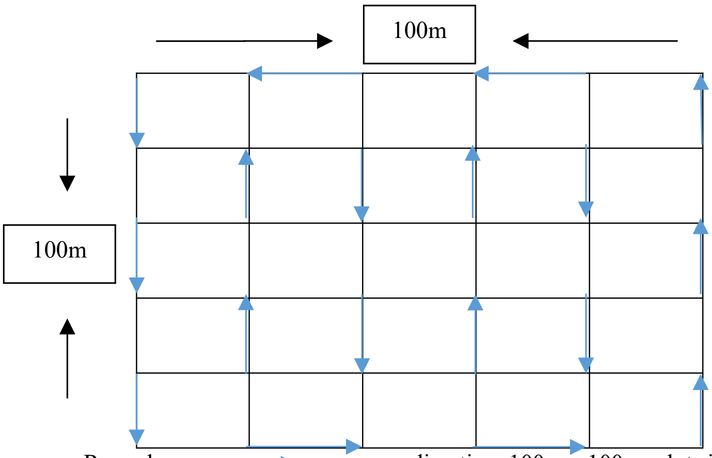
Soil sample collection design and micro climate data are presented the following Figures 3 and 4



Remark: A:lights intensity, B: temperature and area humidity, C: soil sampling, m:Meter

Figure 3. Design of soil sampling and microclimate conditions.

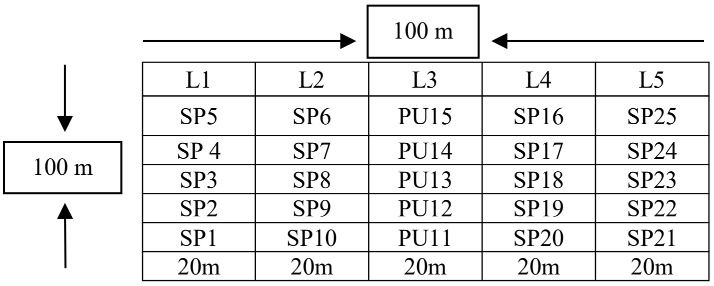
Topography data collection design can be seen in Figure 4.



Remark : → : compass direction, 100m x 100m: plot size

Figure 4. Design of topographic data collection

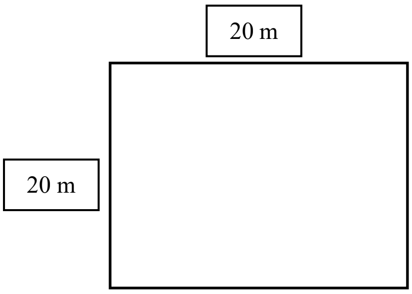
The design of vegettion data can be seen in Figures 5 and 6.



L1	L2	L3	L4	L5
SP5	SP6	PU15	SP16	SP25
SP 4	SP7	PU14	SP17	SP24
SP3	SP8	PU13	SP18	SP23
SP2	SP9	PU12	SP19	SP22
SP1	SP10	PU11	SP20	SP21
20m	20m	20m	20m	20m

Remarks: L: lane, SP: sub plot, 20m: distance between sub plots, 100m x 100m: plot size, m: Meter.

Figure 5. Design of vegetation analysis.



Remark: 20m x 20m: Tree level sub plot, m: Meter.

Figure 6. Design of tree level vegetation inventory.

Data analysis

Soil analyses

The soil that has been taken is then analyzed its physical and chemical properties. Soil physical properties analyzed include: texture, bulk density, porosity and water content, using the Pipette method, while the chemical properties analyzed include pH using the electrode method, CEC Using the Ammonium acetate pH 7 method, the elements Al +++ and H + using the KCl method 1 N, total N elements using Kjeldahl method, organic C elements using Black walkley, C/N ratio using arithmetic methods, elements P_2O5 and K_2O using Bray I methods, saturation Al using arithmetic methods. Soil data analysis results in the soil laboratory will be tabulated and analyzed descriptively quantitative.

Analytical topography

The tabulated land topography data is then processed using ArcView 10.2 Software, and analyzed descriptively and quantitatively.

Micro climate analyses

Micro climate condition data will be tabulated, then will be analyzed using quantitative descriptive analysis methods.

Important Value Index

According to Kacholi (2014), the Importance Value Index (IVI) is used in ecological studies to show the ecological importance of a species in a particular ecosystem. IVI is also used to prioritize species conservation where species with low INP values require high conservation priority compared to species that have high IVI. The value of dominance species is characterized by an index of the important value of the species where IVI = relative density + relative frequency + relative dominance. The IVI value will be analyzed descriptively.

Association of Vegetation

Associations between two plant species were analyzed using a 2x2 contingency table (Mueller-Dombois and Ellenberg 1974). A more complete description can be seen in Table 1.

Table 1. Contingency table form.

Species A / Species B	+	-	
+	a	b	a + b
-	c	d	c + d
	a + c	b + d	N = a + b + c + d

Reference: Mueller-Dombois and Ellenberg (1974)

Remarks :
A = Amount of plot containing species A and species B.
B = Amount of plot containing only species A and no species B.
C = Amount of plot containing only species B and no A.
D = Amount of plot containing neither species A nor species B.
N = Amount of all plots.

Which then aested with chi-square (x^2)

$$X^2 = \frac{(ad - bc)^2 \, x \, N}{(a+b)(c+d)(a+c)(b+d)}$$

And calculated their of coofisien asosiation (C) value

1. If ad $\geq$ bc, so $C = \frac{ad-bc}{(a+b)(b+d)}$
2. If bc > ad and d > a, so $C = \frac{ad-bc}{(a+b)(b+c)}$
3. If bc > ad and a > c, so $C = \frac{ad-bc}{(a+d)(c+d)}$

Positive or negative values from the calculation results indicate positive or negative associations between the two species.

RESULTS AND DISCUSSION

Analysis of soil physical and chemical properties

Results of the analysis of soil physical and chemical properties in the test area in the habitat of *S. macrophylla* trees in the Tane' Olen plot, Setulang Village, Malinau Regency, can be seen in Table 2.

Table 2. Physical properties of soil in Tane‘ Olen, Setulang, Malinau district.

Land condition	Depth (cm)	Bulk density (gram/cm³)*	Porosity (%)*	Water content (%)
Valley	0-10	0.60	77.35	95.37
	10-20	1.13	57.32	40.04
	20-30	1.18	55.54	39.20
	30-40	0.93	64.75	47.49
Slope	0-10	1.05	60.42	48.08

	10-20	1.31	50.60	41.42
	20-30	1.23	53.72	34.88
	30-40	1.31	50.51	39.63
Ridge	0-10	0.83	68.75	61.68
	10-20	1.01	61.92	44.23
	20-30	1.20	54.66	35.53
	30-40	1.10	58.36	34.66

Remark:* Average score for three times repetition

Table 2 showed that at the depth of 0-10 cm the valley, slope and back area having bulk density close to the rather low category (0.60-1.05). This means that the soil conditions in the study area are not able to store water due to the dense soil conditions. According to Casanova et al. (2016); Zeng et al. (2013), soil bulk density conditions are influenced by external conditions, changes associated with various factors and various natural processes such as the result of plant root growth and rainfall.

The porosity value at the depth of 0-40 cm in the valley, slope and back area included in the medium and high categories (63.74%, 53.8% and 60.92%). According to Darusman et al. (2019). the most affecting soil porosity is bulk density and soil particle density, if the bulk density is low then the porosity will increase. Water content in the valley, slope and back area was in the moderate category (41.025-55.61%) with valley area as the highest soil water content. According to Minasny and McBratney (2018), the capacity of available groundwater is an important component for water balance and terrestrial biosphere energy because it can control the rate of evapotranspiration, and support plant growth. The capacity of the soil's available water capacity can increase if there is an increase in soil organic matter.

Soil conditions are generally dominated by Ultisol (advanced development) soil types, namely Typic hapludults (Yellowish Red Podsolik) and some Typic Paleudults (Yellow Podsolic). This soil type is the main land of lowland dipterocarp forest (Ohta and Effendi, 1992).The results of soil texture analysis can be seen in Table 3.

Table 3. Soil texture in Tane' Olen, Setulang village, Malinau district.

Land condition	Depth (cm)	Clay (%)	Sand (%)	Dust (%)	texture (USDA)
Valley	0-20	33.70	50.90	15.40	SCL
	20-40	36.50	49.50	14.00	SC
	40-60	34.00	56.80	9.20	SCL
Slope	0-20	24.70	67.20	8.10	SCL
	20-40	27.30	63.10	9.60	SCL
	40-60	33.10	60.50	6.40	SCL
Ridge	0-20	37.80	54.60	7.60	SC
	20-40	37.40	46.40	16.20	SC
	40-60	40.70	48.00	11.30	SC

Remark:Laboratory of soil test in B2P2EHD and PPHT, Mulawarman University

Table 3 shows that the soil at the study site had a clay texture (somewhat fine) with sandy clay dominance. According to Osman (2013), soil texture refers to the level of fineness or roughness formed by soil particles of various sizes in a soil. At the study site, the highest 0-10 cm water content was in the valley area (95.37%), in the back area 61.68%, and in the slope area the water content was 48.08% (more detailed information can be seen in Table 1). The lower water content in the slope compared to the back and valley areas, proves that water moves to the lower area. This condition will cause surface run off and can cause erosion. Surface run off and erosion will result in loss of nutrients. Pratiwi and Narendra (2012), stated that nutrients in the soil, especially on the surface (top soil) are vulnerable to loss through surface runoff or erosion. Nutrients that dissolve easily in water will be carried along with surface runoff, as well as nutrients present in parts of soil particles will be carried away during erosion and deposited as sediments. Chemical caharacteristics at study area is presented in Table 4.

Table 4. Chemical characteristics of soil in Tane' Olen, Setulang village, Malinau district.

Land condition	Depth (cm)	pH (1: 25)		Cation exchange rates (meg 100gr^{-1})			Organic content (%)		Ratio	Mineral (Mg 100 gram^{-1})	
		H2O	KCl	KTK	Al3+	H+	N. Tot	C.Org	C/N	P2O5	K2O
Valley	0-20	4.6	3.3	7.26	4.92	1.50	0.19	3.65	19	0.89	116.85
	20-40	4.6	3.4	7.25	5.56	1.08	0.12	2.65	22	0.73	73.30
	40-60	4.4	3.4	7.18	5.75	0.92	0.10	2.12	22	1.22	59.00
Slope	0-20	4.1	3.5	5.35	2.75	1.33	0.13	2.31	18	0.65	73.62
	20-40	4.7	3.5	5.30	3.50	0.92	0.07	1.54	22	0.65	58.68
	40-60	4.8	3.5	5.53	3.33	1.42	0.05	1.40	26	0.41	60.90
Ridge	0-20	4.4	3.0	10.81	7.25	2.75	0.09	3.46	39	2.35	120.34
	20-40	3.6	3.3	10.48	7.80	1.83	0.08	2.12	28	0.89	194.09
	40-60	4.4	3.4	10.37	6.83	2.58	0.09	1.54	17	0.65	232.55

Remark: Laboratory of soil test in B2P2EHD and PPHT, Mulawarman University

Table 4 showed that the soil in the study area is very acid (pH = 4.1-4.8). According to Schroeder and Pumphrey (2013), in acid soils, it will inhibit root and plant growth and increase Al levels in the soil. The cation exchange capacit (CEC) in the study area ranges from 5.3 to 10 meg 100 grams^{-1}, indicating that in real studies the value of the CEC is low. According to Perumal et al. (2017a), in general, value ofcation exchange capacity (CEC) is low for surface and subsurface soils in lowland dipterocarp forests.

Al content in the study site showed a high value, especially the soil in the back and valley, which indicated the presence of high toxicity in the soil in the area. Al content in the soil will decrease if the organic matter in the soil increases, because organic matter forms a very strong complex with Al. According to Zaidey et al. (2010), in lowland dipterocarp forests, the soil has a high Al content, making it a major cause of soil acidity.

The N value at the research location showed a value between 0.05% -0.19% which was in the low to very low category. This is supported by Sadeghi et al. (2016) which states that in general, the total amount of nitrogen in tropical rain forests is low. Nitrogen (N) is a plant nutrient that is important for plant growth (Omara et al. 2019) and if the lack of this element can inhibit plant growth (Mehata et al. 2019). According to Omara et al. (2019), the source of N is obtained from organic matter, mineralization and rainfall supply.

Organic C values were high in the valley and back areas and lower in the slope area. This is because the erosion area is more prone to erosion which causes nutrient leaching including organic C. According to Schlesinger and Bernhard (2013), carbon can be stored in the soil 3 times more than in the atmosphere and be an indicator of the abundance and number of species of soil microorganisms (Zhu and Zhu 2015), so that the presence of organic C in the soil will spur microorganism activities thereby increasing the process of soil decomposition and also reactions that require the help of microorganisms, for example P dissolution, and N fixation. Phosphate values were indicated from the P2O5 test value, where the Phosphate content value is high (58.78).

Table 4 showed that the phosphorus content is very low (0.41-1.22 mg 100 gram^{-1}). According to Turner and Engelbrecht (2011), organic phosphorus has an important role in maintaining the availability of phosphorus in lowland tropical rain forests because it functions in root development and plant growth (Abdissa et al. 2011).

Potassium in the valley and slope areas is high and very high values (58.68-116.85 ppp, while for very high regions (120.34-232.55 ppm). According to Mouhamad et al. (2016), the element of potassium (K) is most abundant in the soil compared to other mineral elements. This element has an extraordinary role for plants in plant metobolism, but the availability of K for plants also depends on the nature of the soil, namely: humidity, aeration, temperature, soil treatment systems and dynamics of K. Therefore, the level of K exchange varies between different soils and finally, K absorption affects plant growth and yield.

Topography condition in studi area

According to Li and McCarty (2019), topographic conditions are key parameters that affect the nature of the soil at the earth's surface. Topographic conditions can affect the content of organic matter, clay content, phosphorus, potassium and magnesium concentrations, and soil pH (Kumhalova et al. 2011).

The topography of the study site has a slope of between 0-25% or moderate undulating. Based on the above data showed that the topography of the study area was included in the flat to a rather steep, where the species of *S. macrophylla* is found in many flat and sloping areas that have high environmental humidity, low ambient temperature, water resources high so that it is suitable to live on the riverbank. Jaffar et al. (2018) stated that the root of *S. macrophylla* tree is able to survive and grow under waterlogged conditions with low oxygen availability and is considered a flood tolerant tree.

At the study site, *S. macrophylla* species dominated the tree species (tree profile can be seen in Figure 7). Besides *S. macrophylla*, other tree species were also found namely *Madhuca spectabilis, Myristica villosa Warb, Scorodocarpus borneensis, Eugenia spp, Palaquium spp, Macaranga triloba, Syzygium inophyllum* and *Shorea sp*. The dominance of *S. macrophylla* was influenced by the high ability to germinate of *S. macrophylla* seeds and faster seed germination time (Appanah and Turnbull 1998), thus affecting the rate of regeneration in nature. *S. macrophylla* has wider seed distribution ability because *S. macrophylla* seeds contain *tengkawang* fat which is used by the community and cultivated by the community (Fajri and Fernandes 2015).

Table 5. *S. macrophylla* abundance in study area.

Number	Local name	Scientific name	Family	Relatif density (%)	Relatif dominance (%)	Relatif frequency (%)	Important value index (%)
1.	Tengkawang	*S. macropyilla*	Dipterocarpaceae	7.69	15.35	5.0	28.04
2.	Kajen ase	*M. spectabilis*	Sapotaceae	10.25	7.29	4.61	22.16
3.	Darah-darah	*M. villosa* Warb	Myristicaceae	7.45	4.79	5.0	17.25
4.	Bala seveny	*S. borneensis*	Olacaceae	5.12	5.77	5.0	15.90
5.	Ubah	*Eugenia* spp	Myrtaceae	5.59	3.64	4.61	13.85
6.	Nyatok	*Palaquium* spp	Sapotaceae	4.42	3.70	4.61	12.74
7.	Beneva	*M. triloba*	Euphorbiaceae	4.66	4.32	3.46	12.44
8.	Ehang	*S. inophyllum*	Myrtaceae	5.36	3.14	3.84	12.35
9.	Kaze tenak	*Shorea* sp	Dipterocarpaceae	2.33	6.08	2.69	11.10

Remark: Primary data

Figure 7. A. Tree of *S. macrophylla* and B. Leaf of *S. macrophylla*

Micro climate conditions

Micro climate data collection consists of 3 factors: temperature, humidity and incoming light. A more complete description can be seen in Table 6.

Table 6. Condition of micro climate in Tane' Olen, Setulang village, Malinau district.

Number	**Micro climate**	**Unit**	**Time**	**Repeat 1**	**Repeat 2**	**Repeat 3**	**Average**	**Remark**
1.	Lights	Lm	Morning	350	400	452	400.67	Taken at 8.59
2.	Area temperature	°c	Morning	24	24.5	25	24.5	sunny conditions
3.	Moisture	%	Morning	81	79	80	80	
1.	Light	Lm	Mid day	750	450	207	469	Taken at 12:02
2.	Area temperature	°c	Mid day	26.5	26	24.5	25.67	sunny conditions
3.	Moisture	%	Mid day	76	79	81	78.67	
1.	Light	Lm	Afternoon	369	237	145	250.33	Taken at 16:30
2.	Area emperature	°c	Afternoon	25	24.5	23	24.17	sunny conditions
3.	Moisture	%	Afternoon	84	85	87	85.33	

Remark: Primary data

Table 6 showed that the average temperature at the study site was between 24-26° C. According to Ruchaemi (2013). the temperatures between 25-30 ° C are the optimal temperatures for plants to carry out the assimilation process.

The humidity value in Table 6 is at 78-86%. This showed that the study area has a high humidity. For light intensity values between 12.52% (250.33 Lm) -23.46% (469 Lm) which means the light intensity in the study area is quite low. This is due to the dense tree canopy in the study area which is dominated by *S. macrophylla* species which have wide and dense leaves so that the intensity of the light entering the forest floor is low. This is consistent with the opinion of Panjaitan et al. (2012). the low intensity of incoming light. indicating an increasingly closed environmental condition so that only a little sunlight can enter the forest floor. This is in accordance with the opinion of Ruchaemi (2013). that light intensity is the most important factor for vegetation and the tropics is the most optimum area for growth.

Association with other plants

According to Saiz and Alados (2012). the association of plant species is a fundamental aspect of the ecology of plant communities. Analysis of plant species associations provides information on environmental heterogeneity, biotic interactions and seed dispersal patterns. The results of the analysis of the species association and the association coefficient is presented in Table 7.

Table 7. Value of species association and coefficient of association.

Number	Species association	X^2 count	Association species	C (+/-)
1.	*S. macropylla* with *M. spectabilis*	0.35	-	0.04
2.	*S. macropylla* with *M. villosa* Warb	6.82	-	0.29
3.	*S. macropylla* with *S. borneensis*	0.04	+	0.04
4.	*S. macropylla* with *Eugenia* spp	0.37	+	0.11
5.	*S. macropylla* with *Palaquium* spp	0.37	+	0.11
6.	*S. macropylla* with *M. triloba*	1.21	+	0.16
7.	*S. macropylla* with *S. inophyllum*	3.23	-	0.29
8.	*S. macropylla* with *Shorea* sp	1.92	-	0.24

Remark: X^2 tabulated value at 5% level: 3.841. X^2 tabulated value at 1% level: 6.35

Table 7 showed that the results of the correlation test of 2 species between *S. macropylla* with 8 dominant tree species. where the calculated X values are all smaller than the value of X tabulated except the species of *M. villosa* War, this means that the species of *S. macrophylla* has a real correlation with the *M. villosa* Warb species but has a negative coefficient of association. According to Sofiah et al. (2013). species pairs do not always produce positive relationships. Plant species that have a high presence frequency do not always provide a high positive association value with other species. Likewise species that have a low existence frequency do not always provide a negative association with other species.

The association coefficient (C) is used as a parameter of how big is the relationship between the eight species with *S. macropylla*. there is a positive co-efficient value of the association and there is a negative association coefficient value. Positive coefficient of association is the association of *S. macropylla* with *S. borneensis. Eugenia spp. Palaquium spp* and *M. triloba* tree species. According to Windusari1 et al. (2011). positive associations indicated that the species likes a place with the same environmental parameters. For example a place that tends to get wet and high sunlight intensity to a bit shady. For negative associations. the association of *S. macropylla* with species of *M. spectabilis. M. villosa Warb. S. inophyllum* and *Shorea* sp. Negative associations indicate no tolerance for living together in the same area or the absence of a mutually beneficial relationship (Pratama et al. 2012).

Direction of *S. macrophylla* species development

At present various species of forests are degraded due to anthropogenic activities such as timber extraction, change of cultivation. and the establishment of commercial plantations which cause conversion. fragmentation. and degradation of tropical rain forests. As a result of deforestation. it can lead to damage to environmental conditions by producing high light intensity and severe soil mineral erosion. In general degraded forests can be divided into three types of degraded vegetation. i.e. grasslands after burning. secondary forests for initial succession. and logged-over forests after commercial logging (Daisuke et al. 2013).

Planting native trees is considered an effective rehabilitation method for degraded tropical rain forests. because these trees provide benefits such as wood. food. and medical products (Daisuke et al. 2013). According to Pratiwi et al. (2014). forest and land rehabilitation is absolutely necessary. in addition to meeting the demand for wood as well as to improve environmental conditions. One of the successes of land rehabilitation is knowing the information about the suitability of growing sites for the species being developed. One approach to determine the suitability of growing places for a species is to conduct a study of potential and economic value species in a place (local superior species). which is supported by species distribution data and growth requirements (Pratiwi et al. 2014).

S. macrophylla species can be recommended for planting on degraded tropical forest land. ie pasture after burning (Daisuke et al. 2013). early secondary succession forests (Daisuke et al. 2013; Perumal et al. 2012). and logged-over forests after commercial logging. According to (Perumal et al. 2019; Perumal et al. 2015; Perumal et al. 2017a; Perumal et al. 2017a; Perumal et al. 2017b; Perumal et al. 2012). *S. macrophylla* is one of the valuable wood tree species which has socio-economic and ecological benefits. is beneficial for reforestation and rehabilitation activities.

The importance of this species in land rehabilitation activities. because this species plays a role in maintaining water quality. filtering out pollutants and deposits as well as storing carbon (Utomo et al. 2018; You et al. 2015). Things that must be considered in planting the *S. macrophylla* species are conditions of nutrient content in clay and clay mineral composition. Therefore. the last two factors can be used to evaluate soil fertility. The growth of *S. macrophylla* is also significantly limited by high light intensity in grass land of *Imperata cylindrica*/pastures after burning. because of the results of this study. *S. macropylla* species favor habitats that have low light intensity. In secondary forests and logged-over forests the survival and/or growth of *S. macrophylla* is limited by hard soil conditions in both. This is in accordance with the results of this study, where the soil conditions have a clay texture (rather fine) with the domination of sandy clay. Based on the characteristics of the *S. macrophylla* habitat, this species occurs in a river side condition with a flat and gentle topography with acidic soil conditions and generally less fertile but has good microclimate conditions with temperatures between 24-26^{o}C, high humidity between 78-86% and the light intensity is quite low 12.52 - 23.46%. This species can be recommended to be planted in tropical forest areas that have been degraded by taking into account the micro climatic factors and soil conditions.

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REFERENCES

Abdissa Y, Tekalign T, Pant LM. 2011. Growth. bulb yield and quality of onion (*Allium cepa* L) as influenced by nitrogen and phosphorus fertilization on vertisol i. growth attributes. biomass production and bulb yield. African J Agricultural Research. Volume 6 (14): 3252–3258. https://Doi.Org/10.5897/Ajar10.1024.

Appanah S, Turnbull JM. 1998. A review of dipterocarps : taxonomy. ecology and silviculture. Center for International Forestry Research.

Casanova M, Tapia E, Seguel O, Salazar O. 2016. Direct measurement and prediction of bulk density on alluvial soils of central Chile. Ultural Chilean J Agric Res 76 (1):105-113. doi:10.4067/S0718-58392016000100015.

Daisuke H, Tanaka K, Jawa KJ, Ikuo N, Katsutoshi S. 2013. Rehabilitation of degraded tropical rainforest using dipterocarp trees in Sarawak. Malaysia. Hindawi Publishing Corporation International J Forestry Research. Volume 2013:1-12. Article ID 683017. 11 pages http://dx.doi.org/10.1155/2013/683017.

Darusman, Devianti, Husen E. 2018. Improvement of soil physical properties of cambisol using soil amendment. Aceh Int. J Sci. Technol.. 7(2): 93-102. doi: 10.13170/aijst.7.2. 10119.

Fahrianoor, Windari T, Taharudin, Mar'i R, Maryono. 2013. The practice of local wisdom of Dayak people in forest conservation in South Kalimantan. Indon J Wetlands Environ Manag 1 (1): 37-46.

Fajri M, Fernandes A. 2015. Pola pemanenan buah tengkawang (*Shorea machrophylla*) dan regenerasi alaminya dikebun masyarakat (*The harvesting pattern of tengkawang fruit (Shorea machrophylla) and natural regeneration in community gardens*). J Penelitian Ekosistem Dipterokarpa Volume 1(2):81 [Indonesian]

Hutauruk TR, Lahjie AM, Simarangkir BDAS, Ruslim Y. 2018a. Setulang forest conservation strategy in safeguarding the conservation of non-timber forest products in Malinau District. IOP Conference. Series: Earth Environment Science. Volume 144: 1-9. https://doi.org/10.1088/1755-1315/144/1/012055.

Hutauruk TR, Lahjie AM, Simarangkir BDAS, Aipassa MI, Ruslim Y. 2018b.The prospect of the utilization of Non-Timber Forest Products from Setulang Village forest based on local knowledge of the Uma Longh community in Malinau. North Kalimantan. Indonesia. Biodiversitas. Volume 19 (2): 421-430. [Indonesian]

Istomo, Hidayati T. 2010. Studi potensi dan penyebaran tengkawang (*Shorea* Spp.) di areal IUPHHK-Ha PT. Intracawood Manufacturing Tarakan. Kalimantan Timur (*Study of the potential and distribution of tengkawang (Shorea Spp.) in the IUPHHK-Ha area of PT. Intracawood Manufacturing Tarakan. East Kalimantan*). J Silvikultur Tropika. Volume 01 (01): 11-17. ISSN: 2086-8227 [Indonesian]

Jaffar ANNM, Wasli ME, Perumal M, Lat J, Sani H. 2018. Effects of soil compaction and relative light intensity on survival and growth performance of planted *Shorea macrophylla* (de vriese) in riparian forest Along Kayan Ulu River. Sarawak. Malaysia. Hindawi International J Forestry Research Volume 2018 (2):1-11. Article ID 6329295. 11 pages https://doi.org/10.1155/2018/6329295.

Kacholi DS. 2014. Analysis of structure and diversity of the kilengwe forest in the Morogoro Region. Tanzania. International J of Biodiversity. Volume 2014: 1-8. Article ID 516840. 8 pages. http://dx.doi.org/10.1155/2014/516840

Kettle CJ. 2010. Ecological considerations for using dipterocarps for restoration of lowland rainforest in Southeast Asia. Biodiv Conserv. 19: 1137-1151.

Kumhalova J, Kumhala F, Kroulik M, Matejkova S. 2011. The impact of topography on soil properties and yield and the effects of weather conditions. J Precision Agriculture. Volume 12 (6): 813-830. https://doi.org/10.1007/s11119-011-9221-x.

Li X, McCarty GW. 2019. Application of topographic analyses for mapping spatial patterns of soil properties: geospatial analyses of earth observation (eo) data. Web of Science. http://doi: 10.5772/intechopen.86109.

Maharani R, Fernandes A, Pujiarti R. 2016. Comparison of tengkawang fat processings effect on tengkawang fat quality from Sahan and Nanga Yen Villages. West Kalimantan. Indonesia. Conference Proceedings. Towards The Sustainable Use of biodiversity in a changing environment: From Basic To Applied Research. Aip Publishing.

Matius P, Tjwa SJM, Raharja, Sapruddin, Noor S, Ruslim Y. 2018. Plant diversity in traditional fruit gardens (munaans) of Benuaq and Tunjung Dayaks tribes of West Kutai. East Kalimantan. Indonesia. Biodiversitas. Volume 19 (4): 1280-1288. DOI: 10.13057/biodiv/d190414. [Indonesian]

Mehata M, Cortus E, Niraula S, Spiehs MJ, Darrington J, Chatterjee A, Rahman S, Parker DB. 2019. Aerial nitrogen fluxes and soil nitrate in response to fall-applied manure and fertilizer applications in Eastern South Dakota. Hindawi International J of Agronomy. Volume 2019:1-15. Article ID 8572985. 15 pages https://doi.org/10.1155/2019/8572985.

Merang OP, Lahjie AM, Yusuf S, Ruslim Y. 2018. Productivity of three varieties of local upland rice on swidden agriculture field in Setulang village. North Kalimantan. Indonesia. Biodiversitas. Volume 21 (1): 49-56. [Indonesian]

Minasny B, Mcbratney AB. 2017. Limited effect of organic matter on soil available water capacity. European J Soil Science. 2017:1-9. https://doi: 10.1111/ejss.12475.

Mouhamed R, Alsaede A, Iqbal M. 2016. Behavior of potassium in soil: a mini review. Chemistry International. 2 (1): 58-69.

Mueller-Dombois D, Ellenberg H. 1974. Aims and methods of vegetation ecology. John Willey and Sons. Canada.

Omara P, Aula L, Raun WR. 2019. Nitrogen uptake efficiency and total soil nitrogen accumulation in long-term beef manure and inorganic fertilizer application/ Hindawi International Journal of Agronomy. Volume 2019:1-6. Article ID 9594369. 6 pages. https://doi.org/10.1155/2019/9594369.

Ohta S, Effendi S. 1992. Ultisols of "lowland dipterocarp forest" in East Kalimantan. Indonesia. Soil Sci. Plant Nutr. 38 (2): 197-206.

Osman KT. 2013. Forest soil: properties and management. Springer. London

Panjaitan S, Wahuningtyas RS, Adawiyah R. 2012. Kondisi lingkungan tempat tumbuh *Shorea johorensis* Foxw. Di HPH

Aya Yayang Indonesia. Kalimantan Selatan (*Environmental conditions in which to grow Shorea johorensis Foxw. At Aya Yayang HPH in Indonesia. South Kalimantan*). J Penelitian Dipterokarpa. Volume 6 (1): 11-22. [Indonesian]

Pratama, Arief B, Alhamd L, Rahajoe JS. 2012. Asosiasi dan karakterisasi tegakan pada hutan rawa gambut di Hampagen. Kalimantan Tengah (*Association and characterization of stands in peat swamp forests in Hampagen. Central Kalimantan*). J Teknologi Lingkungan. Edisi Khusus Hari lingkungan Hidup : 69-76. [Indonesian]

Pratiwi, Narendra BH, Hartoyo GME, Kalima T, Pradjadinata S. 2014. Atlas jenis-jenis pohon andalan setempat untuk rehabilitasi hutan dan lahan di Indonesia (*Atlas of local reliable tree species for forest and land rehabilitation in Indonesia*). Forda Press. [Indonesian]

Pratiwi, Narendra B. 2012. Pengaruh penerapan teknik konservasi tanah terhadap pertumbuhan pertanaman Mahoni (*Swietenia Macrophylla* King) Di Hutan Penelitian Carita. Jawa Barat (*Effect of applying soil conservation techniques to the growth of Mahogany* (Swietenia Macrophylla King) *plantations in the Carita Research Forest. West Java*). J Penelitian Hutan Dan Konservasi Alam. Volume 9 (2): 139-150. [Indonesian]

Perumal M, Wasli ME, and Ying. HS. 2019. Influences of inorganic and organic fertilizers to morphological quality attributes of *Shorea macrophylla* seedlings in a tropical nursery. Biodiversitas. Volume 20 (8): 2110-2118. ISSN: 1412-033X. E-ISSN: 2085-4722. DOI: 10.13057/biodiv/d200803.

Perumal M. Wasli ME, Ying HS, Sani H. 2017a. Survivorship and growth performance of Shorea macrophylla (de Vriese) after enrichment planting for reforestation purpose at Sarawak. Malaysia. Online J Biology Science. Volume 17 (1): 7-17.

Perumal M, Wasli ME, Ying HS, Lat J, Sani H. 2017b. Association between soil fertility and growth performance of planted *Shorea macrophylla* (de Vriese) after Enrichment Planting at Rehabilitation Sites of Sampadi Forest Reserve. Sarawak. Malaysia. Hindawi International J Forestry Research. Volume 2017. Article ID 6721354. 16 pages. https://doi.org/10.1155/2017/6721354.

Perumal M, Wasli ME, Sani H, Nahrawi H. 2012. Growth performance of planted *Shorea macrophylla* under line planting technique. In: 4th Regional Conference on Natural Resources in the Tropics. 2012 (NTrop4) : Sustaining Tropical Natural Resources Through Innovations. Technologies and Practices.

Quedraogo I, Nacoulma BMI, Hahn K, Thiombiano A. 2014. Assessing ecosystem services based on indigenous knowledge in south-eastern Burkina Faso (West Africa). Intl J Biodivers Sci Ecosyst Serv Manag 10 (4): 313-321.

Randi A, Julia S, Kusumadewi Y, Robiansyah I, Shomat F, Tanggaraju S, Hamidi A, Juiling S, Bodos V, Maryani A. 2019. *Shorea macrophylla*. The IUCN red list of threatened species 2019: e.T33620A125629642. http://dx.doi.org/10.2305/IUCN.UK.20193.RLTS.T33620A125629642.en

Rikando R. Latifah S. Manurung TF. 2019. Sebaran jenis tengkawang (*Shorea* spp) di hutan tembawang Desa Labian Kecamatan Batang Lupar Kapuas Hulu Kalimantan Barat (*Distribution of tengkawang species* (Shorea spp) *in the Tembawang forest Labian Village Batang Lupar District Kapuas Hulu West Kalimantan*). J Hutan Lestari. Volume 7 (1) : 390-406. [Indonesian]

Ruchaemi A. 2013. Ilmu pertumbuhan hutan (Forest growth Science). Samarinda: Mulawarman University Press. [Indonesian]

Sadeghi SM, Hanum IF, Abdu A, Kamziah IK, Hakeem KR, Ozturk M. 2016. Recovery of soil in hill dipterocarp forest after logging in Kedah. Malaysia. Malayan Nature J. Volume 68 (1 & 2): 187-201.

Saiz H, Alados CL. 2012. Changes in semi-arid plant species associations along a livestock grazing gradient. Plos One 7 (7): 1-9. E40551. http://doi:10.1371/Journal.Pone.0040551.

Schroeder K, Pumphrey M. 2013. It's all a matter of pH: acid soils. aluminum toxicity are on the rise in Eastern Washington. Northern Idaho. Washington Grain Commission reports. http://washingtoncrop.com (accessed 16 Jan. 2016). p. 56–59.

Schlesinger WH, Bernhard ES. 2012. Biogeochemisty: an analysis of global change. 3rd ed. Academic Press. San Diego. CA.

Sofiah S, Setiadi D, Widyatmoko D. 2013. Pola penyebaran. kemelimpahan. dan asosiasi bambu pada komunitas tumbuhan di Taman Wisata Alam Gunug Baung Jawa Timur (*Distribution patterns. abundance. and bamboo associations in plant communities in the Gunug Baung Nature Park in East Java*). Berita Biologi. J Ilmu-Ilmu Hayati. Volume 12 (2): 239-247.

Turner BL, Engelbrecht BMJ. 2011. Soil organic phosphorus in lowland tropical rain forests. Biogeochemistry. 2011:103:297–315 DOI 10.1007/s10533-010-9466-x.

Utomo S, Uchiyama S, Ueno S, Matsumoto A, Widiyatno, Indrioko S, Na'iem M, Tsumura Y. 2018. Effects of pleistocene climate change on genetic structure and diversity of *Shorea macrophylla* in Kalimantan rainforest. Tree Gen Genomes. Volume 14 (4): 14-44.

Widiyatno, Budiadi, Suryanto P, Rinarno YDBM, Prianto SD, Hendro Y. 2017. Recovery of vegetation structure. soil nutrients and late-succession species afters hifting cultivation In Central Kalimantan. Indonesia. J Tropical Forest Science. Volume 29 (2): 151-162.

Windusari Y, Susanto RH, Dahlan Z, Susetyo W. 2011. Asosiasi jenis pada komunitas vegetasi suksesi di kawasan pengendapantailing tanggul ganda di pertambangan PTFI Papua (*Species associations in the succession vegetation community in the deposition area of the double embankment in Papua's PTFI mine*). J Ilmiah Ilmu-Ilmu Hayati Biota.

Volume 16 (2): 242-251. [Indonesian]
Zaidey AK, Arifin A, Zahari I, Hazandy AH, Zaki MH, Affendi H, Wasli ME, Hafiz YK, Shamsuddin, Muhammad MN. 2010. Characterizing soil properties of lowland and hill dipterocarp forest at Peninsular Malaysia. Intenational J Soil Science. Volume 5 (3):112-130.
Zeng C, Wang Q, Zhang F, Zhang J. 2013. Temporal changes in soil hydraulic conductivity with different soil types and irrigation methods. Geoderma 193/194:290-299. doi:10.1016/j. geoderma.2012.10.013.
Zhu X, Zhu B. 2015. Diversity and abundance of soil fauna as influenced by longterm fertilization in cropland of purple soil. China. Soil and Tillage Research. Volume 146: 39-46.

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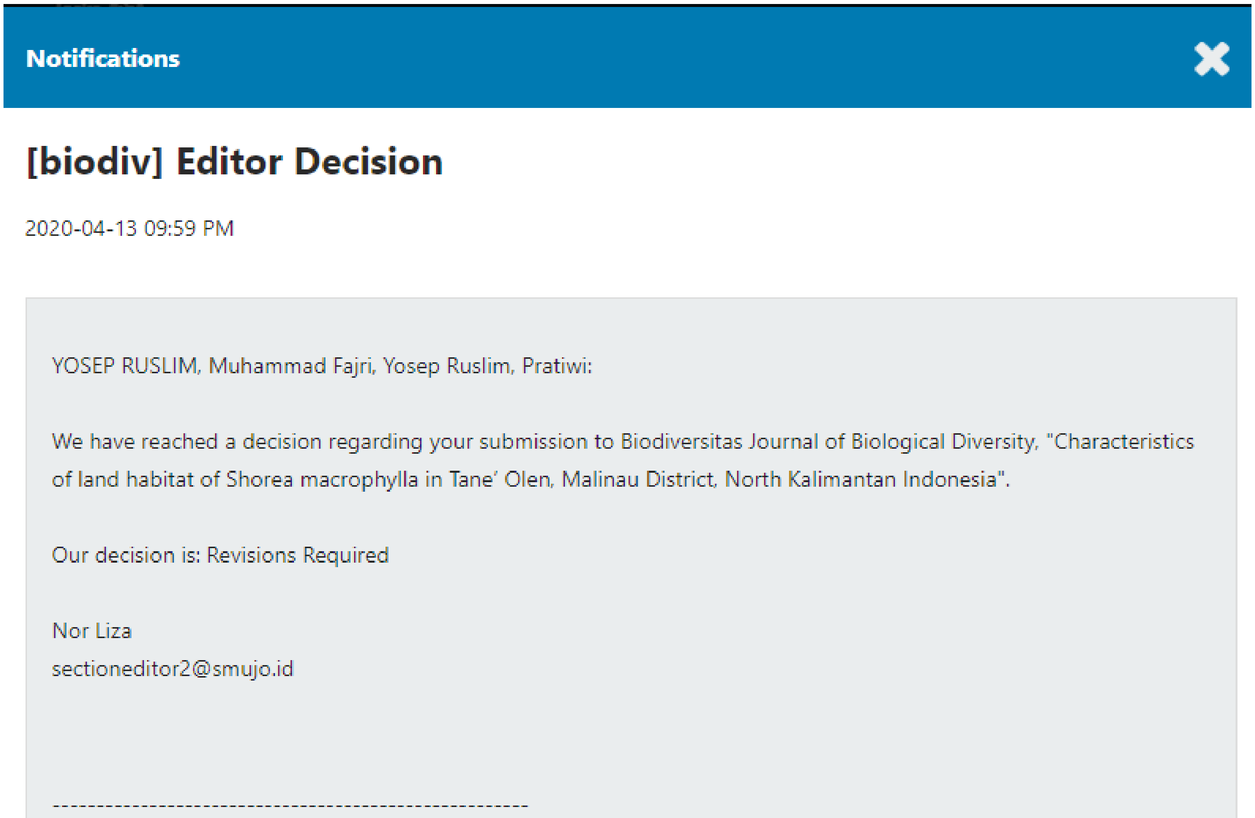

[biodiv] Editor Decision

2020-04-13 09:59 PM

YOSEP RUSLIM, Muhammad Fajri, Yosep Ruslim, Pratiwi:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Characteristics of land habitat of Shorea macrophylla in Tane' Olen, Malinau District, North Kalimantan Indonesia".

Our decision is: Revisions Required

Nor Liza
sectioneditor2@smujo.id

Reviewer L:

Dear the editor of Biodiversitas

The manuscript of Characteristics of land habitat of *Shorea macrophylla* in Tane' Olen, Malinau District, North Kalimantan Indonesia is weak of the research novelty, because the previous research in the BIODIVERSITAS 21: 1467-1475 (Characterization of soil properties in relation to Shorea macrophylla growth performance under sandy soils at Sabal Forest Reserve, Sarawak, Malaysia) is already published in 2020. So, this manuscript should find a strong background and novelty for next publication

Recommendation: Revisions Required

Land habitat characteristics of *Shorea macrophylla* in Tane' Olen, Malinau District, North Kalimantan, Indonesia

Abstract. *Shorea macrophylla* is a tree species in Tane' Olen forest area. This study analyzed the physical, chemical, topographical, and microclimate habitat conditions of the *S. macrophylla* tree. Purposive sampling method was used to distribute the subplots and to the Pipet method was used to analyze the physical properties of the soil. The electrode method, ammonium Acetate pH 7 method, KCl 1 N method, Kjeldahl, Walkley N Black method, calculation method, Bray I method, and Barium chloride method were utilized to analyze the chemical characteristics of the soil and *S. macrophylla* abundance was determined by IVI analysis. The physical properties of soils in the study area have a bulk density of 0.60-1.31 gram cm$^{3-1}$, soil porosity of 50.60%-77.35%, water content of 34.88%-95.37%, soil texture dominated by sand, clay and dust. The chemical condition of the soil were as follows: 3.6-4.8 pH, 0.05%-0.19% N, 1.40%-3.65% organic C, 0.41-2.3 mg 100 gr^{-1} P, 58.68-232.55 mg 100 gr^{-1} K, and 5.35-10.81 meg 100gr $^{-1}$ Cation Exchange Capacity(CEC). Slope ranged between 0-25%. Microclimate conditions were as follows: 24-26.5° C temperature, 76-84% humidity; 350-750 Lm light intensity. Associations with an IVI ≥ 10% are *S. macrophylla*, *Madhuca spectabilis*, *Myristica villosa* Warb, *Scorodocarpus borneensis*, *Eugenia* spp, *Palaquium* spp, *Macaranga triloba*, *Syzygium inophyllum* and *Shorea* sp. Positive associations were observed between *S. macropylla* and *S. borneensis*, *Eugenia* spp, *Palaquium* spp and *M. triloba,* and negative associations were observed between *S. macropylla* and *M. spectabilis*, *M. villosa* Warb, *S. inophyllum,* and *Shorea* sp. *S. macrophylla* grows on riversides with flat and gentle topography, acidic soil conditions, and lower fertility but good microclimate conditions. This species can be recommended to be planted in degrade tropical forest areas if microclimatic factors and soil conditions are taken into account.

Keywords: Habitat, land characteristics, *S. macrophylla*

Running title: Land habitat characteristics of *Shorea macrophylla*

INTRODUCTION

Shorea macrophylla is one of the fastest growing climax tree species of the genera *Shorea* (Perumal et al. 2017). Local communities value this species as a source of wood and fruit (Randi et al. 2019). *S. macrophylla* is known locally in West Kalimantan as the tengkawang tungkul tree and has been cultivated by the Dayak and Malay communities (Fajri and Fernandes 2015). *S. macrophylla* grows in clusters in tropical rain forests with A-type rainfall, on latosol soils at altitudes up to 500 m a.s.l., on acidic soils (pH 4.6-4.9), and a cation-exchange capacity (CEC) of 16.25-19.40 (Istomo and Hidayati 2010). In Sarawak, Sabah, Brunei and Kalimantan, this species is associated with sedimentary soils and is distributed randomly and evenly over riverbanks and areas with sloping or flat topography. It is rarely found on hills. (Randi et al. 2019; Utomo et al. 2018; Perumal et al. 2017).

The wood of *S. macrophylla* is commonly used for timber, veneer and plywood; it is used to construct buildings, shipping wood, musical instruments, furniture, and packing crates (Istomo and Hidayati 2010). The fruit, locally known as tengkawang tungkul (Illipe) nuts, is used as a raw material in soap and other cosmetics, a substitution for brown fat, and a source of vegetable fats (Maharani et al. 2016).

The native population of tengkawang is declining and is, at present, hard to find (Istomo and Hidayati 2010). *S. macrophylla* is one of the most sought-after species in tropical forests. The exploitation of the species for its wood, combined with forest conversion to other uses, have resulted in *S. macrophylla* wood being difficult to find in the market (Rikando et al. 2019).

Tane' Olen is a forested area with a high environmental value that is preserved by the people of Setulang Village (Hutauruk et al. 2018a), a community that manages its forests based on the wisdom of its local communities and sustainable forest management practices (Fahrianoor et al. 2013; Kettle 2010), so that forest sustainability is maintained

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(Hutauruk et al. 2018). Forests are not only a place to live but are also used as a source of food and medicine and economic, social, cultural, and spiritual functions (Merang et al. 2020; Matthew et al. 2018; Quedraogo et al. 2014).

S. macrophylla habitat conditions in secondary forest locations have previously been documented by Jaffar et al. (2018) and Perumal et al. (2017). Perumal et al. (2017) studied the relationship between soil fertility and the growth of *S. macrophylla* trees in enrichment plantings at Sampadi Forest Reserve, Lundu, Sarawak and an adjacent secondary forest. Jaffar et al. (2018) researched the effects of soil compaction and light intensity on the establishment and growth of *S. macrophylla* in riparian forests in Sungai Kayan Ulu Sungai, Serawak, Malaysia. Through the improvement of the company's management system, which is changing the way of harvesting using long cables during skidding activity will reduced the natural forest damage and can increase financial returns from natural forest concessions. Through the improvement of the company's management system, which is changing the way of harvesting using long cables during skidding activity will reduce soil compaction, residual stand damage on the natural forest and can increase financial returns from natural forest concessions (Ruslim et al. 2016). The characteristics of *S. macrophylla* habitat in primary forest locations has not previously been studied. This research supports and supplements previous studies on *S. macrophylla* habitat characteristics, specifically in regards to soil conditions, microclimate, topography, and species associations within natural habitats in primary forest locations.

This study aims to define and describe *S. macrophylla* land habitat characteristics in primary forests by analyzing physical and chemical soil conditions, microclimate conditions, topographic conditions, species associations, and vegetation analysis to index habitat requirements in a study area with characteristic *S. macrophylla* land habitat traits. It is also hoped that the results of this study will benefit conservation efforts of this species, especially on degraded land in the tropical rain forests of North Kalimantan.

MATERIALS AND METHODS

Study area

The study was carried out in the Tane' Olen forest area, Setulang Village, Malinau District, North Kalimantan Utara (3°25'0.86" N and 116°25'52.59" E). The location map is presented in Figure 1.

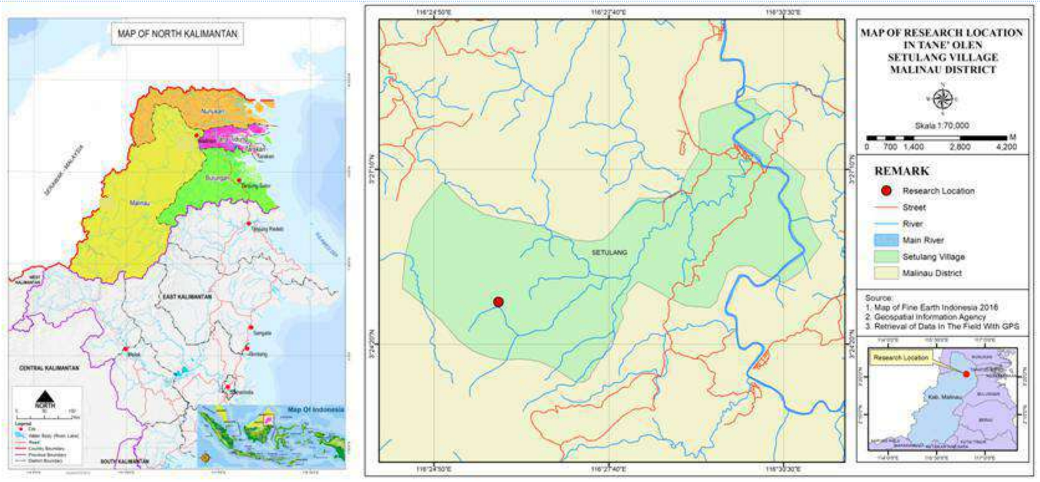

Figure 1. Location of the research in Tane' Olen (●)

Research procedure

The one-hectare research site was sampled using the purposive sampling method and a square plot with a side length of 100 meters (Sari and Maharani 2016). Soil sampling data was taken using a purposive sampling technique with three sampling points in an area of one hectare. The three selected points were located on a hill, a back, and a valley (hills have the highest elevations and a 15-25% slope, backs are located between the valleys and hills and have an 8-15% slope, valleys are the lowest areas and have a 0-8% slope) to ensure an accurate representation of the study site. At each sampling point, soil samples were taken at three depths: 0-20 cm, 20-40 cm, and 40-60 cm. Microclimate data (temperature, humidity, and light intensity) was collected at the same locations. The soil and microclimate data collection design is illustrated in Figure 2. Vegetation data was only collected on trees with a diameter at breast height (DBH) greater than 20.0 cm. (Vegetation data was only collected on large trees because these trees are at the top of the growth cycle and their data can be inferred to represent characteristics favored by seedlings, saplings, and poles of *S. macrophylla*.) Each plot was divided into 25 subplots (20 m x 20 m). Within each subplot, species were identified and DBH recorded for all trees

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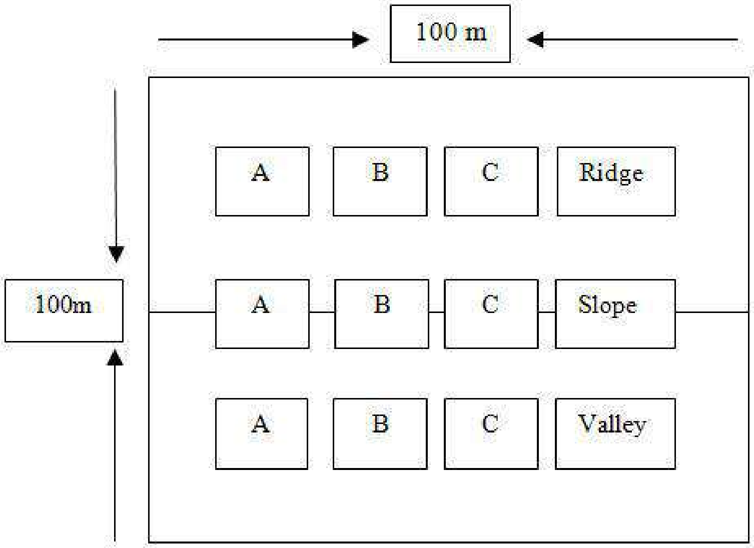
(Widiyatno et al. 2017). Plot-making and field-data collection activities are presented in Figure 2, while sampling design is presented in Figures 3 and 4.

Figure 2. A. Exploration, B. Make a research plot, C. Tree inventory, D. Soil sample collection, E and F. Microclimate data collection

Soil sample collection design and micro climate data are presented the following Figures 3 and 4



Remark: A:lights intensity, B: temperature and area humidity, C: soil sampling, m:Meter

Figure 3. Soil and microclimate sample design

Topography data collection design can be seen in Figure 4.

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The 1 hectare research was conducted using the Purposive Sampling method. The plot is made in a square shape with a side length of 100 meters (Sari and Maharani 2016). In the plot, soil sampling data is taken. Soil sampling using a purposiv

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Deleted[Yosep Ruslim]: **Figure 3.** Design of soil sampling and microclimate conditions

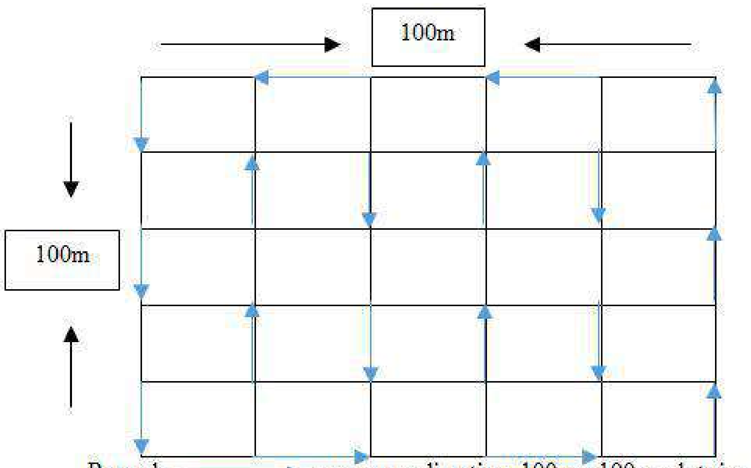

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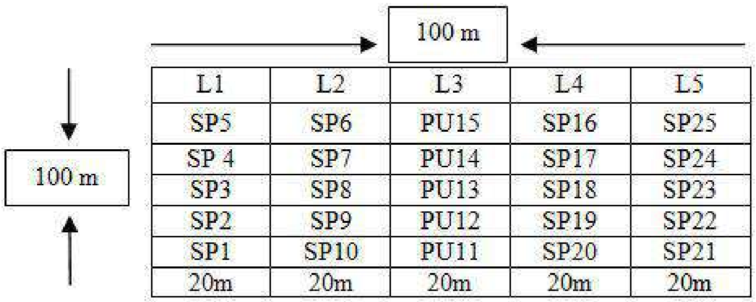
Figure 4. Plot design across topographic features

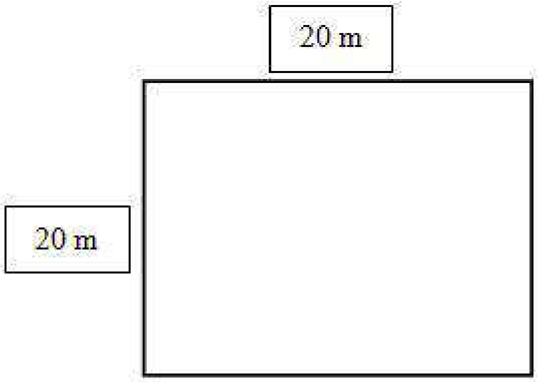
The design of vegetation data can be seen in Figures 5 and 6.



L1	L2	L3	L4	L5
SP5	SP6	PU15	SP16	SP25
SP 4	SP7	PU14	SP17	SP24
SP3	SP8	PU13	SP18	SP23
SP2	SP9	PU12	SP19	SP22
SP1	SP10	PU11	SP20	SP21
20m	20m	20m	20m	20m

Remarks: L: lane, SP: sub plot, 20m: distance between sub plots, 100m x 100m: plot size, m: Meter.

Figure 5. Design of vegetation analysis



Remark: 20m x 20m: Tree level sub plot, m: Meter.

Figure 6. Vegetation inventory design for trees > 20.0 cm DBH.

Data analysis

Soil analyses

Soil samples are analyzed for both physical and chemical properties (Kurnia et al. 2006; Eviati and Sulaeman 2009). Physical properties analyzed included texture, bulk density, porosity, and water content (using the Pipette method). Chemical properties analyzed included pH (using the electrode method), CEC (using the ammonium acetate pH 7 method), elements Al+++ and H+ (using the KCl method 1 N), total N elements (using the Kjeldahl method), organic C elements (using Walkley-Black method), C/N ratio (using arithmetic methods), elements P_2O5 and K_2O (using Bray No I methods), and saturation Al (using arithmetic methods). Soil data analysis results from the soil laboratory will be tabulated and analyzed descriptively and quantitatively.

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Analytical topography

The topographic analysis will describe the topographic conditions favored by *S. macrophylla*.

Microclimate analyses

The analyses of microclimate conditions will provide information on microclimate conditions favored by *S. macrophylla*.

Important Value Index

According to Kacholi (2014), the Importance Value Index (IVI) is used in ecological studies to determine the ecological importance of a species in a particular ecosystem. IVI is also used to prioritize species conservation. Species with low IVI values require a higher conservation priority when compared to species with high IVI. The dominant species, IVI value is a function of several characteristics. (IVI = relative density + relative frequency + relative dominance). IVI values will be analyzed descriptively.

Association of vegetation

Associations between two tree species were analyzed using a series of 2x2 contingency tables (Mueller-Dombois and Ellenberg 1974). A more complete description is presented in Table 1.

Table 1. Contingency table form

Species A **Species B**	+	-	
+	a	b	a + b
-	c	d	c + d
	a + c	b + d	N = a + b + c + d

Reference: Mueller-Dombois and Ellenberg (1974)

Remarks :

a = Amount of plot containing species A and species B.

b = Amount of plot containing only species A and no species B.

c = Amount of plot containing only species B and no A.

d = Amount of plot containing neither species A nor species B.

N = Amount of all plots.

Which then tested with chi-square (x^2)

$$X^2 = \frac{(ad - bc)^2 \, x \, N}{(a+b)(c+d)(a+c)(b+d)}$$

And calculated their association coefficient (C) values

1. If ad > bc, so $C = \frac{ad-bc}{(a+b)(b+d)}$
2. If bc > ad and d > a, so $C = \frac{ad-bc}{(a+b)(b+c)}$
3. If bc > ad and a > c, so $C = \frac{ad-bc}{(a+d)(c+d)}$

Positive or negative values of C indicate a positive or negative relationship between the two species, respectively. A positive relationship indicates that the association between trees is mutually beneficial to each other, while a negative value indicates that the association between trees harms one another.

RESULTS AND DISCUSSION

Analysis of soil physical and chemical properties

Analysis of physical and chemical soil properties

Results of the physical and chemical soil properties analyses for the Tane' Olen plot, Setulang Village, Malinau Regency study area, as they pertain to *S. macrophylla* habitat, can be seen in Table 2.

Table 2. Physical properties of soil in Tane'Olen, Setulang, Malinau District

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Land condition	Depth (cm)	Bulk density (gram/cm³)*	Porosity (%)*	Water content (%)
Valley	0-20	0.60	77.35	95.37
	20-40	1.13	57.32	40.04
	40-60	1.18	55.54	39.20
Slope	0-20	1.05	60.42	48.08
	20-40	1.31	50.60	41.42
	40-60	1.23	53.72	34.88
Ridge	0-20	0.83	68.75	61.68
	20-40	1.01	61.92	44.23
	40-60	1.20	54.66	35.53

Remark:* Average score for three times repetition

At the depth of 0-20 cm, the valley, back, and hill subplots have a low bulk density (0.60-1.05) (Table 2). This means that the soils within the study area are not able to store water due to the dense soil conditions. According to Casanova et al. (2016) and Zeng et al. (2013), soil bulk density conditions are influenced by external conditions and natural processes such as plant root growth and rainfall.

The soil porosity values in the valley, back, and hill subplots decrease with increasing soil depth. The valley subplot has a higher porosity value than the back and hill subplots. According to Darusman et al. (2019), the properties that most affect soil porosity are bulk density and soil particle density; if the bulk density is low then the soil porosity will increase.

Water content in the hill, back, and valley decreases with increasing soil depth. The water content in the hill subplot is higher than the back subplot because the water movement is faster in the slope subplot and the water settles in the lower area, i.e. the valley subplot. This phenomenon results in a higher (95.37%) water content in the valley subplot when compared to the hill and back subplots. Jaffar et al. (2018) reported that *S. macrophylla* plant roots can adapt to high water soil conditions. According to Zhang et al. (2015), water content affects soil moisture and dry soil density; the higher the soil's water content, the higher the soil moisture and the lower the dry soil density. Moist soil conditions encourage *S. macrophylla* roots growth and development. According to Minasny and McBratney (2018), the availability of groundwater is an important component of water balance and the terrestrial biosphere cycle because it can affect evapotranspiration rates and support plant growth.

The results of the soil texture analysis can be seen in Table 3.

Table 3. Soil texture in Tane' Olen, Setulang Village, Malinau District

Land condition	Depth (cm)	Clay (%)	Sand (%)	Dust (%)	texture (USDA)
Valley	0-20	33.70	50.90	15.40	SCL
	20-40	36.50	49.50	14.00	SC
	40-60	34.00	56.80	9.20	SCL
Slope	0-20	24.70	67.20	8.10	SCL
	20-40	27.30	63.10	9.60	SCL
	40-60	33.10	60.50	6.40	SCL
Ridge	0-20	37.80	54.60	7.60	SC
	20-40	37.40	46.40	16.20	SC
	40-60	40.70	48.00	11.30	SC

Remark: Laboratory of soil test in B2P2EHD and Pusrehut, Mulawarman University

The soil texture at the study site generally had a sand fraction between 45-65%, a clay fraction between 35-55%, and a dust fraction between 0-20% (Table 3). This means that the soil texture is sandy clay. According to Osman (2013), soil texture refers to the level of fineness or roughness created by the various-sized soil particles.

Soil types are generally dominated by Ultisol (advanced development) soils, namely Typic Hapludults (Red-Yellow Podsolik) and Typic Paleudults (Yellow Podsolic). These soil types are typically found in lowland dipterocarp forests (Ohta and Effendi 1992).

Chemical soil characteristics of the study area are presented in Table 4.

Table 4. Chemical characteristics of soil in Tane' Olen, Setulang village, Malinau district

Land condition	Depth (cm)	pH (1: 25)		Cation exchange rates (meg 100gr^{-1})			Organic content (%)		Ratio	Mineral (Mg 100 gram^{-1})	
		H2O	KCl	KTK	Al3+	H+	N. Tot	C.Org	C/N	P_2O_5	K_2O
Valley	0-20	4.6	3.3	7.26	4.92	1.50	0.19	3.65	19	0.89	116.85
	20-40	4.6	3.4	7.25	5.56	1.08	0.12	2.65	22	0.73	73.30
	40-60	4.4	3.4	7.18	5.75	0.92	0.10	2.12	22	1.22	59.00
Slope	0-20	4.1	3.5	5.35	2.75	1.33	0.13	2.31	18	0.65	73.62
	20-40	4.7	3.5	5.30	3.50	0.92	0.07	1.54	22	0.65	58.68
	40-60	4.8	3.5	5.53	3.33	1.42	0.05	1.40	26	0.41	60.90
Ridge	0-20	4.4	3.0	10.81	7.25	2.75	0.09	3.46	39	2.35	120.34

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	20-40	3.6	3.3	10.48	7.80	1.83	0.08	2.12	28	0.89	194.09
	40-60	4.4	3.4	10.37	6.83	2.58	0.09	1.54	17	0.65	232.55

Remark: Laboratory of soil test in B2P2EHD and Pusrehut, Mulawarman University

The soil in the study area is very acid (pH = 4.1-4.8) (Table 4). According to Schroeder and Pumphrey (2013), acid soils inhibit root and plant growth and increase Al levels in the soil. The CEC in the study area ranges from 5.3 to 10 meq/ 100 g^{-1}, indicating that the CEC is low. In general, the value of CEC is low in surface and subsurface soils of lowland dipterocarp forests (Perumal et al. 2017a).

Aluminum levels in the study area are high, especially in the back and valley subplots, which indicates high soil toxicity. Al content in the soil decreases with increased organic matter because organic matter forms a strong bond with Al. According to Zaidey et al. (2010), Al is a major cause of soil acidity, and soils in lowland dipterocarp forests have a high Al content.

Nitrogen levels at the research location range from 0.05% -0.19% (low to very low). Sadeghi et al. (2016) also reported low total N levels in tropical rain forest soils. Nitrogen is a nutrient that is important for plant growth (Omara et al. 2019), and N deficiency can inhibit plant growth (Mehata et al. 2019). According to Omara et al. (2019), the main sources of N are organic matter, nitrogen mineralization and rainfall/precipitation.

Organic C values are higher in the valley and back subplots and lower in the hill subplot. The steeper slopes in the hill subplot are more prone to erosion, resulting in organic C and other nutrients leaching into the valley and back subplots. According to Schlesinger and Bernhard (2013), carbon can be stored in the soil three times longer than in the atmosphere and is an indicator of soil microorganism abundance and diversity (Zhu and Zhu 2015). The presence of organic C in the soil spurs microorganism activity and thereby increases the rates of soil decomposition, P dissolution, N fixation, and other microorganism-dependent reactions.

Phosphate was calculated from P2O5 where the Phosphate content was high (58.78). Phosphorus content is very low (0.41-1.22 mg 100 $gram^{-1}$) (Table 4). According to Turner and Engelbrecht (2011), organic P plays an important role in maintaining P availability in lowland tropical rain forests. Phosphorus is essential for root development and plant growth (Abdissa et al. 2011).

Potassium values range from high (58.68-116.85 ppp) in the valley and back subplots to very high (120.34-232.55 ppm) in the hill subplot. According to Mouhamad et al. (2016), K is more abundant in the soil than other mineral elements. This element has an extraordinary role in plant metabolism, plant growth, and yield. Potassium availability depends on soil properties (humidity, aeration, and temperature), soil treatment systems, and the dynamics of K. Therefore, the K exchange level varies between soils.

Topography condition in the study area

According to Li and McCarty (2019), topographic features are key parameters that affect the nature of the soil at the earth's surface. Topographic features can affect organic matter; clay content; P, K, and Mg concentrations; and soil pH (Kumhalova et al. 2011).

The topography of the study site is moderately undulating with a slope of 0-25%. Based on the above data, subplot slopes ranged from flat to a rather steep. *S. macrophylla* is found primarily in flat to sloping areas with high environmental humidity, low ambient temperature, and abundant water. This makes it suitable to live on riverbanks. Jaffar et al. (2018) stated that the roots of the *S. macrophylla* tree are able to survive and grow in anaerobic waterlogged soils and is considered a flood-tolerant tree.

At the study site, *S. macrophylla* was the dominant tree species (Figure 7). Other tree species included *Madhuca spectabilis, Myristica villosa* Warb., *Scorodocarpus borneensis, Eugenia* spp., *Palaquium* spp., *Macaranga triloba, Syzygium inophyllum,* and *Shorea sp. S. macrophylla* dominates the study site due to its high germination rate and faster germination rate (Appanah and Turnbull 1998), its high growth rate (fastest of the genus *Shorea)*, and its status as a climax species along rivers (Perumal et al. 2017).

Table 5. *S. macrophylla* abundance in study area

Number	**Local name**	**Scientific name**	**Family**	**Relatif density (%)**	**Relatif dominance (%)**	**Relatif frequency (%)**	**Important value index (%)**
1.	Tengkawang	*S. macropyilla*	Dipterocarpaceae	7.69	15.35	5.0	28.04
2.	Kajen ase	*M. spectabilis*	Sapotaceae	10.25	7.29	4.61	22.16
3.	Darah-darah	*M. villosa* Warb	Myristicaceae	7.45	4.79	5.0	17.25
4.	Bala seveny	*S. borneensis*	Olacaceae	5.12	5.77	5.0	15.90
5.	Ubah	*Eugenia* spp	Myrtaceae	5.59	3.64	4.61	13.85
6.	Nyatok	*Palaquium* spp	Sapotaceae	4.42	3.70	4.61	12.74
7.	Beneva	*M. triloba*	Euphorbiaceae	4.66	4.32	3.46	12.44
8.	Ehang	*S. inophyllum*	Myrtaceae	5.36	3.14	3.84	12.35
9.	Kaze tenak	*Shorea* sp	Dipterocarpaceae	2.33	6.08	2.69	11.10

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Figure 7. A. Tree of *S. macrophylla* and B. Leaf of *S. macrophylla*

Microclimate conditions

Three microclimate data factors were collected: temperature, humidity, and light intensity (see Table 6 for a more complete description).

Table 6. Microclimate conditions in Tane' Olen, Setulang Village, Malinau District

Number	Micro climate	Unit	Time	Repeat 1	Repeat 2	Repeat 3	Average	Remark
1.	Lights intensity	Lm	Morning	350	400	452	400.67	Taken at 8.59 sunny conditions
2.	Area temperature	°c	Morning	24	24.5	25	24.5	
3.	Moisture	%	Morning	81	79	80	80	
1.	Lights intensity	Lm	Mid day	750	450	207	469	Taken at 12:02 sunny conditions
2.	Area temperature	°c	Mid day	26.5	26	24.5	25.67	
3.	Moisture	%	Mid day	76	79	81	78.67	
1.	Lights intensity	Lm	Afternoon	369	237	145	250.33	Taken at 16:30 sunny conditions
2.	Area emperature	°c	Afternoon	25	24.5	23	24.17	
3.	Moisture	%	Afternoon	84	85	87	85.33	

The average temperature at the study site was between 24-26° C (Table 6). According to Ruchaemi (2013), the optimal temperature for plant assimilation is 25-30° C. Humidity values were high, ranging from 78-86%. Light intensity ranged from 12.52% (250.33 Lm) -23.46% (469 Lm), indicating low light intensity. This is due to a dense tree canopy dominated by *S. macrophylla,* whose dense, wide leaves prevent light from reaching the forest floor. This low light intensity is consistent with the findings of Panjaitan et al. (2012), who found that the closed canopy only allowed a little sunlight to reach the forest floor. These conditions benefit *S. macrophylla* seedlings, which are both shade tolerant and sun intolerant.

Association with other trees

According to Saiz and Alados (2012), plant species associations is a fundamental aspect of the ecology of plant communities. Analysis of plant species associations provides information on environmental heterogeneity, biotic interactions, and seed dispersal patterns. The results of the species association analysis and the association coefficient are presented in Table 7.

Table 7. Value of species association and coefficient of association

Number	Species association	X² count	Association species	C (+/-)
1.	*S. macropylla* with *M. spectabilis*	0.35	-	0.04
2.	*S. macropylla* with *M. villosa* Warb	6.82	-	0.29
3.	*S. macropylla* with *S. borneensis*	0.04	+	0.04
4.	*S. macropylla* with *Eugenia* spp	0.37	+	0.11
5.	*S. macropylla* with *Palaquium* spp	0.37	+	0.11
6.	*S. macropylla* with *M. triloba*	1.21	+	0.16
7.	*S. macropylla* with *S. inophyllum*	3.23	-	0.29
8.	*S. macropylla* with *Shorea* sp	1.92	-	0.24

Remark: X ² tabulated value at 5% level: 3.841. X² tabulated value at 1% level: 6.35

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Table 7 shows the results of a series of 2x2 contingency tests between *S. macropylla* and eight other dominant tree species. The calculated X values are greatest between *S. macropylla* and *M. villosa* Warb, indicating that *S. macrophylla* has a strong but negative association with *M. villosa* Warb. According to Sofiah et al. (2013), species pairs do not always indicate positive relationships. Tree species with high populations are not always associated with another species. Likewise, low-population species are not necessarily negatively correlated with another species.

The association coefficient (C) is used as a parameter of the magnitude of the relationship between the eight species and *S. macropylla* and indicates positive or negative associations. Species that show positive coefficients of association with *S. macropylla* are *S. borneensis, Eugenia spp., Palaquium spp,* and *M. triloba.* According to Windusari1 et al. (2011), positive associations indicate both species like the same environmental conditions; for example, wet conditions, high light intensity, or shade. *S. macropylla* showed a negative association with *M. spectabilis, M. villosa Warb, S. inophyllum,* and *Shorea* sp. Negative associations indicate an intolerance for cohabitation or the absence of a mutually beneficial relationship (Pratama et al. 2012).

Direction of *S. macrophylla* development

At present, tropical forests are being degraded by anthropogenic activities such as timber extraction, agricultural cultivation, and the establishment of commercial plantations. This results in the conversion of forests into agriculture land and the fragmentation and degradation of tropical rain forests. Deforestation damages the environment by increasing light intensity and causing severe mineral soil erosion. In general, degraded forests can be divided into three categories: grasslands after burning, early-succession secondary forests, and commercially logged forests (Daisuke et al. 2013).

Planting native trees is considered to be an effective rehabilitation method for degraded tropical rain forests because native trees provide benefits such as wood, food, and medical products (Daisuke et al. 2013). According to Pratiwi et al. (2014), tropical forest rehabilitation is necessary to both meet the demand for wood and to improve environmental conditions. One key to rehabilitation success is understanding the suitability of each growing sites for each species being developed. One approach to determine the suitability of growing sites for each species is to identify each species' potential, identify locally superior species, and correlate this with species distribution data and growth requirements (Pratiwi et al. 2014).

S. macrophylla is a recommended species for replanting degraded tropical forest land, ie pastures after burning (Daisuke et al. 2013), early-succession secondary forests (Daisuke et al. 2013; Perumal et al. 2012), and commercially logged forests. In commercially logged forests, *S. macrophylla* can be planted using the lines planting model or gaps planting model. In early-succession secondary forests and pasture after burning, *S. macrophylla* requires pioneer plants to assist growth. *S.macrophylla*. *S. macrophylla* is a valuable wood tree species that has socio-economic and ecological benefits and is beneficial for reforestation and rehabilitation activities (Perumal et al. 2012; Perumal et al. 2015; Perumal et al. 2017a; Perumal et al. 2017b; Perumal et al. 2019).

This species is important to land rehabilitation activities because it plays a role in maintaining water quality, filtering out pollutants and deposits, and storing carbon (Utomo et al. 2018; You et al. 2015). Things that must be considered when planting *S. macrophylla* are the nutrient content in clay and the clay mineral composition. These two factors can be used to evaluate soil fertility. The growth of *S. macrophylla* is also significantly limited by the high light intensity in grasslands (*Imperata cylindrica*/ pastures after burning). *S. macropylla* species favor habitats with low light intensity. In secondary forests and logged-over forests, the survival and/or growth of *S. macrophylla* is limited by hard soil conditions. This agrees with the results of this study, where fine sandy clay soils were found.

S. macrophylla grows on riversides with flat and gentle topography, acidic soil conditions, and lower fertility but good microclimate conditions (temperatures between 24-26ºC, high humidity between 78-86%, and a low light intensity between 12.52 - 23.46%). This species can be recommended to be planted in degrade tropical forest areas if microclimatic factors and soil conditions are taken into account.

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REFERENCES

Abdissa Y, Tekalign T, Pant LM. 2011. Growth. bulb yield and quality of onion (*Allium cepa* L) as influenced by nitrogen and phosphorus fertilization on vertisol i. growth attributes. biomass production and bulb yield. African J Agricultural Research. Volume 6 (14): 3252–3258. https://Doi.Org/10.5897/Ajar10.1024.

Appanah S, Turnbull JM. 1998. A review of dipterocarps : taxonomy. ecology and silviculture. Center for International Forestry Research.

Casanova M, Tapia E, Seguel O, Salazar O. 2016. Direct measurement and prediction of bulk density on alluvial soils of central Chile. Ultural Chilean J Agric Res 76 (1):105-113. doi:10.4067/S0718-58392016000100015.

Daisuke H, Tanaka K, Jawa KJ, Ikuo N, Katsutoshi S. 2013. Rehabilitation of degraded tropical rainforest using dipterocarp trees in Sarawak. Malaysia. Hindawi Publishing Corporation International J Forestry Research. Volume 2013:1-12. Article ID 683017. 11 pages http://dx.doi.org/10.1155/2013/683017.

Darusman, Devianti, Husen E. 2018. Improvement of soil physical properties of cambisol using soil amendment. Aceh Int. J Sci. Technol.. 7(2): 93-102. doi: 10.13170/aijst.7.2. 10119.

Eviati and Sulaeman. 2009. Petunjuk teknis analisis kimia tanah, tanaman, air, dan pupuk. Edisi 2. ISBN 978-602-8039-21-5. Balai Penelitian Tanah, Bogor. [Indonesian]

Fahrianoor, Windari T, Taharudin, Mar'i R, Maryono. 2013. The practice of local wisdom of Dayak people in forest conservation in South Kalimantan. Indon J Wetlands Environ Manag 1 (1): 37-46.

Fajri M, Fernandes A. 2015. Pola pemanenan buah tengkawang (*S. machrophylla*) dan regenerasi alaminya dikebun masyarakat. J. Penelitian Ekosistem Dipterokarpa Volume 1 (2) : 81-88. https://doi.org/10.20886/jped.2015.1.2.81-88. [Indonesian]

Hutauruk TR, Lahjie AM, Simarangkir BDAS, Ruslim Y. 2018a. Setulang forest conservation strategy in safeguarding the conservation of non-timber forest products in Malinau District. IOP Conference. Series: Earth Environment Science. Volume 144: 1-9. https://doi.org/10.1088/1755-1315/144/1/012055.

Hutauruk TR, Lahjie AM, Simarangkir BDAS, Aipassa MI, Ruslim Y. 2018b.The prospect of the utilization of Non-Timber Forest Products from Setulang Village forest based on local knowledge of the Uma Longh community in Malinau. North Kalimantan. Indonesia. Biodiversitas. Volume 19 (2): 421-430. [Indonesian]

Istomo, Hidayati T. 2010. Studi potensi dan penyebaran tengkawang (*Shorea* Spp.) di areal IUPHHK-Ha PT. Intracawood Manufacturing Tarakan. Kalimantan Timur (*Study of the potential and distribution of tengkawang (Shorea Spp.) in the IUPHHK-Ha area of PT. Intracawood Manufacturing Tarakan. East Kalimantan*). J Silvikultur Tropika. Volume 01 (01): 11-17. ISSN: 2086-8227. [Indonesian]

Jaffar ANNM, Wasli ME, Perumal M, Lat J, Sani H. 2018. Effects of soil compaction and relative light intensity on survival and growth performance of planted *Shorea macrophylla* (de vriese) in riparian forest Along Kayan Ulu River. Sarawak. Malaysia. Hindawi International J Forestry Research Volume 2018 (2):1-11. Article ID 6329295. 11 pages https://doi.org/10.1155/2018/6329295.

Kacholi DS. 2014. Analysis of structure and diversity of the kilengwe forest in the Morogoro Region. Tanzania. International J of Biodiversity. Volume 2014: 1-8. Article ID 516840. 8 pages. http://dx.doi.org/10.1155/2014/516840.

Kettle CJ. 2010. Ecological considerations for using dipterocarps for restoration of lowland rainforest in Southeast Asia. Biodiv Conserv. 19: 1137-1151.

Kumhalova J, Kumhala F, Kroulik M, Matejkova S. 2011. The impact of topography on soil properties and yield and the effects of weather conditions. J Precision Agriculture. Volume 12 (6): 813-830. https://doi.org/10.1007/s11119-011-9221-x.

Kurnia, U, Agus f, Adimihardja A, Dariah A. 2006. Sifat fisik tanah dan metode analisisnya. Balai Besar Litbang Sumberdaya Lahan Pertanian. Agro inovasi. Bogor. [Indonesian]

Li X, McCarty GW. 2019. Application of topographic analyses for mapping spatial patterns of soil properties: geospatial analyses of earth observation (eo) data. Web of Science. http://doi: 10.5772/intechopen.86109.

Maharani R, Fernandes A, Pujiarti R. 2016. Comparison of tengkawang fat processings effect on tengkawang fat quality from Sahan and Nanga Yen Villages. West Kalimantan. Indonesia. Conference Proceedings. Towards The Sustainable Use of biodiversity in a changing environment: From Basic To Applied Research. Aip Publishing.

Matius P, Tjwa SJM, Raharja, Sapruddin, Noor S, Ruslim Y. 2018. Plant diversity in traditional fruit gardens (munaans) of Benuaq and Tunjung Dayaks tribes of West Kutai. East Kalimantan. Indonesia. Biodiversitas. Volume 19 (4): 1280-1288. DOI: 10.13057/biodiv/d190414. [Indonesian]

Mehata M, Cortus E, Niraula S, Spiehs MJ, Darrington J, Chatterjee A, Rahman S, Parker DB. 2019. Aerial nitrogen fluxes and soil nitrate in response to fall-applied manure and fertilizer applications in Eastern South Dakota. Hindawi International J of Agronomy. Volume 2019:1-15. Article ID 8572985. 15 pages https://doi.org/10.1155/2019/8572985.

Merang OP, Lahjie AM, Yusuf S, Ruslim Y. 2018. Productivity of three varieties of local upland rice on swidden agriculture field in Setulang village. North Kalimantan. Indonesia. Biodiversitas. Volume 21 (1): 49-56. [Indonesian]

Minasny B, Mcbratney AB. 2017. Limited effect of organic matter on soil available water capacity. European J Soil Science. 2017:1-9. https://doi: 10.1111/ejss.12475.

Mouhamed R, Alsaede A, Iqbal M. 2016. Behavior of potassium in soil: a mini review. Chemistry International. 2 (1): 58-69.

Mueller-Dombois D, Ellenberg H. 1974. Aims and methods of vegetation ecology. John Willey and Sons. Canada.

Omara P, Aula L, Raun WR. 2019. Nitrogen uptake efficiency and total soil nitrogen accumulation in long-term beef manure and inorganic fertilizer application/ Hindawi International Journal of Agronomy. Volume 2019:1-6. Article ID 9594369. 6 pages. https://doi.org/10.1155/2019/9594369.

Ohta S, Effendi S. 1992. Ultisols of "lowland dipterocarp forest" in East Kalimantan. Indonesia. Soil Sci. Plant Nutr. 38 (2): 197-206.

Osman KT. 2013. Forest soil: properties and management. Springer. London.

Panjaitan S, Wahuningtyas RS, Adawiyah R. 2012. Kondisi lingkungan tempat tumbuh *Shorea johorensis* Foxw. Di HPH Aya Yayang Indonesia. Kalimantan Selatan (*Environmental conditions in which to grow Shorea johorensis Foxw. At Aya Yayang HPH in Indonesia. South Kalimantan*). J Penelitian Dipterokarpa. Volume 6 (1): 11-22. [Indonesian]

Pratama, Arief B, Alhamd L, Rahajoe JS. 2012. Asosiasi dan karakterisasi tegakan pada hutan rawa gambut di Hampagen. Kalimantan Tengah (*Association and characterization of stands in peat swamp forests in Hampagen. Central Kalimantan*). J Teknologi Lingkungan. Edisi Khusus Hari lingkungan Hidup : 69-76. [Indonesian]

Pratiwi, Narendra BH, Hartoyo GME, Kalima T, Pradjadinata S. 2014. Atlas jenis-jenis pohon andalan setempat untuk rehabilitasi hutan dan lahan di Indonesia (*Atlas of local reliable tree species for forest and land rehabilitation in Indonesia*). Forda Press. [Indonesian]

Perumal M, Wasli ME, and Ying. HS. 2019. Influences of inorganic and organic fertilizers to morphological quality attributes of *Shorea macrophylla* seedlings in a tropical nursery. Biodiversitas. Volume 20 (8): 2110-2118. ISSN: 1412-033X. E-ISSN: 2085-4722. DOI: 10.13057/biodiv/d200803.

Perumal M. Wasli ME, Ying HS, Sani H. 2017a. Survivorship and growth performance of Shorea macrophylla (de Vriese) after enrichment planting for reforestation purpose at Sarawak. Malaysia. Online J Biology Science. Volume 17 (1): 7-17.

Perumal M, Wasli ME, Ying HS, Lat J, Sani H. 2017b. Association between soil fertility and growth performance of planted *Shorea macrophylla* (de Vriese) after Enrichment Planting at Rehabilitation Sites of Sampadi Forest Reserve. Sarawak. Malaysia. Hindawi International J Forestry Research. Volume 2017. Article ID 6721354. 16 pages. https://doi.org/10.1155/2017/6721354.

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Deleted[Windows User]: Pratiwi, Narendra B. 2012. Pengaruh penerapan teknik konservasi tanah terhadap pertumbuhan pertanaman Mahoni (*Swietenia Macrophylla* King) Di Hutan Penelitian Carita. Jawa Barat (*Effect of applying soil conservation techniques to the growth of Mahogany* (Swietenia Macrophylla King) *plantations in the Carita Research Forest. West Java*). J Penelitian Hutan Dan Konservasi Alam. Volume 9 (2): 139-150. [Indonesian]

Perumal M, Wasli ME, Sani H, Nahrawi H. 2012. Growth performance of planted *Shorea macrophylla* under line planting technique. In: 4th Regional Conference on Natural Resources in the Tropics. 2012 (NTrop4) : Sustaining Tropical Natural Resources Through Innovations. Technologies and Practices.

Quedraogo I, Nacoulma BMI, Hahn K, Thiombiano A. 2014. Assessing ecosystem services based on indigenous knowledge in south-eastern Burkina Faso (West Africa). Intl J Biodivers Sci Ecosyst Serv Manag 10 (4): 313-321.

Randi A, Julia S, Kusumadewi Y, Robiansyah I, Shomat F, Tanggaraju S, Hamidi A, Juiling S, Bodos V, Maryani A. 2019. *Shorea macrophylla*. The IUCN red list of threatened species 2019: e.T33620A125629642. http://dx.doi.org/10.2305/IUCN.UK.20193.RLTS.T33620A125629642.en.

Rikando R. Latifah S. Manurung TF. 2019. Sebaran jenis tengkawang (*Shorea* spp) di hutan tembawang Desa Labian Kecamatan Batang Lupar Kapuas Hulu Kalimantan Barat (*Distribution of tengkawang species* (Shorea spp) *in the Tembawang forest Labian Village Batang Lupar District Kapuas Hulu West Kalimantan*). J Hutan Lestari. Volume 7 (1) : 390-406. [Indonesian]

Ruslim Y, Sihombing R, Liah Y. 2016. Stand damage due to mono-cable winch and bulldozer yarding in a selectively logged tropical forest. Biodiversitas 17 (1): 222-228. [Indonesian]

Ruchaemi A. 2013. Ilmu pertumbuhan hutan (Forest growth Science). Samarinda: Mulawarman University Press. [Indonesian]

Sadeghi SM, Hanum IF, Abdu A, Kamziah IK, Hakeem KR, Ozturk M. 2016. Recovery of soil in hill dipterocarp forest after logging in Kedah. Malaysia. Malayan Nature J. Volume 68 (1 & 2): 187-201.

Saiz H, Alados CL. 2012. Changes in semi-arid plant species associations along a livestock grazing gradient. Plos One 7 (7): 1-9. E40551. http://doi:10.1371/Journal.Pone.0040551.

Schroeder K, Pumphrey M. 2013. It's all a matter of pH: acid soils. aluminum toxicity are on the rise in Eastern Washington. Northern Idaho. Washington Grain Commission reports. http://washingtoncrop.com (accessed 16 Jan. 2016). p. 56–59.

Schlesinger WH, Bernhard ES. 2012. Biogeochemistry: an analysis of global change. 3rd ed. Academic Press. San Diego. CA.

Sofiah S, Setiadi D, Widyatmoko D. 2013. Pola penyebaran. kemelimpahan. dan asosiasi bambu pada komunitas tumbuhan di Taman Wisata Alam Gunug Baung Jawa Timur (*Distribution patterns. abundance. and bamboo associations in plant communities in the Gunug Baung Nature Park in East Java*). Berita Biologi. J Ilmu-Ilmu Hayati. Volume 12 (2): 239-247.

Turner BL, Engelbrecht BMJ. 2011. Soil organic phosphorus in lowland tropical rain forests. Biogeochemistry. 2011:103:297–315 DOI 10.1007/s10533-010-9466-x.

Utomo S, Uchiyama S, Ueno S, Matsumoto A, Widiyatno, Indrioko S, Na'iem M, Tsumura Y. 2018. Effects of pleistocene climate change on genetic structure and diversity of *Shorea macrophylla* in Kalimantan rainforest. Tree Gen Genomes. Volume 14 (4): 14-44.

Widiyatno, Budiadi, Suryanto P, Rinarno YDBM, Prianto SD, Hendro Y. 2017. Recovery of vegetation structure. soil nutrients and late-succession species afters hifting cultivation In Central Kalimantan. Indonesia. J Tropical Forest Science. Volume 29 (2): 151-162.

Windusari Y, Susanto RH, Dahlan Z, Susetyo W. 2011. Asosiasi jenis pada komunitas vegetasi suksesi di kawasan pengendapantailing tanggul ganda di pertambangan PTFI Papua (*Species associations in the succession vegetation community in the deposition area of the double embankment in Papua's PTFI mine*). J Ilmiah Ilmu-Ilmu Hayati Biota. Volume 16 (2): 242-251. [Indonesian]

Zaidey AK, Arifin A, Zahari I, Hazandy AH, Zaki MH, Affendi H, Wasli ME, Hafiz YK, Shamsuddin, Muhammad MN. 2010. Characterizing soil properties of lowland and hill dipterocarp forest at Peninsular Malaysia. Intenational J Soil Science. Volume 5 (3):112-130.

Zeng C, Wang Q, Zhang F, Zhang J. 2013. Temporal changes in soil hydraulic conductivity with different soil types and irrigation methods. Geoderma 193/194:290-299. doi:10.1016/j. geoderma.2012.10.013.

Zhang J, Jiang Q, Zhang Y, Dai L, Wu H. 2015. nondestructive measurement of water content and moisture migration of unsaturated red clays in South China. Hindawi Publishing Corporation Advances in Materials Science and Engineering, Volume 2015, Article ID 542538, 7 pages http://dx.doi.org/10.1155/2015/542538.

Zhu X, Zhu B. 2015. Diversity and abundance of soil fauna as influenced by longterm fertilization in cropland of purple soil. China. Soil and Tillage Research. Volume 146: 39-46.

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The characteristics of *Shorea macrophylla*'s habitat in Tane' Olen, Malinau District, North Kalimantan Province, Indonesia

Abstract. *Shorea macrophylla* is a tree species in Tane' Olen forest area. This study analyzed the soil's physical and chemical properties, topography, and microclimate of *S. macrophylla*'s habitat. A purposive method was used to select a sampling plot and to place the subplots. Soil was analyzed to determine the physical properties, i.e., texture, bulk density, porosity, and water content, and the chemical properties, i.e., pH, CEC, total N, organic C, C/N ratio, P, K , and Al saturation. Importance value index was determined for each tree species to know the species composition in the study area. Only the dominant species were presented. The soil in the study area had bulk density of 0.60-1.31 gram cm$^{3-1}$, porosity 50.60%-77.35%, water content 34.88%-95.37%, and soil texture sandy clay. The chemical properties of the soil were as follows: pH was 3.6-4.8, N 0.05%-0.19%, organic C 1.40%-3.65%, P 0.41-2.3 mg 100 gr^{-1}, K 58.68-232.55 mg 100 gr^{-1}, and Cation Exchange Capacity (CEC) 5.35-10.81 meg 100gr $^{-1}$. Slope ranged between 0 and 25%. The microclimate characteristics were as follows: temperature was 24-26.5° C, relative humidity 76-84%, and light intensity 350-750 Lm. Trees species with an IVI ≥ 10% were *S. macrophylla*, *Madhuca spectabilis*, *Myristica villosa* Warb, *Scorodocarpus borneensis*, *Eugenia* spp, *Palaquium* spp, *Macaranga triloba*, *Syzygium inophyllum* and *Shorea* sp. Positive associations were observed between *S. macropylla* and *S. borneensis*, *Eugenia* spp, *Palaquium* spp and *M. triloba,* and negative associations were observed between *S. macropylla* and *M. spectabilis*, *M. villosa* Warb, *S. inophyllum,* and *Shorea* sp. *S. macrophylla* grows on riversides with flat and gentle topography, acidic soil, and lower fertility but with suitable microclimate. This species can be recommended to be planted in degraded tropical forest areas but the microclimate and soil properties should be taken into account.

Keywords: Habitat, land characteristics, *S. macrophylla*

Running title: The characteristics of *Shorea macrophylla*'s habitat

INTRODUCTION

Shorea macrophylla is one of the fastest growing climax tree species of the genera *Shorea* (Perumal et al. 2017). Local communities value this species as a source of timber and fruit (Randi et al. 2019). *S. macrophylla* is known locally in West Kalimantan as the *tengkawang tungkul* tree and has been cultivated by the Dayak and Malay communities (Fajri and Fernandes 2015). *S. macrophylla* grows in clusters in tropical rain forests with type A climate, on latosol soils at altitudes up to 500 m, on acidic soils (pH 4.6-4.9), and a cation-exchange capacity (CEC) of 16.25-19.40 (Istomo and Hidayati 2010). In Sarawak, Sabah, Brunei and Kalimantan, this species is associated with sedimentary soils and is distributed randomly and evenly over riverbanks and areas with sloping or flat topography. It is rarely found on hills. (Randi et al. 2019; Utomo et al. 2018; Perumal et al. 2017).

The timber from *S. macrophylla* is commonly used for construction and to make veneer and plywood, musical instruments, furniture, and packing crates (Istomo and Hidayati 2010). The fruit, locally known as *tengkawang tungkul* (*Illipe*) nuts, is used as a raw material for soap and other cosmetics, a substitution for brown fat, and a source of vegetable fat (Maharani et al. 2016).

The natural population of *tengkawang* is declining and is, at present, hard to find (Istomo and Hidayati 2010) because *S. macrophylla* is one of the most sought-after species in tropical forests. The exploitation of the species for its timber, combined with forest conversion to other uses, has resulted in *S. macrophylla* timber being difficult to find in the market (Rikando et al. 2019).

Tane' Olen is a forested area with a high environmental value preserved by the people of Setulang Village (Hutauruk et al. 2018a), a community that manages its forests based on the local wisdom and sustainable forest management practices (Fahrianoor et al. 2013; Kettle 2010), so the forest sustainability is maintained (Hutauruk et al. 2018). Forests are not only

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a place to live for them, but are also used as a source of food and medicine and economic, social, cultural, and spiritual functions (Merang et al. 2020; Matthew et al. 2018; Quedraogo et al. 2014).

S. macrophylla's habitat characteristics in secondary forest locations have been documented by Jaffar et al. (2018) and Perumal et al. (2017). Perumal et al. (2017) studied the relationship between soil fertility and the growth of *S. macrophylla* in enrichment plantings at Sampadi Forest Reserve, Lundu, Sarawak and an adjacent secondary forest. Jaffar et al. (2018) researched the effects of soil compaction and light intensity on the establishment and growth of *S. macrophylla* in riparian forests in Sungai Kayan Ulu Sungai, Serawak, Malaysia. The improvement of the company's management system, which is changing the way of harvesting using long cables during skidding activity, reduced the natural forest damage and could increase financial returns from natural forest concessions (Ruslim et al. 2016). The characteristics of *S. macrophylla* habitat in primary forest locations had not previously been studied. So, this study aimed to describe the characteristics of *S. macrophylla*'s habitat in primary forests by analyzing the physical and chemical properties of soil, the microclimate, topography, species associations, and vegetation. It is hoped that the results of this study will benefit conservation efforts of this species, especially on degraded land in the tropical rain forests of North Kalimantan.

MATERIALS AND METHODS

Study area

The study was carried out in Tane' Olen forest area, Setulang Village, Malinau District, North Kalimantan Utara Province (3°25'0.86" N and 116°25'52.59" E). The location map is presented in Figure 1.

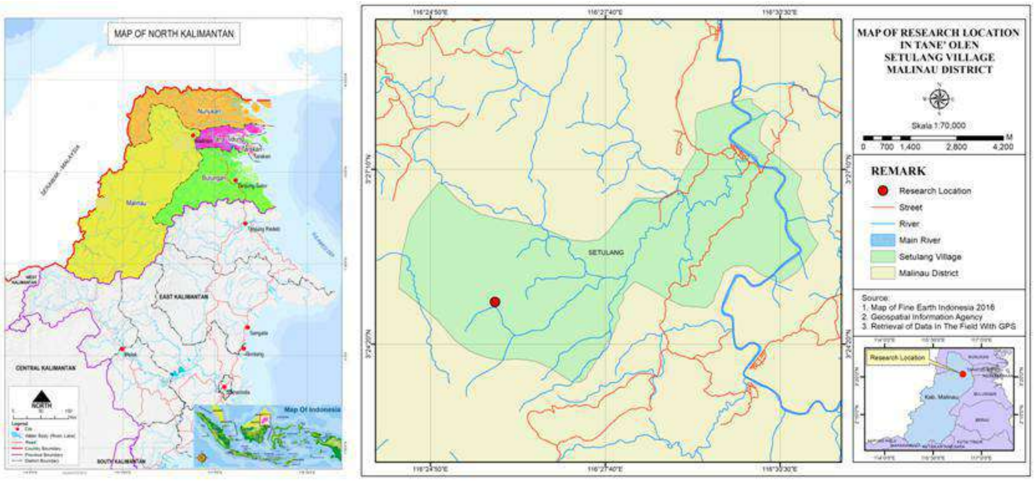

Figure 1. Location of the research in Tane' Olen (●)

Research procedure

A one-hectare research site was selected purposively and sampled using a square plot with a side length of 100 meters (Sari and Maharani 2016). Soil sampling was taken from purposively selected three sampling points, located on a hill, a slope, and a valley (the hill had the highest elevations and a 15-25% slope; the slope was located between the valley and hill, and had an 8-15% slope; the valley was the lowest area and had a 0-8% slope) to ensure an accurate representation of the study site. At each sampling point, soil samples were taken at three depths: 0-20 cm, 20-40 cm, and 40-60 cm. Microclimate data (temperature, humidity, and light intensity) were collected at the same locations. The soil and microclimate data collection design is illustrated in Figure 2. Vegetation data were only collected for trees with a diameter at breast height (DBH) greater than 20.0 cm Each plot was divided into 25 subplots (20 m x 20 m). Within each subplot, the species were identified and DBH recorded for all trees (Widiyatno et al. 2017). Plot-making and field-data collection activities are presented in Figure 2, while sampling design is presented in Figures 3 and 4.

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Figure 2. A. Exploration, B. Research plot making, C. Tree inventory, D. Soil sample collection, E and F. Microclimate data collection

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Soil sample collection design and microclimate data are presented in Figures 3 and 4

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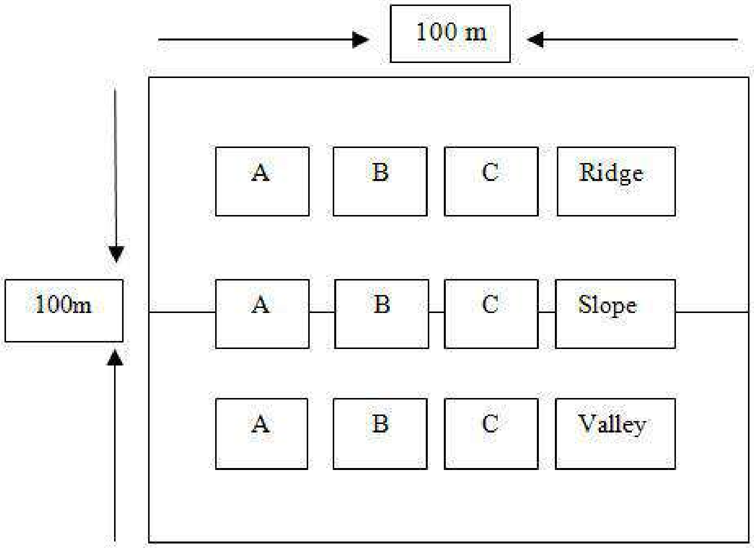
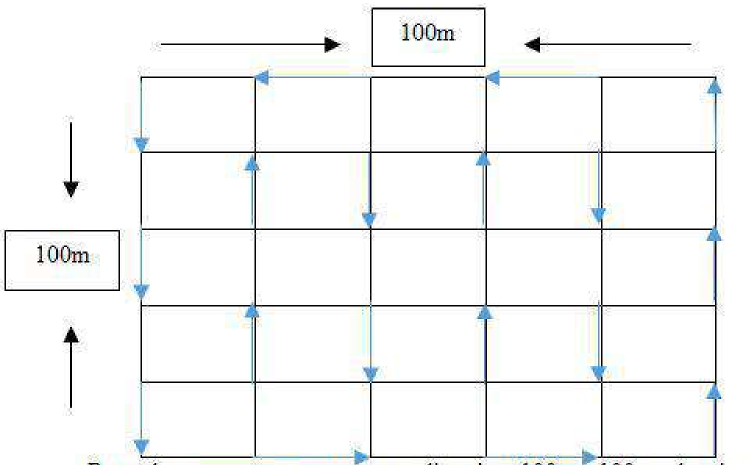


Figure 3. Soil and microclimate sample design. Note: A:lights intensity, B: temperature and area humidity, C: soil sampling, m:Meter

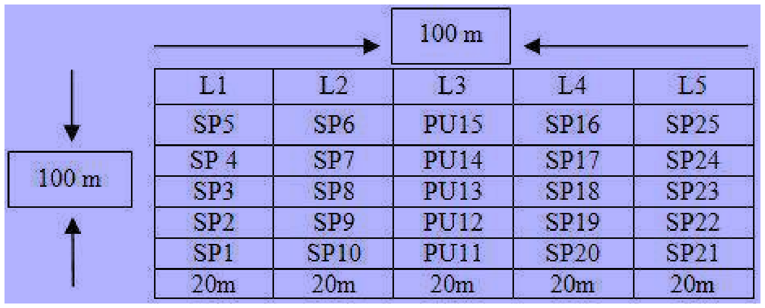
Topography data collection design can be seen in Figure 4.



Remark : → : compass direction, 100m x 100m: plot size

Figure 4. Plot design across topographic features

The design of vegetation data collection can be seen in Figures 5 and 6.



L1	L2	L3	L4	L5
SP5	SP6	PU15	SP16	SP25
SP 4	SP7	PU14	SP17	SP24
SP3	SP8	PU13	SP18	SP23
SP2	SP9	PU12	SP19	SP22
SP1	SP10	PU11	SP20	SP21
20m	20m	20m	20m	20m

Remarks: L: lane, SP: sub plot, 20m: distance between sub plots, 100m x 100m: plot size, m: Meter.

Figure 5. Design of plot and sub-plots for vegetation sampling

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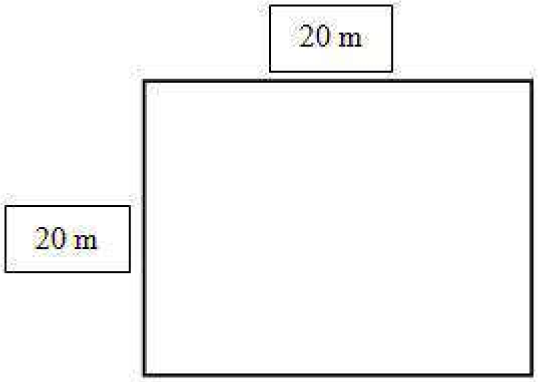

Remark: 20m x 20m: Tree level sub plot, m: Meter.

Figure 6. Vegetation inventory design for trees > 20.0 cm in DBH.

Data analyses

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Soil analyses

Soil samples were analyzed for both physical and chemical properties (Kurnia et al. 2006; Eviati and Sulaeman 2009). Physical properties analyzed were texture, bulk density, porosity, and water content (using the Pipette method). Chemical properties analyzed were pH (using the electrode method), CEC (using the ammonium acetate pH 7 method), elements Al+++ and H+ (using the KCl method 1 N), total N elements (using the Kjeldahl method), organic C elements (using Walkley-Black method), C/N ratio (using arithmetic methods), elements P_2O5 and K_2O (using Bray No I methods), and saturation Al (using arithmetic methods). Soil data analysis results from the soil laboratory were tabulated and analyzed descriptively and quantitatively.

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Analysis of topography

The topographic analysis was done qualitatively to describe the topography suitable for *S. macrophylla*.

Analysis of microclimate

The analysis of microclimate was done qualitatively to provide information on microclimates characteristics suitable for S. *macrophylla*.

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Importance Value Index

According to Kacholi (2014), the Importance Value Index (IVI) is used in ecological studies to determine the ecological importance of a species in a particular ecosystem. IVI is also used to prioritize species conservation. Species with low IVI values require a higher conservation priority than those with high IVI, which is the dominant species. IVI value is a function of several characteristics, and calculated with this formula: IVI = relative density + relative frequency + relative dominance. IVI values were analyzed descriptively.

Association of vegetation

Associations between two tree species were analyzed using a series of 2x2 contingency tables (Mueller-Dombois and Ellenberg 1974). A more complete description is presented in Table 1.

Table 1. Contingency table form

Species A Species B	+	-	
+	A	B	a + b
-	c	D	c + d
	a + c	b + d	N = a + b + c + d

Reference: Mueller-Dombois and Ellenberg (1974)

Remarks :
a = number of plots containing species A and species B.
b = number of plots containing only species A, but no species B.
c = number of plots containing only species B, but no species A.
d = number of plots containing neither species A nor species B.
N = number of all plots.

Then, the data were tested with chi-square (x^2)

$$X^2 = \frac{(ad - bc)^2 \, x \, N}{(a+b)(c+d)(a+c)(b+d)}$$

The association coefficient (C) values were determined as follows:

1. If ad $\geq$ bc, so $C = \frac{ad-bc}{(a+b)(b+d)}$
2. If bc > ad and d > a, so $C = \frac{ad-bc}{(a+b)(b+c)}$
3. If bc > ad and a > c, so $C = \frac{ad-bc}{(a+d)(c+d)}$

Positive or negative values of C indicate a positive or negative relationship between the two species. A positive relationship indicates that the association between trees is mutually beneficial to each other, while a negative value indicates that the association between trees harms one another.

RESULTS AND DISCUSSION

The soil's physical and chemical properties

The physical and chemical properties of soil properties in *S. macrophylla's* habitat can be seen in Table 2.

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Table 2. Physical properties of soil in Tane'Olen, Setulang, Malinau District

Location of soil	**Depth (cm)**	**Bulk density (gram/cm³)***	**Porosity (%)***	**Water content (%)**
Valley	0-20	0.60	77.35	95.37
	20-40	1.13	57.32	40.04
	40-60	1.18	55.54	39.20
Slope	0-20	1.05	60.42	48.08
	20-40	1.31	50.60	41.42
	40-60	1.23	53.72	34.88
Ridge	0-20	0.83	68.75	61.68
	20-40	1.01	61.92	44.23
	40-60	1.20	54.66	35.53

Remark:* Average score from three repetitions

At the depth of 0-20 cm, the valley, slope, and hill subplots had a low bulk density (0.60-1.05) (Table 2). According to Casanova et al. (2016) and Zeng et al. (2013), soil bulk density is influenced by external conditions and natural processes such as plant root growth and rainfall.

The soil porosity values in the valley, slope, and hill subplots decreased with the increasing soil depth. The valley subplot had higher porosity value than the slope and hill subplots. According to Darusman et al. (2019), the properties that affect soil porosity the most are bulk density and soil particle density; if the bulk density is low then the soil porosity will increase.

Water content in the hill, slope, and valley decreased with the increasing soil depth. The water content in the hill subplots was higher than the slope subplots because the water movement is faster in the slope subplots and the water settles in the lower area, i.e., the valley subplots, which resulted in a higher (95.37%) water content in the valley subplots than in the hill and slope subplots. Jaffar et al. (2018) state that *S. macrophylla* plant roots can adapt to high water soil content. Moist soils stimulate *S. macrophylla* roots growth and development. According to Minasny and McBratney (2018), the availability of groundwater is an important component of water balance and the terrestrial biosphere cycle because it can affect evapotranspiration rates and support plant growth.

The results of the soil texture analysis can be seen in Table 3.

Table 3. Soil texture in Tane' Olen, Setulang Village, Malinau District

Location of soil	**Depth (cm)**	**Clay (%)**	**Sand (%)**	**Silt (%)**	**texture (USDA)**
Valley	0-20	33.70	50.90	15.40	SCL
	20-40	36.50	49.50	14.00	SC
	40-60	34.00	56.80	9.20	SCL
Slope	0-20	24.70	67.20	8.10	SCL
	20-40	27.30	63.10	9.60	SCL
	40-60	33.10	60.50	6.40	SCL
Ridge	0-20	37.80	54.60	7.60	SC
	20-40	37.40	46.40	16.20	SC
	40-60	40.70	48.00	11.30	SC

Remark: Laboratory of soil test in B2P2EHD and Pusrehut, Mulawarman University

The soil texture at the study site generally had a sand fraction of 45-65%, a clay fraction 35-55%, and a silt fraction 0-20% (Table 3). This means that the soil texture is sandy clay. According to Osman (2013), soil texture refers to the level of fineness or roughness created by the variously-sized soil particles.

Soil types are generally dominated by Ultisol (advanced development) soils, namely Typic Hapludults (Red-Yellow Podsolik) and Typic Paleudults (Yellow Podsolic). These soil types are typically found in lowland dipterocarp forests (Ohta and Effendi 1992).

Chemical soil characteristics of the study area are presented in Table 4.

Table 4. Chemical characteristics of soil in Tane' Olen, Setulang village, Malinau district

Location of soil	**Depth (cm)**	**pH (1: 25)**		**Cation exchange rates (meg 100gr^{-1})**			**Organic content (%)**		**Ratio**	**Mineral (Mg 100 gram^{-1})**	
		H_2O	**KCl**	**CEC**	**Al3$^+$**	**H$^+$**	**Tot. N.**	**Org C**	**C/N**	**P_2O_5**	**K_2O**
Valley	0-20	4.6	3.3	7.26	4.92	1.50	0.19	3.65	19	0.89	116.85
	20-40	4.6	3.4	7.25	5.56	1.08	0.12	2.65	22	0.73	73.30
	40-60	4.4	3.4	7.18	5.75	0.92	0.10	2.12	22	1.22	59.00
Slope	0-20	4.1	3.5	5.35	2.75	1.33	0.13	2.31	18	0.65	73.62
	20-40	4.7	3.5	5.30	3.50	0.92	0.07	1.54	22	0.65	58.68
	40-60	4.8	3.5	5.53	3.33	1.42	0.05	1.40	26	0.41	60.90
Ridge	0-20	4.4	3.0	10.81	7.25	2.75	0.09	3.46	39	2.35	120.34
	20-40	3.6	3.3	10.48	7.80	1.83	0.08	2.12	28	0.89	194.09

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	40-60	4.4	3.4	10.37	6.83	2.58	0.09	1.54	17	0.65	232.55

Remark: Laboratory of soil test in B2P2EHD and Pusrehut, Mulawarman University

The soil in the study area was very acidic (pH = 4.1-4.8) (Table 4). According to Schroeder and Pumphrey (2013), acidic soils inhibit root and plant growth and increase Al levels in the soil. The CEC in the study area ranged from 5.3 to 10 meq/ 100 g^{-1}, indicating that the CEC was low. In general, the value of CEC is low in surface and subsurface soils of lowland dipterocarp forests (Perumal et al. 2017a).

Aluminum levels in the study area were high, especially in the slope and valley subplots, which indicated high soil toxicity. Al content in the soil decreased with the increasing organic matter because organic matter forms a strong bond with Al. According to Zaidey et al. (2010), Al is a major cause of soil acidity, and soils in lowland dipterocarp forests have high Al content.

Nitrogen levels at the research location ranged from 0.05% to 0.19% (low to very low). Sadeghi et al. (2016) also reported low total N levels in tropical rain forest soils. Nitrogen is important for plant growth (Omara et al. 2019), and N deficiency can inhibit plant growth (Mehata et al. 2019). According to Omara et al. (2019), the main sources of N are organic matter and rainfall/precipitation.

Organic C values were higher in the valley and slope subplots than in the hill subplots. The steeper slopes in the hill subplots are more prone to erosion, resulting in the leaching of organic C and other nutrients into the valley and slope subplots. According to Schlesinger and Bernhard (2013), carbon can be stored in the soil three times longer than in the atmosphere and is an indicator of soil microorganism abundance and diversity (Zhu and Zhu 2015). The presence of organic C in the soil spurs microorganism activity and thereby increases the rates of soil decomposition, P dissolution, N fixation, and other microorganism-dependent reactions.

Phosphate was calculated from P_2O_5 where the Phosphate content was high (58.78), but the phosphorus content is very low (0.41-1.22 mg 100 $gram^{-1}$) (Table 4). According to Turner and Engelbrecht (2011), organic P plays an important role in maintaining P availability in lowland tropical rain forests. Phosphorus is essential for root development and plant growth (Abdissa et al. 2011).

Potassium values ranged from high (58.68-116.85 ppp) in the valley and slope subplots to very high (120.34-232.55 ppm) in the hill subplots. According to Mouhamad et al. (2016), K is more abundant in the soil than other mineral elements. This element has an essential role in plant metabolism, growth, and yield. Potassium availability depends on soil properties (humidity, aeration, and temperature), soil treatment systems, and the dynamics of K. Therefore, the K exchange level varies among soils.

Topography in the study area

According to Li and McCarty (2019), topographic features are key parameters that affect the nature of the soil at the earth's surface. Topographic features can affect organic matter; clay content; P, K, and Mg concentrations; and soil pH (Kumhalova et al. 2011).

The topography of the study site is moderately undulating with a slope of 0-25%. The subplot slopes range from flat to moderately steep. *S. macrophylla* was found primarily in flat to sloping areas with high environmental humidity, low ambient temperature, and abundant water, such as riverbanks. Jaffar et al. (2018) stated that the roots of the *S. macrophylla* are able to survive and grow in anaerobic waterlogged soils and is considered a flood-tolerant tree.

Dominant trees in the study area

At the study site, *S. macrophylla* was the dominant tree species (Figure 7). Other tree species included *Madhuca spectabilis, Myristica villosa* Warb., *Scorodocarpus borneensis, Eugenia* spp., *Palaquium* spp., *Macaranga triloba, Syzygium inophyllum,* and *Shorea sp*. *S. macrophylla* dominated the study site due to its fast germination process and high germination rate (Appanah and Turnbull 1998), its high growth rate (fastest of the genus *Shorea)*, and its status as a climax species along rivers (Perumal et al. 2017).

Table 5. The importance value index of the dominant tree species in the study area

Number	**Local name**	**Scientific Name**	**Family**	**Relatif density (%)**	**Relatif dominance (%)**	**Relatif frequency (%)**	**Importance value index (%)**
1.	Tengkawang	*S. macropyilla*	Dipterocarpaceae	7.69	15.35	5.0	28.04
2.	Kajen ase	*M. spectabilis*	Sapotaceae	10.25	7.29	4.61	22.16
3.	Darah-darah	*M. villosa* Warb	Myristicaceae	7.45	4.79	5.0	17.25
4.	Bala seveny	*S. borneensis*	Olacaceae	5.12	5.77	5.0	15.90
5.	Ubah	*Eugenia* spp	Myrtaceae	5.59	3.64	4.61	13.85
6.	Nyatok	*Palaquium* spp	Sapotaceae	4.42	3.70	4.61	12.74
7.	Beneva	*M. triloba*	Euphorbiaceae	4.66	4.32	3.46	12.44
8.	Ehang	*S. inophyllum*	Myrtaceae	5.36	3.14	3.84	12.35
9.	Kaze tenak	*Shorea* sp	Dipterocarpaceae	2.33	6.08	2.69	11.10

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Figure 7. A. Tree of *S. macrophylla* and B. Leaves of *S. macrophylla*

Microclimate

Three microclimate factors were collected, i.e., temperature, humidity, and light intensity (see Table 6 for a more complete description).

Table 6. Microclimate in Tane' Olen forest

Location	Microclimate	Unit	Time	1-st record	2-nd record	3-rd record	Average	Remark
1.	Light intensity	Lm	Morning	350	400	452	400.67	Taken at 8.59 sunny conditions
2.	Area temperature	°c	Morning	24	24.5	25	24.5	
3.	Moisture	%	Morning	81	79	80	80	
1.	Lights intensity	Lm	Mid day	750	450	207	469	Taken at 12:02 sunny conditions
2.	Area temperature	°c	Mid day	26.5	26	24.5	25.67	
3.	Moisture	%	Mid day	76	79	81	78.67	
1.	Lights intensity	Lm	Afternoon	369	237	145	250.33	Taken at 16:30 sunny conditions
2.	Area emperature	°c	Afternoon	25	24.5	23	24.17	
3.	Moisture	%	Afternoon	84	85	87	85.33	

The average temperature at the study site was 24-26° C (Table 6). According to Ruchaemi (2013), the optimal temperature for plant assimilation is 25-30° C. Humidity values were high, ranging from 78 to 86%. Light intensity was low, ranging from 12.52% (250.33 Lm) to 23.46% (469 Lm) due to dense canopy dominated by *S. macrophylla*, which prevented light from reaching the forest floor. This low light intensity is consistent with the findings of Panjaitan et al. (2012), who found that the closed canopy only allowed a little sunlight to reach the forest floor. These conditions benefit *S. macrophylla* seedlings, which are both shade tolerant and sun intolerant.

Association with other trees

According to Saiz and Alados (2012), plant species association is a fundamental aspect of the ecology of plant communities. Analysis of plant species associations provides information on environmental heterogeneity, biotic interactions, and seed dispersal patterns. The results of the species association analysis and the association coefficient are presented in Table 7.

Table 7. Association of *S. macropylla* with other species

Species association	X² count	Association species	C (+/-)
S. macropylla with *M. spectabilis*	0.35	-	0.04
S. macropylla with *M. villosa* Warb	6.82	-	0.29
S. macropylla with *S. borneensis*	0.04	+	0.04
S. macropylla with *Eugenia* spp	0.37	+	0.11
S. macropylla with *Palaquium* spp	0.37	+	0.11
S. macropylla with *M. triloba*	1.21	+	0.16
S. macropylla with *S. inophyllum*	3.23	-	0.29
S. macropylla with *Shorea* sp	1.92	-	0.24

Remark: X ² tabulated value at 5% level: 3.841. X² tabulated value at 1% level: 6.35

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Table 7 shows the results of a series of 2x2 contingency tests between *S. macropylla* and each of the eight other dominant tree species. The calculated X^2 values were greatest between *S. macropylla* and *M. villosa* Warb, indicating that *S. macrophylla* had a strong but negative association with *M. villosa* Warb. According to Sofiah et al. (2013), species pairs do not always indicate positive relationships. Tree species with high populations are not always associated with another species. Likewise, low-population species are not necessarily negatively correlated with another species.

The association coefficient (C) was used as a parameter of the magnitude of the relationship between the eight species and *S. macropylla* and indicates positive or negative associations. Species that showed positive coefficients of association with *S. macropylla* were *S. borneensis, Eugenia spp., Palaquium spp,* and *M. triloba.* According to Windusari1 et al. (2011), positive associations indicate both species have the same requirement of environmental conditions; for example, wet conditions, high light intensity, or shade. *S. macropylla* showed a negative association with *M. spectabilis, M. villosa Warb, S. inophyllum,* and *Shorea* sp. Negative associations indicate intolerance for cohabitation or the absence of a mutually beneficial relationship (Pratama et al. 2012).

Direction of *S. macrophylla* plantation

At present, tropical forests are being degraded by anthropogenic activities such as timber extraction, agricultural cultivation, and the establishment of commercial plantations. This results in the conversion of forests into agriculture land and the fragmentation and degradation of tropical rain forests. Deforestation damages the environment by increasing light intensity and causing severe mineral soil erosion. In general, degraded forests can be divided into three categories: grasslands after burning, early-succession secondary forests, and commercially logged forests (Daisuke et al. 2013).

Planting native trees is considered to be an effective rehabilitation method for degraded tropical rain forests because native trees provide benefits such as timber, food, and medical products (Daisuke et al. 2013). According to Pratiwi et al. (2014), tropical forest rehabilitation is necessary to both meet the demand for timber and improve environmental conditions. One key to rehabilitation success is the understanding of the suitability of each growing site for each species being planted. One approach to determine the suitability of growing sites for each species is to identify each species' potential, identify locally superior species, and correlate this with species distribution data and growth requirements (Pratiwi et al. 2014).

S. macrophylla is a recommended species for replanting degraded tropical forest land, i.e., pastures after burning (Daisuke et al. 2013), early-succession secondary forests (Daisuke et al. 2013; Perumal et al. 2012), and commercially logged forests. In commercially logged forests, *S. macrophylla* can be planted using the line planting system or gap planting system. In early-succession secondary forests and pasture after burning, *S. macrophylla* requires pioneer plants to assist growth. *S. macrophylla* is a valuable tree species that has socio-economic and ecological benefits and is beneficial for reforestation and rehabilitation activities (Perumal et al. 2012; Perumal et al. 2015; Perumal et al. 2017a; Perumal et al. 2017b; Perumal et al. 2019).

This species is important for land rehabilitation activities because it plays a role in maintaining water quality, filtering out pollutants and deposits, and storing carbon (Utomo et al. 2018; You et al. 2015). Things that must be considered when planting *S. macrophylla* are the nutrient content in clay and the clay mineral composition. These two factors can be used to evaluate soil fertility. The growth of *S. macrophylla* is also significantly limited by the high light intensity in grasslands (*Imperata cylindrical*/ pastures after burning). *S. macropylla* grows well in habitats with low light intensity. In secondary forests and logged-over forests, the survival and growth of *S. macrophylla* is limited by soil compaction. This agrees with the results of this study, where fine sandy clay soils were found.

S. macrophylla grows on riversides with flat and gentle topography, acidic soil, and lower fertility, but with the suitable microclimate (temperature of 24-26ºC, high humidity 78-86%, and a low light intensity 12.52 - 23.46%). This species can be recommended to be planted in degraded tropical forest areas if microclimatic factors and soil conditions are taken into account.

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REFERENCES

Abdissa Y, Tekalign T, Pant LM. 2011. Growth. bulb yield and quality of onion (*Allium cepa* L) as influenced by nitrogen and phosphorus fertilization on vertisol i. growth attributes. biomass production and bulb yield. African J Agricultural Research. Volume 6 (14): 3252–3258. https://Doi.Org/10.5897/Ajar10.1024.

Appanah S, Turnbull JM. 1998. A review of dipterocarps : taxonomy. ecology and silviculture. Center for International Forestry Research.

Casanova M, Tapia E, Seguel O, Salazar O. 2016. Direct measurement and prediction of bulk density on alluvial soils of central Chile. Ultural Chilean J Agric Res 76 (1):105-113. doi:10.4067/S0718-58392016000100015.

Daisuke H, Tanaka K, Jawa KJ, Ikuo N, Katsutoshi S. 2013. Rehabilitation of degraded tropical rainforest using dipterocarp trees in Sarawak. Malaysia. Hindawi Publishing Corporation International J Forestry Research. Volume 2013:1-12. Article ID 683017. 11 pages http://dx.doi.org/10.1155/2013/683017.

Darusman, Devianti, Husen E. 2018. Improvement of soil physical properties of cambisol using soil amendment. Aceh Int. J Sci. Technol.. 7(2): 93-102. doi: 10.13170/aijst.7.2. 10119.

Eviati and Sulaeman. 2009. Petunjuk teknis analisis kimia tanah, tanaman, air, dan pupuk. Edisi 2. ISBN 978-602-8039-21-5. Balai Penelitian Tanah, Bogor. [Indonesian]

Fahrianoor, Windari T, Taharudin, Mar'i R, Maryono. 2013. The practice of local wisdom of Dayak people in forest conservation in South Kalimantan. Indon J Wetlands Environ Manag 1 (1): 37-46.

Fajri M, Fernandes A. 2015. Pola pemanenan buah tengkawang (*S. machrophylla*) dan regenerasi alaminya dikebun masyarakat. J. Penelitian Ekosistem Dipterokarpa Volume 1 (2) : 81-88. https://doi.org/10.20886/jped.2015.1.2.81-88. [Indonesian]

Hutauruk TR, Lahjie AM, Simarangkir BDAS, Ruslim Y. 2018a. Setulang forest conservation strategy in safeguarding the conservation of non-timber forest products in Malinau District. IOP Conference. Series: Earth Environment Science. Volume 144: 1-9. https://doi.org/10.1088/1755-1315/144/1/012055.

Hutauruk TR, Lahjie AM, Simarangkir BDAS, Aipassa MI, Ruslim Y. 2018b.The prospect of the utilization of Non-Timber Forest Products from Setulang Village forest based on local knowledge of the Uma Longh community in Malinau. North Kalimantan. Indonesia. Biodiversitas. Volume 19 (2): 421-430. [Indonesian]

Istomo, Hidayati T. 2010. Studi potensi dan penyebaran tengkawang (*Shorea* Spp.) di areal IUPHHK-Ha PT. Intracawood Manufacturing Tarakan. Kalimantan Timur (*Study of the potential and distribution of tengkawang (Shorea Spp.) in the IUPHHK-Ha area of PT. Intracawood Manufacturing Tarakan. East Kalimantan*). J Silvikultur Tropika. Volume 01 (01): 11-17. ISSN: 2086-8227. [Indonesian]

Jaffar ANNM, Wasli ME, Perumal M, Lat J, Sani H. 2018. Effects of soil compaction and relative light intensity on survival and growth performance of planted *Shorea macrophylla* (de vriese) in riparian forest Along Kayan Ulu River. Sarawak. Malaysia. Hindawi International J Forestry Research Volume 2018 (2):1-11. Article ID 6329295. 11 pages https://doi.org/10.1155/2018/6329295.

Kacholi DS. 2014. Analysis of structure and diversity of the kilengwe forest in the Morogoro Region. Tanzania. International J of Biodiversity. Volume 2014: 1-8. Article ID 516840. 8 pages. http://dx.doi.org/10.1155/2014/516840.

Kettle CJ. 2010. Ecological considerations for using dipterocarps for restoration of lowland rainforest in Southeast Asia. Biodiv Conserv. 19: 1137-1151.

Kumhalova J, Kumhala F, Kroulik M, Matejkova S. 2011. The impact of topography on soil properties and yield and the effects of weather conditions. J Precision Agriculture. Volume 12 (6): 813-830. https://doi.org/10.1007/s11119-011-9221-x.

Kurnia, U, Agus f, Adimihardja A, Dariah A. 2006. Sifat fisik tanah dan metode analisisnya. Balai Besar Litbang Sumberdaya Lahan Pertanian. Agro inovasi. Bogor. [Indonesian]

Li X, McCarty GW. 2019. Application of topographic analyses for mapping spatial patterns of soil properties: geospatial analyses of earth observation (eo) data. Web of Science. http://doi: 10.5772/intechopen.86109.

Maharani R, Fernandes A, Pujiarti R. 2016. Comparison of tengkawang fat processings effect on tengkawang fat quality from Sahan and Nanga Yen Villages. West Kalimantan. Indonesia. Conference Proceedings. Towards The Sustainable Use of biodiversity in a changing environment: From Basic To Applied Research. Aip Publishing.

Matius P, Tjwa SJM, Raharja, Sapruddin, Noor S, Ruslim Y. 2018. Plant diversity in traditional fruit gardens (munaans) of Benuaq and Tunjung Dayaks tribes of West Kutai. East Kalimantan. Indonesia. Biodiversitas. Volume 19 (4): 1280-1288. DOI: 10.13057/biodiv/d190414. [Indonesian]

Mehata M, Cortus E, Niraula S, Spiehs MJ, Darrington J, Chatterjee A, Rahman S, Parker DB. 2019. Aerial nitrogen fluxes and soil nitrate in response to fall-applied manure and fertilizer applications in Eastern South Dakota. Hindawi International J of Agronomy. Volume 2019:1-15. Article ID 8572985. 15 pages https://doi.org/10.1155/2019/8572985.

Merang OP, Lahjie AM, Yusuf S, Ruslim Y. 2018. Productivity of three varieties of local upland rice on swidden agriculture field in Setulang village. North Kalimantan. Indonesia. Biodiversitas. Volume 21 (1): 49-56. [Indonesian]

Minasny B, Mcbratney AB. 2017. Limited effect of organic matter on soil available water capacity. European J Soil Science. 2017:1-9. https://doi: 10.1111/ejss.12475.

Mouhamed R, Alsaede A, Iqbal M. 2016. Behavior of potassium in soil: a mini review. Chemistry International. 2 (1): 58-69.

Mueller-Dombois D, Ellenberg H. 1974. Aims and methods of vegetation ecology. John Willey and Sons. Canada.

Omara P, Aula L, Raun WR. 2019. Nitrogen uptake efficiency and total soil nitrogen accumulation in long-term beef manure and inorganic fertilizer application/ Hindawi International Journal of Agronomy. Volume 2019:1-6. Article ID 9594369. 6 pages. https://doi.org/10.1155/2019/9594369.

Ohta S, Effendi S. 1992. Ultisols of "lowland dipterocarp forest" in East Kalimantan. Indonesia. Soil Sci. Plant Nutr. 38 (2): 197-206.

Osman KT. 2013. Forest soil: properties and management. Springer. London.

Panjaitan S, Wahuningtyas RS, Adawiyah R. 2012. Kondisi lingkungan tempat tumbuh *Shorea johorensis* Foxw. Di HPH Aya Yayang Indonesia. Kalimantan Selatan (*Environmental conditions in which to grow Shorea johorensis Foxw. At Aya Yayang HPH in Indonesia. South Kalimantan*). J Penelitian Dipterokarpa. Volume 6 (1): 11-22. [Indonesian]

Pratama, Arief B, Alhamd L, Rahajoe JS. 2012. Asosiasi dan karakterisasi tegakan pada hutan rawa gambut di Hampagen. Kalimantan Tengah (*Association and characterization of stands in peat swamp forests in Hampagen. Central Kalimantan*). J Teknologi Lingkungan. Edisi Khusus Hari lingkungan Hidup : 69-76. [Indonesian]

Pratiwi, Narendra BH, Hartoyo GME, Kalima T, Pradjadinata S. 2014. Atlas jenis-jenis pohon andalan setempat untuk rehabilitasi hutan dan lahan di Indonesia (*Atlas of local reliable tree species for forest and land rehabilitation in Indonesia*). Forda Press. [Indonesian]

Perumal M, Wasli ME, and Ying. HS. 2019. Influences of inorganic and organic fertilizers to morphological quality attributes of *Shorea macrophylla* seedlings in a tropical nursery. Biodiversitas. Volume 20 (8): 2110-2118. ISSN: 1412-033X. E-ISSN: 2085-4722. DOI: 10.13057/biodiv/d200803.

Perumal M. Wasli ME, Ying HS, Sani H. 2017a. Survivorship and growth performance of Shorea macrophylla (de Vriese) after enrichment planting for reforestation purpose at Sarawak. Malaysia. Online J Biology Science. Volume 17 (1): 7-17.

Perumal M, Wasli ME, Ying HS, Lat J, Sani H. 2017b. Association between soil fertility and growth performance of planted *Shorea macrophylla* (de Vriese) after Enrichment Planting at Rehabilitation Sites of Sampadi Forest Reserve. Sarawak. Malaysia. Hindawi International J Forestry Research. Volume 2017. Article ID 6721354. 16 pages. https://doi.org/10.1155/2017/6721354.

Perumal M, Wasli ME, Sani H, Nahrawi H. 2012. Growth performance of planted *Shorea macrophylla* under line planting technique. In: 4th Regional Conference on Natural Resources in the Tropics. 2012 (NTrop4) : Sustaining Tropical Natural Resources Through Innovations. Technologies and Practices.

Quedraogo I, Nacoulma BMI, Hahn K, Thiombiano A. 2014. Assessing ecosystem services based on indigenous knowledge in south-eastern Burkina Faso (West Africa). Intl J Biodivers Sci Ecosyst Serv Manag 10 (4): 313-321.

Randi A, Julia S, Kusumadewi Y, Robiansyah I, Shomat F, Tanggaraju S, Hamidi A, Juiling S, Bodos V, Maryani A. 2019. *Shorea macrophylla*. The IUCN red list of threatened species 2019: e.T33620A125629642. http://dx.doi.org/10.2305/IUCN.UK.20193.RLTS.T33620A125629642.en.

Rikando R. Latifah S. Manurung TF. 2019. Sebaran jenis tengkawang (*Shorea* spp) di hutan tembawang Desa Labian Kecamatan Batang Lupar Kapuas Hulu Kalimantan Barat (*Distribution of tengkawang species* (Shorea spp) *in the Tembawang forest Labian Village Batang Lupar District Kapuas Hulu West Kalimantan*). J Hutan Lestari. Volume 7 (1) : 390-406. [Indonesian]

Ruslim Y, Sihombing R, Liah Y. 2016. Stand damage due to mono-cable winch and bulldozer yarding in a selectively logged tropical forest. Biodiversitas 17 (1): 222-228. [Indonesian]

Ruchaemi A. 2013. Ilmu pertumbuhan hutan (Forest growth Science). Samarinda: Mulawarman University Press. [Indonesian]

Sadeghi SM, Hanum IF, Abdu A, Kamziah IK, Hakeem KR, Ozturk M. 2016. Recovery of soil in hill dipterocarp forest after logging in Kedah. Malaysia. Malayan Nature J. Volume 68 (1 & 2): 187-201.

Saiz H, Alados CL. 2012. Changes in semi-arid plant species associations along a livestock grazing gradient. Plos One 7 (7): 1-9. E40551. http://doi:10.1371/Journal.Pone.0040551.

Schroeder K, Pumphrey M. 2013. It's all a matter of pH: acid soils. aluminum toxicity are on the rise in Eastern Washington. Northern Idaho. Washington Grain Commission reports. http://washingtoncrop.com (accessed 16 Jan. 2016). p. 56–59.

Schlesinger WH, Bernhard ES. 2012. Biogeochemisty: an analysis of global change. 3rd ed. Academic Press. San Diego. CA.

Sofiah S, Setiadi D, Widyatmoko D. 2013. Pola penyebaran. kemelimpahan. dan asosiasi bambu pada komunitas tumbuhan di Taman Wisata Alam Gunug Baung Jawa Timur (*Distribution patterns. abundance. and bamboo associations in plant communities in the Gunug Baung Nature Park in East Java*). Berita Biologi. J Ilmu-Ilmu Hayati. Volume 12 (2): 239-247.

Turner BL, Engelbrecht BMJ. 2011. Soil organic phosphorus in lowland tropical rain forests. Biogeochemistry. 2011:103:297–315 DOI 10.1007/s10533-010-9466-x.

Utomo S, Uchiyama S, Ueno S, Matsumoto A, Widiyatno, Indrioko S, Na'iem M, Tsumura Y. 2018. Effects of pleistocene climate change on genetic structure and diversity of *Shorea macrophylla* in Kalimantan rainforest. Tree Gen Genomes. Volume 14 (4): 14-44.

Widiyatno, Budiadi, Suryanto P, Rinarno YDBM, Prianto SD, Hendro Y. 2017. Recovery of vegetation structure. soil nutrients and late-succession species afters hifting cultivation In Central Kalimantan. Indonesia. J Tropical Forest Science. Volume 29 (2): 151-162.

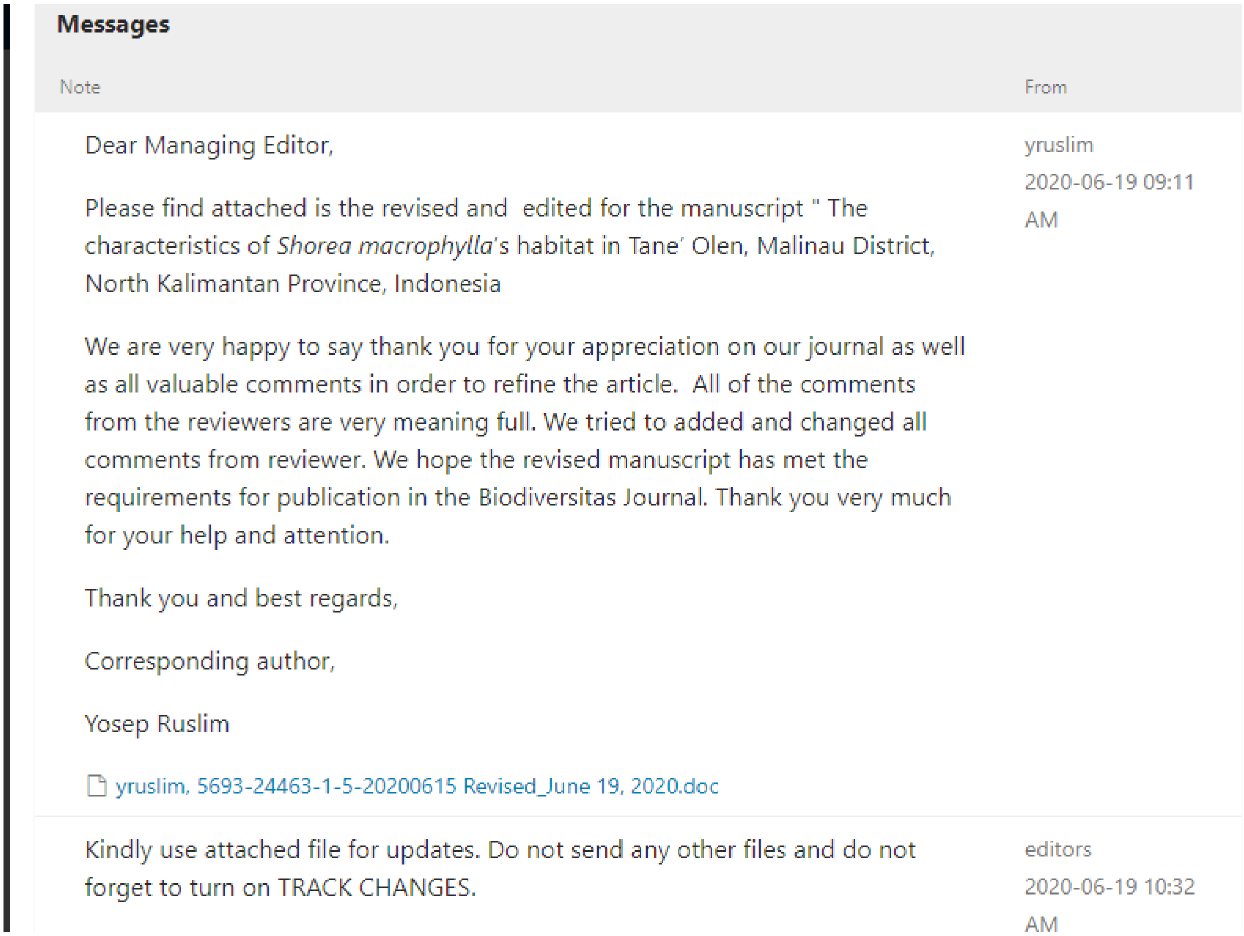
Windusari Y, Susanto RH, Dahlan Z, Susetyo W. 2011. Asosiasi jenis pada komunitas vegetasi suksesi di kawasan pengendapantailing tanggul ganda di pertambangan PTFI Papua (*Species associations in the succession vegetation community in the deposition area of the double embankment in Papua's PTFI mine*). J Ilmiah Ilmu-Ilmu Hayati Biota. Volume 16 (2): 242-251. [Indonesian]

Zaidey AK, Arifin A, Zahari I, Hazandy AH, Zaki MH, Affendi H, Wasli ME, Hafiz YK, Shamsuddin, Muhammad MN. 2010. Characterizing soil properties of lowland and hill dipterocarp forest at Peninsular Malaysia. Intenational J Soil Science. Volume 5 (3):112-130.

Zeng C, Wang Q, Zhang F, Zhang J. 2013. Temporal changes in soil hydraulic conductivity with different soil types and irrigation methods. Geoderma 193/194:290-299. doi:10.1016/j. geoderma.2012.10.013.

Zhang J, Jiang Q, Zhang Y, Dai L, Wu H. 2015. nondestructive measurement of water content and moisture migration of unsaturated red clays in South China. Hindawi Publishing Corporation Advances in Materials Science and Engineering, Volume 2015, Article ID 542538, 7 pages http://dx.doi.org/10.1155/2015/542538.

Zhu X, Zhu B. 2015. Diversity and abundance of soil fauna as influenced by longterm fertilization in cropland of purple soil. China. Soil and Tillage Research. Volume 146: 39-46.



Messages

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The characteristics of *Shorea macrophylla*'s habitat in Tane' Olen, Malinau District, North Kalimantan Province, Indonesia

Abstract. *Shorea macrophylla* is a tree species in Tane' Olen forest area. This study analyzed the soil's physical and chemical properties, topography, and microclimate of *S. macrophylla*'s habitat. A purposive method was used to select a sampling plot and to place the subplots. Soil was analyzed to determine the physical properties, i.e., texture, bulk density, porosity, and water content, and the chemical properties, i.e., pH, CEC, total N, organic C, C/N ratio, P, K , and Al saturation. Importance value index was determined for each tree species to know the species composition in the study site. Only the dominant species were presented. The soil at the study site had bulk density of 0.60-1.31 gram cm^{3-1}, porosity 50.60%-77.35%, water content 34.88%-95.37%, and soil texture sandy clay. The chemical properties of the soil were as follows: pH was 3.6-4.8, N 0.05%-0.19%, organic C 1.40%-3.65%, P 0.41-1.22 mg 100 gr^{-1}, K 58.68-232.55 mg 100 gr^{-1}, and Cation Exchange Capacity (CEC) 5.35-10.81 meg 100gr $^{-1}$. Slope ranged between 0 and 25%. The microclimate characteristics were as follows: temperature was 24-26.5°C, relative humidity 76-87%, and light intensity 145-750 Lm. Trees species with an IVI ≥ 10% were *S. macrophylla*, *Madhuca spectabilis*, *Myristica villosa* Warb, *Scorodocarpus borneensis*, *Eugenia* spp, *Palaquium* spp, *Macaranga triloba*, *Syzygium inophyllum* and *Shorea* sp. Positive associations were observed between *S. macropylla* and *S. borneensis*, *Eugenia* spp, *Palaquium* spp and *M. triloba,* and negative associations were observed between *S. macropylla* and *M. spectabilis*, *M. villosa* Warb, *S. inophyllum,* and *Shorea* sp. *S. macrophylla* grows on riversides with flat and gentle topography, acidic soil, and lower fertility but with suitable microclimate. This species can be recommended to be planted in degraded tropical forest areas but the microclimate and soil properties should be taken into account.

Keywords: Habitat, land characteristics, *S. macrophylla*

Running title: The characteristics of *Shorea macrophylla*'s habitat

INTRODUCTION

Shorea macrophylla is one of the fastest growing climax tree species of the genera *Shorea* (Perumal et al. 2017). Local communities value this species as a source of timber and fruit (Randi et al. 2019). *S. macrophylla* is known locally in West Kalimantan as the *tengkawang tungkul* tree and has been cultivated by the Dayak and Malay communities (Fajri and Fernandes 2015). *S. macrophylla* grows in clusters in tropical rain forests with type A climate, on latosol soils at altitudes up to 500 m, on acidic soils (pH 4.6-4.9), and a cation-exchange capacity (CEC) of 16.25-19.40 (Istomo and Hidayati 2010). In Sarawak, Sabah, Brunei and Kalimantan, this species is associated with sedimentary soils and is distributed evenly over riverbanks and areas with sloping or flat topography. It is rarely found on hills. (Randi et al. 2019; Utomo et al. 2018; Perumal et al. 2017).

The timber from *S. macrophylla* is commonly used for construction and to make veneer and plywood, musical instruments, furniture, and packing crates (Istomo and Hidayati 2010). The fruit, locally known as *tengkawang tungkul* (*Illipe*) nuts, is used as a raw material for soap and other cosmetics, a substitution for brown fat, and a source of vegetable fat (Maharani et al. 2016).

The natural population of *tengkawang* is declining and is, at present, hard to find (Istomo and Hidayati 2010) because *S. macrophylla* is one of the most sought-after species in tropical forests. The exploitation of the species for its timber, combined with forest conversion to other uses, has resulted in *S. macrophylla* timber being difficult to find in the market (Rikando et al. 2019).

Tane' Olen is a forested area with a high environmental value preserved by the people of Setulang Village (Hutauruk et al. 2018a), a community that manages its forests based on the local wisdom and sustainable forest management practices (Fahrianoor et al. 2013; Kettle 2010), so the forest sustainability is maintained (Hutauruk et al. 2018). Forests are not only

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a place to live for them, but are also used as a source of food and medicine and economic, social, cultural, and spiritual functions (Merang et al. 2020; Matthew et al. 2018; Quedraogo et al. 2014).

S. macrophylla’s habitat characteristics in secondary forest locations have been documented by Jaffar et al. (2018) and Perumal et al. (2017). Perumal et al. (2017) studied the relationship between soil fertility and the growth of *S. macrophylla* in enrichment plantings at Sampadi Forest Reserve, Lundu, Sarawak and an adjacent secondary forest. Jaffar et al. (2018) researched the effects of soil compaction and light intensity on the establishment and growth of *S. macrophylla* in riparian forests in Sungai Kayan Ulu Sungai, Serawak, Malaysia. The improvement of the company's management system, which is changing the way of harvesting using long cables during skidding activity, reduced the natural forest damage and could increase financial returns from natural forest concessions (Ruslim et al. 2016). The characteristics of *S. macrophylla* habitat in primary forest locations had not previously been studied. So, this study aimed to describe the characteristics of *S. macrophylla’s* habitat in primary forests by analyzing the physical and chemical properties of soil, the microclimate, topography, species associations, and vegetation. It is hoped that the results of this study will benefit conservation efforts of this species, especially on degraded land in the tropical rain forests of North Kalimantan.

MATERIALS AND METHODS

Study area

The study was carried out in Tane’ Olen forest area, Setulang Village, Malinau District, North Kalimantan Utara Province (3°25’0.86” N and 116°25’52.59” E). The location map is presented in Figure 1.

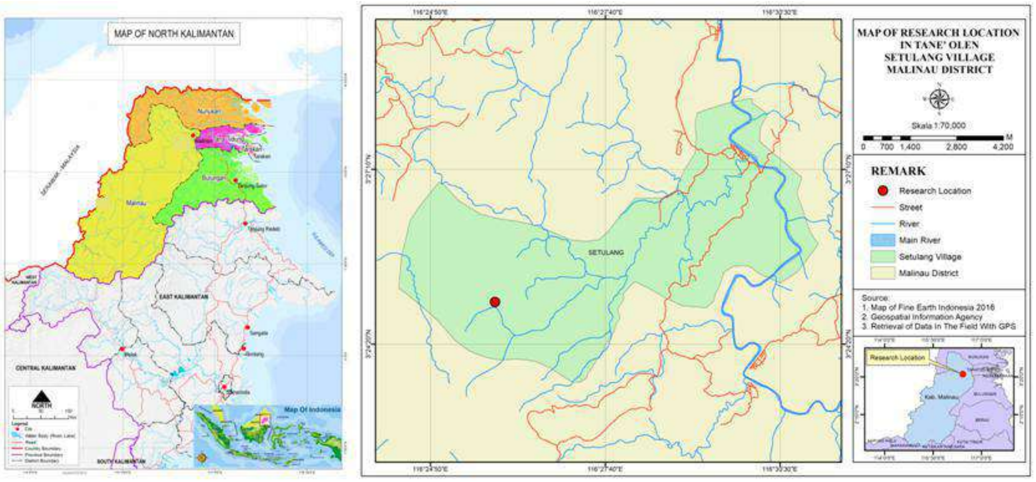

Figure 1. Location of the research in Tane’ Olen (●)

Research procedure

A one-hectare research site was selected purposively and sampled using a square plot with a side length of 100 meters (Sari and Maharani 2016). Soil sampling was taken from purposively selected three sampling points, located on a ridge, a slope, and a valley (the ridge had the highest elevations and a 15-25% slope; the slope was located between the valley and ridge, and had an 8-15% slope; the valley was the lowest area and had a 0-8% slope) to ensure an accurate representation of the study site. At each sampling point, soil samples were taken at three depths: 0-20 cm, 20-40 cm, and 40-60 cm. Microclimate data (temperature, humidity, and light intensity) were collected at the same locations. The soil and microclimate data collection design is illustrated in Figure 2. Vegetation data were only collected for trees with a diameter at breast height (DBH) greater than 20.0 cm. Each plot was divided into 25 subplots (20 m x 20 m). Within each subplot, the species were identified and DBH recorded for all trees (Widiyatno et al. 2017). Plot-making and field-data collection activities are presented in Figure 2, while sampling design is presented in Figures 3 and 4.

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Figure 2. A. Exploration, B. Research plot making, C. Tree inventory, D. Soil sample collection, E and F. Microclimate data collection

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Soil sample collection design and microclimate data are presented in Figures 3 and 4

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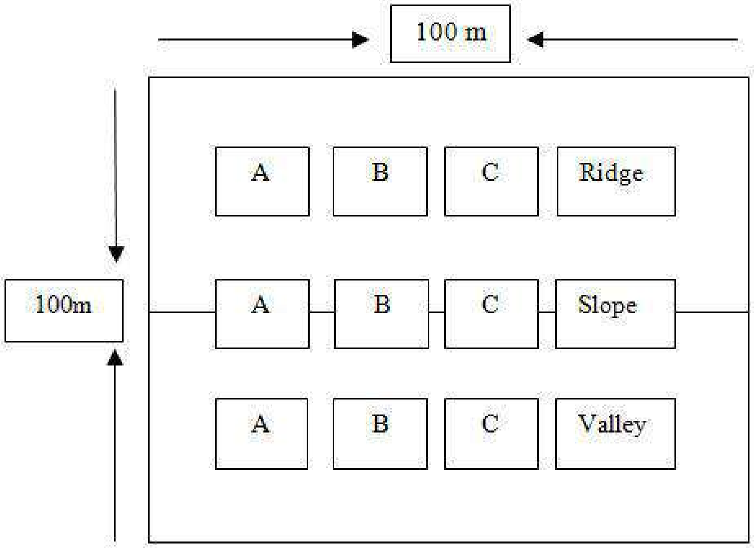

Figure 3. Soil and microclimate sample design. Note: A:lights intensity, B: temperature and area humidity, C: soil sampling, m:meter

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Topography data collection design can be seen in Figure 4.

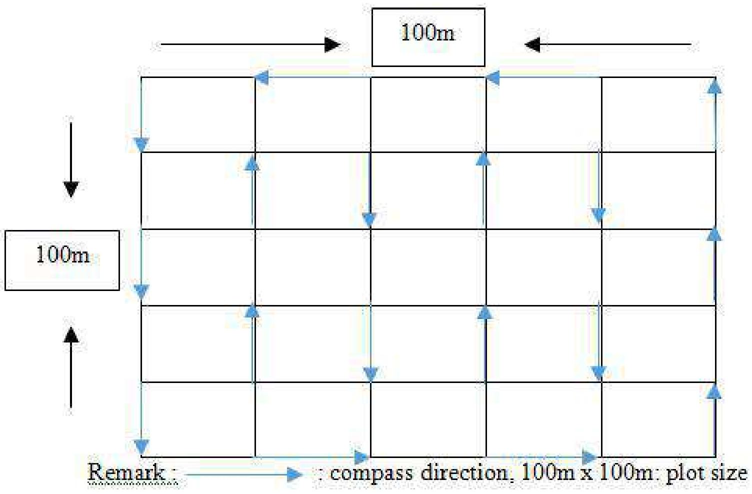
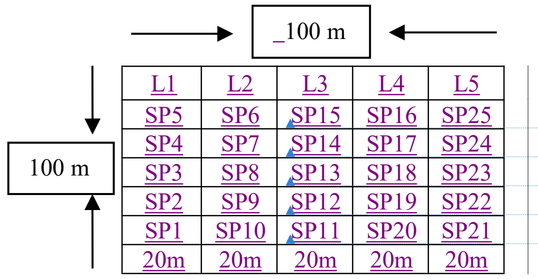


Figure 4. Plot design across contour line

The design of vegetation data collection can be seen in Figures 5



L1	L2	L3	L4	L5
SP5	SP6	SP15	SP16	SP25
SP4	SP7	SP14	SP17	SP24
SP3	SP8	SP13	SP18	SP23
SP2	SP9	SP12	SP19	SP22
SP1	SP10	SP11	SP20	SP21
20m	20m	20m	20m	20m

Remarks: L: lane, SP: sub plot, 20m: distance between sub plots, 100m x 100m: plot size, m: meter.

Figure 5. Design of plot and sub-plots for vegetation sampling

Data analyses

Soil analyses

Soil samples were analyzed for both physical and chemical properties (Kurnia et al. 2006; Eviati and Sulaeman 2009). Physical properties analyzed were texture, bulk density, porosity, and water content (using the Pipette method). Chemical properties analyzed were pH (using the electrode method), CEC (using the ammonium acetate pH 7 method), elements Al+++ and H+ (using the KCl method 1 N), total N elements (using the Kjeldahl method), organic C elements (using Walkley-Black method), C/N ratio (using arithmetic methods), elements P2O5 and K_2O (using Bray No I methods), and saturation Al (using arithmetic methods). Soil data analysis results from the soil laboratory were tabulated and analyzed descriptively and quantitatively.

Analysis of topography

The topographic analysis was done qualitatively to describe the topography suitable for *S. macrophylla*.

Analysis of microclimate

The analysis of microclimate was done qualitatively to provide information on microclimates characteristics suitable for S. *macrophylla*.

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Importance Value Index

According to Kacholi (2014), the Importance Value Index (IVI) is used in ecological studies to determine the ecological importance of a species in a particular ecosystem. IVI is also used to prioritize species conservation. Species with low IVI values require a higher conservation priority than those with high IVI, which is the dominant species. IVI value is a function of several characteristics, and calculated with this formula: IVI = relative density + relative frequency + relative dominance. IVI values were analyzed descriptively.

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Association of vegetation

Associations between two tree species were analyzed using a series of 2x2 contingency tables (Mueller-Dombois and Ellenberg 1974). A more complete description is presented in Table 1.

Table 1. Contingency table form

Species A / Species B	+	-	
+	A	B	a + b
-	c	D	c + d
	a + c	b + d	N = a + b + c + d

Reference: Mueller-Dombois and Ellenberg (1974)

Remarks :

a = number of plots containing species A and species B.
b = number of plots containing only species A, but no species B.
c = number of plots containing only species B, but no species A.
d = number of plots containing neither species A nor species B.
N = number of all plots.

Then, the data were tested with chi-square (x^2)

$$X^2 = \frac{(ad - bc)^2 \; x \; N}{(a+b)(c+d)(a+c)(b+d)}$$

The association coefficient (C) values were determined as follows:

1. If ad ≥ bc, so $C = \frac{ad-bc}{(a+b)(b+d)}$
2. If bc > ad and d > a, so $C = \frac{ad-bc}{(a+b)(b+c)}$
3. If bc > ad and a > c, so $C = \frac{ad-bc}{(a+d)(c+d)}$

Positive or negative values of C indicate a positive or negative relationship between the two species. A positive relationship indicates that the association between trees is mutually beneficial to each other, while a negative value indicates that the association between trees harms one another.

RESULTS AND DISCUSSION

The soil's physical and chemical properties

The physical and chemical properties of soil properties in *S. macrophylla's* habitat can be seen in Table 2.

Table 2. Physical properties of soil at the study site

Location of soil	Depth (cm)	Bulk density (gram/cm³)*	Porosity (%)*	Water content (%)
Valley	0-20	0.60	77.35	95.37
	20-40	1.13	57.32	40.04
	40-60	1.18	55.54	39.20
Slope	0-20	1.05	60.42	48.08
	20-40	1.31	50.60	41.42
	40-60	1.23	53.72	34.88
Ridge	0-20	0.83	68.75	61.68
	20-40	1.01	61.92	44.23
	40-60	1.20	54.66	35.53

Remark:* Average score from three repetitions

At the depth of 0-20 cm, the valley, slope, and ridge subplots had a low bulk density (0.60-1.05) (Table 2). According to Casanova et al. (2016) and Zeng et al. (2013), soil bulk density is influenced by external conditions and natural processes such as plant root growth and rainfall.

The soil porosity values in the valley, slope, and ridge subplots decreased with the increasing soil depth. The valley subplot had higher porosity value than the slope and ridge subplots. According to Darusman et al. (2019), the properties

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that affect soil porosity the most are bulk density and soil particle density; if the bulk density is low then the soil porosity will increase.

Water content in the ridge, slope, and valley decreased with the increasing soil depth. The water content in the ridge subplots was higher than the slope subplots because the water movement is faster in the slope subplots and the water settles in the lower area, i.e., the valley subplots, which resulted in a higher (95.37%) water content in the valley subplots than in the ridge and slope subplots. Jaffar et al. (2018) state that *S. macrophylla* plant roots can adapt to high water soil content. Moist soils stimulate *S. macrophylla* roots growth and development. According to Minasny and McBratney (2018), the availability of groundwater is an important component of water balance and the terrestrial biosphere cycle because it can affect evapotranspiration rates and support plant growth.

The results of the soil texture analysis can be seen in Table 3.

Table 3. Soil texture at the study site

Location of soil	Depth (cm)	Clay (%)	Sand (%)	Silt (%)	texture (USDA)
Valley	0-20	33.70	50.90	15.40	SCL
	20-40	36.50	49.50	14.00	SC
	40-60	34.00	56.80	9.20	SCL
Slope	0-20	24.70	67.20	8.10	SCL
	20-40	27.30	63.10	9.60	SCL
	40-60	33.10	60.50	6.40	SCL
Ridge	0-20	37.80	54.60	7.60	SC
	20-40	37.40	46.40	16.20	SC
	40-60	40.70	48.00	11.30	SC

Remark: Laboratory of soil test in B2P2EHD and Pusrehut, Mulawarman University

The soil texture at the study site generally had a sand fraction of 45-65%, a clay fraction 35-55%, and a silt fraction 0-20% (Table 3). This means that the soil texture is sandy clay. According to Osman (2013), soil texture refers to the level of fineness or roughness created by the variously-sized soil particles.

Soil types are generally dominated by Ultisol (advanced development) soils, namely Typic Hapludults (Red-Yellow Podsolik) and Typic Paleudults (Yellow Podsolic). These soil types are typically found in lowland dipterocarp forests (Ohta and Effendi 1992).

Chemical soil characteristics of the study site are presented in Table 4.

Table 4. Chemical characteristics of soil at the study site

Location of soil	Depth (cm)	pH (1: 25)		Cation exchange rates (meg 100gr^{-1})			Organic content (%)		Ratio	Mineral (Mg 100 gram^{-1})	
		H_2O	KCl	CEC	Al3^{+}	H^{+}	Tot. N.	Org C	C/N	P_2O_5	K_2O
Valley	0-20	4.6	3.3	7.26	4.92	1.50	0.19	3.65	19	0.89	116.85
	20-40	4.6	3.4	7.25	5.56	1.08	0.12	2.65	22	0.73	73.30
	40-60	4.4	3.4	7.18	5.75	0.92	0.10	2.12	22	1.22	59.00
Slope	0-20	4.1	3.5	5.35	2.75	1.33	0.13	2.31	18	0.65	73.62
	20-40	4.7	3.5	5.30	3.50	0.92	0.07	1.54	22	0.65	58.68
	40-60	4.8	3.5	5.53	3.33	1.42	0.05	1.40	26	0.41	60.90
Ridge	0-20	4.4	3.0	10.81	7.25	2.75	0.09	3.46	39	2.35	120.34
	20-40	3.6	3.3	10.48	7.80	1.83	0.08	2.12	28	0.89	194.09
	40-60	4.4	3.4	10.37	6.83	2.58	0.09	1.54	17	0.65	232.55

Remark: Laboratory of soil test in B2P2EHD and Pusrehut, Mulawarman University

The soil at the study site was very acidic (pH = 4.1-4.8) (Table 4). According to Schroeder and Pumphrey (2013), acidic soils inhibit root and plant growth and increase Al levels in the soil. The CEC at the study site ranged from 5.3 to 10 meq/100 g^{-1}, indicating that the CEC was low. In general, the value of CEC is low in surface and subsurface soils of lowland dipterocarp forests (Perumal et al. 2017a).

Aluminum levels at the study site were high, especially in the slope and valley subplots, which indicated high soil toxicity. Al content in the soil decreased with the increasing organic matter because organic matter forms a strong bond with Al. According to Zaidey et al. (2010), Al is a major cause of soil acidity, and soils in lowland dipterocarp forests have high Al content.

Nitrogen levels at the study site ranged from 0.05% to 0.19% (low to very low). Sadeghi et al. (2016) also reported low total N levels in tropical rain forest soils. Nitrogen is important for plant growth (Omara et al. 2019), and N deficiency can inhibit plant growth (Mehata et al. 2019). According to Omara et al. (2019), the main sources of N are organic matter and rainfall/precipitation.

Organic C values were higher in the valley and slope subplots than in the ridge subplots. The steeper slopes in the ridge subplots are more prone to erosion, resulting in the leaching of organic C and other nutrients into the valley and slope subplots. According to Schlesinger and Bernhard (2013), carbon can be stored in the soil three times longer than in the atmosphere and is an indicator of soil microorganism abundance and diversity (Zhu and Zhu 2015). The presence of

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organic C in the soil spurs microorganism activity and thereby increases the rates of soil decomposition, P dissolution, N fixation, and other microorganism-dependent reactions.

Phosphate was calculated from P_2O_5, where the Phosphate content is very low (0.41-1.22 mg 100 gram^{-1}) (Table 4). According to Turner and Engelbrecht (2011), organic P plays an important role in maintaining P availability in lowland tropical rain forests. Phosphorus is essential for root development and plant growth (Abdissa et al. 2011). According to Carstensen, et al. (2018), P deficiency has a major impact on plant growth, development and productivity.

Potassium values ranged from high (58.68-116.85 mg 100 gr^{-1}) in the valley and slope subplots to very high (120.34-232.55 mg 100 gr^{-1}) in the ridge subplots. According to Mouhamad et al. (2016), K is more abundant in the soil than other mineral elements. This element has an essential role in plant metabolism, growth, and yield. Potassium availability depends on soil properties (humidity, aeration, and temperature), soil treatment systems, and the dynamics of K. Therefore, the K exchange level varies among soils.

Topography in the study area

According to Li and McCarty (2019), topographic features are key parameters that affect the nature of the soil at the earth's surface. Topographic features can affect organic matter; clay content; P, K, and Mg concentrations; and soil pH (Kumhalova et al. 2011).

The topography of the study site is moderately undulating with a slope of 0-25%. The subplot slopes range from flat to moderately steep. *S. macrophylla* was found primarily in flat to sloping areas with high environmental humidity, low ambient temperature, and abundant water, such as riverbanks. Jaffar et al. (2018) stated that the roots of the *S. macrophylla* are able to survive and grow in anaerobic waterlogged soils and is considered a flood-tolerant tree.

Dominant trees at the study area

At the study site, *S. macrophylla* was the dominant tree species (Figure 6). Other tree species included *Madhuca spectabilis, Myristica villosa* Warb., *Scorodocarpus borneensis, Eugenia* spp., *Palaquium* spp., *Macaranga triloba, Syzygium inophyllum,* and *Shorea sp. S. macrophylla* dominated the study site due to its fast germination process and high germination rate (Appanah and Turnbull 1998), its high growth rate (fastest of the genus *Shorea)*, and its status as a climax species along rivers (Perumal et al. 2017).

Table 5. The importance value index of the dominant tree species at the study site

Number	**Local name**	**Scientific Name**	**Family**	**Relatif density (%)**	**Relatif dominance (%)**	**Relatif frequency (%)**	**Importance value index (%)**
1.	Tengkawang	*S. macropyilla*	Dipterocarpaceae	7.69	15.35	5.0	28.04
2.	Kajen ase	*M. spectabilis*	Sapotaceae	10.25	7.29	4.61	22.16
3.	Darah-darah	*M. villosa* Warb	Myristicaceae	7.45	4.79	5.0	17.25
4.	Bala seveny	*S. borneensis*	Olacaceae	5.12	5.77	5.0	15.90
5.	Ubah	*Eugenia* spp	Myrtaceae	5.59	3.64	4.61	13.85
6.	Nyatok	*Palaquium* spp	Sapotaceae	4.42	3.70	4.61	12.74
7.	Beneva	*M. triloba*	Euphorbiaceae	4.66	4.32	3.46	12.44
8.	Ehang	*S. inophyllum*	Myrtaceae	5.36	3.14	3.84	12.35
9.	Kaze tenak	*Shorea* sp	Dipterocarpaceae	2.33	6.08	2.69	11.10

Figure 6. A. Tree of *S. macrophylla* and B. Leaves of *S. macrophylla*

Microclimate

Three microclimate factors were collected, i.e., temperature, humidity, and light intensity (see Table 6 for a more complete description).

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Table 6. Microclimate at the study site

Location	Microclimate	Unit	Time	1-st record	2-nd record	3-rd record	Average	Remark
1.	Light intensity	Lm	Morning	350	400	452	400.67	Taken at 8.59 sunny conditions
2.	Temperature	°c	Morning	24	24.5	25	24.5	
3.	Relative humidity	%	Morning	81	79	80	80	
1.	Lights intensity	Lm	Mid day	750	450	207	469	Taken at 12:02 sunny conditions
2.	Temperature	°c	Mid day	26.5	26	24.5	25.67	
3.	Relative humidity	%	Mid day	76	79	81	78.67	
1.	Lights intensity	Lm	Afternoon	369	237	145	250.33	Taken at 16:30 sunny conditions
2.	Temperature	°c	Afternoon	25	24.5	23	24.17	
3.	Relative humidity	%	Afternoon	84	85	87	85.33	

The temperature values at the study site was 24-26,5° C (Table 6). According to Ruchaemi (2013), the optimal temperature for plant assimilation is 25-30° C. Relative humidity values were high to very high, ranging from 76 to 87%. Lights intensity was very low to low, ranging from 7,25% (145 Lm) to 23.46% (469 Lm) due to dense canopy dominated by *S. macrophylla*, which prevented light from reaching the forest floor. This low light intensity is consistent with the findings of Panjaitan et al. (2012), who found that the closed canopy only allowed a little sunlight to reach the forest floor. These conditions benefit *S. macrophylla* seedlings, which are sun intolerant.

Association with other trees

According to Saiz and Alados (2012), plant species association is a fundamental aspect of the ecology of plant communities. Analysis of plant species associations provides information on environmental heterogeneity, biotic interactions, and seed dispersal patterns. The results of the species association analysis and the association coefficient are presented in Table 7.

Table 7. Association of *S. macropylla* with other species

Species association	X² count	Association species	C (+/-)
S. macropylla with *M. spectabilis*	0.35	-	0.04
S. macropylla with *M. villosa* Warb	6.82	-	0.29
S. macropylla with *S. borneensis*	0.04	+	0.04
S. macropylla with *Eugenia* spp	0.37	+	0.11
S. macropylla with *Palaquium* spp	0.37	+	0.11
S. macropylla with *M. triloba*	1.21	+	0.16
S. macropylla with *S. inophyllum*	3.23	-	0.29
S. macropylla with *Shorea* sp	1.92	-	0.24

Remark: X ² tabulated value at 5% level: 3.841. X² tabulated value at 1% level: 6.35

Table 7 shows the results of a series of 2x2 contingency tests between *S. macropylla* and each of the eight other dominant tree species. The calculated X^2 values were greatest between *S. macropylla* and *M. villosa* Warb, indicating that *S. macrophylla* had a strong but negative association with *M. villosa* Warb. According to Sofiah et al. (2013), species pairs do not always indicate positive relationships. Tree species with high populations are not always associated with another species. Likewise, low-population species are not necessarily negatively correlated with another species.

The association coefficient (C) was used as a parameter of the magnitude of the relationship between the eight species and *S. macropylla* and indicates positive or negative associations. Species that showed positive coefficients of association with *S. macropylla* were *S. borneensis, Eugenia spp., Palaquium spp,* and *M. triloba.* According to Windusari1 et al. (2011), positive associations indicate both species have the same requirement of environmental conditions; for example, wet conditions, high light intensity, or shade. *S. macropylla* showed a negative association with *M. spectabilis, M. villosa Warb, S. inophyllum,* and *Shorea* sp. Negative associations indicate intolerance for cohabitation or the absence of a mutually beneficial relationship (Pratama et al. 2012).

Direction of *S. macrophylla* plantation

At present, tropical forests are being degraded by anthropogenic activities such as timber extraction, agricultural cultivation, and the establishment of commercial plantations. This results in the conversion of forests into agriculture land and the fragmentation and degradation of tropical rain forests. Deforestation damages the environment by increasing light intensity and causing severe mineral soil erosion. In general, degraded forests can be divided into three categories: grasslands after burning, early-succession secondary forests, and commercially logged forests (Daisuke et al. 2013).

Planting native trees is considered to be an effective rehabilitation method for degraded tropical rain forests because native trees provide benefits such as timber, food, and medical products (Daisuke et al. 2013). According to Pratiwi et al. (2014), tropical forest rehabilitation is necessary to both meet the demand for timber and improve environmental conditions. One key to rehabilitation success is the understanding of the suitability of each growing site for each species

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being planted. One approach to determine the suitability of growing sites for each species is to identify each species' potential, identify locally superior species, and correlate this with species distribution data and growth requirements (Pratiwi et al. 2014).

S. macrophylla is a recommended species for replanting degraded tropical forest land, i.e., pastures after burning (Daisuke et al. 2013), early-succession secondary forests (Daisuke et al. 2013; Perumal et al. 2012), and commercially logged forests. In commercially logged forests, *S. macrophylla* can be planted using the line planting system or gap planting system. In early-succession secondary forests and pasture after burning, *S. macrophylla* requires pioneer plants to assist growth. *S. macrophylla* is a valuable tree species that has socio-economic and ecological benefits and is beneficial for reforestation and rehabilitation activities (Perumal et al. 2012; Perumal et al. 2015; Perumal et al. 2017a; Perumal et al. 2017b; Perumal et al. 2019).

This species is important for land rehabilitation activities because it plays a role in maintaining water quality, filtering out pollutants and deposits, and storing carbon (Utomo et al. 2018; You et al. 2015). Things that must be considered when planting *S. macrophylla* are the nutrient content in clay and the clay mineral composition. These two factors can be used to evaluate soil fertility. The growth of *S. macrophylla* is also significantly limited by the high light intensity in grasslands (*Imperata cylindrica*/ pastures after burning). *S. macropylla* grows well in habitats with low light intensity. In secondary forests and logged-over forests, the survival and growth of *S. macrophylla* is limited by soil compaction. This agrees with the results of this study, where fine sandy clay soils were found.

S. macrophylla grows on riversides with flat and gentle topography, acidic soil, and lower fertility, but with the suitable microclimate (temperature of 24-26,5°C, high humidity 76-87%, and a low light intensity 7,25-23.46%). This species can be recommended to be planted in degraded tropical forest areas if microclimatic factors and soil conditions are taken into account.

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REFERENCES

Abdissa Y, Tekalign T, Pant LM. 2011. Growth. bulb yield and quality of onion (*Allium cepa* L) as influenced by nitrogen and phosphorus fertilization on vertisol i. growth attributes. biomass production and bulb yield. Afr J Agric Res 6 (14): 3252–3258.

Appanah S, Turnbull JM. 1998. A review of dipterocarps : taxonomy. ecology and silviculture. Center for International Forestry Research.

Carstensen A, Herdean A, Schmidt SB, Sharma A, Spetea C, Pribil M, and Husted S. 2018. The impacts of phosphorus deficiency on the photosynthetic electron transport chain. Plant Physiology 177: 271–284. https://doi.org/10.1104/pp.17.01624.

Casanova M, Tapia E, Seguel O, Salazar O. 2016. Direct measurement and prediction of bulk density on alluvial soils of central Chile. Ultural Chilean J Agric Res 76 (1):105-113. doi:10.4067/S0718-58392016000100015.

Daisuke H, Tanaka K, Jawa KJ, Ikuo N, Katsutoshi S. 2013. Rehabilitation of degraded tropical rainforest using dipterocarp trees in Sarawak. Malaysia. Hindawi Publishing Corporation Int J For Res 2013:1-12. Article ID 683017. 11 pages http://dx.doi.org/10.1155/2013/683017.

Darusman, Devianti, Husen E. 2018. Improvement of soil physical properties of cambisol using soil amendment. Aceh Int. J Sci. Technol.. 7 (2): 93-102. doi: 10.13170/aijst.7.2. 10119.

Eviati and Sulaeman. 2009. Petunjuk teknis analisis kimia tanah, tanaman, air, dan pupuk. Edisi 2. ISBN 978-602-8039-21-5. Balai Penelitian Tanah, Bogor. [Indonesian]

Fahrianoor, Windari T, Taharudin, Mar'i R, Maryono. 2013. The practice of local wisdom of Dayak people in forest conservation in South Kalimantan. Indon J Wetlands Environ Manag 1 (1): 37-46.

Fajri M, Fernandes A. 2015. Pola pemanenan buah tengkawang (*S. machrophylla*) dan regenerasi alaminya dikebun masyarakat. J. Penelitian Ekosistem Dipterokarpa 1 (2) : 81-88. https://doi.org/10.20886/jped.2015.1.2.81-88. [Indonesian]

Hutauruk TR, Lahjie AM, Simarangkir BDAS, Ruslim Y. 2018a. Setulang forest conservation strategy in safeguarding the conservation of non-timber forest products in Malinau District. IOP Conference. Series: Earth Environment Science. 144: 1-9. https://doi.org/10.1088/1755-1315/144/1/012055.

Hutauruk TR, Lahjie AM, Simarangkir BDAS, Aipassa MI, Ruslim Y. 2018b.The prospect of the utilization of Non-Timber Forest Products from Setulang Village forest based on local knowledge of the Uma Longh community in Malinau. North Kalimantan. Indonesia. Biodiversitas 19 (2): 421-430. [Indonesian]

Istomo, Hidayati T. 2010. Studi potensi dan penyebaran tengkawang (*Shorea* Spp.) di areal IUPHHK-Ha PT. Intracawood Manufacturing Tarakan. Kalimantan Timur (Study of the potential and distribution of tengkawang *(Shorea* spp.) in the IUPHHK-Ha area of PT. Intracawood Manufacturing Tarakan. East Kalimantan). J Silvikultur Tropika. 01 (01): 11-17. ISSN: 2086-8227. [Indonesian]

Jaffar ANNM, Wasli ME, Perumal M, Lat J, Sani H. 2018. Effects of soil compaction and relative light intensity on survival and growth performance of planted *Shorea macrophylla* (de vriese) in riparian forest Along Kayan Ulu River. Sarawak. Malaysia. Hindawi Int J For Res 2018 (2):1-11. Article ID 6329295. 11 pages https://doi.org/10.1155/2018/6329295.

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Kacholi DS. 2014. Analysis of structure and diversity of the kilengwe forest in the Morogoro Region. Tanzania. Int J Biodiversity 2014: 1-8. Article ID 516840. 8 pages. http://dx.doi.org/10.1155/2014/516840.

Kettle CJ. 2010. Ecological considerations for using dipterocarps for restoration of lowland rainforest in Southeast Asia. Biodiv Conserv. 19: 1137-1151.

Kumhalova J, Kumhala F, Kroulik M, Matejkova S. 2011. The impact of topography on soil properties and yield and the effects of weather conditions. J Precis Agric 12 (6): 813-830. https://doi.org/10.1007/s11119-011-9221-x.

Kurnia, U, Agus f, Adimihardja A, Dariah A. 2006. Sifat fisik tanah dan metode analisisnya. Balai Besar Litbang Sumberdaya Lahan Pertanian. Agro inovasi. Bogor. [Indonesian]

Li X, McCarty GW. 2019. Application of topographic analyses for mapping spatial patterns of soil properties: geospatial analyses of earth observation (eo) data. Web of Science. http://doi: 10.5772/intechopen.86109.

Maharani R, Fernandes A, Pujiarti R. 2016. Comparison of tengkawang fat processings effect on tengkawang fat quality from Sahan and Nanga Yen Villages. West Kalimantan. Indonesia. Conference Proceedings. Towards The Sustainable Use of biodiversity in a changing environment: From Basic To Applied Research. Aip Publishing.

Matius P, Tjwa SJM, Raharja, Sapruddin, Noor S, Ruslim Y. 2018. Plant diversity in traditional fruit gardens (munaans) of Benuaq and Tunjung Dayaks tribes of West Kutai. East Kalimantan. Indonesia. Biodiversitas. 19 (4): 1280-1288. [Indonesian]

Mehata M, Cortus E, Niraula S, Spiehs MJ, Darrington J, Chatterjee A, Rahman S, Parker DB. 2019. Aerial nitrogen fluxes and soil nitrate in response to fall-applied manure and fertilizer applications in Eastern South Dakota. Hindawi Int J Agron 2019:1-15. Article ID 8572985. 15 pages https://doi.org/10.1155/2019/8572985.

Merang OP, Lahjie AM, Yusuf S, Ruslim Y. 2018. Productivity of three varieties of local upland rice on swidden agriculture field in Setulang village. North Kalimantan. Indonesia. Biodiversitas 21 (1): 49-56. [Indonesian]

Minasny B, Mcbratney AB. 2017. Limited effect of organic matter on soil available water capacity. Eur J Soil Sci 2017:1-9. https://doi: 10.1111/ejss.12475.

Mouhamed R, Alsaede A, Iqbal M. 2016. Behavior of potassium in soil: a mini review. Chem Int 2 (1): 58-69.

Mueller-Dombois D, Ellenberg H. 1974. Aims and methods of vegetation ecology. John Willey and Sons. Canada.

Omara P, Aula L, Raun WR. 2019. Nitrogen uptake efficiency and total soil nitrogen accumulation in long-term beef manure and inorganic fertilizer application. Hindawi Int J Agron 2019:1-6. Article ID 9594369. 6 pages. https://doi.org/10.1155/2019/9594369.

Ohta S, Effendi S. 1992. Ultisols of "lowland dipterocarp forest" in East Kalimantan. Indonesia. Soil Sci. Plant Nutr. 38 (2): 197-206.

Osman KT. 2013. Forest soil: properties and management. Springer. London.

Panjaitan S, Wahuningtyas RS, Adawiyah R. 2012. Kondisi lingkungan tempat tumbuh *Shorea johorensis* Foxw. di HPH Aya Yayang Indonesia. Kalimantan Selatan (Environmental conditions in which to grow *Shorea johorensis* Foxw. at Aya Yayang HPH in Indonesia. South Kalimantan). J Penelitian Dipterokarpa. 6 (1): 11-22. [Indonesian]

Pratama, Arief B, Alhamd L, Rahajoe JS. 2012. Asosiasi dan karakterisasi tegakan pada hutan rawa gambut di Hampagen. Kalimantan Tengah (*Association and characterization of stands in peat swamp forests in Hampagen. Central Kalimantan*). J Teknologi Lingkungan. Edisi Khusus Hari lingkungan Hidup : 69-76. [Indonesian]

Pratiwi, Narendra BH, Hartoyo GME, Kalima T, Pradjadinata S. 2014. Atlas jenis-jenis pohon andalan setempat untuk rehabilitasi hutan dan lahan di Indonesia (*Atlas of local reliable tree species for forest and land rehabilitation in Indonesia*). Forda Press. [Indonesian]

Perumal M, Wasli ME, and Ying. HS. 2019. Influences of inorganic and organic fertilizers to morphological quality attributes of *Shorea macrophylla* seedlings in a tropical nursery. Biodiversitas 20 (8): 2110-2118. [Indonesian]

Perumal M. Wasli ME, Ying HS, Sani H. 2017a. Survivorship and growth performance of *Shorea macrophylla* (de Vriese) after enrichment planting for reforestation purpose at Sarawak. Malaysia. Online J Biol Sci 17 (1): 7-17.

Perumal M, Wasli ME, Ying HS, Lat J, Sani H. 2017b. Association between soil fertility and growth performance of planted *Shorea macrophylla* (de Vriese) after Enrichment Planting at Rehabilitation Sites of Sampadi Forest Reserve. Sarawak. Malaysia. Hindawi Int J For Res Volume 2017. Article ID 6721354. 16 pages. https://doi.org/10.1155/2017/6721354.

Perumal M, Wasli ME, Sani H, Nahrawi H. 2012. Growth performance of planted *Shorea macrophylla* under line planting technique. In: 4th Regional Conference on Natural Resources in the Tropics. 2012 (NTrop4) : Sustaining Tropical Natural Resources Through Innovations. Technologies and Practices.

Quedraogo I, Nacoulma BMI, Hahn K, Thiombiano A. 2014. Assessing ecosystem services based on indigenous knowledge in south-eastern Burkina Faso (West Africa). Intl J Biodivers Sci Ecosyst Serv Manag 10 (4): 313-321.

Randi A, Julia S, Kusumadewi Y, Robiansyah I, Shomat F, Tanggaraju S, Hamidi A, Juiling S, Bodos V, Maryani A. 2019. *Shorea macrophylla*. The IUCN red list of threatened species 2019: e.T33620A125629642. http://dx.doi.org/10.2305/IUCN.UK.20193.RLTS.T33620A125629642.en.

Rikando R. Latifah S. Manurung TF. 2019. Sebaran jenis tengkawang (*Shorea* spp) di hutan tembawang Desa Labian Kecamatan Batang Lupar Kapuas Hulu Kalimantan Barat (*Distribution of tengkawang species* (Shorea spp) *in the Tembawang forest Labian Village Batang Lupar District Kapuas Hulu West Kalimantan*). J Hutan Lestari 7 (1) : 390-406. [Indonesian]

Ruslim Y, Sihombing R, Liah Y. 2016. Stand damage due to mono-cable winch and bulldozer yarding in a selectively logged tropical forest. Biodiversitas 17 (1): 222-228. [Indonesian]

Ruchaemi A. 2013. Ilmu pertumbuhan hutan (Forest growth Science). Samarinda: Mulawarman University Press. [Indonesian]

Sadeghi SM, Hanum IF, Abdu A, Kamziah IK, Hakeem KR, Ozturk M. 2016. Recovery of soil in hill dipterocarp forest after logging in Kedah. Malaysia. Malayan Nature J 68 (1 & 2): 187-201.

Saiz H, Alados CL. 2012. Changes in semi-arid plant species associations along a livestock grazing gradient. Plos One 7 (7): 1-9. E40551. http://doi:10.1371/Journal.Pone.0040551.

Schroeder K, Pumphrey M. 2013. It's all a matter of pH: acid soils. aluminum toxicity are on the rise in Eastern Washington. Northern Idaho. Washington Grain Commission reports. http://washingtoncrop.com (accessed 16 Jan. 2016). p. 56–59.

Schlesinger WH, Bernhard ES. 2012. Biogeochemisty: an analysis of global change. 3rd ed. Academic Press. San Diego. CA.

Sofiah S, Setiadi D, Widyatmoko D. 2013. Pola penyebaran. kemelimpahan. dan asosiasi bambu pada komunitas tumbuhan di Taman Wisata Alam Gunug Baung Jawa Timur (Distribution patterns. abundance. and bamboo associations in plant communities in the Gunug Baung Nature Park in East Java). Berita Biologi. J Ilmu-Ilmu Hayati 12 (2): 239-247.

Turner BL, Engelbrecht BMJ. 2011. Soil organic phosphorus in lowland tropical rain forests. Biogeochemistry. 2011:103:297–315 DOI 10.1007/s10533-010-9466-x.

Utomo S, Uchiyama S, Ueno S, Matsumoto A, Widiyatno, Indrioko S, Na'iem M, Tsumura Y. 2018. Effects of pleistocene climate change on genetic structure and diversity of *Shorea macrophylla* in Kalimantan rainforest. Tree Gen Genomes. Volume 14 (4): 14-44.

Widiyatno, Budiadi, Suryanto P, Rinarno YDBM, Prianto SD, Hendro Y. 2017. Recovery of vegetation structure. soil nutrients and late-succession species afters hifting cultivation In Central Kalimantan. Indonesia. J Trop For Sci 29 (2): 151-162.

Windusari Y, Susanto RH, Dahlan Z, Susetyo W. 2011. Asosiasi jenis pada komunitas vegetasi suksesi di kawasan pengendapantailing tanggul ganda di pertambangan PTFI Papua (Species associations in the succession vegetation community in the deposition area of the double embankment in Papua's PTFI mine). J Ilmiah Ilmu-Ilmu Hayati Biota 16 (2): 242-251. [Indonesian]

Zaidey AK, Arifin A, Zahari I, Hazandy AH, Zaki MH, Affendi H, Wasli ME, Hafiz YK, Shamsuddin, Muhammad MN. 2010. Characterizing soil properties of lowland and hill dipterocarp forest at Peninsular Malaysia. Int J Soil Sci 5 (3):112-130.

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Zeng C, Wang Q, Zhang F, Zhang J. 2013. Temporal changes in soil hydraulic conductivity with different soil types and irrigation methods. Geoderma 193/194:290-299. doi:10.1016/j. geoderma.2012.10.013.

Zhu X, Zhu B. 2015. Diversity and abundance of soil fauna as influenced by longterm fertilization in cropland of purple soil. China. Soil and Tillage Research 146: 39-46.

Deleted[Windows User]: Zhang J, Jiang Q, Zhang Y, Dai L, Wu H. 2015. nondestructive measurement of water content and moisture migration of unsaturated red clays in South China. Hindawi Publishing Corporation Advances in Materials Science and Engineering, Volume 2015, Article ID 542538, 7 pages http://dx.doi.org/10.1155/2015/542538.

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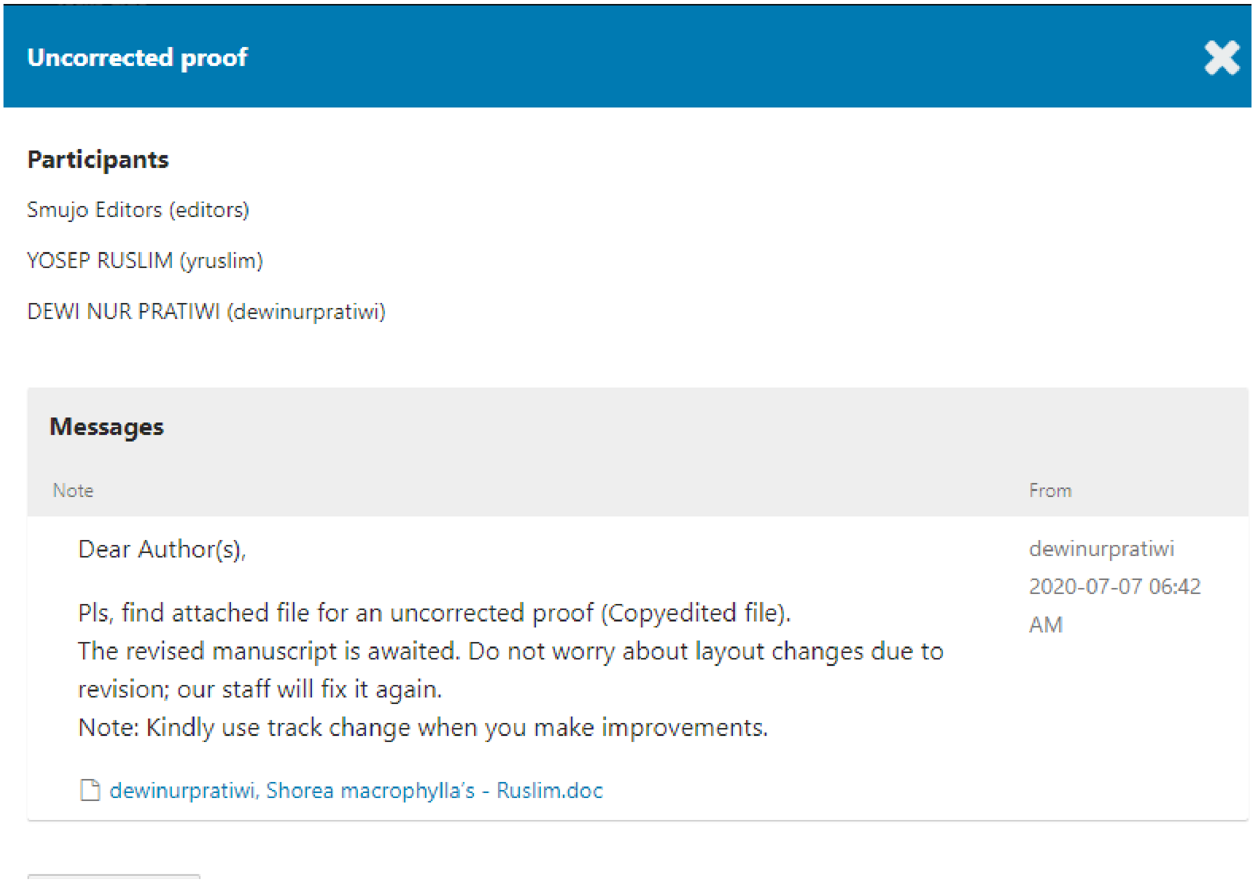

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The characteristics of *Shorea macrophylla*'s habitat in Tane' Olen, Malinau District, North Kalimantan Province, Indonesia

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Abstract. *Fajri M, Pratiwi, Ruslim Y. 2020. The characteristics of* Shorea macrophylla*'s habitat in Tane' Olen, Malinau District, North Kalimantan Province, Indonesia. Biodiversitas 21: xxxx.* *Shorea macrophylla* is a tree species in Tane' Olen forest area. This study analyzed the soil's physical and chemical properties, topography, and microclimate of *S. macrophylla*'s habitat. A purposive method was used to select a sampling plot and to place the subplots. Soil was analyzed to determine the physical properties, i.e., texture, bulk density, porosity, and water content, and the chemical properties, i.e., pH, CEC, total N, organic C, C/N ratio, P, K , and Al saturation. Importance value index was determined for each tree species to know the species composition in the study site. Only the dominant species were presented. The soil at the study site had bulk density of 0.60-1.31 gram cm$^{3-1}$, porosity 50.60%-77.35%, water content 34.88%-95.37%, and soil texture sandy clay. The chemical properties of the soil were as follows: pH was 3.6-4.8, N 0.05%-0.19%, organic C 1.40%-3.65%, P 0.41-1.22 mg 100 gr^{-1}, K 58.68-232.55 mg 100 gr^{-1}, and Cation Exchange Capacity (CEC) 5.35-10.81 meg 100gr $^{-1}$. Slope ranged between 0 and 25%. The microclimate characteristics were as follows: temperature was 24-26.5°C, relative humidity 76-87%, and light intensity 145-750 Lm. Trees species with an IVI $\geq$ 10% were *S. macrophylla*, *Madhuca spectabilis*, *Myristica villosa* Warb, *Scorodocarpus borneensis*, *Eugenia* spp, *Palaquium* spp, *Macaranga triloba*, *Syzygium inophyllum* and *Shorea* sp. Positive associations were observed between *S. macropylla* and *S. borneensis*, *Eugenia* spp, *Palaquium* spp and *M. triloba,* and negative associations were observed between *S. macropylla* and *M. spectabilis*, *M. villosa* Warb, *S. inophyllum,* and *Shorea* sp. *S. macrophylla* grows on riversides with flat and gentle topography, acidic soil, and lower fertility but with suitable microclimate. This species can be recommended to be planted in degraded tropical forest areas but the microclimate and soil properties should be taken into account.

Keywords: Habitat, land characteristics, *S. macrophylla*

INTRODUCTION

Shorea macrophylla is one of the fastest growing climax tree species of the genera *Shorea* (Perumal et al. 2017). Local communities value this species as a source of timber and fruit (Randi et al. 2019). *S. macrophylla* is known locally in West Kalimantan as the *tengkawang tungkul* tree and has been cultivated by the Dayak and Malay communities (Fajri and Fernandes 2015). *S. macrophylla* grows in clusters in tropical rain forests with type A climate, on latosol soils at altitudes up to 500 m, on acidic soils (pH 4.6-4.9), and a cation-exchange capacity (CEC) of 16.25-19.40 (Istomo and Hidayati 2010). In Sarawak, Sabah, Brunei and Kalimantan, this species is associated with sedimentary soils and is distributed evenly over riverbanks and areas with sloping or flat topography. It is rarely found on hills. (Randi et al. 2019; Utomo et al. 2018; Perumal et al. 2017).

The timber from *S. macrophylla* is commonly used for construction and to make veneer and plywood, musical instruments, furniture, and packing crates (Istomo and Hidayati 2010). The fruit, locally known as *tengkawang tungkul* (*Illipe*) nuts, is used as a raw material for soap and other cosmetics, a substitution for brown fat, and a source of vegetable fat (Maharani et al. 2016). The natural population of *tengkawang* is declining and is, at present, hard to find (Istomo and Hidayati 2010) because *S. macrophylla* is one of the most sought-after species in tropical forests. The exploitation of the species for its timber, combined with forest conversion to other uses, has resulted in *S. macrophylla* timber being difficult to find in the market (Rikando et al. 2019).

Tane' Olen is a forested area with a high environmental value preserved by the people of Setulang Village (Hutauruk et al. 2018a), a community that manages its forests based on the local wisdom and sustainable forest management practices (Fahrianoor et al. 2013; Kettle 2010), so the forest sustainability is maintained (Hutauruk et al. 2018). Forests are not only a place to live for them, but are also used as a source of food and medicine and economic, social, cultural, and spiritual functions (Merang et al. 2020; Matthew et al. 2018; Quedraogo et al. 2014).

S. macrophylla's habitat characteristics in secondary forest locations have been documented by Jaffar et al.

(2018) and Perumal et al. (2017). Perumal et al. (2017) studied the relationship between soil fertility and the growth of *S. macrophylla* in enrichment plantings at Sampadi Forest Reserve, Lundu, Sarawak and an adjacent secondary forest. Jaffar et al. (2018) researched the effects of soil compaction and light intensity on the establishment and growth of *S. macrophylla* in riparian forests in Sungai Kayan Ulu Sungai, Serawak, Malaysia. The improvement of the company's management system, which is changing the way of harvesting using long cables during skidding activity, reduced the natural forest damage and could increase financial returns from natural forest concessions (Ruslim et al. 2016). The characteristics of *S. macrophylla* habitat in primary forest locations had not previously been studied. So, this study aimed to describe the characteristics of *S. macrophylla*'s habitat in primary forests by analyzing the physical and chemical properties of soil, the microclimate, topography, species associations, and vegetation. It is hoped that the results of this study will benefit conservation efforts of this species, especially on degraded land in the tropical rain forests of North Kalimantan.

MATERIALS AND METHODS

Study area

The study was carried out in Tane' Olen forest area, Setulang Village, Malinau District, North Kalimantan Utara Province (3°25'0.86" N and 116°25'52.59" E). The location map is presented in Figure 1.

Research procedure

A one-hectare research site was selected purposively and sampled using a square plot with a side length of 100 meters (Sari and Maharani 2016). Soil sampling was taken from purposively selected three sampling points, located on a ridge, a slope, and a valley (the ridge had the highest elevations and a 15-25% slope; the slope was located between the valley and ridge, and had an 8-15% slope; the valley was the lowest area and had a 0-8% slope) to ensure an accurate representation of the study site. At each sampling point, soil samples were taken at three depths: 0-20 cm, 20-40 cm, and 40-60 cm. Microclimate data (temperature, humidity, and light intensity) were collected at the same locations. The soil and microclimate data collection design is illustrated in Figure 2. Vegetation data were only collected for trees with a diameter at breast height (DBH) greater than 20.0 cm Each plot was divided into 25 subplots (20 m x 20 m). Within each subplot, the species were identified and DBH recorded for all trees (Widiyatno et al. 2017). Plot-making and field-data collection activities are presented in Figure 2, while sampling design is presented in Figures 3 and 4. Soil sample collection design and microclimate data are presented in Figure 3 and 4. Topography data collection design can be seen in Figure 4. The design of vegetation data collection can be seen in Figures 5.

Data analyses

Soil analyses

Soil samples were analyzed for both physical and chemical properties (Kurnia et al. 2006; Eviati and Sulaeman 2009). Physical properties analyzed were texture, bulk density, porosity, and water content (using the Pipette method). Chemical properties analyzed were pH (using the electrode method), CEC (using the ammonium acetate pH 7 method), elements Al+++ and H+ (using the KCl method 1 N), total N elements (using the Kjeldahl method), organic C elements (using Walkley-Black method), C/N ratio (using arithmetic methods), elements P_2O5 and K_2O (using Bray No I methods), and saturation Al (using arithmetic methods). Soil data analysis results from the soil laboratory were tabulated and analyzed descriptively and quantitatively.

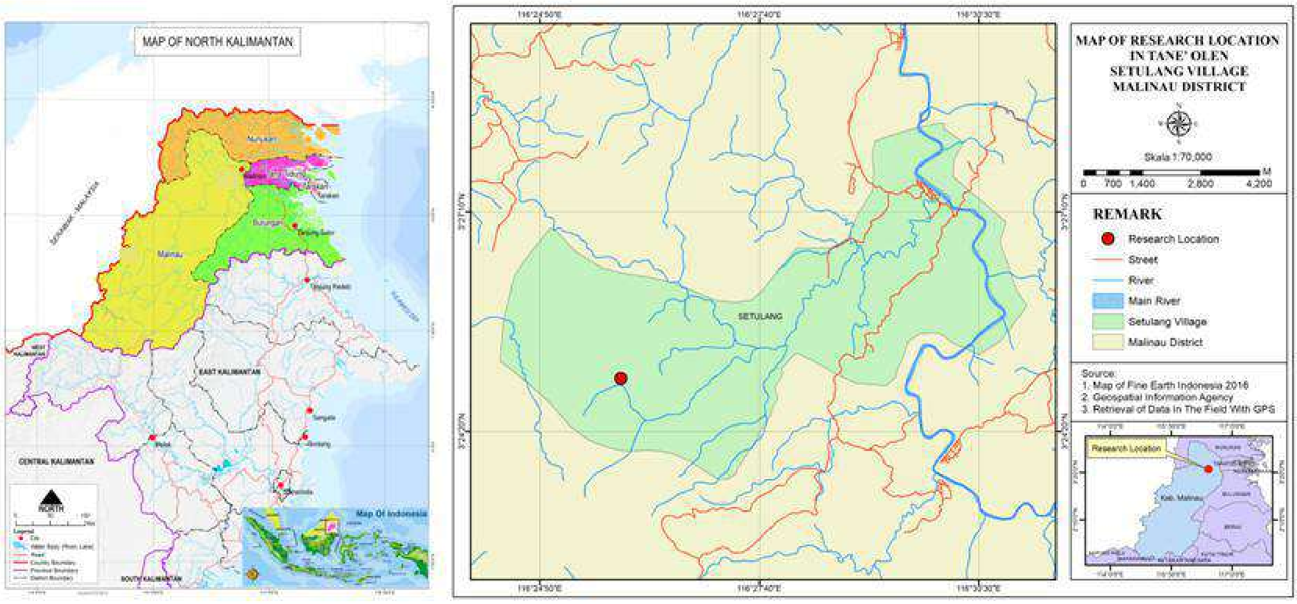


Figure 1. Location of the research in Tane' Olen (●)

Figure 2. A. Exploration, B. Research plot making, C. Tree inventory, D. Soil sample collection, E and F. Microclimate data collection

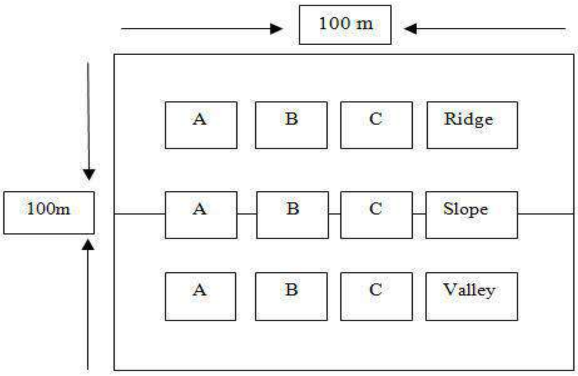


Figure 3. Soil and microclimate sample design. Note: A:lights intensity, B: temperature and area humidity, C: soil sampling, m:meter

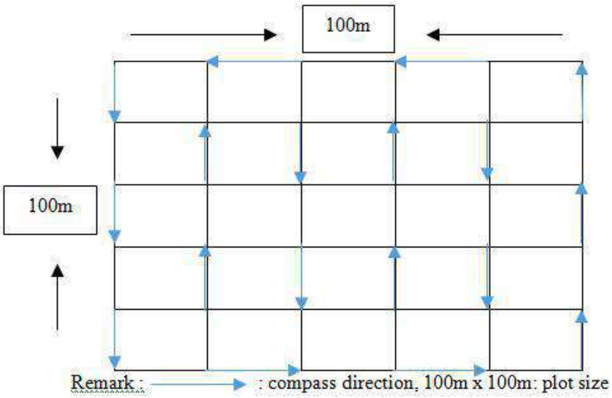
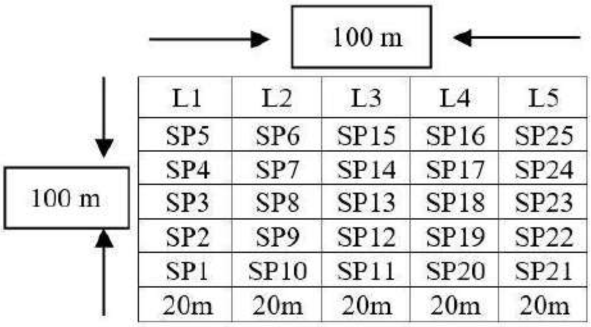


Figure 4. Plot design across contour line.



L1	L2	L3	L4	L5
SP5	SP6	SP15	SP16	SP25
SP4	SP7	SP14	SP17	SP24
SP3	SP8	SP13	SP18	SP23
SP2	SP9	SP12	SP19	SP22
SP1	SP10	SP11	SP20	SP21
20m	20m	20m	20m	20m

Figure 5. Design of plot and sub-plots for vegetation sampling. Note: L: lane, SP: sub plot, 20m: distance between sub plots, 100m x 100m: plot size, m: meter.

Analysis of topography

The topographic analysis was done qualitatively to describe the topography suitable for *S. macrophylla*.

Analysis of microclimate

The analysis of microclimate was done qualitatively to provide information on microclimates characteristics suitable for *S. macrophylla*.

Importance Value Index

According to Kacholi (2014), the Importance Value Index (IVI) is used in ecological studies to determine the ecological importance of a species in a particular ecosystem. IVI is also used to prioritize species conservation. Species with low IVI values require a higher conservation priority than those with high IVI, which is the dominant species. IVI value is a function of several characteristics, and calculated with this formula: IVI = relative density + relative frequency + relative dominance. IVI values were analyzed descriptively

Association of vegetation

Associations between two tree species were analyzed using a series of 2x2 contingency tables (Mueller-Dombois and Ellenberg 1974). A more complete description is presented in Table 1.

Then, the data were tested with chi-square (x^2)

$$X^2 = \frac{(ad - bc)^2 \, x \, N}{(a+b)(c+d)(a+c)(b+d)}$$

The association coefficient (C) values were determined as follows:

If ad $\geq$ bc, so $C = \frac{ad-bc}{(a+b)(b+d)}$

If bc > ad and d > a, so $C = \frac{ad-bc}{(a+b)(b+c)}$

If bc > ad and a > c, so $C = \frac{ad-bc}{(a+d)(c+d)}$

Positive or negative values of C indicate a positive or negative relationship between the two species. A positive relationship indicates that the association between trees is mutually beneficial to each other, while a negative value indicates that the association between trees harms one another.

Table 1. Contingency table form (Mueller-Dombois and Ellenberg 1974)

Species A Species B	+	-	
+	A	B	a + b
-	c	D	c + d
	a + c	b + d	N = a + b + c + d

Note:
a = number of plots containing species A and species B.
b = number of plots containing only species A, but no species B.
c = number of plots containing only species B, but no species A.
d = number of plots containing neither species A nor species B.
N = number of all plots.

RESULTS AND DISCUSSION

The soil's physical and chemical properties

The physical and chemical properties of soil properties in S. *macrophylla*'s habitat can be seen in Table 2.

At the depth of 0-20 cm, the valley, slope, and ridge subplots had a low bulk density (0.60-1.05) (Table 2). According to Casanova et al. (2016) and Zeng et al. (2013), soil bulk density is influenced by external conditions and natural processes such as plant root growth and rainfall.

The soil porosity values in the valley, slope, and ridge subplots decreased with the increasing soil depth. The valley subplot had higher porosity value than the slope and ridge subplots. According to Darusman et al. (2019), the properties that affect soil porosity the most are bulk density and soil particle density; if the bulk density is low then the soil porosity will increase.

Water content in the ridge, slope, and valley decreased with the increasing soil depth. The water content in the ridge subplots was higher than the slope subplots because the water movement is faster in the slope subplots and the water settles in the lower area, i.e., the valley subplots, which resulted in a higher (95.37%) water content in the valley subplots than in the ridge and slope subplots. Jaffar et al. (2018) state that *S. macrophylla* plant roots can adapt to high water soil content. Moist soils stimulate *S. macrophylla* roots growth and development. According to Minasny and McBratney (2018), the availability of groundwater is an important component of water balance and the terrestrial biosphere cycle because it can affect evapotranspiration rates and support plant growth.

The results of the soil texture analysis can be seen in Table 3.

The soil texture at the study site generally had a sand fraction of 45-65%, a clay fraction 35-55%, and a silt fraction 0-20% (Table 3). This means that the soil texture is sandy clay. According to Osman (2013), soil texture refers to the level of fineness or roughness created by the variously-sized soil particles.

Soil types are generally dominated by Ultisol (advanced development) soils, namely Typic Hapludults (Red-Yellow Podsolik) and Typic Paleudults (Yellow Podsolic). These soil types are typically found in lowland dipterocarp forests (Ohta and Effendi 1992).

Chemical soil characteristics of the study site are presented in Table 4.

The soil at the study site was very acidic (pH = 4.1-4.8) (Table 4). According to Schroeder and Pumphrey (2013), acidic soils inhibit root and plant growth and increase Al levels in the soil. The CEC at the study site ranged from 5.3 to 10 meq/100 g^{-1}, indicating that the CEC was low. In general, the value of CEC is low in surface and subsurface soils of lowland dipterocarp forests (Perumal et al. 2017a).

Aluminum levels at the study site were high, especially in the slope and valley subplots, which indicated high soil toxicity. Al content in the soil decreased with the increasing organic matter because organic matter forms a strong bond with Al. According to Zaidey et al. (2010), Al is a major cause of soil acidity, and soils in lowland dipterocarp forests have high Al content.

Nitrogen levels at the study site ranged from 0.05% to 0.19% (low to very low). Sadeghi et al. (2016) also reported low total N levels in tropical rain forest soils. Nitrogen is important for plant growth (Omara et al. 2019), and N deficiency can inhibit plant growth (Mehata et al. 2019). According to Omara et al. (2019), the main sources of N are organic matter and rainfall/precipitation.

Organic C values were higher in the valley and slope subplots than in the ridge subplots. The steeper slopes in the ridge subplots are more prone to erosion, resulting in the leaching of organic C and other nutrients into the valley and slope subplots. According to Schlesinger and Bernhard (2013), carbon can be stored in the soil three times longer than in the atmosphere and is an indicator of soil microorganism abundance and diversity (Zhu and Zhu 2015). The presence of organic C in the soil spurs microorganism activity and thereby increases the rates of soil decomposition, P dissolution, N fixation, and other microorganism-dependent reactions.

Phosphate was calculated from P_2O_5, where the Phosphate content is very low (0.41-1.22 mg 100 gram^{-1}) (Table 4). According to Turner and Engelbrecht (2011), organic P plays an important role in maintaining P availability in lowland tropical rain forests. Phosphorus is essential for root development and plant growth (Abdissa et al. 2011). According to Carstensen, et al. (2018), P deficiency has a major impact on plant growth, development and productivity.

Potassium values ranged from high (58.68-116.85 mg 100 gr^{-1}) in the valley and slope subplots to very high (120.34-232.55 mg 100 gr^{-1}) in the ridge subplots. According to Mouhamad et al. (2016), K is more abundant in the soil than other mineral elements. This element has an essential role in plant metabolism, growth, and yield. Potassium availability depends on soil properties (humidity, aeration, and temperature), soil treatment systems, and the dynamics of K. Therefore, the K exchange level varies among soils.

Topography in the study area

According to Li and McCarty (2019), topographic features are key parameters that affect the nature of the soil at the earth's surface. Topographic features can affect organic matter; clay content; P, K, and Mg concentrations; and soil pH (Kumhalova et al. 2011).

The topography of the study site is moderately undulating with a slope of 0-25%. The subplot slopes range from flat to moderately steep. *S. macrophylla* was found primarily in flat to sloping areas with high environmental humidity, low ambient temperature, and abundant water, such as riverbanks. Jaffar et al. (2018) stated that the roots of the *S. macrophylla* are able to survive and grow in anaerobic waterlogged soils and is considered a flood-tolerant tree.

Dominant trees at the study area

At the study site, *S. macrophylla* was the dominant tree species (Figure 6). Other tree species included *Madhuca spectabilis, Myristica villosa* Warb., *Scorodocarpus borneensis, Eugenia* spp., *Palaquium* spp., *Macaranga triloba, Syzygium inophyllum,* and *Shorea sp. S. macrophylla* dominated the study site due to its fast germination process and high germination rate (Appanah and Turnbull 1998), its high growth rate (fastest of the genus *Shorea)*, and its status as a climax species along rivers (Perumal et al. 2017).

Table 2. Physical properties of soil at the study site.

Location of soil	Depth (cm)	Bulk density (gram/cm³)*	Porosity (%)*	Water content (%)
Valley	0-20	0.60	77.35	95.37
	20-40	1.13	57.32	40.04
	40-60	1.18	55.54	39.20
Slope	0-20	1.05	60.42	48.08
	20-40	1.31	50.60	41.42
	40-60	1.23	53.72	34.88
Ridge	0-20	0.83	68.75	61.68
	20-40	1.01	61.92	44.23
	40-60	1.20	54.66	35.53

Note: *Average score from three repetitions

Table 3. Soil texture at the study site.

Location of soil	Depth (cm)	Clay (%)	Sand (%)	Silt (%)	texture (USDA)
Valley	0-20	33.70	50.90	15.40	SCL
	20-40	36.50	49.50	14.00	SC
	40-60	34.00	56.80	9.20	SCL
Slope	0-20	24.70	67.20	8.10	SCL
	20-40	27.30	63.10	9.60	SCL
	40-60	33.10	60.50	6.40	SCL
Ridge	0-20	37.80	54.60	7.60	SC
	20-40	37.40	46.40	16.20	SC
	40-60	40.70	48.00	11.30	SC

Note: Laboratory of soil test in B2P2EHD and Pusrehut, Mulawarman University

Table 4. Chemical characteristics of soil at the study site.

Location of soil	Depth (cm)	pH (1: 25)		Cation exchange rates (meg 100gr^{-1})			Organic content (%)		Ratio	Mineral (Mg 100 gram^{-1})	
		H_2O	KCl	CEC	Al3^{+}	H^{+}	Tot. N.	Org C	C/N	P_2O_5	K_2O
Valley	0-20	4.6	3.3	7.26	4.92	1.50	0.19	3.65	19	0.89	116.85
	20-40	4.6	3.4	7.25	5.56	1.08	0.12	2.65	22	0.73	73.30
	40-60	4.4	3.4	7.18	5.75	0.92	0.10	2.12	22	1.22	59.00
Slope	0-20	4.1	3.5	5.35	2.75	1.33	0.13	2.31	18	0.65	73.62
	20-40	4.7	3.5	5.30	3.50	0.92	0.07	1.54	22	0.65	58.68
	40-60	4.8	3.5	5.53	3.33	1.42	0.05	1.40	26	0.41	60.90
Ridge	0-20	4.4	3.0	10.81	7.25	2.75	0.09	3.46	39	2.35	120.34
	20-40	3.6	3.3	10.48	7.80	1.83	0.08	2.12	28	0.89	194.09

	40-60	4.4	3.4	10.37	6.83	2.58	0.09	1.54	17	0.65	232.55

Note: Laboratory of soil test in B2P2EHD and Pusrehut, Mulawarman University

Microclimate

Three microclimate factors were collected, i.e., temperature, humidity, and light intensity (see Table 6 for a more complete description). The temperature values at the study site was 24-26,5° C (Table 6). According to Ruchaemi (2013), the optimal temperature for plant assimilation is 25-30° C. Relative humidity values were high to very high, ranging from 76 to 87%. Lights intensity was very low to low, ranging from 7,25% (145 Lm) to 23.46% (469 Lm) due to dense canopy dominated by *S. macrophylla* which prevented light from reaching the forest floor. This low light intensity is consistent with the findings of Panjaitan et al. (2012), who found that the closed canopy only allowed a little sunlight to reach the forest floor. These conditions benefit *S. macrophylla* seedlings, which are sun intolerant.

Association with other trees

According to Saiz and Alados (2012), plant species association is a fundamental aspect of the ecology of plant communities. Analysis of plant species associations provides information on environmental heterogeneity, biotic interactions, and seed dispersal patterns. The results of the species association analysis and the association coefficient are presented in Table 7.

Table 7 shows the results of a series of 2x2 contingency tests between *S. macropylla* and each of the eight other dominant tree species. The calculated X^2 values were greatest between *S. macropylla* and *M. villosa* Warb, indicating that *S. macrophylla* had a strong but negative association with *M. villosa* Warb. According to Sofiah et al. (2013), species pairs do not always indicate positive relationships. Tree species with high populations are not always associated with another species. Likewise, low-population species are not necessarily negatively correlated with another species.

The association coefficient (C) was used as a parameter of the magnitude of the relationship between the eight species and *S. macropylla* and indicates positive or negative associations. Species that showed positive coefficients of association with *S. macropylla* were *S. borneensis, Eugenia spp., Palaquium spp,* and *M. triloba.* According to Windusari1 et al. (2011), positive associations indicate both species have the same requirement of environmental conditions; for example, wet conditions, high light intensity, or shade. *S. macropylla* showed a negative association with *M. spectabilis, M. villosa, S. inophyllum,* and *Shorea* sp. Negative associations indicate intolerance for cohabitation or the absence of a mutually beneficial relationship (Pratama et al. 2012).

Table 5. The importance value index of the dominant tree species at the study site

Local name	Scientific Name	Family	Relatif density (%)	Relatif dominance (%)	Relatif frequency (%)	Importance value index (%)
Tengkawang	*S. macropyilla*	Dipterocarpaceae	7.69	15.35	5.0	28.04
Kajen ase	*M. spectabilis*	Sapotaceae	10.25	7.29	4.61	22.16
Darah-darah	*M. villosa* Warb	Myristicaceae	7.45	4.79	5.0	17.25
Bala seveny	*S. borneensis*	Olacaceae	5.12	5.77	5.0	15.90
Ubah	*Eugenia* spp	Myrtaceae	5.59	3.64	4.61	13.85
Nyatok	*Palaquium* spp	Sapotaceae	4.42	3.70	4.61	12.74
Beneva	*M. triloba*	Euphorbiaceae	4.66	4.32	3.46	12.44
Ehang	*S. inophyllum*	Myrtaceae	5.36	3.14	3.84	12.35
Kaze tenak	*Shorea* sp	Dipterocarpaceae	2.33	6.08	2.69	11.10

Figure 6. A. Tree of *Shorea macrophylla* and B. Leaves of *S. macrophylla*

Table 6. Microclimate at the study site

Location	Microclimate	Unit	Time	1-st record	2-nd record	3-rd record	Average	Remark
1.	Light intensity	Lm	Morning	350	400	452	400.67	Taken at 8.59 sunny conditions
2.	Temperature	°c	Morning	24	24.5	25	24.5	
3.	Relative humidity	%	Morning	81	79	80	80	
1.	Lights intensity	Lm	Mid day	750	450	207	469	Taken at 12:02 sunny conditions
2.	Temperature	°c	Mid day	26.5	26	24.5	25.67	
3.	Relative humidity	%	Mid day	76	79	81	78.67	
1.	Lights intensity	Lm	Afternoon	369	237	145	250.33	Taken at 16:30 sunny conditions
2.	Temperature	°c	Afternoon	25	24.5	23	24.17	
3.	Relative humidity	%	Afternoon	84	85	87	85.33	

Table 7. Association of *S. macropylla* with other species.

Species association	X^2 count	Assoc. species	C (+/-)
S. macropylla with *M. spectabilis*	0.35	-	0.04
S. macropylla with *M. villosa* Warb	6.82	-	0.29
S. macropylla with *S. borneensis*	0.04	+	0.04
S. macropylla with *Eugenia* spp	0.37	+	0.11
S. macropylla with *Palaquium* spp	0.37	+	0.11
S. macropylla with *M. triloba*	1.21	+	0.16
S. macropylla with *S. inophyllum*	3.23	-	0.29
S. macropylla with *Shorea* sp	1.92	-	0.24

Note: X^2 tabulated value at 5% level: 3.841. X^2 tabulated value at 1% level: 6.35

Direction of *S. macrophylla* plantation

At present, tropical forests are being degraded by anthropogenic activities such as timber extraction, agricultural cultivation, and the establishment of commercial plantations. This results in the conversion of forests into agriculture land and the fragmentation and degradation of tropical rain forests. Deforestation damages the environment by increasing light intensity and causing severe mineral soil erosion. In general, degraded forests can be divided into three categories: grasslands after burning, early-succession secondary forests, and commercially logged forests (Daisuke et al. 2013).

Planting native trees is considered to be an effective rehabilitation method for degraded tropical rain forests because native trees provide benefits such as timber, food, and medical products (Daisuke et al. 2013). According to Pratiwi et al. (2014), tropical forest rehabilitation is necessary to both meet the demand for timber and improve environmental conditions. One key to rehabilitation success is the understanding of the suitability of each growing site for each species being planted. One approach to determine the suitability of growing sites for each species is to identify each species' potential, identify locally superior species, and correlate this with species distribution data and growth requirements (Pratiwi et al. 2014).

Shorea macrophylla is a recommended species for replanting degraded tropical forest land, i.e., pastures after burning (Daisuke et al. 2013), early-succession secondary forests (Daisuke et al. 2013; Perumal et al. 2012), and commercially logged forests. In commercially logged forests, *S. macrophylla* can be planted using the line planting system or gap planting system. In early-succession secondary forests and pasture after burning, *S. macrophylla* requires pioneer plants to assist growth. *S. macrophylla* is a valuable tree species that has socio-economic and ecological benefits and is beneficial for reforestation and rehabilitation activities (Perumal et al. 2012; Perumal et al. 2015; Perumal et al. 2017a; Perumal et al. 2017b; Perumal et al. 2019).

This species is important for land rehabilitation activities because it plays a role in maintaining water quality, filtering out pollutants and deposits, and storing carbon (Utomo et al. 2018; You et al. 2015). Things that must be considered when planting *S. macrophylla* are the nutrient content in clay and the clay mineral composition. These two factors can be used to evaluate soil fertility. The growth of *S. macrophylla* is also significantly limited by the high light intensity in grasslands (*Imperata cylindrica*/ pastures after burning). *S. macropylla* grows well in habitats with low light intensity. In secondary forests and logged-over forests, the survival and growth of *S. macrophylla* is limited by soil compaction. This agrees with the results of this study, where fine sandy clay soils were found.

S. macrophylla grows on riversides with flat and gentle topography, acidic soil, and lower fertility, but with the suitable microclimate (temperature of 24-26,5°C, high humidity 76-87%, and a low light intensity 7,25-23.46%). This species can be recommended to be planted in degraded tropical forest areas if microclimatic factors and soil conditions are taken into account.

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REFERENCES

Abdissa Y, Tekalign T, Pant LM. 2011. Growth. bulb yield and quality of onion (*Allium cepa* L) as influenced by nitrogen and phosphorus fertilization on vertisol i. growth attributes. biomass production and bulb yield. Afr J Agric Res 6 (14): 3252–3258.

Appanah S, Turnbull JM. 1998. A review of dipterocarps: taxonomy. ecology and silviculture. Center for International Forestry Research.

Carstensen A, Herdean A, Schmidt SB, Sharma A, Spetea C, Pribil M, and Husted S. 2018. The impacts of phosphorus deficiency on the photosynthetic electron transport chain. Plant Physiology 177: 271-284. DOI: 10.1104/pp.17.01624.

Casanova M, Tapia E, Seguel O, Salazar O. 2016. Direct measurement and prediction of bulk density on alluvial soils of central Chile. Ultural Chilean J Agric Res 76 (1): 105-113. DOI: 10.4067/S0718-58392016000100015.

Daisuke H, Tanaka K, Jawa KJ, Ikuo N, Katsutoshi S. 2013. Rehabilitation of degraded tropical rainforest using dipterocarp trees in Sarawak. Malaysia. Int J For Res. DOI: 10.1155/2013/683017.

Darusman, Devianti, Husen E. 2018. Improvement of soil physical properties of cambisol using soil amendment. Aceh Int. J Sci Technol 7 (2): 93-102. DOI: 10.13170/aijst.7.2. 10119.

Eviati and Sulaeman. 2009. Petunjuk teknis analisis kimia tanah, tanaman, air, dan pupuk. Balai Penelitian Tanah, Bogor. [Indonesian]

Fahrianoor, Windari T, Taharudin, Mar'i R, Maryono. 2013. The practice of local wisdom of Dayak people in forest conservation in South Kalimantan. Indon J Wetlands Environ Manag 1 (1): 37-46.

Fajri M, Fernandes A. 2015. Pola pemanenan buah tengkawang (*S. machrophylla*) dan regenerasi alaminya dikebun masyarakat. Jurnal Penelitian Ekosistem Dipterokarpa 1 (2) : 81-88. DOI: 10.20886/jped.2015.1.2.81-88. [Indonesian]

Hutauruk TR, Lahjie AM, Simarangkir BDAS, Ruslim Y. 2018a. Setulang forest conservation strategy in safeguarding the conservation of non-timber forest products in Malinau District. IOP Conference. Series: Earth Environment Science. 144: 1-9. DOI: 10.1088/1755-1315/144/1/012055.

Hutauruk TR, Lahjie AM, Simarangkir BDAS, Aipassa MI, Ruslim Y. 2018b.The prospect of the utilization of Non-Timber Forest Products from Setulang Village forest based on local knowledge of the Uma Longh community in Malinau. North Kalimantan. Indonesia. Biodiversitas 19 (2): 421-430. [Indonesian]

Istomo, Hidayati T. 2010. Studi potensi dan penyebaran tengkawang (*Shorea* Spp.) di areal IUPHHK-Ha PT. Intracawood Manufacturing Tarakan. Kalimantan Timur. Jurnal Silvikultur Tropika. 01 (01): 11-17. [Indonesian]

Jaffar ANNM, Wasli ME, Perumal M, Lat J, Sani H. 2018. Effects of soil compaction and relative light intensity on survival and growth performance of planted *Shorea macrophylla* (de vriese) in riparian forest Along Kayan Ulu River. Sarawak. Malaysia. Int J For Res 2018 (2): 1-11. DOI: 10.1155/2018/6329295.

Kacholi DS. 2014. Analysis of structure and diversity of the kilengwe forest in the Morogoro Region. Tanzania. Int J Biodivers 2014: 1-8. DOI: 10.1155/2014/516840.

Kettle CJ. 2010. Ecological considerations for using dipterocarps for restoration of lowland rainforest in Southeast Asia. Biodiv Conserv. 19: 1137-1151.

Kumhalova J, Kumhala F, Kroulik M, Matejkova S. 2011. The impact of topography on soil properties and yield and the effects of weather conditions. J Precis Agric 12 (6): 813-830. DOI: 10.1007/s11119-011-9221-x.

Kurnia, U, Agus f, Adimihardja A, Dariah A. 2006. Sifat fisik tanah dan metode analisisnya. Balai Besar Litbang Sumberdaya Lahan Pertanian. Agro inovasi. Bogor. [Indonesian]

Li X, McCarty GW. 2019. Application of topographic analyses for mapping spatial patterns of soil properties. Geospatial Analyses of Earth Observation (EO) data. DOI: 10.5772/intechopen.86109

Maharani R, Fernandes A, Pujiarti R. 2016. Comparison of tengkawang fat processings effect on tengkawang fat quality from Sahan and Nanga Yen Villages. West Kalimantan. Indonesia. AIP Conf Proc 1712, 050022 (2016). DOI: 10.1063/1.4941905.

Matius P, Tjwa SJM, Raharja, Sapruddin, Noor S, Ruslim Y. 2018. Plant diversity in traditional fruit gardens (munaans) of Benuaq and Tunjung Dayaks tribes of West Kutai. East Kalimantan. Indonesia. Biodiversitas. 19 (4): 1280-1288. [Indonesian]

Mehata M, Cortus E, Niraula S, Spiehs MJ, Darrington J, Chatterjee A, Rahman S, Parker DB. 2019. Aerial nitrogen fluxes and soil nitrate in response to fall-applied manure and fertilizer applications in Eastern South Dakota. Int J Agron 2019: 1-15. DOI: 10.1155/2019/8572985.

Merang OP, Lahjie AM, Yusuf S, Ruslim Y. 2018. Productivity of three varieties of local upland rice on swidden agriculture field in Setulang village. North Kalimantan. Indonesia. Biodiversitas 21 (1): 49-56. [Indonesian]

Minasny B, Mcbratney AB. 2017. Limited effect of organic matter on soil available water capacity. Eur J Soil Sci 2017:1-9. DOI: 10.1111/ejss.12475.

Mouhamed R, Alsaede A, Iqbal M. 2016. Behavior of potassium in soil: a mini review. Chem Int 2 (1): 58-69.

Mueller-Dombois D, Ellenberg H. 1974. Aims and methods of vegetation ecology. John Willey and Sons. Canada.

Omara P, Aula L, Raun WR. 2019. Nitrogen uptake efficiency and total soil nitrogen accumulation in long-term beef manure and inorganic fertilizer application. Int J Agron 2019: 1-6. DOI: 10.1155/2019/9594369.

Ohta S, Effendi S. 1992. Ultisols of "lowland dipterocarp forest" in East Kalimantan. Indonesia. Soil Sci. Plant Nutr 38 (2): 197-206.

Osman KT. 2013. Forest soil: properties and management. Springer. London.

Panjaitan S, Wahuningtyas RS, Adawiyah R. 2012. Kondisi lingkungan tempat tumbuh *Shorea johorensis* Foxw. di HPH Aya Yayang Indonesia. Kalimantan Selatan (Environmental conditions in which to grow *Shorea johorensis* Foxw. at Aya Yayang HPH in Indonesia. South Kalimantan). J Penelitian Dipterokarpa. 6 (1): 11-22. [Indonesian]

Pratama, Arief B, Alhamd L, Rahajoe JS. 2012. Asosiasi dan karakterisasi tegakan pada hutan rawa gambut di Hampagen. Kalimantan Tengah. Jurnal Teknologi Lingkungan. Edisi Khusus Hari lingkungan Hidup 69-76. [Indonesian]

Pratiwi, Narendra BH, Hartoyo GME, Kalima T, Pradjadinata S. 2014. Atlas jenis-jenis pohon andalan setempat untuk rehabilitasi hutan dan lahan di Indonesia. Forda Press. [Indonesian]

Perumal M, Wasli ME, and Ying. HS. 2019. Influences of inorganic and organic fertilizers to morphological quality attributes of *Shorea macrophylla* seedlings in a tropical nursery. Biodiversitas 20 (8): 2110-2118. [Indonesian]

Perumal M. Wasli ME, Ying HS, Sani H. 2017a. Survivorship and growth performance of *Shorea macrophylla* (de Vriese) after enrichment planting for reforestation purpose at Sarawak, Malaysia. OnLine J Biol Sci 17 (1): 7-17.

Perumal M, Wasli ME, Ying HS, Lat J, Sani H. 2017b. Association between soil fertility and growth performance of planted *Shorea macrophylla* (de Vriese) after Enrichment Planting at Rehabilitation Sites of Sampadi Forest Reserve. Sarawak. Malaysia. Int J For Res 2017. DOI: 10.1155/2017/6721354.

Perumal M, Wasli ME, Sani H, Nahrawi H. 2012. Growth performance of planted *Shorea macrophylla* under line planting technique. In: 4th Regional Conference on Natural Resources in the Tropics. 2012 (NTrop4): Sustaining Tropical Natural Resources Through Innovations. Technologies and Practices. Universiti Malaysia Sarawak.

Quedraogo I, Nacoulma BMI, Hahn K, Thiombiano A. 2014. Assessing ecosystem services based on indigenous knowledge in south-eastern Burkina Faso (West Africa). Int J Biodivers Sci Ecosyst Serv Manag 10 (4): 313-321.

Randi A, Julia S, Kusumadewi Y, Robiansyah I, Shomat F, Tanggaraju S, Hamidi A, Juiling S, Bodos V, Maryani A. 2019. *Shorea macrophylla*. The IUCN red list of threatened species 2019: e.T33620A125629642. DOI: 10.2305/IUCN.UK.20193.RLTS.T33620A125629642.en.

Rikando R. Latifah S. Manurung TF. 2019. Sebaran jenis tengkawang (*Shorea* spp) di hutan tembawang Desa Labian Kecamatan Batang Lupar Kapuas Hulu Kalimantan Barat (*Distribution of tengkawang species* (Shorea spp) *in the Tembawang forest Labian Village Batang Lupar District Kapuas Hulu West Kalimantan*). J Hutan Lestari 7 (1): 390-406. [Indonesian]

Ruslim Y, Sihombing R, Liah Y. 2016. Stand damage due to mono-cable winch and bulldozer yarding in a selectively logged tropical forest. Biodiversitas 17 (1): 222-228.

Ruchaemi A. 2013. Ilmu pertumbuhan hutan. Samarinda: Mulawarman University Press. [Indonesian]

Sadeghi SM, Hanum IF, Abdu A, Kamziah IK, Hakeem KR, Ozturk M. 2016. Recovery of soil in hill dipterocarp forest after logging in Kedah Malaysia. Malaysian Nature Journal 68 (1 & 2): 187-201.

Saiz H, Alados CL. 2012. Changes in semi-arid plant species associations along a livestock grazing gradient. Plos One 7 (7): 1-9. E40551. DOI: 10.1371/Journal.Pone.0040551.

Schroeder K, Pumphrey M. 2013. It's all a matter of pH: acid soils. aluminum toxicity are on the rise in Eastern Washington. Northern Idaho. WGC Reports. http://washingtoncrop.com/wp-content/uploads/2011/11/Aluminum-Toxicity-article-from-January-2013-Wheat-Life.pdf

Schlesinger WH, Bernhard ES. 2012. Biogeochemisty: an analysis of global change. 3rd ed. Academic Press. San Diego. CA.

Sofiah S, Setiadi D, Widyatmoko D. 2013. Pola penyebaran. kemelimpahan. dan asosiasi bambu pada komunitas tumbuhan di Taman Wisata Alam Gunug Baung Jawa Timur. Berita Biologi. Jurnal Ilmu-Ilmu Hayati 12 (2): 239-247. [Indonesian]

Turner BL, Engelbrecht BMJ. 2011. Soil organic phosphorus in lowland tropical rain forests. Biogeochemistry. 103 (1): 297-315. DOI: 10.1007/s10533-010-9466-x.

Utomo S, Uchiyama S, Ueno S, Matsumoto A, Widiyatno, Indrioko S, Na'iem M, Tsumura Y. 2018. Effects of pleistocene climate change on genetic structure and diversity of *Shorea macrophylla* in Kalimantan rainforest. Tree Genet Genomes 14 (4): 44.

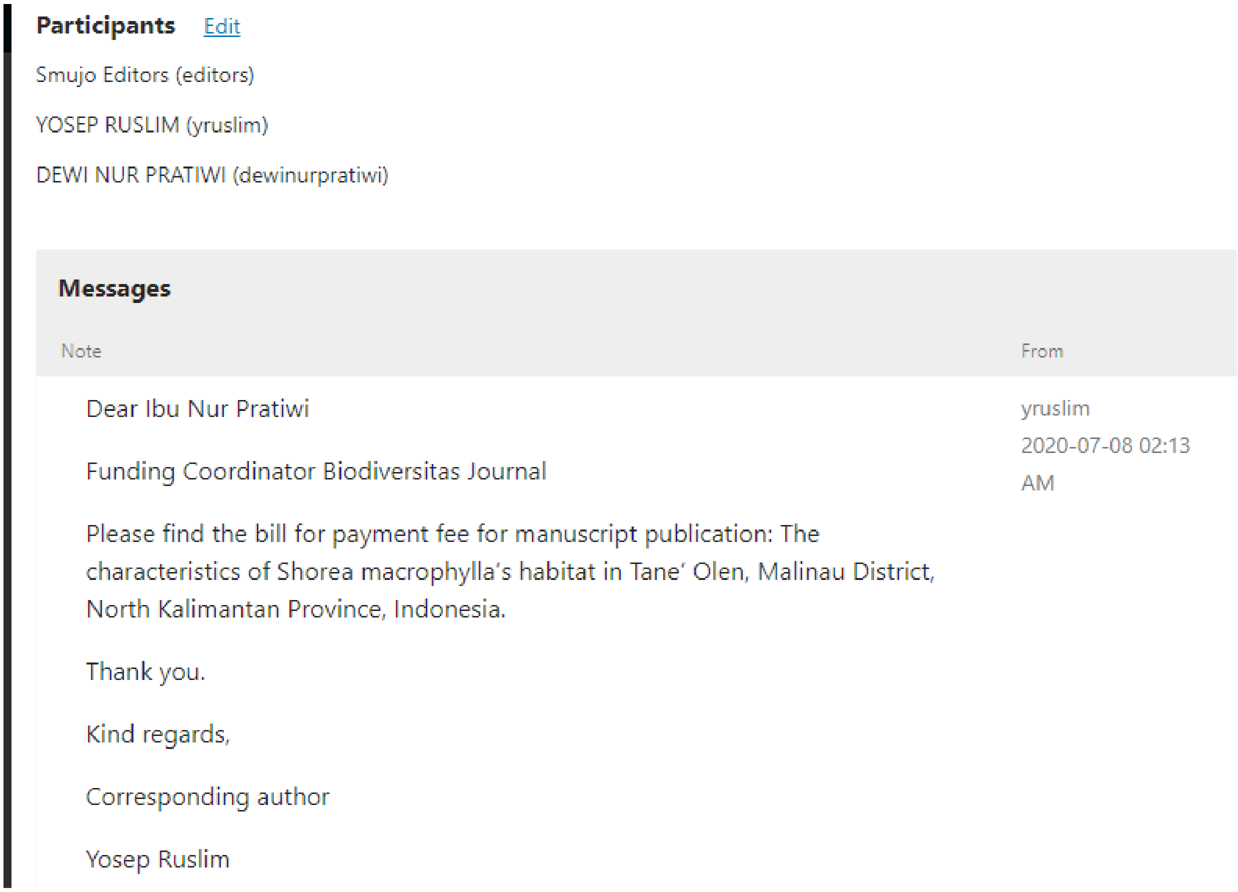
Widiyatno, Budiadi, Suryanto P, Rinarno YDBM, Prianto SD, Hendro Y. 2017. Recovery of vegetation structure. soil nutrients and late-succession species afters hifting cultivation In Central Kalimantan. Indonesia. J Trop For Sci 29 (2): 151-162.

Windusari Y, Susanto RH, Dahlan Z, Susetyo W. 2011. Asosiasi jenis pada komunitas vegetasi suksesi di kawasan pengendapantailing tanggul ganda di pertambangan PTFI Papua. Jurnal Ilmiah Ilmu-Ilmu Hayati Biota 16 (2): 242-251. [Indonesian]

Zaidey AK, Arifin A, Zahari I, Hazandy AH, Zaki MH, Affendi H, Wasli ME, Hafiz YK, Shamsuddin, Muhammad MN. 2010. Characterizing soil properties of lowland and hill dipterocarp forest at Peninsular Malaysia. Int J Soil Sci 5 (3):112-130.

Zeng C, Wang Q, Zhang F, Zhang J. 2013. Temporal changes in soil hydraulic conductivity with different soil types and irrigation methods. Geoderma 193/194:290-299. DOI: 10.1016/j. geoderma.2012.10.013.

Zhu X, Zhu B. 2015. Diversity and abundance of soil fauna as influenced by longterm fertilization in cropland of purple soil. China. Soil Tillage Res 146: 39-46.



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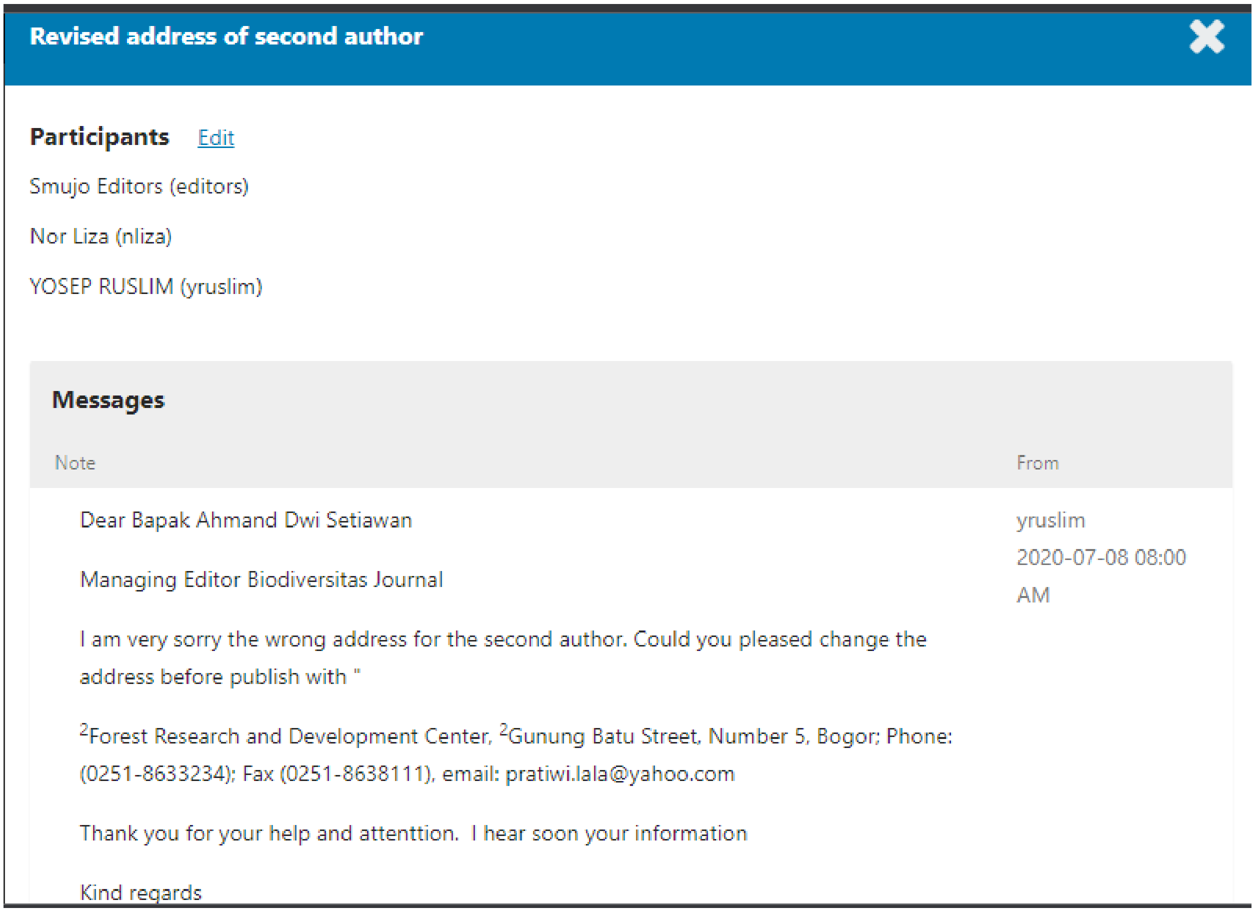

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The characteristics of *Shorea macrophylla*'s habitat in Tane' Olen, Malinau District, North Kalimantan Province, Indonesia

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Abstract. *Fajri M, Pratiwi, Ruslim Y. 2020. The characteristics of* Shorea macrophylla*'s habitat in Tane' Olen, Malinau District, North Kalimantan Province, Indonesia. Biodiversitas 21: xxxx.* *Shorea macrophylla* is a tree species in Tane' Olen forest area. This study analyzed the soil's physical and chemical properties, topography, and microclimate of *S. macrophylla*'s habitat. A purposive method was used to select a sampling plot and to place the subplots. Soil was analyzed to determine the physical properties, i.e., texture, bulk density, porosity, and water content, and the chemical properties, i.e., pH, CEC, total N, organic C, C/N ratio, P, K , and Al saturation. Importance value index was determined for each tree species to know the species composition in the study site. Only the dominant species were presented. The soil at the study site had bulk density of 0.60-1.31 gram cm$^{3-1}$, porosity 50.60%-77.35%, water content 34.88%-95.37%, and soil texture sandy clay. The chemical properties of the soil were as follows: pH was 3.6-4.8, N 0.05%-0.19%, organic C 1.40%-3.65%, P 0.41-1.22 mg 100 gr^{-1}, K 58.68-232.55 mg 100 gr^{-1}, and Cation Exchange Capacity (CEC) 5.35-10.81 meg 100gr $^{-1}$. Slope ranged between 0 and 25%. The microclimate characteristics were as follows: temperature was 24-26.5°C, relative humidity 76-87%, and light intensity 145-750 Lm. Trees species with an IVI $\geq$ 10% were *S. macrophylla*, *Madhuca spectabilis*, *Myristica villosa* Warb, *Scorodocarpus borneensis*, *Eugenia* spp, *Palaquium* spp, *Macaranga triloba*, *Syzygium inophyllum* and *Shorea* sp. Positive associations were observed between *S. macropylla* and *S. borneensis*, *Eugenia* spp, *Palaquium* spp and *M. triloba,* and negative associations were observed between *S. macropylla* and *M. spectabilis*, *M. villosa* Warb, *S. inophyllum,* and *Shorea* sp. *S. macrophylla* grows on riversides with flat and gentle topography, acidic soil, and lower fertility but with suitable microclimate. This species can be recommended to be planted in degraded tropical forest areas but the microclimate and soil properties should be taken into account.

Keywords: Habitat, land characteristics, *S. macrophylla*

INTRODUCTION

Shorea macrophylla is one of the fastest growing climax tree species of the genera *Shorea* (Perumal et al. 2017). Local communities value this species as a source of timber and fruit (Randi et al. 2019). *S. macrophylla* is known locally in West Kalimantan as the *tengkawang tungkul* tree and has been cultivated by the Dayak and Malay communities (Fajri and Fernandes 2015). *S. macrophylla* grows in clusters in tropical rain forests with type A climate, on latosol soils at altitudes up to 500 m, on acidic soils (pH 4.6-4.9), and a cation-exchange capacity (CEC) of 16.25-19.40 (Istomo and Hidayati 2010). In Sarawak, Sabah, Brunei and Kalimantan, this species is associated with sedimentary soils and is distributed evenly over riverbanks and areas with sloping or flat topography. It is rarely found on hills. (Randi et al. 2019; Utomo et al. 2018; Perumal et al. 2017).

The timber from *S. macrophylla* is commonly used for construction and to make veneer and plywood, musical instruments, furniture, and packing crates (Istomo and Hidayati 2010). The fruit, locally known as *tengkawang tungkul* (*Illipe*) nuts, is used as a raw material for soap and other cosmetics, a substitution for brown fat, and a source of vegetable fat (Maharani et al. 2016). The natural population of *tengkawang* is declining and is, at present, hard to find (Istomo and Hidayati 2010) because *S. macrophylla* is one of the most sought-after species in tropical forests. The exploitation of the species for its timber, combined with forest conversion to other uses, has resulted in *S. macrophylla* timber being difficult to find in the market (Rikando et al. 2019).

Tane' Olen is a forested area with a high environmental value preserved by the people of Setulang Village (Hutauruk et al. 2018a), a community that manages its forests based on the local wisdom and sustainable forest management practices (Fahrianoor et al. 2013; Kettle 2010), so the forest sustainability is maintained (Hutauruk et al. 2018). Forests are not only a place to live for them, but are also used as a source of food and medicine and economic, social, cultural, and spiritual functions (Merang et al. 2020; Matthew et al. 2018; Quedraogo et al. 2014).

S. macrophylla's habitat characteristics in secondary forest locations have been documented by Jaffar et al.

(2018) and Perumal et al. (2017). Perumal et al. (2017) studied the relationship between soil fertility and the growth of *S. macrophylla* in enrichment plantings at Sampadi Forest Reserve, Lundu, Sarawak and an adjacent secondary forest. Jaffar et al. (2018) researched the effects of soil compaction and light intensity on the establishment and growth of *S. macrophylla* in riparian forests in Sungai Kayan Ulu Sungai, Serawak, Malaysia. The improvement of the company's management system, which is changing the way of harvesting using long cables during skidding activity, reduced the natural forest damage and could increase financial returns from natural forest concessions (Ruslim et al. 2016). The characteristics of *S. macrophylla* habitat in primary forest locations had not previously been studied. So, this study aimed to describe the characteristics of *S. macrophylla*'s habitat in primary forests by analyzing the physical and chemical properties of soil, the microclimate, topography, species associations, and vegetation. It is hoped that the results of this study will benefit conservation efforts of this species, especially on degraded land in the tropical rain forests of North Kalimantan.

MATERIALS AND METHODS

Study area

The study was carried out in Tane' Olen forest area, Setulang Village, Malinau District, North Kalimantan Utara Province (3°25'0.86" N and 116°25'52.59" E). The location map is presented in Figure 1.

Research procedure

A one-hectare research site was selected purposively and sampled using a square plot with a side length of 100 meters (Sari and Maharani 2016). Soil sampling was taken from purposively selected three sampling points, located on a ridge, a slope, and a valley (the ridge had the highest elevations and a 15-25% slope; the slope was located between the valley and ridge, and had an 8-15% slope; the valley was the lowest area and had a 0-8% slope) to ensure an accurate representation of the study site. At each sampling point, soil samples were taken at three depths: 0-20 cm, 20-40 cm, and 40-60 cm. Microclimate data (temperature, humidity, and light intensity) were collected at the same locations. The soil and microclimate data collection design is illustrated in Figure 2. Vegetation data were only collected for trees with a diameter at breast height (DBH) greater than 20.0 cm Each plot was divided into 25 subplots (20 m x 20 m). Within each subplot, the species were identified and DBH recorded for all trees (Widiyatno et al. 2017). Plot-making and field-data collection activities are presented in Figure 2, while sampling design is presented in Figures 3 and 4. Soil sample collection design and microclimate data are presented in Figure 3 and 4. Topography data collection design can be seen in Figure 4. The design of vegetation data collection can be seen in Figures 5.

Data analyses

Soil analyses

Soil samples were analyzed for both physical and chemical properties (Kurnia et al. 2006; Eviati and Sulaeman 2009). Physical properties analyzed were texture, bulk density, porosity, and water content (using the Pipette method). Chemical properties analyzed were pH (using the electrode method), CEC (using the ammonium acetate pH 7 method), elements Al+++ and H+ (using the KCl method 1 N), total N elements (using the Kjeldahl method), organic C elements (using Walkley-Black method), C/N ratio (using arithmetic methods), elements P_2O5 and K_2O (using Bray No I methods), and saturation Al (using arithmetic methods). Soil data analysis results from the soil laboratory were tabulated and analyzed descriptively and quantitatively.

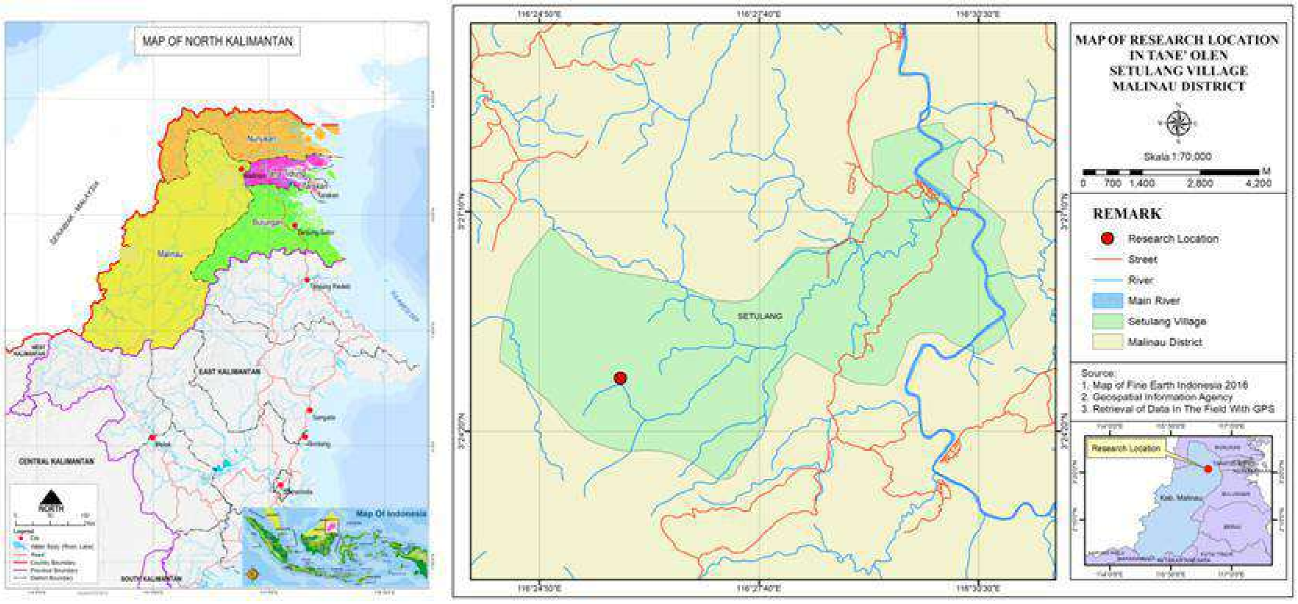

Figure 1. Location of the research in Tane' Olen (●)

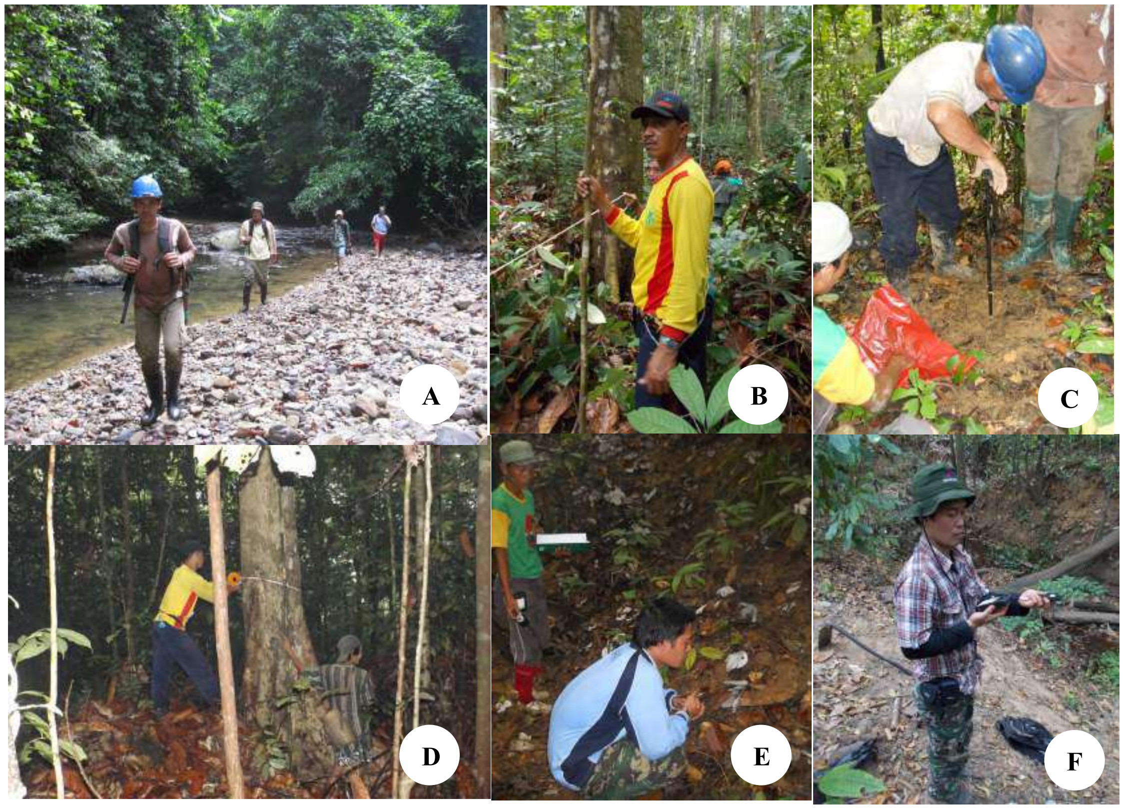

Figure 2. A. Exploration, B. Research plot making, C. Soil sample collection, D. Tree inventory, E and F. Microclimate data collection

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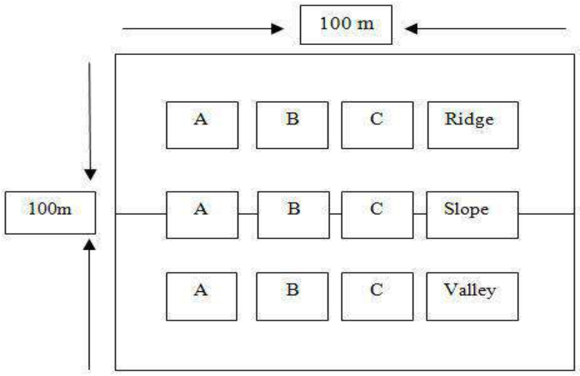


Figure 3. Soil and microclimate sample design. Note: A:lights intensity, B: temperature and area humidity, C: soil sampling, m:meter

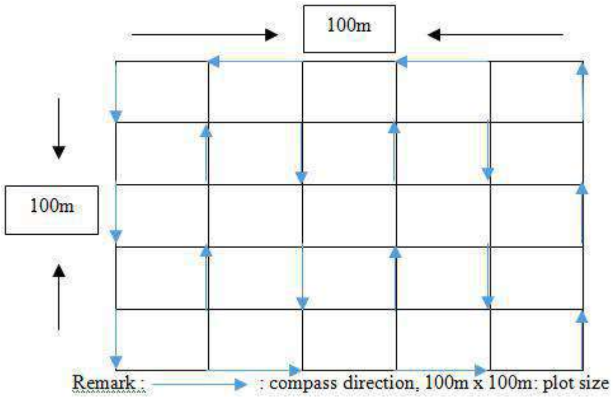
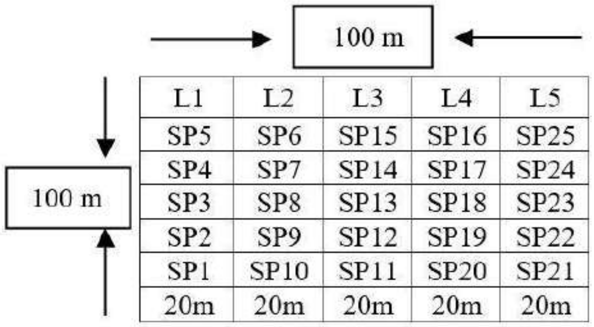


Figure 4. Plot design across contour line.



L1	L2	L3	L4	L5
SP5	SP6	SP15	SP16	SP25
SP4	SP7	SP14	SP17	SP24
SP3	SP8	SP13	SP18	SP23
SP2	SP9	SP12	SP19	SP22
SP1	SP10	SP11	SP20	SP21
20m	20m	20m	20m	20m

Figure 5. Design of plot and sub-plots for vegetation sampling. Note: L: lane, SP: sub plot, 20m: distance between sub plots, 100m x 100m: plot size, m: meter.

Analysis of topography

The topographic analysis was done qualitatively to describe the topography suitable for *S. macrophylla*.

Analysis of microclimate

The analysis of microclimate was done qualitatively to provide information on microclimates characteristics suitable for *S. macrophylla*.

Importance Value Index

According to Kacholi (2014), the Importance Value Index (IVI) is used in ecological studies to determine the ecological importance of a species in a particular ecosystem. IVI is also used to prioritize species conservation. Species with low IVI values require a higher conservation priority than those with high IVI, which is the dominant species. IVI value is a function of several characteristics, and calculated with this formula: IVI = relative density + relative frequency + relative dominance. IVI values were analyzed descriptively

Association of vegetation

Associations between two tree species were analyzed using a series of 2x2 contingency tables (Mueller-Dombois and Ellenberg 1974). A more complete description is presented in Table 1.

Then, the data were tested with chi-square (x^2)

$$X^2 = \frac{(ad - bc)^2 \; x \; N}{(a+b)(c+d)(a+c)(b+d)}$$

The association coefficient (C) values were determined as follows:

If ad ≥ bc, so $C = \frac{ad-bc}{(a+b)(b+d)}$

If bc > ad and d > a, so $C = \frac{ad-bc}{(a+b)(b+c)}$

If bc > ad and a > c, so $C = \frac{ad-bc}{(a+d)(c+d)}$

Positive or negative values of C indicate a positive or negative relationship between the two species. A positive relationship indicates that the association between trees is mutually beneficial to each other, while a negative value indicates that the association between trees harms one another.

Table 1. Contingency table form (Mueller-Dombois and Ellenberg 1974)

Species A **Species B**	+	-	
+	a	b	a + b
-	c	d	c + d
	a + c	b + d	N = a + b + c + d

Note:
a = number of plots containing species A and species B.
b = number of plots containing only species A, but no species B.
c = number of plots containing only species B, but no species A.
d = number of plots containing neither species A nor species B.
N = number of all plots.

RESULTS AND DISCUSSION

The soil's physical and chemical properties

The physical and chemical properties of soil properties in S. *macrophylla*'s habitat can be seen in Table 2.

At the depth of 0-20 cm, the valley, slope, and ridge subplots had a low bulk density (0.60-1.05) (Table 2). According to Casanova et al. (2016) and Zeng et al. (2013), soil bulk density is influenced by external conditions and natural processes such as plant root growth and rainfall.

The soil porosity values in the valley, slope, and ridge subplots decreased with the increasing soil depth. The valley subplot had higher porosity value than the slope and ridge subplots. According to Darusman et al. (2019), the properties that affect soil porosity the most are bulk density and soil particle density; if the bulk density is low then the soil porosity will increase.

Water content in the ridge, slope, and valley decreased with the increasing soil depth. The water content in the ridge subplots was higher than the slope subplots because the water movement is faster in the slope subplots and the water settles in the lower area, i.e., the valley subplots, which resulted in a higher (95.37%) water content in the valley subplots than in the ridge and slope subplots. Jaffar et al. (2018) state that *S. macrophylla* plant roots can adapt to high water soil content. Moist soils stimulate *S. macrophylla* roots growth and development. According to Minasny and McBratney (2018), the availability of groundwater is an important component of water balance and the terrestrial biosphere cycle because it can affect evapotranspiration rates and support plant growth.

The results of the soil texture analysis can be seen in Table 3.

The soil texture at the study site generally had a sand fraction of 45-65%, a clay fraction 35-55%, and a silt fraction 0-20% (Table 3). This means that the soil texture is sandy clay. According to Osman (2013), soil texture refers to the level of fineness or roughness created by the variously-sized soil particles.

Soil types are generally dominated by Ultisol (advanced development) soils, namely Typic Hapludults (Red-Yellow Podsolik) and Typic Paleudults (Yellow Podsolic). These soil types are typically found in lowland dipterocarp forests (Ohta and Effendi 1992).

Chemical soil characteristics of the study site are presented in Table 4.

The soil at the study site was very acidic (pH = 4.1-4.8) (Table 4). According to Schroeder and Pumphrey (2013), acidic soils inhibit root and plant growth and increase Al levels in the soil. The CEC at the study site ranged from 5.3 to 10 meq/100 g^{-1}, indicating that the CEC was low. In general, the value of CEC is low in surface and subsurface soils of lowland dipterocarp forests (Perumal et al. 2017a).

Aluminum levels at the study site were high, especially in the slope and valley subplots, which indicated high soil toxicity. Al content in the soil decreased with the increasing organic matter because organic matter forms a strong bond with Al. According to Zaidey et al. (2010), Al is a major cause of soil acidity, and soils in lowland dipterocarp forests have high Al content.

Nitrogen levels at the study site ranged from 0.05% to 0.19% (low to very low). Sadeghi et al. (2016) also reported low total N levels in tropical rain forest soils. Nitrogen is important for plant growth (Omara et al. 2019), and N deficiency can inhibit plant growth (Mehata et al. 2019). According to Omara et al. (2019), the main sources of N are organic matter and rainfall/precipitation.

Organic C values were higher in the valley and slope subplots than in the ridge subplots. The steeper slopes in the ridge subplots are more prone to erosion, resulting in the leaching of organic C and other nutrients into the valley and slope subplots. According to Schlesinger and Bernhard

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(2013), carbon can be stored in the soil three times longer than in the atmosphere and is an indicator of soil microorganism abundance and diversity (Zhu and Zhu 2015). The presence of organic C in the soil spurs microorganism activity and thereby increases the rates of soil decomposition, P dissolution, N fixation, and other microorganism-dependent reactions.

Phosphate was calculated from P_2O_5, where the Phosphate content is very low (0.41-1.22 mg 100 gram^{-1}) (Table 4). According to Turner and Engelbrecht (2011), organic P plays an important role in maintaining P availability in lowland tropical rain forests. Phosphorus is essential for root development and plant growth (Abdissa et al. 2011). According to Carstensen, et al. (2018), P deficiency has a major impact on plant growth, development and productivity.

Potassium values ranged from high (58.68-116.85 mg 100 gr^{-1}) in the valley and slope subplots to very high (120.34-232.55 mg 100 gr^{-1}) in the ridge subplots. According to Mouhamad et al. (2016), K is more abundant in the soil than other mineral elements. This element has an essential role in plant metabolism, growth, and yield. Potassium availability depends on soil properties (humidity, aeration, and temperature), soil treatment systems, and the dynamics of K. Therefore, the K exchange level varies among soils.

Topography in the study area

According to Li and McCarty (2019), topographic features are key parameters that affect the nature of the soil at the earth's surface. Topographic features can affect organic matter; clay content; P, K, and Mg concentrations; and soil pH (Kumhalova et al. 2011).

The topography of the study site is moderately undulating with a slope of 0-25%. The subplot slopes range from flat to moderately steep. *S. macrophylla* was found primarily in flat to sloping areas with high environmental humidity, low ambient temperature, and abundant water, such as riverbanks. Jaffar et al. (2018) stated that the roots of the *S. macrophylla* are able to survive and grow in anaerobic waterlogged soils and is considered a flood-tolerant tree.

Dominant trees at the study area

At the study site, *S. macrophylla* was the dominant tree species (Figure 6). Other tree species included *Madhuca spectabilis, Myristica villosa* Warb.*, Scorodocarpus borneensis, Eugenia* spp., *Palaquium* spp., *Macaranga triloba, Syzygium inophyllum,* and *Shorea sp*. *S. macrophylla* dominated the study site due to its fast germination process and high germination rate (Appanah and Turnbull 1998), its high growth rate (fastest of the genus *Shorea)*, and its status as a climax species along rivers (Perumal et al. 2017).

Table 2. Physical properties of soil at the study site.

Location of soil	Depth (cm)	Bulk density ($gram/cm^3$)*	Porosity (%)*	Water content (%)
Valley	0-20	0.60	77.35	95.37
	20-40	1.13	57.32	40.04
	40-60	1.18	55.54	39.20
Slope	0-20	1.05	60.42	48.08
	20-40	1.31	50.60	41.42
	40-60	1.23	53.72	34.88
Ridge	0-20	0.83	68.75	61.68
	20-40	1.01	61.92	44.23
	40-60	1.20	54.66	35.53

Note: *Average score from three repetitions

Table 3. Soil texture at the study site.

Location of soil	Depth (cm)	Clay (%)	Sand (%)	Silt (%)	texture (USDA)
Valley	0-20	33.70	50.90	15.40	SCL
	20-40	36.50	49.50	14.00	SC
	40-60	34.00	56.80	9.20	SCL
Slope	0-20	24.70	67.20	8.10	SCL
	20-40	27.30	63.10	9.60	SCL
	40-60	33.10	60.50	6.40	SCL
Ridge	0-20	37.80	54.60	7.60	SC
	20-40	37.40	46.40	16.20	SC
	40-60	40.70	48.00	11.30	SC

Note: Laboratory of soil test in B2P2EHD and Pusrehut, Mulawarman University

Table 4. Chemical characteristics of soil at the study site.

Location of soil	Depth (cm)	pH (1: 25)		Cation exchange rates (meg 100gr^{-1})			Organic content (%)		Ratio	Mineral (Mg 100 gram^{-1})	
		H_2O	KCl	CEC	$Al3^+$	H^+	Tot. N.	Org C	C/N	P_2O_5	K_2O
Valley	0-20	4.6	3.3	7.26	4.92	1.50	0.19	3.65	19	0.89	116.85
	20-40	4.6	3.4	7.25	5.56	1.08	0.12	2.65	22	0.73	73.30
	40-60	4.4	3.4	7.18	5.75	0.92	0.10	2.12	22	1.22	59.00
Slope	0-20	4.1	3.5	5.35	2.75	1.33	0.13	2.31	18	0.65	73.62
	20-40	4.7	3.5	5.30	3.50	0.92	0.07	1.54	22	0.65	58.68
	40-60	4.8	3.5	5.53	3.33	1.42	0.05	1.40	26	0.41	60.90
Ridge	0-20	4.4	3.0	10.81	7.25	2.75	0.09	3.46	39	2.35	120.34
	20-40	3.6	3.3	10.48	7.80	1.83	0.08	2.12	28	0.89	194.09
	40-60	4.4	3.4	10.37	6.83	2.58	0.09	1.54	17	0.65	232.55

Note: Laboratory of soil test in B2P2EHD and Pusrehut, Mulawarman University

Microclimate

Three microclimate factors were collected, i.e., temperature, humidity, and light intensity (see Table 6 for a more complete description). The temperature values at the study site was 24-26,5° C (Table 6). According to Ruchaemi (2013), the optimal temperature for plant assimilation is 25-30° C. Relative humidity values were high to very high, ranging from 76 to 87%. Lights intensity was very low to low, ranging from 7,25% (145 Lm) to 23.46% (469 Lm) due to dense canopy dominated by *S. macrophylla* which prevented light from reaching the forest floor. This low light intensity is consistent with the findings of Panjaitan et al. (2012), who found that the closed canopy only allowed a little sunlight to reach the forest floor. These conditions benefit *S. macrophylla* seedlings, which are sun intolerant.

Association with other trees

According to Saiz and Alados (2012), plant species association is a fundamental aspect of the ecology of plant communities. Analysis of plant species associations provides information on environmental heterogeneity, biotic interactions, and seed dispersal patterns. The results of the species association analysis and the association coefficient are presented in Table 7.

Table 7 shows the results of a series of 2x2 contingency tests between *S. macropylla* and each of the eight other dominant tree species. The calculated X^2 values were greatest between *S. macropylla* and *M. villosa* Warb, indicating that *S. macrophylla* had a strong but negative association with *M. villosa* Warb. According to Sofiah et al. (2013), species pairs do not always indicate positive relationships. Tree species with high populations are not always associated with another species. Likewise, low-population species are not necessarily negatively correlated with another species.

The association coefficient (C) was used as a parameter of the magnitude of the relationship between the eight species and *S. macropylla* and indicates positive or negative associations. Species that showed positive coefficients of association with *S. macropylla* were *S. borneensis, Eugenia spp., Palaquium spp,* and *M. triloba.* According to Windusari1 et al. (2011), positive associations indicate both species have the same requirement of environmental conditions; for example, wet conditions, high light intensity, or shade. *S. macropylla* showed a negative association with *M. spectabilis, M. villosa, S. inophyllum,* and *Shorea* sp. Negative associations indicate intolerance for cohabitation or the absence of a mutually beneficial relationship (Pratama et al. 2012).

Table 5. The importance value index of the dominant tree species at the study site

Local name	Scientific Name	Family	Relatif density (%)	Relatif dominance (%)	Relatif frequency (%)	Importance value index (%)
Tengkawang	*S. macropyilla*	Dipterocarpaceae	7.69	15.35	5.0	28.04
Kajen ase	*M. spectabilis*	Sapotaceae	10.25	7.29	4.61	22.16
Darah-darah	*M. villosa* Warb	Myristicaceae	7.45	4.79	5.0	17.25
Bala seveny	*S. borneensis*	Olacaceae	5.12	5.77	5.0	15.90
Ubah	*Eugenia* spp	Myrtaceae	5.59	3.64	4.61	13.85
Nyatok	*Palaquium* spp	Sapotaceae	4.42	3.70	4.61	12.74
Beneva	*M. triloba*	Euphorbiaceae	4.66	4.32	3.46	12.44
Ehang	*S. inophyllum*	Myrtaceae	5.36	3.14	3.84	12.35
Kaze tenak	*Shorea* sp	Dipterocarpaceae	2.33	6.08	2.69	11.10

Figure 6. A. Tree of *Shorea macrophylla* and B. Leaves of *S. macrophylla*

Table 6. Microclimate at the study site

Location	Microclimate	Unit	Time	1-st record	2-nd record	3-rd record	Average	Remark
1.	Light intensity	Lm	Morning	350	400	452	400.67	Taken at 8.59 sunny conditions
2.	Temperature	°c	Morning	24	24.5	25	24.5	
3.	Relative humidity	%	Morning	81	79	80	80	
1.	Lights intensity	Lm	Mid day	750	450	207	469	Taken at 12:02 sunny conditions
2.	Temperature	°c	Mid day	26.5	26	24.5	25.67	
3.	Relative humidity	%	Mid day	76	79	81	78.67	
1.	Lights intensity	Lm	Afternoon	369	237	145	250.33	Taken at 16:30 sunny conditions
2.	Temperature	°c	Afternoon	25	24.5	23	24.17	
3.	Relative humidity	%	Afternoon	84	85	87	85.33	

Table 7. Association of *S. macropylla* with other species.

Species association	X² count	Assoc. species	C (+/-)
S. macropylla with *M. spectabilis*	0.35	-	0.04
S. macropylla with *M. villosa* Warb	6.82	-	0.29
S. macropylla with *S. borneensis*	0.04	+	0.04
S. macropylla with *Eugenia* spp	0.37	+	0.11
S. macropylla with *Palaquium* spp	0.37	+	0.11
S. macropylla with *M. triloba*	1.21	+	0.16
S. macropylla with *S. inophyllum*	3.23	-	0.29
S. macropylla with *Shorea* sp	1.92	-	0.24

Note: X ² tabulated value at 5% level: 3.841. X² tabulated value at 1% level: 6.35

Direction of *S. macrophylla* plantation

At present, tropical forests are being degraded by anthropogenic activities such as timber extraction, agricultural cultivation, and the establishment of commercial plantations. This results in the conversion of forests into agriculture land and the fragmentation and degradation of tropical rain forests. Deforestation damages the environment by increasing light intensity and causing severe mineral soil erosion. In general, degraded forests can be divided into three categories: grasslands after burning, early-succession secondary forests, and commercially logged forests (Daisuke et al. 2013).

Planting native trees is considered to be an effective rehabilitation method for degraded tropical rain forests because native trees provide benefits such as timber, food, and medical products (Daisuke et al. 2013). According to Pratiwi et al. (2014), tropical forest rehabilitation is necessary to both meet the demand for timber and improve environmental conditions. One key to rehabilitation success is the understanding of the suitability of each growing site for each species being planted. One approach to determine the suitability of growing sites for each species is to identify each species' potential, identify locally superior species, and correlate this with species distribution data and growth requirements (Pratiwi et al. 2014).

Shorea macrophylla is a recommended species for replanting degraded tropical forest land, i.e., pastures after burning (Daisuke et al. 2013), early-succession secondary forests (Daisuke et al. 2013; Perumal et al. 2012), and commercially logged forests. In commercially logged forests, *S. macrophylla* can be planted using the line planting system or gap planting system. In early-succession secondary forests and pasture after burning, *S. macrophylla* requires pioneer plants to assist growth. *S. macrophylla* is a valuable tree species that has socio-economic and ecological benefits and is beneficial for reforestation and rehabilitation activities (Perumal et al. 2012; Perumal et al. 2015; Perumal et al. 2017a; Perumal et al. 2017b; Perumal et al. 2019).

This species is important for land rehabilitation activities because it plays a role in maintaining water quality, filtering out pollutants and deposits, and storing carbon (Utomo et al. 2018; You et al. 2015). Things that must be considered when planting *S. macrophylla* are the nutrient content in clay and the clay mineral composition. These two factors can be used to evaluate soil fertility. The growth of *S. macrophylla* is also significantly limited by the high light intensity in grasslands (*Imperata cylindrical*/ pastures after burning). *S. macropylla* grows well in habitats with low light intensity. In secondary forests and logged-over forests, the survival and growth of *S. macrophylla* is limited by soil compaction. This agrees with the results of this study, where fine sandy clay soils were found.

S. macrophylla grows on riversides with flat and gentle topography, acidic soil, and lower fertility, but with the suitable microclimate (temperature of 24-26,5ºC, high humidity 76-87%, and a low light intensity 7,25-23.46%). This species can be recommended to be planted in degraded tropical forest areas if microclimatic factors and soil conditions are taken into account.

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REFERENCES

Abdissa Y, Tekalign T, Pant LM. 2011. Growth. bulb yield and quality of onion (*Allium cepa* L) as influenced by nitrogen and phosphorus fertilization on vertisol i. growth attributes. biomass production and bulb yield. Afr J Agric Res 6 (14): 3252–3258.

Appanah S, Turnbull JM. 1998. A review of dipterocarps: taxonomy. ecology and silviculture. Center for International Forestry Research.

Carstensen A, Herdean A, Schmidt SB, Sharma A, Spetea C, Pribil M, and Husted S. 2018. The impacts of phosphorus deficiency on the photosynthetic electron transport chain. Plant Physiology 177: 271-284. DOI: 10.1104/pp.17.01624.

Casanova M, Tapia E, Seguel O, Salazar O. 2016. Direct measurement and prediction of bulk density on alluvial soils of central Chile. Ultural Chilean J Agric Res 76 (1): 105-113. DOI: 10.4067/S0718-58392016000100015.

Daisuke H, Tanaka K, Jawa KJ, Ikuo N, Katsutoshi S. 2013. Rehabilitation of degraded tropical rainforest using dipterocarp trees in Sarawak. Malaysia. Int J For Res. DOI: 10.1155/2013/683017.

Darusman, Devianti, Husen E. 2018. Improvement of soil physical properties of cambisol using soil amendment. Aceh Int. J Sci Technol 7 (2): 93-102. DOI: 10.13170/aijst.7.2. 10119.

Eviati and Sulaeman. 2009. Petunjuk teknis analisis kimia tanah, tanaman, air, dan pupuk. Balai Penelitian Tanah, Bogor. [Indonesian]

Fahrianoor, Windari T, Taharudin, Mar'i R, Maryono. 2013. The practice of local wisdom of Dayak people in forest conservation in South Kalimantan. Indon J Wetlands Environ Manag 1 (1): 37-46.

Fajri M, Fernandes A. 2015. Pola pemanenan buah tengkawang (*S. machrophylla*) dan regenerasi alaminya dikebun masyarakat. Jurnal Penelitian Ekosistem Dipterokarpa 1 (2) : 81-88. DOI: 10.20886/jped.2015.1.2.81-88. [Indonesian]

Hutauruk TR, Lahjie AM, Simarangkir BDAS, Ruslim Y. 2018a. Setulang forest conservation strategy in safeguarding the conservation of non-timber forest products in Malinau District. IOP Conference. Series: Earth Environment Science. 144: 1-9. DOI: 10.1088/1755-1315/144/1/012055.

Hutauruk TR, Lahjie AM, Simarangkir BDAS, Aipassa MI, Ruslim Y. 2018b.The prospect of the utilization of Non-Timber Forest Products from Setulang Village forest based on local knowledge of the Uma Longh community in Malinau. North Kalimantan. Indonesia. Biodiversitas 19 (2): 421-430. [Indonesian]

Istomo, Hidayati T. 2010. Studi potensi dan penyebaran tengkawang (*Shorea* Spp.) di areal IUPHHK-Ha PT. Intracawood Manufacturing Tarakan. Kalimantan Timur. Jurnal Silvikultur Tropika. 01 (01): 11-17. [Indonesian]

Jaffar ANNM, Wasli ME, Perumal M, Lat J, Sani H. 2018. Effects of soil compaction and relative light intensity on survival and growth performance of planted *Shorea macrophylla* (de vriese) in riparian forest Along Kayan Ulu River. Sarawak. Malaysia. Int J For Res 2018 (2): 1-11. DOI: 10.1155/2018/6329295.

Kacholi DS. 2014. Analysis of structure and diversity of the kilengwe forest in the Morogoro Region. Tanzania. Int J Biodivers 2014: 1-8. DOI: 10.1155/2014/516840.

Kettle CJ. 2010. Ecological considerations for using dipterocarps for restoration of lowland rainforest in Southeast Asia. Biodiv Conserv. 19: 1137-1151.

Kumhalova J, Kumhala F, Kroulik M, Matejkova S. 2011. The impact of topography on soil properties and yield and the effects of weather conditions. J Precis Agric 12 (6): 813-830. DOI: 10.1007/s11119-011-9221-x.

Kurnia, U, Agus f, Adimihardja A, Dariah A. 2006. Sifat fisik tanah dan metode analisisnya. Balai Besar Litbang Sumberdaya Lahan Pertanian. Agro inovasi. Bogor. [Indonesian]

Li X, McCarty GW. 2019. Application of topographic analyses for mapping spatial patterns of soil properties. Geospatial Analyses of Earth Observation (EO) data. DOI: 10.5772/intechopen.86109

Maharani R, Fernandes A, Pujiarti R. 2016. Comparison of tengkawang fat processings effect on tengkawang fat quality from Sahan and Nanga Yen Villages. West Kalimantan. Indonesia. AIP Conf Proc 1712, 050022 (2016). DOI: 10.1063/1.4941905.

Matius P, Tjwa SJM, Raharja, Sapruddin, Noor S, Ruslim Y. 2018. Plant diversity in traditional fruit gardens (munaans) of Benuaq and Tunjung Dayaks tribes of West Kutai. East Kalimantan. Indonesia. Biodiversitas. 19 (4): 1280-1288. [Indonesian]

Mehata M, Cortus E, Niraula S, Spiehs MJ, Darrington J, Chatterjee A, Rahman S, Parker DB. 2019. Aerial nitrogen fluxes and soil nitrate in response to fall-applied manure and fertilizer applications in Eastern South Dakota. Int J Agron 2019: 1-15. DOI: 10.1155/2019/8572985.

Merang OP, Lahjie AM, Yusuf S, Ruslim Y. 2018. Productivity of three varieties of local upland rice on swidden agriculture field in Setulang village. North Kalimantan. Indonesia. Biodiversitas 21 (1): 49-56. [Indonesian]

Minasny B, Mcbratney AB. 2017. Limited effect of organic matter on soil available water capacity. Eur J Soil Sci 2017:1-9. DOI: 10.1111/ejss.12475.

Mouhamed R, Alsaede A, Iqbal M. 2016. Behavior of potassium in soil: a mini review. Chem Int 2 (1): 58-69.

Mueller-Dombois D, Ellenberg H. 1974. Aims and methods of vegetation ecology. John Willey and Sons. Canada.

Omara P, Aula L, Raun WR. 2019. Nitrogen uptake efficiency and total soil nitrogen accumulation in long-term beef manure and inorganic fertilizer application. Int J Agron 2019: 1-6. DOI: 10.1155/2019/9594369.

Ohta S, Effendi S. 1992. Ultisols of "lowland dipterocarp forest" in East Kalimantan. Indonesia. Soil Sci. Plant Nutr 38 (2): 197-206.

Osman KT. 2013. Forest soil: properties and management. Springer. London.

Panjaitan S, Wahuningtyas RS, Adawiyah R. 2012. Kondisi lingkungan tempat tumbuh *Shorea johorensis* Foxw. di HPH Aya Yayang Indonesia. Kalimantan Selatan (Environmental conditions in which to grow *Shorea johorensis* Foxw. at Aya Yayang HPH in Indonesia. South Kalimantan). J Penelitian Dipterokarpa. 6 (1): 11-22. [Indonesian]

Pratama, Arief B, Alhamd L, Rahajoe JS. 2012. Asosiasi dan karakterisasi tegakan pada hutan rawa gambut di Hampagen. Kalimantan Tengah. Jurnal Teknologi Lingkungan. Edisi Khusus Hari lingkungan Hidup 69-76. [Indonesian]

Pratiwi, Narendra BH, Hartoyo GME, Kalima T, Pradjadinata S. 2014. Atlas jenis-jenis pohon andalan setempat untuk rehabilitasi hutan dan lahan di Indonesia. Forda Press. [Indonesian]

Perumal M, Wasli ME, and Ying. HS. 2019. Influences of inorganic and organic fertilizers to morphological quality attributes of *Shorea macrophylla* seedlings in a tropical nursery. Biodiversitas 20 (8): 2110-2118. [Indonesian]

Perumal M. Wasli ME, Ying HS, Sani H. 2017a. Survivorship and growth performance of *Shorea macrophylla* (de Vriese) after enrichment planting for reforestation purpose at Sarawak, Malaysia. OnLine J Biol Sci 17 (1): 7-17.

Perumal M, Wasli ME, Ying HS, Lat J, Sani H. 2017b. Association between soil fertility and growth performance of planted *Shorea macrophylla* (de Vriese) after Enrichment Planting at Rehabilitation Sites of Sampadi Forest Reserve, Sarawak, Malaysia. Int J For Res 2017. DOI: 10.1155/2017/6721354.

Perumal M, Wasli ME, Sani H, Nahrawi H. 2012. Growth performance of planted *Shorea macrophylla* under line planting technique. In: 4th Regional Conference on Natural Resources in the Tropics. 2012 (NTrop4): Sustaining Tropical Natural Resources Through Innovations. Technologies and Practices. Universiti Malaysia Sarawak.

Quedraogo I, Nacoulma BMI, Hahn K, Thiombiano A. 2014. Assessing ecosystem services based on indigenous knowledge in south-eastern Burkina Faso (West Africa). Int J Biodivers Sci Ecosyst Serv Manag 10 (4): 313-321.

Randi A, Julia S, Kusumadewi Y, Robiansyah I, Shomat F, Tanggaraju S, Hamidi A, Juiling S, Bodos V, Maryani A. 2019. *Shorea macrophylla*, Light Red Meranti. The IUCN red list of threatened species 2019 e.T33620A125629642. DOI: 10.2305/IUCN. UK.20193.RLTS.T33620A125629642.en.

Rikando R. Latifah S. Manurung TF. 2019. Sebaran jenis tengkawang (*Shorea* spp) di hutan tembawang Desa Labian Kecamatan Batang Lupar Kapuas Hulu Kalimantan Barat (*Distribution of tengkawang species* (Shorea spp) *in the Tembawang forest Labian Village Batang Lupar District Kapuas Hulu West Kalimantan*). J Hutan Lestari 7 (1): 390-406. [Indonesian]

Ruslim Y, Sihombing R, Liah Y. 2016. Stand damage due to mono-cable winch and bulldozer yarding in a selectively logged tropical forest. Biodiversitas 17 (1): 222-228.

Ruchaemi A. 2013. Ilmu pertumbuhan hutan. Samarinda: Mulawarman University Press. [Indonesian]

Sadeghi SM, Hanum IF, Abdu A, Kamziah IK, Hakeem KR, Ozturk M. 2016. Recovery of soil in hill dipterocarp forest after logging in Kedah Malaysia. Malaysian Nature Journal 68 (1 & 2): 187-201.

Saiz H, Alados CL. 2012. Changes in semi-arid plant species associations along a livestock grazing gradient. Plos One 7 (7): 1-9. E40551. DOI: 10.1371/Journal.Pone.0040551.

Schroeder K, Pumphrey M. 2013. It's all a matter of pH: acid soils. aluminum toxicity are on the rise in Eastern Washington. Northern Idaho. WGC Reports. http://washingtoncrop.com/wp-content/uploads/2011/11/Aluminum-Toxicity-article-from-January-2013-Wheat-Life.pdf

Schlesinger WH, Bernhard ES. 2012. Biogeochemisty: an analysis of global change. 3rd ed. Academic Press. San Diego. CA.

Sofiah S, Setiadi D, Widyatmoko D. 2013. Pola penyebaran. kemelimpahan. dan asosiasi bambu pada komunitas tumbuhan di Taman Wisata Alam Gunug Baung Jawa Timur. Berita Biologi. Jurnal Ilmu-Ilmu Hayati 12 (2): 239-247. [Indonesian]

Turner BL, Engelbrecht BMJ. 2011. Soil organic phosphorus in lowland tropical rain forests. Biogeochemistry. 103 (1): 297-315. DOI: 10.1007/s10533-010-9466-x.

Utomo S, Uchiyama S, Ueno S, Matsumoto A, Widiyatno, Indrioko S, Na'iem M, Tsumura Y. 2018. Effects of pleistocene climate change on genetic structure and diversity of *Shorea macrophylla* in Kalimantan rainforest. Tree Genet Genomes 14 (4): 44.

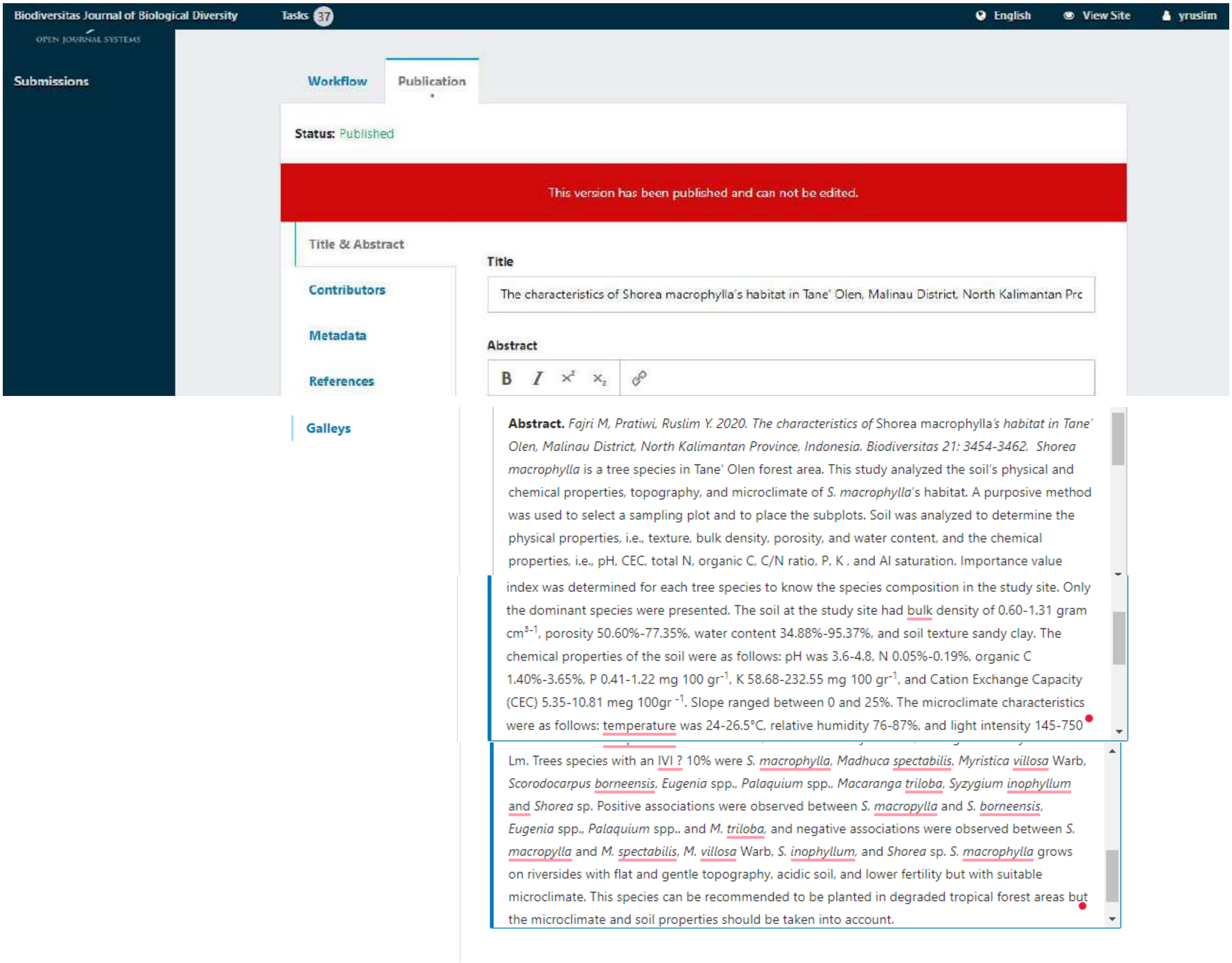
Widiyatno, Budiadi, Suryanto P, Rinarno YDBM, Prianto SD, Hendro Y. 2017. Recovery of vegetation structure. soil nutrients and late-succession species afters hifting cultivation In Central Kalimantan. Indonesia. J Trop For Sci 29 (2): 151-162.

Windusari Y, Susanto RH, Dahlan Z, Susetyo W. 2011. Asosiasi jenis pada komunitas vegetasi suksesi di kawasan pengendapantailing tanggul ganda di pertambangan PTFI Papua. Jurnal Ilmiah Ilmu-Ilmu Hayati Biota 16 (2): 242-251. [Indonesian]

Zaidey AK, Arifin A, Zahari I, Hazandy AH, Zaki MH, Affendi H, Wasli ME, Hafiz YK, Shamsuddin, Muhammad MN. 2010. Characterizing soil properties of lowland and hill dipterocarp forest at Peninsular Malaysia. Int J Soil Sci 5 (3):112-130.

Zeng C, Wang Q, Zhang F, Zhang J. 2013. Temporal changes in soil hydraulic conductivity with different soil types and irrigation methods. Geoderma 193/194:290-299. DOI: 10.1016/j. geoderma.2012.10.013.

Zhu X, Zhu B. 2015. Diversity and abundance of soil fauna as influenced by longterm fertilization in cropland of purple soil. China. Soil Tillage Res 146: 39-46.



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Title

The characteristics of Shorea macrophylla's habitat in Tane' Olen, Malinau District, North Kalimantan Prc

Abstract

Abstract. *Fajri M, Pratiwi, Ruslim Y. 2020. The characteristics of* Shorea macrophylla*'s habitat in Tane' Olen, Malinau District, North Kalimantan Province, Indonesia. Biodiversitas 21: 3454-3462.* *Shorea macrophylla* is a tree species in Tane' Olen forest area. This study analyzed the soil's physical and chemical properties, topography, and microclimate of *S. macrophylla*'s habitat. A purposive method was used to select a sampling plot and to place the subplots. Soil was analyzed to determine the physical properties, i.e., texture, bulk density, porosity, and water content, and the chemical properties, i.e., pH, CEC, total N, organic C, C/N ratio, P, K , and Al saturation. Importance value index was determined for each tree species to know the species composition in the study site. Only the dominant species were presented. The soil at the study site had bulk density of 0.60-1.31 gram cm$^{3-1}$, porosity 50.60%-77.35%, water content 34.88%-95.37%, and soil texture sandy clay. The chemical properties of the soil were as follows: pH was 3.6-4.8, N 0.05%-0.19%, organic C 1.40%-3.65%, P 0.41-1.22 mg 100 gr^{-1}, K 58.68-232.55 mg 100 gr^{-1}, and Cation Exchange Capacity (CEC) 5.35-10.81 meg 100gr $^{-1}$. Slope ranged between 0 and 25%. The microclimate characteristics were as follows: temperature was 24-26.5°C, relative humidity 76-87%, and light intensity 145-750

Lm. Trees species with an IVI ? 10% were *S. macrophylla*, *Madhuca spectabilis*, *Myristica villosa* Warb, *Scorodocarpus borneensis*, *Eugenia* spp., *Palaquium* spp., *Macaranga triloba*, *Syzygium inophyllum* and *Shorea* sp. Positive associations were observed between *S. macropylla* and *S. borneensis*, *Eugenia* spp., *Palaquium* spp.. and *M. triloba*, and negative associations were observed between *S. macropylla* and *M. spectabilis*, *M. villosa* Warb, *S. inophyllum*, and *Shorea* sp. *S. macrophylla* grows on riversides with flat and gentle topography, acidic soil, and lower fertility but with suitable microclimate. This species can be recommended to be planted in degraded tropical forest areas but the microclimate and soil properties should be taken into account.