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Structure and composition of tree community in the upstream area of Batang Mahat Watershed, Lima Puluh Kota District, West Sumatra, Indonesia

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Abstract. *Ekawaty E, Yonariza, Ekaputra EG, Arbain A. 2022. Structure and composition of tree community in the upstream area of Batang Mahat Watershed, Lima Puluh Kota District, West Sumatra, Indonesia. Biodiversitas 23: 687-696.* Land-use change at the upstream area of Batang Mahat Watershed is assumed to cause flood during the rainy season and is related to vegetation community which has been heavily exploited. Information regarding the current vegetation condition in this area has never been studied; therefore, this study aims to investigate the structure and composition of the tree community in the upstream area of Batang Mahat at Jorong Kubu Baru Nagari, Baruh Gunung, Bukit Barisan District. Furthermore, sampling was implemented using three 20x50 m belt-transects with 10 m intervals between each sample. The results showed 1) 116 identified and three unidentified tree samples belonging to 40 families; 2) The trees with the highest important value index (IVI) in transect 1 were *Rhodoleia championii* (63.339%) and *Calophylum soulatteri* (23.697%), in transect 2 *Voacanga foetida* (48.568%) and *Schima wallichii* (32.756%), and in transect 3 *Schima wallichii* (42.964%) and *Voacanga foetida* (40.713%); 3) The saplings with the highest IVI in transect 1 were *Timonius* sp. (33.111%) and *Alstonia* sp. (21.345%), in transect 2 *Hancea pengangensis* (24.551%) and *Sterculia* sp. (21.199%), as well as transect 3 *Voacanga foetida* (42.862%), and *Macaranga lowii* (30.844%); 4) Both vegetation categories have considerably high diversity (H' tree 3.13-3.2, H' saplings 3.04-3.36), and were moderately distributed across studied transects (E1 = 2.025, E2 = 2.089, E3 = 2.016). From the results, it can be concluded that the forest in the upstream area of the Batang Mahat watershed, which was located in Jorong Kubu Baru, Nagari Baruh Gunung, was still in the good category.

Keywords: Composition, natural resources, structure, vegetation

INTRODUCTION

The conversion of forest into other land uses, such as infrastructures, settlements and plantations, has created various environmental problems. The problems caused by forest conversion are more prevalent in tropical regions such as Indonesia. Deforestation and forest degradation in the tropics have devastating impacts on biodiversity (Budiharta et al. 2011), carbon emissions (Budiharta et al. 2018), and global warming (Wahyuni and Suranto 2021) since tropical forests are recognized as an ecosystem with the richest biodiversity and carbon storage. Deforestation that turns into shrubs can also trigger forest fires (Putra et al. 2019). In addition, the gradual decline of forest areas in the tropics constitutes one of the major causes of flood and erosion (Marganingrum et al. 2013; Muchtar and Abdullah 2008; Pawitan 2014).

Forest is created from the aggregation of vegetation which plays an important role in the hydrology process as it prevents rainfall-runoff (Yang et al. 2019). Furthermore, the forest canopy slowdowns rainfall to reach ground surfaces with low kinetic and less harm (Ginebra-solanellas et al. 2020). The rainfall hold-up in the forest canopy is termed interception; meanwhile, intercepted rainfall indirectly affects the river discharge. Moreover, the difference between the maximum and minimum discharge during rainy and dry seasons becomes indifferent when the riparian vegetation is in optimum condition. Hence, the structure and composition of forest vegetation are assumed to influence water management.

Alterations of the vegetation or changes in the forest width tend to significantly affect the hydrological processes in a certain area, which is observed through the flow coefficient, and the amount and hydrographical characters of water flow (Latuamury et al. 2012; Romlah et al. 2018). Regardless of its form, vegetation such as tree communities or grassland has a great potential to prevent erosion and drought (Maridi et al. 2015), and to also reduce pollution in the water body (Sancayaningsih and Mosyaftiani 2015; Xiao and Mcpherson 2016), improve organic contents repair physical properties of the soil, and decrease landslide risks up to minimum level (Zhang et al. 2015).

Land-use change to other uses has caused environmental problems in Indonesia's watersheds, such as flooding and erosion, as happened in the Ciliwung watershed. The forest area had a decreasing trend while the settlements had increased. This land-use change had an impact of reducing infiltration capacity, which resulted in flooding downstream from Ciliwung to Jakarta (Ali et al. 2016). This was because the amount of forest was no longer at least 30% as required in Indonesia's Law No. 26 of 2007 concerning spatial planning. This also happened in Batang Mahat watershed. The upstream area of Batang Mahat riparian experienced deforestation up to 23% between 1999 to 2010 where forests have been converted into plantations, settlements, and other forms of use. This alteration of land use is estimated to play a role in causing flooding (Rusman et al. 2017).

The Batang Mahat riparian is an important watershed area in Lima Puluh Kota District that provides water intake for Koto Panjang Hydropower Plant that supplies electricity for West Sumatra and Riau Provinces. Recently, this area has been reported to experience regular flooding during the rainy season leading to economic and physical loss, as well as deaths.

The majority of the upstream area is located in the Nagari (or village) of Baruah Gunung, Bukit Barisan sub-district, Lima Puluh Kota District. This village is widely known as the producer of tobacco and oranges in West Sumatra. However, there is no new information regarding the forest condition in this upstream area. Therefore, this study aims to explore the structure and composition of vegetation in the upstream area of Batang Mahat in relation to the proper management needed for this area.

MATERIALS AND METHODS

Study area

This study was conducted on September - December 2020 at near springwater at the upstream area Batang Mahat at Jorong Kubu Baru, Nagari Baruah Gunuang, Bukit Barisan Subdistrict, Lima Puluh Kota District, West Sumatra, Indonesia as shown in Figure 1. Temperature range was 21.9-25.9, humidity was 48-77 and rainfall was 51-362.3 (climatology station of Politeknik Pertanian Negeri Payakumbuh 2020) with an elevation between 800-1000 m asl.

Procedure

Sampling was implemented using three 20x50 m belt transects, established with 10m space between one another. The transect was divided into ten plots to facilitate data collection, and each tree within the plot was sampled, while the saplings were collected alternately from within the transect, with a total of five plots in one transect. Standard taxonomical plant samples were taken for trees and saplings and were then identified at Herbarium Universitas Andalas, Padang, Indonesia.

Data analysis

Vegetation analyses were conducted through the implementation of the following formulas (Mueller-Dombois and Ellenberg (1974); Maridi et al. (2014).

$$\text{Dominance} = \frac{Total\ basal\ area\ for\ a\ species}{Total\ sampling\ area}$$

$$\text{Relative Dominance (RD)} = \frac{Dominance\ of\ Species\ i}{Dominance\ of\ all\ species}\ x\ 100\%$$

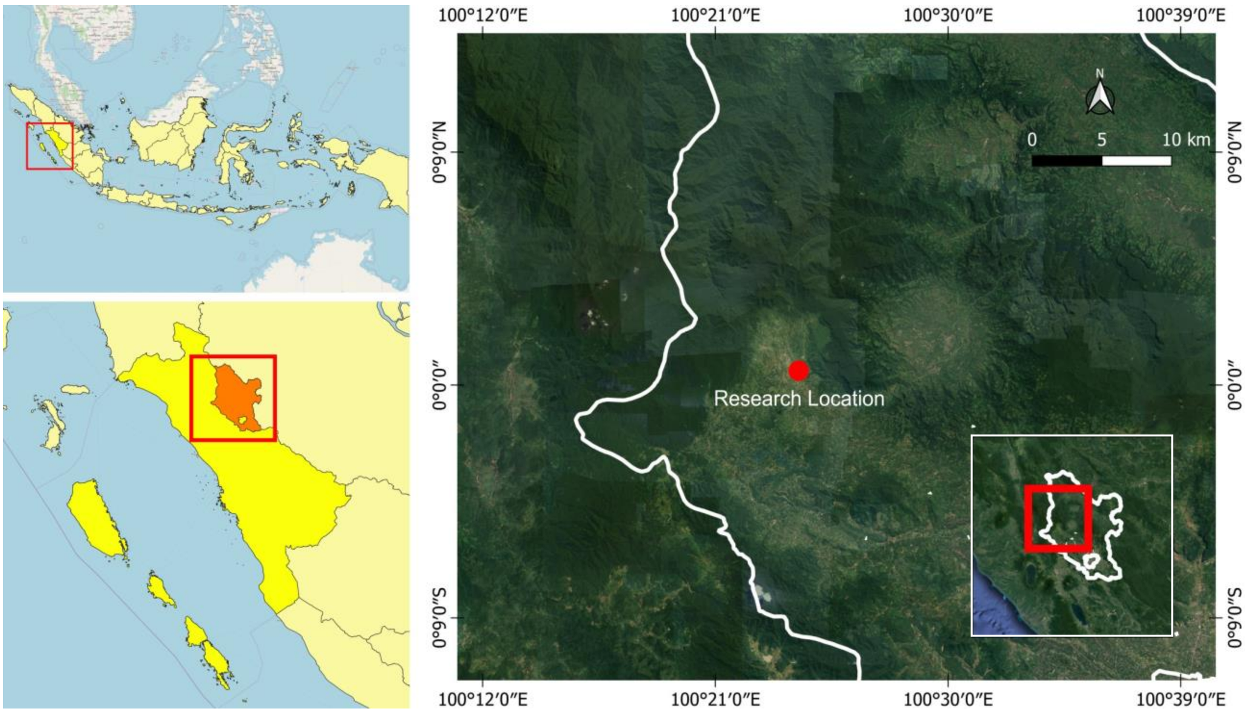

Figure 1. Research area in the upper area of Batang Mahat Watershed, Lima Puluh Kota District, West Sumatra, Indonesia based on landcover condition

The width of the basal area is calculated using tree diameter, with the formula πr^2 or $1/4\pi D^2$ where D = tree diameter.

$$\text{Frequency} = \frac{n\ plot\ for\ species\ i}{Total\ plot}$$

$$\text{Relative frequency (RF)} = \frac{Frequency\ of\ species\ i}{Frequency\ of\ all\ species} x\ 100\%$$

$$\text{Density} = \frac{Total\ individu\ of\ species\ i}{Plot\ width}$$

$$\text{Relative Density (RDen)} = \frac{Density\ of\ species\ 1}{Total\ Density} x 100\%$$

$$\text{Importance Value Index (IVI)} = \text{RD} + \text{RF} + \text{RDen}$$

$$\text{Shannon Wiener Diversity Index (H')} = -\sum_i^s pi \ln pi$$

$$\text{pi} = \frac{ni}{N}$$

$$\text{Evenness Index (E)} = \text{H' x log S}^{-1}$$

Where n_i = IVI of species I, N = total IVI for all species, S = number of total species

RESULT AND DISCUSSION

Species recorded at upstream area of Batang Mahat

Totally 341 individuals were observed in all transect plots. This study identified 116 tree species from 41 families at the upstream area of Batang Mahat. In addition, three unidentified tree species were found as listed below in Table 1.

Table 1 shows that Fagaceae, with a total of 16 species, is the most abundant species and the presence of *Schima wallichii* suggests that the study area is a sub-montane rainforest (Susanto 2012). A previous study reported that species from Fagaceae and Lauraceae were mostly founded in lowland rainforest (Karnawinata 2013). Furthermore, both Fagaceae and Lauraceae were founded in tropical rainforests in Gamboa, Panama (Jemines et al. 2016) as well as in Southeast Asian countries. Aside from *S. wallichii*, other species, including *Lithocarpus* spp., *Palaquium* spp., and *Querqus* spp. were frequently observed in the study area. The sub-montane forest was usually situated between 1000-1500 m elevation. This is in line with this study where the upstream area was located at 800-1000 m. In addition, the species composition was not different from that in Rimbo Panti forest, West Sumatra (Yusuf et al. 2005), the upstream area of Cianjur watershed (Arrijani et al. 2006), montane zone of Gunung Gede Pangrango National Park, West Java (Arrijani 2008) and Mount Sikincau in Bukit Barisan Selatan, South Lampung (Solihah et al. 2014).

Structure of vegetation

The structure of vegetation means looking at the process of tree regeneration in the forest. Sapling would be more than the tree. This means the forest is in a stable state. The vegetation structure is shown in Figure 2 based on the diameter of the stems.

Figure 2 shows that trees with 10-19.9 cm diameter were more predominant in the three studied transects. Trees less than 20 cm were more prevalent in several types of habitats compared to others with bigger diameters. The inverse J diagram suggests small-diameter trees as the most predominant compared to other categories and is predicted to replace bigger diameter trees during the course of forest succession. The bigger the diameter, the lesser the individual tree that remains in a certain environment. In this study, there were only nine trees with a diameter above 40 cm; these include *Rhodoleia championii*, *Calophylum soulatteri*, *Tristanopsis whiteana*, *Guioa sp*., *Lithocarpus meljeri*, *Castanopis sp.1, S. wallichii*, *Lithocarpus cyclophorus*, and *Lithocarpus rein wardtri*. The condition of stem diameter showed that the vegetation is in a stable condition.

Composition of vegetation all transect at Upstream Area of Batang Mahat

The tree composition in the study area was analyzed using three belt transects and the results in Transect 1 are listed below in Tables 2 and 3.

In Table 2, transect 1, 38 tree species were recorded (Table S1) and the highest IVI was found in *Rhodoleia championii* (63.339%), *Calophylum soulatteri* (23.697%), *Eurya acuminata* (20.342%), *Symplocos rubiqinosa* (19.020%) and *Syzygium* sp 3 (10.753%). There were 16 individuals of *R. championii* within Transect 1, which contributed to the increase of the density, frequency, and dominance. In other words, *R. championii* dominated the area in transect 1, as it had prominent value in all ecological indices tested in this study.

In Transect 2, 34 trees species were recorded (Table S3), the tree species with the highest IVI was *Voacanga foetida* (48.568%), *S. wallichii* (32.756%), *Eurya acaminata* (15.929%), *Castanopis* sp 1 (15.454%), *Guioa* sp (15.412%). Therefore, *Voecanga foetida* was more predominant in transect 2.

Transect 3 had 39 trees species were recorded (Table S5). *Schima wallichii*, *V. foetida, Guioa* sp, *Lithocarpus cyclophorus* and *Castarupsis* cf. *inermis* species had the highest IVI for the tree category with 42.964%, 40.713%, 28.868%, 25.995%, and 11.713% respectively.

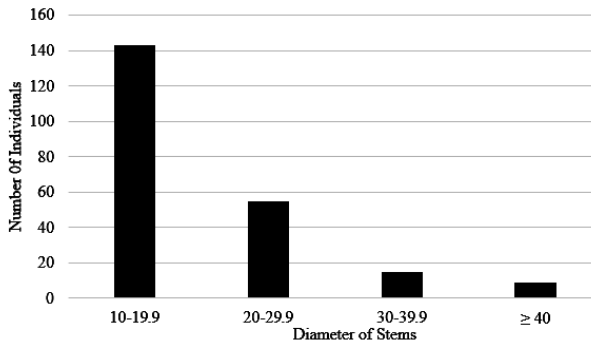

Figure 2. Number individual based on dbh of the stem in all transects at Upstream Area of Batang Mahat Watershed, Lima Puluh Kota District, West Sumatra, Indonesia

Table 1. Species and family of tree recorded at the upstream area of Batang Mahat Watershed, Lima Puluh Kota District, West Sumatra, Indonesia

Family	No. of spesies	Spesies	No. of ind.(s)
Anacardiaceae	2	*Mangifera foetida*	1
		Melanochyla sp.	1
Annonaceae	2	*Alphonsea elliptica*	1
		Xylopia sp.	1
Apocynaceae	2	*Alstonia* sp.	5
		Voacanga foetida	34
Aquifoliaceae	2	*Ilex macrophylla*	1
		Ilex sp.	2
Araliaceae	1	*Arthrophyllum diversifolium*	2
Burseraceae	4	*Canarium littorale*	2
		Santiria apiculata	1
		Santiria rubiginosa	5
		Santiria griffithii	1
Cannabaceae	1	*Gironniera subaequalis*	4
Casuarinaceae	1	*Gymnostoma sumatranum*	3
Clusiaceae	5	*Calophyllum parvifolium*	1
		Calophylum soulattri	6
		Garcinia parvifolia	1
		Garcinia sp. 1	1
		Garcinia sp. 2	1
Cornaceae	1	*Alangium chinense*	1
Ebenaceae	1	*Diospyros* sp.	1
Elaeocarpaceae	6	*Elaeocarpus* cf. *ferrugineus*	6
		Elaeocarpus cupreus	2
		Elaeocarpus floribundus	1
		Elaeocarpus petiolatus	3
		Elaeocarpus sp. 1	1
		Elaeocarpus sp. 2	1
Escalloniaceae	1	*Polyosma illicifolia*	2
Euphorbiaceae	5	*Endospermum diadenum*	2
		Hancea penangensis	9
		Macaranga gigantea	2
		Macaranga lowii	8
		Macaranga pachyphylla	5
Fagaceae	16	*Castanopsis* cf. *inermis*	2
		Castanopsis javanica	2
		Castanopsis sp. 1	1
		Castanopsis sp. 2	1
		Lithocarpus cantleyanus	2
		Lithocarpus conocarpus	2
		Lithocarpus cyclophorus	9
		Lithocarpus elegans	3
		Lithocarpus javensis	3
		Lithocarpus meijeri	4
		Lithocarpus reinwardtii	1
		Lithocarpus sp. 1	1
		Quercus elmeri	7
		Quercus gemelliflora	1
		Quercus subsericea	3
		Quercus oidocarpa	1
Gentianaceae	2	*Fagraea ceilanica*	2
		Fagraea sp.	1
Hamamelidaceae	2	*Exbucklandia populnea*	2
		Rhodoleia championii	20
Ixonanthaceae	1	*Ixonanthes petiolaris*	1
Lamiaceae	2	*Callicarpa* sp.	1
		Vitex vestita	3
Lauraceae	8	*Actinodaphne* sp.	2
		Beilschmiedia sp.	2
		Cinnamomum iners	2
		Cinnamomum sintoc	1
		Endiandra sp.	2
		Litsea grandis	1
		Litsea sp. 1	1
		Litsea sp. 2	1
Leguminosae	2	*Dialium procerum*	1
		Leguminosae sp. 1	1
Magnoliaceae	1	*Magnolia* sp.	1
Malvaceae	1	*Sterculia* sp.	4
Meliaceae	2	*Aglaia* sp.	1
		Lansium sp.	1
Moraceae	3	*Artocarpus kemando*	1
		Artocarpus lakoocha	1
		Ficus sp.	1
Myristicaceae	5	*Gymnacranthera farquhariana*	2
		Horsfieldia brachiata	4
		Horsfieldia polyspherula	2
		Knema latericia	1
		Knema sp.	1
Myrtaceae	12	*Syzygium antisepticum*	1
		Syzygium cymosum	1
		Syzygium muelleri	1
		Syzygium napiforme	1
		Syzygium nigricans	1
		Syzygium racemosum	1
		Syzygium rostratum	1
		Syzygium sp. 1	3
		Syzygium sp. 2	1
		Syzygium sp. 3	3
		Syzygium sp. 4	1
		Tristaniopsis whiteana	2
Pandanaceae	1	*Pandanus* sp	2
Pentaphylacaceae	1	*Eurya acuminata*	11
Phyllanthaceae	2	*Bridelia glauca*	1
		Cleistanthus sp.	2
Polygalaceae	1	*Xanthophyllum obscurum*	2
Primulaceae	1	*Ardisia pterocaulis*	1
Rosaceae	2	*Prunus grisea*	4
		Rosaceae sp. 1	1
Rubiaceae	3	*Porterandia anisophylla*	1
		Tarenna fragrans	1
		Timonius sp.	7
Rutaceae	2	*Melicope hookeri*	6
		Acronychia pedunculata	1
Sabiaceae	1	*Meliosma sumatrana*	1
Sapindaceae	2	*Guioa diplopetala*	1
		Guioa sp.	8
Sapotaceae	3	*Madhuca korthalsii*	3
		Palaquium rostratum	2
		Palaquium sp.	2
Styracaceae	1	*Styrax paralleloneuron*	5
Symplocaceae	2	*Symplocos rubiginosa*	8
		Symplocos sp.	3
Theaceae	3	*Camellia sp.*	1
		Gordonia sp.	2
		Schima wallichii	23
Unidentified	3	Unidentified sp. 1	
Unidentified		Unidentified sp. 2	
Unidentified		Unidentified sp. 3	

Table 2. Tree with the highest Important Value Index (IVI) in transect 1 to transect 3 at Upstream Area of Batang Mahat Watershed, Lima Puluh Kota District, West Sumatra, Indonesia

Transect	Species	Den	RDen (%)	F	RF (%)	D	RD(%)	IVI (%)
1	*Rhodoleia championii*	0.016	20.779	0.800	13.793	8.263	28.767	63.339
	Calophylum soulatteri	0.005	6.494	0.300	5.172	3.456	12.031	23.697
	Eurya acuminata	0.007	9.091	0.400	6.897	1.251	4.355	20.342
	Symplocos rubiqinosa	0.007	9.091	0.300	5.172	1.366	4.757	19.020
	Syzygium sp 3	0.002	2.597	0.200	3.448	1.352	4.707	10.753
2	*Voacanga foetida*	0.010	16.949	1.000	18.868	2.797	12.751	48.568
	Schima wallichii	0.007	11.864	0.500	9.434	2.514	11.458	32.756
	Eurya acaminata	0.004	6.780	0.300	5.660	0.765	3.489	15.929
	Castanopis sp 1	0.001	1.695	0.100	1.887	2.604	11.872	15.454
	Guioa sp	0.001	1.695	0.100	1.887	2.595	11.831	15.412
3	*Schima wallichii*	0.011	13.924	0.500	8.197	6.186	20.843	42.964
	Voacanga foetida	0.016	20.253	0.500	8.197	3.639	12.263	40.713
	Guioa sp	0.007	8.861	0.500	8.197	3.505	11.811	28.868
	Lithocarpus cyclophorus	0.007	8.861	0.400	6.557	3.139	10.577	25.995
	Castarupsis cf. *inermis*	0.002	2.532	0.200	3.279	1.752	5.902	11.713

Note: D: Dominance, RD: Relative Dominance, F: Frequency, RF: Relative Frequency, Den: Density, RDen: Relative Density

Table 3. Sapling with the highest IVI in transect 1 to transect 3 at upstream area of Batang Mahat Watershed, Lima Puluh Kota District, West Sumatra, Indonesia

Transect	Species	Den	RDen (%)	F	RF (%)	D	RD(%)	IVI (%)
1	Timonius sp	0.040	12.500	0.600	8.571	0.644	12.040	33.111
	Alstonia sp	0.024	7.500	0.400	5.714	0.435	8.131	21.345
	Prunus grisea	0.024	7.500	0.600	8.571	0.098	1.826	17.897
	Macaranga pachyphylla	0.008	2.500	0.200	2.857	0.616	11.516	16.873
	Xanthophyllum obscrum	0.008	2.500	0.200	2.857	0.475	8.893	14.250
2	*Hancea pengangensis*	0.056	13.725	0.200	2.632	0.578	8.194	24.551
	Sterculia sp	0.024	5.882	0.600	7.895	0.523	7.421	21.199
	Voacanga foetida	0.024	5.882	0.400	5.263	0.457	6.488	17.633
	Magnolia sp	0.008	1.961	0.200	2.632	0.573	8.130	12.722
	Macaranga lowii	0.024	5.882	0.200	2.632	0.290	4.110	12.624
3	*Voacanga foetida*	0.032	11.765	0.400	6.897	1.306	24.201	42.862
	Macaranga lowii	0.040	14.706	0.400	6.897	0.499	9.241	30.844
	Elaeocarpus sp 1	0.008	2.941	0.200	3.448	0.837	15.505	21.895
	Horsfieldia polypherula	0.016	5.882	0.400	6.897	0.320	5.932	18.711
	Santiria rubiginosa	0.016	5.882	0.400	6.897	0.121	2.246	15.025

Note: D: Dominance; RD: Relative Dominance; F: Frequency; RF: Relative Frequency; Den: Density; RDen: Relative Density

In Table 3, regarding the sapling level, 28 plant species were recorded (Table S2), the highest IVI was found in *Timonius* sp (33.111%), *Alstonia* sp. (21.345%), *Prunus grisea* (17.897%), *Macaranga pachyphylla* (16.873%), and *Xanthophyllum obscrum* (14.250%). Transect 1 was observed to have high diversity for the the tree (H' = 3.20) and sapling (H' = 3.21).

Meanwhile, in the sapling category, *Hancea pengangensis* (24.551%), *Sterculia* sp. (21.199%), *Voacanga foetida* (17.633%), *Magnolia* sp (12.722%), *Macaranga lowii* (12.624%) had the highest IVI in Transect 2. Transect 2 was also categorized with high plant diversity for the tree (H' = 3.20) or sapling (H' = 3.36). The details for this information are shown in Table S4.

In Transect 3, in the sapling category, *V. foetida* (42.862%), *M. lowii* (30.844%), *Elaeocarpus* sp 1 (21.895%), *Horsfieldia polypherula* (18.711%), *Santiria rubiginosa* (15.025%) had the highest IVI. This transect also had high diversity for tree (H' = 3.13) and sapling (H' = 3.04). Table S6 showed the detail of the sapling for Transect 3.

The Ecological important value index (IVI) reflects the dominance of certain plant species within the vegetation community. This index also refers to the adaptability of tree species to the environment and its ecological aspects.

The relative density is a component of IVI used to identify certain species that are superior and dominant over the others in an ecosystem, while the frequency of relative presence shows the distribution of the species in a habitat. Both parameters are good indicators of the species that have a good tolerance for environmental factors such as sunlight, soil, or air humidity. Meanwhile, dominance signifies the superiority of certain species over others, which is indicated in the vegetation community by large tree diameter (Susanto 2012). Aside from this study, *S. wallichii* was also observed to have the highest IVI in the forest of Gunung Gede Pangrango National Park (Arrijani 2008).

The high species similarity between trees and saplings suggests the continuous and constant regeneration within the vegetation community. Therefore, the threat of species loss is reduced in the area. Subsequently, the high species diversity at all study transects signifies the stability of the vegetation community in this area. The three transects were also occupied by mostly uniform tree species, as the evenness indices were closely similar (E1 = 2.025, E2 = 2.089, E3 = 2.016). Meanwhile, since the three transects were located adjacently, the vegetation community had similar species. Studies on the structure and composition of vegetation are conducted to investigate the condition of a forest and provide a reference framework to predict the condition in the next ten years. A previous study reported that the potential dynamics in a forest are anticipated by continuously observing plant species that constitute the vegetation community (Susanto 2012).

A healthy vegetation community has been shown to influence the condition of water management in an area as it slowdowns water runoff and increases underground reserve. In other words, the vegetation community conserves soil and water simultaneously. The frequent flooding and erosion in certain areas indicate indecent vegetation conditions along the watershed (Maridi et al. 2014). Furthermore, the plant roots disrupt the potential of erosion while also reserving groundwater by stabilizing the soil (Mingguo et al. 2007). Even though the woody species richness is reported had no significant connection to soil chemical and physical characteristics (Pourrahmati et al. 2018). Apart from the roots, the canopy also comprises several tree layers that help withstand rainfall and significantly reduce kinetic energy from the running water. Hence, erosion and flooding are prevented.

The vegetation community in the upstream area of Batang Mahat watershed is relatively well-structured, as evidenced by the utilization of Mahat Kuning River, as a water source for three adjacent villages, namely the Nagari of Baruh Gunung, Sungai Naning, and Koto Tangah. Despite this good finding, there are still certain concerns for future destruction in this area, due to the impending extension of tobacco and orange plantations. Consequently, the existence of a decent vegetation community along the watershed of Batang Mahat needs to be prioritized for conservation efforts.

Based on the results, the current condition of the vegetation community in the upstream area of Batang Mahat is not consistent with the frequent flooding and erosion in the adjacent area. Therefore, follow-up studies are needed to identify the root of these environmental problems.

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Table S1. Important Value Index (IVI) for tree in transect 1 at upstream area of Batang Mahat Watershed, West Sumatra, Indonesia

Species	Den	RDen (%)	F	RF (%)	D	RD (%)	IVI (%)
Schima wallichii	0.003	3.896	0.200	3.448	0.406	1.414	8,758
Rhodoleia championii	0.016	20.779	0.800	13.793	8.263	28.767	63,339
Eurya acuminata	0.007	9.091	0.400	6.897	1.251	4.355	20,342
Symplocos rubiqinosa	0.007	9.091	0.300	5.172	1.366	4.757	19,020
Gymnostoma sumatranum	0.002	2.597	0.200	3.448	0.908	3.160	9,205
Alstonia sp	0.001	1.299	0.100	1.724	0.907	3.159	6,182
Syzygium sp 3	0.002	2.597	0.200	3.448	1.352	4.707	10,753
Syzygium sp 1	0.002	2.597	0.100	1.724	0.832	2.898	7,219
Voacanga foetida	0.001	1.299	0.100	1.724	0.133	0.462	3.485
Elaeocarpus cupreus	0.002	2.597	0.200	3.448	0.515	1.792	7.838
Litsea sp	0.001	1.299	0.100	1.724	0.206	0.717	3.740
Quercus subseicea	0.001	1.299	0.200	3.448	0.255	0.888	5.635
Endiandra sp	0.001	1.299	0.100	1.724	0.620	2.158	5.181
Palaquium sp	0.002	2.597	0.100	1.724	1.012	3.523	7.845
Melanochyla sp	0.001	1.299	0.100	1.724	0.117	0.407	3.430
Calophylum soulatteri	0.005	6.494	0.300	5.172	3.456	12.031	23.697
Syzygium nigricans	0.001	1.299	0.100	1.724	0.141	0.491	3.514
Melicope hookeri	0.001	1.299	0.100	1.724	0.079	0.273	3.296
Quercus elmeri	0.001	1.299	0.100	1.724	0.177	0.615	3.638
Santiria rubiginosa	0.001	1.299	0.100	1.724	0.269	0.935	3.958
Elaeocarpus cf *ferrugineus*	0.001	1.299	0.100	1.724	0.317	1.104	4.127
Tristanopsis whiteana	0.001	1.299	0.100	1.724	1.885	6.561	9.584
Elaeocarpus floribundus	0.001	1.299	0.100	1.724	0.113	0.394	3.416
Garcinia parvifolia	0.001	1.299	0.100	1.724	0.272	0.945	3.968
Lithocarpus meijeri	0.001	1.299	0.100	1.724	0.419	1.458	4.481
Lithocarpus cyclophorus	0.001	1.299	0.100	1.724	0.560	1.948	4.971
Quercus gemelliflora	0.001	1.299	0.100	1.724	0.669	2.330	5.353
Porterandia anisophylla	0.001	1.299	0.100	1.724	0.119	0.413	3.436
Gordonia sp	0.001	1.299	0.100	1.724	0.092	0.319	3.342
Mangifera foetida	0.001	1.299	0.100	1.724	0.333	1.160	4.183
Xylopia sp	0.001	1.299	0.100	1.724	0.184	0.640	3.663
Styrax paralleloneuron	0.002	2.597	0.200	3.448	0.301	1.046	7.092
Rosaceae sp1	0.001	1.299	0.100	1.724	0.125	0.434	3.457
Dialium procerum	0.001	1.299	0.100	1.724	0.456	1.587	4.610
Macaranga pachyphylla	0.001	1.299	0.100	1.724	0.090	0.313	3.336
Arthrophyllum diversifolium	0.001	1.299	0.100	1.724	0.152	0.528	3.551
Macaranga gigantea	0.001	1.299	0.100	1.724	0.246	0.856	3.879
Lithocarpus cantleyanus	0.001	1.299	0.100	1.724	0.131	0.455	3.478
Total	0.077	100.00	5.800	100,00	28.725	100.00	300.00

Table S2. Important Value Index (IVI) for saplings in transect 1 at upstream area of Batang Mahat Watershed, West Sumatra, Indonesia

Species	Den	RDen (%)	F	RF (%)	D	RD (%)	IVI (%)
Xanthophyllum obscrum	0.008	2.500	0.200	2.857	0.475	8.893	14.250
Alstonia sp	0.024	7.500	0.400	5.714	0.435	8.131	21.345
Horsfieldia brachiata	0.008	2.500	0.200	2.857	0.096	1.787	7.144
Garcinia sp	0.008	2.500	0.200	2.857	0.073	1.358	6.715
Bellschmiedia sp	0.008	2.500	0.200	2.857	0.127	2.379	7.736
Tristanopsis whiteana	0.008	2.500	0.200	2.857	0.176	3.300	8.658
Hancea penangensis	0.016	5.000	0.200	2.857	0.124	2.318	10.175
Syzygium sp 3	0.008	2.500	0.200	2.857	0.030	0.569	5.926
Lansium sp	0.008	2.500	0.200	2.857	0.335	6.261	11.618
Syzygium sp 4	0.008	2.500	0.200	2.857	0.249	4.663	10.020
Syzygium antisepticum	0.008	2.500	0.200	2.857	0.073	1.358	6.715
Styrax paralleloneuron	0.008	2.500	0.200	2.857	0.042	0.794	6.151
Alphonsea elliptica	0.008	2.500	0.200	2.857	0.100	1.880	7.237
Quercus elmeri	0.008	2.500	0.200	2.857	0.073	1.358	6.715
Pandanus sp	0.016	5.000	0.200	2.857	0.357	6.685	14.542
Santiria rubiginosa	0.008	2.500	0.200	2.857	0.086	1.609	6.966
Calophylum soulattri	0.008	2.500	0.200	2.857	0.454	8.489	13.846
Syzygium muelleri	0.008	2.500	0.200	2.857	0.091	1.697	7.054
Guioa diplopetala	0.008	2.500	0.200	2.857	0.064	1.203	6.560
Camellia sp	0.008	2.500	0.200	2.857	0.151	2.821	8.178
Rhodoleia championii	0.016	5.000	0.400	5.714	0.121	2.257	12.971
Timonius sp	0.040	12.500	0.600	8.571	0.644	12.040	33.111
Prunus grisea	0.024	7.500	0.600	8.571	0.098	1.826	17.897
Melicope hookeri	0.016	5.000	0.400	5.714	0.064	1.203	11.917
Bridelia glauca	0.008	2.500	0.200	2.857	0.068	1.280	6.637
Ardisia pterocaulis	0.008	2.500	0.200	2.857	0.081	1.523	6.880
Tarenna fragrans	0.008	2.500	0.200	2.857	0.042	0.794	6.151
Macaranga pachyphylla	0.008	2.000	0.200	2.857	0.616	11.516	16.873
Total	0.320	100.000	7.000	100.000	5.345	99.992	299.992

Note: D: Dominance; RD: Relative Dominance; F: Frequency; RF: Relative Frequency; Den: Density; RDen: Relative Density

Table S3. Important Value Index (IVI) for tree in transect 2 at upstream area of Batang Mahat Watershed, West Sumatra, Indonesia

Species	Den	RDen (%)	F	RF (%)	D	RD (%)	IVI (%)
Voacanga foetida	0.010	16.949	1.000	18.868	2.797	12.751	48.5683
Santiria rubiginosa	0.001	1.695	0.100	1.887	0.506	2.309	5.8903
Calophyllum parvifolium	0.001	1.695	0.100	1.887	0.611	2.785	6.3671
Rhodoleia championii	0.001	1.695	0.100	1.887	0.292	1.333	4.9146
Elaeocarpus cf *ferrugineus*	0.002	3.390	0.200	3.774	0.389	1.774	8.9377
Schima wallichii	0.007	11.864	0.500	9.434	2.514	11.458	32.7564
Quercus subsericea	0.001	1.695	0.100	1.887	0.131	0.595	4.1772
Elaeocarpus sp 1	0.001	1.695	0.100	1.887	0.408	1.860	5.4418
Exbuklandia populnea	0.001	1.695	0.100	1.887	0.568	2.589	6.1710
Lithocarpus javanensis	0.001	1.695	0.100	1.887	0.356	1.623	5.2051
Arthocarpus conocarpus	0.001	1.695	0.100	1.887	0.209	0.951	4.5324
Styrax parallel loneuron	0.001	1.695	0.100	1.887	0.201	0.916	4.4977
Lithocarpus elegans	0.003	5.085	0.300	5.660	0.992	4.521	15.2659
Macaranga gigantea	0.001	1.695	0.100	1.887	0.088	0.402	3.9838
Meliosma sumatrana	0.001	1.695	0.100	1.887	0.201	0.916	4.4977
Lithocarpus cantleyanus	0.001	1.695	0.100	1.887	0.137	0.623	4.2052
Eurya acaminata	0.004	6.780	0.300	5.660	0.765	3.489	15.9292
Litsea grandis	0.001	1.695	0.100	1.887	0.100	0.457	4.0386
Elaeocarpus petiolatus	0.002	3.390	0.200	3.774	0.811	3.695	10.8588
Guioa sp	0.001	1.695	0.100	1.887	2.595	11.831	15.4123
Castanopis sp.2	0.001	1.695	0.100	1.887	0.127	0.577	4.1588
Macaranga pachphylla	0.002	3.390	0.100	1.887	0.498	2.271	7.5480
Artocarpus lakoocha	0.001	1.695	0.100	1.887	0.502	2.290	5.8721
Palaquium rostratum	0.001	1.695	0.100	1.887	0.174	0.794	4.3761
Symplocos rubiginosa	0.001	1.695	0.100	1.887	0.240	1.096	4.6776
Symplocos sp	0.002	3.390	0.100	1.887	0.135	0.614	5.8907
Cinnamomun sintoc	0.001	1.695	0.100	1.887	0.119	0.541	4.1231
Lithocarpus meljeri	0.002	3.390	0.100	1.887	1.507	6.871	12.1478
Leguminosae sp 1	0.001	1.695	0.100	1.887	0.531	2.419	6.0006
Quercus elmeri	0.001	1.695	0.100	1.887	0.441	2.010	5.5916
Castanopis sp.1	0.001	1.695	0.100	1.887	2.604	11.872	15.4535
Alangium chinense	0.001	1.695	0.100	1.887	0.115	0.524	4.1056
Melicope hookeri	0.001	1.695	0.100	1.887	0.088	0.402	3.9838
Endospermum diadenum	0.001	1.695	0.100	1.887	0.184	0.838	4.4193
Total	0.059	100.000	5.300	100.000	21.938	100.000	299.9997

Table S4. Important Value Index (IVI) for sapling in transect 2 at Upstream Area of Batang Mahat Watershed, West Sumatra, Indonesia

Species	Den	RDen (%)	F	RF (%)	D	RD (%)	IVI (%)
Madhuca korthalsii	0.024	5.882	0.200	2.632	0.191	2.707	11.221
Hancea pengangensis	0.056	13.725	0.200	2.632	0.578	8.194	24.551
Macaranga lowii	0.024	5.882	0.200	2.632	0.290	4.110	12.624
Vitex vestita	0.024	5.882	0.200	2.632	0.290	4.110	12.624
Voacanga foetida	0.024	5.882	0.400	5.263	0.457	6.488	17.633
Schima wallichii	0.016	3.922	0.400	5.263	0.182	2.580	11.765
Timonius sp	0.016	3.922	0.200	2.632	0.234	3.322	9.875
Elaeocarpus cf.ferruginous	0.008	1.961	0.200	2.632	0.290	4.120	8.712
Sterculia.sp	0.024	5.882	0.600	7.895	0.523	7.421	21.199
Lithocarpus conocarpus	0.008	1.961	0.200	2.632	0.412	5.846	10.438
Ficus sp	0.008	1.961	0.200	2.632	0.226	3.208	7.800
Horsfieldia brachiate	0.008	1.961	0.200	2.632	0.176	2.503	7.095
Knema sp	0.008	1.961	0.200	2.632	0.039	0.557	5.149
Ilex macrophylla	0.008	1.961	0.200	2.632	0.033	0.471	5.064
Xanthophyllum obscurum	0.008	1.961	0.200	2.632	0.053	0.749	5.342
Cleistanthus sp	0.016	3.922	0.400	5.263	0.158	2.238	11.423
Elaeocarpus petiolatus	0.008	1.961	0.200	2.632	0.081	1.155	5.747
Arthocarpus kemando	0.008	1.961	0.200	2.632	0.033	0.471	5.064
Quercus elmeri	0.008	1.961	0.200	2.632	0.064	0.912	5.505
Beilschmiedia sp	0.008	1.961	0.200	2.632	0.039	0.557	5.149
Gymnacranthera farguhariana	0.008	1.961	0.200	2.632	0.290	4.120	8.712
Syzygium sp	0.008	1.961	0.200	2.632	0.060	0.856	5.449
Melicope hookeri	0.008	1.961	0.200	2.632	0.133	1.885	6.478
Symplocos sp 1	0.008	1.961	0.200	2.632	0.282	4.000	8.592
Polyosma illicifolia	0.008	1.961	0.200	2.632	0.064	0.912	5.505
Diospyros sp	0.008	1.961	0.200	2.632	0.282	4.000	8.592
Magnolia sp	0.008	1.961	0.200	2.632	0.573	8.130	12.722
Arthrophyllum diversifolium	0.008	1.961	0.200	2.632	0.111	1.572	6.164
Gironniera subaequalis	0.008	1.961	0.200	2.632	0.363	5.147	9.739
Syzygium napiforme	0.008	1.961	0.200	2.632	0.170	2.409	7.002
Alstonia sp	0.008	1.961	0.400	5.263	0.137	1.939	9.163
Aglaia sp	0.008	1.961	0.200	2.632	0.234	3.316	7.908
Total	0.408	100.000	7.600	100.00	7.048	100.000	300.000

Note: D: Dominance; RD: Relative Dominance; F: Frequency; RF: Relative Frequency; Den: Density; RDen: Relative Density

Table S5. Important Value Index (IVI) for tree in transect 3 at upstream area of Batang Mahat Watershed, West Sumatra, Indonesia

Species	Den	RDen (%)	F	RF (%)	D	RD (%)	IVI (%)
Voacanga foetida	0.016	20.253	0.500	8.197	3.639	12.2626	40.713
Schima wallichii	0.011	13.924	0.500	8.197	6.186	20.8431	42.964
Lithocarpus cyclophorus	0.007	8.861	0.400	6.557	3.139	10.5773	25.995
Ilex sp	0.001	1.266	0.100	1.639	0.113	0.3809	3.286
Rhodoleia championii	0.001	1.266	0.100	1.639	0.263	0.8858	3.791
Sterculia sp	0.001	1.266	0.100	1.639	0.129	0.4334	3.339
Canarium littorak	0.002	2.532	0.200	3.279	0.097	0.3271	6.137
Guioa sp	0.007	8.861	0.500	8.197	3.505	11.8108	28.868
Endiandra sp	0.001	1.266	0.100	1.639	0.090	0.3028	3.208
Macaranga pachyphylla	0.001	1.266	0.200	3.279	0.237	0.7988	5.343
Quercus subsericea	0.001	1.266	0.400	6.557	0.516	1.7386	9.562
Gymnostoma sumatranum	0.001	1.266	0.100	1.639	0.219	0.7377	3.643
Fragrae ceilanica	0.001	1.266	0.100	1.639	0.174	0.5872	3.492
Elaeocapus sp 2	0.001	1.266	0.200	3.279	0.792	2.6670	7.211
Elaeocarpus cf. *ferrugineus*	0.002	2.532	0.100	1.639	0.609	2.0524	6.223
Styrax paralle loneuron	0.001	1.266	0.100	1.639	0.095	0.3201	3.225
Quercus elmeri	0.002	2.532	0.200	3.279	0.374	1.2617	7.072
Quercus oldocarpa	0.001	1.266	0.100	1.639	0.097	0.3259	3.231
Endospermum dindenum	0.001	1.266	0.100	1.639	0.804	2.7085	5.614
Fagraea sp	0.001	1.266	0.100	1.639	0.154	0.5184	3.424
Garcinia sp2	0.001	1.266	0.100	1.639	0.317	1.0686	3.974
Exbuklandia populnea	0.001	1.266	0.100	1.639	0.585	1.9713	4.877
Gironniera subequalis	0.002	2.532	0.200	3.279	0.462	1.5553	7.366
Knema latericia	0.001	1.266	0.100	1.639	0.154	0.5184	3.424
Actinodaphne sp	0.001	1.266	0.100	1.639	0.387	1.3036	4.209
Lithocarpus sp1	0.001	1.266	0.100	1.639	0.502	1.6931	4.598
Lithocarpus meijeri	0.001	1.266	0.100	1.639	0.539	1.8157	4.721
Syzygium cymosum	0.001	1.266	0.100	1.639	0.087	0.2916	3.197
Ixonanthes petiolaris	0.001	1.266	0.100	1.639	0.117	0.3937	3.299
Castarupsis cf. *inermis*	0.002	2.532	0.200	3.279	1.752	5.9023	11.713
Cinnamomum inver	0.001	1.266	0.100	1.639	0.079	0.2645	3.170
Castaropsis javanica	0.002	2.532	0.200	3.279	1.435	4.8337	10.644
Lithocarpus rein wardtri	0.001	1.266	0.100	1.639	1.332	4.4898	7.395
Lithocarpus javensis	0.001	1.266	0.100	1.639	0.415	1.3992	4.304
Callicarpa sp	0.001	1.266	0.100	1.639	0.135	0.4539	3.359
Elaeocarpus floribundus	0.001	1.266	0.100	1.639	0.149	0.5037	3.409
Total	0.079	100.000	6.100	100.000	29.678	99.999	299.999

Table S6. Important Value Indeks (IVI) for sapling in transect 3 at upstream area of Batang Mahat Watershed, West Sumatra, Indonesia

Species	Den	RDen (%)	F	RF (%)	D	RD (%)	IVI (%)
Voacanga foetida	0.032	11.765	0.400	6.897	1.306	24.201	42.862
Macaranga lowii	0.040	14.706	0.400	6.897	0.499	9.241	30.844
Lithocarpus cyclophorus	0.008	2.941	0.200	3.448	0.249	4.618	11.008
Horsfieldia polypherula	0.016	5.882	0.400	6.897	0.320	5.932	18.711
Litsea sp	0.008	2.941	0.200	3.448	0.064	1.192	7.581
Santiria apiculata	0.008	2.941	0.200	3.448	0.170	3.146	9.536
Ilex sp	0.008	2.941	0.200	3.448	0.077	1.425	7.815
Lithocarpus javanensis	0.008	2.941	0.200	3.448	0,053	0.979	7.368
Elaeocarpus sp 1	0.008	2.941	0.200	3.448	0.837	15.505	21.895
Santiria rubiginosa	0.016	5.882	0.400	6.897	0.121	2.246	15.025
Fagraea ceilanica	0..008	2.941	0.200	3.448	0.036	0.670	7.060
Santiria griffthii	0.008	2.941	0.200	3.448	0.170	3.146	9.536
Gordonia sp	0.008	2.941	0.200	3.448	0.057	1.047	7.437
Acronychia pendunculata	0.008	2.941	0.200	3.448	0.060	1.118	7.508
Palaguium rostratum	0.008	2.941	0.200	3.448	0.091	1.680	8.070
Actinodaphne sp	0.008	2.941	0.200	3.448	0.033	0.616	7.005
Syzygium racemosum	0.008	2.941	0.200	3.448	0.204	3.781	10.170
Gironniera subcaequalis	0.008	2.941	0.200	3.448	0.326	6.032	12.422
Syzygium rostratum	0.008	2.941	0.200	3.448	0.060	1.118	7.508
Gymnacranthera farguhariana	0.008	2.941	0.200	3.448	0.081	1.508	7.897
Quercus elmeri	0.008	2.941	0.200	3.448	0.249	4.618	11.008
Cinnamomum iners	0.008	2.941	0.200	3.448	0.046	0.848	7.238
Melicope hookeri	0.008	2.941	0.200	3.448	0.190	3.520	9.909
Prunus grisea	0.008	2.941	0.200	3.448	0.064	1.192	7.581
Polyosma illicifolia	0.008	2.941	0.200	3.448	0.033	0.616	7.005
Total	0.272	100.000	5.800	100.000	5.397	99.996	299.996

Note: D: Dominance; RD: Relative Dominance; F: Frequency; RF: Relative Frequency; Den: Density; RDen: Relative Density