TREE COMMUNITIES AND ABOVEGROUND BIOMASS IN THE SUBMONTANE ZONE OF KETAMBE RESORT, MOUNT LEUSER NATIONAL PARK, ACEH

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Abstract: Mount Leuser National Park is one of the largest conservation areas and plays important ecological and economic functions. To support forest management, it is important to gain current vegetation data. The sampling method of a 0.1 hectare plot was carried out on two sampling sites in the submontane zone of Ketambe Resort, Mount Leuser National Park, Aceh. The diversity of trees was not significantly different, while species composition was different. Site one was dominated by *Syzygium* spp. and *Shorea platyclados*, while site two was dominated by *Altingia excelsa* and *Bridelia glauca*. Lauraceae, Myrtaceae, and Dipterocarpace families dominated in both sites. Tree structures formed three strata and showed a good capacity for forest regeneration. The aboveground biomass of site one was higher than site two due to the presence of more large trees. Pioneer species, cultivated plants, a low average wood density, and low aboveground biomass indicated secondary forest characteristics in both sites.

Keywords: secondary forest; biomass; conservation

Abstrak: Taman Nasional Gunung Leuser merupakan salah satu kawasan konservasi yang terluas dan memiliki fungsi ekologi dan ekonomi yang penting. Data vegetasi terkini penting didapatkan untuk mendukung pengelolaan hutan. Metode sampling dengan plot 0,1 hektar dilakukan di dua lokasi pada zona submontana Resort Ketambe, Taman Nasional Gunung Leuser, Aceh. Keanekaragaman jenis pohon tidak berbeda secara nyata sementara komposisi jenis berbeda. Lokasi satu didominasi oleh *Syzygium* spp. dan *Shorea platyclados*, sementara lokasi dua didominasi oleh *Altingia excelsa* dan *Bridelia glauca*. Suku Lauraceae, Myrtaceae dan Dipterocarpace mendominasi pada kedua lokasi. Struktur pohon membentuk tiga strata dan menunjukkan kemampuan regenerasi hutan yang baik. Biomassa pohon di atas permukaan pada lokasi satu lebih tinggi dibandingkan lokasi dua karena lebih banyaknya pohon berukuran besar. Jenis pionir, tanaman budidaya, rata-rata berat jenis kayu dan biomassa di atas permukaan yang rendah mengindikasikan karakteristik hutan sekunder pada kedua lokasi.

Kata kunci: hutan sekunder; biomassa; konservasi

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Introduction

Sumatra Island is a region with high a diversity and endemicity of flora in western Indonesia (Mambrasar et al., 2019), or as known as a biodiversity hot spot (Hrdina & Romportl, 2017). On the other hand, the ecosystem of Sumatra island is categorized as critical and a global conservation priority (Kelman, 2013; Tsujino et al., 2016). Deforestation and illegal logging become threats for the sustainability of flora and ecosystem in Sumatra island (Laumonier et al., 2010; Margono et al., 2012; Poor et al., 2019). Meanwhile, forest degradation in Sumatra from 2000 to 2012 reached 2.9 million hectares and had expanded into conservation areas (Margono et al., 2014). One of the largest conservation areas with a high diversity of flora and ecosystem types in Sumatra island is Mount Leuser National Park (Global Conservation, 2020; TNGL, 2020).

Mount Leuser National Park (MLNP) plays an important role in both ecological and economical functions (Onrizal & Auliah, 2020). Because of these functions, this area has been decided as a Leuser Biosphere Reserve and UNESCO World Heritage Site (Global Conservation, 2020). This park is also a habitat for endemic and threatened fauna and flora, including orangutans, tigers, rhinos, elephants and leopard cats (Collins, 2018; Pusparini et al., 2014; TNGL, 2020).

Ketambe Resort is one of the important sites in MLNP ranging from lowland to submontane zone ecosystem. Laumonier (1997) proposed altitudinal zonation of the Sumatran vegetation at 800-1,400 m a.s.l as a submontane zone. This area is important to study because it is a transition zone from lowland to mountain ecosystem (Dossa et al., 2013; Richards, 1997). Mount Leuser National Park also faced habitat degradation due to illegal logging in the past, shifting cultivation, deforestation, forest fragmentation, mining and forest encroachment (Aththorick et al., 2012; Global Conservation, 2020; Rantona et al., 2019; Samsoedin & Heriyanto, 2010). Studies of vegetation in this area were more focused on lowland ecosystem due to its importance as an orangutan habitat (Amelia et al., 2019; Onrizal & Auliah, 2020). Meanwhile, the latest information about the submontane vegetation conditions is still limited (TNGL, 2020).

This study aims to compare and analyze tree communities and aboveground biomass below and above 1,000 m a.s.l in the submontane zone of Ketambe Resort, MLNP. Tree communities and aboveground biomass can represent vegetation data (Dossa et al., 2013). The latest vegetation data is important to support forest management policies (Onrizal & Auliah, 2020). These data can be used to monitor forest dynamic, degradation level of vegetation and biodiversity lost (Motz et al., 2010). The management can use this information to determine the next step in forest management for example increased protection, change of zone status, and habitat restoration.

Methods

Study area and period

The study was conducted during April 2018 in the submontane zone of Ketambe Resort, Mount Leuser National Park, Aceh Province (figure 1). The MLNP area covers 1,095,592 ha and situated at 96º35"-98º30" E and 2º50"-4º10" N. The climate of MLNP is wet and type A according to the Schmidt and Ferguson classification. Ketambe resort is located in Southeast Aceh with annual rainfall ranges from 2000 mm to 3200 mm and 21.1 °C to 27.5 °C air temperature, while air humidity ranges from 80 % to 100 % (TNGL, 2020).

Figure 1. The study site was located in the submontane zone of Ketambe Resort, Mount Leuser National Park, Aceh (TNGL 2020)

Data collection

Two sampling plots were 0.1 hectares and divided into ten subplots (10 x 10 m^2 in size). The size of the sampling plot referred to Yorks and Dabydeen (1998) and Arellano et al. (2016). The plots were located in the submontane zone of Ketambe Resort, MLNP. Site one was situated at 850-877 m a.s.l, while site two at 1,016-1,070 m a.s.l. All tree species with the diameter at breast height (dbh) $\geq$ 10 cm inside the sampling plot were recorded, including tree species, tree families, individual number, dbh, tree height and crown coverage.

Data analysis

Shannon-Wiener and Evenness index (Magurran, 1988) were used to calculated diversity following this formula:

$$H = -\Sigma pi * lnpi \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$E = \frac{H}{lnS} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

H = diversity index
pi = the proportion of each species in the sample
E = evenness index
S = number of species.

A species-area curve was simulated using EstimateS ver. 9.1.0 (Colwell, 2013). Tree composition was analyzed using the Jaccard similarity index, the important value index (Mueller-Dombois & Ellenberg, 1974) and the family importance value (Mori et al., 1983) . We used the Jaccard index to evaluate similarities between two site following this formula:

$$SJ = \frac{a}{a+b+c} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

S_J = Jaccard similarity coefficient,
a = number of species common to (shared by) quadrats,
b = number of species unique to the first quadrat, and
c = number of species unique to the second quadrat

Important value index (IVI) was calculated using the formula:

$$IVI = RF + RDe + RDo \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

$$RF = \frac{frequency of a species}{frequency of all species} \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

$$RDe = \frac{density of a species}{density of all species} \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

$$RDo = \frac{dominancy of a species}{dominancy of all species} \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

IVI = important value index
RF = Relative frequency
RDe = Relative density
RDo = Relative dominancy

Family important value (FIV) is used to analysis families composition using the formula:

$$FIV = FRDi + FRDe + FRDo \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

FIV = Family important value
FRDi = Family relative diversity
FRDe = Family relative density

FRDo = Family relative dominance

Average wood density was used to identify succession status of the forest. The site was predicted as a secondary forest if the average wood densities were lower than 0.70 g cm^{-3} (Slik et al., 2008). Stratification of trees was illustrated with profile diagram covering 10 x 100 m^2 (Richards, 1997) and divided into three strata, consisting stratum A (tree height > 30 m), stratum B (tree height 15-30 m) and stratum C (tree height < 15m). Aboveground biomass was estimated for wet forest stand (Chave et al., 2005), with the formula:

$$AGBest = \rho + exp\left(-1.239 + 1.980ln(D) + 0.207\left(ln(D)\right)^2 - 0.0281\left(ln(D)\right)^3\right) \text{...(9)}$$

AGB_{est} = Aboveground Biomass estimation (Mg/ha)
D = diameter (m)
Wood density was obtained from ICRAF database (ICRAF, 2020)

Result and Discussion

Summary of the study

The species richness of trees ≥ 10 cm dbh on two sampling plot was 43 species belonging to 34 genera and 21 families. A summary and comparison of two sampling plot are presented in table 1, while the tree species composition is shown in table 2.

Table 1. Summary and comparison of two sampling plot in the submontane zone of Ketambe Resort, Mount Leuser National Park, Aceh with another study in the mountain forest of western Indonesia

Parameters	Site one, Mt. Leuser National Park	Site two, Mt. Leuser National Park	Mt. Pangrango (Yamada, 1975)	Mt. Kerinci (Sulistyawati et al., 2018)
Area (ha)	0.1	0.1	1	1
Altitude (m a.s.l)	850-877	1,016-1,070	1,600	2,182-2,258
Minimum dbh (cm)	10	10	10	10
Species richness	28	28	57	28
Number of genera	24	21	-	-
Number of families	18	15	30	20
Shannon-Wiener	3.17	3.14	3.55	2.89
Evenness index	0.95	0.94	-	-
Jaccard similarity	0.24	0.24	-	-

Parameters	Site one, Mt. Leuser National Park	Site two, Mt. Leuser National Park	Mt. Pangrango (Yamada, 1975)	Mt. Kerinci (Sulistyawati et al., 2018)
Density (ind./ha)	480	540	427	570
Average dbh (cm)	33.95 ± 47.998	20.99 ± 12.08	-	27.02
Average height (m)	22.13 ± 10.60	21.96 ± 7.51	-	-
Basal area (m^2/ha)	127.95	89.011	52.2	51.45
Aboveground biomass (Mg/ha)	253.19	41.76	-	463.13

Tree Diversity

Species richness of tree in two sampling sites was not different. This result is similar to Sulistyawati et al. (2018) but lower Yamada (1975). Lower species richness in two sampling site could be affected by altitude difference, size of the plot and past threats in Ketambe sampling plot. According to Samsoedin & Heriyanto (2010) and Global Conservation (2020), Mount Leuser National Park was threatened by forest fragmentation, illegal logging activities and forest encroachment. A species area curve was simulated to predict the species richness in two sampling sites (figure 2). The species area curve in two sites reached an asymptote when the number of plot 73 plots and number of species 44 in site one and 45 species in site two. The sampling plot covered 63.93 % in site one and 62.5 % in site two of predicted species richness in the study area. This simulation did not show a significant difference in predicted species richness in both sites. The number of sampling plot must be increased to cover all species richness in study sites (Sulistyawati et al., 2018).

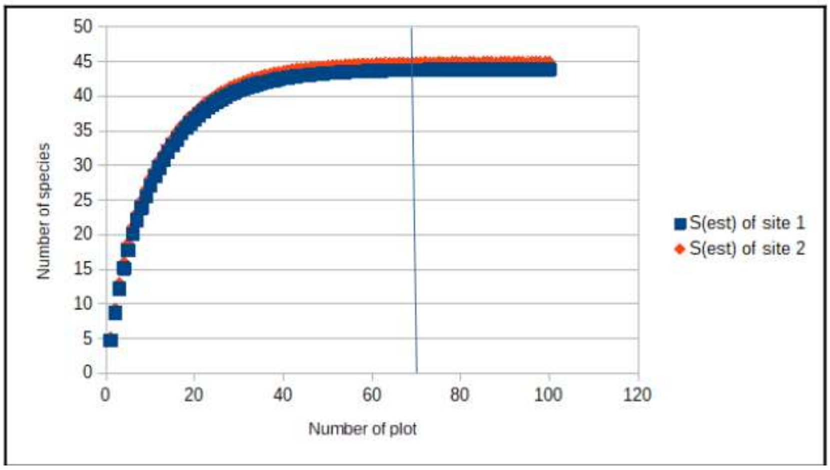


Figure 2. Estimation of species richness using Estimates 9 Windows in two sampling site in the submontane zone of Ketambe Resort, Mount Leuser National Park, Aceh

Even though the species richness was similar to Kerinci plot (Sulistyawati et al., 2018), diversity index in two sampling sites of Ketambe was higher. We predicted the species evenness in Ketambe plots were higher than Kerinci plot and affected this result. Tree abundance of site two was higher than site one but diversity index was not significantly different due to the higher species evenness in site one. Species diversity depends not only on species richness but also on species evenness (Magurran, 1988). Species diversity of two sampling sites were lower than Mount Pangrango plot (Yamada, 1975). Site one and site two were located in the secondary forest while the Mount Pangrango plot was in the primary forest (Yamada, 1975).

Species composition and succession status

Tree species diversity of two sites were not significantly different but the similarity index indicated the difference in species composition. Jaccard similarity index was 0.24 (table 1) and indicated 76 % of dissimilarity of the tree community in two sampling sites. Tree species composition and Important Value Index (IVI) in two sites were shown in table 2 below.

Table 2. Tree species composition, wood densities and important value index of two sampling sites in the submontane zone of Ketambe Resort, Mount Leuser National Park, Aceh

Tree Species	Families	Wood densities (g cm^{-3})*	Site one				Site two			
			RF (%)	RDe (%)	RDo (%)	IVI (%)	RF (%)	RDe (%)	RDo (%)	IVI (%)
Acronychia laurifolia	*Rutaceae*	0.51	1.54	2.08	0.60	4.22	-	-	-	-
Actinodaphne glomerulata	*Lauraceae*	0.59	1.54	2.08	0.83	4.45	-	-	-	-
Aglaia cauliflora	*Meliaceae*	0.76	1.54	2.08	0.60	4.22	2.00	1.85	2.47	6.32
Aglaia sp.	*Meliaceae*	0.76	-	-	-	-	2.00	1.85	0.88	4.73
Altingia excelsa	*Altingiaceae*	0.71	-	-	-	-	6.00	**7.41**	**12.45**	**25.86**
Antidesma montanum	*Phyllanthaceae*	0.66	-	-	-	-	2.00	1.85	1.81	5.66
Beilschmiedia madang	*Lauraceae*	0.51	-	-	-	-	2.00	1.85	1.06	4.91
Bridelia glauca	*Phyllanthaceae*	0.49	1.54	2.08	0.72	4.34	**8.00**	**9.26**	**7.42**	**24.68**
Cinnamomum sintoc	*Lauraceae*	0.56	-	-	-	-	4.00	3.70	3.53	11.23
Citrus hystrix	*Rutaceae*	0.70	-	-	-	-	4.00	3.70	2.42	10.12
Coffea arabica	*Rubiaceae*	0.62	1.54	2.08	0.61	4.23	2.00	1.85	1.06	4.91
Cryptocarya	*Lauraceae*	0.62	2.64	4.17	3.08	9.88	**8.00**	**7.41**	**6.48**	**21.89**

Tree Species	Families	Wood densities (g cm^{-3})*	Site one				Site two			
			RF (%)	RDe (%)	RDo (%)	IVI (%)	RF (%)	RDe (%)	RDo (%)	IVI (%)
ferrea										
Decaspermum fruticosum	*Myrtaceae*	0.71	1.23	2.08	1.54	4.85	-	-	-	-
Diospyros aurea	*Ebenaceae*	0.63	-	-	-	-	2.00	1.85	1.15	5.00
Elaeocarpus pteolaris	*Elaeocarpaceae*	0.52	1.93	4.17	3.08	9.18	-	-	-	-
Endiandra rubescens	*Lauraceae*	0.70	**5.09**	**6.25**	4.62	**15.96**	-	-	-	-
Ficus cuspidata	*Moraceae*	0.48	-	-	-	-	2.00	1.85	0.97	4.82
Ficus drupacea	*Moraceae*	0.44	3.56	2.08	1.54	7.18	2.00	1.85	1.94	5.79
Ficus sp.	*Moraceae*	0.44	-	-	-	-	2.00	1.85	2.66	6.51
Flacourtia rukam	*Salicaceae*	0.87	0.92	2.08	1.54	4.54	-	-	-	-
Garcinia scortechini	*Clusiaceae*	0.80	3.73	**10.42**	**7.69**	**21.84**	4.00	3.70	2.43	10.14
Helicia serrata	*Proteaceae*	0.58	-	-	-	-	2.00	1.85	2.71	6.56
Homalanthus populneus	*Euphorbiaceae*	0.32	2.94	6.25	4.62	13.81	-	-	-	-
Ixora grandifolia	*Rubiaceae*	0.69	-	-	-	-	2.00	1.85	2.73	6.59
Knema laurina	*Myristicaceae*	0.53	1.23	2.08	1.54	4.85	2.00	1.85	1.50	5.35
Litsea cubeba	*Lauraceae*	0.35	1.17	2.08	1.54	4.79	-	-	-	-
Litsea sp.	*Lauraceae*	0.49	3.24	4.17	3.08	10.48	-	-	-	-
Macaranga tanarius	*Euphorbiaceae*	0.48	1.47	4.17	3.08	8.72	6.00	**7.41**	**7.43**	**20.84**
Mallotus sphaerocarpus	*Euphorbiaceae*	0.56	0.67	2.08	1.54	4.30	-	-	-	-
Neolitsea cassiaefolia	*Lauraceae*	0.62	-	-	-	-	2.00	1.85	1.13	4.98
Neolitsea sp.	*Lauraceae*	0.62	-	-	-	-	2.00	1.85	0.97	4.82
Olea javanica	*Oleaceae*	0.70	1.23	2.08	1.54	4.85	-	-	-	-
Phoebe grandis	*Lauraceae*	0.54	-	-	-	-	2.00	1.85	1.94	5.79
Podocarpus neriifolius	*Podocarpaceae*	0.52	3.37	2.08	1.54	6.99	-	-	-	-
Prunus arborea	*Rosaceae*	0.47	2.39	2.08	1.54	6.01	2.00	1.85	1.36	5.21
Shorea ovalis	*Dipterocarpaceae*	0.52	**8.77**	2.08	1.54	12.39	4.00	3.70	3.36	11.06
Shorea platyclados	*Dipterocarpaceae*	0.60	**25.64**	**8.33**	**6.15**	**40.12**	6.00	5.56	**13.04**	24.60

Tree Species	Families	Wood densities (g cm^{-3})*	Site one				Site two			
			RF (%)	RDe (%)	RDo (%)	IVI (%)	RF (%)	RDe (%)	RDo (%)	IVI (%)
Sterculia rubiginosa	*Malvaceae*	0.45	2.02	4.17	3.08	9.27	-	-	-	-
Syzygium pseudomolle	*Myrtaceae*	0.71	0.92	2.08	1.54	4.54	6.00	**7.41**	**6.67**	20.08
Syzygium sp1.	*Myrtaceae*	0.71	5.76	**6.25**	**30.77**	**42.78**	4.00	3.70	3.04	10.75
Syzygium sp2.	*Myrtaceae*	0.71	-	-	-	-	**8.00**	**7.41**	5.39	**20.79**
Syzygium sp3.	*Myrtaceae*	0.71	**15.27**	**6.25**	4.62	**26.14**	-	-	-	-
Turpinia sphaerocarpa	*Staphyleaceae*	0.45	0.74	2.08	1.54	4.36	-	-	-	-

*Source: https://db.worldagroforestry.org/wd.

Important value index showed that site one was dominated by *Syzygium* sp1., *Shorea platyclados, Syzygium* sp3., *Garcinia scortechini* and *Endiandra rubescens.* Site two was dominated by different tree composition, including *Altingia excelsa, Bridelia glauca, Cryptocarya ferrea, Macaranga tanarius* and *Syzygium* sp2. These result indicated tree species composition on site one and two were different. Jaccard similarities index has also explained the difference in trees species composition on both sites (Table 1). The altitude difference and threat level were predicted affecting this result (Dossa et al., 2013; Laumonier, 1997).

The tree species with the lowest IVI in site one was *Acronychia laurifolia* followed by *Aglaia* sp. and *Coffea arabica*. The existence of *Coffea arabica* indicated that site one was used as a cultivation area in the past. Other cultivated plant was *Citrus hystrix* in site two. In site two, the species with the lowest IVI was *Aglaia* sp. followed by *Ficus cuspidata* and *Neolitsea* sp. Species with lower IVI in both sites are more abundant at higher locations (Laumonier, 1997).

Based on the families composition, Lauraceae and Myrtaceae have the highest number of tree species in both sites, followed by Euphorbiaceae and Moraceae. Lauraceae and Myrtaceae families are the richest families in the primary submontane to montane forest of Malesia, as reported by Culmsee et al. (2011) in Lore Lindu Sulawesi and Cahyanto et al. (2019) in Mt. Tilu, West Java. Domination of Moraceae and Euphorbiaceae were characteristic of secondary forest and most of the dominated tree families characterize the mountain ecosystem (Laumonier, 1997; Siregar & Undaharta, 2018).

Family important value (FIV) showed that Lauraceae, Myrtaceae and Dipterocarpace were dominated in both sites (Table 3). Generally, the dominance of Dipterocarpaceae family reflected the lowland rainforest formation (Rahmah et al., 2016), while the higher altitudes forest were represented by Lauraceae and Myrtaceae families (Laumonier, 1997; Sulistyawati et al., 2018). This result added range distribution of Dipterocarpaceae up to lower submontane forest of

Mt. Ketambe. If we compared with the forest vegetation studies in Java Island, Dipterocarpaceae recorded in lowland natural forest, as reported in Bodogol, Gede Pangrango National Park (Helmi et al., 2009), and were not found in the submontane zone, as reported by Cahyanto et al. (2019) in the Mt. Burangrang, Purwaningsih et al. (2017) in Mt. Wilis, and absent in other previous studies in mountain area (Cahyanto et al., 2020; Sulistyawati et al., 2018; Yamada, 1975)

Table 3. Tree Family Important Value (FIV) of two sampling plot in the submontane zone of Ketambe Resort, Mount Leuser National Park, Aceh

Tree Families	Site one				Site two			
	FRDi (%)	**FRDe (%)**	**FRDo (%)**	**FIV (%)**	**FRDi (%)**	**FRDe (%)**	**FRDo (%)**	**FIV (%)**
Altingiaceae	-	-	-	-	3.57	7.41	12.45	23.43
Cluciaceae	3.57	10.42	3.36	17.35	3.57	3.70	2.43	9.71
Dipterocarpaceae	7.14	10.42	31.01	**48.57**	7.14	9.26	16.40	**32.80**
Ebenaceae	-	-	-	-	3.57	1.85	1.15	6.57
Elaeocarpaceae	3.57	4.17	1.74	9.48	-	-	-	-
Euphorbiaceae	10.71	12.50	4.92	28.13	3.57	9.26	7.43	20.26
Lauraceae	17.86	18.75	17.96	**54.56**	21.43	18.52	15.10	**55.05**
Malvaceae	3.57	4.17	0.94	8.68	-	-	-	-
Meliaceae	3.57	2.08	0.60	6.25	7.14	3.70	3.35	14.20
Moraceae	3.57	2.08	3.21	8.86	10.71	5.56	5.57	21.84
Myristicaceae	3.57	2.08	1.11	6.76	3.57	1.85	1.50	6.92
Myrtaceae	14.29	16.67	20.90	**51.85**	10.71	18.52	15.10	**44.34**
Oleaceae	3.57	2.08	1.11	6.76	-	-	-	-
Phyllanthaceae	3.57	2.08	0.72	6.37	7.14	9.26	9.23	25.63
Podocarpaceae	3.57	2.08	3.04	8.70	-	-	-	-
Proteaceae	-	-	-	-	3.57	1.85	2.71	8.13
Rosaceae	3.57	2.08	2.16	7.81	3.57	1.85	1.36	6.78
Rubiaceae	3.57	2.08	0.61	6.26	7.14	3.70	3.79	14.64
Rutaceae	3.57	2.08	0.60	6.25	3.57	3.70	2.42	9.69
Salicaceae	3.57	2.08	5.64	11.29	-	-	-	-
Staphyleaceae	3.57	2.08	0.66	6.32	-	-	-	-

Most of the families can be found on both sites. 13 families can be found on both sites. Elaeocarpaceae, Malvaceae, Oleaceae, Podocarpaceae, Salicaceae and Staphyleaceae were only found in site one, while only three families were only present in site two, including Altingiaceae, Ebenaceae and Proteaceae. The occurrence of Altingiaceae in site two showed the characteristic of mountain forest ecosystem in western Indonesia (Mutaqien & Zuhri, 2011; Sulistyawati et al., 2018; Yamada, 1975). This family was only presented by one species, *Altingia excelsa*. This species also showed a high species important value index in site two. We predicted this species was not found in site one due to the altitude difference. Site one was located at the lower area below 1,000 m a.s.l. We did not find Fagaceae in our sampling plot, in other studies, this family has dominated the mountain area (Cahyanto et al., 2020; Sulistyawati et al., 2018; Yamada, 1975).

The wood densities in site one ranged from 0.32 to 0.87 g cm^{-3} with an average of 0.59 ± 0.14 g cm^{-3}. In site two, wood densities ranged from 0.44 to 0.80 g cm^{-3} with an average of 0.61 ± 0.10 g cm^{-3}. *Homalanthus populneus* had the lowest wood density (0.32 g cm^{-3}) in site one, while *Ficus* spp. in site two (0.44 g cm^{-3}). *Flacourtia rukam* had the highest wood density (0.87 g cm^{-3}) in site one, while *Garcinia scortechini* was in site two (0.80 g cm^{-3}). The average wood density in two sampling site was not significantly different and lower than 0.70 g cm^{-3} and indicated that two sampling site were located in secondary forest. Wood density correlates strongly with the succession status of trees (Slik et al., 2008). The existence of cultivated plant (*Coffea arabica* and *Citrus hystrix*) and domination of pioneer plants in site one, including *Homalanthus populneus*, *Macaranga tanarius*, *Mallotus sphaerocarpus* and *Ficus* spp. also confirmed that two plots were located in secondary forest (Siregar & Undaharta, 2018; Zuhri & Mutaqien, 2013). Disturbed forest formed gaps that caused high penetration of sunlight affecting the growth of pioneer species (Mutaqien & Zuhri, 2011; Purwaningsih et al., 2017). Domination of pioneer species in site one was predicted affecting this result. Pioneer species is a fast growing species and has a low wood density (Chen et al., 2017). A high abundance of fast growing species is secondary forests characteristics, in contrast to the primary forest (Chazdon et al., 2010). Gaps also could cause the invasive species plant growth that slows down the forest succession (Cahyanto et al., 2019; Junaedi & Nasution, 2018).

Tree structure

Horizontal structure is described with individual number distribution and basal area contribution of each dbh class, as shown in figure 3 and figure 4. Individual number distribution of each dbh class also represents population structure (Yamada, 1975).

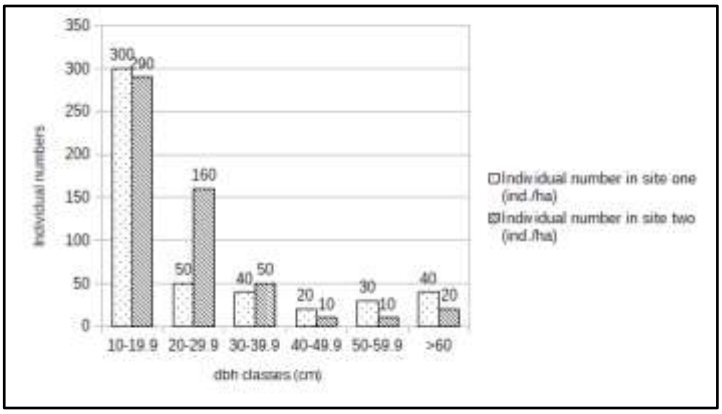


Figure 3. Individual number distribution of each dbh class in the submontane of Ketambe Resort, Mount Leuser National Park, Aceh

Individual number distribution of each dbh class showed that individual number decreased when dbh classes increased in both sites. This pattern formed an inverted J-curve in both sites. The highest individual number was in the lowest dbh class (10-19.9 cm) and decreasing in the highest dbh class (>60 cm). In other words, the number of large trees ($\geq$ 50 cm dbh) is lower than small and medium trees ($\leq$ 50 cm dbh) in both sites.

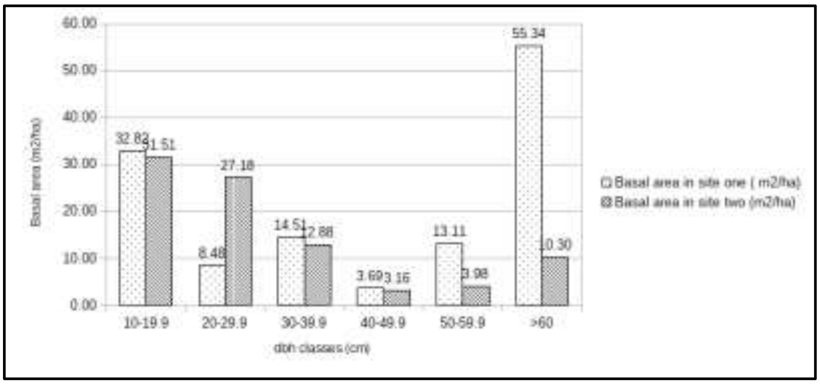
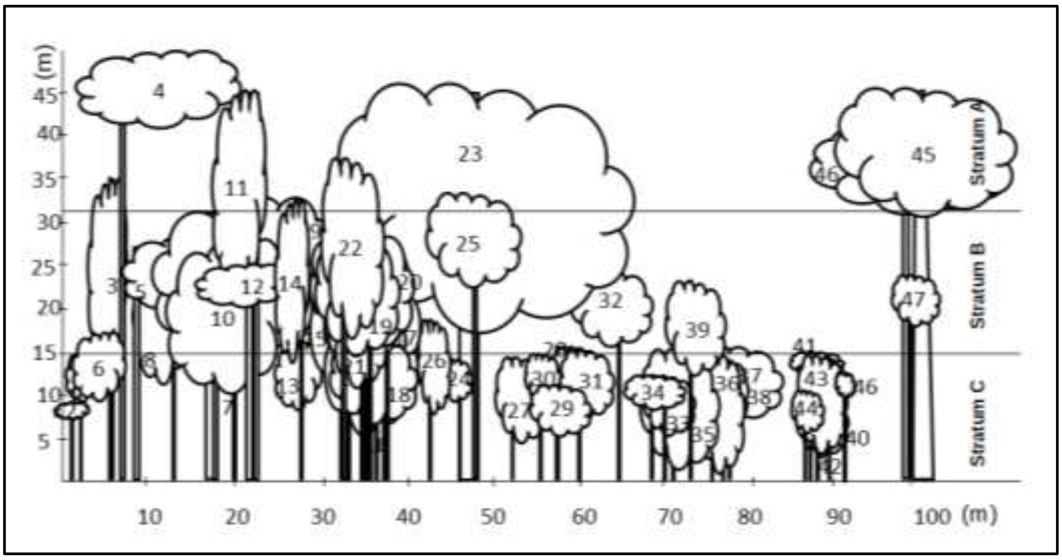


Figure 4. Basal area contribution of each dbh class in the submontane of Ketambe Resort, Mount Leuser National Park

There was a high portion of young tree individuals. It indicated a good capacity for forest regeneration (Purwaningsih et al., 2017; Richards, 1997). This result also similar to other previous studies (Cahyanto et al., 2020; Sulistyawati et al., 2018; Yamada, 1975).

Basal area contribution of each dbh class formed different patterns in site one and site two. Basal area total in site one was higher than site two (table 1). The individual number of large trees ($\geq$ 50 cm dbh) in site one was higher than site two, 14.58 % and 5.56 % respectively. It affected the basal area contribution of each dbh class. Around 53.50 % of basal area total in site one was contributed from large trees, while only 16.04 % of basal area total in site two was contributed from large trees. Even though tree abundance of site two was higher than site one, average dbh and average total height in site one were higher than site two (table 1). It indicated more large trees that were found in site one. The proportion of small and medium trees to basal area total in site two is higher than large trees. This phenomenon can be influenced by the altitude difference and threats level in site two. Site two altitudes were higher than site one, tree sizes tend to be smaller in a higher altitude (Culmsee et al., 2011; Dossa et al., 2013; Reddy et al., 2011).

We constructed a profile diagram to describe vertical forest structure or forest stratification. Stratification is important to study the structure and regeneration capacity of a forest (Richards, 1997; Yamada, 1975). The profile diagram of two sampling sites is shown in figure 5 and figure 7 respectively.



Note: *Acronychia laurifolia* (3), *Actinodaphne glomerulata* (47), *Aglaia* sp.(16), *Bridelia glauca* (24), *Coffea arabica* (29), *Cryptocarya ferrea* (7), *Decaspermum fruticosum* (39), *Elaeocarpus pteolaris* (1, 26), *Endiandra rubescens* (19, 41), *Ficus drupacea* (5), *Flacourtia rukam* (30), *Garcinia scortechini* (2, 21, 27, 37, 46), *Homalanthus populneus* (32, 35, 43), *Knema laurina* (12), *Litsea cubeba* (28), *Litsea* sp. (15, 40), *Macaranga tanarius* (28,42), *Mallotus sphaerocarpus* (36), *Olea javanica* (33), *Podocarpus neriifolius* (48), *Prunus arborea* (22), *Shorea ovalis* (11), *Shorea platyclados* (4, 8, 9, 45), *Sterculia rubiginosa* (6, 31), *Syzygium pseudomolle* (34), *Syzygium* sp2.(10, 18, 20), *Syzygium* sp3. (23), *Turpinia sphaerocarpa* (44)

Figure 5. Stratification of tree community in site one at 850-877 m a.s.l in the submontane zone of Ketambe Resort, Mount Leuser National Park, Aceh

An individual number of each stratum is shown in figure 6. Three strata of trees were found on both sites. The individual number of stratum B and C in both sites were higher than stratum A. The tropical mountain forest can form several strata depending on species composition (Richards, 1997). Sulistyawati et al.

(2018) and Yamada (1975) also found three strata of trees in the montane zone of Sumatra.

Stratum A (total height > 30 m) showed discontinued canopies in site one. Stratum A of site one was dominated by *Shorea platycados*, *Shorea ovalis* and *Syzygium* sp3. About 20 % of the individual number were found in stratum A. Stratum B (15-30 m) and stratum C (<15 m), were formed by connected canopies and relatively small when compared to stratum A. Stratum B dominated by *Syzygium* spp., *Sterculia rubiginosa*, *Endiandra rubescens* and *Elaeocarpus pteolaris.* Stratum C was dominated by *Garcinia scortechini* and *Homalanthus populneus.* The highest individual number was stratum B followed by stratum C and A in site one.

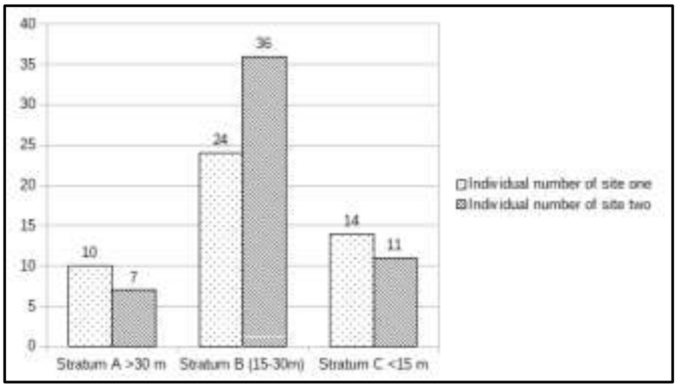
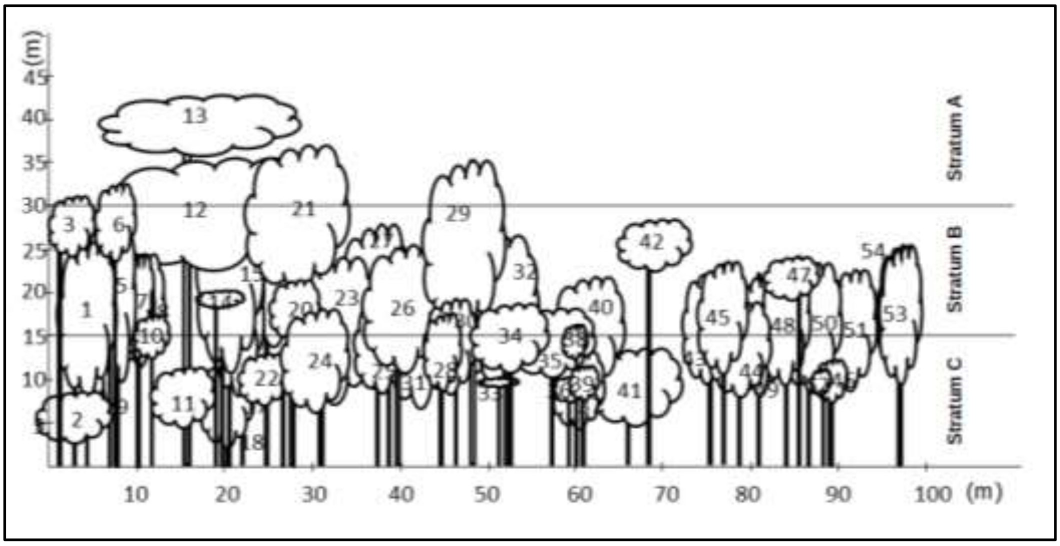


Figure 6. Individual number distribution of each stratum in 10x100 m sampling plot in the submontane zone of Ketambe Resort, Mount Leuser National Park, Aceh



Note: *Aglaia cauliflora* (19), *Aglaia* sp. (38), *Altingia excelsa* (13, 30, 32, 34), *Antidesma montanum* (5), *Beilschmiedia madang* (26), *Bridelia glauca* (10, 14, 28, 40, 53), *Cinnamomum sintoc* (35, 54), *Citrus hystrix* (2, 11), *Coffea arabica* (17), *Cryptocarya ferrea* (24, 36, 39, 43), *Diospyros aurea* (33), *Ficus cuspidata* (46), *Ficus drupacea* (41), *Ficus* sp. (42), *Garcinia* *scortechini* (7, 20), *Helicia serrata* (3), *Ixora grandifolia* (52), *Knema laurina* (48), *Macaranga tanarius* (23, 45, 49, 50), *Neolitsea cassiaefolia* (4), *Neolitsea* sp. (37)., *Phoebe grandis* (27), *Prunus arborea* (8), *Shorea ovalis* (9), *Shorea platyclados* (12, 21, 29), *Syzygium pseudomolle* (1, 6, 51), *Syzygium* sp2. (16, 44), *Syzygium* sp1. (22, 25, 31, 47).

Figure 7. Stratification of tree community in site two at 1,016-1,070 m a.s.l in the submontane zone of Ketambe Resort, Mount Leuser National Park, Aceh

In site two, *Altingia excelsa* and *Shorea platycados* dominated stratum A. *Altingia excelsa* was only found in site two and absent in site one. Domination of *Altingia excelsa* is characteristic of submontane forest in western Indonesia (Zuhri & Mutaqien, 2013). Emergent trees of site one were more dominated by Dipterocarpaceae and Myrtaceae, while site two was dominated by Altingiaceae and Dipterocarpaceae. About 66.67 % of trees occupied stratum B. This stratum was dominated by *Bridelia glauca*, *Macaranga tanarius* and *Syzygium* spp. Meanwhile, *Citrus hystrix*, *Cryptocarya ferrea* and *Ficus* spp. were abundant in stratum C. The lower stratum obtains the lower portion of sunlight, affecting growth and reproduction (Junaedi & Nasution, 2018; Richards, 1997).

Aboveground biomass

Aboveground biomass of trees in site one and site two in the submontane zone of Ketambe Resort, MLNP were 253.01 Mg/ha and 41.76 Mg/ha, respectively (Figure 8). This result was lower than the aboveground biomass of tree in the primary forest of Leuser ecosystem, 659.22 Mg/ha (Aththorick et al., 2012). Although tree abundance of site two was higher than site one, the above-ground biomass of site one was higher than site two. The presence of more large trees (≥ 50 cm dbh) in site one was predicted affecting this result. The aboveground biomass contribution of trees ≥ 60 cm dbh was higher than other diameter class. Dossa et al. (2013) did not find a correlation between altitude and aboveground biomass in their sampling plot.

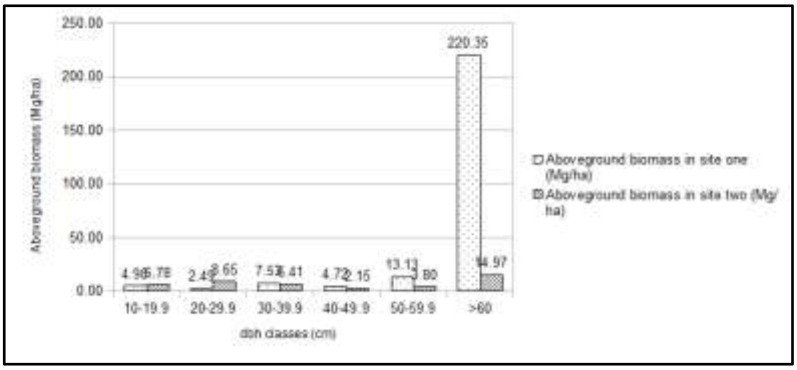


Figure 8. Aboveground biomass contribution of each dbh class in the submontane zone of Ketambe Resort, Mount Leuser National Park, Aceh

Figure 9 showed that the number of large trees in site one was 70 ind./ha (14.58 %) and contributed to 233.48 Mg/ha (92.38 %) of the total above-ground biomass. While in site two, there were only 40 ind./ha of large trees, lower than site one. The contribution of large trees to total above ground biomass in site two was 44.95 %, lower than aboveground biomass contribution of small and medium trees. According to Slik et al. (2013), large trees store large amounts of biomass and vulnerable to changing climate. The contribution of large trees to aboveground biomass was higher in site one, meanwhile, the contribution of small and medium trees was higher in site two. Domination of large trees to aboveground biomass contribution was also found in the permanent plot of Mount Gede Pangrango (Rozak et al., 2017) and Mount Kerinci (Sulistyawati et al., 2018). The altitude difference of two sites was predicted affecting this result. Site two altitudes were higher than site one. In the mountain area, the size of trees tends to be smaller as the altitude increases (Dossa et al., 2013; Laumonier, 1997). Large trees are important for carbon stock, micro climates, food sources, and flora fauna habitats (Chave et al., 2005; Richards, 1997).

The aboveground biomass contribution of three tree species (10.71 % from total species richness) represented 227.32 Mg/ha (89.78 %) of the total biomass in site one (Figure 9). This indicated hyperdominancy of three tree species: *Shorea ovalis*, *Syzygium* sp3. and *Shorea platyclados* in site one. It was similar to other western Indonesian mountain area studies (Rozak et al., 2017; Sulistyawati et al., 2018).

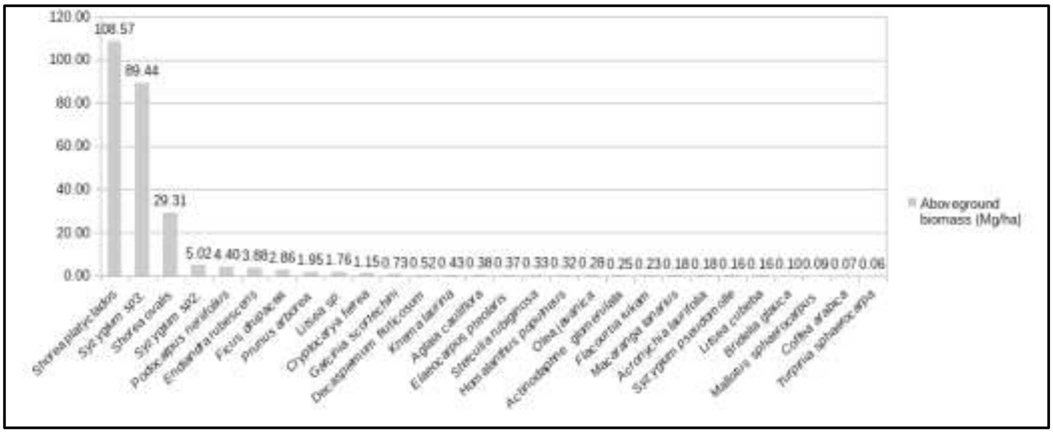


Figure 9. Aboveground biomass contribution of each tree species in site one, submontane zone of Ketambe Resort, Mount Leuser National Park, Aceh

The aboveground biomass contribution of three tree species (10.71 %) represented 25.80 Mg/ha (61.79 %) of the total biomass in site two (Figure 10). This also indicated hyperdominancy of three tree species: *Altingia excelsa*, *Shorea platyclados* and *Syzygium pseudomolle* in site two. Large trees of site two had a

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lower contribution to total aboveground biomass if compared with site one due to the presence of more large trees in site one.

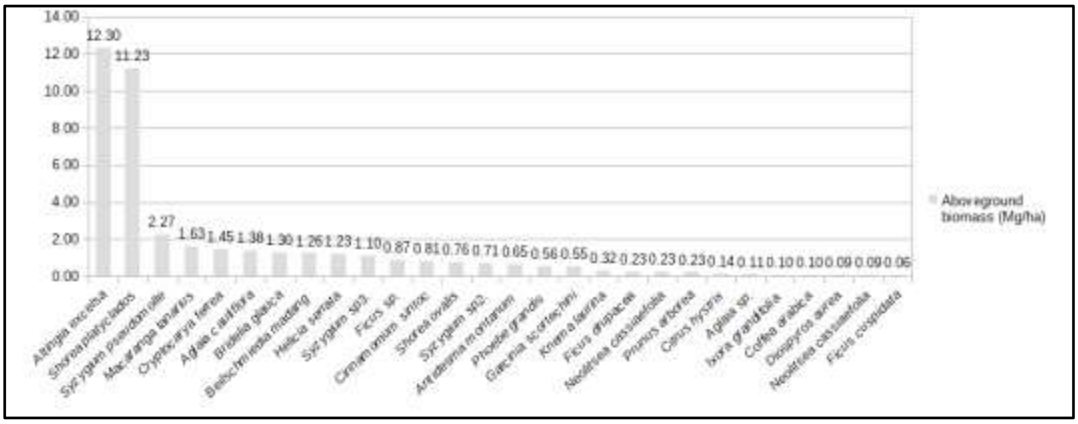

Figure 10. Aboveground biomass contribution of each tree species in site two, submontane zone of Ketambe Resort, Mount Leuser National Park, Aceh

Conclusion

Diversity of trees species was not significantly different at site one and site two in the submontane zone of Ketambe Resort, Mount Leuser National Park, meanwhile tree species composition was different. Tree structures formed three strata and showed a good capacity for forest regeneration. The aboveground biomass of trees in site one was higher than site two due to the presence of more large trees. The occurrence of pioneer species, cultivated species, low average wood density and low aboveground biomass indicated secondary forest characteristics in both sites.

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Contributors

We state that Taufikurrahman Nasution is the main contributor of this paper, while Muhammad Efendi is a member contributor.

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