Preliminary study on plant ecology in Tangkahan Area, Gunung Leuser National Park

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Abstract. Gunung Leuser National Park (NP) is the biggest NP in North Sumatra. Though very few plant ecological studies were conducted there. Most studies in Gunung Leuser NP are related with protected animals, such as Sumatran Tiger, Elephant or Orang Utan. Thus, the aim of this preliminary study is to understand the plant structure and composition in the tropical forest of Gunung Leuser National Park. A 0.5-ha plot was established near Gua Kambing, Tangkahan area in November 2015. All tree species bigger than 15 cm girth were recorded, measured, and identified. The dominant species were from Dipterocarpaceae, followed by Myrtaceae and Achariaceae. The total number of trees was 693 trees or 1,386 trees/ha with the total Basal area was 42.9m²/ha and the biggest diameter was 147cm. The results from diversity index analysis (\(H' = 4.43; D = 0.97; \alpha = 75\)) confirm that the forest area had a relatively high diversity, with Agrostistachis sessilifolia dominates the understory layer. The Gua Kambing area had relatively high plant diversity, less disturbance, and bigger trees than other studied areas in tropical Indonesian forests in Sumatra.

Introduction

Indonesian biodiversity faces direct and indirect threats due to the decrease of forest cover. Forest area in Sumatra, as one of large islands in Indonesia, also suffered the same threats. Margono [1] illustrated the remaining forest cover in Sumatra areas for 20 years from 1990 to 2010. The study quantified about 7.54 Mha of primary forest loss in Sumatra during the two decades, where northern part of Sumatra has rather better condition. This condition is due to the large number of conservation areas and protected forests in the northern Sumatra region. Those conservation areas include Gunung Leuser National Park (Gunung Leuser NP).

Gunung Leuser NP is one of the conservation areas managed by Indonesian Ministry of Environment and Forestry. This national park established in 1980 (Ministry of Agriculture Decree SK Menteri Pertanian Nomor 811/Kpts/Um/II/1980, Ministry of Forestry Decree SK. 6589/Menhut-VII/KUH/2014 and SK.4039/Menhut-VII/KUH/2014) and cover an area of 830,268.95 ha. It is located in two adjacent provinces (Aceh and North Sumatra) in Indonesia and has topographic conditions from the coast (0 m asl) to the mountains (≥ 3,000 m asl).

There are few studies on plant ecology in this area [2–4]. However, those studies were conducted several years ago [4,5] or focused on certain species, such as Raflesia lawangensis, Johannesteijsmannia altifrons and medicinal plants [3,5,6]. Recent studies on flora of Gunung Leuser NP focused in Ketambe
area, western part of the NP, we could not find any research in the eastern part, especially Tangkahan Resort, part of Stabat Area. Further, the other studies mostly focused on animal ecology, since it is in Harimau (Sumatran tiger) distribution areas. Since Gunung Leuser NP is important as habitat for plants and animals in Sumatran region, current information related to plant ecology is a basic requirement in the management of conservation area. Information about plant ecology is also important effort to rehabilitate conservation areas affected by the threat of land use change and several deforestations. In order to understand plant ecology of Gunung Leuser NP, several ecological plots needed to be established to cover whole vegetation variation. This preliminary study aimed to understand the plant structure and composition in the Tropical Forest of Gunung Leuser NP.

Material and Methods

2.1. Study site
The study was conducted in November 2015 in the Tangkahan area, 15km in the northwest of Medan city, North Sumatra. A 0.5 ha plot was established at 3.72° N and 98.06° E. Tangkahan is part of Gunung Leuser border with secondary dryland forest and situated at the junction of two rivers, the Buluh River and the Batang River (Fig. 1). The forest is dominated by Dipterocarpaceae tree species and can be considered as tropical moist forest with the average rainfall 2000-2500 mm/yr. The wettest month is around September to December and the driest month is February [7]. Historically, this forest faced illegal logging trade by local villagers that stopped in 2001 (personal communication). There is no available report to convince this, however few numbers of remaining cut stem can still be found. Currently, Tangkahan forest becomes eco-tourism area managed by local people together with the national park, who play an important role for the conservation in Tangkahan.

Figure 1. Research Plot on Gunung Leuser NP. Gray is primary dryland forest inside the NP, pale white is secondary dryland forest and light grey is shrub. Processed from Land Use Map 2012 (MoEF) and National DEM (BIG Indonesia).
2.2. *Data collection and analysis*

In this preliminary study, we established a 0.5-ha plot at altitude of 320 m asl. (Figure 1). The plot was divided into 50 sub-plots of 10mx10m. All trees with stem girth at breast height (dbh, or at 130cm above the ground) more than or equal to 15cm (dbh 4.77cm) were individually numbered with aluminium tags and mapped the position in the plot [8]. Identification was conducted in the field and samples of unidentified trees were collected for further identification in the Research Center for Biology-LIPI. The Plant List [9] was used to correct identified species name spelling and synonym.

All data were then applied to determine the species dominance using Basal Area (BA), correlation between tree diameter (dbh) and tree height, and the diversity index. The following three diversity indices were calculated, Shannon-Wiener, Simpson’s, and Fisher’ alpha [10].

\[
BA = \frac{1}{4} \pi D^2
\]

BA refers to basal area (m$^2$) and D refers to dbh (m). The diversity index refers to equation (2) until (4).

**Shannon-Wiener**

\[
H' = -\sum_{i=1}^{N} \frac{n_i}{N} \log \frac{n_i}{N}
\]

**Simpson’s Diversity Index**

\[
D = 1 - \sum \frac{n(n - 1)}{N(N - 1)}
\]

**Fisher’s Alpha**

\[
S = \alpha \times \ln \left(1 + \frac{N}{\alpha}\right)
\]

N and n, for Shannon-Wiener and Simpson’s Diversity Index refers to the total number of individuals and number of individuals of each species, respectively. While for Fisher’s alpha, S is number of species, N is total number of individuals, and α is Fisher’s alpha.

Since the research was conducted in 2015, to make sure the forest change around the studied area, analysis on the Normalized Difference Vegetation Index (NDVI) was done. The NDVI derived from Sentinel-2 satellite imagery using Google earth engine for the last 4 years (2016-2019) and the ANOVA Single factor was performed to determine the differences between NDVI results from each year. All of data analysis were conducted using R with Vegan package and ggplot2 package to draw graph of results.

**Results and Discussion**

3.1. *Forest structure*

Tangkahan area consists of hills with some steep slope (45%), the monitoring plot was established in a rather gentle slope area to decrease the effect of slope to the plant diversity inside the plot. Table 1 shows the summary of the vegetation in the plot. The total number of trees in the plot was 693 trees in 0.5 ha or 1,386 trees/ha, and the total Basal Area was 42.90m$^2$/ha. Total number of species found in the plot was 175 species from 48 families. However, we could not identify 5 individuals because lack of leaf samples. The biggest tree diameter found was 147cm of *Shorea parvifolia* (Dipterocarpaceae), this individual was also the highest tree found in the plot (68.9m).

At least 60% (416 individual) of trees found in the plot had diameter less than 10cm dbh and only less than 1% of the trees has diameter more than 80cm (Figure 2). This result was similar with another research conducted in the low land forest of Ketambe, the other side of Gunung Leuser NP [4], other lowland forest in Sumatra [2,11] or lowland forest in Kalimantan [12], where 50-70% of individual has diameter less than 20cm and less than 1% with diameter over 100cm. The result also indicated a dynamic forest condition, which means that the forest trees were not in the same age [13]. Figure 3 shows 10
families with the big total Basal Area (BA). The biggest BA can be found for Dipterocarpaceae (7.9 m²/ha), followed by Myrtaceae (1.7 m²/ha) and Achariaceae (1.3 m²/ha).

Table 1. Summary of plot data.

| Parameter               | Value  |
|-------------------------|--------|
| Number of trees         | 693    |
| Number of species       | 175    |
| Number of families      | 49     |
| BA (m²/ha)              | 42.90  |
| Max diameter (cm)       | 146.87 |
| Shannon diversity index (H’) | 4.429 |
| Simpson diversity index (D) | 0.976 |
| Fishers’α               | 75.096 |

To understand more about the forest structure, analysis on correlation between diameter and tree height were conducted, and the results showed a strong correlation between diameter and tree height (Figure 4, correlation coefficient: 0.82). Trees with diameter less than 50cm mostly stand less than 30m height and trees with diameter more than 80cm stand more than 50m height. Based on Fig. 4 the treetop canopy height was less than 40m. Several trees, such as *Shorea parvifolia*, *Shorea multiflora* (Dipterocarpaceae), *Irvingia malayana* (Irvingiaceae), *Scaphium macropodum* (Malvaceae), and *Carallia brachiata* (Rhizophoraceae) with height from 50m to 68.9m can be considered as emergent trees, where its height was taller than the treetop layer [14].

Figure 2. Diameter distribution of tree according to class diameter.
Figure 3. Ten tree families with the biggest Basal Area (m²/ha).

Figure 4. Correlation between tree diameter and height

The results of NDVI analysis (Figure 5) from 2016 to 2019 shows that there are no significant differences (F value < F criteria; P 0.921) in the vegetation density with year. With these results we are confident that the data presented here are appropriate even though the research was conducted 5 years ago.

Figure 5. The NDVI value from Sentinel-2 satellite imagery for year of 2016 to 2019
3.2. Tree composition
The diversity indexes confirm that the forest area has a relatively high diversity (H’=4.43; D=0.97; α=75) (Table 1). H’ more than 4 and D close to 1 are rarely found and it indicated strongly high diversity [10,15]. Fig. 6 shows 10 families with many species and high density. Dipterocarpaceae was the most diverse tree family in terms of species number (16 species) followed by Burseraceae (15 species), Myrtaceae (12 species), Phyllanthaceae (12 species), and Lauraceae (11 species). Dipterocarpaceae also has the highest number of individual (density) in the plot, followed by Euphorbiaceae, Annonaceae, Fabaceae, and Achariaceae, with 93, 72, 61, 42 and 38 individuals, respectively. Phyllanthaceae, Lauraceae, Ebenaceae, and Anacardiaceae have high species diversities, however low number of individuals, range between 11-22 individuals inside the plot. In the other hand, Fabaceae, Euphorbiaceae, Clusiaceae, and Achariaceae have large number of individual but low in species diversity, only between 4-5 species.

Understory layer inside the plot was dominated by a small tree species of Agrostitchys sessilifolia (Euphorbiaceae) of 50 individuals. This species has diameter varied between 4.8–8.5cm or its girth less than 30cm. This species commonly found in Malaya [16] and can be found in low undulating forest in Malay Peninsula, Borneo and Sumatra with acid sandy soil and sedimentary rock [17,18].

![Figure 6](image_url)

**Figure 6.** Family with the highest species richness and density (number of individuals per family). Family with less than 6 species and/or number of individuals less than 24 cannot be shown in the graph.

The Dipterocarpaceae species can be found scattered in the plot (Figure 7) and composed of trees with rather various size (DBH 4.77–146.87cm). This might indicate that the regeneration process for this dominant family is occurred. However, a closer study on the smaller tree structure, such as seedling and sapling with girth less than 15cm is needed to answer this question.

Dipterocarpaceae composed 13% of the whole population inside the plot and composed of three genera, *Dipterocarpus* (2 species), *Shorea* (11 species) and *Vatica* (3 species). There is almost no gap
inside the plot and there were no *Macaranga* species (Figure 6), the common pioneer species that indicate forest disturbance [19]. Dipterocarpaceae species can be found easily in lowland rain forest of Sumatra and Borneo and dominated the forest [20]. There is no exact factor explains why Dipterocarpaceae family can dominate tropical Asian forest. However, previous research showed the tree characteristic determined its ability to adapt and become dominant tree [20,21]. In Indonesia, this family rarely found in altitude more than 1500m [21]. The study location which was far from human activities get less disturbance thus drive this family to form big and tall individual and become an emergent tree.

The forest composition in this plot was different from the other lowland forest found in Ketambe, the western part of Gunung Leuser NP. Forest area in Ketambe with alluvial soil [4] was dominated by Meliaceae, Sapindaceae, Euphorbiaceae, Urticaceae, Myrtaceae or Phyllanthaceae [4,22]. Dipterocarpaceae can still be found in Ketambe area, however it did not become dominant species in terms of Basal Area or species richness and density. The important species in Ketambe such as *Dendrocnide stimulans* (Urticaceae) and *Paranephelium nitidum* (Sapindaceae) [4] or *Bischofia javanica* (Phyllanthaceae) and *Turpinia sphaerocarpa* (Staphyleaceae) cannot be found in our plot. Differences in plant diversity and composition in the east and western part of Sumatra might be a result of human disturbance, geomorphology and history of the island as explained by Anwar *et al* [15].

![Figure 7. Distribution of Dipterocarpaceae family compared with the other family inside the plot.](image-url)
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