Flora composition and diversity in Mount Sibela Educational Forest, South Halmahera, North Maluku

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Abstract. The Gunung Sibela Educational Forest is part of the nature reserve located on Bacan Island, North Maluku. Flora research in this location is still very limited, therefore this research was carried out as database support for area management. The purpose of this study was to describe the composition and diversity of flora in the Gunung Sibela Educational Forest. Data collection was carried out in block 332 by making 25 plots measuring 20 m × 20 m each. We recorded the number of individuals of each species, also height and diameter specifically for trees in each growth phase. There were 40 plant species from 25 families, dominated by Neolamarckia macrophylla in tree phase (71.95%), Celtis sp. in poles (41.87%) and saplings (22.55%), and Aglaia sp. in seedlings (33.02%). The diversity index was on moderate categories on trees (2.93), poles (2.93) and seedling (2.47), and high on saplings (3.05). The richness index was high on trees, poles, saplings (6.58, 5.18, 6.05 respectively), and moderate on seedlings (3.61). While the evenness index shows the number of individuals for trees, poles, saplings and seedlings tend to be evenly distributed (0.82, 0.93, 0.89, 0.89 respectively).

Overall of this study is the composition of the vegetation in Gunung Sibela Educational Forest contains 40 species of plants and the diversity of species is classified as moderate, and evenness and species richness are classified as high. This indicates that the condition of the vegetation in the research location of the Gunung Sibela Educational Forest is in good condition.

1. Introduction
South Halmahera District is one of the biggest districts in North Maluku Province. Based on the map of forest and water areas of South Halmahera District which is listed in the attachment to the Decree of the Minister of Forestry Number: 415/Kpts-II/1999, South Halmahera has a forest area divided into a nature preserve, protection forest, production forest, limited production forest, convertible production forest and non-forest estate. Gunung Sibela educational forest is a state forest area with special-purpose managed by KPHP Bacan Unit XIII with an area of 286.8 Ha and divided into 3 blocks:
blocks 332, 334, and 338. The educational block is located in block 332 on the edge of Gunung Sibela Nature preserve on Bacan Island.

Each vegetation that grows and develops in a forest have differences that are influenced by the climate type of the area, altitude, and other environmental factors. Vegetation analysis, inventory and monitoring of trees diversity, and forest structure are the key precondition for forest ecosystem control [1]. Lately forest potential has decreased significantly due to illegal logging which causing forest function disruption [2]. This will harm forests as a source of biodiversity. Based on this, conservation efforts are needed to save priority species [3]. The initial effort that can be done is to collect information related to forest vegetation. This can be done by vegetation analysis.

The importance of vegetation analysis (tree structure and composition) has been widely reported [4][5]. Vegetation analysis results will provide information about the continuity of ecosystem functions determined by the existence of vegetation in the area. The stability level of the community and dominant species are analyzed by calculating the importance value index, diversity index, species evenness, and species richness index. Vegetation analysis is very important to predict the vegetation in some areas in the future based on tree structure and composition data including rejuvenation [6]. The stability of biodiversity in nature rejuvenation will determine regeneration of next species diversity [7].

Information about vegetation is very important to manage biodiversity optimally to protect rare and potential species. Community activity inside forest areas disrupted the forest ecosystem. Currently, there are not many vegetation studies carried out in South Halmahera Forest, especially in Bacan Island. Considering the importance of this study, it is necessary to research vegetation analysis in Gunung Sibela Educational Forest. For this reason, this study was conducted to describe the composition and diversity of flora in the Gunung Sibela Educational Forest.

2. Methods
2.1 Study site
The research was conducted in Gunung Sibela Educational Forest block 332, which is a Forest Area with special-purpose education (Kawasan Hutan Dengan Tujuan Khusus - KHDTK). This educational forest covering an area of 84.2 hectares and is located in Production Forest Management Unit Area (KPHP) model Bacan Unit XIII, Bacan Island, South Halmahera, North Maluku. The map of the research location is presented in Figure 1.

![Figure 1. Study site in Gunung Sibela Educational Forest, Bacan Island, North Maluku.](image)

2.2 Procedure
Data collection was carried out in block 332 by making 25 plots measuring 20 m × 20 m each [8][9]. Thus, the total area of the observation plots was 1 Ha or 1.2 % of the total area of the study site. The 20 m × 20 m plots were made for trees observation. Within the plot, the 10 m × 10 m subplot was made for poles observation, then the 5 m × 5 m subplot was saplings, and the 2 m × 2 m subplot for
seedlings and understory plant [10]. The data taken in the field for the tree and pole phase were species name (local and scientific), number of individuals, diameter (dbh) and total height. Meanwhile, for saplings, seedlings, and understory plants, the data taken were only the names of species and the number of individuals. During data collection, the findings of non-timber forest products (NTFPs) were also recorded.

2.3 Data Analysis

Important Value Index (IVI) consists of relative density (RD), relative dominance (RDo), and relative frequency (RF). The data used for this analysis is the number of individuals of each species and the basal area of each species (specifically for the pole and tree phases). For the tree and pole phases, the value of IVI is obtained from the sum of RD, RDo, and RF. While on saplings, seedlings and understory, the values were from RD and RF [11][12][13]. The equations are as follows:

\[
RD = \frac{\text{Number of Individual of the species}}{\text{Number of individuals of all the species}} \times 100\% \quad (1)
\]

\[
RDo = \frac{\text{Total basal area of the species}}{\text{total basal area of all the species}} \times 100\% \quad (2)
\]

\[
RF = \frac{\text{Number of occurrence of the species}}{\text{number of occurrence of all the species}} \times 100\% \quad (3)
\]

Vegetation structure can be assessed based on the distribution of diameter class and tree height in the research location. It should be noted that the vegetation structure analysis for this study was limited to trees in the pole and tree growth phases because diameter and height measurements were only carried out for these two phases. The diameters of each individual pole and tree are divided into eight diameter classes (10 cm intervals): 10 cm – 19.9 cm, 20 cm – 29.9 cm, 30 cm – 39.9 cm, 40 cm – 49.9 cm, 50 cm – 59.9 cm, 60 cm – 69.9 cm, 70 cm – 79.9 cm, and >80 cm. Meanwhile, the height distribution based on tropical rain forest canopy stratification [14]: stratum A (total height > 30 m), stratum B (total height: 20 m – 30 m), stratum C (total height: 4 m – 20 cm), stratum D (total height: 1 m – 4 m), and stratum E (total height: 0 – 1 m).

The value of plant diversity was obtained from the species diversity index (Shannon Wiener Index), species richness index (Margalef Index) and Evenness Index [15]. The formulas used are as follows:

1) Shannon Wiener Index

\[
H' = -\left[ \sum_{i=1}^{S} (pi) (\ln pi) \right] \quad (4)
\]

Where,

\[pi = \frac{ni}{N}\]

\[H' : \text{Shannon Wiener Index}\]

\[ni : \text{The number of individuals of species i}\]

\[N : \text{Total number of individuals}\]

\[S : \text{Species count}\]

The Shannon Wiener index classified into three categories: \(H' > 3\) (high species diversity), \(H' = 1-3\) (moderate species diversity), and \(H' < 1\) (low species diversity) [16].

2) Margalef Index

\[
R = \frac{S-1}{\ln N} \quad (5)
\]

Where,
R : Margalef Index (Species richness index)  
S : Number of species observed  
N : Total number of individuals  
The value of R <3.5 indicates that species richness is low if R = 3.5-5.0 indicates moderate species richness and if R> 5.0 then species richness is high.

3) Evenness Index

\[ E = \frac{H'}{\ln S} \]  

Where,
E : Evenness Index  
H’ : Shanon Wiener Index  
S : Number of species observed  
The evenness index value ranges from 0 - 1, with a value close to 0 if the number of plant species between plots has only a few types of the same, while the value will be close to 1 if the number of species found is almost the same between plots with other plots.

3. Results and Discussion
3.1 Composition of Plants Species in Gunung Sibela Educational Forest
The presence of vegetation in a landscape will have a positive impact on ecosystem balance on a larger scale [16]. Generally, the role of vegetation in an ecosystem is related to carbon dioxide and oxygen regulation in the air; restoration of soil physical, chemical, and biological properties; water management, etc. Although vegetation generally has a positive impact, the effect varies depending on the structure and composition of vegetation. As an example, in general, vegetation will reduce soil erosion rate, but its magnitude depends on the structure and composition of the plant which makes up vegetation formation.

Information on species composition can describe the balance of communities in some forests [18]. Currently, there are many plant species whose benefits for both humans and nature are not yet known. The potential of existing plants must be used wisely and properly, therefore it is necessary to understand the plants that formed vegetation in a forest. This can be done with vegetation analysis, which is a method to learn species composition and vegetation form (structure) or plants community. Based on vegetation analysis results in Gunung Sibela Educational Forest, the main plants that formed the vegetation are trees, from seedling to tree phase (Table 1). In total, there were 40 species from 25 families found in the study site. For each phase, there were 35 species in the tree phase, 23 species of poles, 31 species of saplings, and 16 species of seedlings (including understory).

Table 1. Plants species in Gunung Sibela Educational Forest at each growth phase.

| No | Species             | Local Name | Family            | Growth Phase |
|----|---------------------|------------|-------------------|--------------|
|    |                     |            |                   | T | P | Sa | Se |
| 1  | Adina fagifolia     | lasi       | Rubiaceae         | √ |   |    |    |
| 2  | Aglaia sp.          | langsa hutan | Meliaceae       | √ | √ | √  |    |
| 3  | Albizia saponaria   | fofao      | Fabaceae          | √ | √ | √  | √  |
| 4  | Anisospera costata  | hati besi  | Dipterocarpaceae  |   |   |    |    |
| 5  | Aquilaria sp.       | gaharu     | Thymelaeaceae     | √ | √ |    |    |
| 6  | Bombax ceiba        | kapok hutan | Bombacaceae      |   |   |    |    |
| 7  | Calophyllum inophyllum | bintangur | Clusiaceae        |   |   |    |    |
| 8  | Cananga odorata     | kenanga    | Annonaceae        | √ |   |    |    |
| 9  | Canarium indicum    | kenari     | Burseraceae       | √ | √ |    |    |
| 10 | Celtis sp.          | bido-bido  | Ulmaceae          | √ | √ |    |    |
| 11 | Cinnamomum sp.      | kayu cina  | Lauraceae         |   |   |    |    |
There were 14 species found at each growth phase, from seedlings to tree phase: *Aglaias* sp., *Albizia saponaria*, *Canarium indicum*, *Celtis sp.*, *Cynometra grandiflora*, *Drypetes* sp., *Eugenia* sp., *Garcinia dulcis*, *Homalium foetidum*, *Myristica* sp., *Pometia pinnata*, *Piper aduncum*, *Pomelia pinnata*, *Syzygium malaccense*, *Terminalia bellirica*.

In addition to the plant species in Table 1, non-timber forest product plants were also found, namely: sugar palm (*Arenga pinnata*), woka (*Livistona sp.*), and rattan (* Daemonorops rubra*). Local people use palm trees as raw material for palm sugar. Woka leaves are used by local people for the walls and roofs of garden houses or rice fields, while its trunk is usually used for house terrace poles. Rattan is used by the community to make woven saloi and sosiru. Saloi is a traditional basket bag originating from Halmahera Island, North Maluku. This bag can be carried on the back, usually used by women to carry various needs and crops. Sosiru is a container used for cleaning rice and storing vegetables.

Most of species found in Gunung Sibela Educational Forest were from Fabaceae family, consist of 5 species (*Albizia saponaria, Cynometra grandiflora, Falcatafia falcata, Inocarpus fagifer* and *Intsia*...
bijuga) (Figure 2). Fabaceae have a wide distribution in a tropical areas, including Indonesia. Plants from this family have many benefits to human life such as for food, planting for reforestation, animal feed, tannin producer, medicinal plant, etc [20]. The next most abundant species is Rubiaceae, which consists of 3 species (Adina fagifolia, Neolamarckia macrophylla, and Neonauclea lanceolata). Samama (Neolamarckia macrophylla) was the most dominant tree species found in the Gunung Sibela Educational Forest.

Figure 2. The number of species in each family in Gunung Sibela Educational Forest

3.2 Important Value Index (IVI)

The important value index (IVI) is one of the parameters that can provide an overview of the role of the species in the community [21]. IVI is a very important value in determining how big the role and function of a species is in an ecosystem. This value is obtained from the relative density of the species, the relative frequency in the measured plots, and the relative dominance of a species obtained from the basal area analysis [8]. This IVI was used to determine the dominance of one species over another. In other words, the importance value describes the ecological position of a species in the community. The value of IVI for five species with the highest value in Gunung Sibela Educational Forest is presented in Table 2.

Based on Table 2, the highest IVI value for the tree phase was samama (Neolamarckia macrophylla), the value was 71.95%. Samama is a fast-growing pioneer plant species that grows in the tropics. Like most pioneer species, samama is intolerant plant species and has a fairly strong self-pruning nature. Due to its fast-growing nature, this species has become a priority species to be developed in South Halmahera District [22].

The pole and saplings phases were dominated by Celtis sp. with IVI values of 41.87% and 22.55%, respectively. Dominant species are species that can utilize their environment more efficiently than
other species in the same place. In the seedling phase, it was dominated by *Aglaia* sp., the IVI value was 33.02%. The greater the IVI value of a species, the greater it is level of control over the community, and vice versa. If particular species concerned manage to place most of the available resources compared to other species, that is called species domination [23]. Dominant species are plants that have the highest IVI value in forest vegetation [24]. *Celtis* sp. is commonly found in mountainous areas [25].

### Table 2. Important value index (IVI) in Gunung Sibela Educational Forest at each growth phase

| Growth phase | Species          | IVI (%) |
|--------------|------------------|---------|
| Tree         | *Neolamarckia macrophylla* | 71.95   |
|              | *Celtis* sp.     | 21.74   |
|              | *Pometia pinnata* | 21.61   |
|              | *Eugenia* sp.    | 14.77   |
|              | *Neonauclea lanceolata* | 11.85   |
| Pole         | *Celtis* sp.     | 41.87   |
|              | *Horsfieldia macrocoma* | 25.00   |
|              | *Eugenia* sp.    | 22.32   |
|              | *Aglaia* sp.     | 21.54   |
|              | *Homalium foetidum* | 20.43   |
| Sapling      | *Celtis* sp.     | 22.55   |
|              | *Pometia pinnata* | 19.03   |
|              | *Aglaia* sp.     | 16.71   |
|              | *Myristica* sp.  | 14.39   |
|              | *Drypetes* sp.   | 13.68   |
| Seedling     | *Aglaia* sp.     | 33.02   |
|              | *Garcinia dulcis* | 27.72   |
|              | *Piper aduncum*  | 21.54   |
|              | *Syzygium malaccense* | 20.24   |
|              | *Myristica* sp.  | 18.68   |
| Understory plant | *Asplenium* sp. | 152.32  |
|              | *Pteridium* sp.  | 47.68   |

3.3 Stand Structure

The trees in the Gunung Sibela Educational Forest were grouped into several diameter classes with an interval of 10 cm [26]. The results show that trees with a diameter of 10 – 20 cm have the highest density, while the larger diameter classes have the lower density (Figure 3). The diameter distribution graph forms a reverse-J curve. This pattern is common in the natural mixed-age forest [27][28], as is also shown by the structure of primary forests in other locations in Indonesia, such as on Ternate Island, North Maluku [29]; Seram Island, Maluku [27]; Mount Halimun Salak, Java [9]; and Leuser, Sumatra [28].

Plants in the natural mixed-age forest have different heights and form the stratified canopy. Canopy stratification can provide an overview of successional dynamics [30] and competition that occurs within and between tree species in the forest for light [31]. In addition, information on canopy stratification can also be used to determine the amount of GPP (Gross Primary Productivity) produced by vegetation [32] and its effect on the regeneration of a species [33][34].
The canopy stratum at the study site was stratum A to C (Figure 4), this is because the measurement of tree height at the study site was only done on trees at the growth stage of poles and trees. The results showed that the height of the poles and trees in the location was more than 4 m, therefore the lowest stratum was stratum C. Although no measurements were made on saplings and seedlings, in general, they occupied stratum D and E.

Stratum C on the study site had the highest density (Figure 4), which was 388 individuals/ha (85.27% of the total number of poles and trees). Stratum A only had one individual/ha, while stratum B had 66 individuals/ha. The dominance of stratum C in the study area is due to a large number of younger individuals, as well as the location in an area with high altitudes. In such areas, trees tend to be shorter and fewer [35][36].

3.4 Diversity, Evenness and Species Richness
The biodiversity of plants at a location can be assessed based on three main indices, namely the species diversity index (H'), the species richness index (R), and the species evenness index (E) [15]. Species diversity is a community level characteristic based on its biological organization which can be used to indicated community structure. Based on the results of field observations (Table 3), the level of plant species diversity (H') at the sapling growth phase was in the high category, while other growth phases were in the moderate category.

The high and low diversity index of a plant community depends on the number of species and the number of individuals of each species (species richness). The value of the species richness index (R) generally belongs to the high category for the growth phase of sapling, pole and tree, while seedling was in the medium category. This indicates that the condition of the vegetation in the research location of the Gunung Sibela Educational Forest was in good condition.
Table 3. The index value of diversity, evenness and richness of plants species in Gunung Sibela Educational Forest at each growth phase.

| Growth phase | Diversity Index | Evenness Index | Richness Index |
|--------------|-----------------|----------------|---------------|
|              | value   | category | value | category | value | category |
| Tree         | 2.93    | moderate | 0.82  | high     | 6.58  | high     |
| Poles        | 2.93    | moderate | 0.93  | high     | 5.18  | high     |
| Sapling      | 3.05    | high     | 0.89  | high     | 6.05  | high     |
| Seedling     | 2.47    | moderate | 0.89  | high     | 3.61  | moderate |
| Understory Plant | 0.54 | low       | 0.77  | high     | 0.19  | low       |

The evenness index (E) of species shows how evenly the individuals of each species are distributed in the community. In this study, the level of evenness of species (E) for all tree growth phases and understory were in the high category (0.77 – 0.93). This showed that the distribution of plant species in the Gunung Sibela Educational Forest was evenly distributed.

Understory plants at the study site showed a low level of species diversity because only a few species of ferns were found so that the level of species richness of understory was in a low category. The low level of presence and number of understory species at the research site was due to dense forest conditions which made it difficult for sunlight to enter, making it difficult for understory plants to grow and develop. The presence of ferns that fill the niches of the understory can also be an environmental indicator, that the microclimate at the research site is still well maintained with relatively low temperatures. This is in line with the results of various studies which state that relatives of ferns are often found at low temperatures and high humidity [37].

4. Conclusion

The Gunung Sibela Educational Forest is part of the nature reserve located on Bacan Island, North Maluku. There were 40 plant species from 25 families, dominated by Neolamarckia macrophylla in tree phase (71.95%), Celtis sp. in poles (41.87%) and saplings (22.55%), and Aglaia sp. in seedlings (33.02%). The diversity index was on moderate categories on trees (2.93), poles (2.93) and seedling (2.47), and high on saplings (3.05). The richness index was high on trees, poles, saplings (6.58, 5.18, 6.05 respectively), and moderate on seedlings (3.61). While the evenness index shows the number of individuals for trees, poles, saplings and seedlings tend to be evenly distributed (0.82, 0.93, 0.89, 0.89 respectively). This shows that the distribution of plant species in the Gunung Sibela Educational Forest is evenly distributed.

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