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Research Article

Phytosociology of Trees in Siranggas Wildlife Sanctuary Area, North Sumatra, Indonesia

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ABSTRACT
The lower mountainous region's Siranggas Wildlife Sanctuary is a conservation area with a variety of tree species, however it is susceptible to exploitation-related harm. Despite the area's ecological advantages, little is known about the diversity of tree species and their associations. Therefore, the purpose of this study was to ascertain the Siranggas Wildlife Sanctuary Area's tree species diversity and associations. Using the purposive sampling approach, the study was carried out from March to April 2022. Five plots, each measuring 30 by 60 meters, were set up at various heights. The Importance Value Index (IVI) and the Shannon-Wiener Diversity Index (H') were used to examine the vegetation data. Associations between tree species were identified by considering two species with the highest IVI in the observation plot. The results showed that there were 119 tree species, 38 families, and 79 genera in the Siranggas Wildlife Sanctuary Area. The diversity index across the plot was relatively high with an H' value > 3. Trees with a height of 10 to 15 meters were the prevalent canopy height profile in the plot, while the dominant trunk diameter across the whole plot was 10 to 20 cm. The association that occurred in the study area was the *Schima wallichii – Syzygium cerasiforme* based on two of the greatest IVI and their distribution throughout all plots from varying altitudes. Future forest management and restoration initiatives in the Siranggas Wildlife Sanctuary area can benefit from the presence of both of these species.

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INTRODUCTION

Siranggas Wildlife Sanctuary is a montane forest area that is estimated to have high flora diversity in North Sumatra. This region is considered a conservation area that is highly protected from exploitation activities. The Siranggas Wildlife Sanctuary Forest is a transitional area from lowland to lower montane forests due to its location at an altitude of approximately 800 to 1273 meters above sea level (masl). The lower montane forest ecosystem is a priority area for conservation because of its high biodiversity and is vulnerable to forest conversion activities (Shoo & Catterall 2013). Therefore, for effective management and empowerment of this area, it is crucial to obtain data on the presence of species and important components contained in the ecosystem.

One of the key components of the foundation for the construction and management of conservation areas is an understanding of the diversity of plant species. Additionally, existing forest vegetation patterns that can be known through phytosociology studies also provide important information in the context of the conservation of these areas.

A subfield of vegetation science named phytosociology is concerned with the sociology or societies of plants. This scientific component is crucial for examining the composition and structure of plant communities, which helps to clarify how tree communities relate to other plant communities in a given area (Dengler 2017). Because they store vast amounts of biomass and carbon, trees are a vital component of the global biosphere. Only 12–15 % of the earth's terrestrial area is covered by tropical forests, which are home to approximately 40.000 tree species (Slik et al. 2015) and account for over 60 % of all forest biomass worldwide (Pan et al. 2011). Additionally, tropical forests are crucial to the earth's carbon, water, and other biogeochemical cycles. Due to their significant role in maintaining the sustainability of tropical rainforest ecosystems, trees were selected as the main focus of this study.

Phytosociology studies, specifically in mountainous areas in Indonesia are still very limited. Several studies have been conducted, such as Mirmanto (2013) on Mount Salak West Java, Purwaningsih et al. (2017) on Mount Wilis, East Java, as well as Mansur and Kartawinata (2017) in the Mount Batulanteh area, in Sumbawa, West Nusa Tenggara. In North Sumatra, where Siranggas Wildlife Sanctuary is located, study on tree phytosociology is also still neglected. Thus, the purpose of this study was to ascertain the Siranggas Wildlife Sanctuary Area's tree species diversity and associations. The results are expected to provide tree vegetation information to help forest management and further study related to plant communities. This important information can be scientifically documented, specifically in the Siranggas Wildlife Sanctuary Area.

MATERIALS AND METHODS

Study Site

This study was conducted from March to April 2022 in the Siranggas Wildlife Sanctuary Area, Pakpak Bharat Regency, North Sumatra. Geographically, the area is located between 02°33'48.6"- 02°38'11.3" N and 98°7'22.7"- 98°8'37.3"E with an area of ± 5,657 ha. Administratively, Siranggas is located in 5 districts, namely Kerajaan, Salak, Sitellu Talu Urang Jehe, Tinada, and Pargetteng-getteng Sengkut Districts, Pakpak Bharat Regency, North Sumatra, as shown in Figure 1. The climate is tropical with a relatively high average rainfall, ranging from 1900 to 3000 mm per year, an average temperature of 19.64 °C, and an air humidity of 83.28 %. The topography is very sloppy and steep, with altitudes between 800 – 1275 masl. The lowest area is adjacent to limited-production forests managed by residents. Furthermore, there is a primary forest, which serves as a conservation area from an altitude of 800 masl to the top.

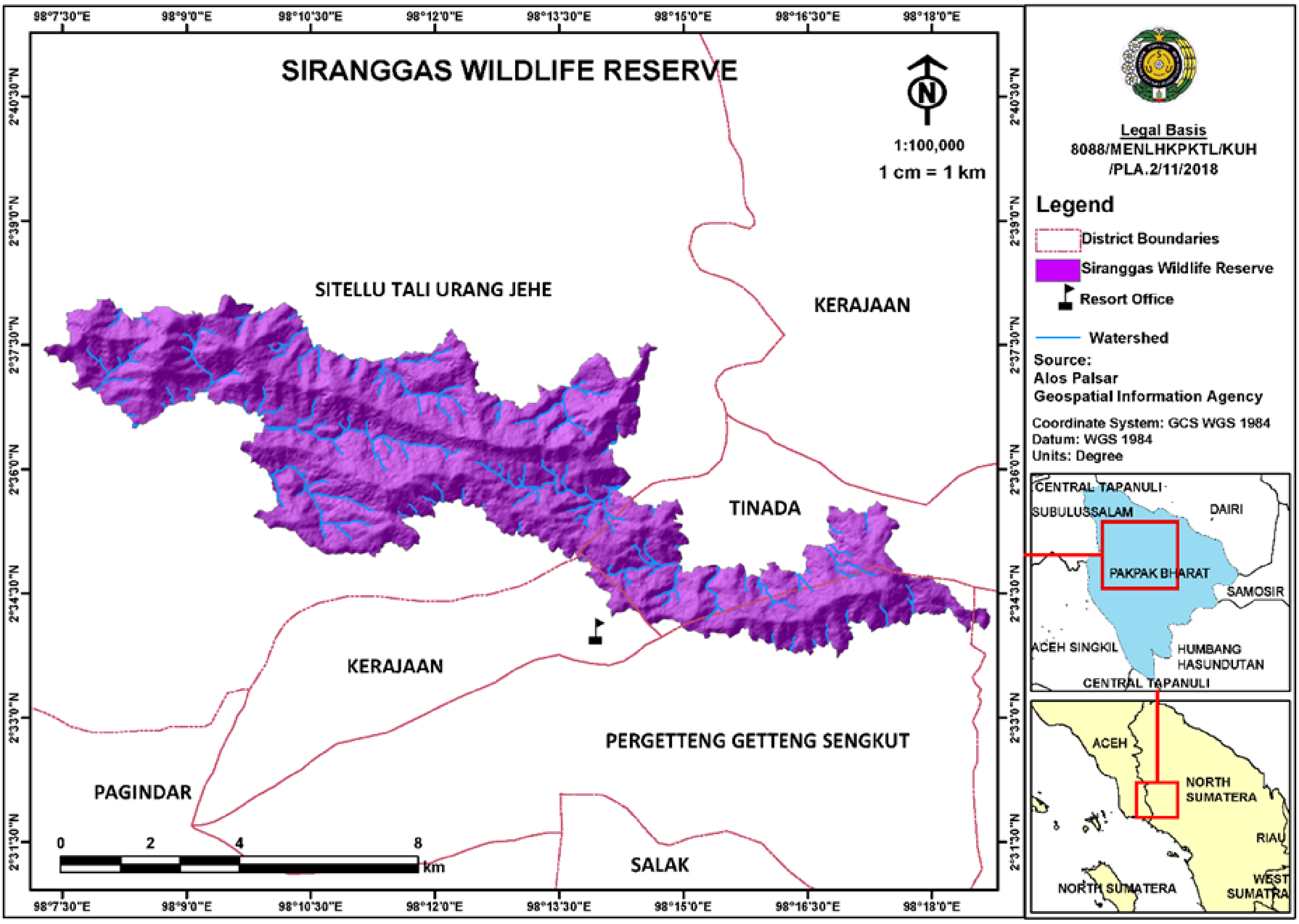

Figure 1. Map of Siranggas Wild Life Sanctuary.

Methods

This study was carried out using the purposive sampling method for plants with tree categories that were considered representative of the forest. Data collection was carried out starting from an altitude of 800 to 1100 masl. As shown in Figure 2, five plots with a size of 60 x 30 meters and 18 subplots measuring 10 x 10 meters in each plot, resulting in 90 subplots with a total area of 9000 m^2. The location of the plot was divided into 5 height zones, namely plot 1 (800 masl), plot 2 (900 masl), plot 3 (1000 masl), plot 4 (1100 masl), and plot 5 (1200 masl). In each subplot, all trees with a Diameter at Breast Height (DBH) ≥ 10 cm were measured using the clinometer. At each location of the plot, environmental parameters were measured as supporting data, including air temperature and humidity using a hygrometer, light intensity using a lux meter, soil temperature and pH with a soil tester, altitude with an altimeter, and coordinate points using the GPS on each plot. Plant species were identified using several identification methods as stated in previous reports (Soepadmo & van Steenis 1972; Geesink et al. 1981; Soerianegara & Lemmens 1994; Lemmens et al. 1995; Keller 1996; Sosef et al. 1998; Soepadmo & Wong 2005; Van Steenis 2006; Soepadmo & Wong 2007).

Data Analysis

The data obtained in the field were calculated as Relative Density (RD), Relative Frequency (RF), Basal Area (BA), Relative Dominance (RD), Important Value Index (IVI), and Diversity Index (H'). Calculations of density, frequency, and dominance values as well as their relative values were based on standard methods (Krebs 2014).

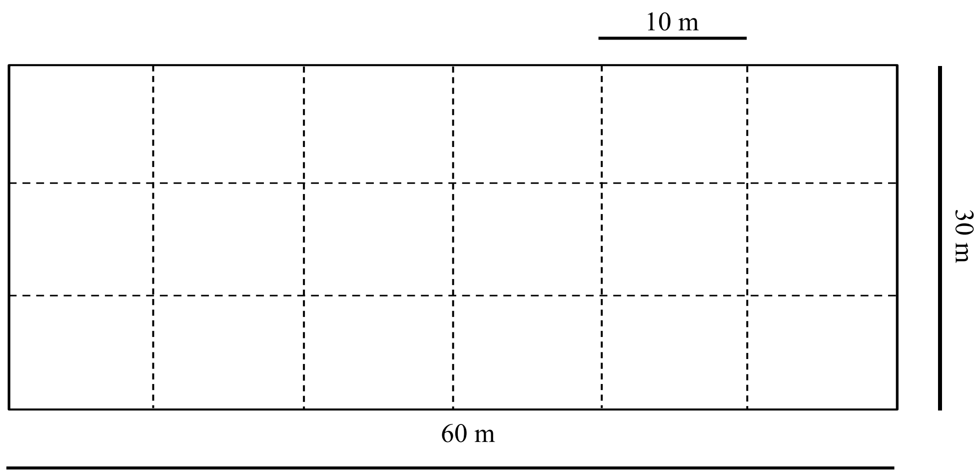

Figure 2. Plot layout and its subplots.

Species Composition

$$\text{Density (D)} = \frac{\text{Number of individuals of a species}}{\text{Total Area}}$$

$$\text{Reative Density (RD)} = \frac{\text{Density of a species}}{\text{Density of all species}} \times 100\ \%$$

$$\text{Frequency (F)} = \frac{\text{Number of individuals}}{\text{Total number of plots}}$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} \times 100\ \%$$

$$\text{Dominance (D)} = \frac{\text{Basal area of a species}}{\text{Total area}}\ m^2\ Ha^{-1}$$

$$\text{Relative Dominance (RD)} = \frac{\text{Dominance of a species}}{\text{Total dominance of all species}} \times 100\ \%$$

Important Value Index (IVI)= RD+RF+RD

Species Diversity

$$H' = -\sum_{i=1}^{S} p_i \ln p_i \quad ; pi = \frac{ni}{N}$$

Description:
ni : Number of individuals of each species
N : The total number of individuals of all species
H' : Shannon-Wiener Diversity Index
ln : Natural logarithm
The Shannon-Wiener Diversity Index is divided into 3 categories:
$H' < 1$ = Low diversity
$1 < H' < 3$ = Moderate Diversity
$H' > 3$ = High diversity

Association and Subassociation

According to Willner (2006), an association is a unit of vegetation in a plant community that has a clear floristic composition and can describe the dominant community. Based on the Braun-Blanquet method (Mueller-Dumbois & Ellenberg 1974), an association can be determined using the distribution of species and their associations. In this method, two species with the highest Important Value Index or those exhibiting distribution most evenly across the study sites are indicative of the associations that occur throughout the observed vegetation. Moreover, sub-association describes associations that occur on a smaller scale and are derived from two species with the highest dominance value of each plot.

RESULTS AND DISCUSSION

Vegetation Characteristics

The results presented in Table 1 showed that the diversity of trees in the Siranggas Wildlife Sanctuary Area, Pakpak Bharat Regency, consisted of 38 families, 79 genera, and 119 species with a total of 268 individuals.

Table 1. Vegetation Characteristics of the Entire Study Plot in Siranggas Wildlife Sanctuary, Pakpak Bharat District.

Vegetation Characteristics	All Plot	Plot 800 masl	Plot 900 masl	Plot 1000 masl	Plot 1100 masl	Plot 1200 masl
Plot size (Ha)	0.9	0.18	0.18	0.18	0.18	0.18
Number of species	119	48	38	39	24	23
Number of genera	79	39	33	32	18	18
Number of families	38	25	24	23	12	15
Total Individuals	268	72	52	64	45	35
Tree density/ hectare	298	400	288	356	250	194
Shannon-Wiener Index (H')	5.04	3.76	3.54	3.50	3.03	3.05

Several characteristics were observed in each vegetation with different altitudes in each plot created. The total area of the plot was 0.9 hectares with the size of each plot measuring 0.18 hectares. Among the 5 plots, the plot at 800 masl was the lowest with the highest richness of species, genera, family, many individuals, tree/hectare density, and the Shannon-Wiener Index. The diversity index between the plots of 800 masl, 900 masl, and 1000 masl was almost the same but dropped significantly from an altitude of 1100 masl and 1200 masl. Based on the Shannon-Wiener diversity index, the entire plot had a high diversity due to the H' > value of 3, the plot elevation of 1100 masl had the lowest value with an H' value of 3.03. This decrease in the value of diversity can be related to the altitude of the area, as studies conducted in the mountain rainforests on Sumatra Island showed a decrease in species richness with increasing altitude above sea level (Ashton 2003; Nishimura et al. 2006). Similarly, a decrease in the richness of tree species was also reported in the mountains of the Java region at varying altitudes ranging from 600 to 2000 masl (Helmi et al. 2009).

Based on environment parameter data obtained from this study, the 1200 masl plot had the lowest air temperature, specifically the soil pH compared to plots at other altitudes. This affected the diversity of tree species that grew on the plot. According to Cheng et al. (2020), soil pH was found to be one of the factors that significantly determined the type of vegetation and the diversity of plant species living in an environment. The diversity of tree species found in the Siranggas Wildlife Sanctuary decreased as the altitude increased, due to the low pH of the soil at altitudes more than 1100 masl.

Canopy Height Class

The measurement of the canopy height carried out on each tree obtained a profile chart as presented below.

The canopy height data in Figure 3 showed that the dominant trees had a height ranging from 10.1 to 15 meters, with the largest number of individuals. The fewest individuals were within the height category of > 30 meters, consisting of 5 individuals from 5 species, namely *Garcinia penangiana*, *Shorea curtisii*, *Santiria apiculata*, *Schima wallichii*, and *Castanopsis argentea*. The tallest tree found was *Shorea curtisii* with a height of 38 meters. Individuals with canopy heights above 30 meters were found only on plots of 800 masl. The study by (Adrah et al. 2021) on variations in canopy height in secondary forests also showed that the average canopy height in lowland areas was higher than that of highlands. This indicated that the height of the tree canopy decreases with increasing elevation due to several factors such as temperature, availability of nutrients, and extremely steep land conditions that can limit the growth of the tree canopy. According to Körner (2012), height was a major obstacle to tree growth in mountainous areas.

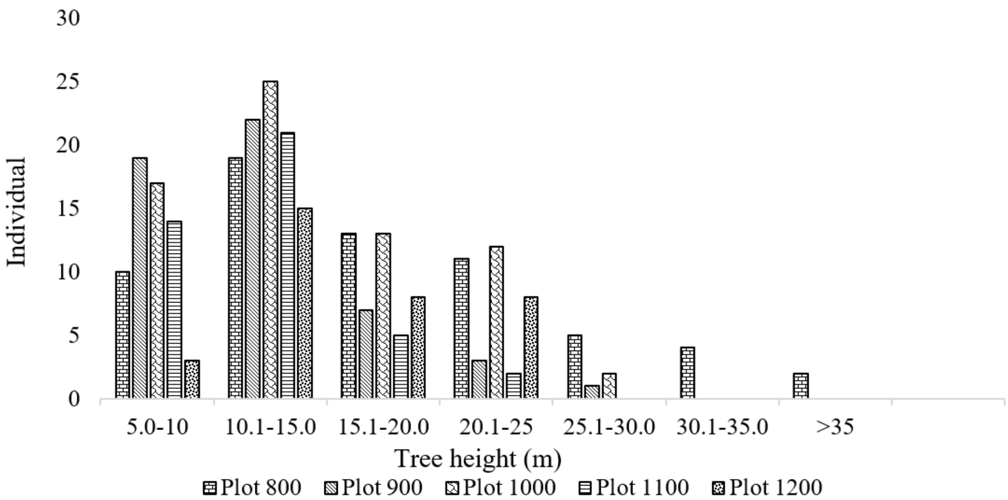

Figure 3. Canopy height profile chart.

The results showed that the tree with the highest canopy was only found in the lowest plot, which was 800 masl, classified as a lowland area. According to Jones et al. (2013), canopy height was a collection of individual tree height data in an area, which was one of the most important forest metrics. Forest canopy elevation played an important role in determining aboveground biomass, forest productivity and restoration, carbon sequestration and reserves, biodiversity, forest resilience to disturbances, climatic extremities such as drought, and tree mortality (Xu et al. 2018; Marselis et al. 2019).

Stem Diameter Class

The profile chart of the tree diameter measurements made on each tree is presented below.

Figure 4 showed that the diameter of the trunk in the range of 10–30 cm had the greatest number of individuals, namely 64.15 %. This value was greater than other diameter classes, consisting of 35.85 % of the diameter class 30.1–40 cm, 40.1–50 cm, and 40.1–50 cm. The lowest number of diameter classes was >70 cm in diameter with only 3 individuals from the entire plot. Based on the results, the size of the tree diameter in the Siranggas Wildlife Sanctuary did not show a decreasing trend. This was indicated by the average tree height which continued to decrease along with the increase in height at the study site. According to Coomes and Allen (2007), the diameter of trees did decrease or increase significantly to an altitude above 1000 masl. This was because individual trees with a diameter above 70 cm could still be found at this elevation.

The average size of the tree diameter did not decrease because the Siranggas Wildlife Sanctuary area was a lower mountainous area and a transition from lowland rainforest to highland forest. Therefore, the size of the trees that grew in the area was not significantly different between altitudes. A study conducted in Gunung Ciremai National Park (Rozak & Gunawan 2015) showed that both the individual density and basal area did not change until the altitude above 2000 masl.

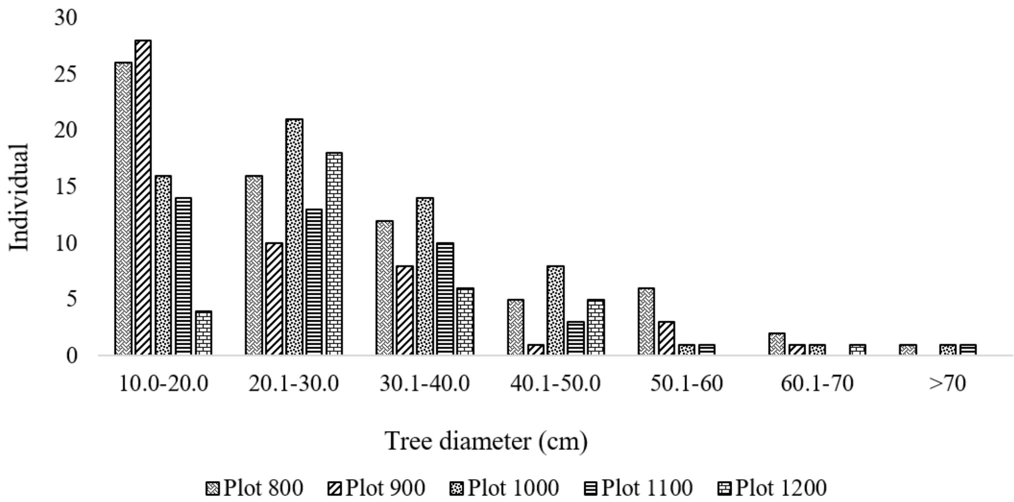

Figure 4. Tree diameter profile chart.

According to Moles et al. (2009), high vertical growth rates allowed trees to physically dominate other plant growth forms when in a suitable environment. Ecological studies relating to the horizontal components of forest structures, such as trunk density and basalt areas, also showed large-scale variations along vast environmental and edaphic gradients (Paoli et al. 2008). However, there was limited information on variations in the vertical components of forest structures and their causes. Several available evidence suggested that the height of the tree, H, for a given diameter (D), might vary significantly among species and across regions (Nogueira et al. 2008). These differences could significantly affect the carbon storage potential of tropical forests. This was because above-ground tropical tree biomass and carbon flux were usually estimated by applying allometric equations only for diameter measurements.

Vegetation Compositions

The vegetation composition of a region could be determined by examining the presence of species at each study site. In this study, the overall vegetation composition of trees from all plots with different heights obtained 79 genera and 38 families, with 10 families having the highest composition, as presented in Figure 5.

Siranggas Wildlife Sanctuary was dominated by the Myrtaceae family at 13.4 %, followed by Lauraceae, Fagaceae, and Myristicaceae with proportions of 10.4 %, 7.8 %, and 6.7 % respectively. The Myrtaceae obtained consisted of 8 species from one genus, namely *Syzygium*, with 36 individuals majorly found within the 1100-meter plot. Montane rainforest in the islands of Sumatra and Kalimantan at altitudes between 800 to 1400 masl were generally dominated by plants from the family of Myrtaceae, Lauraceae, Moraceae, and Meliaceae (Kueh et al. 2017).

According to Saw (2010), species diversity in the lower montane rainforests of Peninsular Malaysia was obtained from more than 900 species of seeded plants. The differences in dominant vegetation became apparent when comparing with lowland forests which were generally dominated by Dipterocarpaceae, Fagaceae family of the genus *Castanopsis*, *Lithocarpus*, *Quercus*, and the species of the Lauraceae family. Therefore, the lower mountain forest was often also called the Oak-Laurel montane forest.

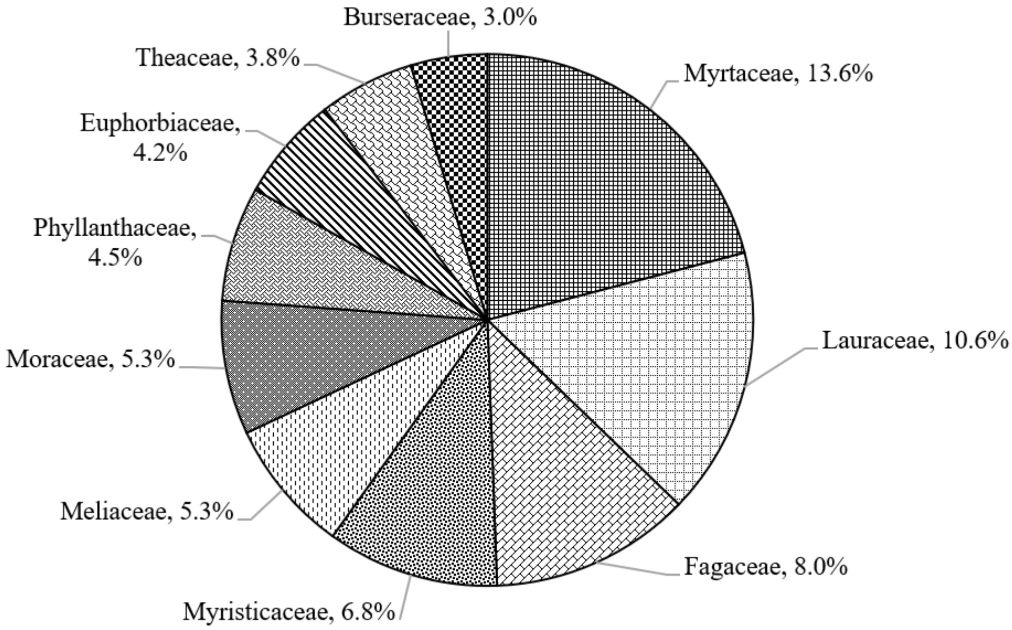

Figure 5. Families with the highest composition found on the study sites.

Association and Subassociation

The grouping of species by the number of plots of the specimen found was used as the basis of the association. A table grouping of all tree species from 5 plots created contained the base field area (m^2) and Important Value Index of each species. Subsequently, the 5 groups of tree species were determined based on the number of plots found.

Plant species that were found throughout the heights were *Schima wallichii*, *Syzygium cerasiforme*, and *Syzygium zeylanicum*. These species were included in group 1, while those found in 4 plots were included in group 2. Furthermore, the species found in 3 plots were included in group 3, those in 2 plots are in group 4, and the species found in only 1 plot were assigned to group 5, as shown in Table 2.

According to Kumaran et al. (2011), the rainforest area of the West Malesia mountains such as Borneo and Sumatra consisted of several important families, namely Fagaceae, Lauraceae, and Myrtaceae. The dominant species of the family Myrtaceae found in the Malesia region was the genus *Syzygium*. This study also observed a high number of individuals in the Myrtaceae family. After the identification process, most of the plant species identified at each height belonged to the Myrtaceae family with a high number of individuals, particularly from the genus *Syzygium*. This genus played a role in the rainforests of the Sumatra region because its flowers were one of the main sources of nectar and fruit for the fauna in the forest (Parnell et al. 2006). Consequently, *Syzygium* had achieved a wide distribution due to the large number of faunas involved in the pollination and seed dispersal of various species in the Syzygium genus in the Siranggas Wildlife Sanctuary.

Grouping types by the degree of consistency (Mueller-Dombois & Ellenberg 1974) obtained 100 % consistency from *Schima wallichii*, *Syzygium cerasiforme*, and *Syzygium zeylanicum*. Based on the consistency and index of the highest importance values of these three species, the tree community from the Siranggas Wildlife Sanctuary Area at an altitude of 800 to 1200 masl could be classified as the *Schima wallichii – Syzygium cerasiforme* or the *Schima – Syzygium* association. This association exhibited the highest Importance Value Index of 83.65 % and 74.93 %, respectively at the study location.

On the plot elevation of 800 masl, the *Styrax benzoin – Syzygium cerasiforme* subassociation could be written as the *Styrax – Syzygium* subassociation with important value indices of 19.51 % and 16.92 %, respectively. Mean-

Table 2. Total Basal Area (TBA) and Important Value Index (IVI) of tree species recorded in five plots in the Siranggas Wildlife Sanctuary.

No	Species	TBA (m^2)	IVI (%)
Association			
1.	*Schima wallichii*	2.19	83.65
2.	*Syzygium cerasiforme*	0.72	74.93
Subassociation at 800 masl			
3.	*Styrax benzoin*	0.49	19.51
4.	*Syzygium cerasiforme*	0.34	16.92
Subassociation at 900 masl			
5.	*Syzygiym cerasiforme*	0.11	19.22
6.	*Schima wallichii*	0.35	15.89
Subassociation at 1000 masl			
7.	*Castanopsis tunggurut*	1.20	45.05
8.	*Gironniera nervosa*	0.50	22.25
Subassociation at 1100 masl			
9.	*Myristica maxima*	0.71	27.80
10.	*Syzygium cloranthum*	0.07	15.36
Subassociation at 1200 masl			
11.	*Dysoxylum cauliflorum*	0.41	26.29
12.	*Baccaurea sumatrana*	0.19	24.25

while, on the 900-meter plot, the *Syzygium cerasiforme* – *Schima wallichii* or *Syzgygium* – *Schima* subassociation had important value indices of 19.32 % and 16.21 %. On the 1.000-meter plot, the *Castanopsis tunggurut*– *Gironniera nervosa* or *Castanopsis* – *Gironniera* subassociation had an important value index of 45.05 % and 22.25 %. The 1.100-meter plot obtained the *Myristica maxima* – *Syzygium cloranthum* or *Myristica* – *Syzygium* subassociation, with important value indices of 41.63 % and 17.36 %. On 1.200-meter plot, *Dysoxylum cauliflorum* – *Baccaurea sumatrana* or the *Dysoxylum* – *Baccaurea* subassociation was obtained, with an important value index of 26.29 % and 24.25 %, respectively.

Schima wallichii was a plant species widely distributed in the southern regions of East Asia to Southeast Asia. Furthermore, this species could grow well in highland areas up to an altitude of 3900 masl. The dominance of this species at almost every altitude was due to its excellent adaptability in extreme environments (Tang et al. 2020). Based on (Bussmann & Paniagua-Zambrana 2021), *Schima wallichii* flowering occurred in the year and its light seeds facilitated easy wind dispersal. These factors allowed a wider distribution of individuals in the Siranggas Wildlife Sanctuary Area at different altitudes compared to other species in this area. This species' resilience to harsh environmental conditions can help future conservation efforts to further understand how this tree can help restore damaged forests from human activities. Given how *Schima wallichii* is also a tree with great economic value, further research about the tree's conservation and cultivation can be done in the future reach even peoples of the surrounding areas to help with forest conservation efforts.

CONCLUSIONS

The diversity of trees in the Siranggas Wildlife Sanctuary Area was categorized as high, consisting of 38 families, 79 genera, and 119 species with a total of 268 individual trees from all plots. The height class of canopies with the highest number of individuals was the class of 10.0 – 15.0 meters with 102 individuals. The tree with the diameter class of 10 – 30 cm had the highest number, comprising 170 or 64.15 % of all individuals found in the plot.

Furthermore, the tree with the highest composition was the Myrtaceae family with an Important Value Index of 13.4 %. The forest communities across 800-1.200 meters altitude had high species richness and were designated as *Schima wallichii – Syzygium cerasiforme* association. This phytosociological data of the two species throughout the research site showed how they can be used to help future forest management to monitor the changes in Siranggas' vegetation and planning for future restoration efforts.

AUTHOR CONTRIBUTION

ESS designed the study, supervised all the process, and edited the manuscript. AFT collected and analysed the data and wrote the manuscript.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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