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Assessing Dipterocarp Diversity at Soraya Research Station, Leuser Ecosystem

Essy Harnelly[1,2*], Irma Fitri[1], Iqbar[1,2], Yunita[1], Hendrix Indra Kusuma[1]

[1] Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh, Indonesia.
[2] Department of Forestry, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh, Indonesia.

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Corresponding Author:
Essy Harnelly
essy.harnelly@usk.ac.id

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Abstract: The Soraya research station is a lowland tropical forest and is included in the management area of the Leuser Ecosystem. This research station has a very high potential for biodiversity. This study aimed to determine the number and types of members of the Dipterocarpaceae tribe and to calculate the quantitative parameters of the plant community. Data collection in this study was carried out using the squared plot method placed randomly at the research location. The analysis used is the Shannon-Wiener diversity index, relative density, relative frequency, relative dominance, and Importance Value Index. The results show that ten species of Dipterocarpaceae belong to various levels of growth, namely seedlings, saplings, poles, and trees. Species of the Dipterocarpaceae spread over 40 plots. *Shorea multiflora* (Burck) Symington is a species that shows a widespread level and high degree of dominance at the study site. Analysis of plant species diversity using the Shannon-Wiener Index shows that both forest types, primary and secondary, are classified into the high species diversity index.

Keywords: Dipterocarpaceae; Diversity; Species; *Shorea multiflora* (Burck)

Introduction

According to a worldwide assessment, the Dipterocarpaceae family has 14 genera and 506 species. Most of this family of plants thrives and spreads in Southeast Asia's lowland forests, especially in Indonesia, where it includes 238 species in nine genera. The presence of emergent and evergreen Dipterocarpaceae species is what primarily distinguishes Indonesian lowland forests. Notably, in primary forests that have not been disturbed, as those in Sumatra and Kalimantan, the richness of Dipterocarpaceae species is especially noticeable (Purwaningsih, 2004; Aston, 1982; Ng et al., 2021; Sam & Nanhe, 2019).

The Leuser Ecosystem Area (Kawasan Ekosistem Leuser/KEL) in Aceh and North Sumatra provinces has been classified as the world's richest tropical forest area, with an exceptionally high degree of biodiversity (Irfan, 2004; Iqbar, 2015; Lestari & Pradana, 2022; Ervany, et al., 2019; Masykur et al., 2023; Djufri, 2015). The Soraya research station forest, part of the KEL, serves as a sanctuary for biodiversity conservation and protection. The forest at Soraya Research Station has enormous potential for effective management of forest resources for conservation and economic objectives. This area is home to a rich range of vegetation and wildlife, including species of great conservation significance that must be preserved in their natural habitat. A significant example is the Dipterocarpaceae family, which has successfully transitioned from logging to secondary forest, demonstrating the ability for spontaneous regeneration and succession in forest ecosystems (Hanafiah, 2017; Purwaningsih & Kintamani, 2018; Hernelly et al., 2020; Ekasari et al., 2024; Susilowati et al., 2024; Firdamayanti et al., 2024).

According to Iqbar (1998), a two-hectare inventory revealed four genera, 11 species, and 145 Dipterocarpaceae individuals. The two most common

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genera in this area are Dipterocarpus and Shorea. Research and monitoring efforts in the Soraya research station region were temporarily halted in 2001 due to adverse security conditions in Aceh (Irfan, 2004; Rachmat et al., 2021; Tirkaamiana et al., 2019; Vebri et al., 2017; Winarni et al., 2023; Latifah et al., 2023), but they were reopened in 2014 (Hanafiah, 2017). The lack of surveillance near the Leuser Ecosystem's southern boundary has resulted in illicit logging in specific areas of the station, causing environmental harm (Hanafiah, 2017; Irwan et al., 2015).

The deforestation will result in the loss of large-diameter trees, especially Dipterocarpaceae. This assertion is further substantiated by the dearth of quantitative data and information concerning the number, distribution, and diversity of Dipterocarpaceae species following two decades of inventory in 1998. Consequently, conducting an inventory study and re-identification of the number, distribution, and diversity of Dipterocarpaceae species in the SP is imperative in Soraya. The results of this study are expected to provide valuable insights into the distribution and diversity of species, thereby enhancing the preservation of Dipterocarpaceae species within their natural habitat in the southern region of KEL and functioning as a conservation strategy.

Method

Research Location

This study was conducted at Soraya Research Station in the Leuser Ecosystem Area of Pasir Belo Village, Sultan Daulat District, Subulussalam City. The study was conducted in the field for three months, from May to August 2018. The data collection method utilized in this study was the squared plot approach (Figure 1), which was intentionally positioned at the research site.

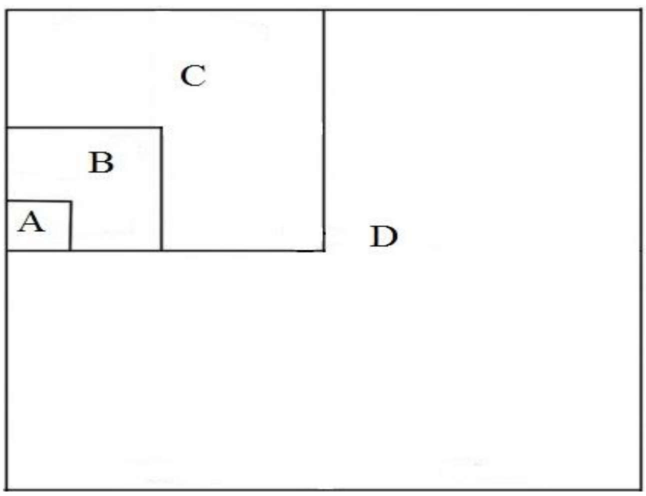

Figure 1. Plot design at the research site using the squared plot method

Sampling and Identification

The sampling was conducted in square sites that were 20 m × 20 m (0.4 ha per plot). The 0.4 ha parcels were randomly assigned to 25 units in the primary forest and an additional 25 units in the secondary forest. This led to the establishment of a total area of two hectares (2 ha) that was designated for data collection. GPS technology was employed to acquire the coordinates of each 20 m × 20 m plot. The coordinate point data from these plots was subsequently employed to characterize the location or distribution of each type of Dipterocarpaceae tribe member in the research location. The data were collected through meticulous measurement and observation of all growth strata within each plot. The diameter of pole and tree-level plants was measured at a height of 1.3 m from the ground (for unrooted plants) and 20 cm above the rods for rooted plants (Nayasilana et al., 2015). Data collection includes the number of species, names of plant species and morphological characters of the Dipterocarpaceae family and supporting data at the research site. Morphological identification of Dipterocarpaceae species refers to identification books such as: *Pedoman Identifikasi Pohon-pohon Dipterocarpaceae Pulau Sumatera* (Newman, et al., 1999; Lee et al., 2002; Ganivet et al., 2020; Latifah & Zahra, 2022; Septria et al., 2018); *Flowering Plants Dicotyledons, Dipterocarpaceae* (Ashton, 2003); *Dipterocarp Biology, Ecology, and Conservation* (Ghazoul, 2016); *Trees of Tropical Asia* (LaFrankie, 2010); and *Dipterocarpaceae in Flora Malesiana* (Ashton, 1982). The accuracy of morphological identification was further validated through the utilization of herbarium collection images and the confirmation of the scientific nomenclature of the species, as facilitated by the online resources www.asianplant.net and http://apps.kew.org.

Data Analysis

The analysis of research data was conducted through vegetation analysis using the Microsoft Excel 2007 program. The data analyzed included density, frequency, dominance, Importance Value Index (IVI), and species diversity index. The IVI index was used to describe and compare the species dominant in the plots. The species with the highest IVI index were designated as the most "important" in a given plot, and this index was employed to ascertain the overall importance of each species in the community structure. The species with the highest IVI was deemed dominant in the community (Noraimy et al., 2014). The following equations were utilized:

$$\text{Important Value (IVI)} = \text{RD} + \text{RCC} + \text{RF} \quad (1)$$

$$\text{Relative Density (RD)} = \frac{\text{The density of a species}}{\text{Total density of all species}} \times 100 \quad (2)$$

$$\text{Relative Canopy Cover (RCC)} = \frac{\text{Canopy of a species}}{\text{Total cover of all species}} \times 100 \quad (3)$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency value of the species}}{\text{Sum of frequency of all species studied}} \times 100 \quad (4)$$

The species diversity index can be determined by the following Shannon-Winner formula:

$$H' = -\sum\left(\frac{n_i}{N}\right)\ln\left(\frac{n_i}{N}\right) \quad (5)$$

Where H' is Shannon's index of species diversity, n_i is the importance value index of species i, and N is the importance value index of the population.

Result and Discussion

Number and Types of Plants

Vegetation analysis performed on 50 plots, each encompassing 1 hectare, in both main and secondary forests with the randomly set square plot approach documented a total of 2.304 unique plants. These individuals were part of 55 families and included 168 plant species. The documented plants were classified into various growth stages: seedlings, saplings, poles, and trees. Species composition analysis in both forest types revealed 10 plant families with the greatest species diversity at the study site. Figure 2 illustrates the distribution of these ten predominant families.

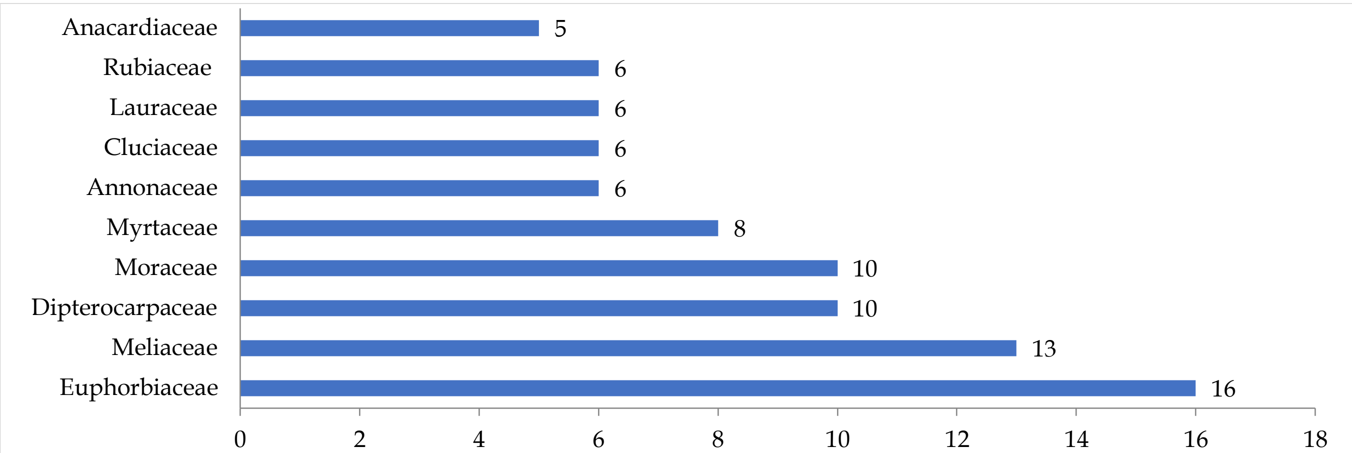

Figure 2. Ten families with the highest number of species in the study site

The results revealed no statistically significant differences in the number of plant species observed at each growth stage between the two forest types. This conclusion is due to the closeness of the two sampling sites, leading to many similarities in the plant species found at both locations. Additionally, both sites were previously designated as HPH (Hak Pengusahaan Hutan/ Forest Concession Rights) concession areas in the 1970s and have since experienced regeneration throughout the ensuing years.

Number and Types of Dipterocarpaceae

The study conducted at the 2-hectare research location identified 228 members from the Dipterocarpaceae family. The specimens were systematically categorized into distinct growth stages: seedlings, saplings, poles, and trees. An ensuing investigation indicated that the population of individuals in both forest types did not demonstrate a significant difference (Table 1). This homogeneity can be ascribed to the same climatic conditions, given that the two areas are in close proximity and exhibit comparable stand density. Kuswandi et al. (2015) assert that density (individuals per hectare) and stand structure indicate the availability of stands at different growth stages. It is claimed that these factors affect the ability of plants to regenerate after disturbance. Thus, the growth prospects at both locations tend to arise concurrently.

Table 1. Number of Individuals and Species of Dipterocarpaceae at Each Growth Stage in Primary and Former Secondary Forest Conditions

Forest Condition	Growth Stages	Number of Individuals	Nnumber of ssspespecie
Primary	Seedlings	30	17
	Saplings	31	
	Poles	12	6
	Trees	42	7
Secondary	Seedlings	42	3
	Saplings	26	5
	Poles	4	2
	Trees	41	8

A taxonomy assessment at the Acehense herbarium identified eleven species of Dipterocarpaceae, spread among both forest types. These results closely align with

Iqbar's (1998) investigation, which revealed eleven species in the same observational region. In primary forests, 10 species were recognized, whereas nine species were discovered in secondary forests (Table 2). The 10 species are classified into three genera: Dipterocarpus, Parashorea, and Shorea. The Shorea genus was the most dominant in the research area. Research conducted by Nayasilana et al. (2015) in Ketambe Research Station and Basyuni et al. (2019) in Sikundur revealed that both locations within Taman Nasional Gunung Leuser (TNGL) were predominantly characterized by the species Shorea.

Table 2. Dipterocarpaceae Species Found at Soraya Research Station based on Forest Conditions

Locals name	Scientific names	Forest condition	
		Primary	Secondary
Keruing biasa	*Dipterocarpus grandiflorus* (Blanco) Blanco	√	√
Keruing-1	*Dipterocarpus baudii* Korth.	√	√
Keruing lagan	*Dipterocarpus humeratus* Slooten	√	√
Entap	*Parashorea lucida* (Miq.) Kurz	√	√
Pepening	*Shorea multiflora* (Burck) Symington	√	√
Semaram	*Shorea lepidota* (Korth.) Blume	√	√
Meranti biasa-1	*Shorea dasyphilla* Foxw.	√	√
Meranti biasa-2	*Shorea johorensis*Foxw.	√	√
Meranti biasa-3	*Shorea leprosula* Miq.	√	√
Semantok	*Shorea glauca* King	√	-

Vegetation Composition

Shorea multiflora (Burck) Symington demonstrates a higher Importance Value Index (IVI) than other Dipterocarpaceae species at the seedling, sapling, pole, and tree stages (Table 3). This suggests that this species may have a greater capacity for sustaining its growth and vitality relative to other Dipterocarpaceae (Kuswandi et al., 2015).

According to Kurniasari (2015), species having an IVI value more than 15% can indicate the dominant species, defined by the highest IVI. This species is rather dominant in main forest environments at the tree level (IVI = 24.65%). At the stage of tree growth, S. multiflora exhibits more adaptation to its surroundings than other species under like circumstances.

Table 3. Important Value Index (IVI) of Dipterocarpaceae Species at Different Growth Stages in Primary Forest

Growth Stages	Species	RD	RF	RCC	IVI
Seedlings	*Shorea multiflora* (Burck) Symington	7.92	3.85	-	11.76
Saplings	*Shorea multiflora* (Burck) Symington	3.67	3.11	-	6.78
	Dipterocarpus grandiflorus (Blanco) Blanco	2.69	1.56		4.25
	Parashorea lucida (Miq,) Kurz	0.24	0.39		0.63
	Dipterocarpus humeratus Slooten	0.24	0.39		0.63
	Dipterocarpus baudii Korth.	0.24	0.39		0.63
	Shorea dasyphylla Foxw.	0.24	0.39		0.63
	Shorea glauca King	0.24	0.39		0.63
Poles	*Parashorea lucida* (Miq,) Kurz	0.72	0.84	0.09	1.66
	Dipterocarpus humeratus Slooten	0.72	0.84	0.17	1.73
	Shorea dasyphylla Foxw.	0.72	0.84	0.10	1.66
	Shorea johorensis Foxw.	0.72	0.84	0.17	1.74
	Shorea multiflora (Burck) Symington	3.62	3.36	3.49	10.47
	Shorea glauca King	2.17	2.52	1.06	5.75
Trees	*Parashorea lucida* (Miq,) Kurz	0.33	0.46	0.01	0.80
	Dipterocarpus grandiflorus (Blanco) Blanco	1.32	1.83	0.38	3.54
	Dipterocarpus baudii Korth	0.33	0.46	0.07	0.86
	Shorea dasyphylla Foxw.	3.31	3.21	1.72	8.24
	Shorea leprosula Miq.	0.33	0.46	0.01	0.80
	Shorea multiflora (Burck) Symington	7.95	5.50	11.20	24.65
	Shorea lepidota (Korth.) Blume	0.33	0.46	0.04	0.83

Compared to other Dipterocarpaceae species, S. multiflora dominated the secondary forest, dominating its competitors from the seedling to tree growth stages (Table 4). Thus, it may be concluded that S. multiflora is the most common Dipterocarp species in both secondary and primary forests. Despite the disturbances caused by illegal logging at the Soraya Research Station, the continued existence of the Dipterocarpaceae species in their natural habitat is evident.

Table 4. Important Value Index (IVI) of Dipterocarpaceae Species at Different Growth Stages in Secondary Forest

Growth Stages	Species	RD	RF	RCC	IVI
Seedling	*Shorea multiflora* (Burck) Symington	10.2	4.12		14.34
	Dipterocarpus grandiflorus (Blanco) Blanco	1.10	1.55	-	2.65
	Shorea lepidota (Korth.) Blume	0.28	0.52		0.79
Sapling	*Shorea multiflora* (Burck) Symington	2.56	2.02		4.59
	Dipterocarpus grandiflorus (Blanco) Blanco	2.28	1.21	-	3.49
	Dipterocarpus humeratus Slooten	0.85	0.81		1.61
	Shorea lepidota (Korth.) Blume	0.57	0.40		0.97
Pole	*Shorea multiflora* (Burck) Symington	2.94	3.30	1.58	7.82
	Shorea dasyphylla Foxw.	0.98	1.10	0.50	2.57
Trees	*Shorea multiflora* (Burck) Symington	6.90	3.26	20.50	30.65
	Shorea dasyphylla Foxw.	3.07	3.26	4.40	10.72
	Shorea lepidota (Korth.) Blume	1.15	1.40	5.95	8.49
	Shorea johorensis Foxw.	1.15	1.40	0.94	3.48
	Dipterocarpus grandiflorus (Blanco) Blanco	1.53	0.93	0.96	3.42
	Shorea leprosula Miq.	0.77	0.93	0.21	1.91
	Parashorea lucida (Miq,) Kurz	0.77	0.47	0.12	1.35
	Dipterocarpus baudii Korth	0.38	0.47	0.14	0.99

Species Diversity Index

The value of the species diversity index (H') of plants at various growth stages in both forest types is presented in Figure 3. This value indicates that the species diversity index in primary and secondary forests in the Soraya Research Station area is high. The species diversity index in these two forest conditions is relatively similar, given their proximity and subsequent shared characteristics. The species diversity index is a metric that quantifies the biodiversity of a forest ecosystem. According to Kuswanda et al. (2008), the maximum H value limit in good forests is in the interval $2.5 \leq H \max \leq 3.5$. Additionally, the species diversity index, as outlined by Fachrul (2007), indicates that values greater than 3 signify abundant species diversity, values between 1 and 3 denote moderate diversity, and values less than 1 suggest limited diversity. When viewed from the perspective of the number of species and the number of individuals per plant species, these conditions imply that both forest types are undisturbed, have been relatively stable, or the vegetation has undergone a succession phase more than 40 years after the concession land use.

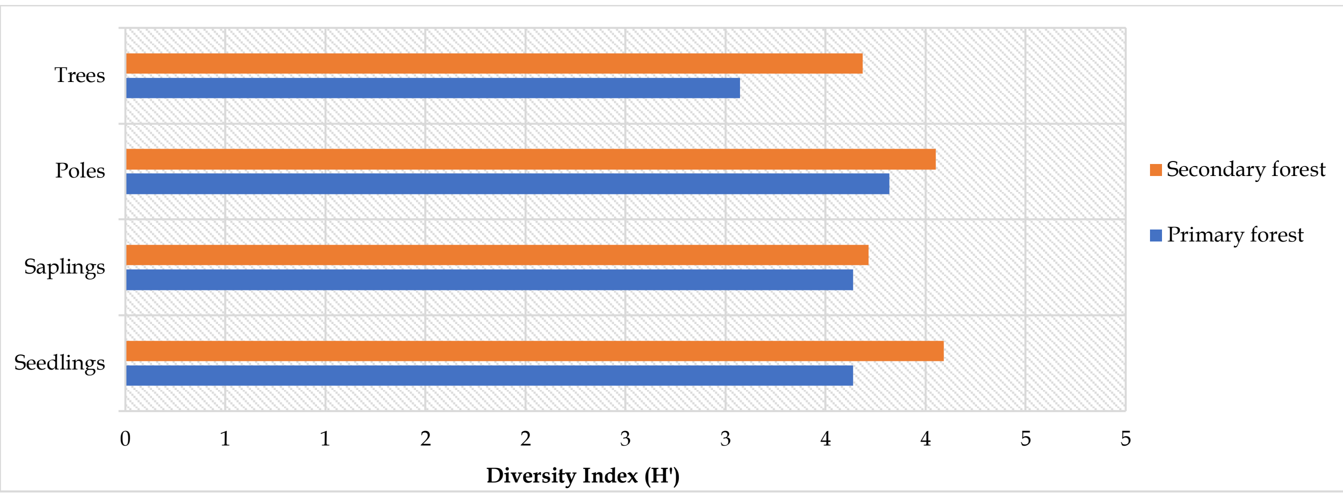

Figure 3. Plant species diversity index values in both forest types

Dipterocarpaceae Species Distribution

The distribution of Dipterocarpaceae species at the research site was determined based on the distribution of each plot. The coordinates of the plots identified for each species were utilized to describe the location or distribution of each species of Dipterocarpaceae. The analysis revealed that Dipterocarpaceae species are distributed across 40 plots in the study area, representing an approximate percentage of 80%. Notably, the species *S. multiflora* exhibits a broad distribution across diverse forest conditions, encompassing seedlings, saplings, poles, and tree growth stages. The species was distributed in 14 plots in primary forest and 11 plots in secondary forest. In contrast, *S. glauca* King exhibited an uneven distribution across both forest types. This species was found in four plots in the primary forest and none in the secondary forest (Table 5).

Table 5. Distribution of Dipterocarpaceae species in the study site.

Species	Primary forest	Growt stages	Secondary forest	Growt stages
Dipterocarpus grandiflorus	N2 54.561 E97 54.799	Sa, T	N2 55.640 E97 55.730	Sa
(Blanco) Blanco	N2 54.849 E97 54.877	Sa	N2 55.409 E97 55.854	Se, T
	N2 54.649 E97 55.136	Sa, T	N2 55.458 E97 55.830	Se, Sa
	N2 54.787 E97 54.779	T	N2 55.453 E97 55.745	Se, Sa ,T
	N2 54.639 E97 55.017	Sa, T		
Dipterocarpus baudii Korth.	N2 54.784 E97 55.294	Sa	N2 55.458 E97 55.830	Sa
	N2 54.951 E97 55.012	T	N2 55.356 E97 55.718	Sa
			N2 55.774 E97 55.739	T
Dipterocarpus humeratus Slooten	N2 54.979 E97 55.127	Sa, P	N2 55.458 E97 55.830	Sa
			N2 55.356 E97 55.718	Sa
Parashorea lucida (Miq.) Kurz	N2 54.784 E97 55.294	Sa	N2 55.356 E97 55.718	T
	N2 54.676 E97 55.267	T		
	N2 54.617 E97 54.864	P		
Shorea multiflora (Burck)	N2 54.979 E97 55.127	Sa, P, T	N2 55.640 E97 55.730	Se, P
Symington	N2 54.847 E97 55.127	Se	N2 55.612 E97 55.796	Se, Sa,P,T
	N2 54.561 E97 54.799	T	N2 55.495 E97 55.949	Sa, P, T
	N2 54.759 E97 55.122	Sa, T	N2 55.407 E97 56.003	Sa
	N2 54.849 E97 54.877	Se,P,T	N2 55.409 E97 55.854	Se, Sa,T
	N2 54.649 E97 55.136	Se,P	N2 55.458 E97 55.830	Se, T
	N2 54.884 E97 55.202	Sa, T	N2 55.453 E97 55.745	Se, T
	N2 54.951 E97 55.012	Sa, T	N2 55.574 E97 55.983	Se
	N2 54.838 E97 54.941	Sa, T	N2 55.510 E97 55.718	Se, Sa, T
	N2 54.705 E97 55.025	T	N2 55.633 E97 55.670	T
	N2 54.787 E97 54.779	Se, Sa,P,T	N2 55.410 E97 56.289	Se
	N2 54.639 E97 55.017	Se, Sa,T		
	N2 55.078 E97 54.902	Sa, T		
	N2 55.143 E97 54.984	Se, Sa		
Shorea lepidota (Korth.) Blume	N2 54.849 E97 54.877	T	N2 55.495 E97 55.949	Sa
			N2 55.510 E97 55.718	Se, T
			N2 55.626 E97 55.606	T
			N2 55.410 E97 56.289	T
Shorea dasyphilla Foxw.	N2 54.979 E97 55.127	T	N2 55.612 E97 55.796	T
	N2 54.561 E97 54.799	T	N2 55.407 E97 56.003	T
	N2 54.494 E97 55.145	T, T	N2 55.408 E97 55.581	P
	N2 54.745 E97 55.169	Sa, T	N2 55.499 E97 56.074	T
	N2 54.784 E97 55.294	T	N2 55.774 E97 55.739	T
	N2 55.097 E97 55.147	T	N2 55.456 E97 55.875	T
	N2 55.143 E97 54.984	T	N2 55.410 E97 56.289	T
Shorea johorensis Foxw.	N2 54.546 E97 55.134	P	N2 55.495 E97 55.949	T
			N2 55.407 E97 56.003	T
			N2 55.414 E97 56.208	T
Shorea leprosula Miq.	N2 54.676 E97 55.267	T	N2 55.574 E97 55.983	T
			N2 55.774 E97 55.739	T
Shorea glauca King	N2 54.979 E97 55.127	P	-	-
	N2 54.912 E97 55.123	P		
	N2 54.847 E97 55.127	P		
	N2 54.617 E97 54.864	Sa		

Note: Se (seedling), Sa (sapling), P (pole), and T (tree)

S. multiflora has been observed to generally grow in groups within a certain distance, according to the extent of the distribution of the parent tree (Wahidah et al., 2015). Prayoga et al. (2019) have shown a clustered distribution pattern in their research at Pemerihan Resort, Bukit Barisan Selatan National Park, by examining the distribution pattern of this species. Wahidah et al. (2015) have indicated that this clustered distribution pattern may be attributed to various factors, including the distribution of the species' generative organs. This suggests that the reproduction of this species produces fruit that either falls close to or a certain distance from the parent tree. *S. multiflora* produces wingless fruits, thereby constraining seed distribution to the immediate vicinity of the parent tree or within specific boundaries. In contrast, *S. glauca* was not detected in both research locations at the tree and seedling growth levels, resulting in the absence of parent trees. However, it was observed at the pole level or at diameters less than 20 centimeters. The absence of parent trees could be attributed to the high loss potential of this species in the study sites, and the absence of mother trees is directly proportional to the presence of fruit as a means of breeding the species in nature.

Conclusion

Ten Dipterocarpaceae species, representing *Shorea*, *Dipterocarpus*, and *Parashorea* genera, were identified. *Shorea multiflora* dominated both primary and secondary forests, as evidenced by its high Importance Value Index. Species diversity was high (H'=3.073-4.091). Because the Soraya Research Station forest is successful, establishing permanent plots is essential for monitoring long-term vegetation dynamics. Critically delineating distinct habitat types within the station is necessary for data reliability and broader use as a research reference.

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Author Contributions
E.H. contributed as a supervisor of research ideas and conceptualization; I.F. contributed to project administration, investigation, and writing – original draft preparation; I. I and Y.Y contributed as a supervisor in research data processing, methodology, and data validation; H.I.K. contributed as an article writer – review and editing. All authors have read and approved the published version of the manuscript.

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Conflicts of Interest
In writing this article, we sincerely declare that no conflict of interest may affect the objectivity and integrity of the results.

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