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Association of *Shorea leprosula* and *Shorea johorensis* Species with other Species in Tropical Forest

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Abstract

Shorea leprosula and *Shorea johorensis* do not live alone, but are associated with other plant species within a forest ecosystem. The relationships or associations of plants in the forest can be positive and negative. Positive association occurs when a plant species is present together with other plant species, while negative association occurs when a plant species is not present together with other plant species. The purpose of this study was to determine the distribution pattern of tree species, the Important Value Index (IVI), the association between species, and the kinship value of *S. leprosula* and *S. johorensis* in the IUPHHK (Timber Forest Product Utilization Business Permit) area of PT. Kemakmuran Berkah Timber, West Kutai Regency, East Kalimantan Province. The results showed that *S. leprosula* had an IVI (Important Value Index) of 15.89% - 42.02% and *S. johorensis* had an IVI of 28.56%. Based on the association of kinship values, there was a significant negative association between *S. leprosula* and *Myristica* sp. and *Cinnamomum* sp., with negative coefficients of 7.28% and 8.83%, respectively. As for the *S. johorensis* species, it was only found in plot 1, with one significant combination with the *Palaquium* sp. species with a positive coefficient of 5.63%. *S. johorensis* plays a significant role in plot 1, while *S. leprosula* shows complex interactions with significant negative species combinations in several plots.

Keywords: Association, IVI, *Shorea johorensis, Shorea leprosula*

1. Introduction

Tropical forests are one of the ecosystems that are rich in biodiversity. It contains various plant species that have an important role in maintaining the balance of the ecosystem and providing benefits for human life. However, some plant species in tropical forests are currently facing the threat of extinction due to various factors such as habitat destruction, climate change, and irresponsible human activities [1].

One of the potential and endangered plant species is *Shorea leprosula* and *Shorea johorensis*. Both species belong to the Dipterocarpaceae family, which has high economic and ecological value. *S. leprosula*, also known as *copper meranti*, has strong wood and is resistant to pests and diseases. Meanwhile, *S. johorensis*, also known as *mangrove meranti*, has good adaptability to coastal environments [2].

An important factor that needs to be considered in the conservation of plant species is the condition of the habitat where it grows. A good habitat that suits the ecological needs of a plant species will provide better opportunities for its survival [3]. In addition, factors such as interactions with other species and their adaptation to environmental changes also play an important role in species preservation. A strategy to protect and restore *S. leprosula* and *S. johorensis* populations is to understand their associations with other species in natural forest ecosystems [4]. Therefore, research on the association of these two plant species with other species in natural forests is very important. By looking at these associations, we can understand more about the ecology and interactions between species in natural forest ecosystems. This research also provided valuable information in efforts to conserve these two plant species.

The research was conducted at IUPHHK (Timber Forest Product Utilisation Business Permit) PT Kemakmuran Berkah Timber, a company engaged in sustainable forest management. This location was chosen because it has a large area of natural forest that is still maintained, making it possible to make comprehensive observations about habitat conditions and interactions between species. The results of this study are expected to contribute to the conservation of *S. leprosula* and *S. johorensis*. With a better understanding of their associations with other species, conservation measures can be designed and implemented more effectively. These species can be conserved both *ex-situ* and *in-situ*, by taking consideration the conditions of their natural habitat.

2. Research Methodology

The research was conducted in the IUPHHK area of PT Kemakmuran Berkah Timber, West Kutai Regency, East Kalimantan Province, Indonesia. Based on the Minister of Forestry Decree No. SK.217/Menhut-II/2008 dated 9 June 2008, the IUPHHK area of PT Kemakmuran Berkah Timber is ±82,810 ha. Geographically the IUPHHK area is located at 114^{o} 28' 55" -114^{o} 59' 26" E and 0^{o} 54' 47" -1^{o} 15' 21" N. Based on the location of government administration, the area is within the Long Pahangai District, West Kutai Regency, East Kalimantan Province. Meanwhile, based on the forest management area, IUPHHK PT Kemakmuran Berkah Timber is within the area Long Bagun Forest Management Unit, West Kutai Regency Forestry Service, East Kalimantan Provincial Forestry Service. According to the division of watershed areas (DAS), the IUPHHK area of PT Kemakmuran Berkah Timber is within the Mahakam watershed area, which is spread across the Nyaan Sub-watershed, Tepai Sub-watershed, Melinga Sub-watershed and Meraseh Sub-watershed.

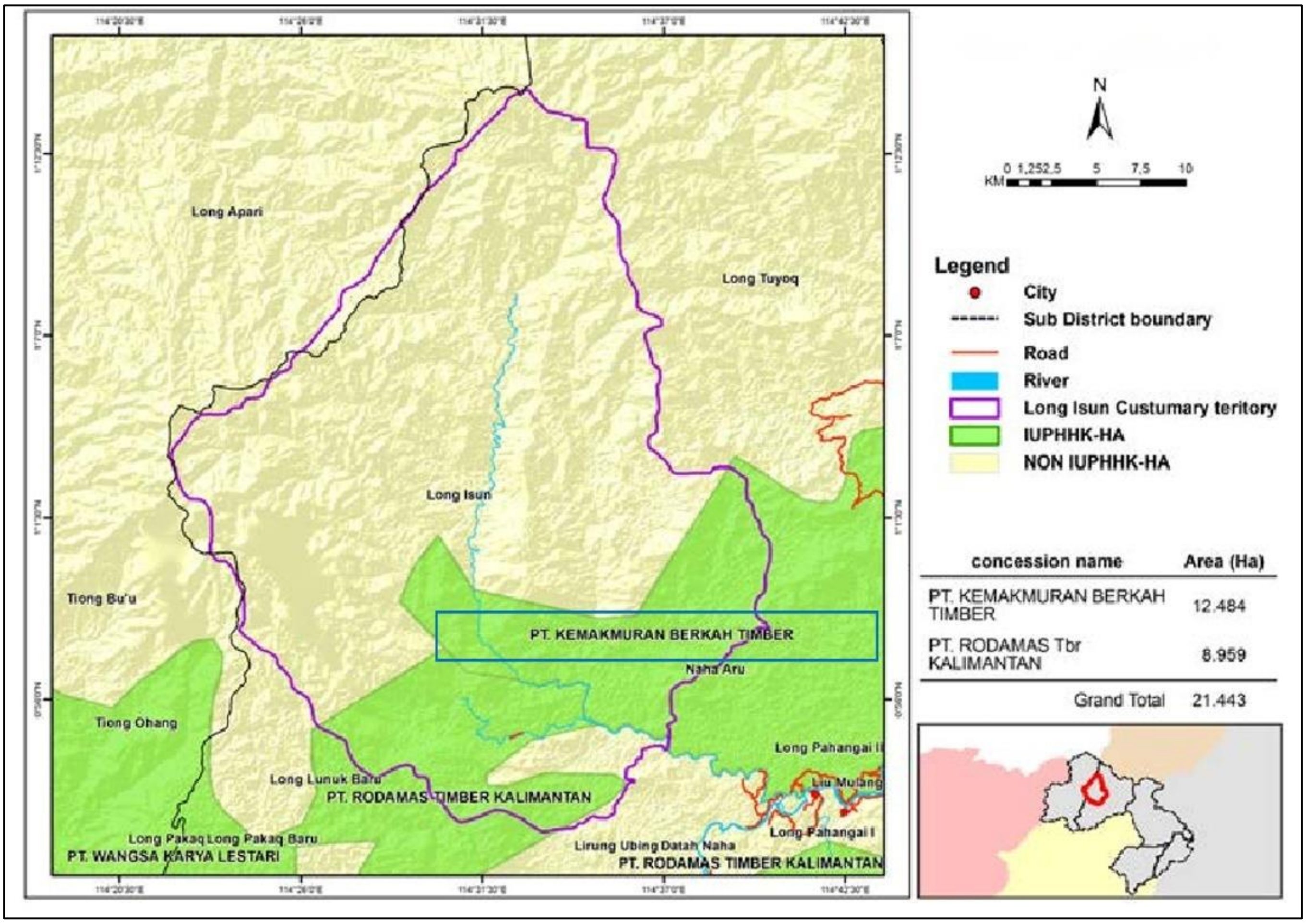

Figure 1. Map of the Research Location in the Concession Area of PT Kemakmuran Berkah Timber

2.1. Data Collection

Secondary and primary data collection, to facilitate the collection of primary data, research plots of an area of 1 hectare as many as 3 plots were made using the purposive sampling method and the plots were selected based on information that the area contained both types of observation targets. The research plots were square with a side length of 100 m horizontal distance, and then an inventory pathway was established with a pathway width of 20 m horizontal distance. To facilitate the tree inventory activities, measurement plots were created in the form of a square with a size of 20 m × 20 m, as many as 25 measurement plots adapted to the width of the path (Figure 2). Where inventory activities start from path 1, using the south-north direction and giving measurement plots numbers as shown in (Figure 2). Taking data on the position of trees against the baseline and path (x and y coordinates) of all species at the tree level and taking coordinate points with GPS.

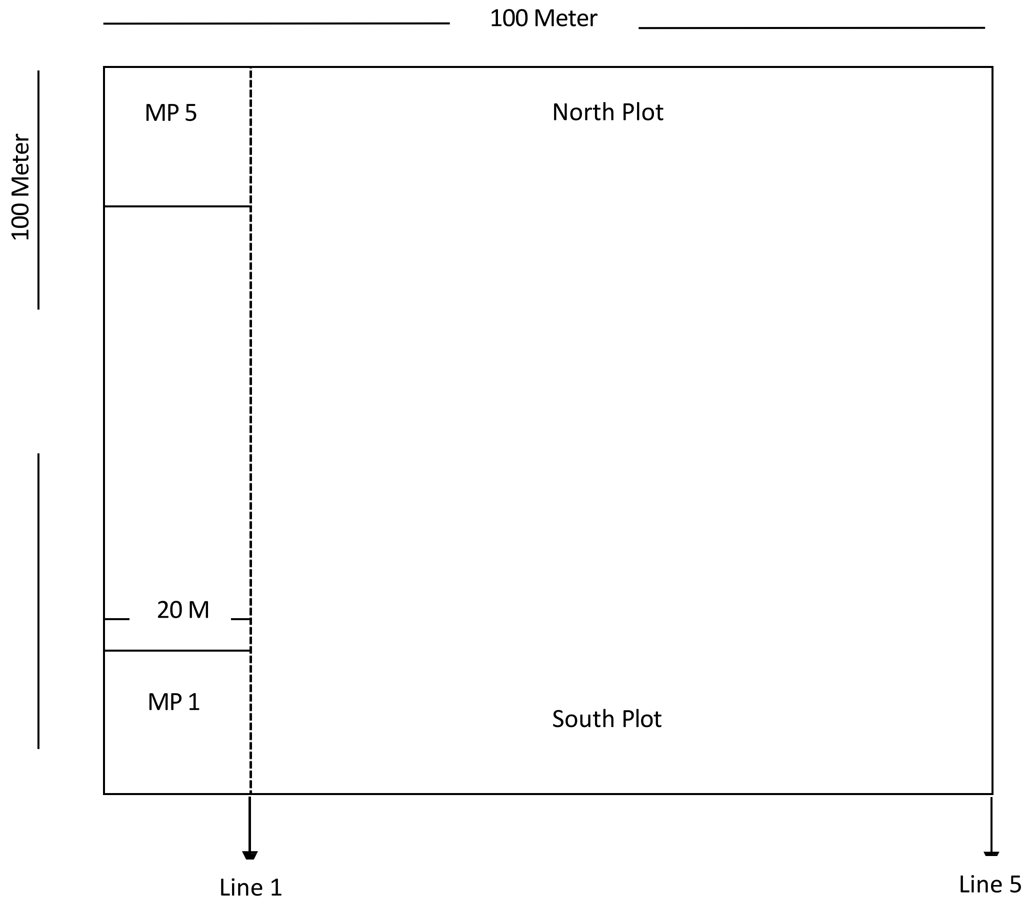

Figure 2. The design of the tree inventory sampling plot is based on an inter-plot size of 100m x 100m, with a measuring plot of 20m × 20m for the trees. (MP: Measuring Plot)

2.2. Importance Value Index (IVI)

The important value index is the sum of species density (RD), species frequency (RF) and species dominance (RDo) with the following formula [5].

$$\text{RD (\%)} = \frac{\text{Number of individuals of one species}}{\text{Total number of individuals of all species}} \times 100\% \quad (1)$$

$$\text{RF (\%)} = \frac{\text{Frequency of one type}}{\text{Total number of individuals of all species}} \times 100\% \quad (2)$$

$$\text{RDo (\%)} = \frac{\text{Base plane area of one type}}{\text{Total number of base areas of all types}} \times 100\% \quad (3)$$

$$\text{IVI (\%)} = \text{RD} + \text{RF} + \text{RDo} \quad (4)$$

Description : Relative Density (RD), Relative Frequency (RF), Relative Dominance (Rdo) and Important Value Index (IVI)

2.3. Association Type

To determine whether the *S. leprosula* and *S. johorensis* tree species have a close relationship with other species and also to determine the relationship between these species in the observation plots, measured by looking at the presence of other species (A) in a 20m x 20m plot of *S. leprosula* and *S. johorensis* tree species. The data obtained were then analysed using a correlation table of two types (2x2) or also called the contingency table as follows [6–8].

Table 1. Contingency table form

Type A / Type B	+	-		
+	a	b	a + b	(5)
-	c	d	c + d	(6)
	a + c	b + d	N = a + b + c + d	(7)

Description:
a : Number of plots containing species A and species B.
b : Number of plots containing species A only, species B not
c : Number of plots containing species B only, species A not
d : Number of plots that do not contain species A and species B.
N : Number of all plots

Furthermore, a direct calculation is carried out without calculating the observation value, namely by using the Chi-Square calculation formula (X^2) calculated as follows:

$$X^2 = \frac{(ad - bc)^2 \times N}{(a+b)(c+d)(a+c)(b+d)} \quad (8)$$

To avoid biased ChiSquare (X^2) values if the value of a, b, c or d in the Contingency table is less than or equal to 5 (five), the calculation is done using the following formula:

$$X^2 = \frac{\{(ad - bc) - N/2\}^2 \times N}{(a+b)(c+d)(a+c)(b+d)} \quad (9)$$

After obtaining the Chi-Square value, testing is then carried out by comparing the Chi-Square count (X^2 count) with the Chi Square table (X^2 table) at a free degree (*df)* equal to 1 (one) at the 5% level (3.84) and the 1% level (6.63) to determine the relationship between types. If the tested X^2 count is greater than or equal to X^2 table at the 1% level, it means there is a very real association, if the tested X^2 count is greater than or equal to X^2 table at the 5% level, it means there is a real association and if the tested X^2 count is smaller than X^2 table at the 5% level, it means there is no association or no real association.

2.4. Association Type

To calculate the value of the relationship between two species in one forest community (positive or negative association), the Association Coefficient (C) or kinship value is calculated using the following formula [9,10].

$$\text{If } ad \geq bc, \text{then } C = \frac{ad - bc}{(a+b)(b+d)} \quad (10)$$

$$\text{If } bc > ad \text{ and } d > a, \text{then } C = \frac{ad - bc}{(a+b)(b+c)} \quad (11)$$

$$\text{If } bc > ad \text{ and } a > c, \text{then } C = \frac{ad - bc}{(a+d)(c+d)} \quad (12)$$

Positive or negative values from the calculation results indicate positive or negative associations between two species. According to Papilaya [11] Positive association means that some species are indirectly related to or dependent on each other, while negative association means that some species tend to negate or exclude others or that two species have different influences or reactions in their environment.

2.5. Association Type

This research employs a digital cartographic approach utilising Geographic Information System (GIS) technology to visualise the spatial distribution of tree vegetation. The mapping process commences with the acquisition of geographic coordinate data for each tree via the Global Positioning System (GPS), which is then transformed into a digital format. Thereafter, the data undergoes processing and analysis using ArcView software to produce a comprehensive spatial representation..

3. Results and Discussion

3.1. Distribution of tree species

Based on the inventory at the study site, 511 species were recorded. There were 83 species in plot 1, 93 species in plot 2 and 166 species in plot 3. However, of the two Shorea species observed, only a few were found in the research plots. The identification results showed 64 *S. leprosula* trees and 5 *S. johorensis* trees. The results also showed that *S. leprosula* and *S. johorensis* were unevenly distributed across the three research plots. Of the two species observed, *S. leprosula* populations were more abundant than *S. johorensis*. Seven tree species of the *Shorea* family and two species of the *Dipterocarpus* family, belonging to the Dipterocarpaceae family, were also found in the study area. S. smithiana was recorded as 6 trees, *S. dasiphylla* as 6 trees, *Shorea* sp as seven trees, *S. macrophylla* as ten trees, *S. seminis* as eleven trees, *S. palembanica* as twelve trees, *S. pagutiana* as sixteen trees, *Dipterocarpus confertus* as three trees and *Dipterocarpus* sp as 29 trees.

This shows that although species from the Dipterocarpaceae family are still commonly found, they do not dominate. The area's character is considered a factor influencing species distribution from this family. Dipterocarpaceae are well adapted to tropical climates and diverse habitats, allowing them to thrive in natural forest ecosystems. Species of the Dipterocarpaceae family have adaptation mechanisms that give them a competitive advantage over other species for sunlight, water, and nutrients. They are also known for their longevity, large tree size, and ability to grow tall with strong root systems. Their seeds are dispersed in natural forests through wind and animals [12,13]. Tree species distribution data for each plot are presented in Figure 3, Figure 4, and Figure 5.

3.2. Tree species distribution pattern

3.3. Based on the findings obtained from analysing the spatial distribution patterns of arboreal species within the defined study area, cartographic depictions show that *S. leprosula* tends to grow in clusters, with its presence scattered throughout the defined study plots. The genetic variability identified in *S. leprosula* was more pronounced than that of *S. johorensis*. This significant genetic heterogeneity in *S. leprosula* may play an important role in promoting its tendency to cluster. Increased genetic diversity in *S. leprosula* populations may be an important determinant affecting growth dynamics, both among groups of individuals and in the wider population [14,15]. Figure 6,

Figure 7, and Figure 8 provide a comprehensive look at the distribution of this species within each plot.

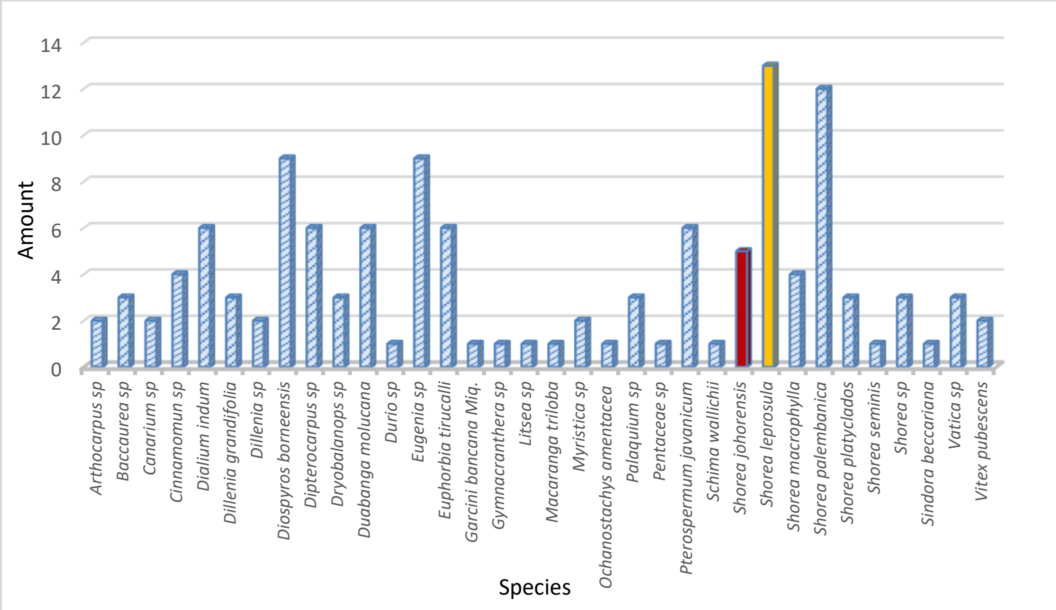

Figure 3. Distribution of flora species composition in observation plot 1 PT Kemakmuran Berkah Timber.

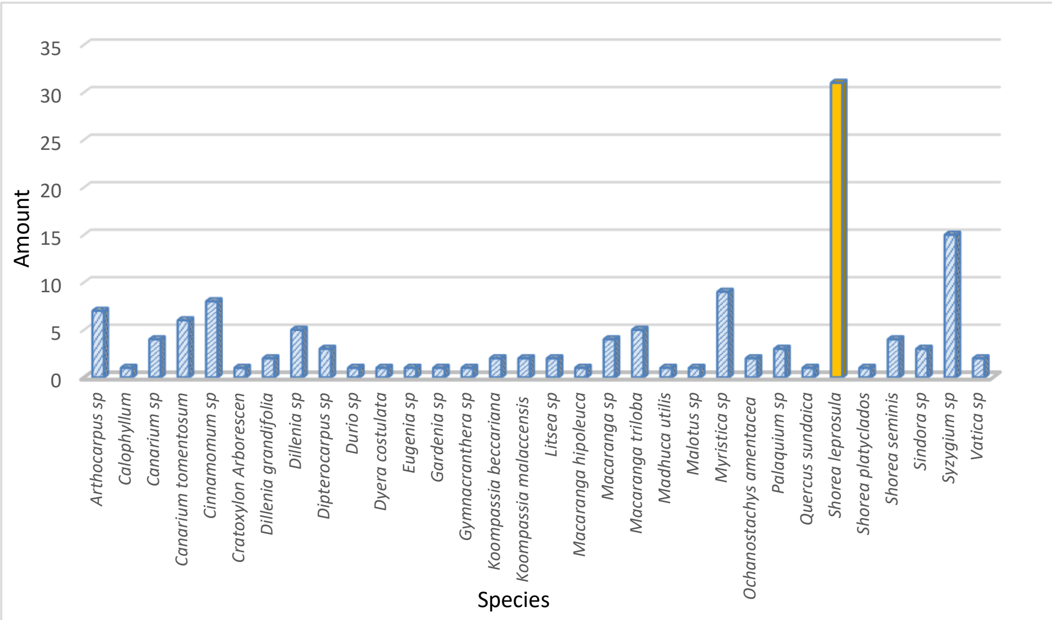

Figure 4. Distribution of flora species composition in observation plot 2 PT Kemakmuran Berkah Timber.

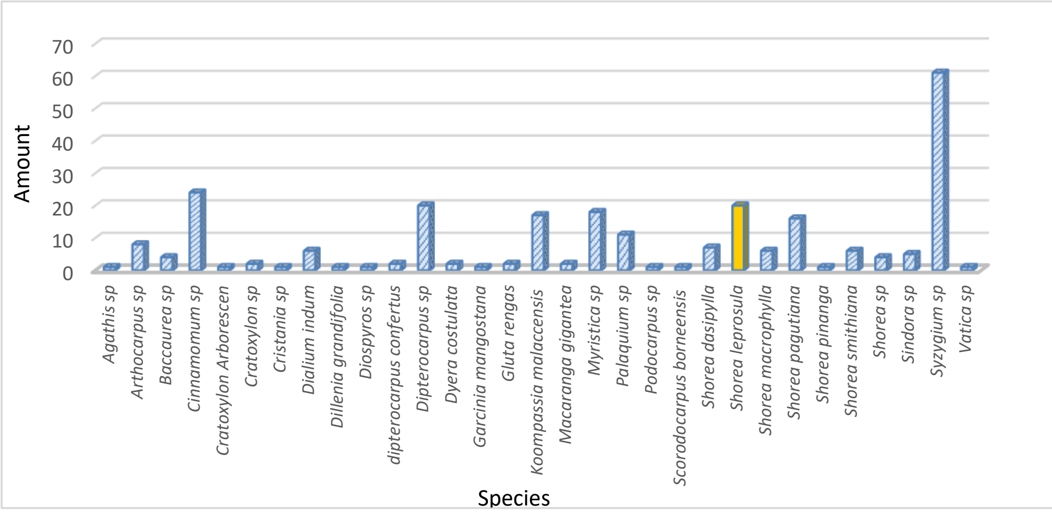

Figure 5. Distribution of flora species composition in observation plot 2 PT Kemakmuran Berkah Timber.

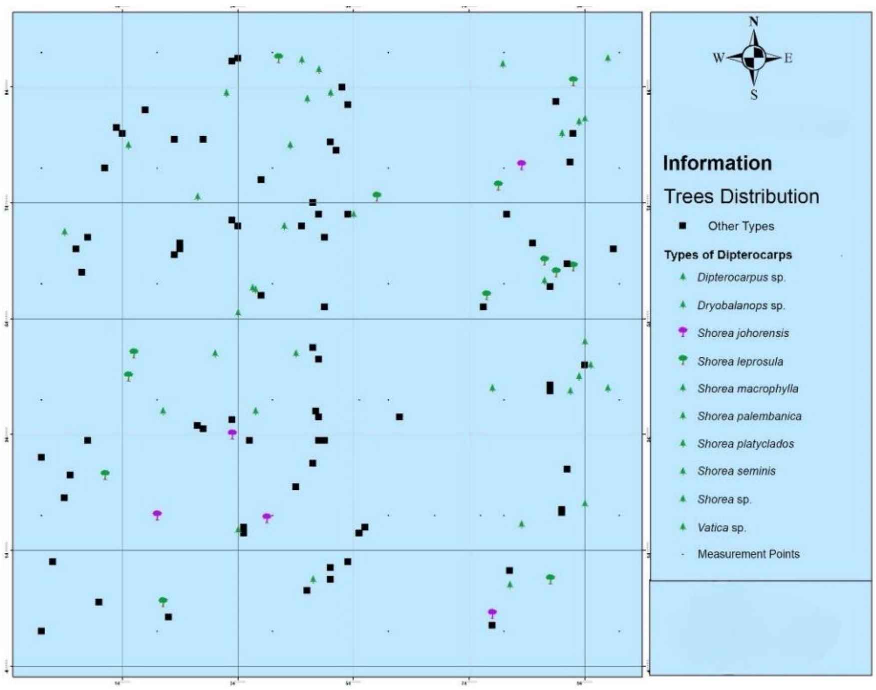

Figure 6. Distribution of tree species within the study plot area, highlighting the location and type of Dipterocarpaceae. The legend distinguishes between different species such as *Dipterocarpus sp.*, *Dryobalanops sp.*, *Shorea johorensis*, *Shorea leprosula* and others, marked with unique symbols for clarity. Black boxes represent other tree species outside the Dipterocarpaceae family (Plot 1).

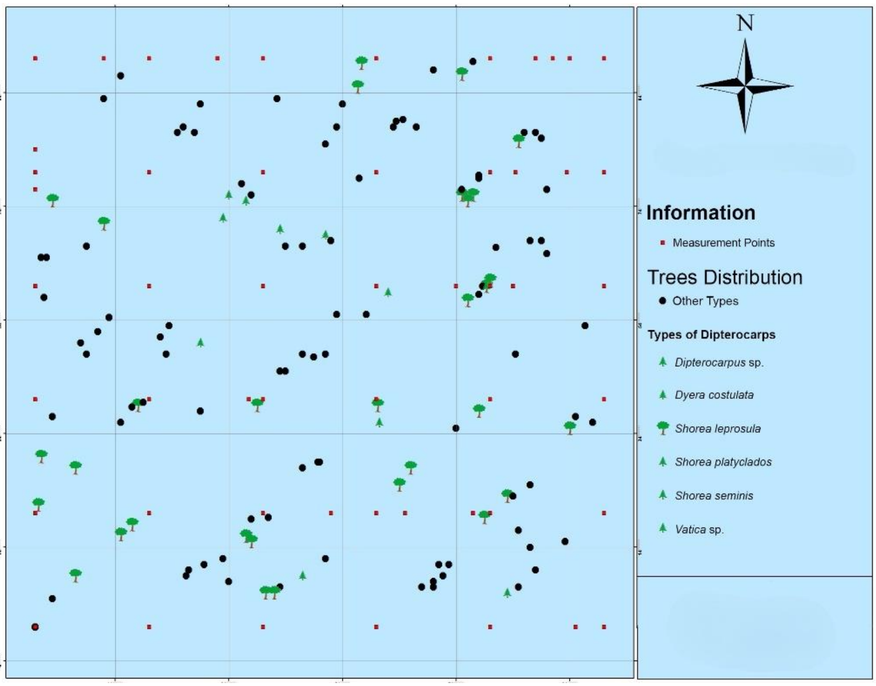

Figure 7. Distribution of tree species within the study plot area, highlighting the location and type of Dipterocarpaceae. The legend distinguishes between different species such as *Dipterocarpus sp.*, *Dyera constulata, Shorea leprosula* and others, marked with unique symbols for clarity. Black boxes represent other tree species outside the Dipterocarpaceae family (Plot 2).

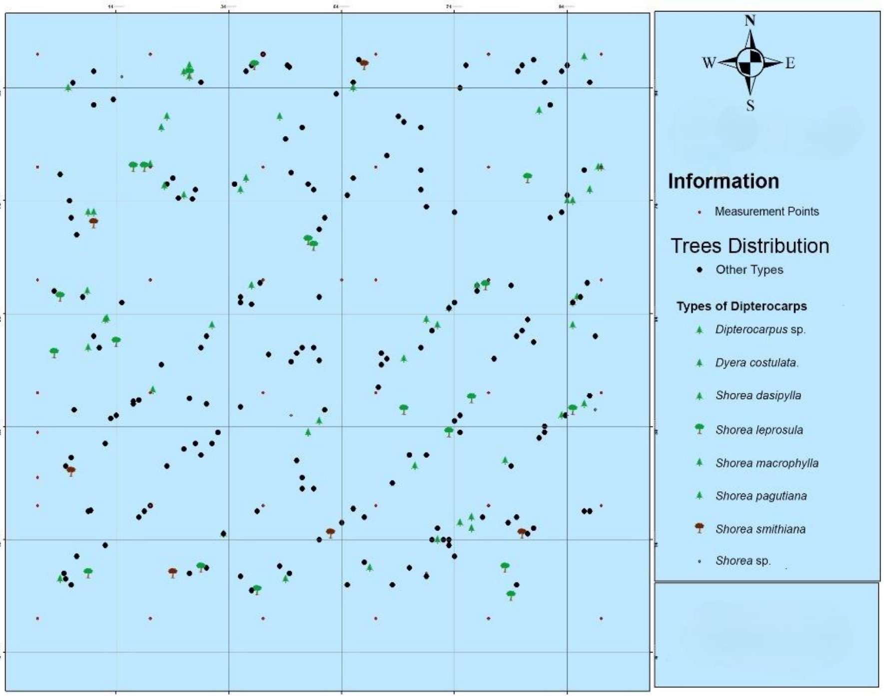

Figure 8. Distribution of tree species within the study plot area, highlighting the location and type of Dipterocarpaceae. The legend distinguishes between different species such as *Dipterocarpus sp.*, *Dyera constulata, Shorea dasiphylla, Shorea leprosula* and others, marked with unique symbols for clarity. Black boxes represent other tree species outside the Dipterocarpaceae family (Plot 3).

3.4. Importance Value Indeks of species

Importance value index (IVI) calculation was conducted to identify the dominating tree species. Based on density, frequency, and species dominance, 30 tree species with IVI ranging from 10.52% to 58.02% were identified from 3 observation plots (Table 2, Table 3, and

Table **4**). Tree species with IVI ≤ 10% in the observation plots are presented in Table 2, Table 3, and

Table **4**.

Table 2. The Importance Value Index (IVI) of the ten most dominant plant species observed in Plot 1 of PT Kemakmuran Berkah Timber

No.	Tree type	RD (%)	RF (%)	RDo (%)	IVI (%)
1	*Shorea palembanica*	9.45	8.08	17.03	34.56
2	*Shorea johorensis*	3.94	4.04	20.58	28.56
3	*Shorea leprosula*	10.24	10.10	0.09	20.43
4	*Shorea platyclados*	2.36	3.03	11.75	17.14
5	*Eugenia* sp	7.09	7.07	0.86	15.02
6	*Diospyros borneensis*	7.09	6.06	0.41	13.56
7	*Dialium indum*	4.72	5.05	2.75	12.52
8	*Euphorbia tirucalli*	4.72	5.05	2.70	12.48
9	*Canarium* sp	1.57	1.01	8.70	11.29
10	*Shorea macrophylla*	3.15	3.03	4.54	10.72

Table 3. The Importance Value Index (IVI) of the ten most dominant plant species observed in Plot 2 of PT Kemakmuran Berkah Timber

No.	Tree type	RD (%)	RF (%)	RDo (%)	IVI (%)
1	*Quercus sundaica*	0.76	1.05	46.48	48.29
2	*Shorea leprosula*	23.66	14.74	3.62	42.02
3	*Syzygium* sp	11.45	11.58	6.46	29.49
4	*Myristica* sp	6.87	6.32	0.64	13.83
5	*Cinnamomum* sp	6.11	7.37	0.33	13.81
6	*Canarium* sp	3.05	3.16	5.91	12.12
7	*Arthocarpus* sp	5.34	6.32	0.25	11.91
8	*Dillenia* sp	3.82	4.21	2.83	10.86
9	*Canarium tomentosum*	4.58	4.21	1.95	10.74
10	*Shorea seminis*	3,05	3,16	3,66	9,87

Table 4. The Importance Value Index (IVI) of the ten most dominant plant species observed in Plot 3 of PT Kemakmuran Berkah Timber

No.	Tree type	RD (%)	RF (%)	RDo (%)	IVI (%)
1	*Syzygium* sp.	24.11	15.69	18.22	58.02
2	*Cinnamomum* sp.	9.49	10.46	0.89	20.83
3	*Shorea pagutiana*	6.32	5.88	7.28	19.49
4	*Myristica* sp.	7.11	8.50	3.67	19.28
5	*Shorea leprosula*	7.91	7.19	0.79	15.89
6	*Dipterocarpus* sp.	7.91	5.23	1.98	15.11
7	*Shorea smithiana*	2.37	3.92	8.26	14.55

8	*Koompassia malaccensis*	6.72	6.54	0.40	13.65
9	*Shorea dasipylla*	2.77	1.96	8.43	13.15
10	*Dipterocarpus confertus*	0.79	1.31	10.26	12.36

Based on the calculation of IVI in plot 1 (Table 2), it can be seen that *S. johorensis* dominates with an IVI of 28.56% and *S. leprosula* with an IVI of 20.43%. Looking at the research conducted in Sangkima, Kutai National Park, shows that *S. johorensis* has a more dominant IVI than other species, which is 43.60% [16]. According to Mawazin and Subiakto [17], dominant species are species that are able to use their living environment more effectively than other species in the same location. This can be seen from the distribution of individuals in the area and the results of the IVI calculation show that both species develop in an environment that matches their habitat. According to Pamoengkas et al. [18] The higher a species' IVI, the more dominant it is in the community where it develops. Higher IVI levels signify greater stability, especially in terms of species resilience and growth rates.

In plot 2 (Table 3) For IVI ≥ 10%, *S. johorensis* was not observed, whereas *S. leprosula* ranked second with an IVI of 42.02%. *S. leprosula* appeared quite dominant compared to other species, indicating its competitive growth ability. The IVI calculation for plot 3 (

Table **4**) showed *S. leprosula* ranking fifth with an IVI of 15.89%. *S. leprosula* dominates natural forests due to its superior adaptation to the growth environment, exhibiting advantages in reproduction and regeneration. Additionally, natural seed dispersal plays a significant role in the dominance of *S. leprosula* in natural forests [19] Although *S. leprosula* may dominate natural forests due to its superior adaptation and strong reproductive capabilities, its impact on ecosystem diversity must be considered. The dominance of a single species can reduce biodiversity, affect ecosystem balance, and influence the long-term sustainability of other species.

3.5. Type association and kinship value

The results of the calculation of the association between *S. leprosula* and *S. johorensis* with other species can be seen in each plot (Table 5).

Table 5. Association values and association coefficients of *S. leprosula* and *S. johorensis* with other

Plot	Type	X_table		X_count	*Shorea leprosula*	
		5%	1%		Association	C(+/-)
1	*Duabanga molucana*	3.84	6.63	5.47	Significant	-
	Shorea macrophylla	3.84	6.63	4.56	Significant	-
2	*Myristica* sp	3.84	6.63	7.28	Highly Significant	-
	Ochanostachys amentacea	3.84	6.63	5.79	Significant	-
	Cratoxylon arborescen	3.84	6.63	4.75	Significant	-
	Durio sp	3.84	6.63	4.75	Significant	-
	Gymnacranthera sp	3.84	6.63	4.75	Significant	-
	Koompassia beccariana	3.84	6.63	4.75	Significant	-
	Macaranga hipoleuca	3.84	6.63	4.75	Significant	-
	Madhuca utilis	3.84	6.63	4.75	Significant	-
	Vatica sp	3.84	6.63	4.75	Significant	-
3	*Cinnamomum* sp	3.84	6.63	8.83	Highly Significant	-
	Arthocarpus sp	3.84	6.63	5.36	Significant	-
	Syzygium sp	3.84	6.63	4.75	Significant	-
					Shorea johorensis	
					Association	C (+/-)
1	*Palaquium* sp	3.84	6.63	5.63	Significant	+

Description: + : Positive association

- : Negative association

From the results of the association analysis between various species (X^2) that showed a real relationship, it was found that in each plot (Table 5), the calculated X^2 value exceeded the critical value of the X^2 table (0.05 and 0.01) by 3.84% and 6.63%. This indicates that *S.*

leprosula species in plots 1, 2, and 3 showed significant combinations of 2 species, 8 species, and 2 species, respectively. In addition, one highly significant combination was found in plot 1 between *S. leprosula* and *Myristica* sp with a negative coefficient of 7.28%, and in plot 3 between *S. leprosula* and *Cinnamomun* sp with a negative coefficient of 8.83%. Negative associations indicate that the occurrence of one species tends to negate the chance of another species occurring in the neighboring area. Therefore, negative association reflects the low probability of the same occurrence in the same place [20]. The existence of negative associations is due to lower inter-species relationships, where this phenomenon does not reflect tolerance for co-existence in the same area or does not provide mutual benefits, especially in terms of sharing living space [7,11].

While *S. johorensis* was only found in plot 1, with one significant combination with *Palaquium* sp. with a positive coefficient of 5.63%. Positive associations among tree species indicate that these species may have similar growing requirements, as species with similar resource requirements tend to cluster together for mutual benefit [21]. Species that have similar site requirements are likely to be positively associated, due to their ability to grow well in similar environmental conditions and benefit from the interaction in terms of food resources [22]. The empirical evidence indicating favorable correlations between *S. johorensis* and various other taxa implies that the conservation of this species may yield enhanced efficacy when integrated with broader ecosystem restoration initiatives. Restoration strategies should prioritize the management of habitats that facilitate the coexistence of species exhibiting positive associations with *S. johorensis*, such as *Palaquium sp.*, thereby augmenting the likelihood of successful restoration outcomes. The interrelations among these species afford a more profound comprehension of the ecological dynamics and habitat necessities of *S. leprosula* and S. *johorensis*, which subsequently can inform the development of more effective conservation methodologies.

4. Conclusions

From the results of this study, a total of 511 tree species were found. However, only a few Shorea species were found, namely 64 *S. leprosula* trees and 5 *S. johorensis* trees. It can be seen that *S. leprosula* dominates with a larger population than *S. johorensis*. Based on IVI, *S. johorensis* dominated the first plot with IVI of 28.56%, while *S. leprosula* dominated the second and third plots with IVI of 42.02% and 15.89% respectively. Then there is a significant negative association between *S. leprosula* with *Myristica* sp and *Cinnamomun* sp, with negative coefficients of 7.28% and 8.83%, respectively. Meanwhile, *S. johorensis* had a positive association indicating the possibility of similar growing site requirements between these species. This provides a clearer picture of the distribution patterns and interactions between tree species in the study area.

Author Contributions

SN: Conceptualisation, Methodology, Software, Investigation, Writing - Review & Editing; **P**: Methodology, Writing - Review & Editing, Supervision; **YM**: Writing - Review & Editing, Software; **WBC**: Writing - Review & Editing; **K**: Writing - Review & Editing.

Conflicts of interest

No conflicts to declare.

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