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Distribution Pattern of *Shorea lepropsula* Miq, Around the Forest Area with Special Purpose (KHDTK) Aek Nauli Indonesia

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Abstract

Shorea leprosula belongs to the Dipterocarpaceae family and grows in Indonesia's tropical forests which have an economic and ecological role. They are a plant in tropical forests that is known as a producer of fruit and tengkawang oil. The presence of S. leprosula trees in the habitat naturally at this time was very hard to find and began to decrease in population. This study aims to determine the potential and distribution pattern of S. leprosula found around KHDTK Aek Nauli. The research method uses the plot path method measuring 20 m × 20 m, the total number of plots is 150 plots. The research results show that the potency of S. leprosula is 63.17 m^3 ha^{-1}. The highest important value index of S. leprosula at the tree level was 25.45%. The distribution pattern of S. leprosula at the sapling, pole, and tree levels was clustered, while the distribution pattern at the seedling level was random. The importance of information about the potential and pattern of S. leprosula to be known as an indicator of the current status of its population at KHDTK Aek Nauli and as an information basis for managing management S. leprosula for support preservation in the forest.

Keywords: forest, distribution, potential, Shorea leprosula, KHDTK

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Introduction

Tropical forests play an important role in terrestrial biodiversity (Kumar et al., 2022). One of the tropical forest areas in Indonesia is the Aek Nauli Special Purpose Forest Area. Forest areas with special purposes (KHDTK) Aek Nauli is one of the KHDTK stipulated by the Decree of the Minister of Forestry Number 39/Menhut-II/2005 dated 7 February 2005 with an area of 1,900 ha. According to the historical function of the forest, KHDTK Aek Nauli originates from the Sibatuloteng Protection Forest (HL) (Maskulino & Panjaitan, 2020).

One of the plants found around KHDTK Aek Nauli is *Shorea leprosula* as a type of plant in the Dipterocarpaceae family which has an economic and ecological role (Pamoengkas et al., 2021). *S. leprosula* (red *meranti*) is a type of plant from the Dipterocarpaceae family and are often found in the tropics (Pamoengkas et al., 2021). This species grows in forests tropical Southeast Asia especially Malaysia and Indonesia (Sumatra, Kalimantan, and Maluku). This type dominated the realization of log production from natural forests and became the primadonna of the plywood and woodworking industries in the 80s90s. Dipterocarpaceae (dipterocarp) is the dominant family that makes up tropical natural forest ecosystems in Indonesia (Nuraina et al., 2018; Rachmat et al., 2021). In the Kalimantan region, it was found that the dipterocarp family is a plant group that has 7 genera or genera (clans), namely *Shorea*, *Parashorea*, *Hopea*, *Dryobalanops*, *Anisoptera*, *Vatica*, and *Dipterocarpus* (Muliadi et al., 2021). While according Soerianegara and Lemmens (1993), a dipterocarp family is a plant group that has 9 genera in the Southeast Asia region, namely *Cotylelobium*, *Upuna*, *Shorea*, *Parashorea*, *Hopea*, *Dryobalanops*, *Anisoptera*, *Vatica*, and *Dipterocarpus*.

Shorea fruit known as *tengkawang* is the name of a fruit and tree from the genus shorea whose fruit produces vegetable oil. The unique nature of *tengkawang* oil makes its price higher than other vegetable oils such as coconut oil. *Tengkawang* oil is used as a substitute for cocoa oil, lipstick, edible oil, and medicinal ingredients (Vebri et al., 2017). The wood, known as *meranti*, can be used for veneer and plywood, besides that, it can also be used for housing buildings, shipping lumber, musical instruments, furniture, and packing crates.

The Dipterocarpaceae family dominates the tropical rainforest canopy in Southeast Asia (Ng et al., 2021). Purwaningsih and Kintamani (2018) stated that of the 52 species of shorea found on the island of Sumatra, 34 species of which grow in lowland rainforest habitats (Saridan, 2016). In Indonesia, *S. leprosula* is only found on the islands of Sumatra and Kalimantan (Lestari & Pradana, 2022). *S.*

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leprosula often referred to as *meranti tembaga*, is a member of the Dipterocarpaceae family, which is the dominant tree species group in the tropical forests of Southeast Asia (Erizilina et al., 2017).

The *S. leprosula* plant is a type of commercial wood that has a high selling value because the wood is favored by the wood processing industry and generates large foreign exchange for the country (Erizilina et al., 2019; Septria et al., 2018). Maximum production of *S. leprosula* with a spacing of 3 m × 2 m was achieved at the age of 47 years with a maximum total volume (TV) of 470.9 m^3 ha^{-1}, an average tree diameter (d) of 40.2 cm and a branch-free height (h) of 12.9 m (Muliadi et al., 2021). The volume potential around KHDTK Aek Nauli based on the volume of trees with a diameter of ≥ 20 cm is 242.049 m^3 ha^{-1} (Panggabean, 2021). *S. leprosula* It is favored by the wood processing industry because it grows relatively fast at around 2 cm $year^{-1}$ and has light wood with a density of 0.3–0.55 g cm^{-1}.

In addition to having an economic function, *S. leprosula* also has an ecological function, namely as a food source and habitat for animals, one of which is the *orangutan*. The Dipterocarpaceae plant family dominates Indonesia's lowland rainforests and is under pressure to produce carbon (Latifah & Zahra, 2022). The ecological function of the *S. leprosula* plant is as a food source and habitat for animals, one of which is the *orangutan*. Species diversity in tropical forests can be defined as the variability of living organisms in an ecosystem. It can also occur as diversity between species and within species in a given ecosystem. It is considered an important component of the ecosystem as it helps in the regulation of hydrology and climate (Kumar et al., 2022).

Species diversity is in decline globally despite the passage of the convention on biological diversity (CBD). Most of the biodiversity hotspots are found in the tropics. These hotspots are characterized by having a large number of endemic and endangered species. The population of Dipterocarpaceae family has experienced a significant decline in the last few decades due to external factors (illegal logging, forest fires, habitat destruction, land conversion, natural disasters) and internal factors (relatively slow growth, relatively long fruit development, irregular fruiting period with sufficient range long, and recalcitrant fruit) (Erizilina et al., 2019). *S. leprosula* was included in the International Union for Conservation of Nature's (IUCN) Redlist data in 2017. *S. leprosula* is listed as "Near Threatened". The population of *S. leprosula* continues to decline from year to year (Lestari & Pradana, 2021).

Utilization of forest functions in North Sumatra related to ecological and economic functions will be optimal if sufficient information on the potential value, diversity, and distribution of *S. leprosula* species is available. *S. leprosula*, is one type *Shorea* spp. recommended by expertsintensive silviculture (SILIN) to be developed on the SILIN engineering TPTJ system (Winarni et al., 2023).

KHDTK have multi-functional potential that can provide economic, environmental, educational, and social benefits for mankind. Exploration of forest and ecological potential in terms of diversity of *S. leprosula* is very relevant as planning materials and policy formulation long-term strategy; medium-term; and KHDTK management operations. Therefore, there are three objectives of this research, namely 1) to identify the potential *S. leprosula*, 2) to calculate the importance value index (IVI) and species diversity, and 3) to determine the distribution pattern of *S. leprosula* in the study site.

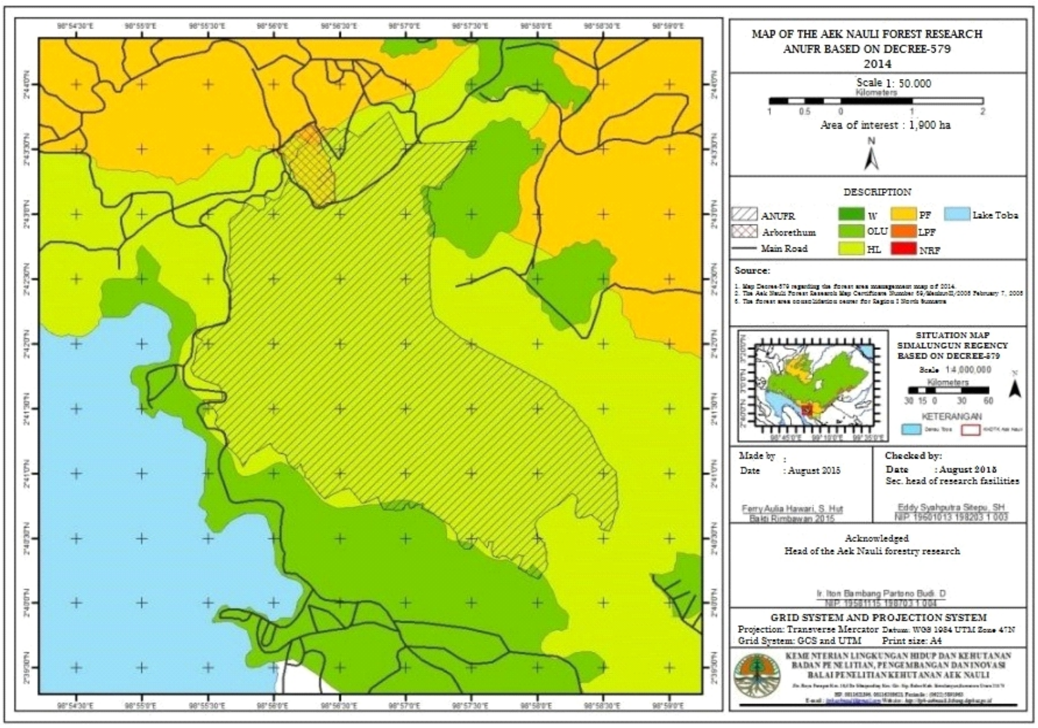

Figure 1 Location of the sample plots at the Aek Nauli Forest Research.

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Methods

Research sites The study was conducted from April to May 2021 around KHDTK Aek Nauli, Simalungun Regency, North Sumatra. Geographically, KHDTK Aek Nauli is located between N2°41′–2°44′ latitude and E98°57′–98°58′ longitude. The research location is in a secondary natural forest area. This area is a mountainous area with an altitude of about 1,100–1,750 m above sea level with a slope between 3–65%. KHDTK Aek Nauli functions as part of the water catchment area (DTA) which has several types of ecosystems which are the habitat of various protected species of plants and wild animals. The Aek Nauli forest area has a very diverse ecosystem. Various ecosystems in KHDTK Aek Nauli can be grouped including primary forest, secondary forest, plantation forest/pine dominance, shrubs and grass, predominance of certain types. Sampling plot at the study site can be seen in Figure 1.

Tools and materials The tools used in this study included a tape measure, raffia rope, map of the research location, christen hypsometer to measure tree height, global positioning system (GPS), tally sheet, phiband to measure tree diameter, digital camera for documentation. Materials used in this research were *S. leprosula* in KHDTK Aek Nauli.

Data collection Data collection was carried out using the grid path method, where the paths intersect the contour lines where the plots are placed discontinuously. Observation paths are made and placed by looking at the presence of vegetation. There are 3 observation lines with a size of 40 m × 1,000 m which are placed by purposive sampling. Each plot lane is made of plots measuring 20 m × 20 m, so there are 50 plots lane^{-1}. The total number of plots made is as many as 150 plots. The design of the observation plot placement can be seen in Figure 2.

Data analysis The potential volume of trees can be calculated by the formula (Istomo & Afnani, 2014) as shown in Equation *[1]*.

$$V = 1/4.\ \pi.(d/100)2.\ T.f \qquad [1]$$

Note : V = branch-free tree volume (m^3); π = 3.14; d = diameter at breast height; t = crown height minus buttress height (m); f = tree shape number (0.6)

The IVI is a quantitative parameter used to express the level of dominance of a species in a plant community. To calculate the IVI, the formula for tree level is used, which is the sum of relative density (RD), relative frequency (RF), and relative dominance (RDo) (Solihah et al., 2014). While for seedlings and saplings, it is the sum of relative density (RD) and relative frequency (RF) (Ismail et al., 2017; Aiko et al., 2021). The IVI can be calculated by formula as shown in Equation *[2]* until Equation *[9]*.

$$\text{Important Value Index (IVI)} = RD + RF + Rdo \text{ (for poles and treess)} \qquad [2]$$

$$\text{Important Value Index (IVI)} = RD + RF \text{ (for seedling and sapling)} \qquad [3]$$

$$\text{Individual Density (D)} = \frac{Number\ of\ individu}{Sample\ plot\ area} \qquad [4]$$

$$\text{Relative Density (RD)} = \frac{D*100\%}{All\ kind\ of\ D} \qquad [5]$$

$$\text{Frequency (F)} = \frac{Number\ of\ species\ plot}{Area\ of\ the\ whole\ plot} \qquad [6]$$

$$\text{Relative Frequency (RF)} = \frac{F*100\%}{All\ kind\ of\ F} \qquad [7]$$

$$\text{Dominance} = \frac{LBDS\ of\ kind}{Sample\ plot} \qquad [8]$$

$$\text{Relative Dominance (Rdo)} = \frac{D_o*100\%}{All\ kind\ of\ D_o} \qquad [9]$$

To find out the distribution pattern of each species is calculated using the Morisita index approach with the formula as shown in Equation *[10]* (Suhartono & Mulyana, 2018).

$$Id = n\frac{(\sum x_i^2 - \sum x_i)}{(\sum x_i)^2 - \sum x_i} \qquad [10]$$

Note: Id = Morisita dispersion index; n = total number of plots; Xi = number of individuals found in each plot

$$Mu = \frac{\chi^2_{0.975} - n + \sum x_i}{(\sum x_i) - 1} \qquad [11]$$

$$Mc = \frac{\chi^2_{0.025} - n + \sum x_i}{(\sum x_i) - 1} \qquad [12]$$

Note: Mu = Morisita index uniform distribution pattern; 0.975 = Chi-square table value with n-1 degrees of freedom

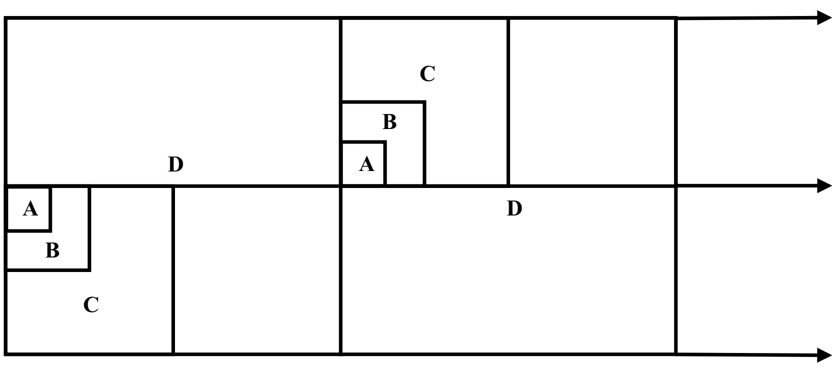

Figure 2 Plot design at the study site. A = sample plot of seedling level (2 m × 2 m); B = sapling level sample plot (5 m × 5 m); C = pole level plant sample plot (10 m × 10 m); D = tree-level plant sample plot (20 m × 20 m).

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and 97.5% confidence interval; Mc = The Morisita index is a clustered distribution pattern; 0.025 = Table Chi-square value with n-1 degrees of freedom and 2.5% confidence interval.

Furthermore, based on the Mu and Mc indices, the Standard Morisita Index (Ip) can be calculated using the formula as shown in Equation *[13]*.

$$Ip = \begin{cases} 0.5 + 0.5\left[\frac{Id-Mc}{n-Mc}\right]; Id \geq Mc > 1 \\ 0.5\left[\frac{Id-1}{Mc-1}\right]; Mc > Id \geq 1 \\ -0.5\left[\frac{Id-1}{Mu-1}\right]; 1 > Id > Mu \\ -05 + 0.5\left[\frac{Id-Mu}{Mu}\right]; 1 > Mu > Id \end{cases} \quad [13]$$

Criteria:
Ip < 0: The distribution pattern of species is even
Ip = 0: The distribution pattern of species is a random type
Ip > 0: The distribution pattern of species is clustered type

Results and Discussion

Potential of *S. leprosula* The potential referred to in this study is the potential volume of stands. Tree dimensions that are very important in estimating tree and stand potential are tree diameter and height. Besides being needed to calculate the basal area of a stand, height and diameter data can also be used to determine tree and stand volume. The results of measurement and data processing showed that the average diameter at breast height at tree level and pole level was 50.3 cm and 13.6 cm, respectively (Figure 3). While the average total height of *S. leprosula* at the tree level was 31.4 m and 13.3 m pole level (Figure 4).

Tirkaamiana et al. (2019) stated that the average diameter increment of *S. leprosula* at a planting width of 3 m was 1.47 cm year^{-1}, and at a planting width of 6 m was 2.08 cm year^{-1}. Tirkaamiana (2020) stated that the results of measuring the diameter of *S. leprosula* with silviculture of selective logging and planting in East Kalimantan at the age of 3, 5, and 7 years were 4.4 cm, 8.7 cm, and 13 cm respectively. Growth patterns of *S. leprosula* in silvicultural systems selective logging and planting lines (TPTJ) in West Kalimantan increased at the age of 1–7 years, some decreased at the age of 4 and 6 years. Exponential growth curve at 1–7 years, with sigmoid curve, short exponential phase, linear phase, and stable phase as physiological maturation (Mutia & Pamoengkas, 2014).

Tree volume is a three-dimensional measure, which depends on basal area, stem height or length, and stem shape factor (Herianto, 2017). Measurement of standing potential must be carried out carefully to obtain an accurate estimate of tree volume, that is, an estimate of the volume that is close to the actual volume value. Information on the number of trees and the volume of each diameter class can be seen in Table 1. The potential volume of *S. leprosula* ranges from 7–333 m^3 ha^{-1} with an average volume of 63.17 m^3 ha^{-1}. Results of other researchers (Saridan, 2016) state that the volume of *Shorea* spp in a mixed Dipterocarp forest lowlands is 38.32 m^3 ha^{-1} at KHDTK Labanan, Berau, East Kalimantan. The largest number of *S. leprosula* trees was in the diameter class of 50 up, namely 18 stems with a volume of 332.95 m^3 ha^{-1}. This information is useful in setting logging with certain height and diameter limits and can be used to determine the structure of a forest stand.

The potential of *S. leprosula* around the KHDTK Aek Nauli is smaller than the potential of the *Shorea* spp stands at the Haurbentes–Bogor KHDTK which ranges from 434.66–551.94 m^3 ha^{-1} (Hersandi, 2014), but greater than the potential of *Shorea* spp in the primary forest of PT. Intracawood Manufacturing Tarakan, East Kalimantan. Istomo and Afnani (2014) reported that the potential of *Shorea* spp. in the primary forest ranged from 11–109 m^3 ha^{-1}, while in RKT 2006 logged-over forest it ranged from 3–51 m^3 ha^{-1}. Hardjana and Suasta (2014) states that the open space for growth is caused by the death (mortality) of the surrounding staple crops, so that competition in getting nutrients and light is reduced, which is one of the factors that can trigger the growth of *S. leprosula*. It can be said that the potential per hectare does not necessarily depend on the total number of species groups. The potential for stands per hectare around KHDTK Aek Nauli depends on the number of trees in the large-diameter class.

The facts found in several locations application of the TPTJ silvicultural system model, species the most widely grown in the cropping line is a type of red *meranti*, because this type can grow on various types of soil and including one type of fast-growing meranti (Karmilasanti & Wahyuni, 2018). The results of Pamoengkas et al.'s research (2021) state that *S. leprosula* growth is influenced by slope class and

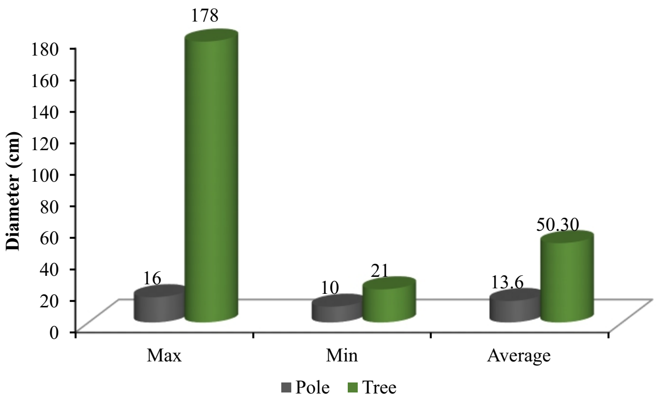

Figure 3 Diameter of *Shorea leprosula* tree level and pole.

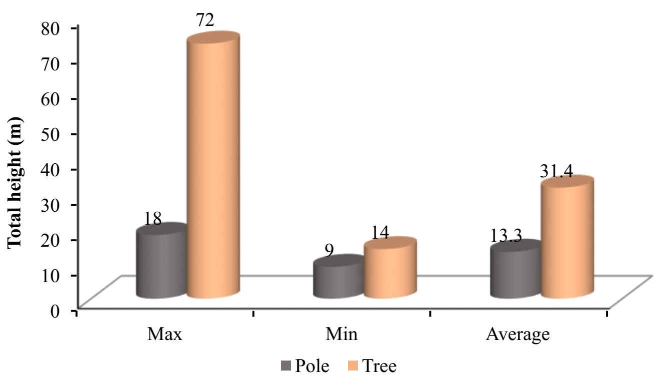

Figure 4 Total height (m) of *Shorea leprosula*.

direction, with the best height growth occurring at 4 m × 8 m, facing north. The best growth in diameter is in the flat slope class, with a north-facing slope, while at 2 m × 2 m, the slope is steep and facing south. Environmental factors like stand density, canopy treatment, soil nutrients, and silvicultural treatment also affect *S. leprosula*'s growth.

Importance value index One of the variables that show the function and degree of control of a plant species in a community is the IVI of that plant species (Paembonan et al., 2019). The greater the IVI value of a species, the greater the level of mastery over the community and vice versa (Irwan et al., 2015).

The number of *S. leprosula* at various vegetation levels can be seen in Figure 5. The highest number of *S. leprosula* was found at the seedling level of 68, and the lowest was at the tree level of 8. The number of *S. leprosula* seedlings which was quite a lot exceeding the level of saplings, poles, and trees indicated that *S. leprosula* seedlings were able to adapt to their environment. This is because the fruiting cycle of *S. leprosula* lasts from December to February. Mature trees will

Table 1 Volumes of *Shorea leprosula* in various diameter classes

Diameter class (cm)	Number of trees (N)	Volume (m^3 ha^{-1})
20–29	11	7
30–39	8	10.28
40–49	8	28.81
50 up	18	332.95
Average volume		63.17

produce abundant fruit throughout the fruiting season, and 14 weeks after flowering, *S. leprosula* fruits will drop to the forest floor. The fallen fruit will later develop into seedlings so that many seedlings grow around the parent *S. leprosula.*

A comparison of the number of *S. leprosula* with other plants at the study site can be seen in Figure 6. The results showed the comparison of the number *of S. leprosula* levels of seedlings, sapling, poles, and trees with all types other than *meranti* at each successive level of 6.1%, 4.6%, 1.1%, and 5.8%, respectively. When compared to the number of *S. leprosula* with the total amount of other vegetation at the study site, *S. leprosula* is still relatively small. Planting and enrichment efforts are needed in KHDTK Aek Nauli to regenerate the presence of *S. leprosula*. Planting activities and a silvicultural approach to restoring soil nutrients as a means of sustainable forest management have the greatest influence on tree species diversity (Latifah et al., 2022).

The results of the vegetation analysis in Table 2 show the highest IVI value *S. leprosula* is the level of the tree that is equal to 25.45%. The IVI at the sapling and pole levels was almost the same, namely 9%, while at the seedling level, it was 10.29%. The IVI of *S. leprosula* at the study site was still relatively higher compared to the results of the study by Prayoga et al. (2019), which shows the number of types of *Shorea* spp. is 11% of the total amount of vegetation making up the forestand INP of 4.32 at Bukit Barisan Selatan National Park Pemerihan Resort.

The species adaptability factor greatly influences the sustainability of vegetation growth from the seedling level to the next growth stage, namely saplings, poles, and so on until they grow into large trees. Species with a high IVI show that they can adapt to their environment and grow well, including being able to obtain sufficient water, sunlight, and nutrients for their growth (Nuraina et al., 2018; Prayoga & Indriyanto,

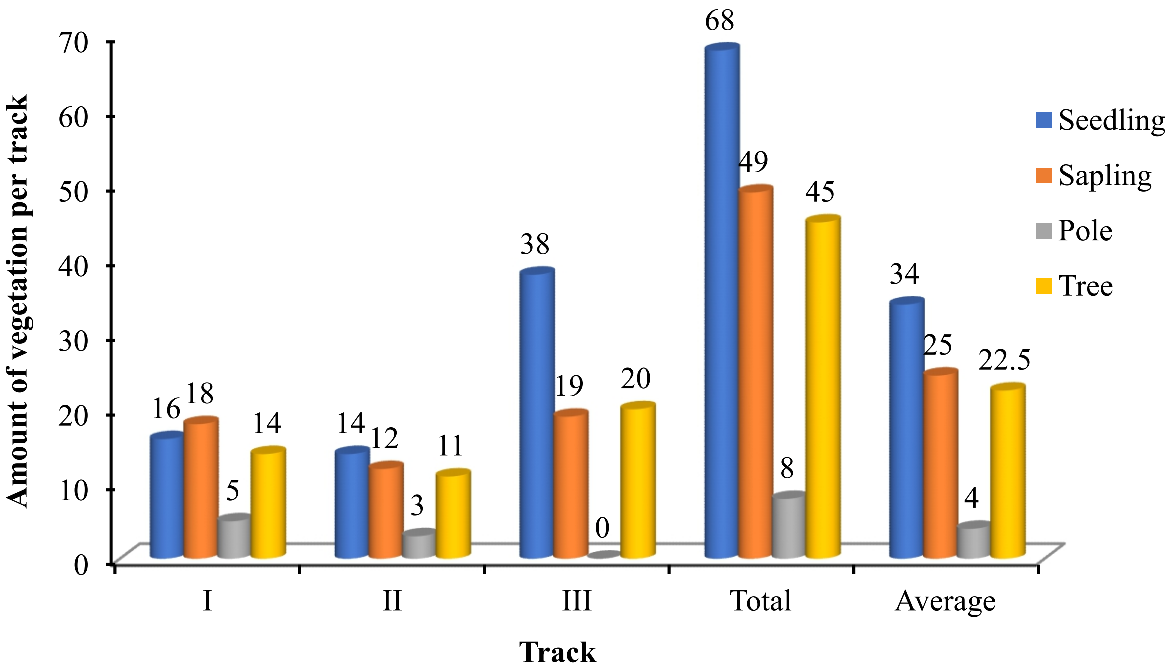

Figure 5 Number of *Shorea leprosula* at the level of seedlings, poles, saplings, and trees.

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2019; Rachmat et al., 2021).

Species diversity seen from the value of dominance (C), species diversity (H'), and evenness of species (E), can be seen in Table 3. The dominance value of a type of vegetation can be calculated based on the value of the diameter of the stem at breast height so that the value of dominance is determined by the density of the vegetation and the average size of the stem diameter.

The pattern of distribution There are three types of species distribution patterns, namely random, clustered, and uniform (Vebri et al., 2017). This study showed that the distribution pattern of *S. leprosula* distribution for saplings, poles, and trees is clustered, as seen from the Morisita Index which has an Ip value of >0. Meanwhile, at the seedling level, the distribution pattern is random with an Ip value = 0 (Table 3).

The distribution pattern of *S. leprosula* at the seedling level is random, caused by homogeneous environments and non-selective behavior patterns. Random distribution patterns are very rarely found in nature, and will only occur if there is no tendency for aggregation (Vebri et al., 2017). While the distribution pattern of *S. leprosula* for saplings, poles, and trees is clustered, this occurs because it is influenced by environmental factors which are classified as bioecological factors (Prayoga et al., 2019). Sholihin et al. (2020) stated that the distribution pattern of *S. leprosula* in three habitats in Gunung Palung National Park has a pattern group distribution. pattern of distribution of plant species tends to cluster, because of the plants reproduce by producing seeds that fall near the mother plant. *S. leprosula* generally has a distribution pattern in the form of colonies in one place or scattered in groups in every region. The shape of the fruit with wings that support the spread of the wind, so that the fruit will fall not far from the parent tree. The cluster distribution pattern in nature for both plants and animals in a population is a common distribution. Climate and nutrient availability are environmental factors that have a significant influence on their distribution. If the parent plant species' environment offers sufficient nutrients for growth, it may form a clustered distribution pattern. The results of Vebri et

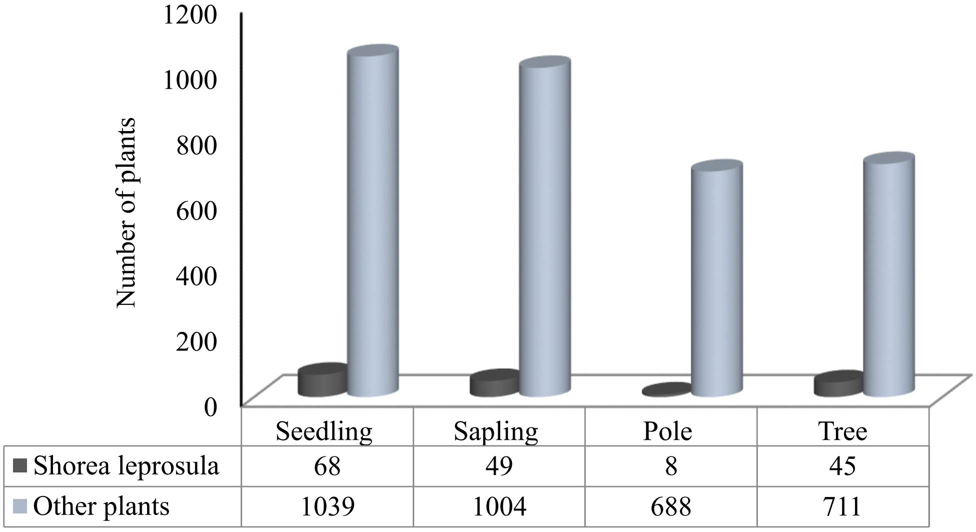

Figure 6 Comparison of the number of *Shorea leprosula* with other plants at the study site.

Table 2 Importance value index of *Shorea leprosula*

Level	K (N ha^{-1})	KR (%)	F	FR (%)	D (m^2 ha^{-1})	Dr (%)	INP (%)
Seedling	1,083.33	6.12	0.14	4.17			10.29
Sapling	125.33	4.70	0.16	4.40	-	-	9.10
Pole	5.33	1.17	0.12	1.40	0.01	6.47	9.04
Tree	7.5	6.52	0.62	6.29	0.03	12.64	25.45

Table 3 Distribution patterns of *Shorea leprosula*

Level	$\sum X_i$	$\sum X_i^2$	id	Your	Mc	Ip	Distribution pattern
Seedling	48	126	5.19	3.51	4.95	0	Random
Sapling	68	346	9.15	2.76	3.77	0.04	Clustered
Pole	8	12	10.71	17.87	27.53	0.18	Clustered
Tree	45	87	3.18	3.68	5.22	0.41	Clustered

al.'s research (2017) show that the distribution patterns of *Shorea* spp. at the tree level are clustered.

The distribution pattern is related to the bioecological factors that influence the individuals studied (Pratiwi, 2017). Bioecological factors are generally divided into two, namely, physical or abiotic factors which consist of non-biological environmental factors such as climate (air temperature, air humidity, light intensity), soil, and other physical environmental conditions and biotic factors such as humans, animals, and microorganisms (Jayadi, 2015). In addition to competition and environmental factors, plants that reproduce by producing seeds that fall close to their parents or rhizomes that produce vegetative tillers that are still close to their parents both contribute to the cluster distribution pattern (Prayogo et al., 2019).

Conclusion

The potential of *S. leprosula* based on tree volume is 63.17 m^3 ha^{-1}. One of the important ecological indicator indices, namely the IVI, vegetation analysis results show that *S. leprosula* tree species dominate at the tree level with an IVI of 25.45%. In general, the distribution pattern of *S. leprosula* in KHDTK Aek nauli were clustered.

Recommendation

There is an urgent need to carry out *Shorea* spp. conservation efforts, namely the development of *Shorea* spp. Forest accompanied by debriefing activities by making nurseries, intensive silvicultural patterns, dipterocetum development, forest and land rehabilitation, and routine forest safety patrols.

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