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Floristic composition and diversity at Keruing (*Dipterocarpus* spp.) habitat in Tangkahan, Gunung Leuser National Park, Indonesia

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Abstract. *Susilowati A, Rachmat HH, Elfiati D, Hidayat A, Hadi AN, Zaitunah A, Nainggolan D, Ginting IM. 2021. Floristic composition and diversity at Keruing (*Dipterocarpus spp.*) habitat in Tangkahan, Gunung Leuser National Park, Indonesia. Biodiversitas 22: 4448-4456.* *Dipterocarpus* spp., or locally known as Keruing, is a wood-producing tree and has high economic value. Keruing also produces derivative products in oil and oleoresin, which are widely used as raw materials for medicines and perfumes. Keruing natural population has been severely declining caused by habitat alteration and also over exploitation. Therefore, information on the composition and diversity of the floristic community at their habitat is important as an initial step in designing conservation actions. This study aims to determine the floristic composition and diversity at the keruing habitat in the Tangkahan area, Gunung Leuser National Park (Gunung Leuser NP). A line transect has been used to establish a purposive sampling in particular forest areas where the population of the keruing is known to grow naturally. Four line transects, each with five nested plots, totaling 110 plots, were established to gather data at four growth stages. The results found 47 species at the seedling stage, 43 species at the sapling stage, 48 species at the pole stage and 65 species at the tree stage. There were three species of keruing in the research location, namely *Dipterocarpus haseltii*, *Dipterocarpus costulatus* and *Dipterocarpus elongatus* Korth with low IVI values at each stage. *D. haseltii* was only found at the seedling, pole and tree stage with IVI values of 0.32, 0.30, and 6.90, respectively. *D. costulatus* was only found at the tree level with an IVI value of 3.43, while *D. elongatus* found at the sapling and tree stage with an IVI of 0.30 and 3.42, respectively. The diversity index in the research location was in the medium category at the seedling, sapling, and pole levels with a value of 2.96, 2.86, and 2.92, respectively and was classified as high at the tree level with a value of 3.18. The evenness index (E') in all growth stages is high or evenly distributed with the value of E' > 0.75. The species diversity in research location classified into medium-high category although in each stage showing dynamic on species domination. Disturbed habitat due to illegal logging and land conversion caused a problem on keruing regeneration. Conservation efforts, including active monitoring keruing occurrence, ex-situ conservation, and artificial regeneration, are needed to avoid keruing from extinction.

Keywords: diversity, habitat, keruing, species composition

INTRODUCTION

Keruing (*Dipterocarpus* spp.) is the third-largest genus in the family of Dipterocarpaceae (Ashton 1982; Newman et al. 1999; Khan et al. 2020). The geographical distribution of Keruing is scattered in several areas in Southeast Asia, including China, western Sri Lanka, Burma, Indochina, southern China, Thailand, Indonesia to the west of part of Malesia (Kartawinata 1983). So far, 38 keruing species have been recorded to be distributed in Indonesia, and most of them grow in primary forests on the islands of Kalimantan and Sumatra (Kartawinata 1983).

Keruing is a large tree with a height of 40-50 m and a diameter ranging from 100-150 cm, with straight trunks, hairy twigs, rough or smooth with visible stacked leaf marks (Soerianegara and Lemmens 2002; Aslam et al. 2015). It is known as a commercial wood producer that has been widely used in the wood processing industry (Dewi & Supartini 2017), with good strength and durability (Seng 1990). Keruing also produces oleresins (Dyrmose et al. 2017; Suiuay et al. 2019) and oils (Roschat and Kunchalee 2020) with high economic value. Of the 69 keruing species, twenty can produce oil with medicinal and fragrance properties (Boer and Ella 2001). Keruing oil contains several chemical compounds such as humulene, sesquiterpene alcohol (Aslam et al. 2015), oleanilic acid (Senathilake et al. 2017), and vaticaffinol (Chen et al. 2017), which are useful as diuretic drugs, wound infections (Kim et al. 2021), inflammatory symptoms (Yang 2013), gout (Chen et al. 2017) and antifilariae (Senathilake et al. 2017).

The high prices of wood, oil, and keruing oleoresin (Dyrmose et al. 2017), cause this species to be a target for continued exploitation (Susilowati et al. 2021, Dwiyanti et al. 2014). Previous studies report that keruing species are under high threat due to illegal timber extraction and disturbed habitat (Rugayah et al. 2017; Robiansyah 2017; Rachmat et al. 2018). High exploitation without conservation effort (Denny and Susilo 2019; Nguyen et al.

2020), specific habitat requirement (Purwaningsih 2004; Shivaprasad et al. 2017), and long flowering period (Harrison et al. 2005, Shivaprasad et al. 2017) also accelerate the population decline of keruing in its natural habitat. There are 25 species of keruing in Indonesia that are listed in the International Union for Conservation of Nature (IUCN) red list with vulnerable status (1 species), endangered (1 species), and critically endangered (23 species).

Gunung Leuser National Park (Gunung Leuser NP) is one of the world heritages located in North Sumatera, Indonesia. The high level of biodiversity in these locations has created ecological niches and habitats suitable for a wide variety of wildlife. For example, one of the Gunung Leuser NP areas that have become a biodiversity hotspot and ecotourism area is Tangkahan. As a conservation area, Tangkahan has several important fauna species, namely six primate species (Sumatran orangutan, siamang, gibbon, kedih, long-tailed monkey, and beruk), small squirrel, hornbill bird, srigunting batu, and eagle. In addition to animals, the Tangkahan area is home to various trees, and is generally dominated by the Dipterocarpaceae family (Sari 2014; Susanti et al. 2021).

T here is little research on plant ecology in Gunung Leuser NP (Susanti et al. 2021), let alone research focused on Keruing. Previous ecological studies on the plant were conducted several years ago (Sambas and Siregar 2004) or only focused on certain species, such as *Koompasia excelsa* and medicinal plants (Nurtjahja et al. 2013; Warsodirejo et al. 2020). Recent research on Gunung Leuser NP flora has focused on the Ketambe region, Sikundur, and other restoration areas. The other studies mostly focused on animal ecology since Sumatran tiger (*Panthera tigris sumatrae*) distribution areas. The research focused on Keruing in Gunung Leuser NP is essential considering the threats to its natural population and the fact that Gunung Leuser NP is known as a natural habitat for several keruing species (Sri 2011), especially in dry lowland forest ecosystems with an elevation of 10-300 m above sea level (de Wilde and Duyfjes 1996).

The information on species distribution, composition, and structure of vegetation in one particular habitat reveals the existence and quality of a forest community. This effort is carried out by measuring the presence of tree species at each stage of growth, possible threats, and conservation efforts in the future (Villa et al. 2019; Borogayari et al. 2018). The vegetation structure is also largely determined by habitat characteristics, species diversity, and the regeneration status of a species (Kashe et al. 2021). Research on the keruing distribution have been conducted by some researcher such as in Riau and Riau Islands (Subiakto et al. 2016; Heriyanto et al. 2019), on the small islands of the west coast of mainland Sumatra (Rachmat and Subiakto 2015), Lampung (Wardhani and Heriyanto 2015) and Bengkulu (Hidayat et al. 2017). However, information regarding keruing distribution in North Sumatra, which is considered to have a fairly wide natural habitat for keruing, especially in Gunung Leuser NP has not been available. A preliminary study conducted by Sari (2014) revealed the presence of keruing at an altitude of 130-1,200 m asl in the Gunung Leuser NP area. However, information related to keruing population structure and the diversity in the area are still lacking. Therefore, this study was conducted to determine the structure and composition of species in the keruing habitat in Tangkahan, Gunung Leuser NP as an initial step in determining future conservation action.

MATERIALS AND METHODS

Research location and period

This research was conducted on September 2020-March 2021 in the Tangkahan area, Gunung Leuser NP, Langkat Regency, North Sumatra Province (Figure 1). The area is a natural forest area with a hilly to steep topography with an altitude of 100-700 m asl. The average temperature at the study site ranged from 21.1˚C-27.5˚C with humidity between 80-100%. The average rainfall of this area ranges from 2,000-2,500 mm/yr (Susanti et al. 2021) and is dominated by Dipterocarpaceae family. Historically, this forest was pressured by illegal logging by local villagers, which ended in 2001 (Wiratno 2013), and is currently managed by a local villager in partnership with the national park administrator as an ecotourism area destination.

Data collection

The research was conducted using the combination method of plotted paths. The path was determined purposively based on the keruing and information from forest officials, local community knowledge, and previous studies (i.e., Jumawan 2015; Rachmat et al. 2018). The distance between lanes varied depending on location conditions from the closest 80 m to the farthest 100 m. The variables recorded included the number of individuals of all species in each growth stage in the sample plots as well as the height and diameter of breast height (dbh) at the pole and tree levels. Each growth stage was assessed in different plot sizes, including 2 x 2 m for seedlings, 5 x 5 m for saplings, 10 x 10 m for pole, and 20 x 20 m for tree levels. The growth stages were determined as follow seedling (height 1.5 m), sapling (height > 1.5 m, dbh < 10.0 cm), pole (10 cm < dbh < 20 cm) and tree (dbh >20 cm). Data collection was carried out on ten lines, with the number of plots for each growth phase was 110 plots or a total of 440 plots from seedling to tree level. Species identification was carried out by employing a botanist. The specimens of ambiguous species were taken to be identified later in the herbarium. These field data collected were then used to measured the relative value of density, frequency, and basal area.

Data analysis

The concept of Importance Value Indexs (IVI) developed by Curtis and McIntosh (1950), Phillips (1959), and Misra (1968) Rastogi (1999), and Sharma (2003) were employed for dominance and biological success measurement in the research location. IVI of each species was obtained by summing the relative value of density, frequency, and basal area.

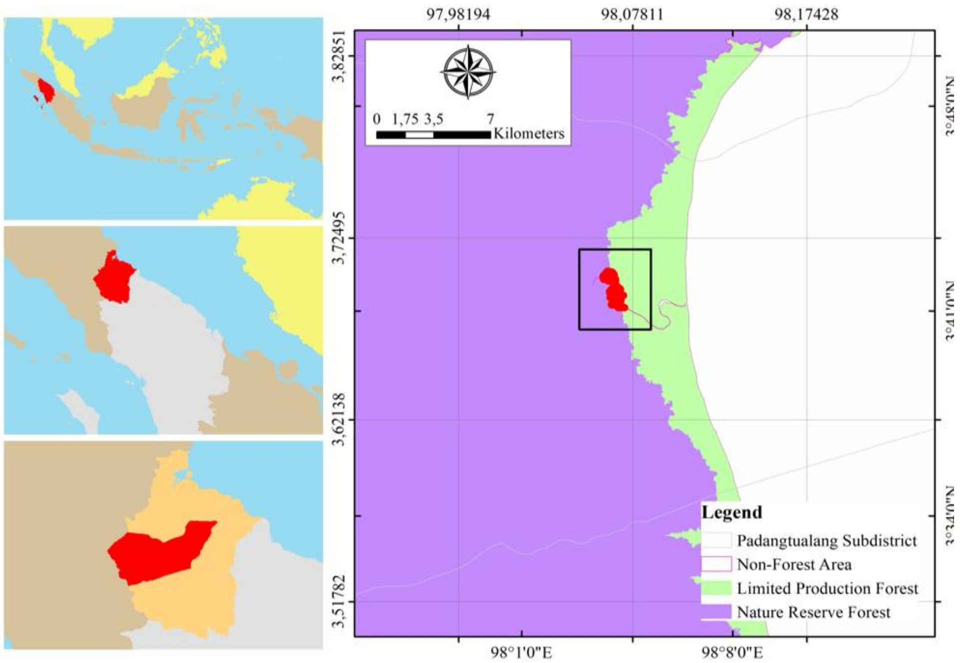

Figure 1. Map of research Location in Tangkahan, Gunung Leuser National Park, North Sumatra, Indonesia.

Relative density (RD)

Relative density denotes an individual average proportion of a particular species compared with the total individual number of observed species in a research area is referred to as relative density. It was calculated using the following formula:

$$\text{Relative Density} = \frac{\text{total number of individual species}}{\text{total number of all individual of species}} \; x\ 100\%$$

Relative frequency (RF)

Frequency indicates by the occurrence of a species on an observed compared to the occurrence of species in all sampling plots. It was calculated using the following formula:

$$\text{Relative Frequency} = \frac{\text{Frequency of respective species}}{\text{Frequency of all species}} \; x\ 100\%$$

Relative basal area (RBA)

Relative basal area or relative dominance is defined as is the total individual basal area of a species covered by the stems and was calculated using the following formula:

$$\text{Relative Dominance} = \frac{\text{Basal area of species}}{\text{Basal area of all species}} \; x\ 100\%$$

Important value index (IVI) is a quantitative parameter used to determine the control of a species in a plant community. The Important Value Index was obtained by the formula:

For tree species, IVI = RD + RF + RBA
For seedlings and saplings, IVI = RD + RF

Species diversity

Various diversity indicators were calculated by using the Shannon-Wiener index (H′), Margalef index (R), and Evenness (E). The species diversity was determined by using Shannon-Wiener and formulated as follows:

$$H' = \Sigma \text{ pi ln pi};$$

Where pi is pi denotes the species individual percentage and all individuals in a forest. The species richness (R) was estimated using the Margalef index with the following formula:

$$R= S\text{-}1/\text{Ln (No)}$$

Where; S is the species number in the observed plot, and No denotes the individual total number in the observed plot. The index of evenness (E) is used to calculate individual dispersion/distribution. Individual dispersion/distribution is determined using the Evenness index (E), which is calculated as follows:

$$E = S / (\log \text{ni} - \log \text{ns});$$

Where; S is the species number found in the plot, ns and ni denote density values of the highest and the lowest important species, respectively. The dispersion of a species is categorized as low uniformity if $0 < E < 0.5$ and high uniformity if $0.5 < E < 1$.

RESULTS AND DISCUSSION

Species composition

The Tangkahan forest area is a typical tropical rain forest in Gunung Leuser NP, distinguished by its high tree species diversity, varying stages of tree growth, and big tree dimensions. There has been very limited research on the tree species in this area. Sari (2014) and Susanti et al. (2021) conducted previous studies on plant ecology in this area and showed that the Dipterocarpaceae was the dominant family in Tangkahan area. The results of the study found that there were variations in the dominance of dipterocarp species at each growth stage.

Regarding keruing, our research found three keruing species namely, *D. haseltii*, *D. costulatus,* and *D. elongatus* which were distributed at different growth stages. *D. haseltii* is a large, buttressed tree with a dense hemispherical crown, also known as keruing bunga or palahlar. This species is a ridge-dwelling upper canopy tree of undisturbed mixed coastal dipterocarp forest and survives as pre-disturbed remnant trees in secondary forest. These species are classified as endangered (EN) on the IUCN red list due to overexploitation of its wood and land conversion activities (Ly et al. 2017). *D. costulatus,* also known as the keruing kipas, is a native tree of Indonesia, Malaysia, and Singapore. The species occur in lowland forests on alluvium, sandy, peat, and heath soils, all threatened habitats. Because of anthropogenic pressures on the forest for agricultural expansion and logging, these landscapes are decreasing. Much of Sumatra's lowland forest is also being destroyed (Smith et al. 2018). According to the IUCN, the species is listed as near threatened (NT) due to its recent condition and threat (Barstow 2019). *D. elongatus,* also known as keruing minyak, is a big tree with a height of up to 65 m, a straight trunk, cylindrical stems, and the diameter of up to 260 cm. It occurs in secondary and primary forests, as well as freshwater swamp forests, and also is largely affected by microclimate factors such as soil physical and slope. Keruing minyak is listed as critically endangered (CR) by the IUCN due to habitat loss and land conversion (Ashton 1988).

Specific information regarding this species reproductive biology and propagation is still scarce. But some researchers reported that the species flowers in mast years, every four to five years (Ghazoul 2016; Shivaprasad et al. 2017). Dipterocarprs flowers were produced on racemose inflorescences of three to twenty flowers. The flowers were insect-pollinated by *Apis dorsata* (Harison et al. 2005). However, seeds are commonly used for propagation in the Dipterocarpus genus. The seeds of Dipterocarpus have a recalcitrant characteristic and contain starch grains as reserve components. The seeds still in the parent tree have pre-dispersal seed predators such as parquet, rodent, and insect species. After dispersing from the parent tree, Dipterocarp seeds have post dispersal seed predators and are scattered on the forest floor (Bagchi et al. 2011). Vertebrates, particularly wild boar (*Sus barbatus*) and rodents, were potential seed predators. Pigs are voracious predators of dipterocarpus seeds. However, they do not attack the seedlings (Wells and Bagchi 2005). The Dipterocarpus genus commonly regenerates under the shade of a forest. Under the shade, seedlings and saplings can live for many years. Young trees survive in the shade of a forest, but they demand more light (Ghazoul 2016). All keruing species populations had declined due to anthropogenic pressures on forests for agriculture activities, illegal logging, specific microsite preferences, and reproductive biology characteristics. We found a dynamic pattern on keruing distribution in all development stages throughout our study.

Seedling stage

The presence of seedlings is an important indicator of the natural regeneration of tree species in an ecosystem. At the seedling stage, 47 species were found, with a total of 1,042 individuals. *Shorea leprosula* was the species with the highest IVI followed by *Diospyros blancoi, Nephelium juglandifolium, Syzygium lineatum, Palaquium gutta, Syzygium fastigiatum, Litsea* sp.*, Petungah* spp.*, Knema cinerea, Shorea faguetiana* (Table 1). At the seedling stage, only *Dipterocarpus haseltii* were found in rank 37 of the 47 species found. *Dipterocarpus elongatus* and *Dipterocarpus grandiflorus* were not found at this stage. The abundance of *S. leprosula* seedlings and the low number of keruing seedlings were considered related to the suitability of the light and habitat needs. According to Steur et al. (2020), the presence of local light variation may influence the growth and abundance of herbaceous layers, young trees, and seedlings. Furthermore, Do et al. (2020) also stated that the forest canopy density influences the availability of forest floor light and varies over time as the forest develops. In old-growth tropical forests, light competition significantly impacts seedling's recruitment (Born et al. 2015).

Shorea leprosula or red meranti is one of the dipterocarp species targetted for illegal logging. As a result of these conditions, this species is included in the IUCN red list with endangered status (Ashton 1998). Red meranti has a semi-tolerant character to light. The light requirement at the seedling level for this species ranged from 50-85% and increased in line with the growth phase (Widiyatno et al. 2020). Of the three keruing species, only *D. haseltii* was found in this stage. The abiotic factor may contribute to keruing seedling survival. Maua et al. (2020) stated that the suitability of species regeneration might be linked to suitable microsites, such as variation in resource availability and species-specific effects.

Table 1. The top ten rank of species based on important value index (IVI) at seedling stage

Rank*	Scientific name	RD	RF	IVI
1	*Shorea leprosula*	19.67	17.52	37.20
2	*Diospyros blancoi*	10.26	9.21	19.48
3	*Nephelium juglandifolium*	8.63	8.09	16.72
4	*Syzygium lineatum*	6.14	7.42	13.55
5	*Palaquium gutta*	5.75	5.84	11.60
6	*Syzygium fastigiatum*	5.08	5.62	10.70
7	*Litsea* sp.	4.79	4.72	9.51
8	*Petungah* spp.	4.31	4.49	8.81
9	*Knema cinerea*	3.74	4.27	8.01
10	*Shorea faguetiana*	4.31	3.59	7.91
37	*Dipterocarpus haseltii*	0.95	0.22	0.32

Notes: * show the ranking based on IVI

The composition of species revealed inter and intraspecies ecological effects and had a significant impact on seedling recruitment at the local scale (Chua and Pott 2018). Once the structure of a forest stands impacts the distribution of nutrients, light, and air on a small scale, the species composition is an abstraction of intra and inter-species local ecological effects (Cole et al. 2011; Mayoral et al. 2019). Both have a significant impact on seedling development. Density influences not only the availability of seeds, but also the physical and biological processes of seed germination, live growth, and seedling growth (Lutz et al. 2012; Dong et al. 2017).

The heavy, dense canopy and lack of parent trees are thought to be the cause of the small number of this keruing in the seedling stage. Do et al. (2020) found substantial mortality for *D. kerii* seedlings at low light intensity. Another study on *D. alatus* conducted by Dongsansuk et al. (2020) showed the high survival of seedlings on 50% light intensity compared to 10%, 30%, and 100%. On *D. hasseltii*, Wardhani (1990) stated that light intensity 50% produces better seedling growth. Another study conducted by Ashton (1988) found 40-70% light intensity for *D. elongatus*. As is well known, the Dipterocarpus genus is a semi-tolerant species that requires shade to develop (Ghazoul 2016) and grows optimally in the shade ranging from 40-70% (Heyne 1987). In addition to light factors, seed predators and limited parent trees likely also contributed to the small number of keruing seedlings in the research location. The edible keruing fruit is preferred by animals such as wild boars, pigs, primates, and birds and this also decreases their germination rate at the forest floor (Iku et al. 2017; Denny and Susilo 2019).

Sapling stage

A total of 43 species with 1,250 individuals were found in the observation plot for the sapling stage. The ten species with the highest IVI were *Shorea leprosula*, *Diospyros blancoi*, *Syzygium lineatum*, *Palaquium gutta*, *Litsea sp*, *Syzygium fastigiatum*, *Nephelium juglandifolium*, *Shorea faguetiana*, *Petungah* spp., and *Knema cinerea* (Table 2). *Shorea leprosula* was the highest IVI at the sapling stage, with an IVI value of 33.07%. For keruing species, *D haseltii* and *D. elongatus* only ranked 39 and 40, respectively of 43 species. Only one individual of each species was found.

A study conducted by Denny and Susilo (2019) on *D. gracilis* found that the absence of the juvenile stage indicated the possible unavailability of suitable microsites for seed germination. Another threat to natural regeneration is many natural seed predators of the dipterocarps that hinder natural regeneration. The obstacle can begin with pre-dispersal seed predators, namely seed predation, which occurs while the seeds are still attached to the parent tree and have not yet spread. Pre-dispersal seed predators for potential dipterocarps are parquet birds, rodents, and other insect species (Bagchi et al. 2011). The suitability of light intensity also influencing the sapling survival of the keruing species. At the seedling level, keruing seedlings are more shade tolerant and can survive competition with lower forest layers. However, at a later stage of development, keruing seedlings are generally light tolerant species. Therefore, keruing seedlings will grow optimally in stands with medium density (Ghazoul 2016). The survival and growth rate of keruing are highly dependent on a canopy gap and the availability of light. Thus, limited light sources can lead to large numbers of individuals between seedlings and larger diameter classes.

Pole stage

At the pole stage, there were 48 species with a total number of 499 individuals. The ten species with the highest IVI values can be seen in Table 3. They were *Shorea leprosula, Syzygium fastigiatum, Litsea sp, Knema cinerea, Nephelium juglandifolium, Shorea faguetiana, Hopea dryobalanoides, Beilschmiedia cf. dictyoneura, Mangifera foetida, Baccaurea racemosa.* Still, *Shorea leprosula* ranked first at this stage. At the pole stage, no keruing species were found.

Table 2. The top ten rank of species based on important value index (IVI) at sapling stage

Rank*	Scientific name	RD (%)	RF (%)	IVI (%)
1	*Shorea leprosula*	17.12	15.95	33.07
2	*Diospyros blancoi*	13.52	9.79	23.31
3	*Syzygium lineatum*	12.08	8.88	20.96
4	*Palaquium gutta*	5.6	6.61	12.21
5	*Litsea* sp.	5.92	5.47	11.39
6	*Syzygium fastigiatum*	4.88	6.15	11.03
7	*Nephelium juglandifolium*	4.72	4.78	9.50
8	*Shorea faguetiana*	4.4	4.56	8.96
9	*Petungah* spp.	4.72	3.87	8.59
10	*Knema cinerea*	3.12	4.10	7.22
39	*Dipterocarpus haseltii*	0.08	0.22	0.30
40	*Dipterocarpus elongatus*	0.08	0.22	0.30

Notes: * show the ranking based on IVI

Table 3. The top ten rank of species based on important value index (IVI) at pole stage

Rank*	Scientific name	RD (%)	RF (%)	RBA (%)	IVI (%)
1	*Shorea leprosula*	30.46	22.44	30.63	83.53
2	*Syzygium fastigiatum*	7.41	8.03	7.31	22.76
3	*Litsea* sp.	7.21	7.76	6.61	21.58
4	*Knema cinerea*	6.01	7.48	5.76	19.25
5	*Nephelium juglandifolium*	5.41	5.82	5.36	16.59
6	*Shorea faguetiana*	3,61	3,32	3,93	10,86
7	*Hopea dryobalanoides*	3,81	2,77	3,78	10,36
8	*Beilschmiedia cf. dictyoneura*	2,81	3,32	3,12	9,24
9	*Mangifera foetida*	2,81	3,32	2,33	8,46
10	*Baccaurea racemosa*	2,40	3,32	2,33	8,06

Notes: * show the ranking based on IVI

At pole stage, *Diospyros blancoi* was no longer among the top 10 species with the highest IVI. Other species were newly listed, such as *Hopea dryobalanoides*, *Beilschmiedia cf. dictyoneura, Mangifera foetida,* and *Baccaurea racemosa*. *Diospyros blancoi*, also known as bisbul, is one of the fruit-producing species and is reported to be one of the orangutan feeds. The absence of bisbul from the top ten ranking of pole and tree levels could be a result of logging activities that resulted in the loss of several parent trees. The presence of *Hopea dryobalanoides, Beilschmiedia cf. dictyoneura, Mangifera foetida*, and *Baccaurea racemosa* in the ten species that have the highest IVI to be something interesting because these species were not listed on top ten ranks in the seedling and sapling stage. *Hopea dryobalanoides* is a member of the dipterocarp family, which is also experiencing a population decline and is listed by IUCN with the least concern status (Barstow 2018). *Beilschmiedia cf. dictyoneura* is a member of the Lauraceae family known as medang. Although not listed by the IUCN, this species is nevertheless a target of illegal logging due to the market demand for its wood. *Mangifera foetida,* or Bacang, is a known fruit producer. In GLNP, bacang flower and fruit were source of orangutans (*Pongo abelii*) feed. Similarly, bacang, *Baccaurea racemosa*, or menteng fruit is a food source for orangutans (Nayasilana et al. 2015).

Tree stage

At the tree stage, there were 66 species with a total of 876 individuals. *Shorea leprosula* continued on the top position in IVI, followed by *Litsea* sp., *Nephelium juglandifolium, Shorea faguetiana, Syzygium fastigiatum, Pometia* spp, *Koompassia malaccensis, Neobalanocarpus heimii, Palaquium gutta,* and *Castanopsis acuminatissima* (Table 4). At the tree stage, three keruing species were found, namely *D. haseltii* which ranked 12th, *D.costulatus* ranked 23rd and *D. elongatus* ranked 24th.

Several species that were not in the top ten highest IVI in the juvenile stages were among the top ten list at the tree stage, including *Pometia* spp, *Koompassia malaccensis*, *Neobalanocarpus heimii*, and *Castanopsis acuminatissima*. This result implies the dynamic condition of the vegetation in the Tangkahan area. Only *Shorea leprosula, Litsea sp, Nephelium juglandifolium*, *Shorea faguetiana,* and *Syzygium fastigiatum* were consistently on the top ten ranks of IVI from all growth stages. This shows the importance of these species in the Tangkahan. The high IVI describes the species' optimum ability in terms of nutrient utilization, growth environments, and distribution, allowing them to be abundant in the habitat (Naidu et al. 2021). In contrary with the dominant species, no keruing species were found in the top ten IVI at all stages. The three keruing species revealed in the research area were found in small numbers. *D. haseltii* was found at the seedling, sapling, and tree stage with IVI values of 0.32%, 0.30% and 6.90%, respectively. *D. elongatus* was only found at the sapling, and tree stages with an IVI of 0.30%, and 3.32%. Meanwhile, *D. costulatus* was only found at the tree stage with an IVI of 3.43%.

The lack of keruing individuals at each growth stage indicates that the keruing natural regeneration was already impaired, and the habitat had been disturbed. The effects of anthropogenic disturbances on plant composition and plant diversity have been investigated in many studies all over the world. Eshaghi et al. (2018) illustrated that pole and tree cutting had significant influences on decreasing biomass and plant diversity and changing the species distribution pattern. Furthermore, Mohammed et al. (2021) found that 85 percent of tree species have a poor regeneration state as a result of human disturbance, and some species are only found in the mature stage. The human disturbance through illegal logging in Tangkahan is considered one of the causes of the disturbance of keruing regeneration in that area. Illegal logging with the target of valuable timber and land clearing for oil palm plantations has occurred in Tangkahan since the 1920s. Later, the area was converted to ecotourism from 1999 to 2004 (Wiratno 2013). Before the year 2000, illegal logging exploited large trees with higher market values, such as keruing. There is no available report to support that data, although a few numbers of the remaining cut stem can still be seen. The wood extraction of keruing affects the keruing population, and some keruing species were absent at the tree stage. Existing logging has increased the intensity of light reaching the forest floor by opening up the forest canopy. Keruing's juvenile stage did not grow optimally owing to the significantly decreased canopy. Another study conducted by Robiansyah (2017) on *D. littoralis* on Nusakambangan Island found that the juvenile stage population was lower than that of the mature stage. The conversion of forest to plantations is suspected to be the cause of this condition. On *D. turbinatus*, Dey and Akhter (2020) reported that human intervention affected the establishment of new seedlings, and their transition to mature stands is very poor.

Table 4. The top ten rank of species based on important value index (IVI) at tree stage

Rank*	Scientific name	RD (%)	RF (%)	RBA (%)	IVI (%)
1	*Shorea leprosula*	26.48	15.23	24.53	66.24
2	*Litsea* sp.	7.31	8.12	5.81	21.24
3	*Nephelium juglandifolium*	6.74	6.60	4.25	17.58
4	*Shorea faguetiana*	4.11	3.72	5.33	13.17
5	*Syzygium fastigiatum*	4.34	4.74	3.42	12.50
6	*Pometia* spp.	3.77	4.74	3.31	11.82
7	*Koompassia malaccensis*	2.05	2.20	6.27	10.52
8	*Neobalanocarpus heimii*	3.31	3.21	3.68	10.21
9	*Palaquium gutta*	3.08	4.06	2.45	9.59
10	*Castanopsis acuminatissima*	2.63	3.55	3.27	9.45
12	*Dipterocarpus haseltii*	2.28	1.52	3.09	6.90
23	*Dipterocarpus costulatus*	1.02	1.35	1.05	3.43
24	*Dipterocarpus elongatus*	0.79	1.18	1.34	3.32

Notes: * shows the ranking based on IVI

Table 5. Diversity, evenness, and species richness index for species at *Dipterocarpus* spp. habitat

Plant stage	Species diversity (H')	Evenness (E)	Species richness (R)	Number of species
Seedling	2.96	0.77	6.62	47
Sapling	2.89	0.77	5.89	43
Pole	2.92	0.75	7.57	48
Tree	3.18	0.76	9.45	66

The loss of numerous keruing species at the tree stage affected keruing regeneration since the parent trees producing seed for regeneration were no longer there. As it was well known, timber extraction may lead to changes in plant species' competitors, changes in the movement of pollen, changes in the pattern of seed dispersal by animal vectors, and a reduction of plant and animal population numbers. Because animals pollinate a large number of tropical trees, changes in plant diversity and pollinator habitat destruction will have a major impact on pollination success rates. In addition to illegal logging and the fruit predator, seed supply factors play a role in the low number of keruing regeneration. Keruing is one species with a long flowering and fruiting period (Harrison et al. 2005) that occurs every five to six years. Pillay et al. (2018), stated that timber extraction significantly affects the process of seedling recruitment. The remaining reproductive age trees in logged forests produce smaller seeds than trees in the non-logged forest. In logged forests, the contribution of functional vertebrates in seed predation increased, while non-vertebrate seed predation decreased. The density dependence strength of dipterocarps can change at different life stages (Widiyatno et al. 2017).

Species diversity

The species composition in a particular ecosystem might have an impact on the community and composition of the plant structure of such an ecosystem. Wang et al. (2020) stated that the diversity of species might reflect the stability of plant communities. Species diversity was quantified using three components: richness, evenness, and disparity. The value of species diversity in the tree stage is higher than in the saplings and seedlings stage (Table 5). The Shanon-Wiener index in the tree stage was 3.18, followed by seedling (2.96) and pole (2.92). In most ecological studies, the values for this index ranged between 1.5 and 3.5 and rarely exceeding 4. Different diversity values in tree stages can be caused by a various factor. Light competition is one of the factors influencing vegetation's ability to survive. The dense canopy and large trees in the study area made it difficult for light to reach the forest floor, resulting in inhibited growth of vegetation at lower stages such as seedlings, saplings, and poles. Several species of trees were unable to grow and develop under the shade of the parent tree, and that some of them were even extinct. This condition will contribute to the diversity values obtained.

The species evenness index (E) can reflect a species distribution in a community. The evenness index of species also influences the community's stability in an ecosystem. In this study, the value of E ranged from 0.75-0.77 and was classified as high. A community will have low evenness if there is a significant disparity of individual numbers within each species and vice versa. The heterogeneous components of natural forest and a fairly constant number of individuals influence species evenness and increase the plant community. According to Pavoine et al. (2019), evenness will be maximal and uniform if all species have the same number of individuals.

Species richness is defined as the species total number in the population (Aisling et al. 2018). Forest trees offer natural resources and suitable habitats for general species in the forest. The diversity and richness of tree species are important to total forest biodiversity (Malik et al. 2016). The estimated value of species richness in this research ranged from 5.89 to 9.45. The tree stage had the highest value for species richness (Table 5), indicating that species diversity is higher in this stage than in others. The variation of species richness and diversity for both tree species and seedlings can be attributed to the habitat heterogeneity represented by soil chemical properties, environmental factors (Tilk et al. 2017), and human disturbance (Biswas and Mallik 2010).

Land conversion and illegal logging for keruing species are still occurring in Tangkahan area. In relation to the research location, which is a part of a well-protected national park (Poor et al. 2019), disturbances to vegetation caused by anthropogenic activity were still found (Pandiangan et al. 2017). In terms of conservation, the findings of this study can be used to encourage GLNP area administrators to prioritize biodiversity protection in this location. The success of a nature tourism activity can be measured in terms of the beneficial interaction between biodiversity dynamics, local communities, and the nature tourism activity itself (Ross and Wall 1999). Examples of activities that integrate keruing conservation with ecotourism include enrichment and monitoring of keruing species by nature tourism actors or raising awareness of nature tourism actors about the keruing species in the Gunung Leuser NP area.

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