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Species Composition and Stand Structure of Dipterocarpaceae in Chini Watershed Forest, Pekan, Pahang, Malaysia

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ABSTRACT. A study was conducted in the Chini Watershed Forest, Pekan, Pahang, to assess the species composition, stand structure, distribution, and total biomass of Dipterocarpaceae. The primary objective was to understand the ecological characteristics of this important forest ecosystem. Five plots, each measuring 25 x 20 m, were randomly selected, covering a total area of 0.25 ha. Within each plot, all trees with a diameter at breast height (DBH) of ≥ 5.0 cm were tagged and measured. A total of 27 individual trees belonging to Dipterocarpaceae were recorded, representing three genera and ten species. *Shorea* emerged as the dominant genus with six species, alongside *Hopea* and *Vatica*. The stand structure analysis revealed that 55% of all individuals fell within the lowest DBH class (5.0 - 14.9 cm), indicating a relatively young population. In terms of density, *Shorea maxwelliana* exhibited the highest density at 24 individuals per hectare. Among the species, *Hopea griffithii* had the highest frequency, present in four out of the five plots, with a frequency of 80%. The basal area (BA) was determined to be 10.08 m^2/ha, with *Shorea leprosula* having the highest basal area at 4.17 m^2/ha at the species level. These findings contribute to our understanding of the Dipterocarpaceae community in the Chini Watershed Forest and may have implications for its ecological management and conservation.

Keywords: Chini Watershed Forest, Dipterocarpaceae, Species composition, Stand structure

INTRODUCTION

In recent decades, rapid economic growth and development have taken place around the Tasik Chini area. According to Mushrifah et al. (2005), anthropogenic activities such as logging and oil palm plantations established in the 1980s and ecotourism activities in the 1990s have had a detrimental effect on the ecological functions and biological diversity in Tasik Chini. Land-use activities around Tasik Chini have transformed many forest areas into tourist infrastructure, agricultural and mining areas, and even local settlements (Sujaul et al., 2012). The development activities carried out have a great impact on the ecological, biological, and hydrological functions of the lake system. Some parts of the primary forest areas have been logged and disturbed, and now the forest that grows back surrounding the Tasik Chini basin is known as the regeneration forest (Gan and Abdul Aziz, 2005). This logging

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activity has caused problems for the ecology as well as the environment in a broad sense. As a result, the rate of soil erosion and soil deposition increased, causing the depth of the lake to decrease. Apart from that, logging activities have also caused many high-quality logs to be cut down. Several forest areas in the watershed areas have been cut down and replaced with iron ore mining, oil palm cultivation, logging, and the development of local community activity centres. These have disturbed the ecosystem and ecology around the Chini watershed areas. Looking at the state of Chini watershed areas, which are currently experiencing habitat reduction and fragmentation, studies on the composition, stand structure, and distribution of Dipterocarpaceae trees are needed.

This study was conducted based on the rationale of providing references, guidance, and information to stakeholders related to the Dipterocarpaceae found in the forest area at the Chini watershed after several changes and developments that took place around the area. Based on past studies conducted by many researchers, their studies are more focused on community structure and biomass on the ground of all tree species present in their study plots. For instance, a study by Khairil et al. (2011) focused on community structure and biomass estimation for all tree species with diameters of 5 cm and above in three forest types, namely inland forests, seasonal flood forests, and riparian forests. In addition, a study conducted by Mohd Fairuz (2007) also focuses on similar aspects that involve the composition, diversity, and biomass estimation of tree species at diameters of 5 cm and above in the Chini Forest Reserve. Lastly, a study conducted by Norsiah (2004) also involved the composition and diversity of tree species found in riparian forests in Tasik Chini Forest Reserve, Pahang. Therefore, specific studies on the composition, distribution pattern, and even the total biomass of the family Dipterocarpaceae have never been conducted in the area. The objectives of this study are to determine the species composition, stand structure, and distribution pattern of Dipterocarpaceae found in the Chini watershed forest.

METHODOLOGY

Tasik Chini (3° 15 ’40 “N, 120° 45’ 40” E) is about 100 km from Kuantan and 60 km from Pekan. The journey to this lake takes through the Kuantan-Segamat Highway, which is the main road to Chini town and the Chini-Salong road, and through the road from Kuantan to Kampung Belimbing or Kampung Rambai near Maran. Then, continue through the waterway by boat down the Sungai Pahang before entering Kuala Sungai Chini, which is 4.8 km from the Sungai Pahang (Mushrifah Idris et al., 2005).

Tasik Chini is the second largest natural lake in Peninsular Malaysia after Tasik Bera. This lake system contains 12 open freshwater bodies that connect each other and form this lake (Figure 1). This body of water is known as ‘sea’ by the local Orang Asli. The bodies of water consist of Laut Gumum, Laut Pulau Balai, Laut Chenahan, Laut Tanjung Jerangking, Laut Kenawar, Laut Serodong, Laut Melai, Laut Jemberau, Laut Batu Busuk, Laut Labuh, Laut Genting Teratai and Laut Mempitih. The total area of this body of water is about 202 ha. The lake was originally surrounded by 5,087 ha of lowland dipterocarp forest. It was gazetted on December 7, 1989, under Section 62 (1) of the National Land Code (S.62 (1) KTN) as a Wildlife and Ecotourism Protection Area (DARA, 1994; Sulong and Mohd Ekhwan,

2006). This protected area shares borders with FELDA Chini in the east, northeast and southeast, and in the northwest with FELDA Terapai. In the south and southwest, the lake is bordered by the Chini Forest Reserve.

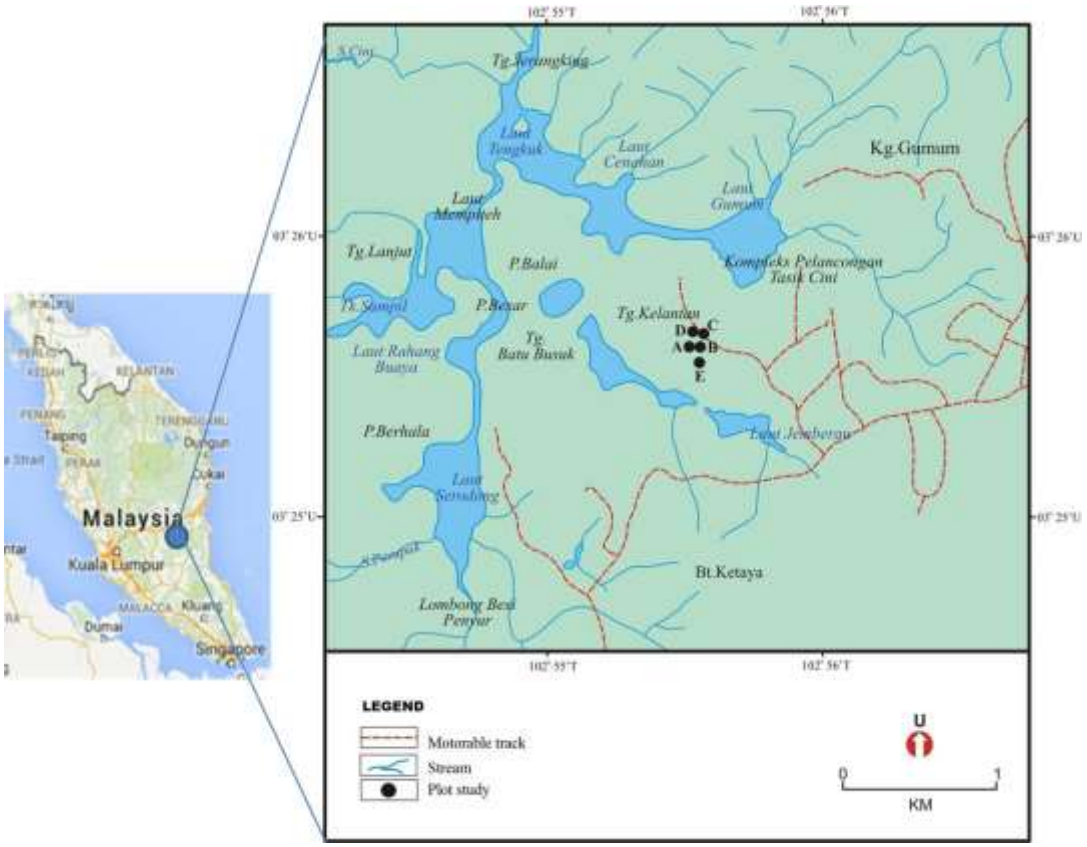

Figure 1. Map of Peninsular Malaysia showing the study location in the Chini Basin Forest, Pekan, Pahang.
Source: GIS Laboratory, Faculty of Social Sciences and Humanities, UKM (2015)

For this study, five plots measuring 25 m x 20 m each were constructed at random, and the total area of the plot is 0.25 ha (Figure 1). Each plot is constructed using raffia ropes, measuring tape, wooden spikes, and compasses, and wooden spikes are placed at each corner of the plot to mark the end of each corner of the constructed plot. The compass is used to obtain a rectangular plot with a 90° angle. Meanwhile, to get the coordinates of the study plot, the 'Global Positioning System' (GPS) was used, and the reading of the coordinates of each study plot was recorded.

Diameter measuring tape is also required to measure trees 5.0 cm in diameter and above at breast height (DBH). The measurement technique to measure the diameter of a tree is at a height of 1.3 m from the ground surface or 0.3 m from the top of the buttress for trees with high buttresses. Trees that have been measured in diameter are marked with paper tags to facilitate the process of sample collection and species identification and avoid confusion in recording data.

For the purpose of species identification, voucher specimens were collected, including flowers and fruits, if available, to be used as reference specimens. Only one specimen is required for each species. Then, the specimens were arranged on newspaper sheets, grouped according to the study plot, and tied neatly. Next, the specimen was placed in a plastic

bag. 96% alcohol is poured into plastic bags to wet the entire newspaper. Afterwards, the specimens were rearranged on folded sheets of different newspapers in tiers and then clamped with pieces of wood before being neatly tied. The specimen is placed in the oven for about a week at 60°C to dry.

Once the specimen is completely dried, each sample is identified using the key comparison method in the book, as in Tree Flora of Malaya (Whitmore, 1972, 1973; Ng, 1978, 1989), Flora of Peninsular Malaysia (Kiew et al., 2010, 2011, 2012, 2013), Flora Malesiana (Ashton, 1982), and Foresters' Manual of Dipterocarps (Symington, 1943). In addition, the identification of specimens is also done by comparing the specimens with specimens found in the herbarium of Universiti Kebangsaan Malaysia, Bangi (UKMB), the herbarium of the Forest Research Institute Malaysia (KEP), and by referring to experienced botanists. To get the correct spelling of species and family names as well as the status of endemic species, use the checklist provided by Turner (1995).

To achieve the objectives of this study, several ecological parameters were used. The species composition of dipterocarps can be calculated by dividing the number of individual trees in the study area by the number of genera and species. In addition, to determine the abundance of genera and species of dipterocarps, abundance parameters are applied that include density and basal area based on Brower et al. (1997). The stand structure of trees based on DBH classes was also determined. The conservation status of every species was determined by Chua et al. (2010).

RESULTS AND DISCUSSION

A total of 318 individual trees with a diameter of ≥ 5 cm DBH were counted in a study plot covering an area of 0.25 ha in the Chini watershed forest, Pahang. The floristic composition indicates that there were 144 species, 91 genera, and 34 families present in the study plots. For Dipterocarpaceae, a total of ten species, three genera, and 27 individuals were recorded. The total number of Dipterocarpaceae species found in this study was 8.5% of the total species recorded in Peninsular Malaysia. There were three genera of dipterocarps that occur in the study plots in the Chini watershed forest, namely *Shorea*, *Hopea* and *Vatica*. *Shorea* is the largest genus with the highest number of species at six, or about 9.7% of the total species recorded in Peninsular Malaysia. Species recorded from this genus are *Shorea maxwelliana*, *S. leprosula*, *S. balanocarpoides*, *S. macroptera*, *S. hopeifolia* and *S. ovalis*, while *Hopea* has recorded two species, or 6.1% of the total species recorded in Peninsular Malaysia, namely *H. pubescens* and *H. griffithii*. *Vatica* was also recorded with two species, namely *V. nitens* and *V. umbonata*. This number represents 9.1% of the total species found in Peninsular Malaysia. All species found in this study plot are species commonly found in lowland dipterocarp forest areas (Symington, 1943; Chua et al., 2010). Table 1 shows a comparison between the number of species found in the study plot and the number of species found in Peninsular Malaysia.

Table 1. Comparative list of the total species of the Dipterocarpaceae in the 0.25 ha plot at the Chini watershed forest, Pahang and Peninsular Malaysia.

No.	Genus	Total number of species in the study plots	Total number of species in Peninsular Malaysia	Percentage (%)
1	*Hopea*	2	33	6.1
2	*Shorea*	6	62	9.7
3	*Vatica*	2	22	9.1
	Total	10	117	8.5

As a comparison with previous studies, Norsiah (2004), who conducted a study in the riparian forests at Chini Forest Reserve, has only recorded two individuals of Dipterocarpaceae in her plots, consisting of one species and one genus, namely *Shorea macroptera*. In addition, Norwahidah (2005), who conducted a comparative study of tree species between the riparian forest and inland forest near Tasik Chini, found that two genera with four species and five individuals of the Dipterocarpaceae were found in the riparian forest plot, while one species with two individuals was found in the inland forest plot. Another study conducted by Khairil (2010) in Chini watershed forest, Pahang, recorded 143 individuals of Dipterocarpaceae from 28 species and five genera in the inland forest, while in the seasonal flood forest, 70 individuals, 10 species, and five genera were recorded, and 56 individuals, 10 species, and five genera were recorded on a plot of 0.7 ha of riparian-type forest. The comparison of species composition in this study and other studies conducted in Tasik Chini is shown in Table 2.

Table 2. Comparison of the composition of Dipterocarpaceae family species in this study and other studies conducted in Lake Chini.

Studies	Forest types	Plot size (ha)	Total number of genus/genera	Total number of species
Norsiah (2004)	Riparian	0.4	1	1
Norwahidah (2005)	Riparian	0.2	2	4
	Inland	0.2	1	1
Mohd Fairuz (2007)	Bukit Chini plot	0.2	2	4
	Sungai Melai plot	0.2	2	3
Khairil (2010)	Inland	1.4	5	28
	Seasonal flood	0.9	5	10
	Riparian	0.7	5	10
This study	Inland	0.25	3	10

A higher total number of species of Dipterocarpaceae was also reported in the primary lowland dipterocarp forests of Peninsular Malaysia. For instance, a study conducted by Manokaran and Swaine (1994) in Sungai Menyala Forest Reserve and Pasoh Forest Reserve found that Dipterocarpaceae are the most common family found in Menyala Forest Reserve. The total number of species for Dipterocarpaceae in the two-hectare plot in the Menyala Forest Reserve was 16 species, while the total number of dipterocarp species in the eight-hectare plot in the Pasoh Forest Reserve was 26 species. Meanwhile, in the 50-ha plot at Pasoh Forest Reserve, Negeri Sembilan, Appanah and Weinland (1993) recorded seven genera and 30 species of Dipterocarpaceae. In general, primary dipterocarp forests record a higher number of dipterocarp species than ever before. Scales of disturbance, soil types and forest types affect the total number of species and their composition.

The species-area curve is the relationship between the area of the habitat area or part of the habitat area and the total number of species found in the particular area. In the graph of the species-area curve based on the number of species and size of the study area in Figure 2, the first four species of dipterocarps were found in the first plot, and then there was an addition of species in the second plot. In the third plot, the other three species began to appear and then remained in a constant state, with no increase in additional species in the fourth plot. Then, in the fifth plot, there were two additional species. The graph of these species has not yet reached the asymptotic value, which means that the observing species are still not sufficient to describe the overall composition of the Dipterocarpaceae family in the study area. As a conclusion, when the size of the study area increases, more additional record species will appear, and a sufficient number will be visible when this graph reaches the asymptotic value.

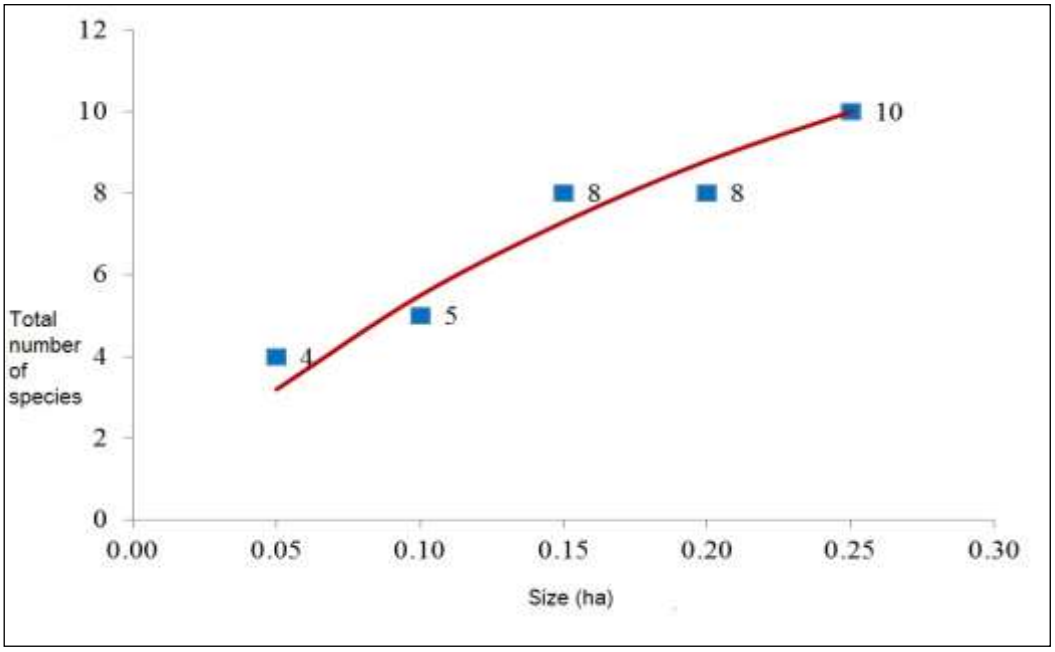

Figure 2. Graph of species area curve based on the total number of species and the size of plot studies in the 0.25 ha plot at Chini watershed forest, Pahang.

The stand structure of trees in the Chini watershed forest of Pahang was classified into seven classes of diameter with an interval of 10 cm each, ranging from a DBH class of 5.0 - 14.9 cm to a DBH class of ≥ 65 cm (Figure 3). The diameters of all the trees in the Dipterocarpaceae that have been observed range from 5.5 cm to 69.2 cm. The first DBH class (5.0 - 14.9 cm) showed the highest total number of individuals with 15 stems (55.56%). The inverted 'J' curve pattern can be seen up to the fourth DBH class (35.0 - 44.9 cm) when only one individual was recorded. Subsequently, the very low total number of trees in the fifth DBH class (45.0 - 54.9 cm) and the sixth DBH class (55.0 - 64.9 cm) with three and two individuals, respectively. This may be due to the study area that has been disturbed because the study area is located near the Tanjung Kelantan Recreational Forest, where there is a Chini Resort built for tourism purposes in the area (Gan and Abdul Aziz 2005).

This inverted 'J' curve pattern can also be observed in other studies conducted in Tasik Chini, such as those by Khairil (2010) in three forest types at Chini Watershed Forest, Pahang. The highest total number of trees was recorded in the

first DBH class (5.0 - 14.9 cm) with 2891 individuals, while only 65 individual trees were recorded in the last DBH class (> 55.0 cm). The same inverted 'J' curve pattern was also reported by Mohd Fairuz (2007) in the two plots at Bukit Chini and Sungai Melai. Most studies in Peninsular Malaysia also reported the same condition, such as those by Hazreen (2014) in Bukit Sai Forest Reserve, Terengganu, and Nizam et al. (2012) in Gunung Belumut Recreational Forest, Johor.

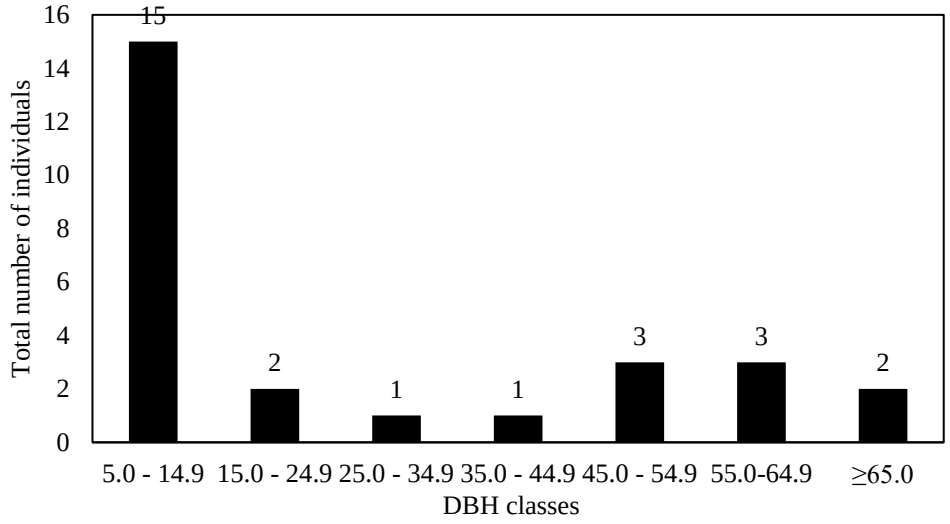

Figure 3. Stand structure of Dipterocarpaceae trees in seven DBH classes in a 0.25 ha plot at Chini watershed forest, Pahang.

Meanwhile, the largest tree in the study plots was *Shorea balanocarpoides* with a diameter of 69.2 cm DBH, followed by *S. leprosula* (66.6 cm DBH) and *S. ovalis* (64.8 cm DBH) (Table 4.4). The absence of dipterocarp trees with a diameter of > 100 cm DBH in the logged dipterocarp forest indicates that the trees that reach that size have been cut down by loggers. Dipterocarp trees with a diameter of > 100 cm can only be found in undisturbed primary dipterocarp forests.

Table 3. Ten leading the largest dipterocarp trees in 0.25 ha plot at Chini watershed forest, Pahang.

Species	DBH (cm)
Shorea balanocarpoides	69.2
Shorea leprosula	66.6
Shorea ovalis	64.8
Shorea leprosula	64.8
Hopea griffithii	62.4
Shorea leprosula	46.6
Shorea macroptera	45.0
Shorea leprosula	45.0
Hopea griffithii	43.6
Hopea griffithii	31.8

Based on the census, the total tree density for the Dipterocarpaceae in the 0.25 ha plot in the Chini watershed forest, Pahang, was 108 trees/ha. At the species level, *Shorea maxwelliana* had the highest density of 24 individuals/ha. This is followed by *Hopea griffithii* and *S. leprosula* with densities of 20 ind/ha each. Table 4 shows the list of species of

the Dipterocarpaceae with their density in the study plot.

Table 4. List of Dipterocarpaceae species with their density in the 0.25 ha plot at the Chini watershed forest, Pahang.

Species	Total number of individuals	Density (ind/ha)
Shorea maxwelliana	6	24
Hopea griffithii	5	20
Shorea leprosula	5	20
Shorea balanocarpoides	2	8
Shorea macroptera	2	8
Vatica nitens	2	8
Vatica umbonata	2	8
Shorea hopeifolia	1	4
Shorea ovalis	1	4
Hopea pubescens	1	4

The total basal area (BA) for the Dipterocarpaceae in the study plot at the Chini watershed forest, Pahang, was estimated at 10.08 m^2/ha. At the species level, *Shorea leprosula* contributed the highest basal area of 4.17 m^2/ha, followed by *Hopea griffithii* with 2.17 m^2/ha and *S. balanocarpoides* with 1.52 m^2/ha (Table 5). Based on Table 5, *S. maxwelliana* has recorded a lower basal area value, although it was represented by six individuals, compared to *S. balanocarpoides,* which was only represented by two individuals. This is because *S. maxwelliana* is only represented by small individuals with a range of 5.5 - 15.0 cm compared to *S. balanocarpoides,* which recorded the highest DBH measurement of 69.2 cm.

Table 5. Basal area of all species of Dipterocarpaceae in the 0.25 ha plot at Chini watershed, Pahang.

Species	Total number of individuals	Basal area (m^2/ha)
Shorea leprosula	5	4.17
Hopea griffithii	5	2.17
Shorea balanocarpoides	2	1.52
Shorea ovalis	1	1.32
Shorea macroptera	2	0.65
Shorea maxwelliana	6	0.14
Shorea hopeifolia	1	0.04
Vatica umbonata	2	0.03
Vatica nitens	2	0.03
Hopea pubescens	1	0.02

Only one endemic species in Peninsular Malaysia was recorded in this study, namely *Hopea pubescens*. This species is only found in Kelantan and Pahang. All species of Dipterocarpaceae found in the study plot in the Chini Basin Forest, Pahang, are listed in Chua et al. (2010) (Table 6). *Hopea pubescens* was categorized as endangered, while *Hopea griffithii*, *Shorea balanocarpoides*, *S. hopeifolia*, *S. ovalis* and *Vatica nitens* are categorized as near threatened.

Table 6. The conservation status of Dipterocarpaceae species found in a 0.25 ha plot at Chini watershed forest, Pahang, based on Chua et al. (2010)

Species	Status
Hopea griffithii	Near threatened
Hopea pubescens	Endangered
Shorea balanocarpoides	Near threatened
Shorea hopeifolia	Near threatened
Shorea leprosula	Least concern
Shorea macroptera	Least concern
Shorea maxwelliana	Least concern
Shorea ovalis	Near threatened
Vatica nitens	Near threatened
Vatica umbonata	Least concern

This underscores the critical need for conservation measures in the Chini watershed forest to ensure the preservation of its vital ecological functions.

CONCLUSION

In conclusion, while this study recorded a relatively low total number of dipterocarp species in the Chini watershed forest, it remains a vital habitat for certain common species, particularly those endemic to lowland regions, such as *Hopea pubescens*. It is noteworthy that all identified Dipterocarpaceae species are listed under conservation status in the Malaysia Plant Red List, underscoring their significance in biodiversity conservation. The findings of this study hold the potential for enhancing the documentation of Dipterocarpaceae communities and promoting more organized forest resource management. Practical applications of these results include aiding in the systematic preservation and sustainable utilization of these valuable natural resources. However, further extensive research is imperative, focusing on specific aspects such as conservation strategies and ecological dynamics. Preserving these natural treasures is not only a responsibility but also a necessity to safeguard biodiversity and maintain ecological stability for future generations. Strategic forest conservation and management should be prioritized to ensure the long-term sustainability of our ecosystems and biological diversity.

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AUTHOR CONTRIBUTIONS

Writing original draft: Ahmad Fitri Zohari, Nik Hazlan Nik Hashim; Data curation: Nik Norafida Nik Ali, Kamilah Hanani Kamin; Formal analysis: Mohd Azman Kholid, Ahmad Mutaqqin Mohd Nor; Writing review & editing: Engku Azlin Rahayu Engku Ariff; Project administration: Abdul Latiff;

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DATA AVAILABILITY

Not applicable.

COMPETING INTEREST

The authors declare that they have known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

COMPLIANCE WITH ETHICAL STANDARDS

Not applicable.

SUPPLEMENTARY MATERIAL

Not applicable.

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