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# The diversity and use of dwarf swamp forest vegetation in a tropical floodplain lake in West Kalimantan, Indonesia

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**Abstract:** To alleviate the consequence of severe biodiversity threats, fifteen national priority lakes to be rehabilitated have been declared in Indonesia. Lake Sentarum National Park (LNSP), one of the lakes, is a distinctive floodplain lake that exhibits significant vegetation and flora diversity. One particular ecosystem type in the area is dwarf swamp forest vegetation, which displays enormous amounts of floral vegetation in that area. This study intends to uncover vegetation data in the dwarf swamp forest habitat, which currently has relatively limited data series about its diversities. The vegetation specimens were collected using a 50 x 50 m line transect. Fourteen species from ten families were collected from six observation stations. The most prevalent vegetation is *C.* cf. *ensifolius*, *I. mentangis*, and *B. acutangula*. The species diversity index (H') is 1.78 (low category), and the small lake area has a greater species variety than the river area in the LNSP area. Furthermore, we found that dwarf swamp forest vegetation is mainly used as food for *Apis dorsata* honey bees to produce forest honey. The findings of this study will be helpful as a fundamental reference for future monitoring, research, and conservation efforts in the park.

**Keywords:** floodplain, Lake Sentarum, National Park, species diversity, dwarf swamp forest

## 1. Introduction

Indonesia, as a mega biodiversity country in the world, has abundant and unique biodiversity hotspots (Rintelen *et al.,* 2017). One of the spots is the tropical swamp forests located in Kalimantan (Muchlisin *et al.*, 2015). The swamp forests also play a significant role in preventing floods during rainy seasons and supplying fresh water for agriculture and aquacultural activities and settlements (Djufri *et al.*, 2016).

Research on flora biodiversity, especially the composition of vegetation, is essential as baseline data to plan better conservation and monitoring strategies. However, the data on plant species diversity in Kalimantan's DSF still needs to be upgraded, as the last research was conducted almost a decade ago (e.g., Randi *et al.* 2014). More importantly, according to our best knowledge there are scarce studies on the biodiversity of swamp forests, particularly in tropical areas.

In our case study, we selected a dwarf swamp forest (DSF) in Lake Sentarum National Park (LSNP), West Kalimantan, Indonesia, because it is located in one of fifteen national conservatory priority lakes in Indonesia (Ministry of Environment and Forestry/ MoEF, 2011). Further, it is also selected as it exhibits

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a wide and unique diversity of vegetation or flora (Anshari *et al.,* 2002). DSF is a type of vegetation composed of small trees and shrubs, about 5-8 meters tall, that can be inundated for up to eleven months each year (on average 9.5 months), with a maximum water level of 5.5 meters (Balai TNDS, 2008). Due to this unique and dynamic environmental condition, the forest is made up of several plant species that have adapted to areas that are almost always flooded with water throughout the year (Anshari *et al.*, 2002).

This study intends to uncover vegetation data in the DSF in LSNP area, where knowledge still needs to be discovered. Our research can fill the aforementioned knowledge gap as well as provide a theoretical contribution to the science of plant biodiversity. Furthermore, this study provides upgrades on the most recent biodiversity data in the study area, which can aid its monitoring and conservation efforts.

## 2. Methods

### 2.1. Study Site

LSNP is one of Indonesia's floodplain lakes classified as a Ramsar site since 1994 (Giesen, 1995; Anshari *et al.*, 2002). The forest area covers approximately 2.362 ha or 1.81% of the overall area of LSNP (Giesen & Anshari, 2016). The forest vegetation in the area has a relatively high diversity of species, and many of these species are endemic and specific to this forest ecosystem type (Randi *et al.*, 2014).

A number of endemic plant species can be found in LSNP, including *Casaeria* sp (limut), *Croton cf ensifolius* (melayak), *Dichilanthe-borneensis* (berus), *Eugeissona ambigua* (ransa), *Helicia cf petiolaris* (putat rimba), *Korthalsella cf germinans* (paha buntak), *Microcos cf stylocarpus* (tengkurung asam), *Rhodoleia spp* (insang dungan), *Ternstroemia cf toguian*, and *Vatica cf umbronata* (menungau) (Giesen, 1996).

As a floodplain lake, LNSP experiences frequent floods during wet seasons, when around 80 lakes are charged (Anshari *et al.*, 2001). However, during dry periods, the lakes are either partially or entirely emptied or completely (ibid). This unique condition creates a network of interconnecting seasonal lakes surrounded by swamp forests, peat swamp forests, and dry lowland forests on isolated hills (Andryannur *et al.*, 2022). Further, the specific hydrological patterns make the lakes contribute substantial parts to the water level of its main river, the Kapuas River (Hidayat, 2018; Hidayat, 2017).

Based on the average canopy heights, the forest ecosystem in LSNP is divided into seven types: dwarf swamp forest/rampak gelagah (Figure 1), short swamp forest/gelagah (kenarin-menungau-kamsia reed forests and kawi-kamsia reed forests), tall swamp forest/pepah forests (kelansau-kelansau pepah forests), and tall swamp forest/pepah forests (pepah kelansau-emang-melaban and pepah ramin-mentangur kunyit forests), riparian forests, hill forests, kerangas forests, and former agricultural land (Balai TNDS, 2008). The plant species diversity in each habitat is modest, but the overall plant diversity is very high, with a total of 262 species identified (Giesen, 2000).

### 2.2. Data Collection

Three 50 m x 50 m transects were set in six sampling sites in August and September 2016. The sites were tagged as Seriang River (Station 1), Majang Lake (Station 2), Tekenang (Station 3), Penyelawat Peat River (Station 4), Genali Lake (Station 5) and Sumbai Lake (Station 6). The sites were chosen using a purposive random sampling method, with locations representing different ecosystem types:

- The river area (Seriang River)
- The peat area (Penyelawat Peat River)
- The area of small lakes (Lake Majang, Lake Genali, and Lake Sumbai)
- The lake's middle area (Tekenang)

The numbers of representative sampling locations are different in each sampling time due to the water inundation level during the wet and dry seasons (Table 1).

Besides that, an interview process was also carried out in this research. A series of face-to-face interviews were conducted with the aid of four local field assistants and LSNP officers (4 people). Interviews were conducted to verify the laboratory-identified plant types locally and to collect information on the local use of the plants.

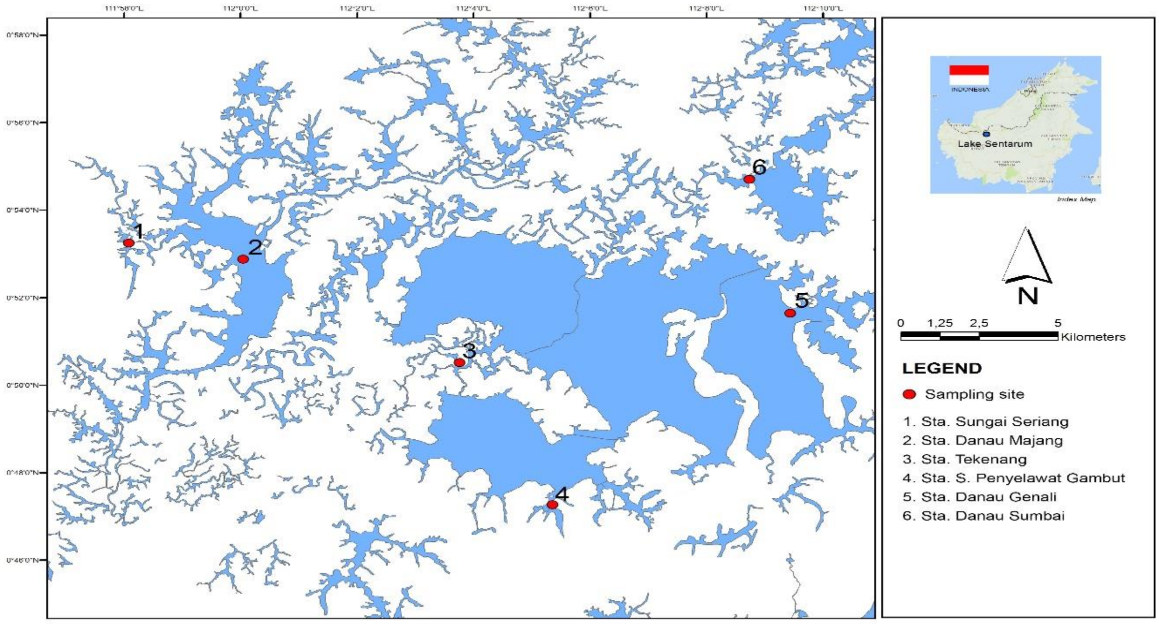


Figure 1. Sampling locations for dwarf swamp forest vegetation in the LSNP

Table 1. Sampling locations

| Station | Sampling location | Geographic Coordinates | Ecosystem Type |
|---|---|---|---|
| 1 | Seriang River | 00° 53' 248" N - 111° 58' 076" E | River area |
| 2 | Lake Majang | 00° 52' 785" N - 111° 59' 939" E | Small lake |
| 3 | Tekenang | 00° 50' 512" N - 112° 03' 753" E | Middle area lake |
| 4 | Penyelawat Peat River | 00° 47' 265" N - 112° 05' 347" E | River area (Peat) |
| 5 | Lake Genali | 00° 51' 639" N - 112° 09' 431" E | Small lake |
| 6 | Lake Sumbai | 00° 54' 701" N - 112° 08' 733" E | Small lake |

## 2.3 Data Analysis

At the observation site, the species, family, and number of individuals found for each plant sample were recorded. At the initial stage, the specimens are morphologically identified (flowers, leaves, and shoots) in the field. At the same time, we also recorded the number of individuals for each species. Then, the samples were made into herbariums and photographed using a digital camera. Next, the herbariums were sent to the Research Center for Biosystematics and Evolution - National Research and Innovation Agency (BRIN) for further identification.

Further, using the obtained data, we calculated the Important Value Index/ IVI (Equation 1) and the Shannon-Wiener Diversity Index/ H' (Equation 2). The IVI is an index to represent the importance of a species shown by the level of the number of individuals, density, and frequency (Indriyani *et al.* 2017). The Index of Shannon-Wiener's Species Diversity (H') was examined using the criteria according to Barbour *et al.* (1999) and Djufri (2002). The H' value is categorized as: very high category (H'> 4), high category (H'≤ 3-4), medium category (H'≤ 2-3), low category (H'≥ 1-2), and very low category (H'< 1).

$$IVI = Species\ density + Species\ frequency\ of\ occurence \quad \text{....Eq. 1}$$

$$\mathrm{H}' = -\sum_{\mathrm{i}=1}^{\mathrm{n}} P_i (\ln \mathrm{pi}) \quad \text{....Eq. 2}$$

where:

H' : Shannon-Wiener Index of Species Diversity

$P_i$ : Species-i relative abundance (ni/N)

$n_i$ : Number of species-i

N : Total number of individuals

Meanwhile, species density and species frequency of occurrence are calculated using Equations 3 to 4 as follows:

$$\text{Species density (SP)} = \frac{\text{number of individuals for species} - \text{i}}{\text{the area of the sample plot}} \quad \text{.... Eq. 3}$$

$$\text{Relative density (RD)} = \frac{\text{density for species} - \text{i}}{\text{density all species}} \quad \text{....Eq. 4}$$

$$\text{Species frequency (SF)} = \frac{\text{number of plot samples of species} - \text{i is found}}{\text{the total number of sample plots}} \quad \text{.... Eq. 5}$$

$$\text{Frequency Relative (FR)} = \frac{\text{frequency of species} - \text{i}}{\text{the total number of all species}} x 100\% \quad \text{....Eq. 6}$$

## 3. Results and Discussion

### 3.1. Vegetation Composition

There were fourteen plant species categorized into ten families that were collected in our study sites (Table 2). Among the identified species, most of them were sampled from Stations 2 and 5, followed by Stations 3, 6, 1, and 4, respectively. The most prevalent species were *C.* cf. *ensifolius*, *I. mentangis*, and *B. acutangula* revealed by the high percentage of individual numbers (25,63, 21,42 and 20,49%) and their occurrence in all sampling sites (Figure 2). The research results are in accordance with the work of Balai TNDS (2008) and Giesen (2016).

Further, the sites with the highest individual numbers were Sites 5 and 6 as opposed to Sites 1 and 4. Meanwhile, the sites with the highest numbers of species were Sites 2, 3, 5, and 6, as opposed to Sites 1 and 4. Thus, overall, the sites located in the small lake ecosystem type (sites 2, 3, 5, and 6) have higher diversities than the riverine ecosystem type (sites 1 and 4). This circumstance can be attributed to the mineral richness of the small lake ecosystem, which leads to high plant diversities (Furey & Tilman, 2021).

Another major finding that should be highlighted is that *C.* cf. *ensifolius*, *B. acutangula*, and *I. mentangis* were identified at all research stations (Figure 2). This is because these three plants are the species that generally structuring dwarf swamp forest formations (Balai TNDS, 2008). The research results are in accordance with what was found by Giesen (2016) elucidating that dwarf swamp forests are generally composed of *Croton* cf. *ensifolius* (melayak), *Ixora mentangis* (mentangis), *Barringtonia acutangula* (putat), *Memecylon edule* (kebesi), *Timonius salicifolius* (temirit), *Szygium claviflora* (kemasung), *Garcinia borneensis* (empanak), *Carallia bracteata* (kayu tahun), *Gardenia tentaculata* (landak), and *Pternanda teysmanniana* (gelagan).

We noted that the diversity of vegetation species in the dwarf swamp forest will have an impact on the water quality and biota. One reason underpinning this condition is that the plants that remain submerged in water for an extended period might give additional periphyton. Periphyton community growing on the submerged substrate in water could serve as a preferred natural food item for herbivorous and omnivorous fish (Biswas *et al.,* 2022). However, if the flood season is prolonged, it may cause the dying of the plants and their decaying may cause acidic waters (Utomo and Asyari, 1999). As a consequence, the fish biota that sustains in this environment is the type that is acid resistant and tolerant to low oxygen level; such as snakeheads and kissing gouramies (Xie *et al.*, 2017; Ahmadi, 2021).

In short, the dwarf swamp forests of LSNP exhibit unique ecosystem characteristics and support high plant and animal diversities, as hinted by Giesen and Anshari (2016). Furthermore, the ecosystem also operates as a buffer for the Kapuas River, absorbing ¼ of peak floods and maintaining water levels in the dry season by delivering 50% of dry season flow in the upper Kapuas River (ibid). Therefore, it is considered a valuable ecosystem to be preserved.

Table 2. The composition and distribution of dwarf swamp forest vegetation at each observation station in LSNP

| No | Family/Species | Local Name | Station 1 | 2 | 3 | 4 | 5 | 6 | Total per Species | % |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Euphorbiaceae** | | | | | | | | | |
| 1 | *Croton* cf. *ensifolius* | Melayak | 216 | 427 | 138 | 261 | 1297 | 267 | 2,606 | 25.63 |
| 2 | *Malotus sumatranus* | Belantik | - | - | 1 | - | - | - | 1 | 0.01 |
| | **Lecythidaceae** | | | | | | | | | |
| 3 | *Barringtonia acutangula* | Putat | 393 | 10 | 17 | 838 | 1 | 824 | 2,083 | 20.49 |
| | **Rubiaceae** | | | | | | | | | |
| 4 | *Ixora mentangis* | Mentangis | 30 | 425 | 1,038 | 51 | 38 | 555 | 2,137 | 21.02 |
| 5 | *Timonius salicifolius* | Temirit | 320 | 146 | 124 | 19 | 28 | - | 637 | 6.26 |
| | **Melastomataceae** | | | | | | | | | |
| 6 | *Memecylon edule* | Kebesi | - | 20 | - | - | 1,897 | 13 | 1,930 | 18.98 |
| | **Myrtaceae** | | | | | | | | | |
| 7 | *Szygium claviflora* | Kemasung | 5 | 10 | - | 3 | 15 | 380 | 413 | 4.06 |
| 8 | *Szygium durifolium* | Kayu ubah | - | 4 | - | - | - | 2 | 6 | 0.06 |
| 9 | *Szygium* sp. | Jijab | - | - | 2 | - | 1 | 34 | 37 | 0.36 |
| | **Pandanaceae** | | | | | | | | | |
| 10 | *Pandanus helicopus* | Rasau | - | 20 | - | - | 200 | - | 220 | 2.16 |
| | **Rhizophoraceae** | | | | | | | | | |
| 11 | *Carallia bracteata* | Kayu tahun | - | 71 | 5 | - | 3 | - | 79 | 0.77 |
| | **Capparaceae** | | | | | | | | | |
| 12 | *Crateva religiosa* | Punggu | - | - | 2 | - | - | 9 | 11 | 0.11 |
| | **Clusiaceae** | | | | | | | | | |
| 13 | *Garcinia borneensis* | Empanak | - | 3 | - | - | 4 | - | 7 | 0.07 |
| | **Leguminosae** | | | | | | | | | |
| 14 | *Crudia teysmannii* | Timba tawang | - | 1 | - | - | - | - | 1 | 0.01 |
| | **Total number of individuals** | | **964** | **1,137** | **1,327** | **1,172** | **3,484** | **2,084** | **10,168** | **100** |
| | **Total number of species** | | **5** | **11** | **8** | **5** | **10** | **8** | | |

(a) (b) (c)

Figure 2. The dominant vegetation of dwarf swamp forest in the LSNP area; (a) *Croton* cf. *ensifolius*, (b) *Ixora mentangis*, (c) *Barringtonia acutangula*

### 3.2. The importance and diversity of the vegetation

The calculated species frequency (SF), frequency relative (FR), species density (SD), density relative (RD), the important value index (IVI), and species diversity (H') (Table 3) present similar conclusions that *C.* cf. *ensifolius*, *I. mentangis*, and *B. acutangula* had the highest frequency/distribution. Further, we underline that *C.* cf *ensifolius* is an adaptive endemic species that can be found in all ecosystem types with a frequency value of 22.22 (Table 3). Meanwhile, other species are categorized as lower-range endemic species with a relative frequency value of less than 20. More importantly, *C.* cf. *ensifolius* is one of the most important pioneer species in LSNP (Giesen, 2000). At the same time, *C.* cf. *ensifolius*, *I. mentangis*, *B. acutangula*, and *M. edule* have the highest relative density values that show a strong pattern of adaptation to the environment.

Meanwhile, the obtained IVI (Table 3) demonstrates that *C.* cf. *ensifolius*, *I. mentangis*, *B. acutangula*, and *M. edule* have the highest IVI values. The plant species with high IVI values play a significant role in their communities (Asmayannur *et al.*, 2012). This result indicates that *C.* cf. *ensifolius*, *I. mentangis*, *B. acutangula*, and *M. edule* are the vegetations that have the most significant roles in the communities. On the contrary, *M. sumatranus* and *C. teysmannii* are non-dominant and poorly distributed at the observation sites.

At the same time, the calculated H' is 1,78, which indicates low category diversity (Barbour *et al.*, 1999; Djufri, 2002). This low diversity is because the vegetation found in the dwarf swamp forest type is just a few species in the LSNP area. A community is considered to have high species diversity if it contains numerous species. In contrast, a community is considered to have low species diversity if it contains just a few species. Setiawan *et al.* (2017) state that diversity is most valuable when all individuals come from different genera or types, while it is least valuable when all individuals come from the same genus or species.

Table 3. Values for dwarf swamp forest vegetation relative frequency, relative density, important value index, and species diversity index

| Family | Species | SF | FR | SD | DR | IVI | H' |
|---|---|---|---|---|---|---|---|
| Euphorbiaceae | *C.* cf *ensifolius* | 1.00 | 22.22 | 0.06 | 25.63 | 47.85 | 0.35 |
| | *M. sumatranus* | 0.06 | 1.23 | 0.00 | 0.01 | 1.24 | 0.00 |
| Lecythidaceae | *B. acutangula* | 0.67 | 14.81 | 0.05 | 20.49 | 35.30 | 0.33 |
| Rubiaceae | *I. mentangis* | 0.67 | 14.81 | 0.05 | 21.02 | 35.83 | 0.38 |
| | *T. salicifolius* | 0.50 | 11.11 | 0.01 | 6.26 | 17.38 | 0.17 |
| Melastomataceae | *M. edule* | 0.28 | 6.17 | 0.04 | 18.98 | 25.15 | 0.32 |
| Myrtaceae | *S. claviflora* | 0.39 | 8.64 | 0.01 | 4.06 | 12.70 | 0.13 |
| | *S. durifolium* | 0.11 | 2.47 | 0.00 | 0.06 | 2.53 | 0.00 |
| | *Szygium* sp. | 0.17 | 3.70 | 0.00 | 0.36 | 4.07 | 0.02 |
| Pandanaceae | *P. helicopus* | 0.22 | 4.94 | 0.01 | 2.16 | 7.10 | 0.08 |
| Rhizophoraceae | *C. bracteata* | 0.17 | 3.70 | 0.00 | 0.78 | 4.48 | 0.04 |
| Capparaceae | *C. religiosa* | 0.11 | 2.47 | 0.00 | 0.11 | 2.58 | 0.01 |
| Clusiaceae | *G. borneensis* | 0.11 | 2.47 | 0.00 | 0.07 | 2.54 | 0.01 |
| Fabaceae | *C. teysmannii* | 0.06 | 1.23 | 0.00 | 0.01 | 1.24 | 0.00 |
| **Total** | | **4.50** | **100** | **0.26** | **100** | **200** | **1.78** |

SF = Species frequency, FR = Frequency Relative, D = Density, DR = Density Relative, IVI = Important Value Index, H' = Species Diversity Index

### 3.3. The use of the vegetations

The diverse uses of LSNP's plant species include wild animal consumption, human consumption, building materials, medicine, and other applications, with honey production as the most distinguished feature (Table 4). The results align with the conclusion of Sufardi (2015) that swamp woods give both ecological and economic benefits to the community, such as honey producers. In the study area, the use of forest honey is a common community economic activity in the LSNP area, particularly in traditional zones, in an effort to meet traditional community needs (Andryannur *et al*., 2022). Further, West Kalimantan is known as one of Indonesia's top producers of forest honey, with LNSP as the central producer (Kotimah *et al*., 2023). The abundance of lofty trees as a favorable home for forest honey bees (*Apis dorsata*) (Figure 3) endorses this benefit (Wardhani *et al.* 2022; Wijayanti *et al*., 2022; Ratnasari *et al*., 2022).

Table 4. The uses of dwarf swamp forest vegetation in LSNP

| No | Species | Usage |
|---|---|---|
| 1 | *C.* cf. *ensifolius* | Produces forest honey |
| 2 | *B. acutangula* | Produces forest honey, medicinal plants |
| 3 | *I. mentangis* | Produces forest honey, medicinal plants |
| 4 | *T. salicifolius* | Building materials (piles) |
| 5 | *M. edule* | Produces forest honey, medicinal plants |
| 6 | *S. claviflora* | Produces forest honey |
| 7 | *S. durifolium* | Human consumption (fruit), medicinal plants, building materials (boards) |
| 8 | *Szygium* sp. | Wildlife consumption (the fruit is eaten by fish), a place for fish breed |
| 9 | *C. bracteata* | Produces forest honey |
| 10 | *C. religiosa* | Human consumption (leaves), wildlife consumption (flowers eaten by proboscis monkeys), animal feed |
| 11 | *G. borneensis* | Wildlife consumption (the fruit is eaten by fish) |
| 12 | *M. sumatranus* | Produces forest honey |
| 13 | *C. teysmannii* | Produces forest honey |

(a) (b)

**Figure 3.** The uses of dwarf swamp forest vegetation by fauna in the LSNP area: a. Wild honey bees (*Apis dorsata*) as producers of forest honey, b. Fish nests as breeding places during high water/floods (in *C.* cf. *ensifolius* or *S. claviflora* plants) (source: www. jungledragon.com; Authors' personal documentation)

Besides serving as honey producers, the flora is also used as medicinal herbs. *B. acutangula*, *I. mentangis*, *M. edule*, and *S. durifolium* are among the medicinal plants found in DSF (Table 5). Moreover, around 40 species of medicinal plants are in the LSNP area, and they are used as medicinal plants by the locals (Balai TNDS, 2008; Ginting *et al.*, 2017).

Table 5. The uses of dwarf swamp forest vegetation as medicinal plants

| No | Species | The utilization |
|---|---|---|
| 1 | *B. acutangula* | Scab medicine (shoot) |
| 2 | *I. mentangis* | Scab medicine (shoot) |
| 3 | *M. edule* | Canker sore medicine (fruits) |
| 4 | *S. durifolium* | Stomach medicine (fruits) |

## 4. Conclusions

The dwarf swamp forest in LSNP supported low-level plant diversity, with several important species such as *C.* cf. *ensifolius*, *I. mentangis*, *B. acutangula*, and *M. edule*. Higher plant diversity occurred in small lake-type ecosystems and mainly were used as honey bee homes and medicinal sources. Considering its importance for both ecological and economic benefits, the preservation of the forest is crucial. This study arranges basic information for the development and monitoring of appropriate conservation planning. It can be applied as an input in the biodiversity data bank that can be used as a reference for future monitoring and research.

## Data availability statement

Data used in this study can be requested from the corresponding author.

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## Conflict of interest

The authors declare there is no conflict of interest.

## Authors contribution

**RK, ES, MSS,** and **PL** (the main contributors): idea concept, data collection, conceptualization, data analysis, and writing the original draft. **EP, DO, AW, IGAAPP,** and **DA** (the supporting contributors): review and editing and writing methodology.

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