

Community structure and diversity of tree species in a lowland dipterocarp forest of Sungai Lalang Forest Reserve, Selangor, Malaysia

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Abstract. Pardi F, Rambey R, Ruziman HH. 2026. Community structure and diversity of tree species in a lowland dipterocarp forest of Sungai Lalang Forest Reserve, Selangor, Malaysia. *Biodiversitas* 27 (1): d270107. <https://doi.org/10.13057/biodiv/d270107>. Lowland dipterocarp forests in Peninsular Malaysia are biodiversity hotspots that play crucial roles in carbon storage but are increasingly threatened by logging, land conversion, and recreational pressures. Quantitative data on their community structure remain limited, particularly for Sungai Lalang Forest Reserve (SLFR), Selangor. To fill this gap, this study aimed to assess floristic composition and diversity, and estimate biomass and carbon stock in SLFR. In doing so, ten plots covering three hectares were established to enumerate trees with a diameter at breast height ≥ 5 cm. The tree community comprised a wide representation of families and genera, with Fabaceae emerging as the most species-rich, while *Elateriospermum tapos* (Euphorbiaceae) was identified as the dominant species. Diversity was moderate, but species evenness was low, reflecting uneven distribution across taxa. Despite this, the forest stored a significant carbon, with an estimated 304.86 t/ha, indicating its primary role as an important carbon sink. Importantly, seven threatened species were recorded, including *Hopea auriculata* and *Palaquium burckii* (Critically Endangered), *Anisoptera costata* and *Neobalanocarpus heimii* (Endangered), *Ctenolophon parvifolius*, *Pentace macrophylla* and *Shorea inappendiculata* (Vulnerable). Their occurrence urges the conservation importance of SLFR as a reservoir of dipterocarp diversity and a refuge for threatened taxa. Management strategies should prioritize stricter regulation of recreational activities, targeted enrichment planting, and the protection of threatened species. By integrating biodiversity conservation with climate mitigation goals, sustainable management of SLFR will directly contribute to the objectives of Sustainable Development Goal 15.

Keywords: Carbon stock, dipterocarp diversity, endemism, forest resilience, tree community

INTRODUCTION

Tropical forests are the most species-rich terrestrial ecosystems, harboring more than two-thirds of the world's biodiversity while playing essential roles in carbon storage, nutrient cycling, and climate regulation (Corlett and Primack 2011; Malhi et al. 2014). These ecosystems are composed of complex plant communities dominated by trees of varying sizes and supported by shrubs, herbs, and climbers that form multi-layered canopies and understories, sustaining a wide range of life forms (Zhang et al. 2017). Through these vertical and horizontal structural layers, tropical forests regulate ecological processes, maintain ecosystem stability, and support intricate interactions between organisms and their physical environment (Evariste et al. 2010). Among tropical forest types, Southeast Asian lowland dipterocarp forests represent one of the most important biodiversity hotspots, renowned for their exceptional tree diversity, floristic turnover, and structural heterogeneity (Whitmore 1988; Slik 2005). Malaysia, in particular, is highly significant, supporting an estimated 15,000 plant species, of which trees constitute the majority of the flora in Peninsular Malaysia (Saw 2010). Many of these species are endemic, and others are increasingly vulnerable to human pressures,

making Malaysian forests critical for both regional and global biodiversity conservation.

Despite their ecological value, tropical forests in Southeast Asia are experiencing an unprecedented decline (Struebig et al. 2025). Deforestation and degradation caused by logging, agricultural expansion, and infrastructure development are accelerating biodiversity loss and releasing large amounts of stored carbon, exacerbating global climate change (Ramírez-Marcial et al. 2001; Pardi et al. 2023). In Malaysia, forest cover has declined markedly over the past decades. Based on a report by the Forestry Department of Peninsular Malaysia in 2022, about a 30% reduction in forested areas occurred over 20 years, equating to the loss of 8.92 million ha and releasing 5.16 billion tonnes of CO₂ equivalent emissions. These losses are largely associated with illegal logging, conversion to oil palm and durian plantations, and other forms of land development (Pardi et al. 2023). The impacts extend beyond biodiversity decline, leading to soil erosion, reduced water quality, and diminished ecosystem resilience. Recreational activities such as camping, trekking, and off-trail access have emerged as additional threats, causing vegetation trampling, soil compaction, wildlife disturbance, and increased fire risk (Buckley 1991). Such cumulative pressures underscore the urgency of

conserving Malaysia's remaining lowland dipterocarp forests, which take millions of years to establish but can be rapidly degraded by unsustainable human activities.

Within this national context of forest decline, the Sungai Lalang Forest Reserve (SLFR) in Selangor represents a biologically important but under-researched ecosystem. As a lowland dipterocarp forest, SLFR harbors a diverse tree community, yet its floristic composition and ecological role remain insufficiently documented in contemporary scientific literature. Previous studies across Peninsular Malaysia have emphasized the distinctiveness of tree communities shaped by evolutionary antiquity and long-term ecological processes. For instance, Fatma et al. (2016) documented *Shorea acuminata*, *Shorea leprosula*, and *Vitex pinnata* in Kenaboi Forest Reserve, while Fitri et al. (2022) reported *Aporosa arborea*, *Saraca cauliflora*, and *S. leprosula* in Kuala Keniam, Taman Negara. These findings illustrate the high species turnover and habitat-specific patterns characteristic of dipterocarp forests. However, existing ecological assessments of SLFR are fragmented, providing only partial accounts of floristic diversity and lacking systematic evaluations of biomass, carbon stock, and species conservation status (Sasse et al. 2010). Given the mounting anthropogenic pressures, particularly from recreational activities, such data gaps hinder the capacity to evaluate the reserve's ecological contributions and to design evidence-based conservation measures. Comprehensive baseline information on tree community structure, diversity, and ecosystem functions is therefore essential for positioning SLFR within the broader framework of Malaysia's forest conservation priorities.

In light of these considerations, the present study was designed with three objectives: (i) to quantify tree community composition and diversity indices in SLFR, (ii) to evaluate biomass and carbon stock across representative sampling

plots, and (iii) to assess the conservation status of recorded tree species according to IUCN Red List criteria.

MATERIALS AND METHODS

Research area

Sungai Lalang Forest Reserve lies at the coordinates 03°05' N, 101°52' E in Semenyih, Selangor (Figure 1). The total area originally covered 16,712 ha, only 13,592 ha were gazetted as a forest reserve in 1997 by the Selangor state government, while the remaining area was excised for non-forest uses, primarily agricultural expansion and residential development (Sasse et al. 2010). The elevation ranges from 50 to 800 m above sea level. The mean annual temperature is approximately 25.5-26.0°C, with minimum and maximum averages of 21 and 30°C, respectively. The area receives a mean annual precipitation of about 2,400 mm, with 15-29 wet days per month and rainfall concentrated during the northeast monsoon. Potential evapotranspiration averages 90-100 mm per month, reflecting the humid conditions characteristic of tropical lowland dipterocarp forests. The forest is characterized by a mosaic of lowland and hill dipterocarp formations, dominated by *Shorea* species (Haneda et al. 2005). It is considered ecologically representative of dipterocarp forests in Peninsular Malaysia. The soils are mainly Acrisol and sandy clay types (Lee et al. 2016), which influence tree species distribution and productivity. According to Sasse et al. (2010), the reserve plays a significant role in providing timber sources, regulating the climate and nutrient cycles, controlling floods, and providing habitats to thousands of animals and plants. In addition, this forest serves as a catchment area for Semenyih Dams, which store and provide water supplies to residents of Klang Valley and Hulu Langat District.

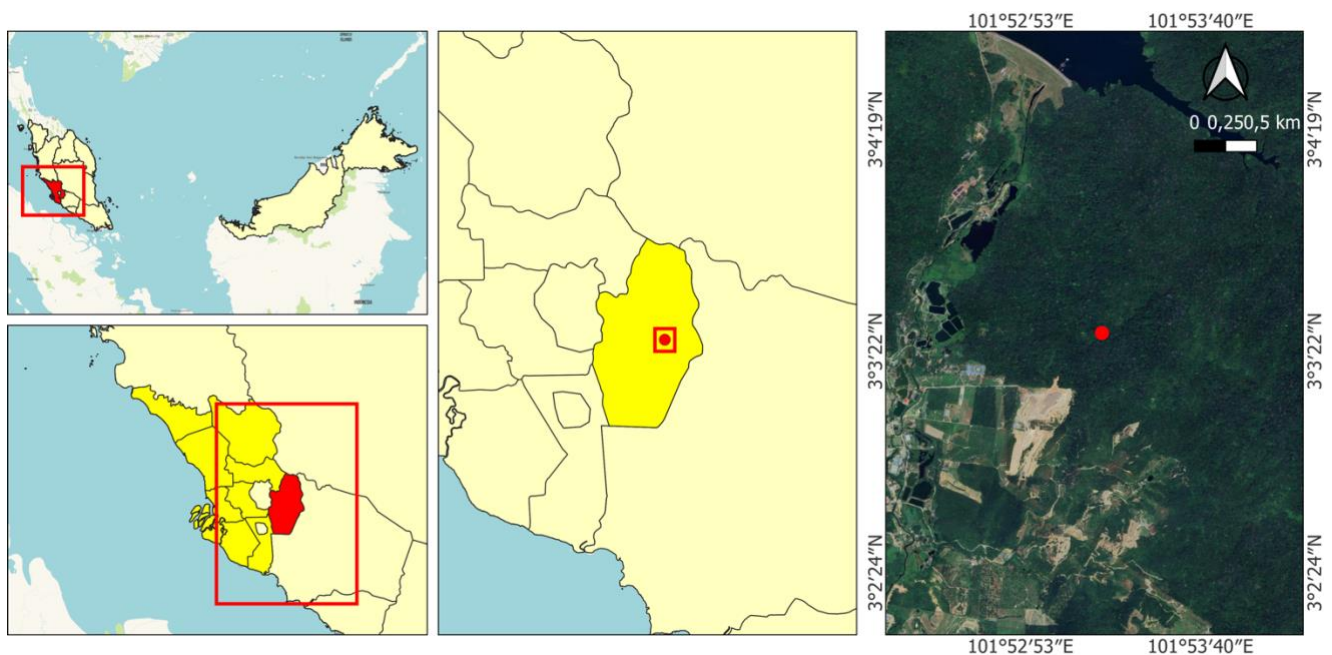


Figure 1. Map of study area in Sungai Lalang Forest Reserve (SLFR), Semenyih, Selangor, Malaysia

Data collection procedure

Tree sampling

In this study, ten sampling plots, each measuring 60 m x 50 m, were established across a 3-hectare area. The plot size of 60 m x 50 m (3,000 m²) was chosen based on established practices in tropical forest research (Slik et al. 2003; Chave et al. 2005), where plot sizes ranging from 2,500 m² to 5,000 m² have been widely used to effectively capture tree species diversity, composition, and biomass while maintaining fieldwork feasibility. The plots were situated within lowland forest zones at elevations below 300 m above sea level.

All trees with DBH ≥ 5 cm were measured for diameter, identified to species level and recorded for frequency and abundance. Trees with a minimum diameter of 5 cm at breast height (DBH) were included in this study to capture a broader representation of the forest structure, including both mature trees and larger saplings. This threshold is commonly used in tropical forest studies (e.g., Ruziman et al. 2022; Pardi et al. 2023) to ensure that ecologically relevant individuals contributing to forest regeneration, diversity, and early successional dynamics are accounted for. All specimens (including fruit and flower, if any) of each measured tree were collected for the preparation of voucher specimens and species identification. Voucher specimens were prepared and deposited in the herbarium of Universiti Teknologi MARA for reference and verification. Identification of plant specimens was done after the drying process (Forman and Bridson 1992) with the aid and help of an experienced plant taxonomist by utilizing the taxonomic keys of Symington (1948), Wyatt-Smith and Vincent (1962) and Keys in Malaya's Tree Flora by Whitmore (1988). Additionally, Turner (1995) and The International Plant Name Index (2021) were used as references for the nomenclature of the tree species.

Data analysis

Species diversity and composition

Tree species in the 3-ha plots were tabulated and summarized to determine floristic composition and abundance. Species dominance and composition were determined using the Importance Value Index (IVI), calculated by summing relative density, relative frequency, and relative dominance (Curtis and McIntosh 1951). Species diversity was assessed using the Shannon-Wiener (H'), Margalef's species richness (D_{mg}), and Pielou's Evenness (E) indices. These were computed with PAST ver5.2.1 (Hammer et al. 2001).

Biomass

Above-ground biomass (AGB) was estimated using the moist-forest allometric model of Chave et al. (2005, Eq. 1):

$$AGB = 0.0509 \times \rho \times D^2 \times H \quad (1)$$

Where ρ is wood density (g cm⁻³), D is diameter at breast height (cm), and H is total tree height (m). Below-

ground biomass (BGB) was estimated following Niiyama et al. (2010), using the root-to-shoot ratio model (Eq. 2):

$$BGB = 0.199 \times (AGB)^{0.899} \quad (2)$$

BGB was estimated using allometric relationships described by Niiyama et al. (2010). Tree biomass was estimated by combining above-ground (AGB) and below-ground (BGB) values. Total carbon stock was obtained by multiplying total biomass (AGB + BGB) by a conversion factor of 0.47, as recommended by Zaki et al. (2018).

Conservation status

The conservation status of all identified tree species was determined according to the IUCN Red List 2024. Species were classified into 9 categories, namely Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), and Not Evaluated (NE). Species categorized as CR, EN, and VU were grouped as threatened species.

RESULTS AND DISCUSSION

Floristic composition

A total of 502 trees with DBH of ≥ 5 cm was enumerated in 3.0 ha of Sungai Lalang Forest Reserve (Table 1). Floristic composition consisted of trees belonging to 36 families, 71 genera, and 76 species. The most speciose family was Fabaceae with 9 species, followed by Dipterocarpaceae, Euphorbiaceae, and Malvaceae, which shared the same number of 5 species. The Fabaceae family comprised the highest number with 9 genera, followed by Euphorbiaceae (5 genera) and Dipterocarpaceae (4 genera). The predominance of Fabaceae in Sungai Lalang Forest Reserve reflects a broader floristic pattern observed across Peninsular Malaysia, where leguminous trees are particularly well represented. This trend is attributable to the region's position within the pantropical megathermal zone, recognized as a global center of diversity for millettoid and phaseoloid lineages of Papilionoideae (Oyebanji et al. 2023). Evidence from long-term inventories and plot-based studies across Malaysia consistently demonstrates the integration of Fabaceae within highly species-rich assemblages. For example, 171 species were documented in a single hectare of lowland forest at Bangi (Lajuni and Latiff 2013), 35 species in 0.49 ha at Pulau Banding (Awang et al. 2023), 88 species in understory plots at Gunung Stong (Abdullah et al. 2024), and within numerous plant vegetations along elevational turnover at Teramuo Hill (Noweg et al. 2024). Within this context, the representation of Fabaceae at Sungai Lalang is not an isolated occurrence. Still, it forms part of a wider biogeographic signal, showing the ecological prominence of this family across both lowland and hill Dipterocarp forests of Malaysia.

Table 1. Summary of tree families and species with their conservation status and distribution at Sungai Lalang Forest Reserve

Species	Family name	No. of individuals	Density (stem/ha)	IUCN status (ver 2024-2)	Distribution (Turner 1995)
<i>Elateriospermum tapos</i> Blume	Euphorbiaceae	52	17.3	LC	Throughout
<i>Cinnamomum iners</i> (Reinw. ex Nees & T.Nees) Blume	Lauraceae	40	13.3	LC	Common throughout
<i>Diospyros oblonga</i> var. <i>oblonga</i>	Ebenaceae	30	10.0	LC	Kd, Pn, Kl, Tg, Pk, Ph, Jh, Sp
<i>Pometia pinnata</i> J.R.Forst. & G.Forst.	Sapindaceae	29	9.7	LC	Throughout
<i>Litsea costata</i> (Blume) Boerl.	Lauraceae	24	8.0	Not evaluated	Pk, Ph
<i>Saraca thaipingensis</i> Cantley ex Prain	Fabaceae	21	7.0	LC	MI and Ph northward
<i>Palaquium burckii</i> H.J.Lam	Sapotaceae	20	6.7	CR	Pontian, Jh.
<i>Ochanostachys amentacea</i> Mast.	Olacaceae	15	5.0	LC	Kd, Pn, Kl, Tg, Pk, Ph, Sl, NS, MI, Jh, Sp
<i>Rhodamnia cinerea</i> Jack	Myrtaceae	14	4.7	LC	Common throughout
<i>Hydnocarpus castanea</i> Hook.fil. & Thomson	Achariaceae	13	4.3	Not evaluated	P. Langkawi, Pn, Tg, Pk, Ph, NS, Jh
<i>Gymnacranthera farquhariana</i> (Wall. ex Hook.fil. & Thomson) Warb.	Myristicaceae	13	4.3	LC	Pn, Tg, Pk, Ph, Sl, MI, Jh, Sp
<i>Spondias pinnata</i> (L.fil.) Kurz	Anacardiaceae	13	4.3	LC	Kd, Pk, P. Langkawi
<i>Strombosia javanica</i> Blume	Olacaceae	12	4.0	LC	Kd, Pn, Kl, Pk, Ph, Sl, NS, Jh, Sp
<i>Shorea inappendiculata</i> Burck	Dipterocarpaceae	11	3.7	VU	Jh
<i>Xerospermum noronhianum</i> (Blume) Blume	Sapindaceae	11	3.7	LC	Widespread
<i>Maasia glauca</i> (Hassk.) Mols, Kessler & Rogstad	Annonaceae	11	3.7	LC	Tg, Pk, Ph, Sl, Jh, Sp
<i>Calophyllum inophyllum</i> L.	Calophyllaceae	10	3.3	LC	Kd, Pn, Kl, Pk, Ph, Sl, NS, MI, Jh, Sp
<i>Artocarpus rigidus</i> Blume	Moraceae	9	3.0	LC	Throughout
<i>Cinnamomum altissimum</i> Kosterm.	Lauraceae	8	2.7	LC	Pn, Kl, Tg, Pk, Ph, Sl, Jh
<i>Kokoona ochracea</i> (Elmer) Merr.	Celastraceae	8	2.7	LC	Pk, Sl, NS, Jh
<i>Neobalanocarpus heimii</i> (King) P.S.Ashton	Dipterocarpaceae	8	2.7	EN	Widespread
<i>Pellacalyx saccardianus</i> Scort.	Rhizophoraceae	7	2.3	LC	Widespread
<i>Koompassia malaccensis</i> Maingay	Fabaceae	7	2.3	LC	Throughout
<i>Lithocarpus javensis</i> Blume	Fagaceae	7	2.3	LC	Ulu Selangor, Sl
<i>Huberantha rumphii</i> (Blume ex Hensch.) Chaowasku	Annonaceae	6	2.0	LC	Kd, Tg, Pk, Ph, Sl, NS, MI, Jh, Sp
<i>Shorea parvifolia</i> Dyer	Dipterocarpaceae	5	1.7	LC	Kd, Pn, Kl, Tg, Pk, Ph, Sl, NS, MI, Jh, Sp
<i>Parkia speciosa</i> Hassk.	Fabaceae	5	1.7	LC	Widespread
<i>Nephelium lappaceum</i> L.	Sapindaceae	5	1.7	LC	Scattered in the wild
<i>Epicharis cumingiana</i> (C.DC.) Harms	Meliaceae	5	1.7	LC	Throughout
<i>Dyera costulata</i> (Miq.) Hook.fil.	Apocynaceae	4	1.3	LC	Kd, Kl, Tg, Pn, Pk, Ph, Sl, NS, MI, Jh, Sp
<i>Endospermum diadenum</i> (Miq.) Airy Shaw	Euphorbiaceae	4	1.3	LC	Common throughout
<i>Scaphium macropodum</i> (Miq.) Beumée ex K.Heyne	Sterculiaceae	4	1.3	LC	Kd, Pn, Kl, Tg, Pk, Ph, Sl, NS, MI, Jh, Sp
<i>Albizia splendens</i> Miq.	Fabaceae	3	1.0	LC	Scattered throughout
<i>Mangifera quadrifida</i> Jack ex Roxb.	Anacardiaceae	3	1.0	LC	Kd, Kl, Tg, Pk, Ph, Sl, MI, Jh, Sp
<i>Meiogyne virgata</i> (Blume) Miq.	Annonaceae	3	1.0	LC	Kd, Tg, Pk, Ph, Sl, MI, Jh, Sp
<i>Memecylon edule</i> Roxb.	Melastomataceae	3	1.0	LC	Kd, Kl, Tg, Pk, Ph, Sl, NS, MI, Jh, Sp
<i>Adinobotrys atropurpureus</i> (Wall.) Dunn	Fabaceae	3	1.0	Not evaluated	Widespread
<i>Aglaia malaccensis</i> (Ridl.) Pannell	Meliaceae	3	1.0	NT	Kd, Kl, Tg, Pk, Ph, Sl, NS, MI, Jh
<i>Sloetia elongata</i> (Miq.) Koord.	Moraceae	3	1.0	Not evaluated	Kd, Pn, Tg, Pk, Ph, Sl, NS,

<i>Porterandia anisophylla</i> (Jack ex Roxb.) Ridl.	Rubiaceae	3	1.0	Not evaluated	Jh, Sp Kd, Tg, Pn, Pk, Ph, Sl, NS, Ml, Jh, Sp
<i>Vitex pinnata</i> L.	Lamiaceae	3	1.0	LC	Throughout
<i>Archidendron bubalinum</i> (Jack) I.C.Nielsen	Fabaceae	2	0.7	LC	Widespread
<i>Baccaurea motleyana</i> (Müll.Arg.) Müll.Arg.	Phyllanthaceae	2	0.7	LC	Scattered throughout
<i>Ixonanthes icosandra</i> Jack	Ixonanthaceae	2	0.7	LC	Throughout
<i>Lithocarpus ewyckii</i> (Korth.) Rehder	Fagaceae	2	0.7	LC	Kl, Tg, Pk, Ph, Sl, NS, Ml, Jh, Sp
<i>Pimelodendron griffithianum</i> (Müll.Arg.) Benth. ex Hook.f.	Euphorbiaceae	2	0.7	LC	Kl, Tg, Pk, Ph, Sl, NS, Ml, Jh, Sp
<i>Xanthophyllum flavescens</i> Roxb.	Polygalaceae	2	0.7	LC	Widespread
<i>Agrostistachys borneensis</i> Becc.	Euphorbiaceae	2	0.7	LC	Throughout
<i>Trema orientalis</i> (L.) Blume	Cannabaceae	2	0.7	LC	Main Range and near Kuala Lumpur
<i>Pternandra coerulea</i> Jack	Melastomataceae	2	0.7	LC	Kd, Pn, Kl, Tg, Pk, Ph, Sl, NS, Ml, Jh, Sp
<i>Pterospermum javanicum</i> Jungh.	Malvaceae	1	0.3	LC	Kd, Pn, Tg, Pk, Ph, Sl, Ml, Jh, Sp
<i>Actinodaphne pruinosa</i> Nees	Lauraceae	1	0.3	LC	Kd, Pn, Sl, NS, Ml, Sp
<i>Artocarpus odoratissimus</i> Blanco	Moraceae	1	0.3	NT	
<i>Chrysophyllum cainito</i> L.	Sapotaceae	1	0.3	LC	
<i>Coelostegia griffithii</i> Benth.	Malvaceae	1	0.3	LC	Scattered throughout
<i>Ctenolophon parvifolius</i> Oliv.	Ctenolophonaceae	1	0.3	VU	Ps, Kd, Tg, Pn, Pk, Ph, Sl, NS, Ml, Jh, Sp
<i>Dialium procerum</i> (Steenis) Steyaert	Fabaceae	1	0.3	LC	Pk, Ph, Sl, NS
<i>Durio zibethinus</i> Murray	Malvaceae	1	0.3	DD	
<i>Garcinia griffithii</i> T.Anderson	Clusiaceae	1	0.3	LC	Scattered throughout
<i>Gonystylus brunnescens</i> Airy Shaw	Thymelaeaceae	1	0.3	NT	Pn, Tg, Pk, Ph
<i>Hopea auriculata</i> Foxw.	Dipterocarpaceae	1	0.3	CR	Ph, Jh
<i>Pentace curtisii</i> King	Malvaceae	1	0.3	NT	Ps, Kd, Pn, Kl, Tg, Pk, Ph, Sl
<i>Phyllanthus emblica</i> L.	Phyllanthaceae	1	0.3	LC	Scattered throughout
<i>Callicarpa maingayi</i> King & Gamble	Verbenaceae	1	0.3	LC	Widespread
<i>Gironniera nervosa</i> Planch.	Ulmaceae	1	0.3	LC	Kd, Pn, Kl, Tg, Pk, Ph, Sl, NS, Ml, Jh, Sp
<i>Pterocymbium tinctorium</i> (Blanco) Merr.	Malvaceae	1	0.3	LC	NS northward
<i>Balakata baccata</i> (Roxb.) Esser	Euphorbiaceae	1	0.3	LC	Throughout
<i>Flacourtia rukam</i> Zoll. & Moritzi	Flacourtiaceae	1	0.3	LC	Widespread
<i>Adenantha pavonina</i> L.	Fabaceae	1	0.3	LC	Wild on East Coast and offshore islands
<i>Pentace macrophylla</i> King	Malvaceae	1	0.3	VU	Tg, Pk, Sl, Jh
<i>Adina trichotoma</i> (Zoll. & Moritzi) Benth. & Hook.f. ex B.D.Jacks.	Rubiaceae	1	0.3	Not evaluated	Scattered
<i>Cynometra malaccensis</i> Meeuwen	Fabaceae	1	0.3	NT	Pk, Ph, Sl, Ml
<i>Lansium domesticum</i> Corrêa	Meliaceae	1	0.3	Not evaluated	Widespread
<i>Ochreinauclea maingayi</i> (Hook.f.) Ridsdale	Rubiaceae	1	0.3	LC	Tg, Pn, Pk, Ph, Sl, NS, Ml, Jh, Sp
<i>Anisoptera costata</i> Korth.	Dipterocarpaceae	1	0.3	EN	Widespread
<i>Barringtonia acutangula</i> (L.) Gaertn.	Lecythidaceae	1	0.3	LC	Kd, Tg, Pk, Ph, Jh

Table 2. Shannon's diversity (H'), evenness (E), and Margalef's richness index (D_{mg}) values from this research and other different forests in Peninsular Malaysia

Research	Areas	Shannon's diversity index (H')	Evenness index (E)	Margalef's richness index (D_{mg})
This study	Sungai Lalang Forest Reserve (3.0 ha)	3.68	0.52	12.06
Hayati et al. (2020)	Royal Belum State Park, Perak (1.0 ha)	5.14	0.92	41.30
Natasha et al. (2020)	Pulau Jerejak, Pulau Pinang (0.5 ha)	3.60	0.81	13.02
Fitri et al. (2019)	Gunung Tebu Forest Reserve (0.8 ha)	5.16	0.93	38.32

Tree species diversity, evenness, and richness

Tree communities in Sungai Lalang Forest Reserve recorded a Shannon-Wiener diversity index (H') of 3.68 (Table 2). This value indicates a relatively diverse assemblage of tree species, comparable to other lowland dipterocarp forests in Peninsular Malaysia. Species evenness, however, was low ($E = 0.52$), reflecting an uneven distribution of individuals among species. *Elateriospermum tapos* was particularly dominant, with 52 individuals, whereas 25 species (32.9%) were represented by a single individual, thereby contributing to the reduced evenness (Table 1). Margalef's richness index ($D_{mg} = 12.06$) suggested moderate richness, although the index is sensitive to sample size (Magurran 1988). Comparisons with other forest areas reported varying levels of diversity, evenness, and richness. Hayati et al. (2020) showed higher values in Royal Belum State Park ($H' = 5.14$, $E = 0.92$, $D_{mg} = 41.3$), while Natasha et al. (2020) documented similar diversity in Pulau Jerejak ($H' = 3.60$) with higher evenness ($E = 0.81$) and richness ($D_{mg} = 13.02$). In Gunung Tebu Forest Reserve, Terengganu, the floristic diversity was recorded with higher diversity and richness ($H' = 5.16$, $D_{mg} = 38.32$) but similar evenness ($E = 0.93$) (Fitri et al. 2019). These comparisons suggested that Sungai Lalang Forest Reserve fell in the range of the reported values for lowland dipterocarp forests, with relatively lower evenness compared to some areas. Further research could investigate the drivers of tree species distribution and dominance in the reserve to gain a deeper understanding of the ecological dynamics.

Abundance parameters and species importance

The total density of trees in Sungai Lalang Forest Reserve was 167 stems/ha (Table 1). The family of Lauraceae contributed the highest density with 24 stems/ha (14.37%), followed by Euphorbiaceae and Sapindaceae with 20 and 15 stems/ha at 11.98% and 8.98%, respectively (Table 3). *E. tapos* had the highest density with 17 stems/ha (10.18%), followed by *Cinnamomum iners* and *Diospyros oblonga* var. *oblonga* with 13 and 10 stems/ha at 7.78% and 5.99%, respectively. Euphorbiaceae, Fabaceae, and Lauraceae dominated the frequency of tree species in SLFR. At the species level, *C. iners* was recorded with the highest frequency (100%), followed by *E. tapos* and *D. oblonga* var. *oblonga* (90%). The total basal area in SLFR was 40.42 m²/ha, with Euphorbiaceae contributing the largest share (8.71 m²/ha), followed by Dipterocarpaceae (7.55 m²/ha) and Sapindaceae (4.62 m²/ha). Among species, *E. tapos* accounted for the highest basal area (7.0 m²/ha), while *Pometia pinnata* and *Shorea inappendiculata* contributed 3.9 m²/ha each, respectively. Tree density was estimated at 167 stems/ha, comparable with other lowland dipterocarp forests (Atanasso et al. 2019), reflecting a relatively dense ecosystem. Lauraceae and Euphorbiaceae showed the highest family-level densities, while *E. tapos* and *C. iners* emerged as the most dominant species, reflecting their ecological adaptability and competitive ability. The consistent occurrence of families such as Euphorbiaceae, Fabaceae, and Lauraceae across all plots indicates broad ecological distribution in the forest reserve.

Table 3. Summary of tree density, frequency and Importance Value Index (IVI) of three leading families and species at Sungai Lalang Forest Reserve, Selangor

Parameters	Family	Numbers	Species	Numbers
Density stems/ha)	Lauraceae	24	<i>Elateriospermum tapos</i>	17
	Euphorbiaceae	20	<i>Cinnamomum iners</i>	13
	Sapindaceae	15	<i>Diospyros oblonga</i> var. <i>oblonga</i>	10
Frequency	Euphorbiaceae	100	<i>Cinnamomum iners</i>	100
	Fabaceae	100	<i>Elateriospermum tapos</i>	90
	Lauraceae	100	<i>Diospyros oblonga</i> var. <i>oblonga</i>	90
IVI (%)	Euphorbiaceae	13.06	<i>Elateriospermum tapos</i>	10.38
	Lauraceae	10.12	<i>Pometia pinnata</i>	6.17
	Dipterocarpaceae	9.60	<i>Cinnamomum iners</i>	5.32

However, the total basal area (40.42 m²/ha) was lower than values reported in other Malaysian forests (Fitri et al. 2019; Norazlinda et al. 2016). Several ecological factors may account for this difference. Lower basal area is often associated with forest stands in earlier successional stages or those recovering from past disturbances, which typically support higher stem density but smaller mean diameters (Naidu and Kumar 2016). Selective logging, soil compaction from recreational use, and variation in edaphic conditions may also constrain tree growth and diameter expansion, thereby reducing basal area despite moderate stem density. In contrast, forests with higher basal area usually represent older stands dominated by large-diameter trees, reflecting advanced structural development and longer recovery periods (Magurran 1988; Fitri et al. 2019). In this context, the relatively low basal area of SLFR suggests a forest structure shaped by past disturbance and uneven successional progression, with species such as *E. tapos* occupying a central role in maintaining stand structure.

The Importance Value Index (IVI) was determined using the sum of relative density, relative frequency and relative dominance for each species (Curtis and McIntosh 1951). This index provides an integrated measure of species importance within the forest community, with a theoretical maximum of 300. Species with higher IVI are considered more dominant and ecologically significant. In this study, Euphorbiaceae again showed the highest value at 13.06%, followed by Lauraceae (10.12%) and Dipterocarpaceae (9.6%). At the species level, *E. tapos* led with an IVI of 10.38%, ahead of *P. pinnata* (6.17%) and *C. iners* (5.32%). Therefore, *E. tapos* can be considered the most dominant species in the community, while Euphorbiaceae represents the most ecologically important family. The community patterns in SLFR suggest a forest undergoing mid-successional dynamics. The coexistence of light-demanding

species such as *E. tapos* with shade-tolerant Lauraceae indicates that both gap-phase regeneration and canopy stabilization processes are occurring. Disturbances, including historical logging and current recreational use, likely facilitated the establishment of pioneer or disturbance-adapted species. At the same time, Dipterocarps and other late-successional taxa continue to shape forest structure. The mixture of successional strategies aligns with observations in Southeast Asian lowland dipterocarp forests: disturbed stands often undergo an initial proliferation of pioneer taxa like *Macaranga* and *Mallotus* (Slik et al. 2003), while regeneration of late-successional Dipterocarps is disrupted (Pillay et al. 2018). Landscape-level studies, such as Bunyavejchewin et al. (2019), also reported biomass recovery following disturbance, with species composition shaped strongly by historical disturbance patterns. These studies may be related to the current condition or successional dynamics observed in SLFR.

Biomass and carbon content

The total biomass of trees with DBH of 5.0 and above was estimated at 648.62 t/ha (Table 4). A total of 558.43

t/ha (86.09%) and 90.18 t/ha (13.91%) was contributed by above-ground and below-ground biomass, respectively. Based on 502 trees enumerated during the survey, Euphorbiaceae was recorded as the family with the largest biomass of 148.81 t/ha, followed by Dipterocarpaceae and Sapindaceae at 145.66 t/ha and 75.17 t/ha, respectively. *E. tapos* recorded the highest biomass with 118.2 t/ha, followed by *S. inappendiculata* and *P. pinnata* at 76.48 t/ha and 65.71 t/ha, respectively. The total tree biomass in Sungai Lalang Forest Reserve was estimated at 648.62 t/ha, indicating substantial carbon storage capacity for a lowland dipterocarp forest. This value lies within the range reported for other Malaysian forests but reflects site-specific variation. For example, Hulu Langat Forest Reserve recorded 567.03 t/ha (Fitri et al. 2020), while Bukit Panchor State Park reported 686.9 t/ha (Norazlinda et al. 2016). Similar estimates have also been documented in Gunung Stong Tengah Forest Reserve (Norashikin et al. 2015) and Pahang National Park (Zani et al. 2018), showing regional heterogeneity in biomass linked to species composition, stand structure, and disturbance history.

Table 4. Summary of total biomass and carbon stock for all families at Sungai Lalang Forest Reserve, Selangor

Family	BA (m ² /ha)	AGB (t/ha)	BGB (t/ha)	TB (t/ha)	Carbon stock (t/ha)
Achariaceae	0.45	4.90	0.74	5.63	2.65
Anacardiaceae	0.55	5.82	0.87	6.68	3.14
Annonaceae	0.59	6.06	0.92	6.98	3.28
Apocynaceae	0.22	2.80	0.43	3.22	1.51
Calophyllaceae	0.38	4.02	0.60	4.62	2.17
Cannabaceae	0.23	3.47	0.55	4.02	1.89
Celastraceae	0.29	3.14	0.47	3.61	1.70
Clusiaceae	0.03	0.33	0.05	0.38	0.18
Ctenolophonaceae	0.21	3.11	0.49	3.60	1.69
Dipterocarpaceae	7.55	123.80	21.86	145.66	68.46
Ebenaceae	1.22	13.46	2.02	15.48	7.28
Euphorbiaceae	8.71	128.14	20.66	148.81	69.94
Fabaceae	2.74	34.92	5.42	40.33	18.96
Fagaceae	0.57	7.12	1.09	8.21	3.86
Flacourtiaceae	0.13	1.71	0.26	1.98	0.93
Ixonanthaceae	0.23	3.16	0.49	3.64	1.71
Lamiaceae	0.01	0.09	0.01	0.10	0.05
Lauraceae	4.18	53.02	8.25	61.26	28.79
Lecythydaceae	0.02	0.14	0.02	0.16	0.08
Malvaceae	0.81	11.65	1.84	13.47	6.33
Melastomataceae	0.13	1.32	0.20	1.52	0.71
Meliaceae	0.32	3.47	0.52	3.99	1.88
Moraceae	0.80	10.24	1.61	11.85	5.57
Myristicaceae	0.38	3.93	0.59	4.52	2.12
Myrtaceae	0.73	8.57	1.30	9.88	4.64
Olacaceae	2.53	35.02	5.55	40.60	19.08
Phyllanthaceae	0.19	2.33	0.35	2.68	1.26
Polygalaceae	0.03	0.21	0.03	0.24	0.11
Rhizophoraceae	0.24	2.49	0.37	2.86	1.34
Rubiaceae	0.17	1.79	0.27	2.06	0.97
Sapindaceae	4.62	64.83	10.33	75.17	35.33
Sapotaceae	0.88	10.16	1.56	11.72	5.51
Sterculiaceae	0.09	0.86	0.13	0.98	0.46
Thymelaeaceae	0.02	0.23	0.03	0.27	0.13
Ulmaceae	0.03	0.26	0.04	0.29	0.14
Verbenaceae	0.16	1.88	0.28	2.16	1.02
Total	40.42	558.43	90.18	648.62	304.85

At the family level, Euphorbiaceae contributed the largest share of biomass (148.81 t/ha), followed by Dipterocarpaceae (145.66 t/ha) and Sapindaceae (75.16 t/ha). Although less abundant, Euphorbiaceae species attained larger diameters, which accounted for their disproportionate contribution. This observation is consistent with other studies emphasizing the influence of tree size on biomass accumulation in tropical forests (Norashikin et al. 2015; Zani et al. 2018). At the species level, *E. tapos* was the most dominant contributor with 118.2 t/ha, followed by *S. inappendiculata* (76.48 t/ha) and *P. pinnata* (65.71 t/ha). The uneven biomass distribution among species likely reflects differences in growth strategies, competitive ability, and responses to light availability. The estimated carbon stock in SLFR was 304.86 t/ha, comprising 262.46 t/ha from above-ground biomass and 42.4 t/ha from below-ground biomass. This value is comparatively higher than several other lowland forests in Peninsular Malaysia, including Bukit Nanas Forest Reserve (Faedah et al. 2013) and Kota Damansara (Ruziman et al. 2022), highlighting the role of SLFR as an important carbon reservoir. Family-level contributions were dominated by Euphorbiaceae (69.94 t/ha) and Dipterocarpaceae (68.46 t/ha), while *E. tapos* again ranked highest among species, storing 55.55 t/ha of carbon. Variation in carbon stock across sites is strongly influenced by species composition, stand age, and edaphic conditions (Ruziman et al. 2023). The prominence of large-statured families such as Dipterocarpaceae and Euphorbiaceae in SLFR explains its comparatively high storage capacity, while past disturbance and soil fertility likely also play a role.

Endemism and conservation status

A total of 6 of 76 species were identified as endemic in Sungai Lalang Forest Reserve. Ng et al. (1990) stated that 2,830 tree species were identified in Peninsular Malaysia, with 746 (26.4%) reported to be endemic. Therefore, *Actinodaphne pruinosa*, *Callicarpa maingayi*, *Cinnamomum altissimum*, *Hopea auriculata* and *Pellacalyx saccardianus*, are endemic species that represented local endemism within study plots (Table 1). These results showed that the presence of endemic species highlights ecological uniqueness of Sungai Lalang Forest Reserve with locally restricted taxa (Bryan 2002).

A total of seven tree species recorded in Sungai Lalang Forest Reserve were classified as threatened under the IUCN Red List of Threatened Species Ver 2024-2 (IUCN 2025) (Table 1). These comprised two Critically Endangered (*H. auriculata*, *Palaquium burckii*), two Endangered (*Anisoptera costata*, *Neobalanocarpus heimii*), and three Vulnerable species (*Ctenolophon parvifolius*, *Pentace macrophylla*, *S. inappendiculata*). Four of these belong to the Dipterocarpaceae, a family recognized as one of the most vulnerable groups in Southeast Asia due to its high commercial value as a timber source and continuing deforestation pressures (Richter and Gottwald 1996). The concentration of threatened dipterocarps in this reserve is consistent with earlier reports from other Malaysian forests, such as Kota Damansara, Bukit Tarek, and Ulu Gombak, where Dipterocarpaceae was also identified as the most

threatened family (Ruziman et al. 2022). The co-occurrence of threatened dipterocarps with moderate species diversity and uneven distribution in SLFR indicates the ecological fragility of this lowland dipterocarp ecosystem. Recreational pressures, particularly soil compaction and trampling from camping and trekking, impede seedling recruitment and hinder natural regeneration, thereby intensifying long-term vulnerability. To address these threats, management interventions should prioritize regulating visitor access, decreasing recreational impacts, and enforcing protection for IUCN-listed and endemic species, alongside active restoration measures such as targeted enrichment planting of dipterocarp seedlings. The high biomass and carbon stock recorded further highlight SLFR's dual role as a biodiversity reservoir and a significant carbon sink, linking local conservation to global climate mitigation. Forest landscapes also provide broader ecosystem services, including clean water, air quality regulation, biodiversity protection, and cultural benefits that support both rural and urban communities—ensuring these benefits requires integrated and sustainable forest management. In alignment with SDG 15, conservation strategies must balance ecological integrity with recreational and ecotourism opportunities by strengthening regulation, promoting environmental education, and harmonizing development with natural forest settings. Such approaches will safeguard biodiversity, enhance climate resilience, and sustain the long-term ecological and societal functions of Sungai Lalang Forest Reserve.

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