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Population Assessment, Updated Description, and Prediction of Habitat Distribution for the Sumatran Endemic Tree *Magnolia calophylloides* (Magnoliaceae)

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Abstract

Background and Background Aim: *Magnolia calophylloides* Figlar & Noot. is a narrowly endemic Indonesian species, currently listed as Data Deficient on the IUCN Red List. Originally described from Mount Kerinci in 1914, it was last recorded in the wild in 1972. This study aimed to update knowledge on its distribution, population size and structure, habitat preferences, threats, and conservation status. **Methods:** Field surveys were conducted at historical sites on Mount Kerinci and Mount Tujuh, and a previously unsurveyed area, Ladeh Panjang, in Jambi Province. We assessed population metrics, habitat characteristics, and threats, and updated the species' taxonomic description based on live observations. Species distribution modeling was used to predict potential habitat suitability. **Results:** A total of 389 individuals were recorded across the three sites, with 316 (81%) mature. Flowering and fruiting individuals enabled the first photographic documentation of fresh flowers and revision of its morphological description. The primary threats observed were logging and forest conversion to agriculture. Based on population size, extent of occurrence (97.79 km^2), and area of occupancy (32 km^2), we recommend reclassifying M. calophylloides as Endangered under IUCN criteria B1ab+B2ab(i,ii,iii,v); C2a(i). **Conclusions:** *M. calophylloides* is confirmed as a montane forest specialist with a highly restricted elevational range (1,861–2,322 m) and very limited distribution in Sumatra. Its small population and continued habitat loss highlight the species' vulnerability. **Implications for Conservation:** Targeted conservation is urgently needed. Priorities include habitat protection, enforcement against illegal logging, community-based forest management, and surveys in nearby suitable areas such as Mount Masurai. The species' unique traits and evolutionary significance also make it a strong candidate for further research and a flagship for montane forest conservation in Sumatra.

Keywords

data deficient, IUCN red list, montane plant, threatened plant, West Malesia

Introduction

Magnolia is one of the genera in the Magnoliaceae family, with around 363 species (POWO, 2025). The species of this genus are distributed in the temperate and tropical regions of Eastern and Southeast Asia, as well as the Americas (Rivers et al., 2016). The center of species diversity for *Magnolia* is China, with 114 species, followed by Vietnam (56), Colombia (37), and Mexico (35) (Linsky et al., 2022). Some of the species are economically important as ornamental plants and as sources of natural aromatic and bioactive compounds (Yahaya et al., 2022).

A total of 344 species of *Magnolia*, accounting for more than 94% of the total species, have been assessed for their conservation status according to the IUCN Red List categories and criteria (IUCN, 2025). Of those with a conservation status, 158 species (45.9%) are threatened with extinction, with the categories of Critically Endangered (55), Endangered (103), and

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Vulnerable (32). Agriculture, silviculture, and ranching are known to be the main threats to these threatened species (Linsky et al., 2022; Rivers et al., 2016). In addition, there are 98 species (28%) with insufficient data on their population status and threats, and therefore assessed as Data Deficient (DD).

In Indonesia, there are 28 species of *Magnolia*, 6 of which are endemic (Linsky et al., 2022). All of these species are listed on the IUCN Red List (IUCN, 2025), with one species classified as Critically Endangered (*Magnolia banghamii* (Noot.) Figlar & Noot.), one as Endangered (*Magnolia sulawesiana* Brambach, Noot. & Culmsee), one as Near Threatened (*Magnolia borneensis* Noot.), five species categorized as Least Concern, and 20 species (70.4%) assessed as Data Deficient (DD). The high proportion of DD species highlights ongoing data gaps that impede a comprehensive understanding of the extinction risks and conservation needs of *Magnolia* species in Indonesia.

Magnolia calophylloides Figlar & Noot. is an Indonesian endemic species currently listed as Data Deficient (DD) under the IUCN Red List (Khela, 2014). It was originally described as *Manglietia calophylla* Dandy, based on a type specimen collected in 1914 from Mount Kerinci, in Kerinci Seblat National Park, Jambi Province (Dandy, 1928). Since then, the species has had a limited collection history. Between 1956 and 1972, only four additional specimens were recorded from another area of Kerinci Seblat National Park: three from the Mount Kerinci area—Jacobs s.n. and Meijer 6453 in 1956, and Jacobs 4327 in 1957—and one from nearby Mount Tujuh to the east, collected by Morley in 1972 (Morley 471). The species was included in Nooteboom's monographic treatment for Flora Malesiana in 1988 and was later reassigned to the genus *Magnolia* as *Magnolia calophylloides* in 2004 (Figlar & Nooteboom, 2004). However, these classifications were based solely on herbarium specimens, with no accompanying field data on living populations. To support effective conservation of this narrowly endemic species, there is an urgent need for updated morphological data, a clear understanding of its current population status, and an assessment of threats in its natural habitat.

In the present study, we conducted population surveys for *M. calophylloides* at previously known locations and surrounding areas. The aims were to assess its current population size and structure, distribution, habitat characteristics, and potential threats, as well as to improve the morphological description of the species. The data collected from these surveys were used to reassess the conservation status of *M. calophylloides* using the IUCN Red List categories and criteria. Furthermore, we performed species distribution modeling to predict the species' potential range. The results of this modeling can serve as guidelines for future population surveys and reinforcement activities.

Methods

Study Site

Surveys for *M. calophylloides* were conducted at previously known locations on Mount Kerinci and Mount Tujuh in Jambi Province. Additionally, Ladeh Panjang, located approximately 8 km west of Mount Kerinci (Figure 1), was surveyed to assess whether the species occurs beyond its known range. All three locations are situated within Kerinci Seblat National Park (KSNP). Spanning 1,389,509 hectares, KSNP extends across four provinces: Jambi, West Sumtera, Bengkulu, and South Sumatra. The park is characterized by its mountainous landscape, with Mount Kerinci standing as its highest peak at 3,805 meters above sea level. Classified as Type A (wet) in the Schmidt and Ferguson climate system, KSNP experiences an average annual rainfall of 2,991 mm and typically has fewer than two dry months annually. The temperature range falls between 16° and 28° Celsius, while the relative humidity varies from 77% to 92% (Balai Besar Taman Nasional Kerinci Seblat, 2018).

Population Surveys and Plant Materials Collection

The search for *M. calophylloides* was conducted using a focused survey method (Brewer, 2013), targeting areas with a high probability of encountering the species. Survey locations were selected based on herbarium specimen records, published literature, and insights from local communities and national park staff. Once individuals were located, measurements of diameter at breast height (DBH) and total height were taken, and geographic coordinates were recorded using a GPS device. The reproductive maturity of each tree was assessed by noting the presence or absence of flowers and/or fruits. At each site, key environmental variables were recorded, including elevation (in meters above sea level), slope gradient, and slope aspect. Potential threats to the species in its immediate surroundings were also documented. Additionally, herbarium specimens were collected to support detailed morphological analysis and to improve the description of the species.

Conservation Status Assessment

Using data collected from the field surveys, we reassessed the conservation status of *M. calophylloides* based on criteria B (geographic range), C (small population size and decline), and D (very small or restricted population) of the IUCN Red List (IUCN, 2012). The extent of occurrence (EOO) and area of occupancy (AOO) for criterion B were calculated using GeoCAT (https://geocat.kew.org/; Bachman et al., 2011) with a 2 × 2 km grid cell. For criteria C and D, we estimated the species' population size by counting the number of mature individuals.

Species Distribution Modeling

Occurrence data for *M. calophylloides* were obtained from population surveys conducted during the present study, resulting in 389 georeferenced occurrence records. Predictor variables were categorized into two groups—bioclimatic and topographic—to account for differences in data types and spatial sources that could influence model performance.

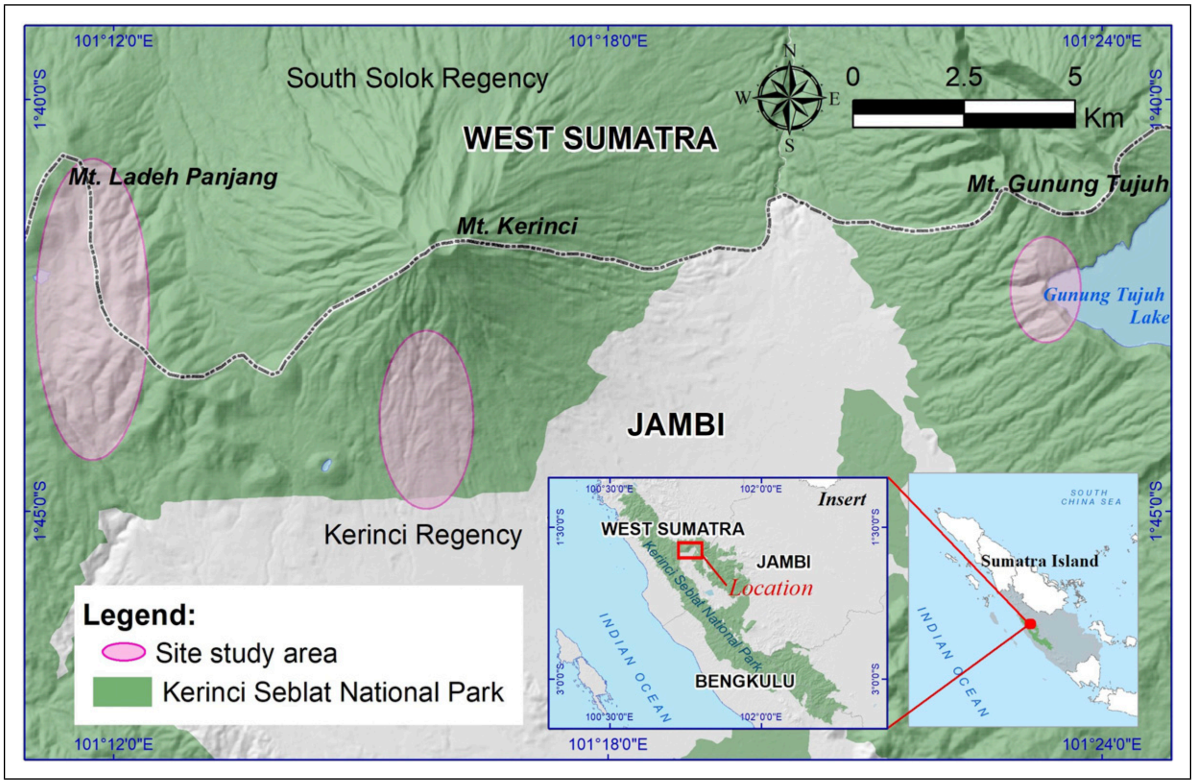

Figure 1. Study sites for the population survey of *Magnolia calophylloides*

Bioclimatic variables were sourced from WorldClim version 2.1 (Fick & Hijmans, 2017). Given the species' endemic nature and limited ecological information, all 19 bioclimatic variables were retained to minimize the risk of excluding potentially important environmental factors, even if their individual contributions were relatively small. Topographic variables—including elevation, slope, and aspect—were derived from Indonesia's national elevation dataset (DEMNAS) (Wilson et al., 2000). All variables were resampled to a 30-meter resolution and clipped to the extent of Kerinci Seblat National Park, encompassing the provinces of Jambi, West Sumatra, Bengkulu, and South Sumatra. Elevation and slope were treated as continuous variables, whereas aspect was categorized into seven classes following Van Zuidam's classification system (van Zuidam & van Zuidam-Cancelado, 1978).

$$S_{xn} = \sum_{i=1}^{n} \frac{\dfrac{Nxn}{\left(N_{total} \times \left(\dfrac{Vp_{xi}}{Vp_{total}}\right)\right)}}{\sum \dfrac{Nx}{\left(N_{total} \times \left(\dfrac{Vp_{xi}}{Vp_{total}}\right)\right)}} \tag{1}$$

where:
Sxi: Score of maxent result i.
Nx: Number of variables composing maxent result i.
Ntotal: Total number of variables of all maxent result i to n.
Vpxi: Value of variable influence in maxent result i.
Vptotal: Total number of influences of all maxent result i to n.

The species distribution model (SDM) for *M. calophylloides* was developed using the Maximum Entropy algorithm (MaxEnt) version 3.4.4 (Phillips et al., 2006), integrated with Geographic Information System (GIS) analyses. This integration aimed to enhance the precision of habitat suitability modeling for the species. Spatial data standardization was a crucial step in preparing inputs for MaxEnt; GIS procedures were conducted to harmonize spatial formats and derive additional variables for the model (Supplemental Material 1). Interpretation of MaxEnt outputs followed standard practices widely applied in recent studies (Iryadi et al., 2024; Merow et al., 2013; Sutomo et al., 2025). Each MaxEnt output includes contribution values for all predictor variables, which were used to guide a scoring process based on their relative influence. These scores formed the basis for a GIS-based overlay analysis (equation (1)), which combined outputs from both the bioclimatic and physical variable models for final SDM integration (Supplemental Material 1) (Sutomo et al., 2023).

Results

Species Identification and Description

We successfully located *M. calophylloides* in all three surveyed areas (Figure 2). Most of the individuals were in a state of producing flowers and/or fruits, and therefore, allowing us

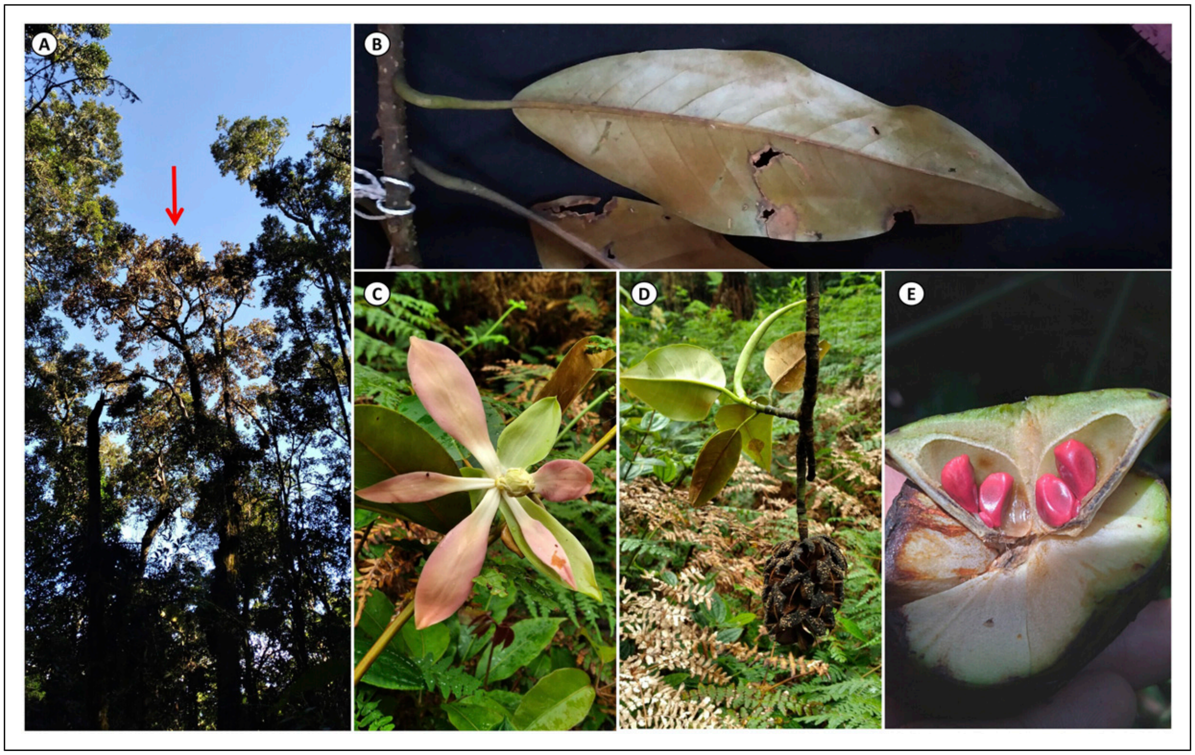

Figure 2. *Magnolia calophylloides* Figlar & Noot. in Kerinci Seblat National Park, Jambi Province: (A) Emergent tree with a reddish canopy (red arrow), (B) Leaf with densely minutely reddish-brown appressed hairs, (C) Flower, (D) Mature fruit, and (E) Seeds. Photographs by Iyan Robiansyah

to document the first image of fresh flowers of the species. *Magnolia calophylloides* is an emergent tree that can be easily distinguished from other *Magnolia* species by the combination of the following characteristics: stipules only adnate to the very base of the petiole, glabrous peduncles, and the underside of the leaves densely covered with minute, reddish-brown appressed hairs. The latter feature gives the canopy a reddish appearance and makes individuals easier to spot.

From its first description by Dandy (1928) to the monographic Flora Malesiana (Nooteboom, 1988), the morphological description of the species has generally excluded living characters. The amended description—combining the protologue, Nooteboom (1988), and recent observations (with additional characters in italics)—is as follows:

Magnolia calophylloides Figlar & Noot., Blumea 49: 95 (2004), amended description.

≡ *Manglietia calophylla* Dandy, Bull. Misc. inform. Kew: 46 (1928b) Type: Sumatra, Korinchi Peak, 7300 ft, 3 May 1914, Robinson & Kloss 200 (holotype: BM; isotype: K-image! [K000681535], SING).

non *Magnolia calophylla* (Lozano) Govaerts in D.-G.Frodin & R.H.A.Govaerts, World Checkl. & Bibliogr. Magnoliaceae: 27 (1996) non *Dugandiodendron calophyllum* Lozano, Caldasia 12: 283 (1978).

Huge tree, up to 30 m tall, with up to 2 m dbh; *buttress up to c. 1.8 m tall*; *bark apparently flaking off, outer bark grey.* Branch *terete, 5–8 mm across*, glabrous, *lenticellate*. Stipule adnate to the very base of the petiole, *light yellowish green, 4.3 cm long*, with reddish brown hairs especially at the margin, or nearly glabrous, *caducous*. Leaves elliptic-, ovate-, to obovate-oblong, 10–20 × 4–8 cm, *plain green above*, *slightly shiny*, reddish beneath, light yellowish green above when young, base vary from cuneate to nearly rounded, margin entire, apex acuminate; midrib prominent beneath, lateral veins 10–15, raised on both surfaces, forming an indistinct intramarginal veins, intramarginal veins similar to reticulations; glabrous above, lower surfaces covered with reddish brown, short hairs; petiole *geniculate in the lower third to lower half*, *2*–2.5 cm long. Inflorescence terminal, 1-flowered, peduncle c. 2 cm long, up to c. 3 cm in fruiting, glabrous; flowers with tepals 9, *3 outer light green with white base*, *4.2–5.0 × 2.0–2.1 cm, concave, 7-veined, apex acute, slightly hooded*, *reflexed*; *middle whorl tepals narrowly spathulate, 4.9–6.1 × 1.5 cm, lower ¼ to 1/3 white, upward pink red, apex acute or shortly acuminate, glabrous, 7-veined, veins immersed, often indistinct; inner row tepals oblanceolate, 4.4–4.6 × 0.9–1.0 cm, white in the lower third, pink red upward, apex subacuminate, glabrous.* Stamens on 10 mm long axis, *c. 74, creamy white, with terminal appendix of c. 3–5 mm long, glabrous*. Gynoecium ellipsoid, *1.8 × 1.1 cm*, carpel 12–20, glabrous*, greenish white*, *style subulate, 4–6 mm long*, glabrous. Fruits *ovoid*, 4.5–5.5 × 3.5–5 cm, carpel *12*–20 per fruit, *light green when mature, often red-tinged, blackish when dry,* surfaces *lenticellate*, *rounded at apex.* Seeds 4 per carpels, flat ovoid, c. 7 × 4 mm, *aril pink red*.*Population status*.

A total of 389 individuals were found, of which 316 (81.23%) were mature (Figure 3). The distribution was as follows: 127 individuals (98 mature) at Mt. Kerinci, 85 individuals (54 mature) at Gunung Tujuh, and 177 individuals (164 mature) at Ladeh Panjang. The populations were dominated by mature individuals, with the largest diameter at breast height recorded as approximately 2 meters, found in Mt. Kerinci.

Populations of *M. calophylloides* in Mt. Kerinci, Gunung Tujuh, and Ladeh Panjang were located in mountain forests at an elevation range of 1864-2322 m, 1993-2196 m, and 1950-2101 m, respectively. In Ladeh Panjang, individuals were found on relatively flatter terrain (slope range: 0-32°, mean: 14.39 ± 0.52°) compared to those in Mt. Kerinci (slope range: 7-55°, mean: 28.78 ± 1.04°) and Gunung Tujuh (slope range: 5-50°, mean: 26.66 ± 1.44°). Regarding slope aspect, the species was found on west-facing slopes in Ladeh Panjang, south-facing slopes in Mt. Kerinci, and south–southwest-facing slopes in Gunung Tujuh.

Threats and Conservation Status Assessment

We observed that logging and forest conversion into agricultural fields were the main threats to *M. calophylloides* (Figure 4). These threats were noted at Mt. Kerinci and Gunung Tujuh, while no such threats were observed at Ladeh Panjang. In the areas around the national park, where most local residents are farmers, many forests have been converted into agricultural fields for crops such as potatoes, tomatoes, chilies, and cabbage. Additionally, the timber of *M. calophylloides* is highly valued by locals for construction and furniture. During the survey, we observed several stumps of the species, indicating logging activities by local people.

The EOO and AOO of *M. calophylloides* were 97.79 km^2 and 32 km^2, respectively. With only three known locations, the species qualifies as Endangered (EN) under criteria B1ab+B2ab (i,ii,iii,v) of the IUCN Red List. Threats from logging and habitat conversion are inferred to cause a continuing decline in EOO (subcriterion b(i)), AOO (b(ii)), area, extent, and quality of habitat (b(iii)), and number of mature individuals (b(v)). Under criterion C, the species qualifies as Endangered (EN) C2a(i) due to having fewer than 2,500 mature individuals, with fewer than 250 mature individuals in each subpopulation. Under criterion D, the species is assessed as Vulnerable (VU) D1 because the number of mature individuals is below 1,000.

Potential Distribution

The species distribution models based on climatic and topographic data yielded high AUC values of 0.900 and 0.992, respectively, indicating strong model performance and high predictive reliability (Crego et al., 2014; Hosmer et al., 2013). Among the climatic variables, the most influential were the maximum temperature of the warmest quarter (Bio10), precipitation of the driest month (Bio14), and minimum temperature of the coldest month (Bio6). For the topographic variables, elevation contributed most significantly to the model (Supplemental Material 2). Model results suggest that *M. calophylloides* prefers specific environmental conditions: (i) maximum temperature of the warmest quarter: 12–15°C, (ii) minimum temperature of the coldest month: 6–10°C, (iii) precipitation of the driest month: 75–80 mm, and (iv) elevation: 2,000–2,300 meters above sea level (Figure 5).

The MaxEnt model based on topographic variables predicted a broader spatial distribution of *M. calophylloides* compared to the model using climatic variables (Supplemental Material 3). Using Equation (1), a scoring approach was applied based on the relative contribution of each variable, enabling the development of standardized score values for both topographic and bioclimatic MaxEnt layers (Supplemental Material 2). These scored layers were then overlaid using GIS techniques to generate a combined suitability model, representing the integrated potential distribution of *M. calophylloides* (Figure 6). The resulting maps indicate that areas with moderate to very high probabilities of occurrence are confined to just two provinces: Bengkulu and West Sumatra. High to very high suitability zones were

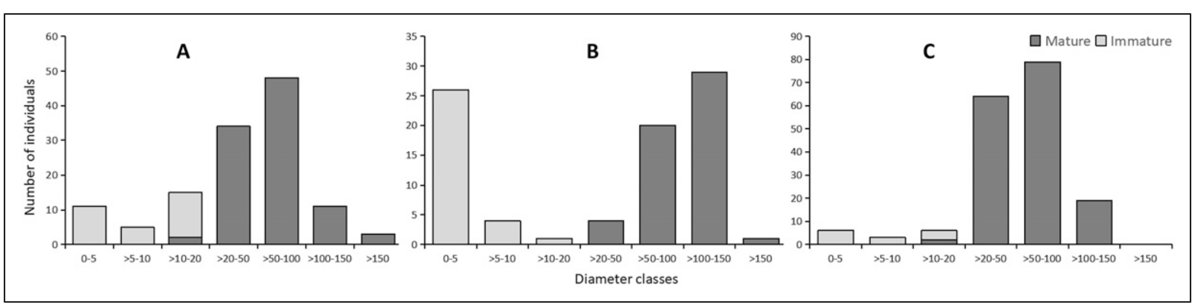

Figure 3. Population structure of *Magnolia calophylloides* Figlar & Noot. based on diameter at breast height (dbh) classes: (A) Mt. Kerinci, (B) Gunung Tujuh, and (C) Ladeh Panjang

Figure 4. Threats to *Magnolia calophylloides* Figlar & Noot.: (A) Tree stump of *Magnolia calophyloides* remaining as a result of illegal logging activity; and (B) Forest habitat of *Magnolia calophylloides* converted into agricultural fields. Photographs by Iyan Robiansyah

predominantly located within Kerinci Seblat National Park and the highland areas surrounding Lake Gunung Tujuh. Medium suitability areas were scattered across the northern part of Pesisir Selatan Regency (West Sumatra), following the same mountain range as the Kerinci Seblat region. Additionally, a more isolated medium-suitability area was identified in Merangin Regency (Jambi), specifically on the eastern slopes of Mount Masurai. However, this area was

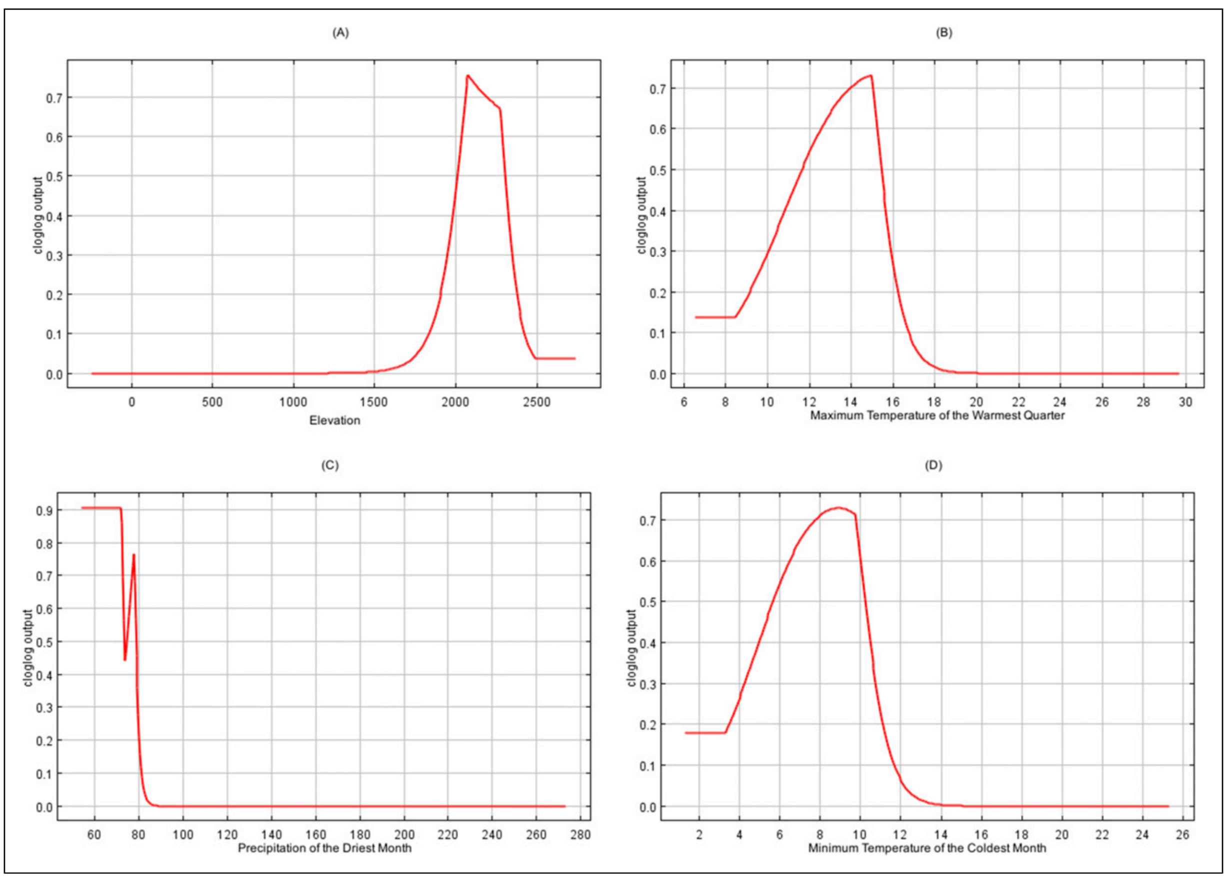

Figure 5. Response curves of the four environmental variables with the highest contribution to the distribution modeling of *Magnolia calophylloides*: (A) elevation, (B) maximum temperature of the warmest quarter, (C) precipitation of the driest month, and (D) maximum temperature of the coldest month

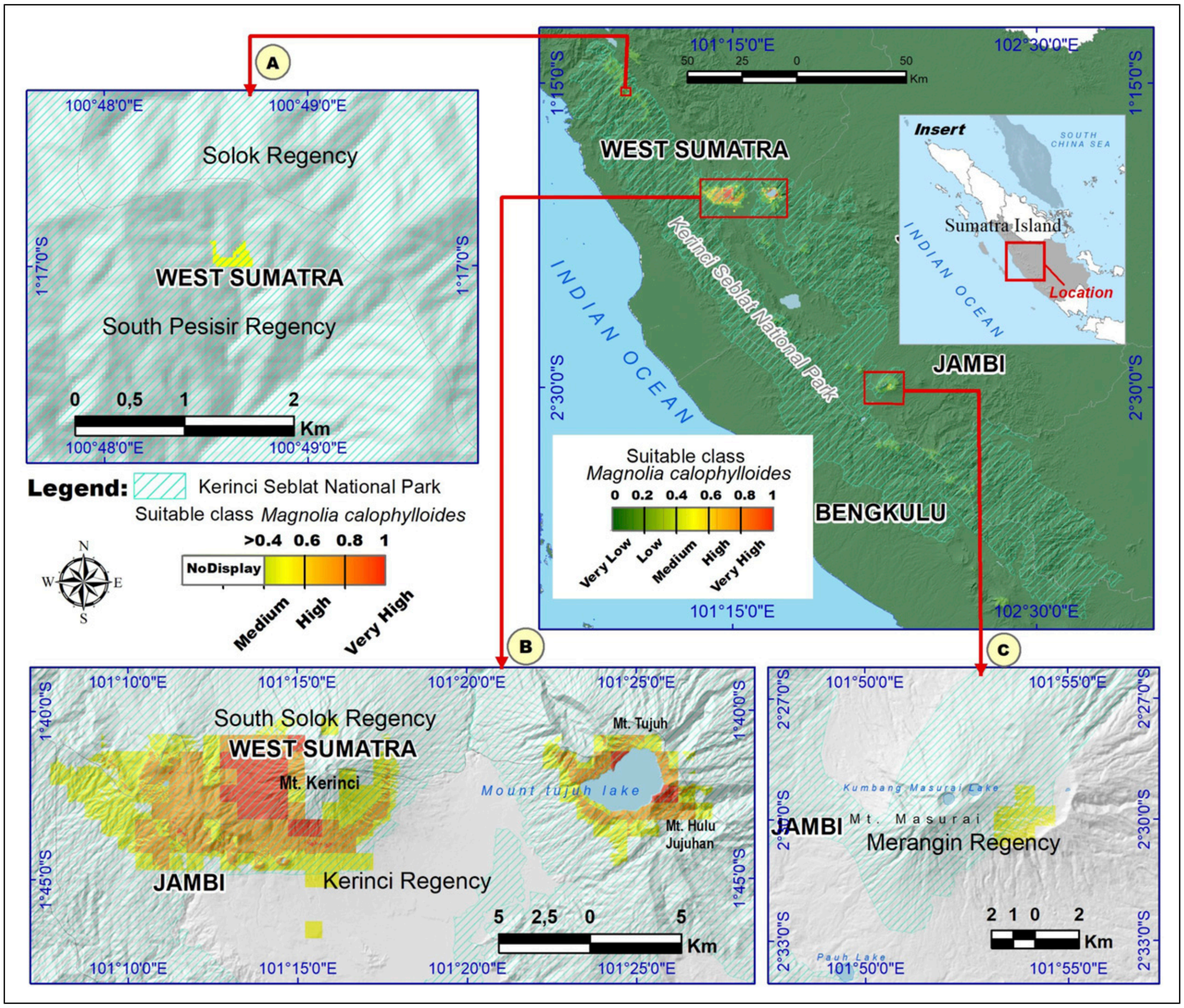

Figure 6. Predicted suitable habitat for *Magnolia calophylloides* based on Maxent modeling incorporating both climatic and topographic variables

relatively small, covering only about 416 hectares. Overall, the combined area classified as having moderate to very high suitability amounts to approximately 13,477.03 hectares, representing just 0.14% of the total area of the two provinces.

Discussion

Our study shows that *Magnolia calophylloides* is currently known from three locations within Mount Kerinci Seblat National Park and is considered a narrowly endemic tree species. In Sumatra, two other *Magnolia* species also exhibit restricted geographic distributions: *M. banghamii* (Nooteboom, 1988; Robiansyah et al., 2023) and *M. lanuginosoides* (Nooteboom, 1988). Local endemicity in the genus *Magnolia* has been partially studied—for example, in *Magnolia calimaensis*, where endemicity may be caused by frequent geitonogamy and self-pollination (Bocanegra-González et al., 2024). Therefore, *M. calophylloides* provides a promising opportunity to further explore the biology of narrowly endemic tree species. From a geological perspective, it is noteworthy that this species is only known from two volcanic summits, one of which is still active. In addition to geological factors, the species occurs on volcanic-derived soils, likely Andosols, characterized by well-drained, acidic substrates with high organic matter content, suggesting that edaphic factors play an important role in shaping its distribution. The narrow endemicity of this large tree species appears to be linked to the combined influence of volcanism and soil conditions. Volcanism has been shown to influence on relief, landscape, soil, climate and biodiversity, to which species can respond diversification and can ultimately drive evolutionary processes (Sanín et al., 2024). Based on these findings, further studies involving *M. calophylloides* are encouraged to better understand the evolutionary history of endemic trees in Mount Kerinci and Mount Tujuh. Such research would not only shed light on the natural history of these two mountains but also contribute to a broader understanding of Sumatra's biodiversity and evolutionary dynamics.

Data collected in the present study further support the distinct taxonomic status of *M. calophylloides*. In his protologue, Dandy (1928) described the species as clearly distinct from *M. sumatrana* var. *glauca* sensu Ridley (1917), based on features such as the pubescence of the abaxial leaf surface, as well as differences in leaf size, shape, and texture. Our observations add floral traits to this distinction: while *M. sumatrana* var. *glauca* has creamy white inner perianth segments, *M. calophylloides* displays pink-red segments with a white base. Recent field observations from our study have also expanded knowledge of the species' phenology. Previously, flowering was documented only in October (Nooteboom, 1988); our data now confirm that flowering also occurs in July. Fruiting remains documented from May to August, with no new data extending that range (Nooteboom, 1988). This floral coloration may be significant for future studies on flower color evolution in Magnoliaceae (e.g., Shrestha et al., 2014), a subject not yet thoroughly investigated in the family. Although Nooteboom (1988) mentioned that *M. calophylloides* has white or yellow flowers, we have excluded this from our revised description. That information was based on a herbarium label (Kostermans 23848) from a cultivated plant, and none of the wild-collected specimens report flower color. In summary, both herbarium and field evidence now clearly support the distinction of *M. calophylloides* from *M. sumatrana* var. *glauca*, based not only on dried specimens but also on characteristics observed in living plants.

Magnolia calophylloides is confined to highland habitats, occurring in montane (1,861 m a.s.l.) to upper montane forests (2,322 m a.s.l.). This limited elevational range supports its distinction from *M. sumatrana* var. *glauca*, a species found across a much broader altitudinal gradient—from lowland forests (500 m a.s.l.) to the upper montane–subalpine transition zone (2,400 m a.s.l.) (Nooteboom, 1988). A specimen with white flowers, cultivated in the Cibodas Botanical Garden, has been observed at 1,450 m a.s.l.; however, it is unclear whether this elevation reflects the plant's natural provenance or simply the garden's growing conditions. The former is unlikely, as much of the original habitat around Kerinci was converted to tea plantations as early as the 1920s.

Due to its narrow geographic range, low population size, and ongoing threats from logging and forest conversion to agriculture, *M. calophylloides* qualifies for the IUCN threat categories EN B1ab + B2ab(i,ii,iii,v) and EN C2a(i), as well as VU D1. According to IUCN guidelines, a species must be assigned to the highest applicable category of threat. Therefore, we propose Endangered (EN) B1ab + B2ab(i,ii,iii,v); C2a(i) as the updated conservation status for *M. calophylloides*. This proposed category differs from its current status of Data Deficient (DD) on the IUCN Red List (Khela, 2014) and reflects that the species is now considered to be facing a very high risk of extinction in the wild. Immediate and coordinated conservation actions are essential to safeguard the future of this narrowly endemic species.

The modeling results indicate that suitable habitats for *M. calophylloides* are primarily located in mountainous regions at elevations ranging from 2,000 to 2,300 meters, characterized by humid conditions and mild temperatures. This elevation range closely aligns with the species' known distribution, which spans from 1,861 to 2,322 meters. Habitat suitability modeling reveals that *M. calophylloides* occupies a highly restricted ecological niche, with suitable areas limited primarily to the provinces of Bengkulu and West Sumatra. The concentration of high to very high suitability zones within Kerinci Seblat National Park and the surrounding highlands, such as Lake Gunung Tujuh, suggests that protected montane forests are critical refugia for this species.

Predicted moderately suitable areas in the southern part of the study area, particularly around Mount Masurai (Jambi Province), indicate potentially supportive environmental conditions for *M. calophylloides*. However, the likelihood of this species occurring there needs to be reconsidered because our model predictions are based on abiotic variables without considering biotic interactions, such as competition or habitat occupancy by conspecifics. Therefore, it is likely that this suitable southern zone is currently occupied by other Magnolia species with overlapping ecological requirements, rather than by *M. calophylloides* itself. Field verification through targeted botanical surveys is needed to confirm the true species composition in this area.

Despite the existence of these potentially suitable areas, the overall extent of suitable habitat for *M. calophylloides* remains very limited and is largely confined to mountainous environments. This limited distribution increases its vulnerability to climate change (Gomes et al., 2015) and anthropogenic pressures. Our findings highlight the potential for undiscovered populations and the urgency of focused conservation actions, particularly in montane forest ecosystems, supported by landscape-level conservation planning.

Implications for Conservation

Our findings highlight the urgent need for targeted conservation efforts to protect *M. calophylloides*, a narrowly endemic tree species now confirmed to be at high risk of extinction in the wild. With only 389 individuals (316 Mature and 73 Junevile) and suitable habitat limited to approximately 13,477 hectares across Bengkulu and West Sumatra, the species faces significant threats from logging and agricultural expansion—particularly in areas outside protected zones. Its reliance on high-elevation montane forests, many of which are located within Kerinci Seblat National Park, underscores the critical role of these habitats as ecological refuges. Effective conservation strategies should focus on preserving remaining forest cover, strengthening enforcement against illegal logging, promoting community-based forest management. In addition, genetic diversity studies across the three known subpopulations are urgently needed to understand population structure, gene flow, and inbreeding risks, which are essential for designing scientifically informed conservation strategies. Conducting targeted field surveys in nearby medium-suitability areas such as Mount Masurai to locate potential undiscovered populations. Additionally, the species' unique evolutionary history and distinctive morphological traits make *M. calophylloides* a valuable subject for further scientific study and a flagship species for conserving the rich biodiversity of Sumatra's montane ecosystems.

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Supplemental Material

Supplemental material for this article is available online.

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