

# THE SABAH PLANT RED LIST OF DIPTEROCARPACEAE: IDENTIFYING HIGH-DENSITY OF THREATENED SPECIES IN PERMANENT FOREST ESTATE

\*R.J. Majapun, S.T.L Tsen & E. Khoo

Forest Research Centre, Sabah Forestry Department,  
P.O. Box 1407, 90715 Sandakan, Sabah, Malaysia.

\*Email: Richard.Majapun@sabah.gov.my

## ABSTRACT

The Dipterocarps, a vital family of tropical hardwood trees, play a crucial role in maintaining the ecological balance of Southeast Asian forests but are increasingly threatened by deforestation, habitat fragmentation, and climate change. In Sabah, located on the island of Borneo, 96 out of 182 dipterocarp species are listed as threatened on the Sabah Regional IUCN Red List, where 92% of these species are found within permanent forest estates. This study focuses on assessing the hotspots of these threatened species across the PFE and forest districts in Sabah. Utilising occurrence data from The Sabah Plant Red List of Dipterocarpaceae (2022), we generated heatmaps for Critically Endangered (CR), Endangered (EN), and Vulnerable (VU) species using R software and QGIS. The analysis mapped species occurrences within the PFE, highlighting key biodiversity hotspots by forest districts, such as Telupid, Beluran, Deramakot, and Tongod, where high densities of threatened species were concentrated. Treating these reserves as interconnected ecosystems and focusing on both ex-situ and in-situ conservation methods will significantly enhance the protection of threatened dipterocarp species across districts in the region.

**Keywords:** Threatened dipterocarp species, IUCN Red List, permanent forest estates, heat map, conservation, biodiversity hotspots.

## 1. INTRODUCTION

The Dipterocarpaceae family, a critical component of Sabah's timber industry, accounts for 90% of timber exports from North Borneo and was a central focus of early recollection efforts. Since Meijer and Wood's initial compilation of North Borneo Dipterocarps in 1964, the recorded number of dipterocarp species in Sabah has increased from 150 to 183 (Ashton, 2004). However, during the cross-checking process for "The Sabah Red List of Dipterocarpaceae", it was found that the specimen listed as *Shorea richetia* belonged to a different family, reducing the total number of recorded dipterocarp species in Sabah to 182. These species span across Sabah's land area designated as permanent forest estate (PFE) which includes Forest reserves, Parks, Wildlife sanctuaries and Wildlife conservation areas (SFD, 2020). These species span across 48% of Sabah's land area designated as forest reserves, with 1.688 million hectares classified as Totally Protected Areas (TPAs). These TPAs, which include Protection Forests, Virgin Jungles, and Wildlife Reserves, where logging are prohibit and are reserved for watershed protection, research, and conservation (SFD, 2020). Of the 21 natural forest formations within these reserves, 40% are lowland mixed dipterocarp forests (LMDFs). When accounting for state parks, wildlife sanctuaries, and other conservation areas, the total protected area amounts to at least 26% of Sabah's land. The book "Sabah Plant Red List of Dipterocarpaceae" (Khoo *et al.*, 2022) provides comprehensive documentation of the conservation status of dipterocarp species within these protected areas, based on regional assessments. This study further emphasises the importance of identifying and visualising areas of high density for threatened dipterocarp species within permanent forest estates to guide future conservation efforts.

## 2. MATERIALS AND METHODS

### 2.1 Study area and data collection

The study was conducted in Sabah, Malaysia, with a focus on permanent forest estates (PFE) that serve as critical habitats for dipterocarp species. These areas are of conservation importance due to the high occurrence of threatened dipterocarp species, which are facing significant pressures from deforestation, habitat fragmentation and climate change. The occurrence data for dipterocarp species under threatened categories: Critically Endangered (CR), Endangered (EN), and Vulnerable (VU) were sourced from *The Sabah Plant Red List of Dipterocarpaceae* (Khoo *et al.*, 2022). Geospatial data, including PFE and district boundaries, were provided by the Sabah Forestry Department (SFD).

## 2.2 Data processing and analysis

Species occurrence data were processed into spatial point datasets and integrated with PFE boundary using R software and QGIS (version 3.28.12). Heatmaps were generated to illustrate the distribution of threatened dipterocarp species, identifying key biodiversity hotspots within the PFE. A spatial join was conducted to summarise species occurrences within each PFE, enabling a ranking of PFE based on the number of threatened species present. Each PFE was further categorised by forest districts to reveal patterns of forest connectivity, biodiversity distribution, and potential conservation priorities across different forest administrative regions. This approach allowed for a comprehensive analysis of forest networks and the identification of critical areas for targeted conservation efforts.

## 3. RESULTS AND DISCUSSION

Approximately 1,695 occurrences or points have been recorded for threatened species across 140 PFE in Sabah, encompassing a total of 88 species. This includes 70 occurrences for species classified as Critically Endangered (CR) across 18 species, 219 occurrences for species categorised as Endangered (EN) involving 23 species, and 1,406 occurrences for species classified as Vulnerable (VU) covering 47 species. This data highlights the distribution and conservation status of species within the region, underscoring the need for targeted conservation efforts for those in the highest risk categories.

### 3.1 The Critically Endangered dipterocarp in Sabah's PFE

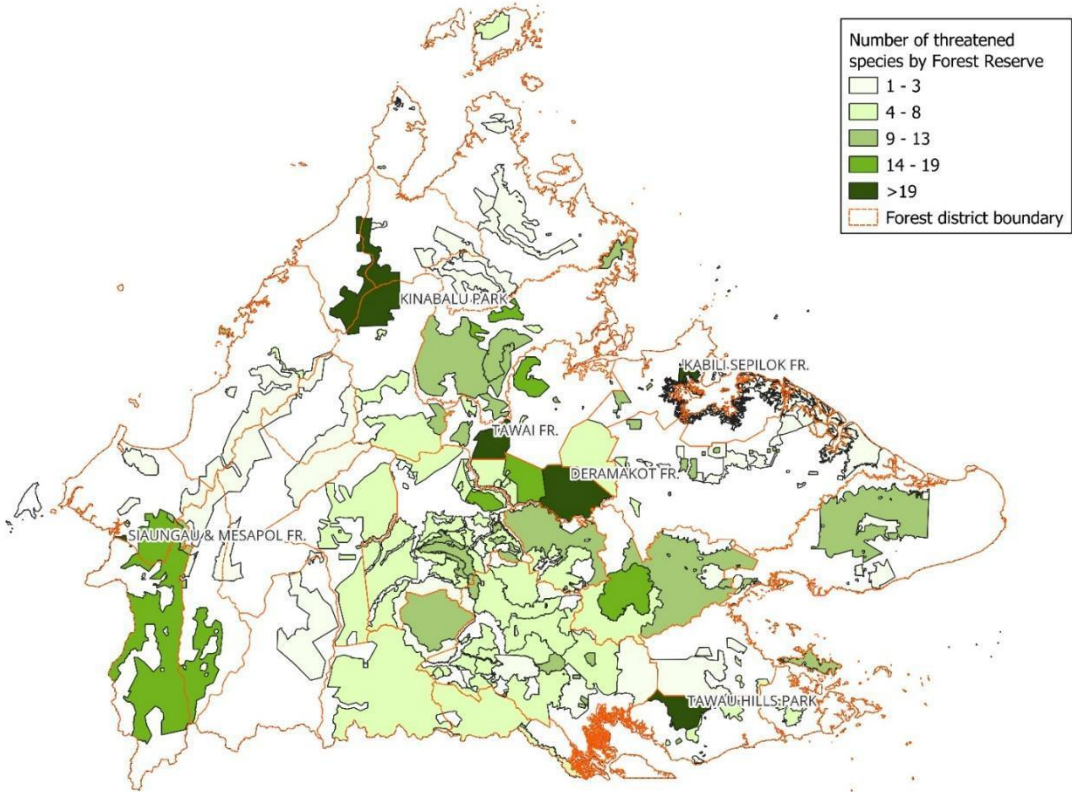
The critically endangered (CR) Dipterocarp species recorded in Sabah's PFE exhibit a diverse but uneven distribution across different locations. The species include *Anisoptera laevis*, *Dipterocarpus condorensis* ssp. *penangianus*, *Dipterocarpus crinitus*, *Dipterocarpus lamellatus*, *Dryobalanops aromatica*, *Dryobalanops rappa*, *Hopea centipeda*, *Hopea pedicellata*, *Shorea biawak*, *Shorea platycarpa*, *Shorea quadrinervus*, *Shorea retusa*, *Shorea revoluta*, *Shorea slootenii*, *Shorea teysmanniana*, *Upuna borneensis*, *Vatica havilandii*, and *Vatica venulosa*. Among these, *Dipterocarpus crinitus*, *Dipterocarpus lamellatus*, *Dryobalanops aromatica* are predominantly recorded in the Siaungau & Mesapol Forest Reserve (FR). Species such as *Dipterocarpus condorensis* ssp. *penangianus*, *Shorea biawak*, *Hopea pedicellata*, *Upuna borneensis*, *Shorea teysmanniana*, and *Shorea slootenii* are much rarer, with only one or two occurrences observed.

Siaungau & Mesapol FR stands out among the other PFE with the highest number of CR species. Other reserves such as Gunong Lumaku FR, Nurod-Urod FR, and Sapulut FR also recorded occurrences of CR species, albeit in much lower numbers. In contrast, some species were recorded in only one reserve, like *Anisoptera laevis* in Gunong Lumaku FR and *Shorea platycarpa* in Sipitang FR, highlighting their rarity. The comparison reveals that while some species like *Dipterocarpus crinitus* and *Dryobalanops aromatica* are more widespread, others are extremely rare and were recorded in only a few instances, such as *Dipterocarpus lamellatus* that were only recorded in Siaungau & Mesapol FR, pointing to the critical need for focused conservation efforts, particularly for those species with very limited occurrences.

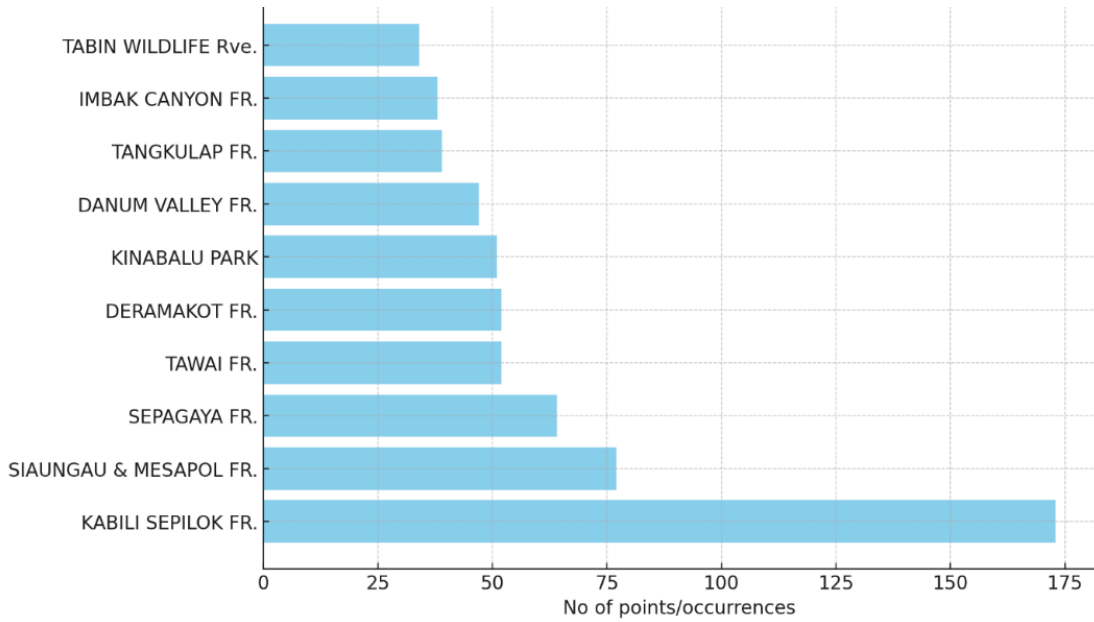
### 3.2 Threatened species based on permanent forest estates

Siaungau & Mesapol FR., Tawai FR. and Kabili Sepilok FR. are notable for their high species richness, hosting 26, 25, and 24 species, respectively (Fig. 1). These areas are recognised as critical biodiversity hotspots and are essential targets for conservation efforts. In terms of occurrences, Kabili Sepilok FR. recorded the highest number (173), followed by Siaungau & Mesapol FR. (77) and Sepagaya FR. (64), underscoring significant population presence and frequent biodiversity observations in these regions (Fig. 2).

Kabili Sepilok FR., in particular, excels in both species diversity and occurrences, marking it as a crucial site for biodiversity preservation. Similarly, Siaungau & Mesapol FR., with its 26 species and high occurrence count, highlights its critical role in conservation. Conversely, some reserves, like Babanga FR., Balat Damit Wildlife, and Balembang FR., exhibit low species diversity, with only one species recorded, necessitating focused conservation strategies. Other reserves, such as Kinabalu Park and Deramakot FR., also show substantial species diversity, each recording over 20 species. This data indicates reserves like Kabili Sepilok FR., Siaungau & Mesapol FR., and Tawai FR. not only experience frequent biodiversity monitoring but also support a wide variety of species, making them key areas for ongoing conservation and research.

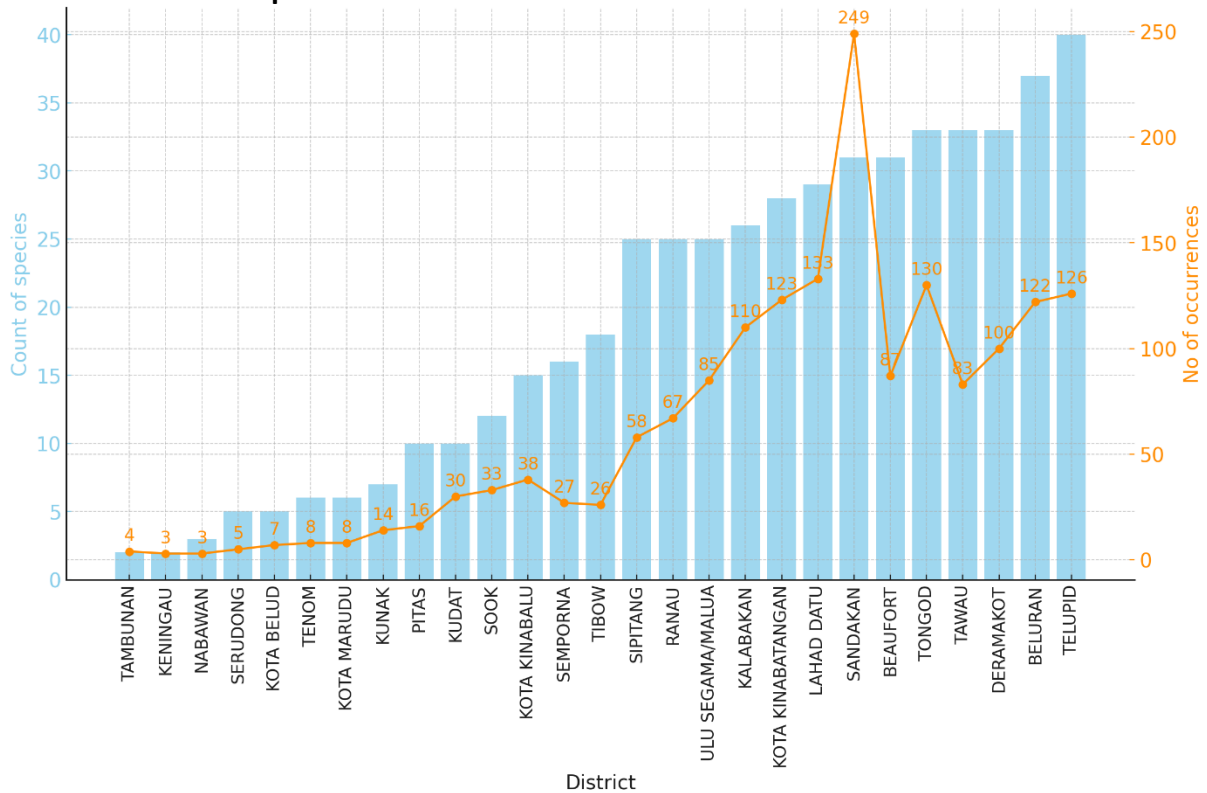


**Figure 1.** Spatial distribution of threatened dipterocarp species across Sabah's permanent forest estates.



**Figure 2.** Top 10 permanent forest estates in occurrences of threatened dipterocarp species.

### 3.2 Threatened species based on District



**Figure 3.** Distribution of threatened species and their occurrences across forest districts.

The district with the highest number of threatened species is Telupid, with 40 species, while Sandakan records the highest number of occurrences at 249, despite having a relatively lower species count (Fig. 3). The figure highlights a general upward trend in both species count and occurrences across the districts, although the number of occurrences fluctuates significantly. Some districts, such as Tawau and Kalabakan, show fewer

species but a higher number of occurrences, indicating that species count does not necessarily correlate with the frequency of occurrences.

### 3.3 The top five forest districts with the highest number of threatened species

The top five districts namely Telupid, Beluran, Deramakot, Tongod, and Tawau, emerge as critical biodiversity hotspots in Sabah, with the highest counts of threatened species (Fig. 4). Telupid ranks first with 40 species and 126 occurrences within six forest reserves, followed by Beluran with 37 species and 122 occurrences within six forest reserves. Deramakot (4 FR.) and Tongod (11 FR.), both hosting 33 species, have 100 and 130 occurrences, respectively, indicating substantial survey coverage and their importance for habitat management. Tawau, also with 33 species and 83 occurrences within 10 FR, signalling its priority status despite slightly lower survey intensity.

To safeguard the biodiversity in the top five districts, Telupid, Beluran, Deramakot, Tongod, and Tawau, targeted conservation actions are essential. Prioritizing species recovery programs for critically endangered species, with a focus on habitat restoration and continuous monitoring, will be key to their survival. Enhanced monitoring across these districts is crucial to track changes in species populations and habitats, facilitating adaptive management and ensuring effective conservation outcomes.

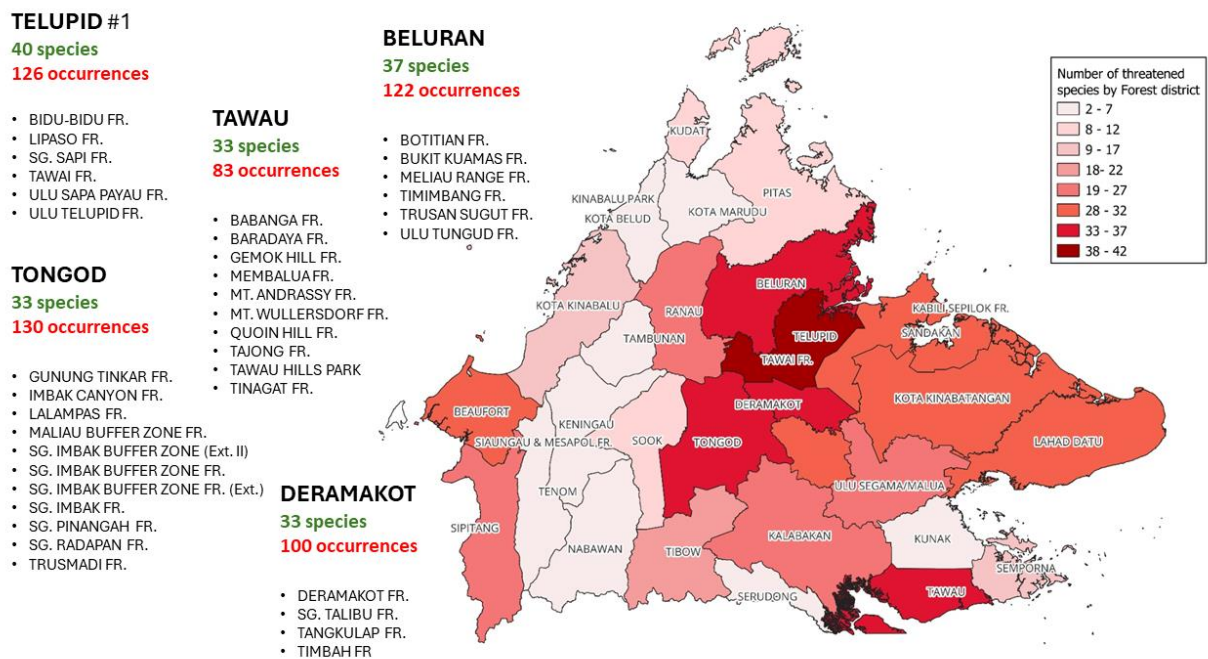


Figure 4. Map of threatened species and occurrences based on district.

### 3.3 Recommendations

Telupid, Beluran, Deramakot, and Tongod stand out as critical biodiversity hotspots in Sabah, with the highest counts of threatened species and survey occurrences. To maximise the conservation potential in these districts, it is crucial to treat their forest reserves as part of a unified ecosystem network. This approach will help capture 68.18% of Sabah's threatened dipterocarp species. By doing so, these districts can serve as a state conservation hub for restoration and ex-situ collection, while also enhancing genetic preservation across the forest network, ensuring better genetic diversity and resilience.

An integrated strategy combining ex-situ efforts (like establishing seed banks and nurseries for dipterocarp restoration) with in-situ conservation (such as habitat protection and restoration) is essential for sustaining critically endangered species. Additionally, enhancing habitat preservation to prevent deforestation and

expanding protected areas will be key. Establishing wildlife corridors to link forest reserves between Deramakot and Tongod can further strengthen species migration and population stability. This network would not only enhance species sustainability but also align with larger conservation initiatives, such as the Heart of Borneo project, which aims to boost regional biodiversity.

In Tawau, where forest reserves are easily accessible and surrounded by urban development, there is an opportunity to blend conservation with recreational activities. Creating amenity forests for hiking and other activities such in Bukit Gemok Information Centre and Membalua Forest Recreation site, can increase environmental awareness. This initiative would also engage the urban community, generating support for conservation through Payment for Ecosystem Services (PES) schemes, further securing forest protection. Other established nature recreation sites with ecotourism potential include Kun Kun River (Deramakot), Centre of Sabah (Tongod), Tawai Rainforest Camp and Tuaty Gallery - Death March Route (Telupid). These sites offer opportunities to promote both conservation and sustainable tourism.

Finally, involving local communities in Beluran through sustainable activities such as agroforestry will help ensure that conservation efforts are economically viable. These initiatives can generate local economic benefits while fostering strong community support for biodiversity protection.

By positioning Telupid as the core of conservation and linking Beluran, Deramakot, and Tongod into a unified strategy, Sabah can enhance the protection of its threatened species, promote long-term biodiversity conservation, and encourage sustainable development throughout the region.

#### **4. CONCLUSIONS**

This study assesses the spatial distribution of IUCN-listed threatened dipterocarp species within Sabah's forest reserves. By identifying key conservation areas and analysing the relationship between reserve size and species richness, it provides valuable visual guidance for prioritising conservation efforts. The findings emphasise the critical importance of Telupid, Beluran, Deramakot, and Tongod as biodiversity hotspots in Sabah, making them central to conservation strategies. Treating these forest reserves as interconnected ecosystems and focusing on both ex-situ and in situ conservation methods will significantly enhance the protection of endangered species in the region.

#### **ACKNOWLEDGMENTS**

We would like to extend our deepest gratitude to Datuk Frederick Kugan, Chief Conservator of Forests, and Dr. Arthur Chung of the Sabah Forestry Department for their invaluable support. Finally, we wish to acknowledge the dedicated efforts of the field staff and research assistants from the Forest Research Centre Sepilok, whose crucial contributions have been instrumental in the success of dipterocarp conservation initiatives in Sabah.

#### **REFERENCES**

- Ashton P.S. (2004) Dipterocarpaceae. In: Soepadmo, *et al.* (Eds.) Tree Flora of Sabah and Sarawak. Volume 5: 63–388. Forest Research Institute Malaysia, Kuala Lumpur, Sabah Forestry Department, Sandakan and Sarawak Forestry Department, Kuching.
- Khoo, E., Tsen, T. L. S., Lee, Y. L., Sugau, J. B., Pereira, J. T., Nilus, R., & Maycock, C. R. (2022). The Sabah Plant Red List of Dipterocarpaceae. Sabah Forestry Department, Sandakan, Malaysia.
- Meijer, W., & Wood, G. H. S. (1964). Dipterocarps of Sabah (North Borneo). Sabah Forestry Record 5. Forest Department, Sandakan, Malaysia.
- Sabah Forestry Department (2020). Annual report 2020. Sabah Forestry Department, Sandakan. 346 pp. <https://forest.sabah.gov.my/images/pdf/publication/annualreport/ar2020.pdf>