

Mapping the Distribution of Mangrove in Malaysia Using Geographic Information System (GIS)

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Abstract

In Malaysia, mangroves are distributed along sheltered coastlines in the tropics and sub-tropics, and are facing various threats, including deforestation, pollution, and climate change. To make matters worse, there is a scarcity of detailed information on the distribution of mangroves in Malaysia that can cause difficulties in developing effective management and conservation measures to preserve the long-term sustainability of these critical ecosystems. This study aims to review the availability of mangroves in Malaysia and map their distribution using Geographic Information System (GIS) technology. By integrating the usage of GIS and spatial and attribute data that have been gained from Malaysia Biodiversity Information System (MyBIS), Forest Research Institution (FRIM), and other literature reviews, 51 mangrove species from 13 states in Malaysia have been mapped. The study utilizes various GIS tools, such as attribute tables, hotspot analysis, and queries, to analyze spatial patterns of mangrove distribution and inform conservation efforts. The findings contribute to the understanding of mangrove distribution in Malaysia and the development of effective conservation strategies, ultimately supporting the sustainable use and preservation of mangrove ecosystems in this country.

1. Introduction

In Malaysia, mangrove forests are one of the major types of wetland forest where it serves as the key life support systems. Protected coasts, estuaries, rivers and certain near-shore islands are the places where mangrove forests can be found [2]. They serve both, the environment and humans, by stabilising coastal regions, preventing erosion, and acting as a nursery for a variety of fish and other marine creatures. Furthermore, mangrove forests are significant carbon sinks, storing significant amounts of carbon in their biomass and sediments [3]. Besides, due to its extreme condition, it can hold incredibly unique creatures that can adapt to the conditions.

However, mangrove forests are threatened by habitat loss and degradation due to anthropogenic activities such as aquaculture, logging, and coastal development and climatic vulnerability. These threats cause extreme decline in the species diversity index in many areas [1]. Therefore, mapping the distribution of mangroves using Geographical Information Systems (GIS) can be an important tool for understanding the extent and patterns of mangrove cover in the country, as well as identifying the type of species that inhabited the area.

In Malaysia, there is a scarcity of detailed information on the distribution and abundance of mangroves. The latest study on the mapping of mangrove forests in Malaysia was made by Omar and Misman back in 2022 [4].

However the map that has been produced from the study does not have enough information. The study only visualized the cover area of mangroves in Malaysia without any other additional information on the mangroves such as the location, the attribute data and the spatial analysis, which is very crucial in conservation efforts. Because of this knowledge vacuum, developing effective management and conservation measures to preserve the long-term sustainability of these critical ecosystems is difficult.

2. Methods

2.1 Data Collection

This phase focused on the process of data collection for this study. Identifying the types of data needed was crucial. Based on prior research, two types of GIS data were used: spatial and attribute data. The spatial data, stored in raster and vector formats, provided the visual representation of the mangrove distribution map, while the attribute data described its classifications.

Both types of data have been gained from Malaysia Biodiversity Information System (MyBIS), Forest Research Institute Malaysia (FRIM) and literature reviews. Spatial data that has been used for this study were satellite imagery of Malaysia from Google Earth and a map that consists of polygons of mangrove forest in Malaysia from FRIM. Besides, attribute data that has been used in this study also has been gained from MyBIS and also other literature reviews. The attribute data consisted of mangrove information such as scientific name, common name, family, residential status, IUCN Red List status, and Malaysia Plant Red List status. Fig. 1 shows the attribute data of mangroves that are available on the MyBIS website.



Fig. 1 Attribute data from MyBIS websites

2.2 Data Processing

Following the collection of these data sources, data processing was carried out using Quantum Geographical Information System (QGIS), a robust geographic information system programme. In QGIS, there were various steps involved in the data analysis process. First of all is the insertion of spatial data which is the satellite imagery that has been obtained from Google Earth which has been served as the basemap of the distribution mapping and a vector layer of Malaysia mangrove forest in the polygon. After these two data have been correctly georeferenced to match the QGIS spatial reference system as a basemap, the data on the distribution of the mangroves has been added. Fig. 2 until Fig. 4 shows the spatial data that has been added to the QGIS system.



Fig. 2 Satellite imagery of Malaysia

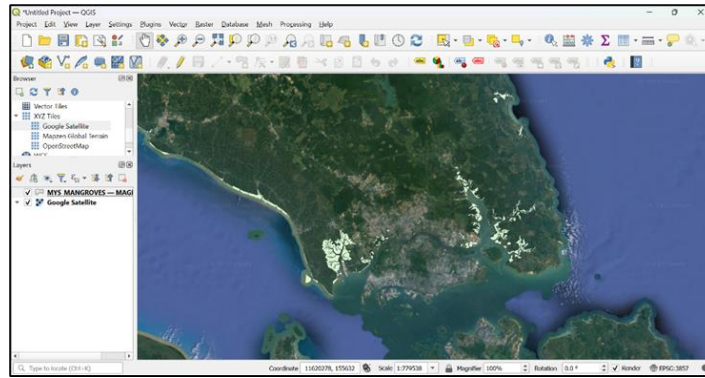


Fig. 3 Polygon of mangrove area in Johore

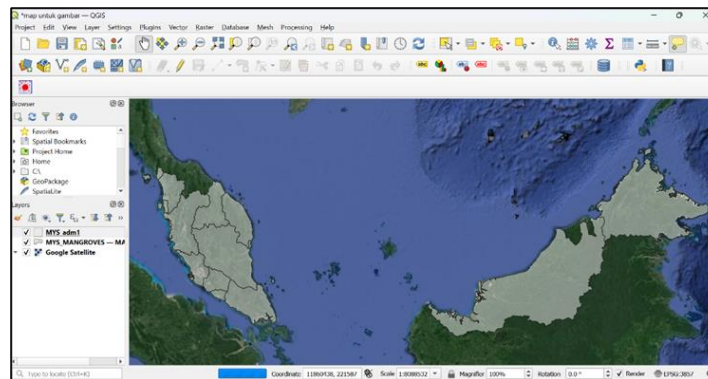


Fig. 4 The polygon of Malaysia

2.2.1 Attribute Data

The attribute data used for map development consisted of mangrove information such as scientific name, common name, family, residential status, IUCN Red List status, and Malaysia Plant Red List status where all of the data has been gained from MyBIS websites.

Table 1 Attribute data of mangroves available on the MyBIS website

Scientific Name	Common Name	Family	Residential	IUCN Red List	Malaysia Plant Red List	State
<i>Acanthus ebracteatus</i>	Sea Holly	Acanthaceae	Native	LC	NE	Johore Kedah Pahang
<i>Acanthus ilicifolius</i>	Holy Mangrove		Native	LC	NE	Johore Kedah Pahang Penang Perak Perlis
<i>Avicennia marina</i>	Api-api Jambu		Native	LC	NE	Johore Kedah Pahang Penang Sabah
<i>Avicennia officinalis</i>	Api-api Ludat		Native	LC	NE	Johore Kedah Penang Perak Terengganu

NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, EN = Endangered, CR = Critically Endangered

Table 1 (continued)

<i>Calamus erinaceus</i>	Rotan	Arecaceae	Native		NE	Johore N. Sembilan
<i>Licuala spinosa</i>	Mangrove Fan Palm		Native		NE	Johore Pahang Selangor
<i>Nypa fruticans</i>	Nipah		Native	LC	NE	Johore Kedah Penang Sabah Sarawak Selangor Terengganu
<i>Phoenix paludosa</i>	Mangrove Date Palm		Native	NT	NE	Kedah Pahang Sarawak Terengganu
<i>Dolichandrone spathacea</i>	Tui	Bignoniaceae	Native	LC	NE	Johore Kedah Pahang Terengganu
<i>Lumnitzera littorea</i>	Teruntum Merah	Combretaceae	Native	LC	NE	Johore Kedah Pahang Terengganu
<i>Excoecaria agallocha</i>	Bebuta	Euphorbiaceae	Native	LC	NE	Johore Pahang Penang Perak Sabah Sarawak Terengganu
<i>Dalbergia candenatensis</i>	Firefly Mangrove Tree	Fabaceae	Native	LC	NE	Johore Kedah Pahang Terengganu
<i>Barringtonia acutangula</i>	Putat	Lecythidaceae	Native	LC	LC	Johore Kedah Kelantan Malacca Pahang Penang Perak Perlis Selangor Terengganu
<i>Barringtonia racemosa</i>	Putal Kedul		Native	LC	LC	Johore Kedah Pahang Selangor Sarawak
<i>Intsia bijuga</i>	Merbau Ipil	Leguminosae	Native	NT	NE	Sarawak
<i>Lagerstroemia calyculata</i>		Lythraceae	Native			Perlis
<i>Lagerstroemia floribunda</i>	Crepe Myrtle		Native		NE	Selangor
<i>Lagerstroemia langkawiensis</i>	Bungor Langkawi		Native	EN	NE	Selangor
<i>Lagerstroemia pustulata</i>	Perlimpong Hutan		Native	DD		Sabah

NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, EN = Endangered, CR = Critically Endangered

Table 1 (continued)

<i>Lagerstroemia speciosa</i>	Bongor Biru		Native	LC	NE	Pahang Selangor
<i>Pemphis acidula</i>	Mentigi		Native	LC	NE	Johore Pahang
<i>Rotala wallichii</i>			Native		NE	Selangor
<i>Sonneratia alba</i>	Perepat		Native	LC	NE	Johore Kedah Pahang Penang Perak Sabah Terengganu
<i>Sonneratia caseolaris</i>	Berembang		Native	LC	NE	Johore Kedah Selangor
<i>Sonneratia griffithii</i>	Griffith's Mangrove Apple		Native	CR	NE	Johore
<i>Sonneratia ovata</i>	Gedabu		Native	NT	NE	Johore Kedah Pahang Terengganu
<i>Heritiera littoralis</i>	Dungun	Malvaceae	Native	LC	NE	Johore Kedah Pahang Sabah Selangor Terengganu
<i>Thespesia populnea</i>	Bebaru		Native	LC	NE	Sarawak
<i>Xylocarpus granatum</i>	Nyireh Bunga	Meliaceae	Native	LC	LC	Johore Kedah Malacca N. Sembilan Pahang Perak Sabah Sarawak Selangor Terengganu
<i>Xylocarpus moluccensis</i>	Nyireh Batu		Native	LC	NT	Johore Kedah N. Sembilan Pahang Perak Sarawak Selangor Terengganu
<i>Xylocarpus rumphii</i>	Rumphius' Mangrove Apple		Native		LC	Johore Kedah N. Sembilan Pahang Penang Perak Terengganu
<i>Acrostichum speciosum</i>	Kacahang	Primulaceae	Native	LC	NE	Sarawak
<i>Aegiceras corniculatum</i>	Black Mangrove		Native	NT	NE	Johore Kedah Pahang Terengganu

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Table 1 (continued)

<i>Bruguiera cylindrica</i>	Berus	Rhizophoraceae	Native	LC	NE	Johore Kedah Penang Perak Terengganu
<i>Bruguiera gymnorhiza</i>	Tumu		Native	LC	NE	Johore Kedah Pahang Terengganu
<i>Bruguiera gymnorhiza</i>	Tumu Merah		Native	LC	NE	Johore Kedah Pahang Penang Sabah
<i>Bruguiera hainesii</i>	Berus Mata Buaya		Native	CR	NE	Johore Sabah Terengganu
<i>Bruguiera parviflora</i>	Lenggadai		Native	LC	NE	Johore Kedah Penang Perak
<i>Bruguiera sexangula</i>	Tumu Putih		Native	LC	NE	Johore Kedah Terengganu
<i>Carallia brachiata</i>	Meransi		Native		NE	Kedah Kelantan N. Sembilan Pahang Selangor Terengganu
<i>Carallia eugenioidea</i>	Sea Takok		Native			Kedah
<i>Ceriops decandra</i>	Tengar		Native	NT	LC	Johore
<i>Ceriops tagal</i>	Tengar Samak		Native	LC	NE	Johore Kedah N. Sembilan Terengganu
<i>Ceriops zippeliana</i>	Lalang Bakau		Native	LC	LC	Johore Kedah N. Sembilan Sabah Terengganu
<i>Gynotroches axillaris</i>	Mata Keli		Native	LC	NE	Kedah Kelantan Pahang Terengganu
<i>Kandelia candel</i>	Berus-berus		Native	LC	NE	Johore
<i>Pellacalyx axillaris</i>	Membuloh Bulu		Native		NE	Pahang Terengganu
<i>Pellacalyx saccardianus</i>	Membuluh		Native	LC	NE	Kedah Kelantan Pahang Selangor Terengganu

NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, EN = Endangered, CR = Critically Endangered

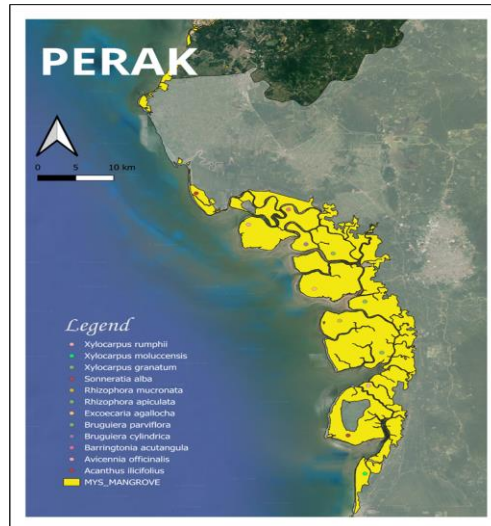


Fig.6 The distribution of mangroves in Perak

3.2 Attribute Data

In this study, GIS data has been divided into two general parts: attribute data and spatial data. The attributes consist of information related to spatial features, including scientific name, common name, residence, IUCN Red List, Malaysia Red Plant List, coordinates, and location by state. In contrast, spatial data provides a visual representation of geographic space, stored as raster and vector types that are related to the geometries of spatial features. This information takes advantage of the QGIS software, where all the details related to mangroves can be presented in a more organized manner within a table. Fig. 7 illustrates an example of attribute data by layer.

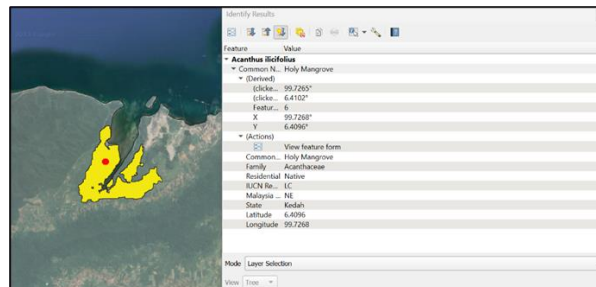


Fig. 7 Attribute data for *Acanthus ilicifolius* in Kedah

3.3 Spatial Analysis

This analysis aids researchers in comprehending spatial distribution, proximity analysis, and even terrain analysis. The limited availability of detailed mangrove maps and data hinders the comprehensive assessment of mangrove distribution, which is essential for effective conservation and management of these critical ecosystems [5]. Therefore, efforts to improve data collection, and mapping at a broader scale are crucial to enhance the application of spatial analysis tools [11]. Two examples of spatial analysis that can be conducted from this mapping are query and hotspot analysis.

3.3.1 Query

Intersection query is a typical form of query that focuses on detecting characteristics that intersect or overlap with a specific geographic region or feature [6]. This tool can be used in a situation where a researcher uses the intersection queries to extract information about the features that fall within a particular area, in this study is identifying the states in Malaysia that have same species of mangroves. Fig. 8 shows the intersection query between the states in Malaysia and *Sonneratia alba*.



Fig. 8 The intersection query of Malaysia and *Sonneratia alba*

From the figure, it can be concluded that *Sonneratia alba* can be found in Johore, Kedah, Kelantan, Pahang, Perak and Sabah. Besides, study on the factors that influencing the distribution of *Sonneratia alba* can also be done in the future by referring to this query. In the conservation context, this type of analysis can provide valuable information such as identification of areas where different features overlap. It can yield essential information for conservation and management efforts. Utilizing GIS, this analysis can reveal crucial insights into species coexistence, habitat suitability, biodiversity hotspots, ecosystem resilience, and management prioritization. These findings are vital for comprehending the biodiversity and ecological dynamics of mangrove ecosystems, evaluating habitat suitability for various species, identifying areas of concern for conservation efforts, and prioritizing conservation and management efforts based on unique species compositions or high species richness.

3.3.2 Hotspot Analysis

Hotspot analysis is a spatial analysis technique that uses vectors to identify locations of statistically significant hot spots and cold spots in the data by aggregating points of high or low values [7]. This tool can provide valuable insights into the distribution of mangroves in Malaysia. Fig. 9 shows the map of hotspot analysis of mangroves in Malaysia.

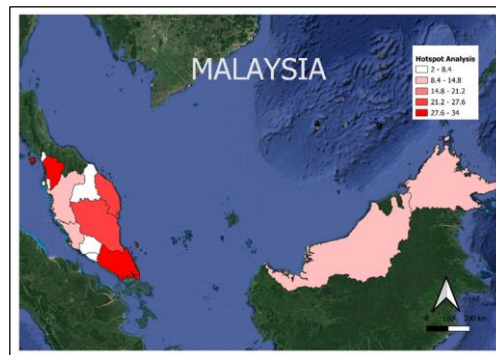


Fig. 9 Hotspot analysis of mangroves distribution in Malaysia

From the map, it can be concluded that Johore has the highest number of mangroves which is around 27 to 34 species while Kelantan, Malacca, Negeri Sembilan, Penang, and Perlis have the lowest number of mangroves which is around 2 to 8 species. Johore has recorded the highest number of mangroves species in Peninsular Malaysia due to the fact that Johore has the highest number of mangroves forest in Peninsular Malaysia. The Pulau Kukup mangrove forest in Johor is the largest uninhabited mangrove forest in the world and has been designated as a national park and a Ramsar site [8][9]. Similar study has been made by Corlett on mapping and monitoring of mangrove forest changes in Peninsular Malaysia used remote sensing and GIS to identify areas with high mangrove cover and targeted these areas for conservation and management [10].

This valuable information can be used in various conservation and management actions. For the area with the highest mangrove concentration, it is important to prioritize conservation efforts, such as the establishment of protected areas, sustainable management practices, and monitoring programs to safeguard the biodiversity and ecological functions of these significant habitats. Additionally, the high-concentration areas can be targeted for scientific research to better understand the factors contributing to their richness and to inform conservation strategies.

On the other hand, the areas with the lowest mangrove concentrations should be the focus of restoration and reforestation initiatives, as well as measures to address the factors leading to their decline, such as habitat degradation, human activities, and climate change. The results can also guide policy-making and resource allocation to support the sustainable use and protection of mangroves in these areas.

4. Conclusion

In conclusion, the use of GIS for mapping the distribution of mangroves in Malaysia provides a wealth of information beyond merely locating the species. From the result, 51 species from 13 states in Malaysia have been mapped. The mapping allows different types of spatial analysis to be done. For instance, the state that has the highest number of mangroves, which is Johore, has been identified from the hotspot analysis. Additionally, the intersection query of mangrove species, for example, *Sonnerati alba*, has been conducted and identified. These findings highlight the importance of prioritizing conservation efforts, such as the establishment of protected areas, sustainable management practices, and monitoring programs, in high-concentration areas of a species to safeguard the biodiversity and ecological functions of these significant habitats.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design, data collection, methodology, analysis and interpretation of results:** Noor Azlin Harun, Nazirah Mohamad Abdullah, Nurul Hazirah, Nurmasitah Amran and Nur Hidayah Nasir. All authors reviewed the results and approved the final version of the manuscript.

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