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Mapping the distribution of the in Nepenthes Malaysia using Geographical Information System (GIS)

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Nepenthes, distribution, mapping, Geographic Information System (GIS), QGIS, spatial analysis, biodiversity, Malaysia.

Abstract

This research study aims to investigate the distribution of Nepenthes species in Malaysia using Geographic Information Systems (GIS) technology. The study focuses on the species across the country and utilizes open-source software, QGIS, for mapping and spatial analysis. This study being conducted due to the lack of information of distribution on Nepenthes species in Malaysia, and there is a need to review and map their availability using Geographic Information Systems (GIS) where it achieves the objective of this study. The objectives are reviewing the availability of the different species of Nepenthes in Malaysia and map the distribution of Nepenthes of different species. The species of the Nepenthes that being recorded in this study is 26 species. Method that being used is by gained the secondary data of the distribution of the Nepenthes from the literature review and Malaysia Biodiversity Information System (MyBis). Then the analysis and mapping of the species being run using the QGIS software. As for the result, comprehensive map of the distribution of nepenthes species in Malaysia being created. As for the recommendation for future studies on the Nepenthes species in Malaysia should consider obtaining more detailed and accurate data on their distribution. This can be achieved by conducting field surveys and collecting data on the locations of Nepenthes species, which can then be used to create more comprehensive maps using GIS technology.

1. Introduction

Nepenthes, also known as tropical pitcher plants, are a captivating genus of carnivorous plants with a wide ecological distribution. They are found in diverse environments such as high humidity, dense and shaded forests, clear-cut forests, roadsides, and disturbed fields [1]. This genus is primarily distributed across the Malay Archipelago, including Borneo, Sumatra, Peninsular Malaysia, and the Philippines. Nepenthes are renowned for their unique nutritional interaction, as they have adapted to nutrient-poor soils and have evolved to attract, trap, and digest prey using their characteristic pitcher [2].

Actually, Indonesia and Malaysia both have a high number of Nepenthes species. However, Indonesia holds the highest number of species, with 139 species recorded to date [3]. Among these, 68 species inhabit various islands of Indonesia, with 34 species in Sumatra, 22 in Kalimantan, 3 in Java, 11 in Sulawesi, 3 in Maluku, and 11 in Papua [1][3]. This makes Indonesia one of the countries with the greatest diversity of Nepenthes in the world. In contrast, Malaysia has over 40 species recorded [1] and this species primarily found in both lowland and

highland forests [4]. These species can also be observed in disturbed areas such as roadsides and abandoned mining sites [4]. Right now in Malaysia there are lack of distribution information on Nepenthes species and this research study aim to overcome it by reviewing it species availability in Malaysia and try to make a map of it availability and distribution using geographical information system (GIS).

A Geographic Information System (GIS) is an expansive system comprising computer software, personnel, data, and hardware, designed to facilitate the manipulation, examination, and visualization of data and information linked to specific geographical locations on the Earth's surface. The definition of GIS may vary depending on the perspective or disciplinary background. Some definitions focus on its association with maps, while others highlight the database or software toolkit, and some emphasize its applications in decision support. To truly understand and effectively utilize GIS, it is important to examine both its functions and components. In the context of this research study, GIS is utilized as a tool to map the distribution of Nepenthes in Malaysia, utilizing computer technology to analyze and depict the geographical spread of these plants [5]. GIS software can perform similar functions, such as mapping, analyzing, and sharing geospatial data, there are significant differences between proprietary and open-source GIS software. Proprietary GIS software, like ArcGIS, requires licensing fees and is often more expensive than open-source alternatives. On the other hand, open-source GIS software, such as QGIS and GRASS GIS, is free to use and does not require any licensing fees [6]. However, open- source GIS software may still have costs associated with training, implementation, and development time to customize the solution. By using GIS, the lack of doesn't have an up-to-date mapping of the Nepenthes species in Malaysia could be defeat by making the latest and complete information about the availability and distribution of Nepenthes in Malaysia.

2. Methods

2.1 Flowchart of the research

The flow chart illustrated the rough flow of conducting this research, beginning with the collection of data. The data was acquired from a secondary source, comprising pre-existing information. Malaysia Biodiversity Information System (MyBIS) served as the secondary data source. Subsequently, the data was utilized to generate a map illustrating the distribution of *Nepenthes*, employing the QGIS software. Finally, the complete distribution map of *Nepenthes* in Malaysia was created.

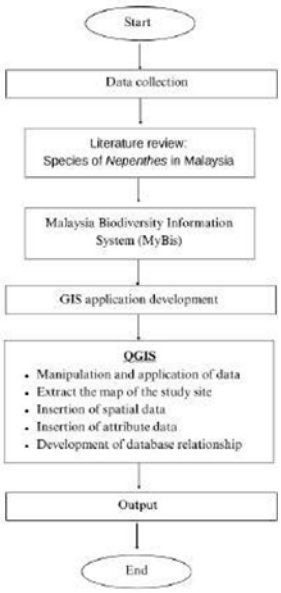

Fig. 1 *Flowchart of the procedure*

2.2 Study Site

A broad range of *Nepenthes* species, notably rare and endemic pitcher plants, were present in Malaysia, which was well renowned for its rich biodiversity. It was crucial to remember that Malaysia was geographically split into Peninsular Malaysia and Malaysian Borneo (Sabah and Sarawak), each of which supported a unique *Nepenthes* species.

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Fig. 2 *Map of Malaysia*

2.3 Data collection

This stage concentrated on gathering data for the research, with a key emphasis on determining the necessary data types. Based on the studies, two categories of GIS data were employed: spatial data and attribute data. The spatial data, available in raster and vector formats, served to visually depict the distribution of mangroves on the map, while the attribute data provided details on their classifications.

Both types of data have been gained from Malaysia Biodiversity Information System (MyBIS) and literature reviews. Spatial data that has been used for this study were satellite imagery of Malaysia from Google Earth. 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 Nepenthes information such as scientific name, common name, family, residential status, IUCN Red List status, and Malaysia Plant Red List status.

2.4 Data analysis

Once the secondary data sources were gained, the next step was to analyze the data using QGIS, a comprehensive geographic information system program. Several steps were involved in the data analysis process in QGIS: established BIDARA database to promote further research advancements and moving towards modernization by digitizing physical specimen, thus safeguarding the specimen with data. These effort promotes further research advancement and commitment to nationhood and community.

1. Data Import
   Begin by inserting layer the map of Malaysia into the QGIS. It was checked that the map wasgeoreferenced correctly to align with the spatial reference system used by QGIS.

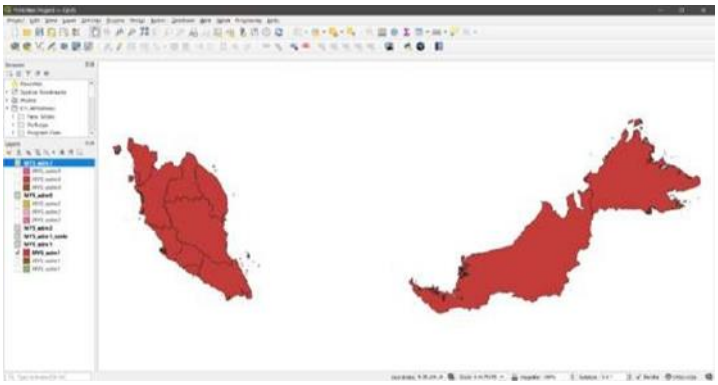

Fig. 3 *Insertion of Malaysia map into QGIS*

2 Secondary Data Integration
Next, the data collected from MyBIS was imported into QGIS. This information could include Nepenthes distribution, species diversity, and other important properties. It was checked that the secondary data was in a compatible format, such as CSV or shapefile, and that it had geographic coordinates or a unique identifier that could be linked to the source data.

Table 1 *Table data on species and location of Nepenthes in Peninsular Malaysia*

Species	Localities
Nepenthes alba	Malaysia, Pahang, Gunung Tahan. Muhammad Ikhwanuddin M.E. MDI 12346, 8February 2019 (MDI)
N. albomarginata	Malaysia, Kedah, Gunung Jerai FR, Compartment 20-23. Kamarul Hisham, M., Noorsiha, A. & Kueh, H.L Malaysia, Pulau Pinang, Bukit Bendera, Mohd Norfaizal, G., MDI 12337, 16 December 2018 (MDI)
N. ampullaria	Malaysia, Johor, Gunung Ledang. Ruth Kiew Malaysia, Johor, Mersing. Rohana M.S Malaysia, Terengganu, Sungai Tong. MDI 12341, Mohd. Norfaizal, G. Amin Asyraf, T., Dome, N. 31 January 2019 (MDI). Malaysia, Selangor, Sungai Karang FR, Tanjung Karang.
N. benstonei	Malaysia, Kelantan, Machang, Bukit Bakar. FRI 53169. Yao, T.L. Duistermart, H. Kiew, R. Kueh, H.L Malaysia, Kelantan, Machang, Bukit Bakar Summit. MDI 12333. Mohd Norfaizal, G. & Salmaniza, S. 5 March 2019 (MDI) Malaysia, Terengganu, Gunung Tebu. FRI 13147. Mohd Shah, Ahmad Shukor, Mahmud Awang.
N. gracilis	Malaysia, Pahang, Temerloh, Tasik Bera. FRI52720. Rafidah, A.R., Mohd. Nazri, A., Kueh, H.L Malaysia, Bangi, UKM Bangi. MDI 12336. Mohd. Norfaizal, G. & Amin Asyraf, T. 15 December 2018. (MDI) Malaysia, Kedah, Pulau Langkawi, FRI63422. Beentje, H.J., Rosdi, M., Angan.
N. macfarlanei	Malaysia, Pahang, Bentong, Gunung Ulu Kali. FRI 52572. Nor Ezzawanis, A.T. Malaysia, Pahang, Summit Ridge of Gunung Ulu Kali to Gunung Rajah. Lilian Chua.FRI 40516. Malaysia, Pahang, Pathway to Telekom Telecommunication Tower, Genting Highlands. MDI 12331. Mohd Norfaizal, G. & Amin Asyraf, T. 9 December 2018. (MDI).
N. mirabilis	Malaysia, Selangor, Hulu Selangor, Bukit Tunggal FR. FRI 73129. Chew, M.Y., Mohd Hairul, M.A. & Mohd Afiq, K. Malaysia, Selangor, Puncak Alam. MDI 12416. Mohd Norfaizal, G. Anuar Rasyidi, M.N., Ahmad Syahman, M.D.& Muhammad Syakir. 30 December 2018. (MDI)
N. ramispina	Malaysia, Selangor, Gunung Bunga Buah. FRI65498. Yao, T.L. Kiew, R. & Jun, W. Malaysia, Pahang, Pathway to Telekom

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N. sanguinea	Telecommunication Tower, Genting Highlands. MDI 12332. Mohd Norfaizal, G. & Amin Asyraf, T. 9 December 2018. (MDI). Malaysia, Terengganu, Hulu Terengganu, Gunung Padang. FRI70887. Mohd Hairul, M.A., Imin, K., Rafidah, A.R. Ummul Nazrah, A.R. Kueh, H.L. Malaysia, Selangor, Gunung Ulu Semangkok. MDI 12418. Mohd Norfaizal, G. Anuar Rasyidi, M.N., Ahmad Syahman, M.D.& Muhammad Syakir. Malaysia, Perak, Gunung Hijau summit plateau, FRI 40475. 6 September 1994.
N. rafflesiana	Malaysia, Johor, Kluang, Kluang FR, Gunung Belumut. FRI60328. Chew, M.Y. & Teo, Y.L. 10 August 2009. (FRI) Malaysia, Johor, Gunung Ledang, FRI33511. Lilian Chua. -Malaysia, Ayer Hitam Utara, Johor -Malaysia, HS Panti, Johor
N. latiffiana *N. domei* *N. malayensis*	Malaysia, Terengganu, Gunung Sarut, Setiu (MDI) Malaysia, Terengganu, Gunung Sarut, Setiu (MDI) Malaysia, Terengganu, Gunung Sarut, Setiu (MDI)

3 Data Join and Attribute Management

To merge main and secondary data based on a common attribute or geographical location, a data join or spatial join process was used. This connected the data attribute information to the appropriate locationson the original data (map of Malaysia).

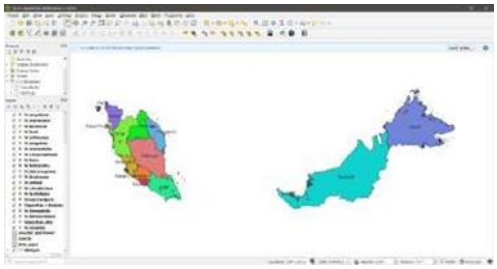

Fig. 3 *Insertion of Malaysia map into QGIS*

4 Symbolization and Styling

To visualize the distribution of Nepenthes on a map, appropriate symbolization and style techniques were used in QGIS. Different colours or symbols were assigned to indicate different Nepenthes speciesor density levels. The data source's attribute data was used to categorize and symbolize the Nepenthes distribution, including information about species name, common name and others

5 Spatial Analysis

To merge main and secondary data based on a common attribute or geographical location, a data join or spatial join process was used. This connected the data attribute information to the appropriate locationson the original data (map of Malaysia).

6 Map Layout Design

In QGIS, an aesthetically beautiful and informative map layout was created. The legend, scale bar, north arrow, and any additional features required were arranged. Labels or annotations were used to emphasize essential features or discoveries from the data analysis.

7 Map Output

After completing the data analysis and map layout creation, the completed map was exported as an image file or printed straight from QGIS. This map illustrated the distribution of Nepenthes in Malaysia by inserting the data received from MyBIS into the map of Malaysia.

3. Result and Discussion

3.1 distribution of Nepenthes in Malaysia

The end result of this research is the map of distribution of the Nepenthes in Malaysia. The map layout will display the output from the mapping using QGIS software that being show in the Fig. 4.

From the Fig. 4 the legend on the left shows the Nepenthes species that gain from the data collection, each species represented by a different colour point on the map. Ecologists and biologists generally use this type of map to study the range and habitat preferences of various species. Such maps can aid conservation efforts by showing places where specific species are prominent, as well as in understanding how species distributions may overlap or where unique species are situated [7].

According to the Fig. 4, the diversity of Nepenthes species in Malaysia is quite high, with various species distributed across the mainland and the Borneo region, including the states of Sabah and Sarawak. This region's diversity is unsurprising because Borneo and the Malay Peninsula are known biodiversity hotspots, particularly for endemic species like Nepenthes as stated by [7].

From this study their ecological preference also being found where, Different Nepenthes species in Malaysia have distinct ecological preferences, which contribute to their distribution patterns. For example Four Nepenthes species in Peninsular Malaysia are restricted to montane habitats, such as N. macfarlanei, N. gracillima, N. sanguinea, and N. ramispina. Some Nepenthes species, like N. mirabilis, are found primarily in lowland areas and Nepenthes species like N. ampullaria and N. rafflesiana are found in exposed habitats like roadside and forest edges [8].

The distribution of Nepenthes in Malaysia is relatively poor compared to other tropical countries. In Peninsular Malaysia, there are only 11 species of Nepenthes presently recognized, while in Borneo, there are 36 species, representing the greatest diversity of Nepenthes species in Southeast Asia [8]. The Nepenthes flora in Peninsular Malaysia is also less diverse than that of Malaysian and Bruneian Borneo, which has relatively few modern records [8]. In comparison, the Nepenthes flora in the Philippines, Sumatra, and Java is more diverse, with a higher number of species present [10].

Conservationists could use this information to protect areas with high species diversity, while researchers could study the ecological needs of each species and their evolutionary relationships. According to [10], Nepenthes is frequently discovered in nutrient-poor environments, they are valuable to scientists studying plant adaptations to difficult habitats.

Fig. 4 *Map distribution of the Nepenthes in Malaysia*

3.2 Attribute data

The two main categories of GIS data used in this study are attribute data and spatial data. The attribute comprises of a species description and spatial feature location characterization. On the other hand, spatial data stored as raster and vector types connected to the geometries of spatial features give visual representation of geographic

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space. The benefits of QGIS software include the ability to display all information relating to the nepenthes species in a more organized manner in a table. Fig. 5 shows the example of attribute table.

The attribute data in this study provided valuable insights into the distribution and ecology of these unique plant species. The attribute data included information on the species name, taxonomy, common name, IUCN status, and location of Nepenthes in Malaysia. It also helped in conducting spatial analysis to visualize the distribution of Nepenthes species. The spatial analysis involved doing spatial searches, recognizing hotspot locations, and conducting statistical research to better understand the spatial features of Nepenthes in Malaysia that could be done in the future research.

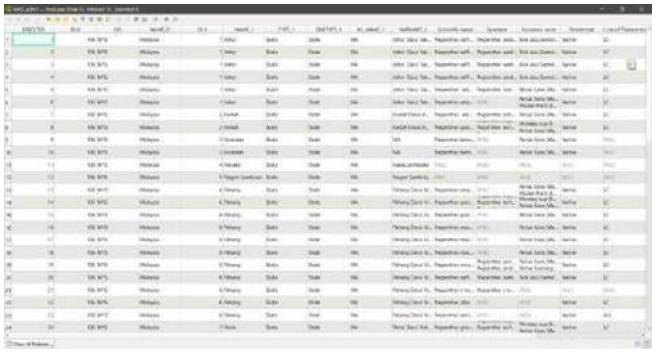

Fig 5 *Attribute table of the Nepenthes species*

3.3 Data analysis

Spatial analysis in QGIS is being used in data analysis. It entails doing spatial searches, recognising hotspot locations, estimating density, and conducting statistical research in order to better understand the spatial features of *Nepenthes* in Malaysia.

3.4 Map distribution of *Nepenthes* in Sabah, Malaysia

Fig. 6 show an illustration about the spread of various *Nepenthes* species across the Sabah which one of the state in Malaysia. This map is one of the example when, the map in Fig. 6 being zoom in into the selected region. This type of map does not have many different from the distribution map of *Nepenthes* in Malaysia, but this map is more focuses on the selected location such as state (Sabah) like in the map. According to the map legend, it only show the *Nepenthes* species that can be found in Sabah not like the previous map that show all the list of the Nepenthes species in Malaysia. Where it want to show that QGIS also can show the information of the distribution species on the selected location.

The distribution of Nepenthes in Sabah, Malaysia, is significant where most of it display high degrees of endemism and are often restricted to single areas. For instance, some species can only be found in specific locations such as Mount Kinabalu and the neighboring Mount Tambuyukon [12]. From the Fig. 6 the single area that can be found many different species of *Nepenthes* in single area around the Mount Trusmadi.

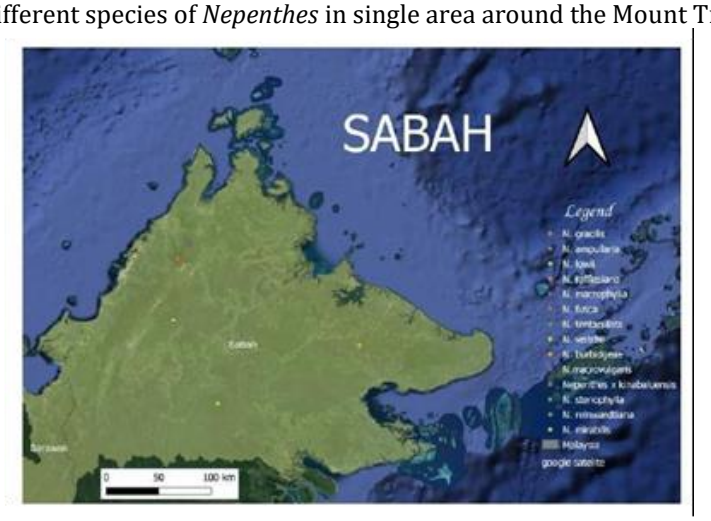

Fig. 6 *Map distribution of Nepenthes in Sabah, Malaysia*

3.5 Map hotspot location of Nepenthes in Malaysia

According to [14], biodiversity hotspots are regions that are exceptionally abundant in various species, including those that are rare or facing threats of extinction, or often a mix of such biological attributes. In term of this study hotspot means that the area that have various species of nepenthes from all level of status IUCN Red List of Threatened Species. Using hotspot analysis in QGIS software the area that have the highest number of difference species of the nepenthes can easily being recognized. Fig 7 show that the area that being classifies as hotspot area of Nepenthes is Sabah, where from the legend it the map show that the number of species can be count in Sabah is between 12-15. Based on the data from the data collection, Sabah have the highest number of Nepenthes species which are 14 species, so it prove that the hotspot analysis in QGIS create an analysis help in observe the distribution of the Nepenthes.

The high number of Nepenthes species in Sabah, Malaysia, can be related to its location on the island of Borneo, which is known for its rich biodiversity and as a center of diversity for Nepenthes. Borneo, shared by Indonesia, Malaysia, and Brunei, is home to a significant number of Nepenthes species, with the greatest biodiversity found on the island. The volcanic soils in the region, resulting from the presence of numerous active volcanoes, provide an environment suitable for the growth of Nepenthes [13][14]. These plants are known to thrive in poor nutrient soils, such as acidic and low-nutrient volcanic soils, which are prevalent in areas with volcanic activity [15]. The ando soils, developed on andesitic volcanic sediments, are among the most fertile soils in the country and are found in the northeastern coast of Sumatra, contributing to the favorable habitat for Nepenthes [16][17]. The unique environmental conditions, including the presence of volcanic soils, high humidity, and precipitation, have likely contributed to the high diversity of Nepenthes species in Sabah and the broader Borneo region [14]. Therefore, the proximity to Indonesia, with its volcanic soils and high number of Nepenthes species, may have influenced the favorable habitat for these carnivorous plants in Sabah, Malaysia.

Furthermore, the map might help to direct research and conservation goals by showing areas where field studies and protective actions may be most advantageous. It also has implications for ecotourism, as regions rich in Nepenthes species are appealing to nature enthusiasts and can give economic advantages to local people if managed sustainably.

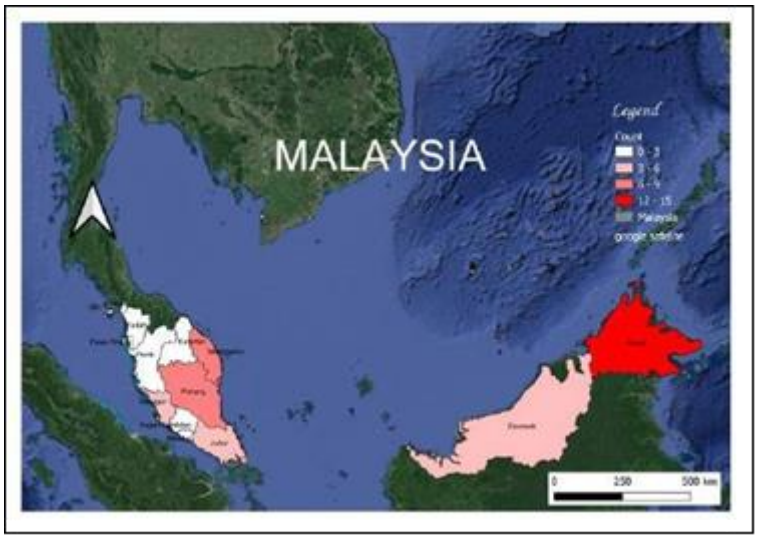

Fig. 7 *Map hotspot location of Nepenthes in Malaysia*

3.6 Spatial query

A spatial query is a sort of database query that can be used in geographical information systems (GIS) to retrieve data based on the spatial relationship between distinct data points. Spatial queries, for example, can be used to find all items within a certain distance of a point, all objects that cross or touch a specific area, or all objects included within a specific zone. These queries are crucial in GIS analysis because they allow for the manipulation and analysis of geographical data in order to discover patterns, trends, and correlations in a spatial context [18]. In this study query being made from the intersect between the map of Malaysia and the species that being choose. Where the selected feature from is the map of Malaysia and by comparing the features from is the species that being chosen. As example in Fig. 8 Nepenthes rafflesiana being the species that being chosen and Fig. 9 show the result of the query analysis.

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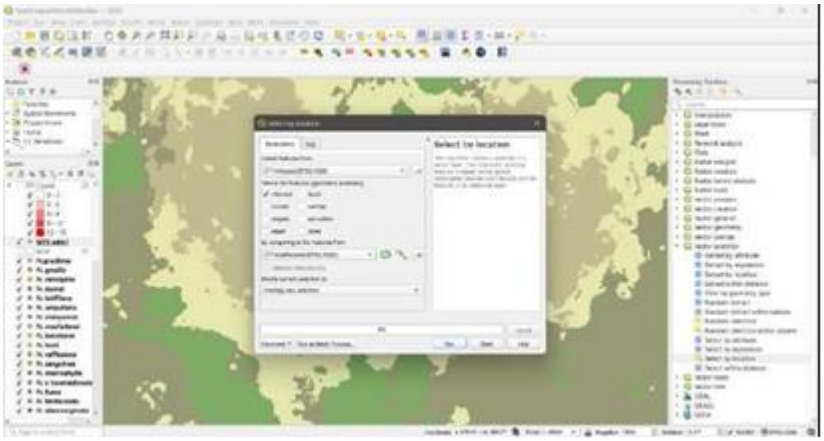

Fig. 8 *Query intersect between map of Malaysia and Nepenthes rafflesiana*

Fig. 9 *Map result from the query*

4. Conclusion

In conclusion this study highlighted about the technology that can be used in Geographical Information System (GIS) to create and access information related to *Nepenthes* distribution in Malaysia using an open source software QGIS. From the result and analysis this study it proved the objective of this study that want to map the distribution of *Nepenthes* of different species and review it availability in Malaysia.

There is limitation in this study, the limitation is lack of comprehensive information on Nepenthes species in Malaysia, as the data obtained from MyBIS only provides information on the number of species, their names, and the states in which they are found, without details about their locations. This limitation may result inan incomplete understanding of the distribution of Nepenthes species in Malaysia. Furthermore, the study relies on the availability and accuracy of the data obtained from MyBIS, which may be subject to errors or inconsistencies in the information provided.

Despite the limitation, the study provides valuable insights into the distribution of Nepenthes species in Malaysia and demonstrates the potential of using GIS and spatial queries to enhance our understanding of these unique plant species. The maps created using QGIS can serve as a foundation for further research and conservation efforts, and the study's focus on the species found in Malaysia highlights the need for increased protection and conservation efforts in this region.

Based on the limitation mentioned in the previous paragraph, it is recommended that future studies on Nepenthes species in Malaysia should consider obtaining more detailed and accurate data on their distribution. This can be achieved by conducting field surveys and collecting data on the locations of Nepenthes species, which can then be used to create more comprehensive maps using GIS technology. As a result this study capable in helping on the conservation effort of the Nepenthes species. Not only that it also help in preserve our natural heritage.

Acknowledgement

We would like to acknowledge the invaluable support and assistance received from the staff and researchers at MyBIS for their dedication in compiling and sharing the essential secondary data crucial to our research. Additionally, our gratitude extends to the academic community at Universiti Tun Hussein Onn Malaysia (UTHM) for their continuous encouragement and guidance throughout this research endeavor. Special thanks are also extended to the all people that contributed to the success of this study, whether directly or indirectly.

Conflict of Interest

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

Author Contribution

The author confirms sole responsibility for the following: ***study conception and design***, ***data collection***, ***analysis*** *and* ***interpretation of results***, *and* ***manuscript preparation***.

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