Distribution of Mangroves in Kedah, Malaysia: A Remote Sensing and Ground-Truth Based Assessment

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Abstract. Mangroves are acknowledged for its ability in attenuating waves. The 2004 tsunami evidenced that mangroves shielded area encountered minimal damages compared to the unprotected coastlines. However, the status of mangroves nowadays is declining at an alarming rate due to natural disaster threats and anthropogenic factors. This study hereby aims to assess the distribution and species of mangroves in Kedah. Landsat-8 OLI images were utilized for mangroves distribution and species mapping by using GIS software. A number of 43 points were surveyed during ground-truthing in order to verify the mapping produced. The maps revealed that mangroves are abundantly grow in estuaries of Merbok - Kuala Kedah, and Langkawi. Five species from two families of mangroves were found which are including Rhizophora Apiculata, Avicennia Marina, Rhizophora Mucronata, Avicennia Officianalis, and Avicennia Alba, in order of dominance. Current mangroves cover age should be conserved and protected from any threats and human activities since a loss of approximately 2308 hectares of mangroves were observed compared to the status in 2012.

1. Introduction
Mangroves offer important ecosystem services and functions that benefited the surrounding communities. They serve as a natural protection barrier against the erosive wave, strong coastal wind, tsunamis, torrential storms and other natural disaster. Attributed with above-ground root structures, network of trunk and branches [1] give these mangroves trees the ability to attenuate incoming waves. The intricate root system creates drag force and act as shock absorber in reducing the wave and hydraulic forces.

Indian Ocean Tsunami (IOT) 2004 that claimed thousands of lives and left great damages has emphasized the role of mangroves in acting as the first line coastal protection. The natural protection from the dense and healthy mangroves along the coastline [2, 3] has slowed down the tsunami strikes and safeguard the coastline [4]. However, the status of mangroves nowadays is of great concern due to numerous anthropogenic factors and natural disaster threats. Subsequent to that, hectares of mangroves have been planted as an initiative to rectify the degraded area.

The application of remote sensing and Geographical Information System (GIS) has been widely utilized nowadays especially in mapping the current mangroves areas and monitoring the conditions and changes of the mangroves over certain period [5, 6, 7, 8, 9, 10]. The remote sensing technology enables
the acquisition of information over large area from distance instead of conducting on-site observation. On this basis, remote sensing and GIS technology have been adopted in order to achieve the purpose of this study which is aimed to assess the mangroves distribution and species in Kedah, Malaysia.

2. Methodology

2.1 Study Area
Kedah state (Figure 1), which is located on the west coast of Peninsular Malaysia has been undertaken to be the site for this study. Kedah is bordered by Penang on the south and Perlis on the north. The state was also experiencing the 2004 tsunami disaster. Some part of Kedah namely Kuala Muda and Kuala Teriang had been affected during the tragedy.

Figure 1. Kedah State

This study covers both the mainland of Kedah and Langkawi island. Eight (8) study areas were selected for field assessment meanwhile 43 points within the area were established for ground-truthing purposes. These are including Kuala Muda, Merbok, Sungai Daun, Kangkong, Kuala Kedah, Jerlun, Sungai Melaka and Kuala Teriang.

2.2 Ground Data Collection
Field assessment comprises of the identification of mangroves species. The specific coordinate was also recorded by using hand-held Global Positioning System (GPS). The locations were taken as the reference points to validate the real ground and remote sensing data. Field assessment data provides initial overview of the sites and helps in developing the mangroves mapping.

Interviews with the local communities residing near to the study areas were also conducted. This helps to verify the history of the site whereby there might be replantation done earlier or some other changes occur over the time due to development which eventually affected the population of the mangroves at the sites.

2.3 Remotely Sensed Data Processing
Remote Sensing and Geographical Information System (GIS) tools were employed to uniquely map the mangroves distribution and mangroves species in Kedah. Image processing and mapping were performed in GIS platform, using ArcGIS version 10.3.
Satellite images of Landsat-8 Operational Land Imager (OLI) [11, 12] were utilized in this study. These images are available at U.S Geological Survey (USGS) Earth Explorer website. To produce Kedah mapping, two scenes with path/row ID of 128/056 and 129/056 were used for further processing. The scenes dated 24th January 2019 and 4th March 2019 respectively were selected due to the minimal cloud cover over Kedah boundary which was below 10%. Besides that, the satellite images ranges within January to June 2019 will only be opted in order to provide the current mangroves distribution in Kedah.

The higher spectral reflectance resulting mangroves to appear in a darker shade than the other vegetation with a lower spectral reflectance [11, 13]. A new shapefile of Kedah boundary was created using IGIS Map Tool. Kedah, as the region of interest in this study was extracted from the raster cells. The supervised classification through Maximum Likelihood Classification [4, 14] was then adopted as the method to classify the land cover into five different classes including water, urban, mangroves, forest and agriculture. Five (5) to ten (10) training samples were assigned to each class. These training sets help the software to recognize the other land cover based on the same pattern of the assigned pixels.

Mangroves class was extracted from the land cover map. Similar steps were taken in performing the species-level classification. However, in this study, only the true mangroves species from the four main species of mangroves were considered. These are including Avicennia sp., Sonneratia sp., Rhizophora sp., and Bruguiera sp. Nypa fruticans and other mangroves associate species, although abundant were not counted in this study.

The final classification results of land cover and mangroves species were converted into vector form maps. The conversion enables for further refinement and editing. Ground-truth was conducted at 43 points to fulfil the verification process and accuracy assessment of the produced maps with the real ground data [2].

3. Result and Discussion

3.1 Land Cover Mapping

The land cover map in Figure 2 shows agriculture field as the largest land cover among other classes with the percentage and area of 49.07% and 468,817.36 ha respectively. The agriculture field comprises of mainly paddy field and other vegetation such as palm oil and shrubs. Meanwhile, only 0.58% of mangroves found, which correspond to an area of 5,533.13 ha.
Figure 4. (a)-(e). Mangroves coverage as marked in point A, B, C, D, E in Figure 3 respectively

Mangroves are abundantly populated in the estuaries than along the coastlines. The area of each class of land cover is demonstrated in Table 1 below.

Table 1. Area of each class of land cover

| Class       | Area (ha) |
|-------------|-----------|
| Water       | 9824.09   |
| Build-up    | 146470.15 |
| Mangrove    | 5533.13   |
| Forest      | 324671.91 |
| Agriculture | 468817.36 |

Table 2. Confusion Matrix for Supervised Classification

| Classified Category | Actual Category Classified | Total | User’s Accuracy (%) |
|---------------------|-----------------------------|-------|---------------------|
|                     | Water | Urban | Mangroves | Forest | Agriculture |
| Water               | 4     | 1     | 0         | 0      | 0           | 5     | 80.00 |
| Urban               | 0     | 11    | 0         | 0      | 0           | 11    | 100.00 |
| Mangroves           | 0     | 0     | 12        | 3      | 0           | 15    | 80.00 |
| Forest              | 0     | 0     | 0         | 2      | 0           | 2     | 100.00 |
| Agriculture         | 0     | 0     | 0         | 0      | 10          | 10    | 100.00 |
|                     | 4     | 12    | 12        | 5      | 10          | 43    | 91.67 |

Total producer’s accuracy (%) 100.00 91.67 100.00 40.00 100.00
A confusion matrix was developed to evaluate the accuracy of the classification which are including user’s accuracy and total producer’s accuracy for each category. The classified data was compared with 43 points observed from the ground-truth data with the overall accuracy of 93.02%.

3.2 Mangroves Distribution in Kedah
The land cover map also indicates that dense mangroves are growing at the estuaries of Merbok - Kuala Muda (marks as Point E in Figure 3) and near Kilim, Langkawi (marks as Point A in Figure 3). Due to the medium resolution of the satellite images, some sparsely distributed mangroves stretch at the fringe coastal areas cannot be fully captured and classified as mangroves during the GIS classification process.

Some of the mangroves appear as agriculture land. This is most probably related to the spectral reflectance and tone image of the mangroves which nearly resemble agriculture’s. High resolution of images would help in producing more accurate mapping. Figure 4 illustrates the larger scaled size of mangroves coverage at the specific point as marked in Figure 3 previously.

A study in 2012 [15] assessing the mangroves cover in Peninsular Malaysia indicated that 7,841.25 ha of mangroves were found in Kedah. This shows a loss of approximately 2,308 hectares of mangroves in Kedah in comparison with this findings. Mangroves stretch at the border of Kuala Muda and Pulau Pinang is part of the mangroves coverage area that has undergone degradation.

![Figure 5. Current Development at Kuala Muda - Pulau Pinang border](image)

![Figure 6. Species of Mangroves found in Kedah](image)
Current condition as observed from Google Earth revealed that only small patch of mangroves inhabiting the area. Urbanization has taken place and destroyed the mangroves in order to make room for the development. Taman Permatang Katong (refer Figure 5) that stands within the area was developed to relocate the victims affected during 2004 tsunami, as claimed by the community.

![Mangroves Zonation According to Species](image)

**Figure 7.** Mangroves Zonation According to Species

Field assessment revealed five species from two families of mangroves at the sites surveyed. Out of five (5) dominant and non-dominant mangroves species, only four (4) were captured in the map (Figure 6). This is due to the lower distribution of the other species, *Avicennia Alba*. The Table 3 shows the area of each species with *Rhizophora Apiculata* appears to be the highest distribution followed by *Avicennia Marina, Rhizophora Mucronata, Avicennia Officianalis*.

| Species          | Area (ha) |
|------------------|-----------|
| A. Marina        | 1313.767788 |
| R. Mucronata     | 571.057204  |
| R. Apiculata     | 3420.612226 |
| A. Officianalis   | 281.690296  |
| **TOTAL:**       | **5533.13 ha** |

It can be analyzed that *Avicennia* sp. were mostly dominated at the frontal areas while *Rhizophora* sp. were mostly growing at the estuaries and towards the landwards. According to their common zonation, *Avicennia* sp. usually occur as the pioneer species. This species has the characteristics to tolerate with high salinity.

Compared to *Avicennia* sp. which abundantly grow towards the seaward, the *Rhizophora* sp. in the other hand are mostly found towards the landward [16]. *Rhizophora* sp. are dominant in the frequently flooded area of normal high tide.

Figure 7 below demonstrates the mangroves zonation as can be observed in Merbok - Kuala Muda estuaries. *Avicennia* sp. that are represented by turquoise and pink colour mostly dominated the frontier area. Meanwhile *Rhizophora* sp. are mostly occurring in a farther area from the seawards.

### 3.3 Mangroves Condition

At most of the sites, mangroves are markedly taller and denser as it grow landward. Many younger and smaller mangroves found inhabited at the frontier of the intertidal zone. Some replantation of mangroves were observed at few sites such as Kuala Muda and Kuala Teriang. Both sites were affected when the Indian Ocean Tsunami struck in 2004 [17].
Replantation of mangroves have been implemented at the affected areas within the stretch of Kuala Muda such as Kampung Sayak on 7th February 2005 [18]. Kampung Sayak which is located northern to Kampung Masjid, experienced lesser damages. According to previous study [19], Kampung Masjid was among the most affected along the stretch of Kuala Muda area during the 2004 tsunami.

In addition to that, as visited during the field assessment, many young mangroves were found growing at the frontier area near Kampung Masjid (Figure 8), which is believed were replanted few years back. It can be seen that only some part of the shoreline which is likely forming a plotting area are populated by mangroves.

![Figure 8. Mangroves in coastline of Kampung Masjid, Kuala Muda](image)

Meanwhile in Kuala Teriang, there were some bamboos found at the ground which were probably being used as previous replantation method or technique. Replantation in Kuala Teriang since 2005 was claimed to be a success effort where healthy mangroves found growing at the site [17].

![Figure 9. Scarp formation in Merbok coastline](image)

Scarp formation was observed at Merbok site (Figure 9) where the mud has been slowly eroded at a great depth. The sand can be seen covering the intertidal zone just before the muddy part. Many mangroves trunks were seen toppled to the ground at the frontier part of the mangroves area. Aside from the eroding mud, the severe wave conditions could contribute to this situation. Such damage in mangroves area might destabilize coastal areas which subsequently will accelerate shoreline erosion.

Another degradation of mangroves that was found is as per depicted in Figure 10. Some part of the mangroves area might have undergone mangroves clearance for future development. As shown in the figure, the area stands in between two dense populated mangroves and is believed to have been cut down earlier.
Figure 10. Clearance of Mangroves in Kuala Kedah

4. Conclusion
Mangroves stretch and distribution in Kedah is dominant in estuaries of Merbok - Kuala Kedah and Langkawi, with the most abundant species of *Rhizophora Apiculata*. The total mangroves coverage is 5,533.13 hectares as per mapped through ArcGIS, which has actually degraded by 2,308 hectares than in 2012 [15]. An effective replantation considering the right replantation method planted at the right and suitable site need to be implemented for a success replantation. Areas which had previously been affected by the 2004 tsunami should be given extra attention for any disaster might occur anytime in the future.

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