Determination of Mangrove Adequacy as Natural Coastal Defence Against Wave Dynamics Using Remote Sensing Analysis for Southern Kedah Coastline

By

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Dissertation submitted in partial fulfilment of

the requirement for the

Bachelor of Engineering (Hons) Civil

September 2017

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil & Environmental Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL & ENVIRONMENTAL)

Approved by,

____

(AP Ahmad Mustafa bin Hashim)

UNIVERSITI TEKNOLOGI PETRONAS

SERI ISKANDAR, PERAK

September 2017

CERTIFICATION OF ORIGINALITY

This is to hereby certify that this submission is my own work under my own responsibility, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted by the university or any other educational institution except where due acknowledgment is made in the thesis. Any contribution made by colleagues throughout the research whom I have worked with is fully acknowledged.

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FAZIRA BINTI MOHAMMAD ROOM

ABSTRACT

Malaysia had been hit by the Indian Ocean Tsunami (IOT) 2004 which has took 68 lives of Malaysia and thousands lives from the other affected countries. Kedah was one of the most affected states in northern Peninsular Malaysia. It is proved that less severe damaged found at area with presence of mangroves fringe on its coastline. It also has been proven by many researches on mangroves' abilities in protecting the coastline by reducing the impact of the wave actions. However, if the Peninsular Malaysia is about to hit by tsunami again, it is unidentified if the current mangrove forest along the coastlines are able to reduce the impact of the tsunami's waves just like how they did before. Therefore, this study aims to fully acknowledged and assess current condition of the mangrove forest along the Kedah's coastline and evaluate their performances as the reliable natural coastal protector towards wave actions. By using both remote sensing and Geographical Information System (GIS), the Kedah's coastline was successfully assessed of their existing condition and it was found that some of the study area had enough mangrove belt as coastal defence against the approaching significant wave height while some other stretches were insufficient, and the forest had a degrading condition. The findings also had developed future mangrove replanting scheme which had considered some engineering-basis principle based on the current site conditions so that the mangrove belt is able to re-establish and perform at their best conditions.

ACKNOWLEDGEMENTS

My humble gratitude to the Almighty for His countless blessings, I was given an opportunity to complete my Final Year Project (FYP) within two study semesters at Universiti Teknologi PETRONAS. I am so thankful to my parents and family for always supporting me continually.

First and foremost, huge thanks I bid to my FYP supervisor Associate Professor Ahmad Mustafa bin Hashim his endless guidance and support throughout my research. It has been such wonderful opportunity of having fruitful experience of conducting academic research with such a knowledgeable person in the study area. Next, big appreciation I bid to DHI Water & Environment (M) Sdn Bhd for providing the helpful data for me to achieve my research objectives.

Next, my truthful appreciation I bid to Mr. Meor Asniwan, Mr Zaid and Mr Azran, technicians of Offshore and Hydraulics laboratory for their constant help and guidance while conducting the site assessment. Not to forget, thank you to Mr. Khairuddin, a forest ranger from Matang Mangrove Eco-Educational Centre for the early guidance when I was still learning about mangrove.

Thank you to all friends and lecturers for always be there when I need assistance, seeking opinions and knowledge.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Synonymous to the 'harbour wave' term, tsunami is described as the large waves oscillations in harbours and enclosed water bodies which is caused by earthquakes, volcanic eruption, land slide and slumps (Teo et al., 2009). Highlighting the nearest tsunami event with Malaysia is the Indian Ocean Tsunami (IOT 2004) on 26th December 2004. Since the tsunami was triggered by the massive earthquake, with magnitude of MW 9.1 epicentre 30 kilometres off the west coast of Northern Sumatera, Indonesia. The tsunami caused severe impacts to the countries surrounding the Bay of Bengal such as Sri Lanka, Myanmar, Thailand and Indonesia (Asmawi & Ibrahim, 2013; Teo et al., 2009).

The coastal area of Malaysia is still susceptible to natural threats from the open ocean including coastal erosions, storm surges and tsunamis. Addressing the possible threats to its coastal area, several solutions were adapted to lessen the severity of these impact. One of the subtle and natural solutions are the mangroves. Teo et. al (2009) concluded that mangroves forests contribute vital influence on the hydrodynamic processes of tsunami waves whereby it would reduce the impacts of the tsunami. Hence, reducing the impact of flooding. Asmawi et al. (2013) also founded that during the IOT phenomenon, the least damaged were found at villages with the mangrove forest belt. It has been fairly proved that mangroves are naturally able to dissipates the wave energy (Jusoff & Taha, 2008).

1.2 Problem Statement

Malaysia is one of the Asian countries which was affected by impact of Indian Ocean Tsunami on December 2004. Tsunami impact on socio-economic and environmental was not as bad as faced by the neighbouring Asian country such as Indonesia and Sri Lanka. This is because the epicentre of the earthquake was less close to Malaysia as it was at the west coast of North Sumatera, Indonesia (Asmawi & Ibrahim, 2013; Teo et al., 2009) Nevertheless, it is not wise to stay calm and assuming that this region would able to escape the tsunami or claiming that tsunami would not able to cause tremendous impact on our land. Hence, it is compulsory to conduct in-depth case-study and researches on how to improve our coastal defence system.

During the Indian Ocean Tsunami (IOT) on December 2004, many parts of Malaysia was saved by its natural coastal defence which are the mangrove forests (Hashim and Shahruzzaman, 2017). These mangroves supposed to reduce the tsunami waves impacts on the coastal area. On the specific IOT itself, Kedah faced quite serious damages despite of the presence of the mangroves on its coastal areas. Asmawi and Ibrahim (2013) stated that the disaster had cost the communities of Kuala Muda, Kedah high toll of human lives, injuries, family networks, homes and livelihoods. They also added that fishermen were one of the majority who suffered the most damage in terms of housing and livelihood losses. This incident makes the adequacy of mangrove on Kedah's coastlines questionable on how much it capable to weaken strong waves such as the energetic tsunami waves.

Kedah's Meteorological Director stated that there is possibility that Kuala Muda and Pulau Langkawi still have potential to engage with tsunami (Bernama, 2015). Thus, it is crucial for mangrove forests on Kedah's coastline to achieve their best condition in preparing not only for the future tsunamis but also daily wave forces. Since the IOT tragedy, many countries realized the importance of mangrove as wave attenuator and started to grow mangroves along their coastlines. In Malaysia, replanting mangroves programs are not new and has been implemented to many coastal areas and by many organizations. However, most of the replantation programs were conducted differently and simply ends after replanting the mangrove's saplings on the chosen site. Meanwhile, the certainty of successful growth of those saplings are important to ensure the mangroves soon able to play its destined role.

1.3 Objectives of Study

1. To assess current condition of mangrove forest along the shoreline of Kedah by using remote sensing and Geographic Information System (GIS) applications.
2. To evaluate the performance of existing mangrove as coastal defence against wave actions.
3. To establish proper engineering basis for future planning and management of mangrove forest by using remote-sensing analysis and GIS approaches.

1.4 Scope of Study

Other than Penang, Langkawi Islands, Perak and Selangor, the IOT has claimed lives in Kota Kuala Muda, Kedah (Asmawi & Ibrahim, 2013). Based on their field observation, most of the villages located along the coastal area were affected severely by the tsunami event. Hence, this study was involving the coastline of Kedah state and focusing more on area that has been affected by IOT 2004.

Besides that, this study was using both remote sensing analysis and GIS applications to analyse and extract and process relevant data from the satellite images. The software mainly used for this research especially in the satellite images processing was QGIS Desktop version 2.18.11. Data from observations and measurements taken from site visits were part of the important ground information.

CHAPTER 2

LITERATURE REVIEW

2.1 The Mangrove Forest

Mangrove forests typically made up of salt tolerant species of trees, shrubs or woody plants since they grow abundantly in saline soil and brackish water which are subject to fresh and salt water inundation (Ibharim et al., 2015). Mangroves are defined as tree, shrub, palm or ground fern, which exceeds one half meter in height, and typically grow above mean sea level in the intertidal zone of marine coastal environments (Alemán et al., 2010).

In Peninsular Malaysia, mangroves’ habitat exists along the west coast which is particularly in the coasts of Perak, Selangor, Johor and Kedah. Most of the mangrove forests are mostly discovered on sheltered coasts such as lagoons, muddy shorelines, rivers, estuaries, and some near-shore islands since they are quite influential towards tidal activities (Ibharim et al., 2015; Jusoff & Taha, 2008).

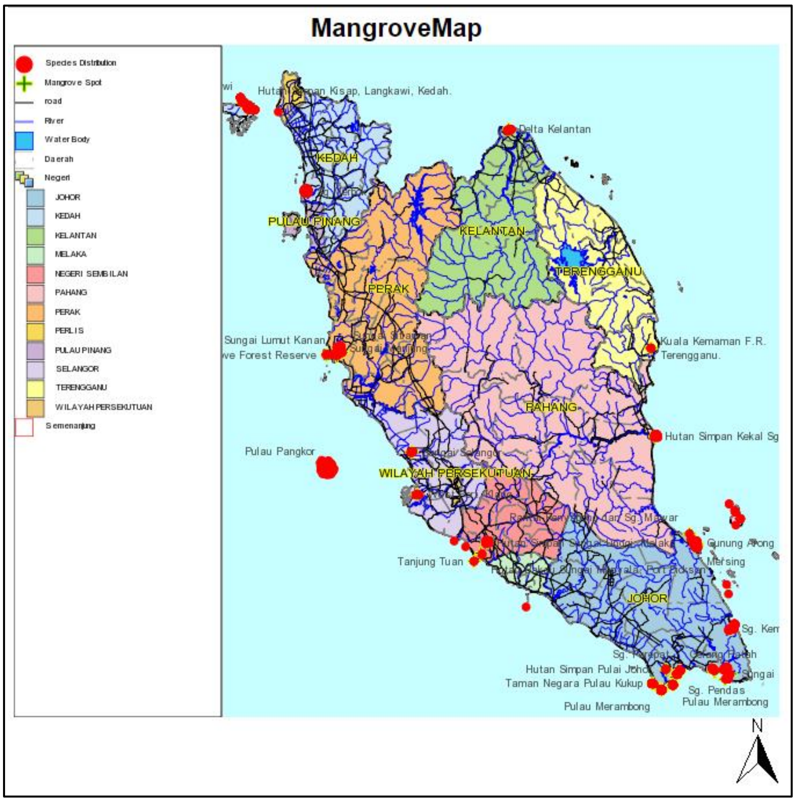


Figure 2.1: Mangrove forest distribution in Peninsular Malaysia

Hadi et al. (2003) claimed that hydrological factor dominantly influences the structure and function of mangrove ecosystems. They also added that the biogeochemical and trophodynamic processes, including forest structures and growth are closely related to the water movement. Mangrove plays essential roles in the ecosystem ecologically, environmentally, biologically, medically and economically (Ibharim et al., 2015). To mention some, mangrove ecosystems offer habitats for many flora and fauna which live in close interaction with the mangrove vegetation (Alemán et al., 2010).

Other than that, importance of mangrove's forest includes providing precious goods and services in economics provisions such as production of poles, charcoal and fuel wood while environmentally, the system supports broad range of functions such as protecting the coastlines, food resources, spawning and breeding ground for marine life, (Jusoff & Taha, 2008) and most importantly, act as barrier by reducing both height and forces of the waves (Hashim & Catherine, 2013; Hashim et al., 2010; Jusoff & Taha, 2008).

2.2 Mangrove's roles in wave attenuation.

Coastal areas with bare land and has no presence of mangroves was believed to reduce the wave impact naturally by the bottom friction (Hashim & Catherine, 2013). The importance of mangrove forest in protecting the coastlines from wave actions are undoubtable (Hamzah et al. 2009). In fact, Teo et al. (2009) has proved that mangroves are very helpful in reducing the impact of tsunami in the main river and swampy areas while Hamzah et al. (2009) found that this forest acts as buffer for the surrounding communities as well as protecting the coastlines from wave actions. The effectiveness of the mangrove forest in dissipating the wave was proved by IOT 20014. Figure 2.2 below shows how vegetation reduced tsunami impact at Pangandaran Beach.

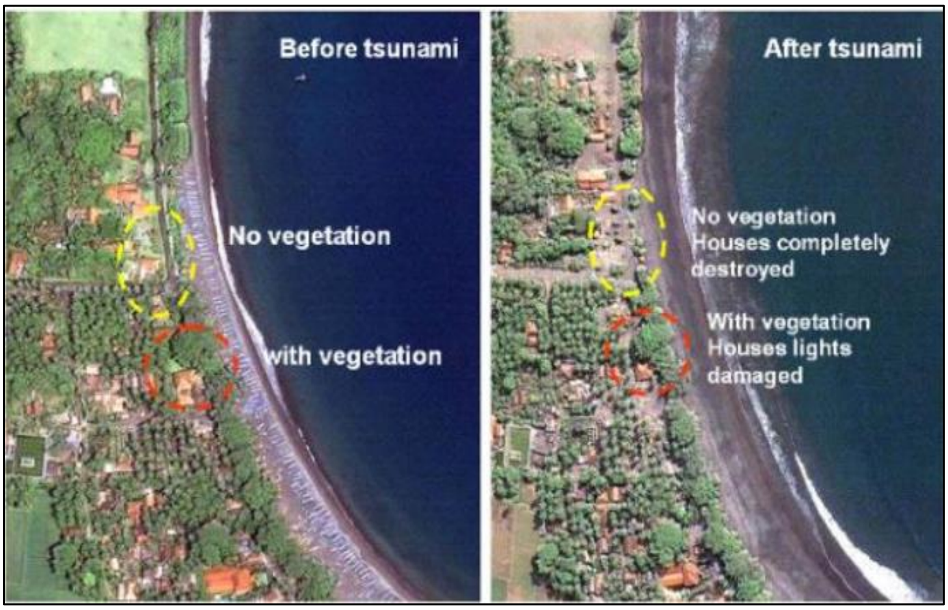


Figure 2.2: Ikonos imagery before and after 2006 West Java tsunami (source: CRPS, www.crips.nus.edu.sg)

This coastal greenbelt protects the land from powerful waves and wind, by absorbing and decreasing the wave's amplitude (height) and energy (Herison et al., 2014). Bottom friction and multiple interactions between wave motions and mangrove roots and trunks are the main energy dissipation mechanism (Hadi et al., 2003). Since the bottom friction coefficient of the mangroves forest is still undiscovered, bottom friction was omitted in from consideration of their research. Another main energy dissipation mechanism was interactions between winds with mangrove's leaves and branches (Rasmeemasmuang & Sasaki, 2015).

According to Rasmeemasmuang & Sasaki (2015), waves were generated and move towards the shore as the results from interaction of the winds with water surface over a time and distance. Either the wind has produced the waves or strengthens them, mangrove's thick branches and leaves shielded the coast and lessen the force of the wind. Instead of directly reduces the wave action, this mechanism causes the wave height lesser and less forceful compare to areas without vegetation.

Directly, mangroves able to attenuate waves and surges by creating additional drag against wave forces physically through their trunks, root systems, leaves and pneumatophores (Marois & Mitsch, 2015). Wave reduction rate are influential according to many factors such as its species, density of the forest, band width and age of the mangroves (Hashim & Catherine, 2013). Moreover, mangrove vegetation features differ from site to site in terms of the composition of its species, density, forest width, age distribution, size of trees and root configuration.

Species composition influences the capability of mangrove in dissipating wave energy (Hashim & Catherine, 2013). *Avicennia marina* which grows well with dirty and muddy water condition is an important species in wave attenuation and it also acts as a form of antidote to abrasion. (Herison et al., 2014). Mazda et al. (1997) investigated a mangrove reforestation area with *Kandelia candel* species and found that it has significantly reduced swell with periods of 5-8 seconds and protected the coast. Within 100 m of *Sonneratia* forests was able to reduce waves by 50% (Alongi, 2008). *Rhizophora* species creates more friction to waves *Rhizophora* species creates more friction to waves (Hadi et al., 2003; Hashim & Catherine, 2013).

On the other scope, denser mangrove forest attenuate waves better than forests with lower density of mangroves (Hadi et al., 2003; Hashim & Catherine, 2013; Hashim et al., 2013; Mazda et al., 1997). During IOT, villages behind dense or open mangrove forests endured lesser damage than villages unprotected by mangrove (Marois & Mitsch, 2015). Kathiresan & Rajendran (2005) suggested human inhabitation to be distanced more than a kilometre from the shoreline in elevated places, behind high-density of mangrove or other coastal vegetation for safety purposes.

The age of the mangrove tree can be signified by the height of the tree, the diameter of root and trunk (Hadi et al., 2003) and density of the stem (Hashim & Catherine, 2013). As the trunk diameter of the tree increasing with age (Marois & Mitsch, 2015), the resistance to wave damage increases (Hashim & Catherine, 2013). Mazda et al. (1997) stated that, on areas with young mangrove trees, the drag force generated to attenuate the waves are less effective when compared to the area with sufficiently tall mangroves where the rate of wave reductions was large as 20%.

Hashim and Catherine (2013) conducted their studies in quantifying the wave height reduction respective to various mangrove densities and different tree arrangements. Despite of different tree arrangements, they found that in 100 m wide mangrove forest, the difference of the wave reduction for both arrangements was lesser than 10% which was less significant. Besides that, mangroves attenuate waves indirectly by enhancing the stabilization and formation of coastal soil with their intricate root system (Marois & Mitsch, 2015).

CHAPTER 3

METHODOLOGY

3.1 Study Area

After Perlis, Kedah was one of the most northern and western state in the Peninsular Malaysia. Generally, the state of Kedah has a tropical climate with significant rainfall even at the driest of the month. Facing the Straits of Malacca, Kedah's coastline was literally having less wave impact compared to the states facing the South China Sea such as Terengganu and Kelantan. Kedah water was identified as the fishing areas in the Straits of Malacca (Natural Resources and Environment (NRE), 2011). This was explained by the fisherman's villages and residents along the coastline.

This study area covers about 24.9 kilometres of coastline from north to south, from Pantai Murni to Kota Kuala Muda. This study focuses on the southern area of Kedah as the most affected area by the IOT 2004 for was the southward shore after Tanjung Dawai (DID, 2005). After Sungai Melaka, Langkawi, Kota Kuala Muda has the highest maximum inundation distance which is about 400 meters inland. Even with the presence of rock revetment in the shore, it still could not save the lives of 11 tsunami victims. Figure 3.1 below illustrates the area affected by tsunami which was involved in this study.

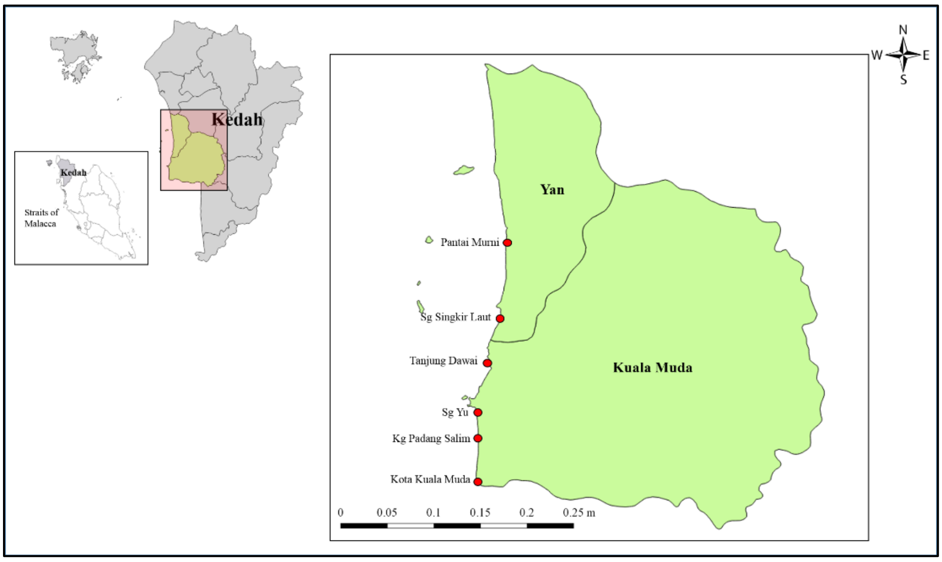


Figure 3.1: Study area

Four of six study areas were in the Kuala Muda district which were Kota Kuala Muda, Kampung Padang Salim, Sungai Yu and Tanjung Dawai. According to Faezah & Farah, 2011, among the district main land-use activity is agriculture followed by forest land, mangroves, aquaculture, housing and others activity such as industry and commercial which was confirmed according to the visit carried out lately. Other than that, Kampung Singkir Laut is a small fishing village situated near the tip of the southern coastline with generally quite hilly surrounding and covered with secondary forest. In the meantime, Pantai Murni was one of the famous beach with increasing number of visitors and lately has granted with Tourism Facilities Improvement Project supported by the federal government.

3.2 Satellite Image Processing

Since early 1970's, Landsat satellite images provided multispectral data of the earth environment. This research was utilizing satellite image data of Landsat 8 OLI, medium-resolution data image which available (free) in the Earth Explorer website and was fully-analysed by using remote sensing analysis and Geographical Information System (GIS) applications. Satellite images has been extensively used in mangrove studies especially for classifying, mapping, change detections and monitoring of the forests (Kamaruddin, Fujii, & Shivakoti, 2015).

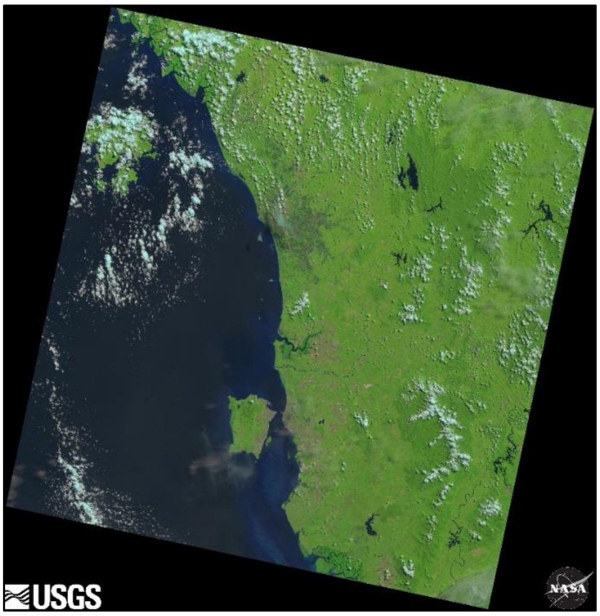


Figure 3.2: Satellite Images of Landsat 8 OLI which covers the whole Kedah's coastline

At the beginning process of analysing the satellite images, pre-processing procedures were carried out to ensure better accuracy and less disturbances on the data. These pre-processing procedures includes geometric, radiometric and atmospheric corrections. The image was clipped into smaller area of interest of study area by using the shapefile of the district which were the Kuala Muda and Yan districts of Kedah state. Next, the band of the images were setup to 5-4-3 because such band set is more suitable in differentiation mangrove and classifying the vegetation. Hamzah et. al (2009) also chose the same band combination for mangrove classification using Landsat TM image and SPOT XS image.

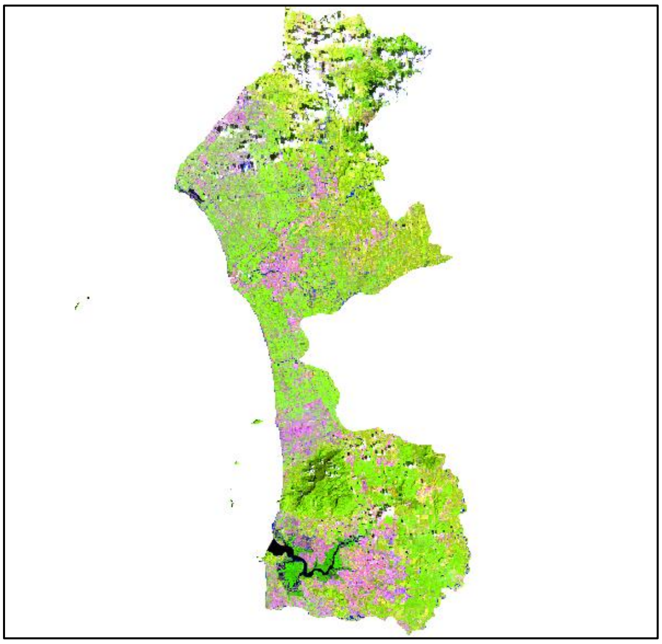


Figure 3.3: Clipped satellite images for land cover classification process.

Table 3.1: The details of selected Satellite Image

Satellite	Landsat 8 OLI
Acquisition Date	2017/01/08
Landsat ID	LC08_L1TP_128056_20170118_20170311_01_T1
Collection Category	T1
Collection Number	1
WRS Path	128
WRS Row	56
Land Cloud Cover (%)	16.67
Scene Cloud Cover (%)	19.24

The satellite image classification was carried out by using the supervised classification. Collected data from the field, visual interpretation of Google Earth images and the Landsat 8 OLI images were combined to analyse the spectral characteristic of study area's common land use and to ensure the accuracy of mangrove forest classification assessment also to calibrate and validate the land use categories. The pixels of the image undergone a stratified random sampling pattern where Region Growing Algorithm (ROI) were manually drawn as and saved as the training inputs. Six major classes were delineated: water, built-up, mangrove, bare soil, agriculture and aquaculture. (Table 3.2)

Table 3.2: Class definitions

Classes	Classification class definitions
Water	All areas with open water without emerging vegetation
Built-up	All areas covered with artificial facilities
Mangrove	All areas with mangrove
Bare Soil	All areas with exposed soil or dried aquaculture ponds.
Agriculture	All areas covered by crops, shrubs, grass, or forests.
Aquaculture	All areas of aquaculture ponds and used for water activities.

From the land cover classification, land use of mangrove which was the Macro Class 3 was extracted and created into a new layer. This vector layer of mangrove was then used to clip the corrected satellite images to proceed with the next classification process which was to classify the mangrove according to their species. Once the mangroves were classified according to their species, *Rhizophora* species was extracted and further classified into their age. The *Rhizophora* were classified into four categories of age which are 1 to 5 years old, 6 to 10 years old, 11 to 15 years old and 16 to 20 years old.

3.3 Site Investigation

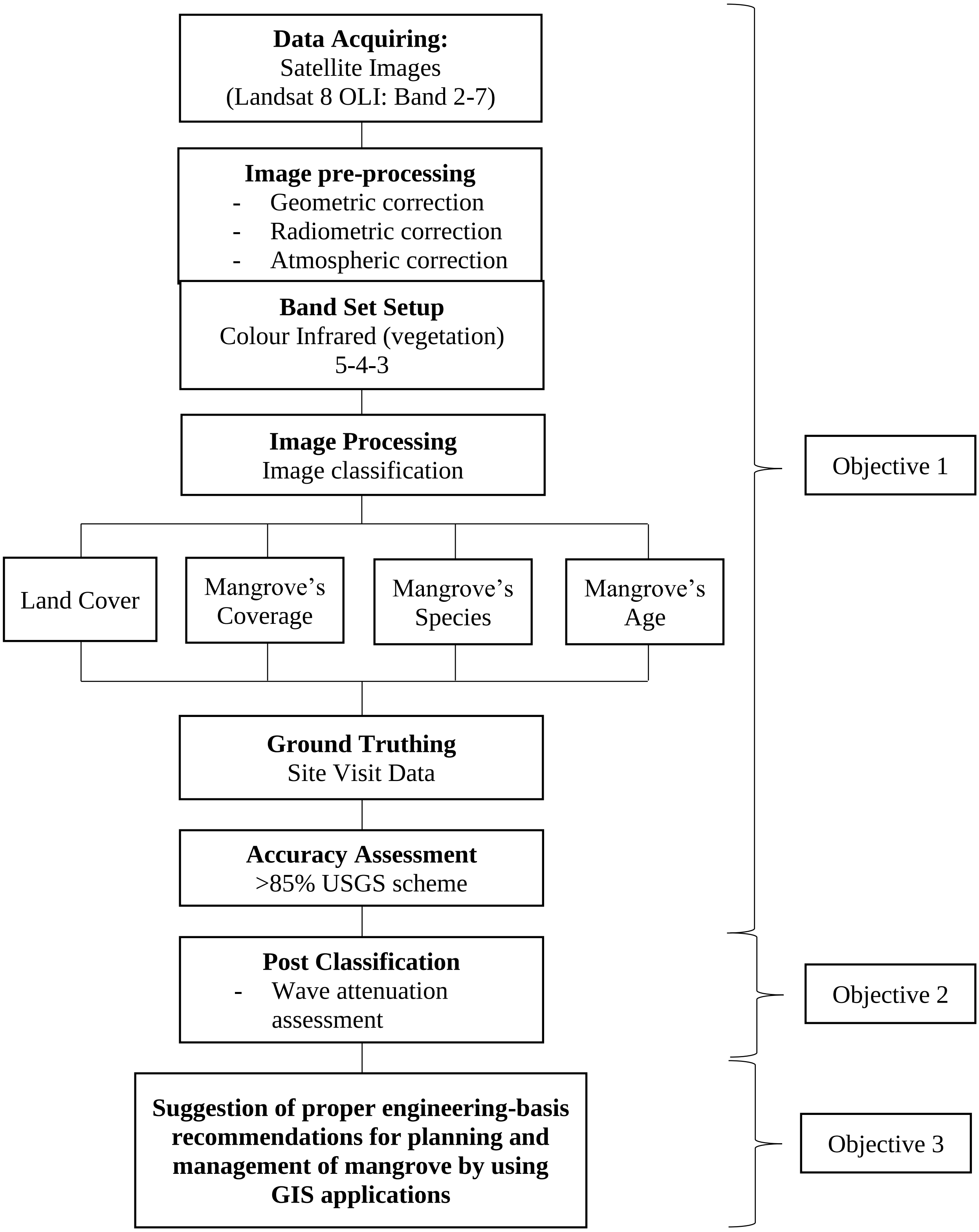
A preliminary site visit was carried out for a simple introduction to the researcher about mangrove forest, mangrove species and their characteristics. This small visit was very helpful as it would make the researcher gets familiar to the mangrove trees and easier to identify its species when it comes to the real field work later.

Few site investigations were carried out along the study area where some observations and measurements were made. At each site, random sampling plots of (30 x 30 meters) were established and was set as the representative of general condition of the mangrove forest in the area. Meanwhile, in the plot, selected matured mangrove trees of different age were identified and detailed measurements were carried out. Among the collected data were the species of the mangrove, tree height, number of branches also the diameter trunk and branch. Besides that, wave height at some point along the study area was also recorded for reference.

This site investigations or also known as the ground truthing process help the study in assessing the current condition of the mangrove forests where detail observations and some simple interviews with the locals were also carried out for additional information. This is important where these data were used in for the next process which was the accuracy assessment. Both data from results of the image classification and ground truthing data were compared and assessed where the accuracy of these data was identified according to the United States Geological Survey (USGS) scheme.

From here, these data were used to evaluate the performances of the assessed mangrove forests towards the significant approaching wave height. At the end of this research, the outcome of this remote sensing analysis would formulate suggestions and recommendations for proper engineering-basis for planning and management of mangrove which was suitable for the study site or any other site with similar conditions and characteristics.

3.4 Project Flow



3.5 Project Key Milestones and Timelines

No	Milestone	Deadline
1	Submission of Research Title	15th May – 19th May 2017
2	Literature Review	15th May – 23rd June 2017
3	Submission of Extended Proposal	19th June – 23rd June 2017
4	Data Acquisition and Preprocessing	3rd – 14th July 2017
6	Data Processing	3rd July – 18th August 2017
7	Preliminary Site Visit	17th July – 21st July 2017
8	Submission of Interim Draft Report	7th August – 11th August 2017
9	Real Site Visit	14th August – 18th August 2017
10	Ground Truthing and Accuracy Assessment	11th September – 13th October 2017
11	Submission of Progress Report	23rd – 27th October 2017
12	Post Classification (Wave Attenuation Assessment)	9th October -17th November 2017
13	Proposing engineering solutions and recommendations for mangrove management.	23rd October – 30th November 2017
14	Pre-Sedex	13th – 17th November 2017
15	Submission of Draft Final Report	13th – 17th November 2017
16	Submission of Dissertation (soft bound)	27th Nov – 1st Dec 2017
17	Submission of Technical Paper	27th Nov – 1st Dec 2017
18	VIVA	4th – 8th December 2017
19	Submission of Project Dissertation (Hard Bound)	18th – 22nd December 2017

3.5.1 Project Gantt Chart I

No	Detail/Work	Week														
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
2	Literature Review															
4	Data Acquisition (Satellite Images, Aerial Photograph)															
5	Image Preprocessing (Corrections)															
6	Image Processing (Classifications)															
7	Preliminary site visit: Introduction to Mangrove															
9	Following Site Visit															

3.5.2 Project Gantt Chart II

No	Detail/Work	Week														
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	Ground Truthing															
2	Accuracy Assessment															
4	Post Classification (Wave Attenuation Assessment)															
5	Proposing engineering solutions and recommendations for mangrove management.															

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Establishment of existing condition of mangrove forest in area affected by IOT 2004.

4.1.1 Kota Kuala Muda, Kedah

Kota Kuala Muda, Kedah was one of the area affected by tsunami that was chosen as one of the study area. Based on observations and assessment made on the study site, the mangrove species identified came from the *Sonneratia* genus. Most of the trees were about the same height which also means they were about the same age. Based on rough estimation, these mangroves were replanted less than 10 years back as the plant was considered young. The mangrove plants that were more seaward were much smaller which could be explained due to their exposure to the waves breaking.

Figure 4.1: Young mangrove trees of *Sonneratia* genus spotted at Kota Kuala Muda coastlines.

The mangroves were live on the mud which was in front of the existing rock revetment as shown in Figure 4.2. These mangroves need to grow up and became mature enough to be able to attenuate waves affectively provided there were no harm by the wave actions that would affect their growth and survivability in the coastline.

Figure 4.2: Existing rock revetments protecting Kota Kuala Muda from wave actions.

4.1.2 Kampung Padang Salim, Kedah

Kampung Padang Salim which was located at the north of Kuala Muda used to have dense mangrove forest. Based on the observations, the mangrove forests were degrading due to the limited amount of muddy soil to hold the trees. The remaining mangrove tress as shown in Figure 4.3 were the ones that still standing on the mud which was probably harden. This explained why the remaining trees were separated sparsely in random location. The mangrove species found in Kampung Padang Salim were mangroves from the *Sonneratia* genus.

Figure 4.3: Remaining *Sonneratia* tree in front of rock revetments.

Based on the condition of the deteriorating sparse forest, these mangroves can no longer dissipate waves effectively and protected the shore as how it used to.

Figure 4.4: Degraded mangrove trees (forest) at Kampung Padang Salim’s shoreline.

Plus, the wave actions were eroding the muddy soil which was very important for the mangrove survivability. Therefore, the last protection of the shore was applied which was the construction of the rock revetments which was reported by the villagers, recently build by the DID Kedah.

Figure 4.5: Constructed rock revetment to protect the shoreline from wave actions.

4.1.3 Kampung Sungai Yu, Kedah

Kampung Sungai Yu has a mangrove forest consisting *Rhizophora Apiculata* and *Rhizophora Mucronata* species. There mangrove forest was a result of successful replantation program by the Forest Research Institute Malaysia (FRIM) back in 2007. As reported by the villagers, FRIM were still constantly monitoring the condition of their mangroves until recently.

Figure 4.6: Replanted mangrove forests of *Rhizophora Apiculata* and *Rhizophora Mucronata* in Sungai Yu.

The forest was quite dense with density 0.64 tree/m² and maximum band width of 60 meters. However, there was evidence that this forest was affected by rough wave actions especially during high tides as shown in Figure 4.7. This forest would eventually degrading as the wave actions keep eroding the muddy soil in the shoreline.

Figure 4.7: Wave actions eroding the muddy soil during high tides.

At the edge of this replantation forest, there were not enough mangroves to protect shoreline. To avoid the wave actions from eroding the shore further landward and affecting the closest resident, DID Kedah decided to put the protection measure to address this problem from worsening as shown in Figure 4.8.

Figure 4.8: Recently constructed rock revetments to protect the coastline.

4.1.4 Kampung Huma, Tanjung Dawai

Kampung Huma, Tanjung Dawai was among the chosen area with mangrove replantation program which was organized by Sahabat Alam Malaysia, *Campus Environmentalist* (CARE) Institut Pendidikan Guru Kampus Tuanku Bainun (IPGKTB), Jabatan Perhutanan Negeri Kedah in 2009 and 2011. Based on site assessment which was carried out at the edge of this vast mangrove forest, among the species spotted were *Rhizophora Apiculata* species and mangrove from the *Sonneratia* genus. These trees were quite matured with age about 15 to 20 years and above.

Figure 4.9: Mangrove forest of *Sonneratia* genus and *Rhizophora Apiculata* species

4.1.5 Sungai Singkir Laut, Kedah

Sungai Singkir Laut, Kedah has a rock revetment extended to the shore as it was attached with the breakwater nearby fishermen's navigation channel. Mangroves tree were found to be behind (landward) of the revetments. There were quite number of species found on the mangroves such as *Bruguiera Sexagulata* species and few species from the *Sonneratia* genus. These trees were matured and expected had age of 15 to 10 years and above. Presence of sediments were found behind the revetments and this sediment has covered most of the mangrove roots and makes it quite challenging to identify the species based on the roots. These mangrove forest were quite dense, and it extend north from the navigation channel. However, it was difficult to assess further due to presence of shrubs and thick grass.

Figure 4.10: Rock revetments extended from the breakwater to the shoreline.

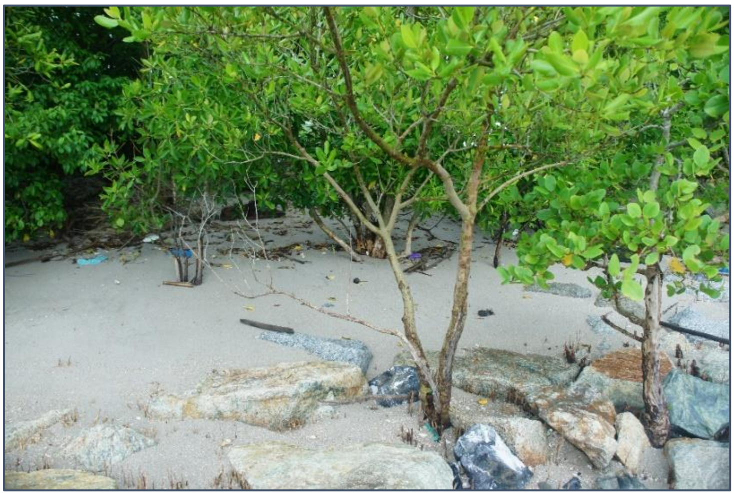


Figure 4.11: Sediments covered the roots of the mangrove trees.

4.1.6 Pantai Murni, Yan, Kedah

From site assessment in Pantai Murni, the mangroves were found very sparse. The only species found was the mangrove from the *Sonneratia* genus and very small in amount. The age of the mangrove was also young which was about 5 years old. Based on comparison made from the remote sensing and historical images from Google Earth, this site used to have a dense mangrove forest with a about 50 meters band width. However, these forests were gone and replaced by the aquaculture facilities. This situation proved that over the years mangrove forests in Kedah lessened due to land demand not only for development purposes but also for agriculture and aquaculture projects (Jusoff & Taha, 2008).

Figure 4.12: Measuring the height of the *Sonneratia*.

4.1.7 Overall Species Distribution in Study Area

From the assessment made on the study area, 35 mangrove trees were identified which was the mix of both matured and unmatured tree from various species. Most of the species found on site were *Rhizophora Apiculata* and *Rhizophora Mucronata*. Table 4.1 present the mangrove species found on the coastline of the study area while Figure 4.13 illustrates the species distribution of the mangrove species. The dominating species that were found in the site were *Rhizophora*, followed by *Sonneratia* species and *Bruguiera*. From the site assessment, the *Avicennia* species was not found.

Table 4.1: Mangrove species found at sampling site.

Location	*Rhizophora*		*Bruguiera*	*Sonneratia*	*Avicennia*
	R. Apiculata	*R. Mucronata*			
Kota Kuala Muda	0	0	0	4	0
Sungai Yu	4	4	0	0	0
Kampung Padang Salim	0	0	0	2	0
Tanjung Dawai	3	3	0	2	0
Sungai Singkir Laut	1	1	1	1	0
Pantai Murni (Sungai Yan)	1	1	0	3	0

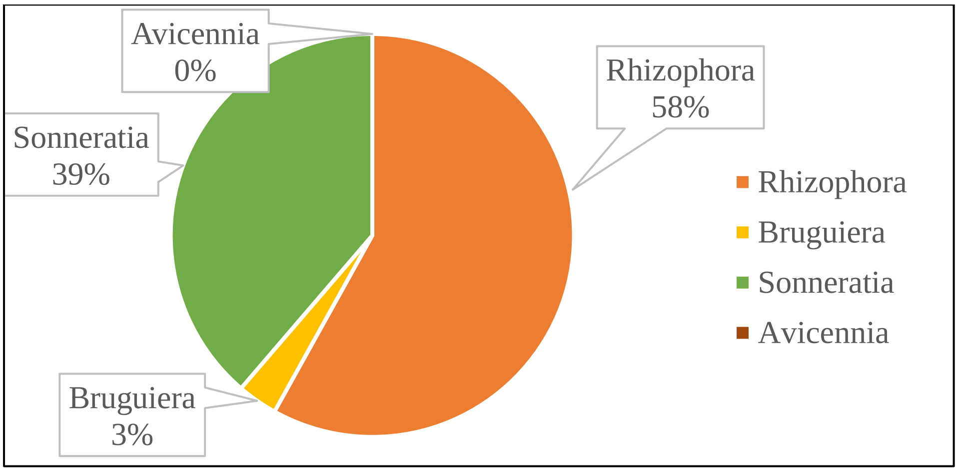


Figure 4.13: Overall Species Distribution in the Study Area

4.3 Satellite Image Classification

4.3.1 Land Cover Classification

The satellite image was processed, and the land cover was classified as shown in Figure 4.14 while the classification report was as shown in Table 4.2.

Table 4.2: Classification report of Land Cover Classification.

Class	Pixel Sum	Percentage (%)	Area (m^2)
1 - Water	45,867	0.53	41,280,300.00
2 - Built-up	382,283	4.44	344,054,700.00
3 - Mangrove	1,598,060	18.54	1,438,254,000.00
4 - Bare Soil	61,015	0.71	54,913,500.00
5 - Agriculture	841,147	9.76	757,032,300.00
6 - Aquaculture	157,935	1.83	142,141,500.00

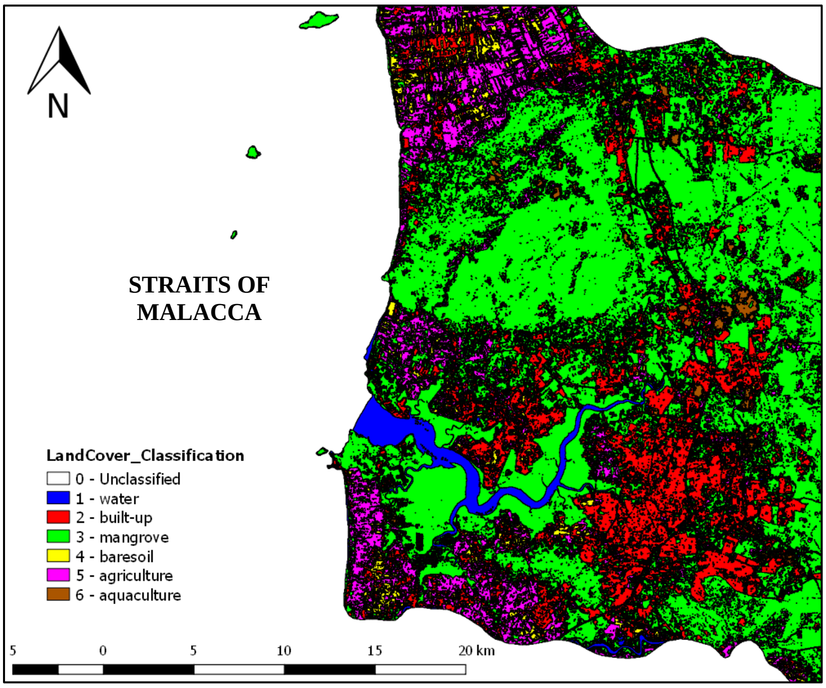


Figure 4.14: Classification of Land Cover of Study Area.

From the classification result, the mangrove was found in abundant amount in the estuary area around Sungai Merbok. About 3000 hectares of this precious mangrove forest with various mangrove species had been declared as the United Nations Educational, Scientific and Cultural Organization (UNESCO) Biosphere Reserves

(Bernama, 2015; Md Nasir, 2016). Meanwhile, the mangroves around the study area. The agriculture activities were quite close to the coastline especially the aquaculture activities. Based on visual interpretation made in Google Earth, the land cover of the aquaculture (nearby to the study) area was compared throughout the years. It was found that the land cover of aquaculture used to be covered by mangrove forests especially the one near to the coastlines.

4.3.2 Classification of Mangrove Species

Table 4.3: Classification report of Mangrove Species Classification

Class	Pixel Sum	Percentage (%)	Area (m^2)
1 - Avicennia/Sonneratia	600,137	6.97	540,123,300
2 - Rhizophora	997,923	11.59	898,130,700

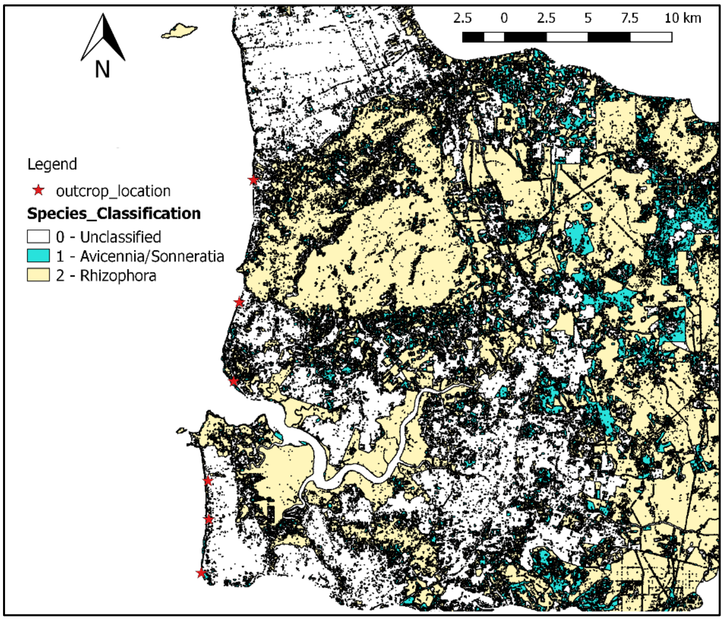


Figure 4.15: Classification of mangrove species in study area

From the classification species result, *Rhizophora* species has higher percentage compared to *Sonneratia* species. The significant amount of *Rhizophora* must be due to their involvement as the chosen species during the replantation program carried out along the southern coastline of Kedah especially the replanted mangroves at Sungai Yu and Tanjung Dawai. Furthermore, *Rhizophora* species creates greater friction in attenuating waves as claimed by Mazda et al, 1997.

4.3.3 Classification of Age of *Rhizophora* sp.

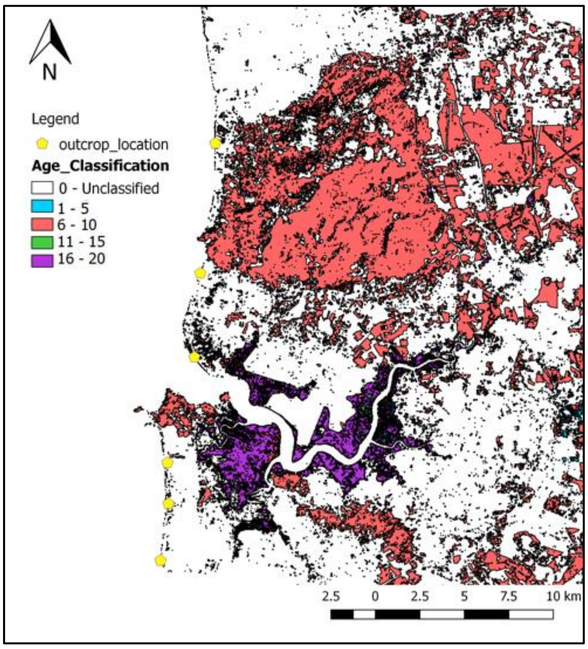


Figure 4.16: Classification of Age of *Rhizophora* species.

Figure 4.16 shows the classification of age of Rhizophora from range of 1 to 5 years old, 6 to 10 years old, 11 to 15 years old and 16 to 20 (and above) years old. Most of the *Rhizophora* in the UNESCO Biosphere Reserves were matured mangrove which were 16 to 20 years old and above.

4.4 Performances of existing mangrove against wave actions

The capabilities of the existing mangrove forest in attenuating waves on the study area was assessed based on their existing mangrove conditions and composition. This condition involving the integration of important parameters such as the species distribution, the density of the mangrove forest, the band width of the forest and also the age of the mangrove trees (Hashim, 2013). Therefore, the classification of the age of *Rhizophora* species was overlaid in the Google Earth for better and relatable visual representation of the mangrove in the study area.

In the meantime, raw wave data dated from 1st January 2012 until 31st December 2014 was obtained from DHI Water & Environment (M) Sdn Bhd. From these raw data, the average significant wave height was calculated. The wave data was plotted in the QGIS software by using the average significant wave height values.

Table 4.4: Summarized average significant wave height from raw data.

Point ID	Longitude	Latitude	Average Significant Wave Height (m)
1	100.203	5.98317	0.5
2	100.203	5.71191	0.6
3	100.158	5.46742	0.5
4	100.108	5.29431	0.6

From the plot in Figure 4.17, it could be concluded that the whole study area had been receiving average significant wave height of about 0.523 meters. Therefore, this wave height data compared with the capability of the mangrove forest to attenuate the waves according to their existing condition to derive the most suitable replanting scheme.

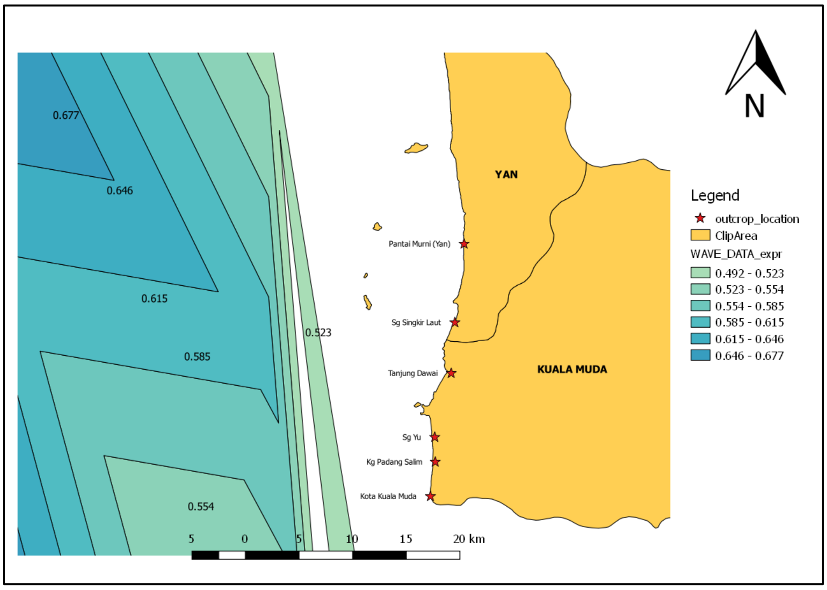


Figure 4.17: Contour of average significant wave height in the study area.

Kota Kuala Muda

Figure 4.18: No *Rhizophora* species found in Kota Kuala Muda

Accurately, there was no *Rhizophora* tree found in the area where site assessment was conducted at about 100 meters stretch of coastline. The only species found was *Sonneratia* species which was quite young and sparse in density. According to Mazda et al, 2006, Sonneratia forest of 100 meters wide able to reduce the wave energy by 50%. However, these young and less dense *Sonneratia* species has a band width of about 10 meters.

Kampung Padang Salim

Even though the mangrove of *Sonneratia* species found in Kampung Padang Salim were grown and matured, it was undeniable that the whole forest was degrading. The mud on the coastline were washed away by the wave actions. Only the tree with harder mud materials able to sustain themselves in such conditions but soon they would also be affected by the waves. The authorities took immediate action by layering the shoreline with rock revetments to stop the land from retreating due to wave actions. This was concluded that the mangrove forests in Kampung Padang Salim (restricted to study area only) were no longer able to attenuate waves effectively. Moreover, the decreasing amount of muddy soil on the shore also affecting the planning of any mangrove rehabilitation program in future.

Figure 4.19: Mangrove trees survived in the remaining mud.

Figure 4.20: Rock revetments installed on the coastline as protection.

Kampung Sungai Yu

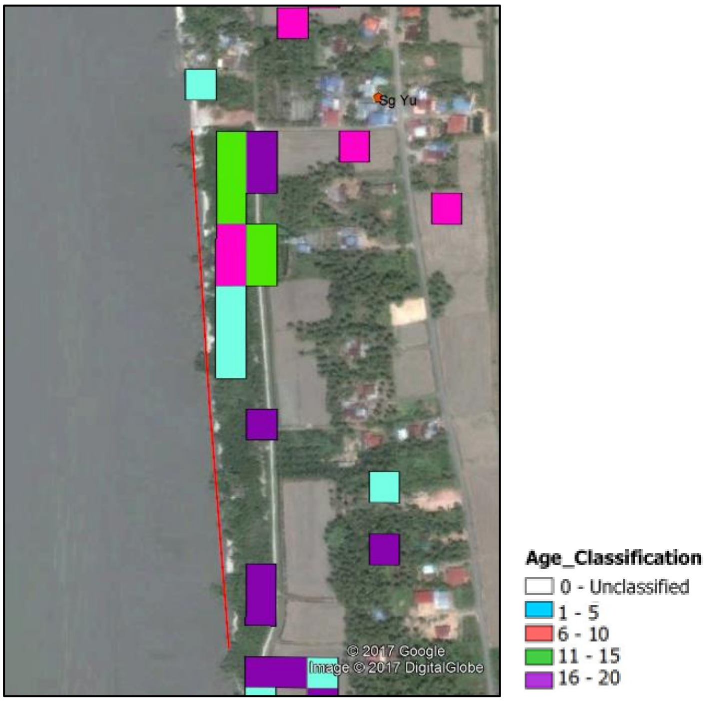


Figure 4.21: Age distribution of *Rhizophora* species in Sungai Yu

The replanted mangrove forests in Sungai Yu has various range of age from 1 to 20 years old. However, based on observations made during the site assessment, the trees were about the same height which would also represent their same age. The mangrove sample taken was from the edge of the forest (refer green area in Figure 4.21) matched with the extracted result from the remote sensing analysis which shows the three was about 15 years old in age. Based on 60 meters band width of the forest (measured from Google Earth) this forest was able to dissipate about 50% of the wave height.

Kampung Huma, Tanjung Dawai

Based on remote sensing analysis, facing seaward Tanjung Dawai was delineated by *Sonneratia* species and followed by Rhizophora species (refer Figure 4.22) The *Rhizophora* forest has the most trees of age ranging from 6-15 years old. The trees of age from 10-15 years old was front lining the 6-10 years old trees which may due different time or layer of conducted replanting program.

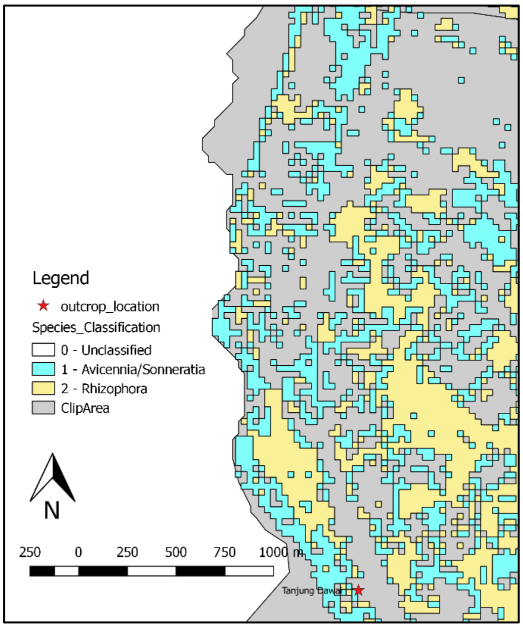


Figure 4.22: Close view of mangrove species distribution in Tanjung Dawai

The stretch of mangrove forest in Tanjung Dawai was separated into 4 different stretch labelled as A, B, C and D (refer figure 4.23). Each stretch was about 300 meters long. For stretch A, the mangrove forest consists of mostly *Sonneratia* species has band width of ranging from 80 meters to 100 meters. Hence this stretch can reduce wave height up to 50%. Stretch B also consists of mostly *Sonneratia* species with band width ranging from 100 to 250 meters. Meanwhile, stretch C has a thick forest of both *Sonneratia* and *Rhizophora* species with (combined) band width of ranging from 250 meters to 300 meters wide. Thus, both stretch B and C can attenuate the wave height completely. Meanwhile, the last stretch D has band width ranging from 300 meters to 50 meters wide with thick forest of *Sonneratia* species.

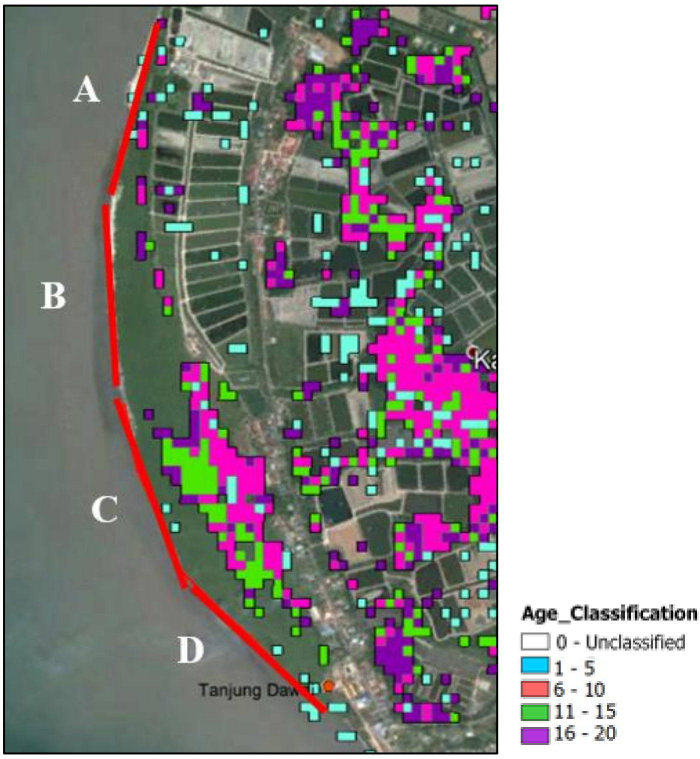


Figure 4.23: Age classification of *Rhizophora* species at Tanjung Dawai

<u>Sungai Singkir Laut</u>

From the result of remote sensing analysis, *Rhizophora* species spotted in Sungai Singkir Laut was in the range of age 1-5 years and 16-20 years. From the site assessment, there also other species of mangrove such as *Sonneratia* and *Bruguiera* species. This stretch composition may have mangrove forest of variety species with band width of 30 to 50 meters.

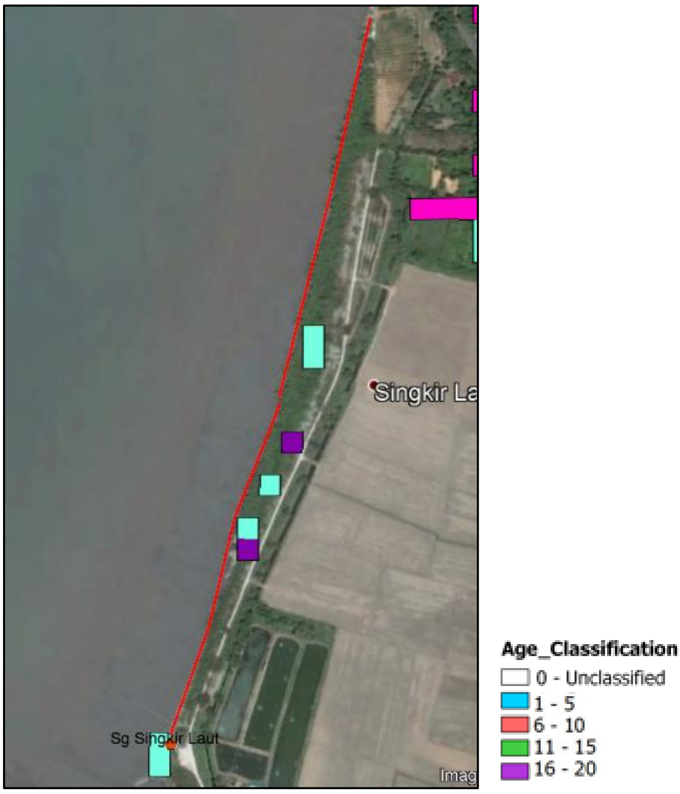


Figure 4.24: Age classification of *Rhizophora* species at Sg. Singkir Laut

<u>Pantai Murni</u>

Figure 4.25: Age classification of *Rhizophora* species at Pantai Murni

Based on remote sensing analysis, Pantai Murni has mangrove of young *Rhizophora* species (age 1-5 years old) with band width of 10 meters. This forest needed extra band of mangroves so that it capable to reduce more wave energy and act as the shoreline defence against wave actions effectively.

4.5 Proposed Rehabilitation Mangrove Belt for the Coastline

The proposed rehabilitation mangrove belt for the coastlines was derived based on the findings as in previous discussions. Based on research made by Mohammad et al., 2014, they ranked the Peninsular Malaysia has very low vulnerability index with coastal significant wave height lower than 0.5 meter. Therefore, this research derived rehabilitation initiatives based on suggestion to reduce the average significant wave height of 0.523 meters of the study area to 50% lower. The graph shown in Figure 4.26 below was derived from few researchers' findings on the relationship between the *Rhizophora* species' age, arrangement, band width and the percentage of wave dissipation (Hashim et al. 2013).

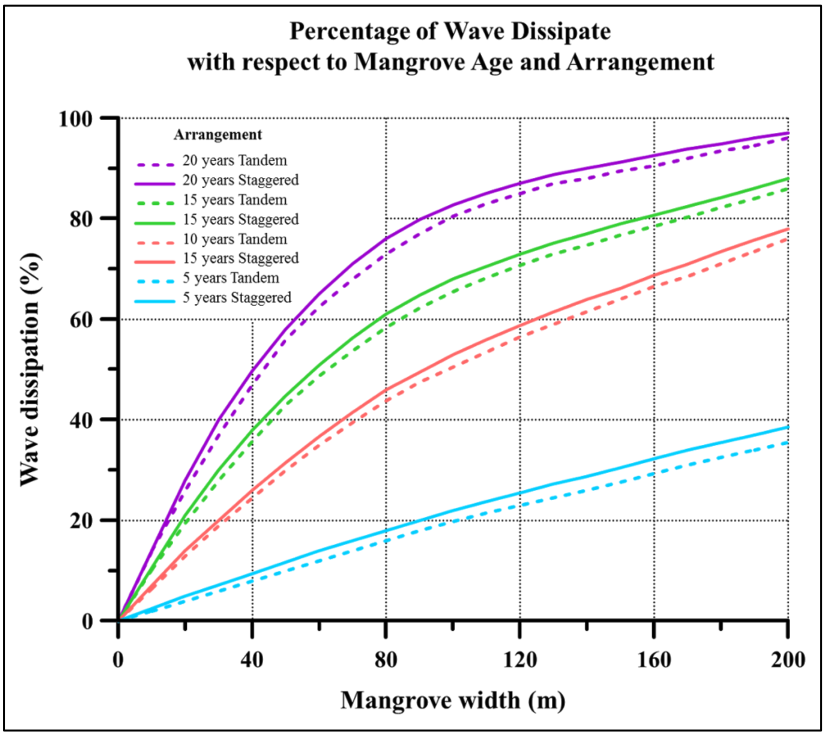


Figure 4.26: Percentage of Wave Dissipate Respect to *Rhizophora*'s Age and Arrangement.

Table 4.5: Derivation of Proposed Rehabilitation Scheme for Southern Coastline of Kedah.

	Existing Condition				**Suggestion for Rehabilitation**			
Site	**Band Width, b (m)**	**Major Species Involved**	**Age (years)**	**Percentage of wave dissipation**	**Percentage of wave dissipation (Needed)**	**Suggested Species**	**Suggested Age (years)**	**Suggested Addition Band Width, b (m)**
Kota Kuala Muda	10	*Sonneratia*	<5	0.1	0.4	*Rhizophora*	15	160
Sungai Yu	60	*Rhizophora*	<20	0.5	0	*Rhizophora*	15	160
Tanjung Dawai (Kampung Huma)	A: min 80	*Sonneratia*	>15	0.5	0	*Rhizophora*	5	0
	B: min 100	*Sonneratia*	>15	>0.5	0	*Rhizophora*	5	0
	C: min 250	*Sonneratia, Rhizophora*	>15	>0.5	0	*Rhizophora*	5	0
	D: min 50	*Sonneratia*	>15	>0.25	0.25	*Rhizophora*	10	100
Sg Singkir Laut	min 30	*Sonneratia*	>15	0.3	0.2	*Rhizophora*	5	100
Pantai Murni	10	*Rhizophora*	<5	<0.1	0.4	*Rhizophora*	15	200

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This research able to fully acknowledge and assess current condition of the mangrove forest along the Kedah's coastline as well as evaluating their performances as the reliable natural coastal protector towards wave actions. By using both remote sensing and Geographical Information System (GIS), the Kedah's coastline was fully assessed on its capability to counter average significant wave heights. Significant mangrove areas in southern Kedah's coastline were deteriorating and subjecting the coastline to further damage due possible wave attacks. Some of the mangrove belt was sufficient but some was not enough to dissipate wave actions depending on the forest band width and the forest's wave dissipation abilities. The best rehabilitation program in providing adequate mangrove belt was effectively developed with consideration of proper engineering-basis to ensure its successfulness.

5.2 Recommendations

Based on the research conducted, it was highly recommended for future studies involving remote sensing analysis of satellite images to use the images captured by the satellite during low-tide because larger tidal ranges of low tide and high tide would result in greater spectral changes for mangrove forests (Zhang et a, 2017). Next, more studies should be carried out investigating the suitable age of saplings which most suitable to be planted for effective rehabilitation program according to each species, natural roles and abilities as a component in the coastal defence mechanism. This is to ensure each species able to be established perfectly and able to play their roles.

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