ASSESSMENT ON CAPABILITY OF MANGROVE FORESTS AT KUALA SEPETANG AGAINST WAVE ATTACK USING GIS APPLICATION

by

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
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January 2015

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the reference and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(NOR KHALIDA BINTI ABD KADIR)

ABSTRACT

Mangrove forests, that is not being treated or not being acknowledged as in the past, has recently been and recognized as the valuable ecosystem. Mangrove forests are important for coastal ecosystems, serving numerous environmental services and ecological functions. Mangrove forest also plays an important function as an erosion control because it decelerates the wave before it hits the coastline area including protection from strong storm and wind. But, it does not. Mangrove forests also has been traditionally utilised by the local people for full range of purposes. However, the global mangrove forest is declining much faster than others typical forest. There is so much pressure on the mangroves itself as human exploitation heightened. Natural disaster such as tsunami back in 2004 and other extreme environmental disaster has endangered and caused further losses of mangrove forests. It is important to check the capability of the existing mangrove forests along the coastline area in withstanding the wave attack. This can enhance the managing of the mangrove areas more effectively and preserve it as it supposed to live for a long time. By using GIS application, the mangrove study area which is Kuala Sepetang is mapped based on their mangroves characteristic in attenuating the waves. After some analysis with the previous studies, the final map of the study area is produced. The result shows the study area is actually good enough in protecting the coastal area by attenuating at least 90% of the incoming waves towards the sea. It is then provided with the field observation done during the project on going.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Mangrove or “mangal” is widely known as the natural coastal protection. In order to protect the coastline area, most of the coastal area in Malaysia use mangroves that act as a very good natural coastal barrier for stability. Mangrove forest is functioned as an erosion control because it decelerating the wave before it hits the coastline area.

Clough (2013) mentioned mangroves aids coastal protection in several unique approaches. Mangrove eventually helps to reduce coastal erosion rate and including protection from strong storm and wind. Some of the ecological services provided by mangroves is the enhancement of estuarine and coastal fisheries, trapping sediments and act as sheltering for coral reefs or marine lives, and providing self-scoured, deep and navigable channels (Wolanski, 2007).

Several of the previous studies mainly discussed the mangroves changes over the years and the forecasting the shoreline changes including the depletion of mangrove cover. Natural processes of coastal area such as sea level rise and storm surge are affecting the mangrove forests. Impact from natural disaster seems make it more obvious of its functioning as coastal protection. After several tragedies happen a few years ago, the awareness of mangrove and its importance has increased. A lot of mitigation and corrective measure have been progressing day by day.

Remote sensing and geographic information systems (GIS) tools is widely known and used by the intelligent people to deliver and monitor a lots range of system not only for local but also globally since the last few decades (Hamzah et al.,2009). GIS also have been used in many case studies in order to monitor and manage the mangrove forest as it is a significant task to assess and take control any change of this ecosystem.

In order to enhance the managing of the mangrove areas more effectively, it is vital to have an assessment of mangrove forest capability at Kuala Sepetang area against wave attack. Identification and analysis of the protection performance conditions of the mangroves along the coastline area is needed for future references in order to protect the endangered mangroves.

1.2 PROBLEM STATEMENT

Experiencing the tsunami tragedy back in 2004 has boost up the study about the importance of mangrove areas as the natural shoreline protector. Mangroves are well known because of its ability to protect the coastline mostly from strong waves and winds.

However, in the past two decades, almost all the mangroves areas have experienced major net losses. One of the study mentioned, the degrading of mangroves is caused by human activities (Faridah et al., 2014). According to Alongi (2008), mangrove forests also exposed in tidal environment where changes in sea level over long timescales happened.

In concerning of threaten mangrove forest, Government has urge to protect the coastal areas in the interest to avert more mangroves losses. This also include the other environmental policies that are needed to maintain the extend and longevity of the mangrove ecosystem (Jusoff, 2008). Studies and research about mangrove forests in coastal protection is vital in order to overcome the major issues indicating the mangrove forests.

The development of new technologies as in GIS and remote sensing are widely used for the studies to portray more realistic behaviour of mangroves in order to manage and protect the mangroves forest itself. Thus, to facilitate continuous monitoring and assessment of mangrove changes, a group of researchers has used mainly GIS and remote sensing in their study (Dahdouh-Guebas, 2002; Hamzah & Omar, 2011; Kairo, Kivyatu, & Koedam, 2002; Phan, 2006; Ramachandran, 1998; Sulong et al., 2002; Wang et al., 2003). Remote sensing data and GIS are used to assess biodiversity and land cover transformation as well as classification index at the mangrove landscape (Khuzaimah et al., 2013). Assessment of the existing mangrove forest is important as it shows the real time potential and its function as coastal protection especially at Kuala Sepetang area.

1.3 OBJECTIVES

The objective of this study:

1. To assess the of mangrove forests capability at Kuala Sepetang against wave attack.
2. To identify and analyse the protection performance conditions of the mangroves along the coastline area represented by GIS application.

1.4 SCOPE OF STUDY

The study area, Kuala Sepetang is located in the district of Taiping, situated in northern state of Perak, Malaysia. Matang's geographical coordinates are 4° 49' 0" North, 100° 41' 0" East (Figure 1). It is widely known as the coastal area with mainly covered by mangrove forests.

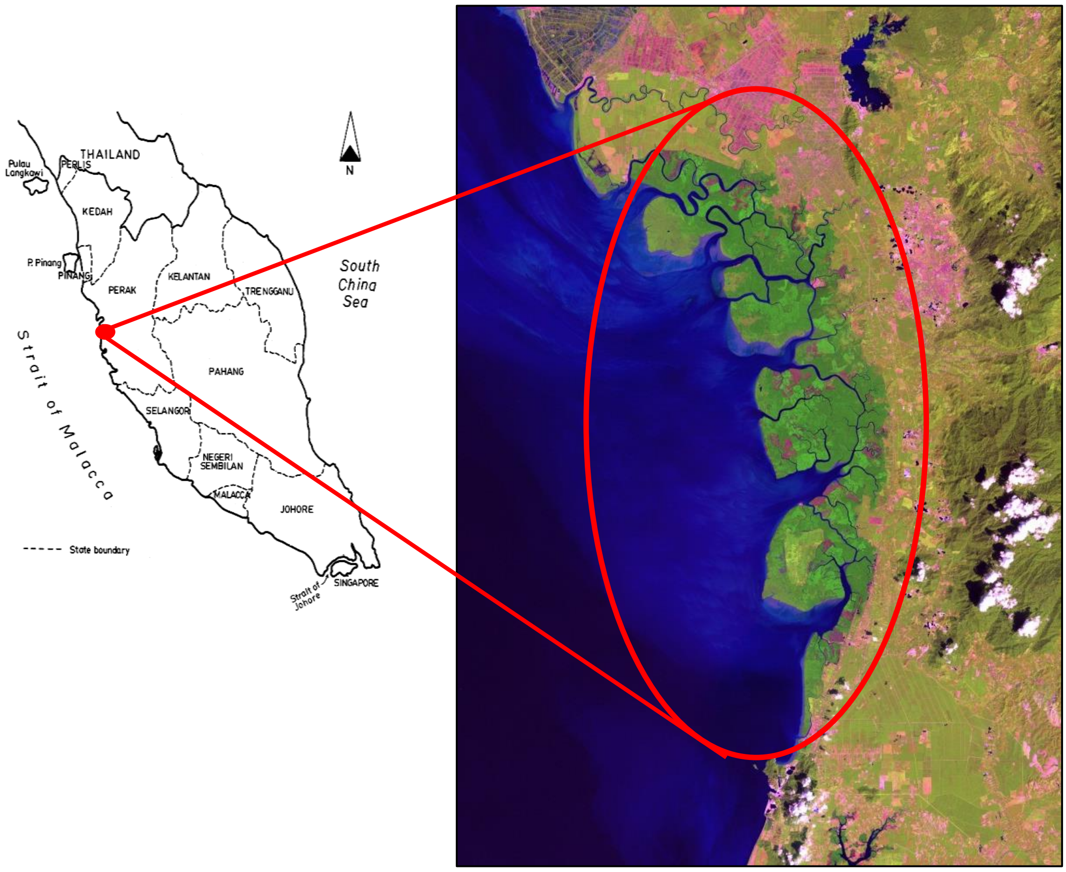


Figure 1 Location map of the study area, Kuala Sepetang, Matang, Perak

There are basically two types of data used in this study, which are satellite data and field observation data. This study will be conducted in two main phases: interpretation and analysis of satellite Landsat TM imagery. The results were carried out during ground truthing to assess the accuracy of classification mangrove forest types map compared the real condition on the ground. Both phases were linked to GIS processing for spatial analysis and digital map production. Then, a field observation will be carried out at selected locations along Matang's mangrove forests to verify the results produced from the image processing and to investigate factors contributing to the problem and the changes.

Generally, there are three parts to be covered in this study to accomplish the target. The first important part is collecting the data. The satellite images of the study area need to be acquired ahead. Several types of satellite images with good high resolution need to be analysed and choose the one that suitable to be used in the project. Then, after identifying the study area, several data from the field site need to be gathered. Some of the mangroves data such as, the species, types, age and density can be collected at the study area.

The second part is data image processing on the selected satellite images using GIS software. In this part, the author is using GIS software to indicate the mangrove study area based on their performance conditions. The third part is data analysis. The analysis will be done by producing a map that representing the mangrove area using some of the mangrove performance conditions. Hence, the assessment of the existing mangrove forests capability against the wave attack can be done.

CHAPTER 2

LITERATURE REVIEW

2.1 MANGROVE FOREST

Figure 2 Mangrove areas in Peninsular Malaysia for 2010 (Faridah-Hanum et al., 2014)

3.7% of total global mangrove area is acknowledged as Malaysia's mangroves forest (Giri et al., 2011). The coast of Malaysia stretches for 4675 km which consider Peninsular Malaysia for 2068 km and East Malaysia with 2,607 km of coastline length. While it is estimated about 5700 km^2 from the coastline area is covered with the mangrove forests.

Mangroves basically have approximately 16 families and 40 to 50 species based on classification. Mangrove forest in Malaysia is unique with diverse ecosystem. Based on ("Friends of Mangrove," 2013) most of the mangroves are usually from *Avicennia, Rhizophora, Sonneratia and Bruguiera.* There are several types other than the family of species above that include *Malvaceae, Palmae, Acanthaceae, Pteridaceae* and others.

Mangrove species distinguish easily by their own uniqueness. It can be easily identified typically based own their special roots which can be found grown in the muddy area in the inter-tidal zones. The root system works in a way that it traps soil and facilitates as habitat or shelter for numerous species of flora and fauna. The fact that it is situated in between the tidal zones, become a good reason for mangroves area to be an excellent coastal protection against wave attack or other threaten event.

2.2 MANGROVES AS COASTAL PROTECTION

Several unique adaptations of mangrove trees that support them to endure in the harsh mangrove areas need to face the fierce wave first before it hit the other part of coastline area. Mazda et al. (2006) presented that the wave reduction depends on the mangrove species, vegetation condition, water depth and the incident wave condition. However, *Sonneratia sp.* of mangroves plays an important role due to its unique vertical configurations in reducing the sea waves.

Capacity of mangrove to attenuate wind and swell waves reviewed by McIvor et al., (2012) proved that the vital factor affecting wave attenuation in mangroves is the density of obstacles that waves encounter as they move through mangrove, and the height relative to the water depth. Basically, these obstacles or these mangroves have successfully attenuated the wave. But it generally depends in the width of mangrove forest, mangrove tree morphology relative to water depth, topography and wave height.

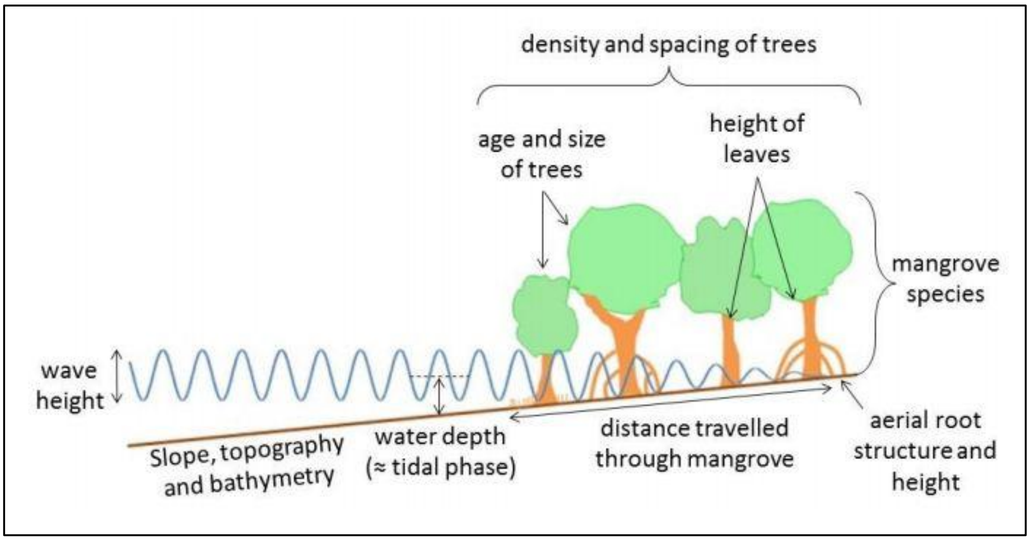


Figure 3 Factors affecting wave attenuation in mangroves McIvor et al., (2012)

Furthermore, the laboratory study by (Hashim & Catherine, 2013) proved the facts that mangroves are able to attenuate the wave. Mangrove species, its density, band width and mangrove age are the usual factor that influencing the wave reduction rate. For the experiment, they used 20 years old *Rhizophora* tree and it is scaled down by a factor of 10. As the result, they found out that, in the area with mangrove forest clearly able to reduce the wave two times better than the area without mangroves. Another study of field observation for wave reduction also verified the fact that mangroves are able to attenuate the wave depending on several factor as such variability of mangrove vegetation structure and the incident wave height (Horstman et al., 2014).

Coastal erosion now can be specify as the most concern thing that every nations need to focused on. According to (Ong & Gong, 2013), coastal erosion is subjective towards the coastline shape, wave directions, wave energy, velocity of current and tidal amplitude. However, it can be affected predominantly by strong near shore currents and wind waves. In this study also state that mangrove actually helps to protect from coastal erosion by their dense below-ground root systems that acts to hold the sediments. Besides, their above-ground roots and trunks successively decelerate the water flowing hence reducing surface erosion of the coastline area.

As mentioned by Faridah-Hanum et al. (2014), some of the mangrove forests in Malaysia are experiencing a lot of changes in term of mangrove cover. There are several facts that led to significant mangrove losses. First major causes is direct conversion of mangrove areas to other land uses, mostly for aquaculture and agricultural. In addition, coastal erosion also gives a huge impact for the endangered mangroves.

One example for the mangrove changes is mangrove areas in Pulau Langkawi. Latiff (2012) discovered in 1980, the whole mangrove cover for Pulau Langkawi is about 37 km^2 and subsequently, 11 years after that, the extent of the mangroves areas decreased by 10.6% to 33 km^2. Most of the changes are caused for aquaculture, resorts, chalets and others uses to maximize the beautiful landscape of Pulau Langkawi for eco-tourism purpose.

2.3 APPLICATION OF GIS FOR COASTAL AREA

Table 1 Previous studies of application of GIS for coastal area

SOURCE	**LOCATION, REMOTE SENSING**	**HOW IS THE SATELITTE IMAGES USED?**
Long & Skewes, (1996)	Southern Gulf of Carpentaria, Australia Landsat TM	10 training set of area were mapped in full mangrove cover. The highest and lowest training set values for each band is defined and mapped for the remaining mangroves. More sub-area is defined based on the distance from water and ground elevation [higher and lower than 10 m above mean sea level (MSL)].
Kairo, Kivyatu, & Koedam, (2002)	Kiunga Marine Protected Area, Lamu, Kenya aerial photographs	Medium scale of black and white panchromatic aerial photograph is used. Tone, crown texture, mangrove structures and tree height are useful in differentiating the mangrove species.
Sulong et al., (2002)	Kemanan, Terengganu Aerial photograph and Landsat TM	Classification for the mangroves of the district of Kemaman were done using both 1 : 5000 aerial photographs and Landsat TM imageries. Aerial photograph is used for the identification of the mangrove forest characteristic. While for Landsat imagery, the false colour of thematic band 4-5-3(red-green-blue) was prepared for the visualization. Last, ground trothing is done to verify naming of the forest types.
Hamzah et al. (2009)	Selangor Landsat TM, Landsat ETM+ and SPOT XS	Several sets of satellite imageries were used to identify the distribution and areas of existing mangrove forests and changes for that area from 1989 to 2007. It was first exported the data into shp. file then it is edited in GIS.

After years, there is a lots of new advance technology invented to illustrate more meaningful studies regarding the coastal area. Visualisations of the world have been critically improved by the usage of satellite images. Satellite images of Landsat, SPOT, of IKONOS are the popular among the researchers as it provide relatively high resolution of earth observation data. Landsat imagery is acquired from the NASA Landsat satellite's sensors. Landsat 7 is the most popular satellite for the past few years. It has the best quality imagery by using ETM+ sensor following the World Reference System. The geo-reference format for Landsat imagery includes a UTM projection and a WGS84 datum.

CHAPTER 3

METHODOLOGY

This study basically to assess the capability of mangrove forest against the wave attack at Kuala Sepetang area. Critical literature reviews are important in order to identify what is the aspect that needs more attention as to express the capability of the mangroves area. Therefore by using GIS application, we can identify the mangroves area based on their specification such as age and types. From these results, we can then analyse the capability of the mangrove forest as we compared it with previous studies done by Hashim & Catherine, (2013) relating the wave reduction by mangrove forest based on laboratory study. The derivation of this interaction is used to assess the capability of the mangroves forests in withstanding the incoming wave attack.

Several visits to the study area also need to be conducted as a validation to the analysis data collected before. From these site visits, a few data of the mangroves tree and its surrounding will be collected as evidence to the illustration presented by the GIS application.

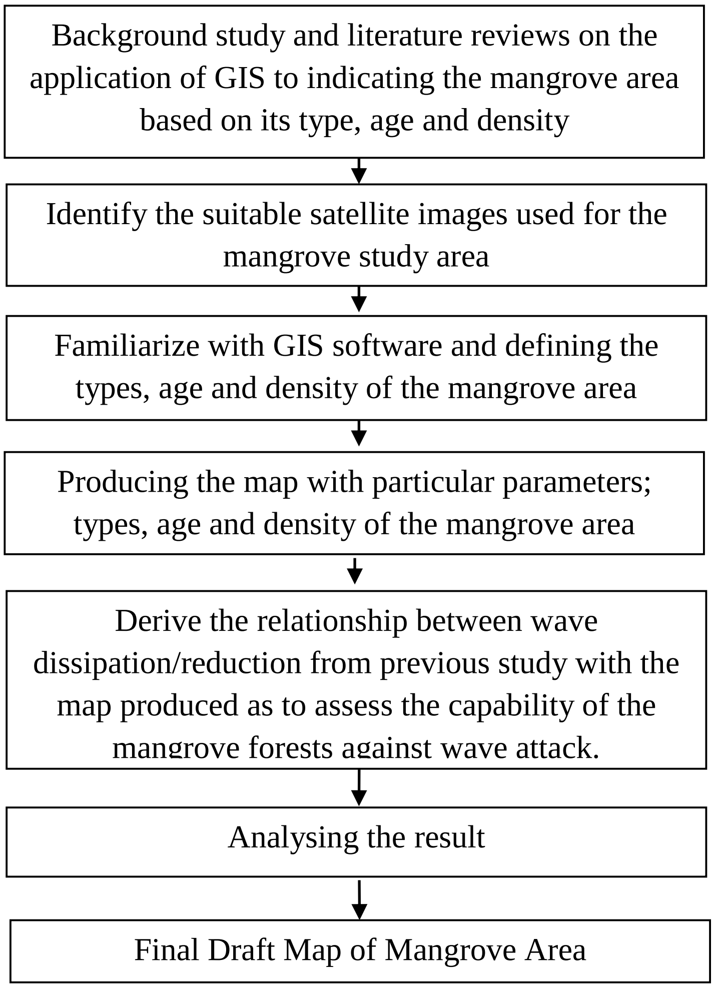


Figure 4 Research methodology and project activities

3.1 Field Assessment or Ground Truthing

This study is basically a simplified approach of mangrove forest assessment in withstanding the wave attack. The first method is the field assessment or ground thruting. The study area is chosen based on the accessibility of the area and also the information that can be provided by the local authority or the management of that area. These two are the important factor that contributing to the selection of the study area. For the first site visits, Kuala Gula, Balik Pulau, Kuala Muda and Kuala Sepetang were the areas that are classified to be the possible study area. From these sites, Kuala Sepetang was the most suitable locations as it can be easily access and it has their own management so that it will be easier to get the information for the study.

The next site visits it to gather all the information needed as the input for the GIS analysis later on. First input is the types of the mangroves at Kuala Sepetang. The forester at Kuala Sepetang was helping in order to recognize and classify each of the mangroves there. The density also being calculated based on the information given by the forester and a few locations at the study area was calculated for the confirmation. Next is the age of the mangrove forest which is done also by the help of the forester. Each of the mangroves especially Rhizophora sp. age is calculated basically by its own features such as, its roots and the trunk diameter. These three inputs are next used in the GIS framework while comparing it with the previous study.

Figure 5 Measuring the Age of Mangrove Trees

To further validate the final result of this assessment, there is another visit to the study area after the GIS analysis is finish. This final visit is used to survey the validity of the three data input used earlier for the GIS framework.

3.2 GIS Analysis

This study was using the satellite images and then analyse the result with the comparative analysis done with the previous study. Satellite images of recent years with medium resolution were used for the study. The suitable satellite images is chosen and downloaded from the USGS (U.S. Geological Survey) website. The image is then will be transfer for the GIS framework for next analysis. For this study, Landsat 8 OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor) are used. It is from the panchromatic satellite with ETM+ thermal sensor. The satellite images is classify as 8-bit quality band file with 0.52 - 0.90 µm and 15 metres pixel resolution.

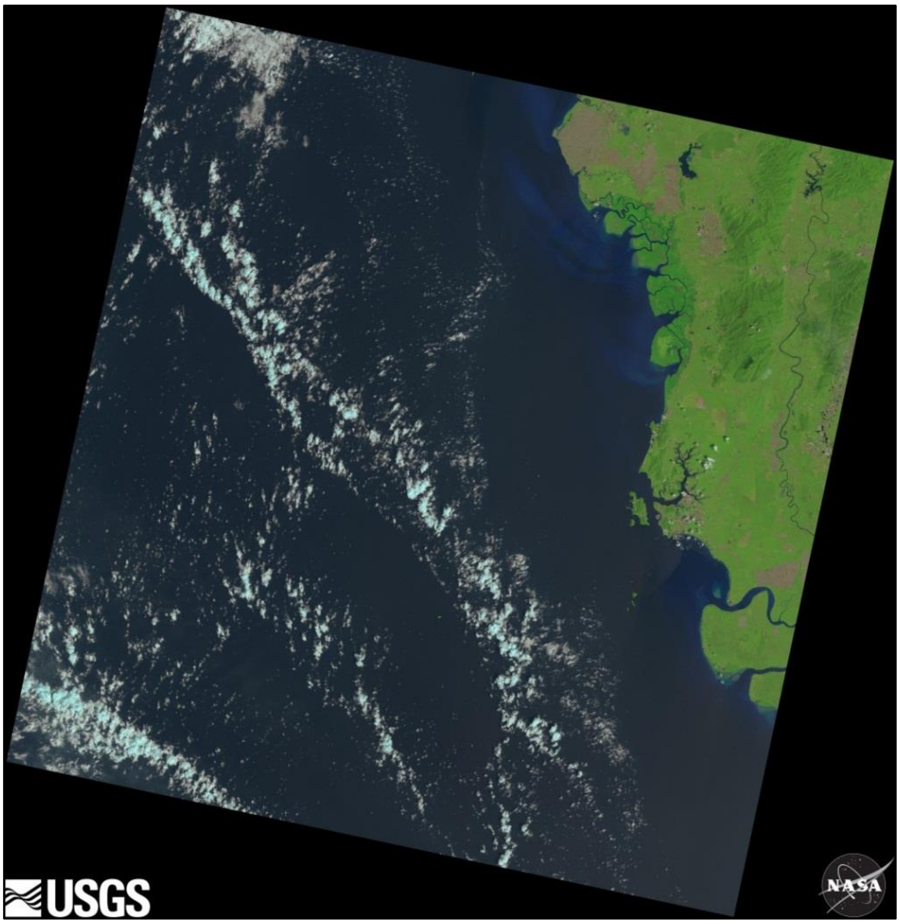


Figure 6 Landsat Look "Natural Colour" Image: Landsat 8 Path 128 Row 57

Figure 7 Clip of Kuala Sepetang area from the satelitte images.

The inputs earlier from the field assessment is then transfer into the GIS software. Each of the inputs is classified based on the own parameters. All of the inputs is used and compared with the previous study. The graph (APPENDIX 5) used shows the percentage of wave reduction for the parameters inputs earlier. There graph basically have the mangrove ages, density and the types used for their study. Hence, the inputs are then being compared with the value in the graph to get the percentage of wave reduction then to assess the study area.

CHAPTER 4

RESULTS AND DISCUSSION

As been discussed by Hizamri Hashim & Ariffin (2014), remote sensing and GIS is considered as the new alternative for mangrove mapping technology as it tolerates information to be gathered and used it for the management purposes. Nowadays, with the serious increasingly awareness about the importance of mangroves, satellite images is used as it gives more accurate information. It is crucially needed in classifying and delineating mangrove forests in order to determine the functional forest classes into management zones.

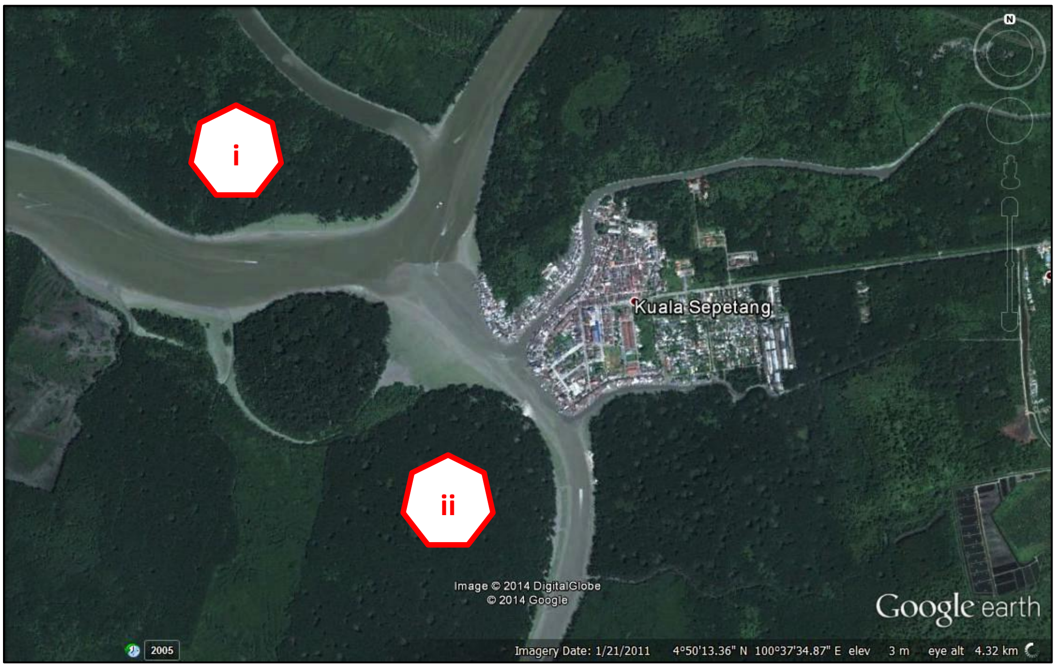


Figure 8 Kuala Sepetang Mangrove Area (i) The productive forest (ii) Virgin Jungle Reserve

Kuala Sepetang or Matang mangroves have its own management systems. Ismail (2014) in his research stated that the mangroves are managed by dividing the forest into Working Class. Currently, Matang mangroves are in the third 30-year rotation period which will continue until 2039. From the field observation on 18th December 2014, several areas that have been mentioned before as it included in the management zones is been observed. The productive forest (production of timber) area has a buffer zone that length about 5 to 10 m of mangrove covers that cannot be cut. Hence, mangrove forest behind the buffer zone is then used for the timber productions and other uses. It also has been informed by En. Mohammad Razalee, Forester of Kuala Sepetang, mangroves cover in Kuala Sepetang has been experiencing degradation. The virgin jungle reserve (VJR) is actually a wild mangrove without any interruption from human activities. But, from figure (ii) the mangrove cover of VJR area has been loss about 25 to 30m in 30 years.

From previous studies, Hamzah et al., (2009) several sets of satellite images need to be utilised to identify distribution and areas of currently existing mangroves and changes that have undergone within that area. Ramachandran (1998) in his research also stated, the application of GIS in analysing the trends and assessing the changes that have occurred in different subjects helps in management decision making process. Overlaying analysis of GIS allows monitoring the variation of mangrove for each type and different time intervals and to establish an accurate map of fluctuations of mangrove area quickly. The coastal ecosystems are to be monitored periodically for better management plans. There is another study by Hamzah and Omar (2011) which is forecasting the future impacts cause by coastal erosion and sea level rise towards mangroves forest at the coast of Kuala Langat, Selangor. The coastal vulnerability index (CVI) is utilized to provide understanding into the possible coastal changes due to seal level rise.

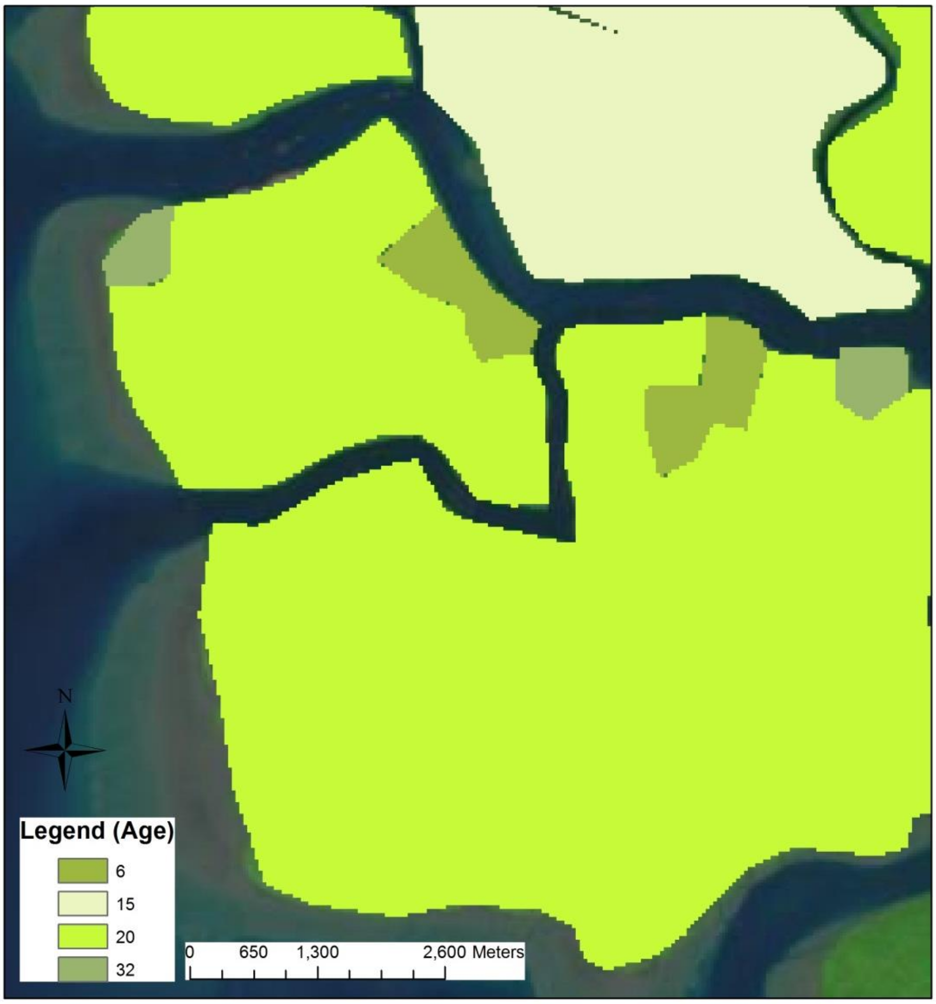


Figure 9 The distribution of mangrove forest in Kuala Sepetang area according to their age.

From the field observation data and analyses, the age of the mangrove in the study area is distributed as above figure. In Kuala Sepetang, there are already differentiate some of the area for different purposes. The 6 years old mangrove which is about 3% of the study area is actually the new planted mangroves, while about another 18% is 15 years old, and it is ready to be served for timber production purposes. Others are mainly about 20 year's old mangrove and another 1% of the area is gazette as the Virgin Jungle Reserve.

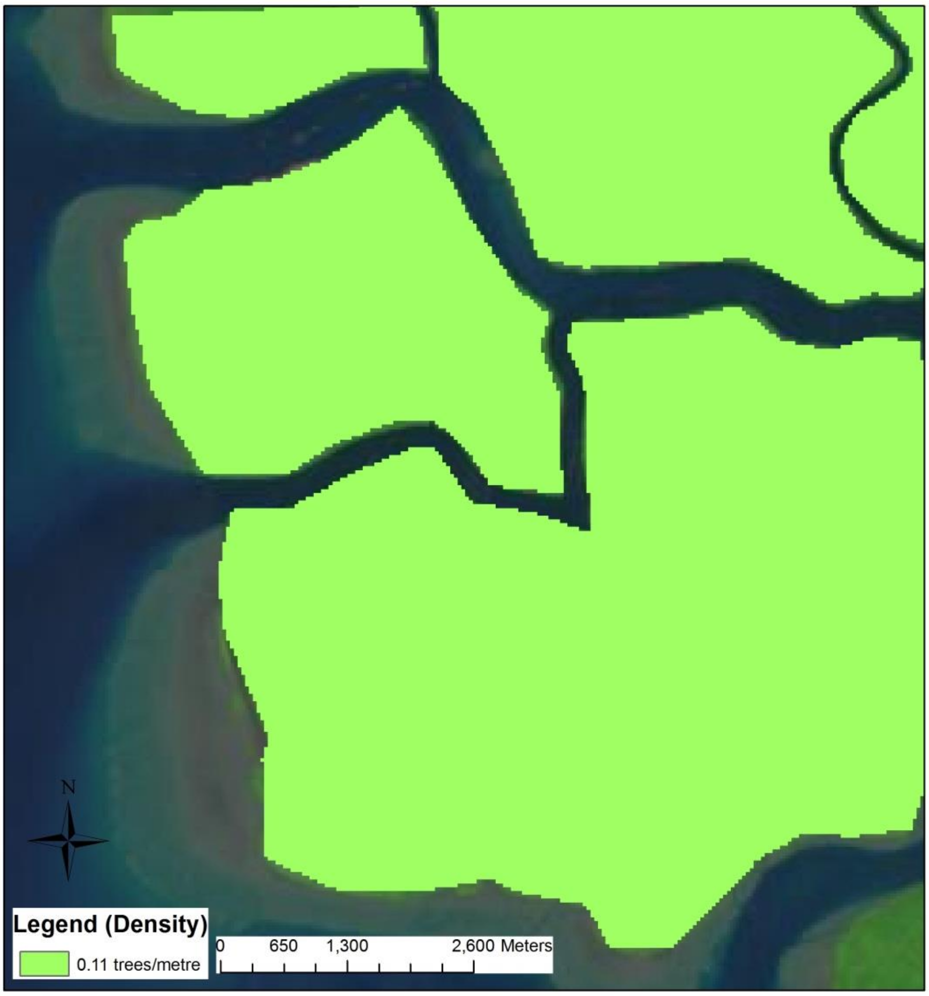


Figure 10 The distribution of mangrove forest in Kuala Sepetang area according to their density.

In Kuala Sepetang area, the density of the mangrove forests can classify as average of 0.11 trees /metre^2. The management of the mangrove forest at Kuala Sepetang has their own specification on planting the mangroves at that area. They are planting the mangroves with spacing of 1.2 meters and 1.8 meters respectively (Hashim & Catherine, 2013). Hence, the comparative analysis done shows that this mangrove area is an average of sparse.

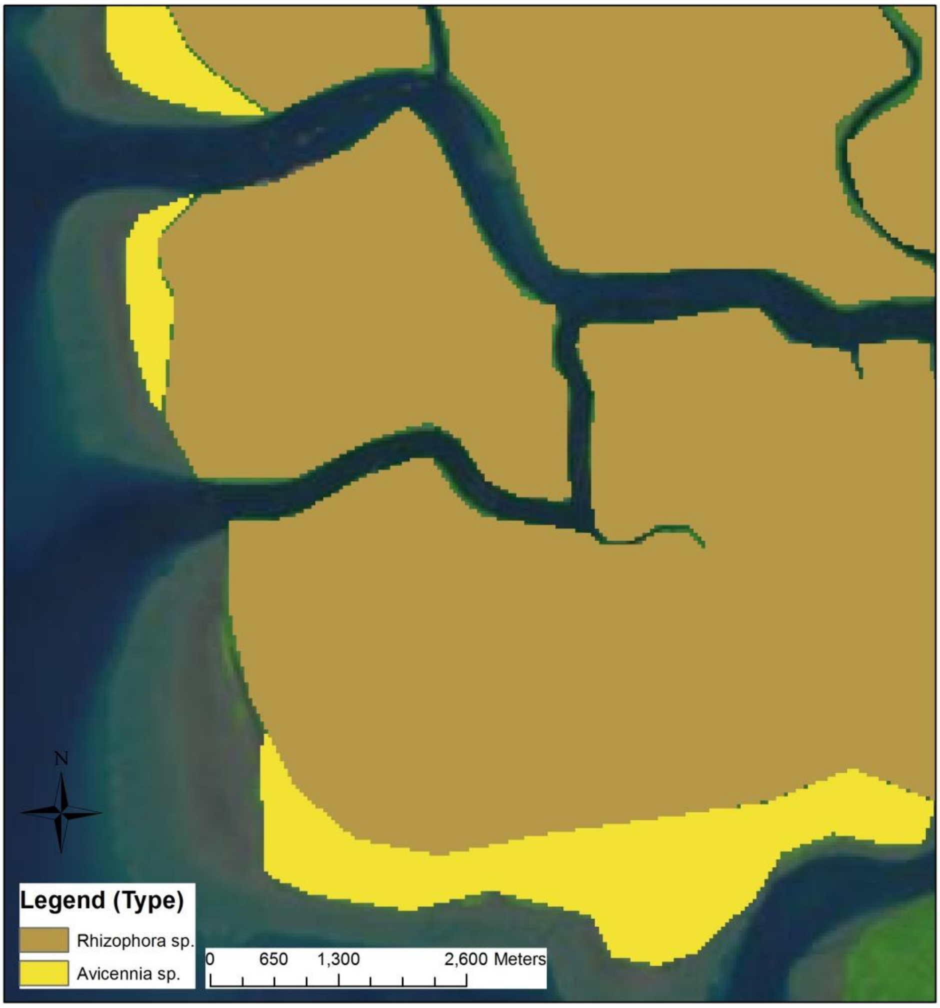


Figure 11 The distribution of mangrove forest in Kuala Sepetang area according to their type.

From above figure, Kuala Sepetang area is mainly covered with *Rhizopora sp.* while another 10% is covered by *Avicennia sp.* . Previously, in the literature review, it has been proved that rhizophora is one of the best wave attentuater among other mangrove species. Laboratory studies by Hashim and Catherine (2013) stated that 80m wide of this type of mangrove forest is good enough to reduce wave height by 80%. This study area is already wide enough in order to attentuate the wave coming toward the mangrove forest.

Figure 12 Vulnerability grade for the mangrove forest in Kuala sepetang area with the capability in attentuating the incoming wave height.

The map is produced by deriving the relationship between the wave dissipation or wave attenuate from previous study done by Hashim and Catherine (2013) with the field data from the ground truthing done during the project activities. The vulnerability grade is characterized based on the percentage of wave reduction from the graph in APPENDIX 5. There are basically 4 type of vulnerability grade for this assessment:

Table 2 Vulnerability Grade

Vulnerability Grade	Percentage of Wave Reduction (%)
None	80
Low	70
Moderate	60
High	<50

From Figure 12, the study area can be concluding to have a good characteristic as the coastal protection because it can attenuate almost more than 80% of the incoming wave. The outer layer of the study area is covered with *Avicennia sp.* which is about 0.5km to 1km wide. The other part of mangrove forest of *Rhizophora sp.* is ranging between 7km to 8km from Kuala Sepetang towards the sea. This wide of mangroves forest is good enough to protect the coastal communities at Kuala Sepetang area. There is one more coastal community near the river mouth of Sungai Sangga Besar, Kuala Sepetang. There area is called Kuala Sangga Village with population about 300 people.

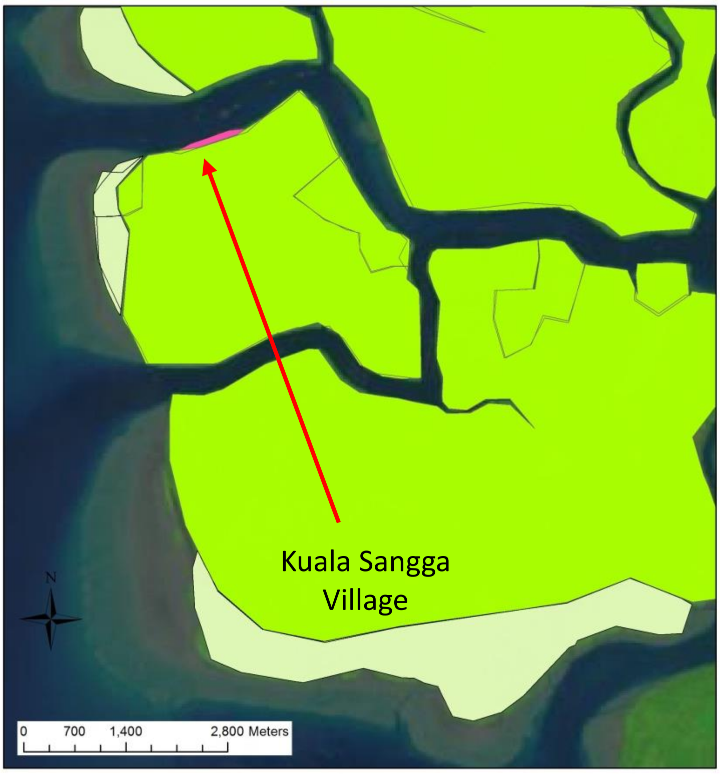


Figure 13 Location of Kuala Sangga Village

Figure 14 Vulnerability grade for the mangrove forest in Kuala Sangga Village area with the capability in attenuating the incoming wave height.

This area is quite far from the open sea although it is situated at the river mouth of that area. The village is located about 1km from the open sea. The mangrove forest width is actually good enough in protecting the village area. This area is classified as not vulnerable area from the incoming sea waves.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

It is showed in the map produced that which area is good enough in protecting the coastal area. Mangrove ages, types, density and wide of the area play important roles in attenuating the waves. The study area is basically had more than sufficient wide of mangrove forests to attenuate the wave. Through the study, the age of the mangroves also plays important roles in attenuating the waves; however in this study area is mainly covered with 20 years old *Rhizophora sp.* which is found by Hashim and Catherine (2013) as the good matured age for the mangrove to attenuate the waves. It actually can reduce about 4 times larger wave compared to the area without mangroves cover. Hence, that is why almost all of the area as presented in the map can attenuate at least 80% of the incoming waves.

Vulnerability and the assessment of the mangrove forest against the wave attack are done by this simplified approach as it helps showing which existing area is vulnerable or not. In Kuala Sepetang area, almost 90% of the total study area can attenuate wave coming from the sea. Furthermore, in Kuala Sangga area too, the mangrove forests acts it best to reducing the incoming wave from the sea. Based on the results of this study, mitigation measures should be considered for securing the future of these mangrove ecosystems and also the coastal communities at the study area.

REFERENCES

Alongi, D. M. (2008). Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. *Estuarine, Coastal and Shelf Science, 76*(1), 1-13. doi: http://dx.doi.org/10.1016/j.ecss.2007.08.024

Clough, B. (2013). *Continuing the Journey Amongst Mangroves*: International Society for Mangrove Ecosystems.

Dahdouh-Guebas, F. (2002). The use of remote sensing and GIS in the sustainable management of tropical coastal ecosystems. *Environment, Development and Sustainability, 4*(2), 93-112.

Faridah-Hanum, I., Latiff, A., Khalid Rehman, H., & Munir, O. (2014). *Mangrove Ecosystems of Asia Status, Challenges and Management Strategies*.

Friends of Mangrove. (2013). Retrieved 30 October, 2014, from http://www.friendsofmangrove.org.my/

Giri, C., Ochieng, E., Tieszen, L., Zhu, Z., Singh, A., Loveland, T., . . . Duke, N. (2011). Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography, 20*(1), 154-159.

Hamzah, K. A., & Omar, H. (2011). Vulnerability Assessment of Coastal Zones Using Geospatial Technologies. *IUFRO World Series Vol. 29*, 10.

Hamzah, K. A., Omar, H., Ibrahim, S., & Harun, I. (2009). Digital change detection of mangrove forest in Selangor using remote sensing and geographic information system (GIS). *The Malaysian Forester, 72*(1), 61-69.

Hashim, A. M., & Catherine, S. M. P. (2013). A Laboratory Study on Wave Reduction by Mangrove Forests. *APCBEE Procedia, 5*(0), 27-32. doi: http://dx.doi.org/10.1016/j.apcbee.2013.05.006

Hizamri Hashim, & Ariffin, R. (2014, November 24-26, 2014). *MATANG MANGROVES THROUGH THE PASSAGE OF TIME*

Paper presented at the Matang Mangrove Forest Management Conference

Casuarina@Meru Hotel, Ipoh Perak

Horstman, E. M., Dohmen-Janssen, C. M., Narra, P. M. F., van den Berg, N. J. F., Siemerink, M., & Hulscher, S. J. M. H. (2014). Wave attenuation in mangroves: A quantitative approach to field observations. *Coastal Engineering, 94*(0), 47-62. doi: http://dx.doi.org/10.1016/j.coastaleng.2014.08.005

Ismail, S. M. (2014, November 24-26, 2014). *MATANG MANGROVES THROUGH THE PASSAGE OF TIME.* Paper presented at the Matang Mangrove Forest Management Conference, Casuarina@Meru Hotel, Ipoh Perak.

Jusoff, K. (2008). Managing Sustainable Mangrove Forests in Peninsular Malaysia. *Journal of Sustainable Development, 1*, 88-96. doi: 10.5539/jsd.v1n1p88

Kairo, J., Kivyatu, B., & Koedam, N. (2002). Application of remote sensing and GIS in the management of mangrove forests within and adjacent to Kiunga Marine Protected Area, Lamu, Kenya. *Environment, Development and Sustainability, 4*(2), 153-166.

Khuzaimah, Z., Ismail, M., & Mansor, S. (2013). Mangrove Changes Analysis by Remote Sensing and Evaluation of Ecosystem Service Value in Sungai Merbok's Mangrove Forest Reserve, Peninsular Malaysia. In B. Murgante, S. Misra, M. Carlini, C. Torre, H.-Q. Nguyen, D. Taniar, B. Apduhan & O. Gervasi (Eds.), *Computational Science and Its Applications – ICCSA 2013* (Vol. 7972, pp. 611-622): Springer Berlin Heidelberg.

Latiff, A. (2012). Conservation strategies for endangered mangrove swamp forests in Malaysia. *Pakistan J Bot, 44*, 27-36.

Long, B. G., & Skewes, T. D. (1996). A Technique for Mapping Mangroves with Landsat TM Satellite Data and Geographic Information System. *Estuarine, Coastal and Shelf Science, 43*(3), 373-381. doi: http://dx.doi.org/10.1006/ecss.1996.0076

Mazda, Y., Magi, M., Ikeda, Y., Kurokawa, T., & Asano, T. (2006). Wave reduction in a mangrove forest dominated by Sonneratia sp. *Wetlands Ecology and Management, 14*(4), 365-378. doi: 10.1007/s11273-005-5388-0

McIvor, A., Möller, I., Spencer, T., & Spalding, M. (2012). Reduction of wind and swell waves by mangroves. *Natural Coastal Protection Series: Report 1, Cambridge Coastal Research Unit Working Paper 40*.

Ong, J. E., & Gong, W. K. (2013). *Structure, function and management of mangrove ecosystems*: International Society for Mangrove Ecosystems.

Phan, M. (2006). Application of Remote Sensing and GIS Tools for Recognizing Changes of Mangrove Forests in Ca Mau Province, Dept. Marine Environment & amp. *Ecology*.

Ramachandran, S. (1998). Application of remote sensing and GIS. *Madras University*.

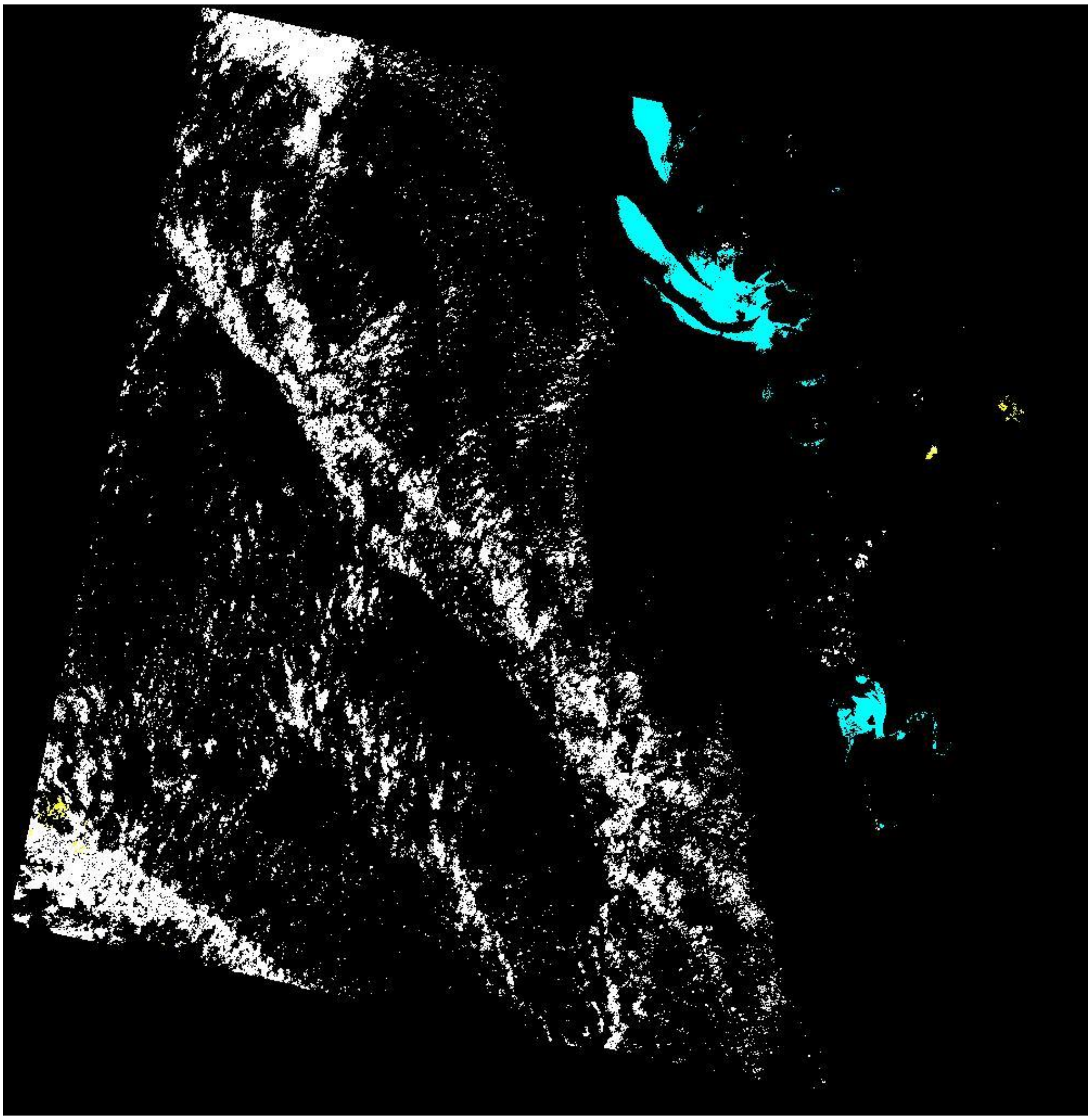
Sulong, I., Mohd-Lokman, H., Mohd-Tarmizi, K., & Ismail, A. (2002). Mangrove mapping using Landsat imagery and aerial photographs: Kemaman District, Terengganu, Malaysia. *Environment, Development and Sustainability, 4*(2), 135-152.

Wang, Y., Bonynge, G., Nugranad, J., Traber, M., Ngusaru, A., Tobey, J., . . . Makota, V. (2003). Remote sensing of mangrove change along the Tanzania coast. *Marine Geodesy, 26*(1-2), 35-48.

Wolanski, E. (2007). Protective functions of coastal forests and trees against natural hazards. *Coastal protection in the aftermath of the Indian Ocean tsunami: What role for forests and trees*.

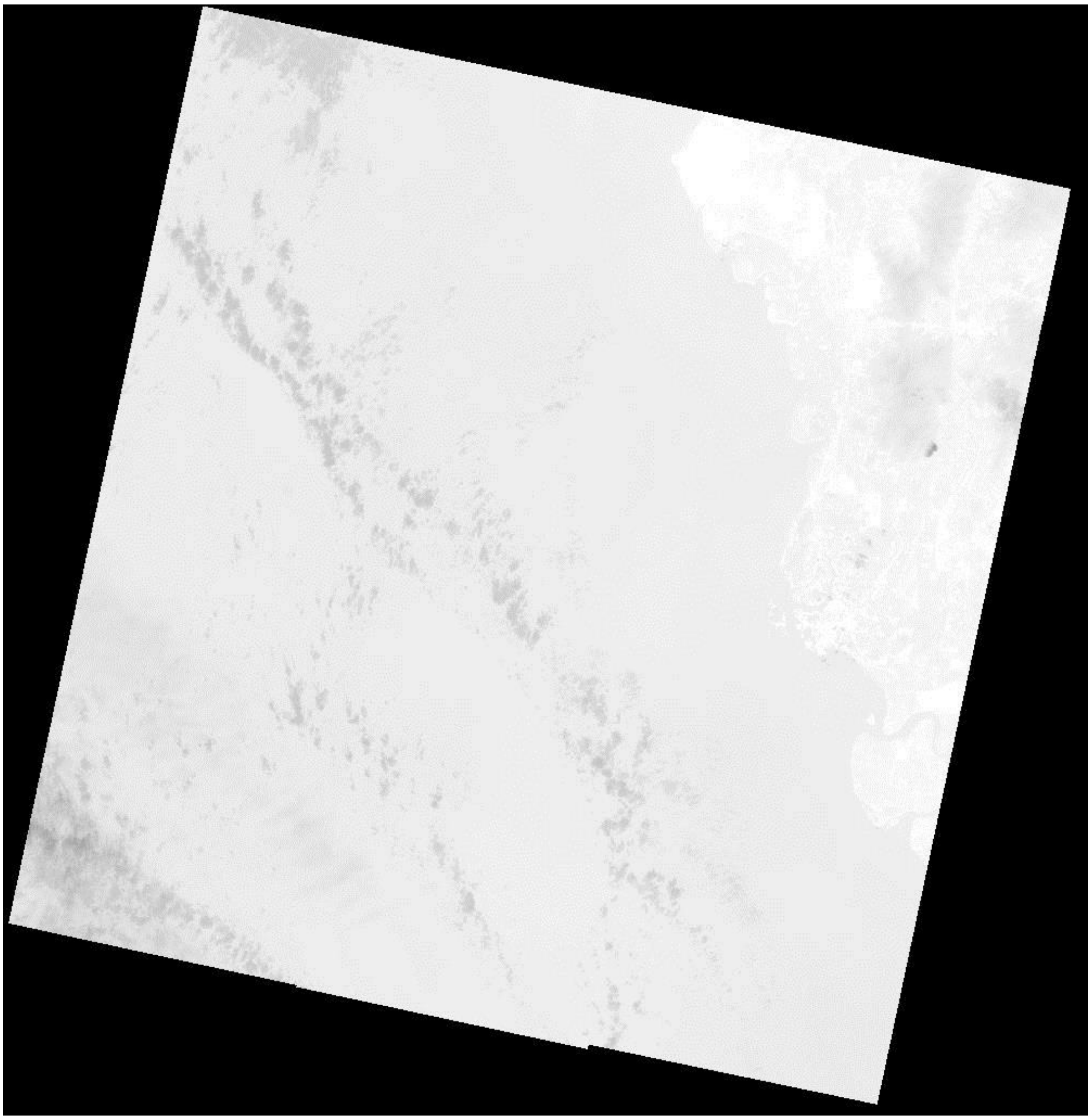
APPENDICES

APPENDIX 1



LandsatLook "Quality"

APPENDIX 2



LandsatLook "Thermal" image.

APPENDIX 3

Table : Metadata of the satellite image used in the project

Data Set Attribute	**Attribute Value**
Landsat Scene Identifier	LC81280572014042LGN00
WRS Path	128
WRS Row	057
Target WRS Path	128
Target WRS Row	057
Full or Partial Scene	FULL
Nadir/Off Nadir	NADIR
Data Category	NOMINAL
Bias Parameter File Name OLI	LO8BPF20140211031534_20140211040321.01
Bias Parameter File Name TIRS	LT8BPF20140211031140_20140211040414.01
Calibration Parameter File	L8CPF20140101_20140331.03
RLUT File Name	L8RLUT20130211_20431231v09.h5
Roll Angle	-.001
Station Identifier	LGN
Day/Night	DAY
Data Type Level 1	L1T
Sensor Identifier	OLI_TIRS
Date Acquired	2014/02/11
Start Time	2014:042:03:35:00.4562330
Stop Time	2014:042:03:35:32.2262290
Image Quality	9
Scene Cloud Cover	9.18

Sun Elevation	55.3522211
Sun Azimuth	122.53693076
Geometric RMSE Model X	5.406
Geometric RMSE Model Y	5.314
Browse Exists	Y
Processing Software Version	LPGS_2.3.0
Center Latitude	4°20'21.52"N
Center Longitude	100°07'29.71"E
NW Corner Lat	5°23'10.54"N
NW Corner Long	99°28'13.91"E
NE Corner Lat	5°01'41.12"N
NE Corner Long	101°08'55.36"E
SE Corner Lat	3°17'04.27"N
SE Corner Long	100°46'34.36"E
SW Corner Lat	3°38'44.41"N
SW Corner Long	99°06'07.27"E
Center Latitude dec	4.33931
Center Longitude dec	100.12492
NW Corner Lat dec	5.38626
NW Corner Long dec	99.47053
NE Corner Lat dec	5.02809
NE Corner Long dec	101.14871
SE Corner Lat dec	3.28452
SE Corner Long dec	100.77621
SW Corner Lat dec	3.64567
SW Corner Long dec	99.10202

APPENDIX 4

Kuala Sepetang Mangrove Area (i) The productive forest (ii) Virgin Jungle Reserve

(i) The productive forest (Production of timber)

(ii) Virgin Jungle Reserve

APPENDIX 5

Figure used to derive the relationship between wave dissipation from the previous study by (Hashim & Catherine, 2013) and (Hashim & Noraini) with the map produced.