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MULTI METHOD ANALYSIS FOR IDENTIFYING THE SHORELINE EROSION DURING NORTHEAST MONSOON SEASON

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Abstract: The occurrences of natural hazard is increasing in frequency and brings with it various impacts on coastal areas, such as coastal erosion along the shoreline of Malaysia. The study of National Coastal Erosion Study (NCES) on 2015 revealed that 8840 km of shoreline in Malaysia with 1,347.6 km were subjected to erosion. The present study selected seven locations in Kuala Terengganu since Terengganu is exposed to the northeast monsoon which could potentially cause coastal erosion. In order to identify the changes in the shoreline of the selected study areas, 2014SPOT-5 and 2016 WorldView-3 images were processed using ArcGIS software to determine the shoreline changes and to categorise the erosion which has occurred. Results show that the erosion in Zone B is more dynamic compared to that in Zone A, as shown by the highest rate8.04% of erosion from Pantai Rhu extending to Pantai Marang. Erosion in Pantai Batu Buruk and Kuala Ibai, respectively with Zone A dominated by the anthropogenic and natural factors, while Zone B dominantly by natural factor only. Therefore, finding an empirical study of analyse the shoreline erosion in Malaysian monsoon environment might provide valuable information for sustainability coastal management.

Keywords: Coastal erosion, geospatial, Kuala Terengganu, monsoon, wave modelling

Introduction

Shoreline is defined as the line where land and water surface meet at a particular elevation (Fazly Amri Mohd *et al*., 2018; Misra & Balaji, 2015; O'Carroll 2010). In fact, Cooper & Pilkey (2004) contended that shoreline continuously change its shape and position due to dynamic environmental conditions; they also asserted that shoreline can also be categorized as the most crucial component in research which involve sea level rise, shore protection, tidal inundation, land subsidence, and erosion sedimentation process. These physicals processes contribute to shoreline change and formation of coastal landscape. Furthermore, the diverse development project carried out close to or around the shoreline area exert great pressure on the area and could lead to various coastal hazards such as soil erosion, sea water intrusion, coral bleaching, and altered shorelines (Kuleli *et al.*, 2011; Jaafar *et al.*, 2016). As the level of the world ocean rises, low-lying coastal area could potentially disappear and coastal areas could experience frequent flooding (Mohd *et al.*, 2018). Sarkar (2014) and Mohd *et al.,* (2018) contended that the occurrences of extreme high water events that are related to storm surges, high tides, surfaces waves, and flooding rivers will also increase in frequency. This increase, which is brought about monsoon changes, is sufficient to cause global sea level rise and have a profound impact on developing countries such as Malaysia.

In the Peninsular Malaysia, the east coast (especially Terengganu) is more exposed to climate change which will affect the livelihood of the communities and cause damage to the infrastructure in comparison to the areas in the west coast (Muhammad *et al.*, 2016). Mohd Fadzil Mohd Akhir & Chuen, (2011) and Ariffin *et al.,* (2018) mentioned that the east coast of Peninsular Malaysia, which faces the South China Sea, is exposed with the northeast monsoon storm which is prone to cause coastal erosion. This assertion is supported by the findings of studies conducted by Brijker *et al.*,(2007) and Oppo *et al.*, (2009).They found that since the central region of Terengganu experiences the Asian monsoon system, this area holds important geological records and is able to provide an understanding of monsoon variation with time and the impact of changes in coastal systems (Adiana *et al.*, 2011; Mohd Fadzil Mohd Akhir & Chuen, 2011).

Recently, several approaches for mapping shorelines and detecting changes have been utilized; for instance, traditional shoreline mapping in small areas is done by using conventional field survey method. However, conventional methods such as aerial photo and ground survey are costly and require trained staff, in addition to being time consuming.

Hence, other options, such as remote sensing and Geographic Information System (GIS), have been widely used to improve conventional methods (Shin & Kim 2015). These methods have the benefit of being able to provide high resolution images which could then be used with high spatial resolution satellite imaging systems such as Ikonos and Quickbird to produce stereo images. Tetuko and Sumantyo (2017) and Devi *et al.*, (2015) stated that several satellite remote sensing data has provided real data which can be used to monitor coastal resources.

This study will also attempt to analyse the potential of using in geospatial technique for determining shoreline erosion by utilizing GIS and Remote Sensing. By the end of this study, a map will be produced which depicts the determined erosion categories.

Study Area

The study areas in this research are located in the east coast of Malaysia along the Kuala Terengganu coastline. The length of Kuala Terengganu coastline is about 33 km. The study area as shown on Figure 1 is divided into two zones: Zone A comprises of Pantai Batu Buruk, which is close to jetty breakwater, Kuala Ibai, which is located in the river mouth area, and Pantai Chendering, which is located near the headland. Zone B includes the areas of Pantai Ru close to the port, Pantai Rusila, and Pantai Marang which is close to the jetty breakwater. These two zones were selected based on the type of land use which urban and development in that area. Helmy *et al.*, (2018) stated Kuala Terengganu's main town is located along this coastline to the southeast of Terengganu River and various construction developments have taken place including hotels, schools, residences, hospitals, recreation areas and Sultan's castles located along the coast.

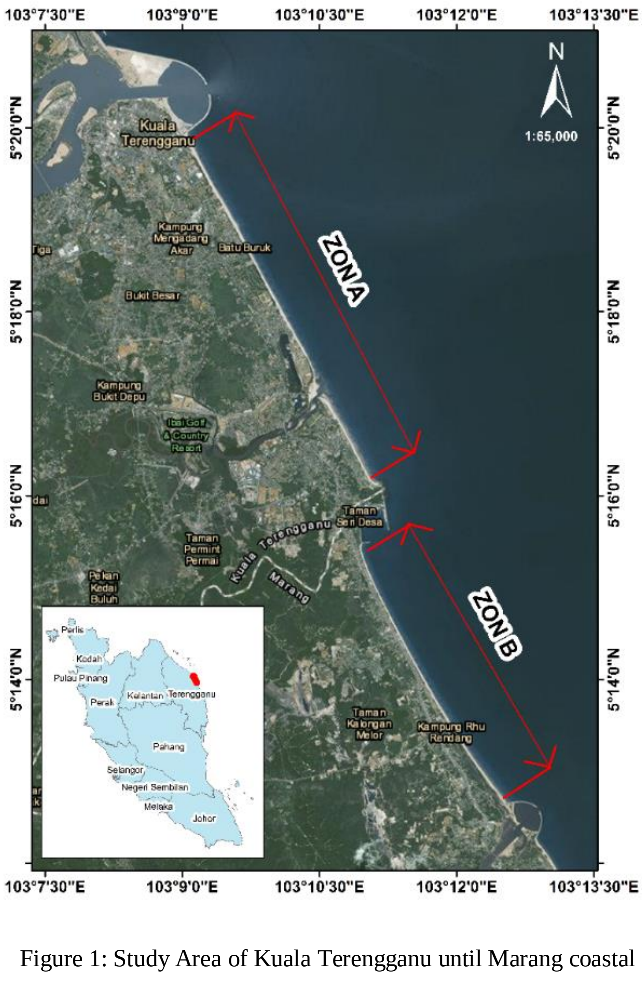

Figure 1: Study Area of Kuala Terengganu until Marang coastal

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Materials and Methods

In this study, the ranking of erosion determined by using the K1, K2 and K3 formula which are based on certain physical parameters, such as length of eroded shoreline, rate of shoreline change, physical erosion score, land use, building, utilities, and facilities which have been collected along the coastline. A comprehensive study done by National Coastal Erosion Study (NCES) 2015 determined the erosion category using physical and economic parameters formula. Therefore, it may be argued that erosion will increase if both parameters are high; all calculations can be made by referring to Table 1.

Table 1: Derivation of formula for category of erosion

No.	Parameters	Formulas
1.	Length of eroded shoreline (m)	This length can be measured by refer to the satellite image that had been digitized using ArcGIS. The length refers to the eroded shoreline area from one point to another point.
2.	Erosion Rate (m/year)	This value also can be obtained by referring to the attribute table i ArcGIS. Erosion rate = Width of the Coast / Range Per Year
3.	Physical Erosion Score	Relate with the erosion rate.
4.	Land use, Building, Utilities and Facilities	This data was collected by the physical observation during site visit.
5.	Economic Score	The total up of scoring from land use, building, utilities and facilities with the weightage given.
6.	Total Score	The value relates with the multiplying of Physical Erosion score and Economic Score. **Total score** = Physical Erosion Score x Economics Score

Department of Irrigation and Drainage (DID) develop and divided the erosion into three categories, namely critical (K1), significant (K2), and acceptable (K3) as below (Department of Irrigation & Drainage 2015);

i. K1 (Critical Erosion): Fast retreating coastline at a rate of more than 4m/year in areas with fairly dense human settlement, some commercial/industrial activities, and served by significant public infrastructure and facilities.

ii. K2 (Significant Erosion): Retreating coastline at a rate of between 1 and 3.9m/year with small occupied areas, some agricultural activities, and served by relatively minor public infrastructure and facilities.

iii. K3 (Acceptable Erosion): Slowly retreating coastline of less than 1m/year in areas with no human settlement, minimal agricultural activities, and not served by public infrastructure and facilities.

This study used GIS technique to determine shoreline changes. The estimation of wave pattern in the Kuala Terengganu area done using MIKE-21. It will explain all the processes involved in this study up to the production of the Kuala Terengganu coastline map which depicts the level of erosion. This study found that two types of images were used in 2014 and 2016, namely SPOT-5 and WorldView-3 as shown in Table 2.The purpose of selecting satellite images in this study was to obtain the shoreline position using digitizing approach in order to further determine the rate of shoreline changes along Kuala Terengganu's coast.

Table 2: Description of the satellites used (Kruse & Perry, 2013; Zhang *et al.*, 2013)

No	Type of Satellite	Electromagnetic Spectrum	Resolution Image
1	SPOT 5	4 Multispectral: B1: 0.5 – 0.59 µm	10 m X 10 m
		B2: 0.61 – 0.68 µm	10 m X 10 m
		B3: 0.78 – 0.89 µm	10 m X 10 m
		SWIR: 0.5 – 0.59 µm	20 m X 20 m
		Panchromatic: 0.51 – 0.78 µm	5 m / 2.5 m
2	WorldView-3	8 Multispectral: Coastal: 400 - 450 nm Blue: 450 - 510 nm Green: 510 - 580 nm Yellow: 585 - 625 nm Red: 630 - 690 nm Red Edge: 705 - 745 nm Near-IR1: 770 - 895 nm Near-IR2: 860 - 1040 nm	1.24 m
		Panchromatic: 450 - 800 nm	31 cm

Image Processing

The raw images have to go been through several processes before they are qualified for use in identifying the shoreline of Kuala Terengganu. The steps involved are geometric correction, resolution merge, pixel size resampling, and image mosaic. Geometric correction is a process registering spatial coordinates on satellite images according to actual position. This image has been encountered a geomatics correction process with distributed ground control point (GCP) all over the image to give the best coverage. Meanwhile, root-mean square error (RMSE) for each image were maintained below a pixel resolution value. This study used Rectified Skew Orthomorphic (RSO) projection as a reference system. Resolution merge was used to merge high spatial resolution image with a multispectral image to produce a better contrast and high quality output.

Next, the image mosaic process was carried out to combine multiple images into a single or tiled image. The metadata of these images was also changed in the combining process. Pixel size resampling was done since this project uses different types of satellite images, namely SPOT 5 and WorldView-3. This process will resample the image pixel into a different pixel resolution without altering the coordinate system. In this study, the multispectral SPOT 5 imagery was resampled to higher resolution by referring to the WorldView-3 image. As a result, the spatial resolution of SPOT 5 images was produced much finer resolution and same spatial resolution of WorldView-3 images i.e. 0.31 m.

Extraction of Shoreline Changes

This process was done to convert from analogue to digital format. The shoreline was digitized along the coastline by using the ArcGIS software. Shoreline is the line where the land and water meets. Determination of shoreline position was categories as a difficult things because shoreline is very subjective due to different perspective. This study used permanent structure and agricultural area as a boundary mark between terrestrial and oceans. Hwang (1981), and Hoeke *et al.,* (2001) also using the agricultural line as a border line for determination of shoreline in their study. Two (2) lines of the Terengganu shoreline were produced in the shape file format. Each line will have attributes and contains relevant information. Two (2) lines of the Terengganu shoreline were produced in the shape file format. Each line will have attributes and contains relevant information.

The attribute table defines the characteristic of the data, which were used to identify the conditions for erosion or accretion; six (6) types of data characteristics should be added in the attribute table in order to obtain the erosion rate along the coast, namely, length of erosion or accretion, area, width, range per year, and erosion.

Observation of erosion via qualitative analysis

A basic interview involved to get information from the coastal communities as a qualitative approach. In order to identify the public awareness and perception of shoreline changes and its impact among coastal communities, two way communication interview were conducted. Thus, a total 150 respondents were involved in this interviewed session by randomly selected. According to McNamara (1999), interviews are particularly useful for getting the story behind a participant's experiences. The interviewed was conducted to respondents who live within 1 km from the coastal area.

Wave simulation

To support the case of erosion, a wave model was generated using the MIKE21 (DHI 2011) to estimate wave pattern during the northeast monsoon for the years 2014 and 2016. The wave modelling process consists of mesh grid based on C-Map bathymetry input with an average depth ranging from -0.2 m near the coast to approximately -60.0 m offshore. However, the water level forcing for the three open boundaries, i.e. boundary 2 (south), boundary 3 (east), and boundary 4 (north), were specified based on global tide model prediction provided in MIKE21 (Awang *et al*., 2014).

The wave hydrodynamic model was forced by a series of wind data extracted from the European Centre for Medium-Range Weather Forecasts (2017) source offshore. The data of wind inshore was extracted from the Spectral Wave Flexible Mesh (SW) program. SW was calibrated by testing the influence of bottom friction and its influence on wave breaking in comparison to *in-situ* data between the periods from November 2013 to February 2014. It has been shown that a combination of adjustable parameters results in the best agreement between the measured and calculated data sets by using a wave growth formula with an RMSE of 0.29 (Ariffin *et al.*, 2016a). Wave parameters (significant wave height and direction) were extracted from this program.

Results and Discussion

This section will be discussed the results based on two (2) sections which are erosion losses and cause of erosion and Physical factors responsible for coastal erosion.

Erosion losses and cause of erosion

Table3 shows the values and percentages of erosion and accretion along the Kuala Terengganu shoreline from 2014 to 2016. The rate of erosion in the study areas ranges from 9.00 to 28.00 meter per year, while the rate of accretion varies from 10.00 to 32.00 meter per year.

Table 3: Rate of shoreline change per year along the Kuala Terengganu coastal area

Location	Length of shoreline (km)	Rate (m/year)		Percentage (%)	
		Accretion	Erosion	Accretion	Erosion
Zone A					
Pantai Batu Buruk	2.39	31.20	15.90	1.31	0.67
Kuala Ibai	2.28	20.86	20.70	0.91	0.91
Pantai Chendering	2.30	23.20	11.20	1.00	0.49
Zone B					
Pantai Rhu	1.54	10.60	10.50	0.69	0.68
Pantai Rusila	2.32	16.60	27.80	0.72	1.20
Pantai Marang	1.62	21.40	12.80	1.32	0.79
TOTAL	13.99	136.76	108.60	6.79	5.37

The highest rate of erosion occurred in Pantai Rusila, Kuala Ibai, and Pantai Batu Buruk at a rate of 15.90 to 27.80 meter per year. The highest rate of accretion occurred in Kuala Ibai, Pantai Marang, Pantai Chendering, and Pantai Batu Buruk at a rate of between 20.86 and 31.20 meter per year. This proves that sandy beaches along this study area are more vulnerable to erosion, which is at a moderate level. Table 3 shows the overall percentage of erosion based on the K1 to K3 erosion categories along the Kuala Terengganu coastal area.

All categories were determined based on the guidelines provided by the Department of Irrigation and Drainage (DID). Based on the tabulated data, two (2) categories of erosion, K1 and K2, were observed in Pantai Batu Buruk, Kuala Ibai and Pantai Rhu. One (a) category of erosion was observed in both Pantai Chendering and Pantai Rusila; the erosion in Pantai Rusila is categorized as K1, while the erosion in Pantai Chendering is categorised as K2. Two (2) categories of erosion, K2 and K3, were observed in Pantai Marang as shown in Table 4.

Table 4: Overall percentage of erosion level

Location	Length of Shoreline (m)	Length of Erosion Level (m)		
		K1	K2	K3
Zone A				
Pantai Batu Buruk	3,930	2,979.80	950.20	-
Kuala Ibai	2,280	1,421.77	858.22	-
Pantai Chendering	2,300	-	2,300.00	-
Zone B				
Pantai Rhu	1,540	898.40	641.59	-
Pantai Rusila	2,320	2320.00	-	-
Pantai Marang	1,620	-	508.30	1,111.70
TOTAL	13,990	7,619.98	5,258.30	1,111.70
Overall Percentage		54.46%	37.58%	7.95%

Physical factors responsible for coastal erosion

According to the Terengganu Economic Planning Unit, the population in Zone A is growing rapidly (as a city centre) with many comprehensive development such as government buildings, hospitals, and residential areas. Zone B is an area resided predominantly by fishermen. Majority of the coastal communities stated that erosion occurs during the northeast monsoon. As a result, third quarter of the communities are aware about the coastal erosion.

On the other hand, there are two conflict opinions with regard to the factors causing erosion. In Zone A, respondents stated that the anthropogenic factor causing erosion is the jetty breakwater in the Terengganu River and Chendering Harbour. They also stated that a natural dynamic can be observed in the Kuala Ibai river mouth. In fact, most respondents stated that the coastline in Zone B is eroded due to natural phenomena.

On Figure 2, wave modelling shows that wave propagation from Kapas Island to the shoreline in Zone B, especially in Pantai Rusila and Pantai Marang, is changing. A significant wave height was observed in Pantai Rusila, which subsides in Pantai Marang. A general observation shows that wind speed in 2014 blew predominantly to the coastline with strong (H_s) being observed along the coastlines. The pattern of wave distribution is similar although the wave in Zone A is stronger than that in to Zone B.

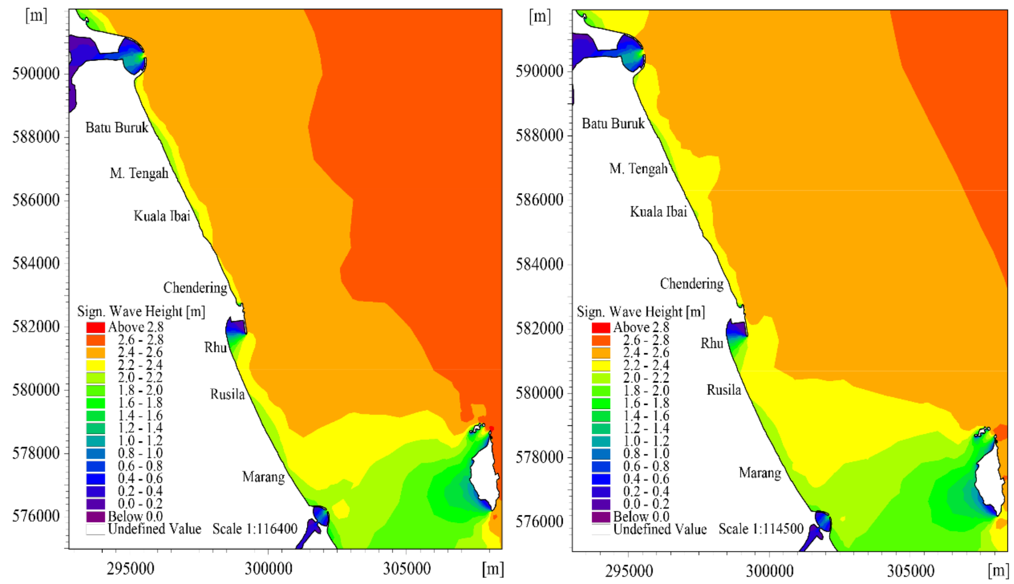

Figure 2: Significant wave height (H_s) modelling comparisons during northeast monsoon; 2014 (left) and 2016 (right)

Some areas along the Terengganu shoreline are experiencing significant changes are caused by several different factors, such as wave, monsoon, wind, tidal inundation, sea level rise, and human activities along the shoreline (Shaffril *et al.,* 2011). These findings are congruous with that of Husain & Yaakob (1995); the results of their research show that certain section of the Terengganu coastal area is undergoing severe erosion.

A study by the National Coastal Erosion Study (NCES) in 1985 foundthat the critical areas undergoing erosion are those close to the Terengganu estuary and Chendering (Unit Perancang Ekonomi, 1985). This due to the natural dynamic morphology of the Terengganu estuary, while Chendering beach is located between headland and harbour which produce higher energy, especially in the form of wave and current (Jeofry & Rozainah, 2013). According to Tonyes *et al*., (2015), sand can be eroded or accreted by the complex tidal current in the harbour and near the headlands. The complex bathymetry and tidal currents in the harbour create a complex circulation near the headlands and in the embayment, which regulate the formation of sandbank in the area.

The east coast of Peninsular Malaysia receives maximum rainfall during the northeast monsoon (Suhaila *et al.,* 2010; C. L. Wong *et al.,* 2016; P. P. Wong, 1981). However, the sediments found on the beach is dependent upon the nature of the waves. Ariffin *et al*., (2018) has shown that the study area is exposed to wave attacks from the South of China Sea. Futhermore, the strong wind during the northeast monsoon brings storm with strong wave (Ariffin *et al.*, 2018).

Erosion usually occurs during the northeast monsoon, meanwhile accretions happen during the southwest monsoon (Wong, 1981). The wind during the northeast monsoon season is strong enough to blow coarse materials inland. The east coast of Peninsular Malaysia, especially Terengganu, receives maximum rainfall during the northeast monsoon (Ariffin *et al*., 2018; Wong 1981). The distribution of highest rainfall can cause flooding in the coastal valley and areas close to the river mouth (Vousdoukas *et al.,* 2012).

Figure 3 Zone A (Left) shows that Zone A undergoes rapid erosion, especially in Pantai Batu Buruk. Kuala Terengganu district is separated into the northern and southern regions, which are separated by the Terengganu river. The city of Kuala Terengganu is placed along this shoreline to the southeast of Terengganu river and many construction developments have taken place which include hotels, infrastructural features and the Sultan's palace which are situated along the coast (Helmy *et al*., 2018).

The erosion problem occur at Zone Adue to the high energy circulation which is produced by the jetty breakwater constructed atKuala Terengganu of river mouth. According to a study conducted byPattiaratchi *et al*., (2009), coastal structurescan produce high energy with eddies and shorelines may retreat .

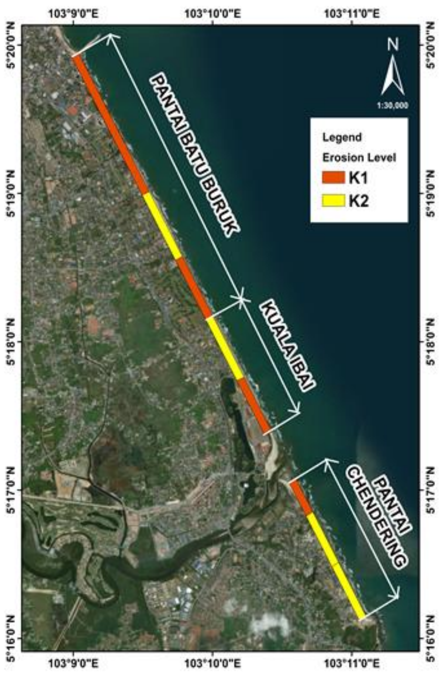

Figure 3: Erosion and accretion level at Zone A

This finding is consistent with that made by Rosnan *et al.,* (1994), which the Kuala Terengganu town is located along this shoreline. The feedback from the interview survey shows that most of the study area has been undergoing erosion due to the many development projects taking place along the coastline. Additionally, natural hazard can cause erosion and accretion, especially around river mouth areas with natural dynamic impact; one instance of this is Pantai Kuala Ibai (Patsch & Griggs, 2008; Pranzini *et al.*, 2013; Sudha Rani *et al.*, 2015) as shown on Figure 4. Helmy *et al.*, 2018 had mentioned that only a few coastal for example, the Batu Buruk coast and Kuala Ibai coast along of this shoreline are more stable compared to Northern of Kuala Terengganu shoreline caused by attraction tourist area that has undergone common compacting of the sand on the beach for the purpose of mitigation.

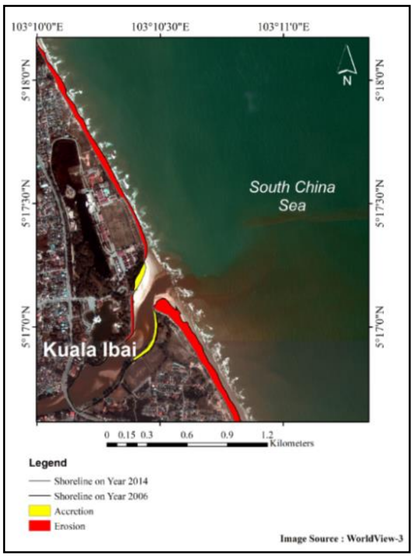

Figure 4: Shoreline changes at Kuala Ibai shoreline on years 2006 and 2014

All three categories of erosion was observed to occur in Pantai Chendering in the Marang area shown on Figure 5. The findings also show that Pantai Rusila undergoes a high rate of erosion compared to Pantai Ru and Marang. The geomorpholgy of Pantai Rusila is located directly facing the open South China Sea without any protective coastal structure, headland or island. Hence this area recieves a severe impact from natural hazard such as northeat monsoon storm. Wave propagation in this area increases from the island and the Chendering harbour to the coastline.However, Pantai Marang has a low erosion impactsince it is protected by Kapas Island. These findings are congruous with that made by De Falco *et al.*, (2016), which show that the area directly opposite the island is sheltered by shallow areas and changing wave parameters.

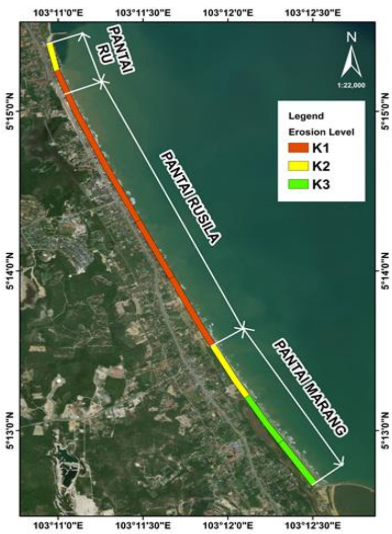

Figure 5: Shoreline changes at Kuala Ibai shoreline on years 2006 and 2014

It is crucial to establish the connection between natural hazard and anthropogenic factors that brought about the changes along shorelines. This will provide an understanding of the negative impact of past coastal development and how the sand brought from nearby rivers by monsoon affect the dynamic equilibrium process. According to Mohd Nadzir *et al.*, (2014), the coastal zone is rich with resources that can support the country's economic growth. They emphasised the importance of recognizing sustainable development, sensitivity of coastal processes, and the environment.

Community's Perception on Coastal Erosion Issue in Terengganu

Based on the questionnaire survey conducted to 150 respondents, 120 respondents (80%) responded to 'yes' to the question on the existence of issues of coastal erosion occurring along the Terengganu coastline and only 30 respondents (20%) of respondents gave the opposite view as shown on Figure 6.

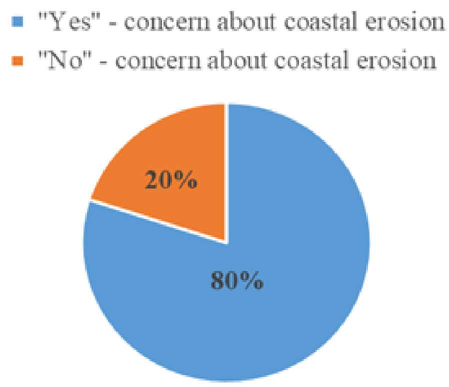

Figure 6: Respondents' perception on the existence of coastal erosion in Pahang

In terms of severity, this question was dedicated to them based on their observation on living near the affected area. The result shows that, 85% said that the shoreline in Kuala Terengganu to Marang was seriously affected, followed by moderately affected with 10%. Only 5% responded with not affected. This shows that the community living by the sea could aware of the coastal area was suffering from erosion.

Besides, the verification assessment of this study was done by National Coastal Vulnerability Index Study (NCVI) 2015 which mentioned and proved that these area especially Pantai Batu Buruk, Pantai Kuala Ibai and Pantai Rusila were classified as K1 and K2 category based on the threat caused to the existing shore based facilities of substantial economic value Figure 7 indicates the severity level of coastal erosion in Zone A and Zone B based on the questionnaire survey conducted.

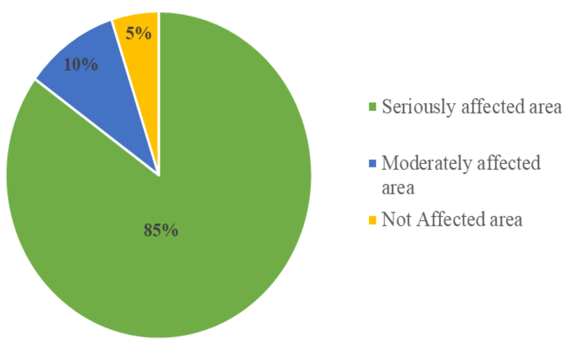

Figure 7: Categories of affected area due to coastal erosion in Pahang.

Conclusion

The present study has shown how physicals processes and other factors could have a profound impact in changing the shoreline of Terengganu. The categories of erosion in this study show the level of erosion which occur in two different zones. Zone A can be described as the shoreline impacted by anthropogenic activities and natural hazard, while the Zone B is predominantly impacted by natural hazard. Even though other factors have a slow onset in contributing to shoreline erosion and accretion, they should not be ignored due to their long term consequences. Mitigation measures need to be taken which takes into consideration the uncertainty of erosion and other factors. Hence, there is also a need to link adaptation with risk, uncertainty, and vulnerability. The findings of the present study outline the critical areas and provide guidelines to agencies planning mitigation methods. Government and non-government organizations need to play a prominent role in developing well-designed adaptation measures to prevent erosion before it has a negative impact on communities living close to the coastline.

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