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Impact of Shoreline Changes to Pahang Coastal Area by Using Geospatial Technology

(Impak Perubahan Persisiran Kawasan Pantai Pahang dengan Menggunakan Teknologi Georuang)

FAZLY AMRI MOHD, KHAIRUL NIZAM ABDUL MAULUD*, RAWSHAN ARA BEGUM,
SITI NORSAKINAH SELAMAT & OTHMAN A. KARIM

ABSTRACT

Malaysia has a long coastline stretching over 4,809 km where more than 1,300 km of beaches are experiencing erosion. Coastal erosion is recognised as the permanent loss of land and habitats along the shoreline resulting in the changes of the coast. Thus, it is important to detect and monitor shoreline changes especially in Pahang coast by identifying the rate of shoreline erosion and accretion. This study used temporal data and high spatial resolution imagery (SPOT 5) using remote sensing and GIS techniques to monitor shoreline changes along 10 study locations, which is from Cherating to Pekan of the Pahang coast. The total length of shoreline changes is about 14 km (14035.10 m) where all these areas are very likely to experience erosion ranging from 0.1 to 94.7 ha. On the other hand, these coastal areas found a minimal accretion with increased sediment from 0.1 to 2.8 ha. Overall, the coastal areas are exposed to higher erosion process than accretion with a very high vulnerability of erosion rate from 1.8 to 20.9 meter per year. The findings on monitoring shoreline changes and identifying vulnerable erosion areas might be useful in the policy and decision making for sustainable coastal management.

Keywords: Accretion; coastal changes; erosion; geospatial; vulnerability

ABSTRAK

Malaysia mempunyai garis pantai sepanjang 4,809 km dengan lebih daripada 1,300 km pantai mengalami hakisan. Hakisan pantai dikenal pasti sebagai kehilangan tanah dan habitat yang kekal di sepanjang garis pantai yang mengakibatkan perubahan pantai. Oleh itu, adalah penting untuk mengesan dan memantau perubahan pantai terutamanya di pantai Pahang dengan mengenal pasti kadar hakisan dan penambahan pantai. Kajian ini menggunakan beberapa imej satelit beresolusi tinggi (SPOT 5) pada masa yang berbeza dengan menggunakan teknik penderiaan jauh dan GIS. Kawasan kajian adalah 10 lokasi yang terletak dari Cherating ke Pekan, Pahang. Keputusan kajian mendapati jumlah panjang perubahan garis pantai adalah lebih kurang 14 km (14035.10 m) dengan semua kawasan ini berkemungkinan terhakis antara 0.1 hingga 94.7 hektar. Sebaliknya, kawasan pesisir ini menemui penambahan minima dengan nilai sedimen daripada 0.1 hingga 2.8 hektar. Secara keseluruhannya, kawasan pesisir terdedah kepada proses hakisan yang lebih tinggi daripada penambahan dengan kadar kerentanan hakisan yang sangat tinggi daripada 1.8 hingga 20.9 meter setahun. Keputusan pemantauan perubahan pesisiran pantai dan pengenalpastian kawasan yang berkerentanan rendah dapat digunakan dalam membuat dasar dan keputusan bagi meningkatkan mutu pengurusan pantai.

Kata kunci: Georuang; hakisan; kerentanan; pemendapan; perubahan pantai

INTRODUCTION

Coastal areas are categorized by high concentrations of human settlements where population density is usually three times the global mean (Small & Nicholls 2003). Climate change impacts in coastal areas and cities are a major concern in Malaysia. Pahang is one of the largest states which are located on the east coast of Peninsular Malaysia. Coastal areas in Pahang offer many beautiful beaches with fascinating landscape and scenery, which capture the attention of visitors and tourists. Cherating, Teluk Chempedak, Tanjung Lumpur and Pantai Sepat are the most attractive beaches in Pahang, which attract people for recreational activities (Azid et al. 2015; Tobergte & Curtis 2013). Malaysia's coastline is over 4,809 km where more than 1,300 km of Malaysian beaches are experiencing erosion (Ong 2014). Its coastal and marine areas will be impacted by the sea level rise, increases in sea surface temperature as well as changes in storm intensity and wave action which pose a serious threat and vulnerability to the coastal community, which include coastal erosion and inundation, storm-surge flooding, loss of physical property and livelihood damages. Hari Prasad and Darga Kumar (2014) had mentioned that coastal erosion is recognized as the permanent loss of land and habitats along the shoreline, resulting in the transformation of the coast.

The shoreline is the boundary intersection between the coastal land and the surface of sea water body that keeps changing its shape and position continuously due to dynamic environmental conditions. The change in shoreline is mainly associated with waves, tides, winds, periodic storms and sea level change and human activities (Husain & Yaakob 1995; Yoo et al. 2014). Furthermore, Chang and Lai (2014) explained that shoreline problems occur over decadal time scales and are related to daily, monthly and seasonal variations in tides, currents, wave climate and anthropogenic factors. In recent decades, the problems of climate change, especially sea level rise (SLR) and its impacts on low lying coastal areas, have caused worldwide attention to the management of coastal ecosystems (Cui et al. 2015; Nicholls & Cazenave 2010). Coastal erosion is always accompanied with a shoreward recession of the shoreline and the loss of land area which also largely depends on the nature of the waves. However, large waves pose a major threat to people and assets located close to the coastline, mostly due to their capability during storms (Wdowinski et al. 2016; Whittaker et al. 2016). Consequently, the impacts of coastal erosion and flood in closely populated and infrastructure rich coastal cities have received much attention. The shoreline changes its shape and size from time to time as a response to waves, currents and tides. Thus, it is important to detect and monitor shoreline changes from Cherating to Pekan coastal areas in Malaysia. Satellite remote sensing data provides real time data which can be used to monitor coastal areas and resources (Devi et al. 2015).

MATERIALS AND METHODS

STUDY AREA

The study area is based on the coastal areas from Cherating to Pekan along the coast of Pahang state, which are located in the east coast of Peninsular Malaysia facing the South China Sea. The coastal areas are low lying areas between the latitude 4° 07' 38.39" and 3° 32' 5.25" East and longitude 103° 23' 44.68" and 103° 27' 41.08" North. However, the study area covered approximately 83.91 km of the coastal length from Cherating to Pekan where sand materials make up the entire shoreline. The geomorphology of coastal areas along the Cherating to Pekan is a sandy type. The climate of Pahang is characterized by the Northeast monsoon which prevails between November and March. The annual temperature is between 25.6 °C and 27.8 °C (Malaysian Meteorological Department 2016). This study identifies 10 stations based on 10 locations from Cherating to Pekan coastal areas namely Pantai Cherating; Legend Villa Resort; Sungai Ular; Pantai Balok; Kelab Golf Pahang; Taman Gelora; Pantai Sepat; Sungai Penor; Kampung Cherok and Tanjung Agas as shown in Figure 1.

DATA ACQUISITION

Data used in this study was obtained from different temporal resolutions covering the coastlines from Cherating to Pekan. Temporal resolution refers to the data acquisition between the changes of 2006 and 2014.

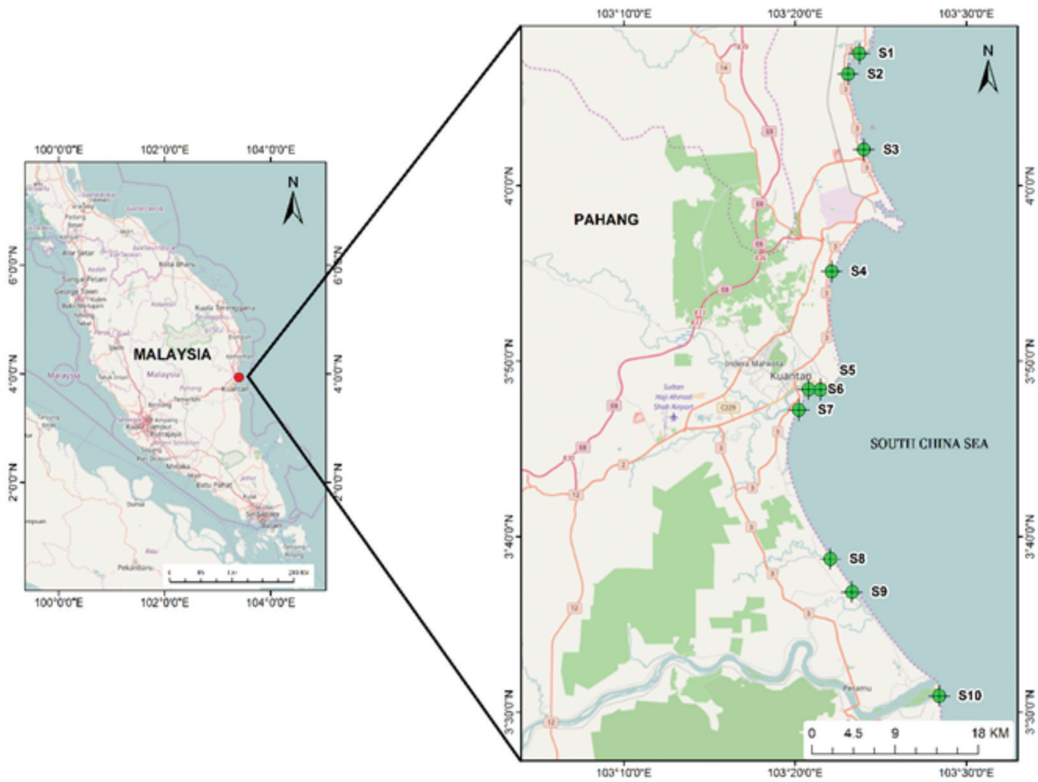

FIGURE 1. Shoreline along Cherating to Pekan of Pahang coast in Peninsular Malaysia

Table 1 presents data acquisition regarding data types, date and time of acquisition and spatial resolution. In this study, the projection system used for image satellite is Geodetic Datum of Malaysia (GDM) 2000. The purpose of acquisition date of this research relies on the available satellite operation while capturing the images and at the same time, avoiding cloudy and bad weather conditions on this area. Remotely sensed data can provide valuable primary estimates of change and is a unique tool for research and for monitoring coastal areas (Ciavola et al. 1999; Yang et al. 1999). These technologies are useful for monitoring and predicting the shoreline erosion pattern and beach sediment responses to coastal dynamics for management purposes (Saravanan 2014). Maglione et al. (2014) had mentioned that shoreline extraction through remote sensing practises depends on the different spectral properties or spectral responses of water and other land surfaces at different wavelengths. Commonly, in remote sensing principal, the shoreline can be extracted from a single band image, since the reflectance of water is nearly equal to zero in the reflective infrared bands.

DATA PROCESSING AND ANALYSIS

The SPOT 5 satellite with different temporal conditions was used for data acquisition and extraction of shoreline. The spatial resolution of the satellite images for SPOT 5 has the accuracy of up to 2.5 m. Using the high resolution satellite imagery, the shoreline detection can be used to map and monitor the dynamic changes of shoreline along the coast of Cherating to Pekan.

LAND USE CLASSIFICATION

Data from satellite sensors become an important tool in monitoring and studying land use and land cover changes. Early research in the application of satellite sensor images for shoreline mapping relied on spatial resolution satellite sensor images (Dwivedi 1997; Frihy et al. 1998). Remote sensing provides the benefit of rapid data acquisition of land use information at a lower cost than ground survey methods (Pal & Mather 2004). A number of techniques exist to classify the coastal land use and land cover categories in remotely sensed images using Erdas Imagine, version 10.4. Usually, the Maximum Likelihood classification represents the most established method (Jensen 2005). Generally, this classification technique is one of the popular methods of classification in remote sensing, which a pixel with the maximum likelihood classified is categorized into the corresponding class. The formula of Maximum Likelihood classification was shown as (1) and (2) as follow:

$$L_k = P\left(\frac{k}{X}\right) = \frac{p(k) * p\left(\frac{X}{K}\right)}{\sum p(i) * p\left(\frac{X}{i}\right)} \quad (1)$$

where P(k) is the prior probability of class k; $P\left(\frac{X}{k}\right)$ is the conditional probability to observe X from class k.

Generally P (k) is assumed to be equal to each other and $\sum P(i) * P\left(\frac{X}{i}\right)$ is also common to all classes. Therefore L_k depends on $P\left(\frac{X}{k}\right)$ as the probability density function. In this study, the multiple bands of remote sensing data for the classes of interest can be expressed using the formula as follows:

$$L_k(X) = \frac{1}{(2\pi)^{\frac{n}{2}} \left|V_i\right|^{\frac{1}{2}}} \exp\left[-\frac{1}{2}(X - M_i)^T V_i^{-1} (X - M_i)\right] \quad (2)$$

where n is the number of bands; X is the image data of n bands; V_i: is the Covariance matrix; V_i^{-1}: is the inverse of covariance matrix; $(X - M_i)^T$ is the transpose vector of $(X - M_i)$ and M_i is the mean vectors.

DIGITIZING

The GIS analysis has been used to determine the rate of shoreline changes of 10 locations from Cherating to Pekan coastal areas which occurred in the classified images. The boundaries of water and land from supervised classification were delineated through on-screen digitizing by ArcGIS software. The erosion and accretion polygons are displayed into the map of the areas affected by a Pahang shoreline change. From the GIS analysis, the rate of erosion and accretion can be calculated from these polygons automatically. A comparison of the shoreline positions in 2006 and 2014 shows a locally significant retreat.

RESULTS AND DISCUSSION

MONITORING OF SHORELINE CHANGES

Based on the analysis using the satellite image and GIS, the detection of shoreline changes was monitored. The

TABLE 1. Data acquisition from satellite image

Types of data	Date of acquisition	Tidal Height	Event	Time of acquisition	Spatial resolution	Path/Row
SPOT 5	02/07/2006	2.5 m	High Tide	11.49 am	2.5 m	273/341
SPOT 5	22/08/2014	2.2 m	High Tide	11.00 am	2.5 m	
SPOT 5	20/07/2006	1.9 m	Low Tide	11.49 am	2.5 m	273/343
SPOT 5	05/08/2014	1.8 m	Low Tide	11.03 am	2.5 m	

erosion and accretion area is displayed in Figure 2. The value of erosion and accretion among 10 study locations of temporal changes between 2006 and 2014 was determined as shown in Table 2. Pantai Balok and Tanjung Agas have indicated the higher value of eroding i.e. 26.8 and 94.7 ha, respectively. The changing patterns of shoreline for both areas showed a very active process of erosion. This is consistent with the shoreline erosion findings of Azid et al. (2015), which showed that Tanjung Lumpur to Cherok Paloh of Pahang coasts had significant changes of the coastal shorelines between 1996 and 2004. Coastal areas of Pantai Cherating, Legend Villa Resort and Sungai Ular were found to show a minimum amount of shoreline eroding consisting of 0.1 to 0.5 ha while Pantai Balok, Kelab Golf Pahang, Taman Gelora and Pantai Sepat did not have any accretion process along the shorelines.

On the other hand, the study results found that the coastal areas such as Pantai Cherating, Legend Villa Resort, Sungai Ular, Sungai Penor, Kampung Cherok Paloh and Tanjung Agas exhibited the presence of sediment accretion ranging between 0.1 and 2.8 ha. The low amount of the sediment will decrease the coastal vulnerability. The accretion shoreline with the high value of 2.8 and 1.0 ha was found at Legend Villa and Sungai Penor. However, a coastal area i.e. Legend Villa Resort was found to have a higher accretion process than the rate of erosion.

The erosion rate (m/yr) for the study areas between 2006 and 2014, ranges from 1.8 to 20.9 meter in a year. This indicates that all the study locations from Cherating

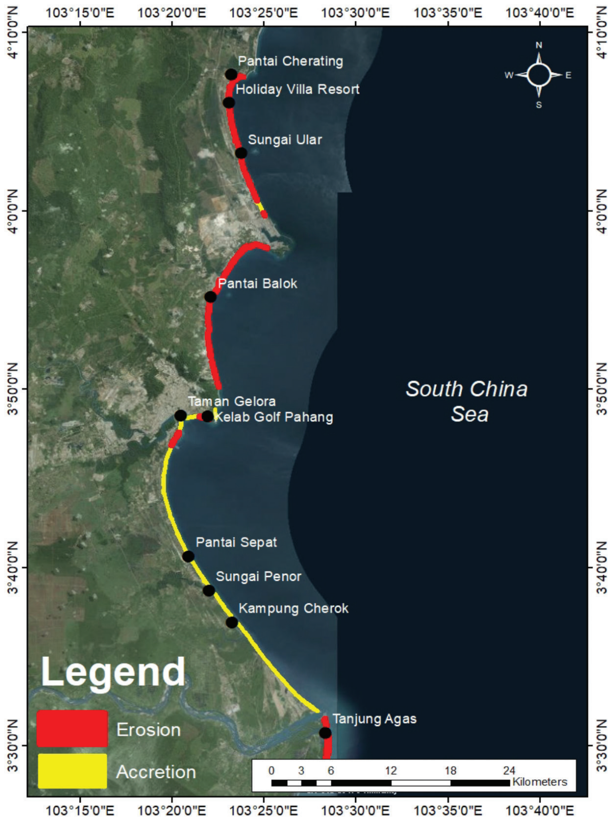

FIGURE 2. The erosion and accretion areas along the study areas

TABLE 2. Eroding and accretion shoreline along Cherating to Pekan on the year 2006 to 2014

No	Location	Coordinate Lat (Degree) / Long(Degree)	Length of shoreline changes (m)	Coastal width (m)	Eroding (Ha)	Accreting (Ha)	Erosion rate (m/yr)
1	Pantai Cherating	4.127331					
		103.387450	584.9	23.30	0.2	0.1	2.9
2	Legend Villa Resort	4.101000					
		103.385233	930.0	14.90	0.1	2.8	1.8
3	Sungai Ular	4.053781					
		103.396500	879.6	12.60	0.5	0.2	3.3
4	Pantai Balok	3.919247					
		103.368764	5346.5	109.6	26.8	-	13.5
5	Kelab Golf Pahang	3.807731					
		103.365694	858.2	145.0	3.7	-	17.9
6	Taman Gelora	3.808464					
		103.341747	531.4	116.7	2.5	-	14.4
7	Pantai Sepat	3.676887					
		103.348667	1317.7	76.3	7.7	-	9.4
8	Sungai Penor	3.645147					
		103.367494	1249.3	49.6	1.2	1.0	6.1
9	Kampung Cherok Paloh	3.615114					
		103.388369	1062.2	118.7	5.5	0.3	14.6
10	Tanjung Agas	3.511964					
		103.472656	1585.4	168.9	94.7	0.9	20.9
	Total		14345.2		142.9	5.3	

to Pekan coastal areas are exposed to erosion problems. The greatest extent of erosion has been experienced in the coastal areas of Pantai Balok, Kelab Golf Pahang, Taman Gelora, Kampung Cherok Paloh and Tanjung Agas with a rate of 13.5 to 20.9 m/yr. The findings by Mohd Zaini et al. (2015) were supported as his study showed a serious erosion problem that occurred at some coastal parts such as Pantai Teluk Sisek to Pantai Taman Gelora and along Pantai Sepat. However, the erosion and accretion of shoreline changes can be an indication of the most vulnerable coastal areas if no protective and mitigation measures are taken.

Among the 10 coastal areas, 95% of coasts were identified as eroding while 5% were accreting. Hence, the coastal areas from Cherating to Pekan are very much vulnerable to erosion. The main cause of coastal erosion might be due to the combined actions of the natural physical processes such as the monsoon and tides, changes in sea level and various human activities. However, the cumulative effects of stormy climate and various human actions may contribute to shoreline changes along the coastlines of Cherating to Pekan in Pahang. The findings of Raj (1982) were supported as the study showed that tides are mainly of semi-durnal frequency along Pahang throughout the year with the indication that Kuantan's tidal range is between 2 and 2.5 m. Thus, the high velocity and northeasterly winds result during the northeast monsoon lead to the erosion and rapid lateral transport of beach sediment.

Generally, coastal areas are sensitive and hazard-prone areas, therefore, any development activity needs to be highly evaluated for its possible disturbances. Hazards in coastal areas can be found through erosion activity and caused by environmental change and human actions (Adger 2005). However, shoreline erosion damages the coastal ecosystem which also reduces the ability of the coastal areas to adapt. Coastal zones in Malaysia are used for a variety of purposes such as tourism, fisheries, transportation, mining and communication (Ramli 2008). Therefore, it is important to study the impact of the coastal ecosystem due to the event of coastal erosion.

IMPACTS OF SHORELINE EROSION

There are five major land use classes that were identified and mapped from SPOT 5 satellite imageries to determine the changes. These classes are: Water bodies, coastal forest, green area, open development, land and sand. The spatial distribution of these six land use classes for 2006 and 2014 is shown in Figure 3.

After analyzing the land use classification, this study determines the land use patterns of the shoreline along the coastal areas. From Cherating to Kuantan, the land use patterns are dominating urban housing areas and forest areas between 2006 and 2014 while high density urban housing has been developed near the industrial areas of

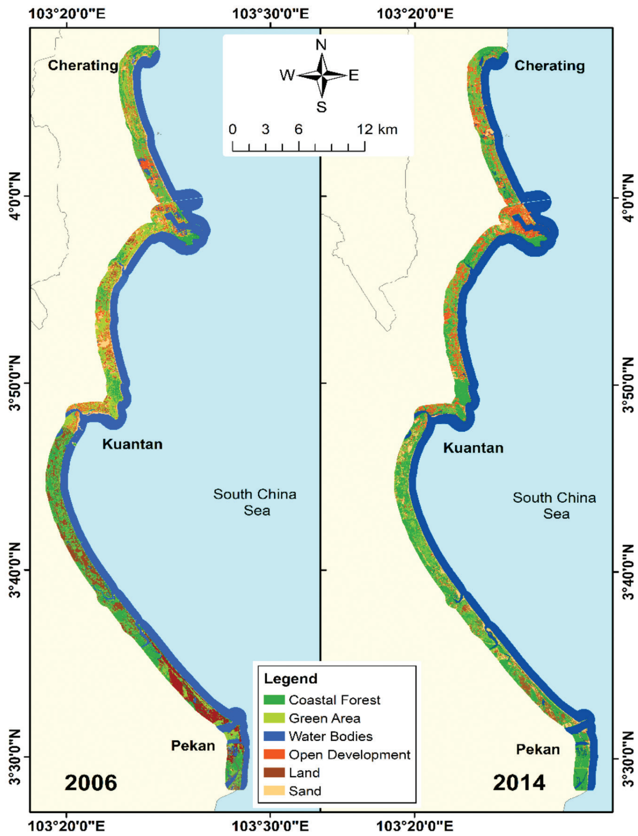

FIGURE 3. Land use and land cover classification along Cherating to Pekan, Pahang on year 2006 and 2014

Pantai Balok by 2014. Kuantan is a capital city of Pahang state which is located at the center of the Cherating to Kuantan. This might be the reason for employment opportunity from this new development, the expansion of beach resorts and tourism areas are changing from medium density to high density urban housing.

From Kuantan to Pekan, agricultural plantations such as coconut, paddy, rubber, oil palms and the development of new urban housing are evident. The land use between 2006 and 2014 showed almost similar land use land cover patterns but in Tanjung Agas, the areas of aquaculture have been expanded by 2014 and known as rural areas. Figure 5 shows the loss of land due to shoreline erosion in Sungai Ular and Sungai Penor, Pahang.

From the perspectives of shoreline erosion impacts on tourism activities, Kuantan district is the capital of Pahang state which is located at the Kuantan River mouth and between the coasts of Cherating and Pekan. Thus, this study indicates that the study areas offer many beautiful beaches with fascinating landscape and scenery, which capture the attention of local and foreign visitors. Similar results were also reported in the studies of Mohd Zaini et al. (2015) where it stated that Cherating, Teluk Chempedak, Tanjung Lumpur and Pantai Sepat are the most beautiful beaches in Pahang, which attract people for tourism and recreational activities along the coasts, providing great socio-economic and environmental values, especially for the local population and the country's economy. As this study shows, approximately 143 ha of coastlines have undergone erosion problems, the total number of visitors and the values from tourism and recreational activities might be decreased and threatened due to the coastal erosions

In addition, mangroves are one of the most affected coastal ecosystems due to shoreline erosion, despite their important social and ecological roles. Pahang coastline is one of the sheltered estuaries where mangroves are confined (Yahaya & Ramu 2003). Mangrove habitat plays a critical role in trapping sediments, thereby stabilizing coastlines and protecting coral reefs and sea grass fields from waves and storms. These habitat areas enable the preservation of water quality and the reduction of pollution by filtering suspended materials and assimilating dissolved nutrients, as well as enable the management of fishery reserves. With the large amount of land loss, the coastal areas also experience the destruction of wetlands and mangrove plants which has a negative effect on wildlife and the surrounding environment. Figure 4 shows the effect of shoreline erosion occurs at mangrove areas in Sungai Penor. The shoreline erosion causes to loss and death of the mangrove habitats.

Conclusion

Coastal areas are very dynamic and monitoring the shoreline changes is important in environmental protection and sustainable coastal management. Along the 10 study locations of Pahang coasts, the total length of shoreline changes was found to be about 14 km (14035.10 m). Remarkably, Pantai Balok and Tanjung Agas were highly eroded with a land loss of 26.8 ha and 94.7 ha, respectively.

The coastal areas from Cherating to Pekan experienced a very high vulnerability with the erosion rate of 1.8 to 20.9 meter (m) per year (yr). The greatest extent of erosion was found on the coastal areas of Pantai Balok, Kelab Golf Pahang, Taman Gelora, Kampung Cherok Paloh and Tanjung Agas with a rate of 13.5 to 20.9 m/yr. Generally, the coastal areas of Pahang are exposed to higher erosion process than accretion.

Using temporal data with the integration of satellite imagery and GIS technique provides representative findings and valuable information to identify highly vulnerable coastal areas which might be useful in policy and decision making for protective and mitigation measures towards sustainable coastal management.

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FIGURE 4. Damages of infrastructures and mangrove habitats due to shoreline erosion on Pahang coastal areas

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Fazly Amri Mohd, Khairul Nizam Abdul Maulud* & Othman A. Karim
Department of Civil & Structural Engineering
Faculty of Engineering & Built Environment
Universiti Kebangsaan Malaysia
43600 UKM Bangi, Selangor Darul Ehsan
Malaysia

Khairul Nizam Abdul Maulud*
Earth Observation Centre
Institute of Climate Change (IPI)
Universiti Kebangsaan Malaysia
43600 UKM Bangi, Selangor Darul Ehsan
Malaysia

Rawshan Ara Begum & Siti Norsakinah Selamat
Institute of Climate Change (IPI)
Universiti Kebangsaan Malaysia
43600 UKM Bangi, Selangor Darul Ehsan
Malaysia

*Corresponding author; email: knam@ukm.edu.my

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