Determination the Impact of Sea Level Rise to Shoreline Changes Using GIS

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Abstract—**Climate change, weather and the ozone depletion has a significant association with the sea level rise and the movement of sea water. While the behavior of the sea level rise affects the changes of shoreline through processes of accretion and erosion can be analyzed in a Geographic Information System (GIS) by measuring differences in past and present shoreline locations. In this study, ArcGIS and MIKE21 software is used to generate spatial model to identify the shoreline changes at Batu Pahat and projection the sea level rise of year 2020 and 2040, thus able to identify areas that will be flooded based on the predicted sea level rise data. Based on topographic maps and satellite imagery, changes can be seen from 1984 up to 2013. Forecasting the coastal changes according to the projected sea-level rise up to 2020 and 2040 was able to provide warnings and guidance in planning all local activities. The impact of continuous sea level rise causing shoreline erosion and saltwater intrusion in agriculture area and destroying coconut plantation near Padang Terbang and shrinking mainland at Sungai Lurus. Total eroded area is 415.47 hectare and total accretion is 68.52 hectare. Accretion occurred due to deposition of sediment that is caused by longshore sediment transport or from the critical erosion area. The impacted area from sea level rise predictions is Sungai Ayam, Sungai Suloh Besar, Sungai Koris, Sungai Lurus, Sungai Senggarang, Sungai Parit Botak, Sungai Tongkang and Sungai Rengit**.

Keywords-Sea level rise; shoreline changes; Geographic Information System (GIS); erosion and spatial model.

I. INTRODUCTION

The phenomenon of sea level rise is one of the effects of global warming and Malaysia is taking this issue seriously. The studies conducted by the Intergovernmental Panel on Climate Change (IPCC) found that in the 21st century, the sea level is expected to rise from 18 to 66 cm [1-2]. Australian researchers predicted a sea level rise (SLR) of 0-1 meter during the 21st century [3]. Sea level rise was identified as one of the factors leading to coastal erosion [4]. Base on the study conducted by the National Hydraulic Research Institute of Malaysia (NAHRIM), Peninsular Malaysia will experience sea level increase with the range of 0.253m to 0.517m by the year 2100 (from year 2010 as baseline) or 2.7mm to 7.0mm / year [5-6]. The most affected areas will be regions within Sabah, Sarawak including Batu Pahat, Johor, which is anticipated to increase between 0.432 until 1.064 meter. Batu Pahat is one of the districts under the governance of Johor Darul Takzim, located towards the south of Peninsular Malaysia. The issues on the sea level rise at Batu Pahat started to receive special attention when an article was published on a national newspaper uncovered that Batu Pahat may go into underwater. Since then, numerous research institutes and private agencies have specifically looked and closely monitored on the shoreline of Batu Pahat. The objective of this study is to identify the shoreline changes and the impact due to sea level rise.

The shoreline of Batu Pahat is from latitude 1.62˚ to 1.87˚ N, longitude 102.78˚ to 103.19˚ E, and consists of six mukims of Lubok, Bagan, Minyak Beku, Kampung Bahru, Sungai Punggor and Sungai Kluang. The study area covers about 2 kilometers both for inland and seaward. The shoreline of Batu Pahat practically has no beach, mostly mudflat which may extend seawards up to about 2 km. Field work notably showed that Batu Pahat has limited accessible beach. A small sandy narrow beach at the Sungai Lurus offers the nearest beach to the locals, although during the field trip, only the coastal fisheries boats were visible. The coast of Batu Pahat has two small islands, i.e. Pulau Sialu and Pulau Tikus.

II. METHODOLOGY

ArcGIS software is used to generate spatial model to identify the shoreline changes [7]. Figure 1 show the spatial model generated in ArcGIS to identify the eroding and accreting shoreline. Shoreline topographic map year 1984 from Department of Survey and Mapping Malaysia (JUPEM) and shoreline data extract from Spot 5 image year 2013 were used in this analysis. The data overlay concept in ArcGIS software allow surface elevation for projected sea level rise 2020 and 2040 generate from MIKE 21 can be overlay with shoreline and satellite imagery data, thus able to identify areas that will be flooded based on the predicted sea level rise data.

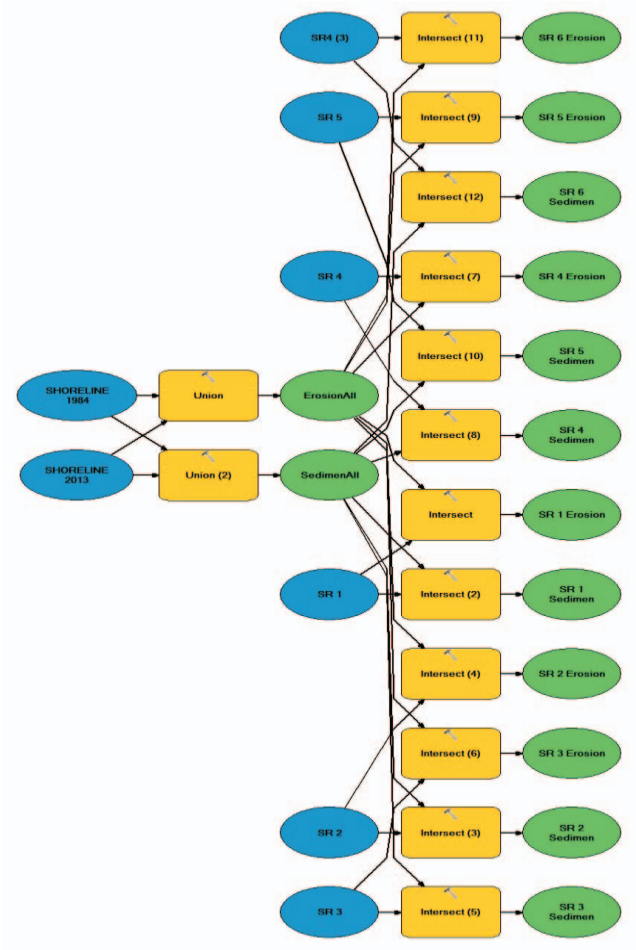

Figure 1: Shoreline Changes Spatial Model

III. RESULT AND DISCUSSION

A. Shoreline Changes Analysis

Mapping the shoreline has been done by the JUPEM since 1984. Changes in the shoreline are always occurring over time and weather until now. Based on topographic maps and satellite imagery, changes can be seen from 1984 up to 2013. Figure 2 shows the shoreline changes at Sungai Lurus. The shoreline change from 1984 to 2013 was about 50 meters to 200 meters. Average of annual change is 1.5 meters to 7 meters. The Changes between year 2011 to the year 2013 is from 1 meter to 25 meters.

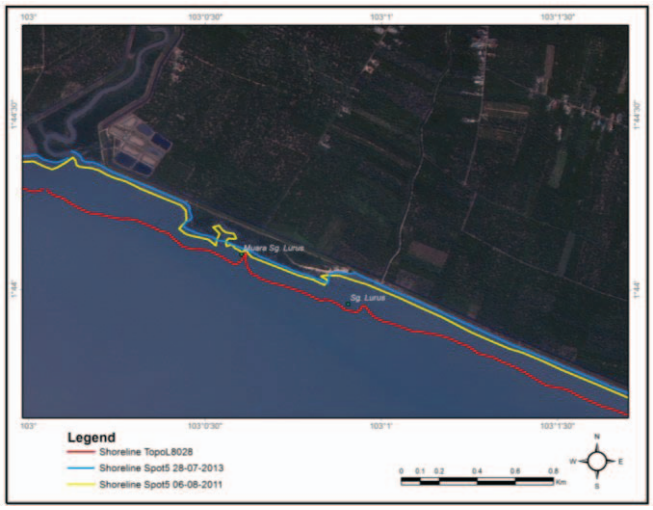

Figure 2: Shoreline changes at Sungai Lurus from 1984, 2011 and 2013.

B. Changes along the shoreline

Ocean current, wave and wind are the main factor for beach formation. These factors contribute to shoreline changes at Batu Pahat. The changing of coastline includes accretion and erosion processes. Total eroded area is 415.47 hectare and total accretion is 68.52 hectare. Accretion occurred due to deposition of sediment cause by longshore sediment transport or from the critical erosion area. Based on the Figure 3, high deposition occurs at southeast Tanjung Segenting (MU3-1), east and west sungai Suloh (MU4-1), northwest and southeast of the sungai Bagan (MU6-2). Critical erosion occurred at the northwestern sungai Rengit (MU5-3) and Sungai Punggor (MU5-1), northwestern and southeastern Sungai Ayam (MU3-2) also at sungai Koris (MU4-2) and Sungai Lurus (MU4-3). Detail accreting and eroding shoreline at Batu Pahat for every MU is shown in Table 1.

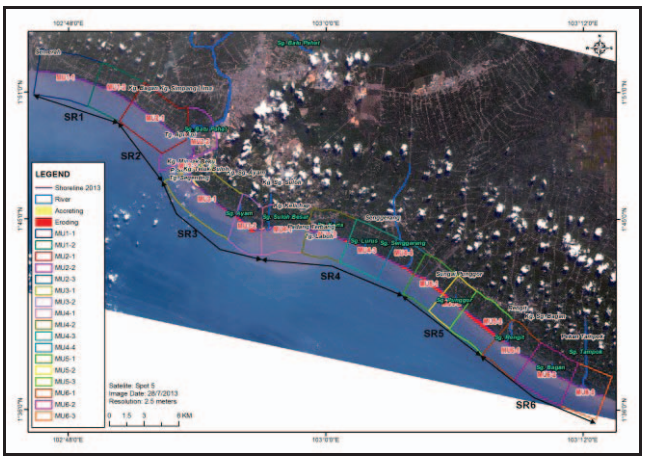

Figure 3: Current shoreline condition at Batu Pahat

Table 1: Accreting and eroding shoreline at Batu Pahat

Sub Reach	Management Unit	Location	Shoreline Length (m)	Eroding (Ha)	% Eroding	Accreting (Ha)	% Accreting	Shoreline Changes Index
SR1	MU1-1	Pt. Semerah - Pt Sidek	5,308.57	3.25	0.67	0.00	0.00	0.03
	MU1-2	Pt. Sempadan - Pt. Besar	3,616.35	5.08	1.05	2.02	0.42	
SR2	MU2-1	Pt. Besar - Tg. Api-Api	6,405.50	8.57	1.77	6.82	1.41	0.066
	MU2-2	Sg. Batu Pahat - Telaga Batu Pahat	4,138.05	1.10	0.23	0.79	0.16	
	MU2-3	Telaga Batu Pahat - Tg. Segenting	1,493.56	0.00	0.00	0.00	0.00	
SR3	MU3-1	Tg. Segenting - Sg. Ayam	7,071.97	21.41	4.42	22.19	4.58	0.299
	MU3-2	Sg. Ayam - Sg. Suloh Kechil	3,042.07	49.06	10.14	4.10	0.85	
SR4	MU4-1	Sg. Suloh Kechil - Padang Terbang	4,790.60	6.44	1.33	18.73	3.87	0.191
	MU4-2	Padang Terbang - Sg. Terus	4,832.45	43.53	8.99	0.00	0.00	
	MU4-3	Sg. Terus - Pt. Kongsi	3,700.30	37.53	7.75	0.00	0.00	
	MU4-4	Pt. Kongsi - Pt. Kg. Baharu	2,757.57	28.23	5.83	0.00	0.00	
SR5	MU5-1	Pt. Kg. Baharu - Sg. Berong	3,240.65	56.89	11.76	0.00	0.00	0.238
	MU5-2	Sg. Punggor - Sg. Mengkudu	2,289.19	26.65	5.51	0.00	0.00	
	MU5-3	Sg. Mengkudu - Sg. Dulang	4,183.33	95.63	19.76	0.00	0.00	
SR6	MU6-1	Sg. Dulang - Sg. Jambi	3,859.74	28.89	5.97	0.00	0.00	0.177
	MU6-2	Sg. Jambi - Sg. Meriong Kechil	5,044.78	3.19	0.66	13.88	2.87	
	MU6-3	Sg. Meriong Kechil - Sg. Besar	4,252.64	0.00	0.00	0.00	0.00	
		TOTAL	**70,027.33**	**415.47**	**85.84%**	**68.52**	**14.16%**	**1.00**

The shoreline in MU3-1 is mostly accreting at southeast Tanjung Segenting about 4.58% (22.19 hectare) as in Figure 4 and photo 1. The eroding shoreline mostly happened at northwest Sungai Ayam about 4.42% (21.41 hectare) as in photo 2. The shoreline MU3-2 covers from Sungai Ayam to Sungai Suloh Kechil about 3.04 km length. The eroding shoreline at MU3-2 is about 10.14% (49.06 hectare) and accreting shoreline is 0.85% (4.1 hectare). The shoreline at this MUs cover by mangrove forest.

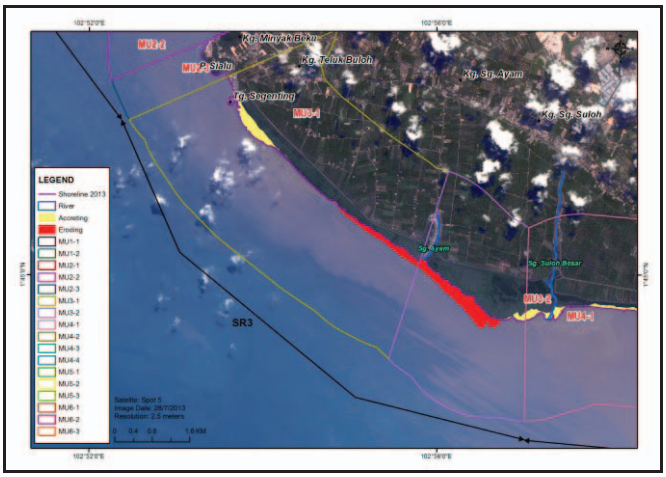

Figure 4: Critical shoreline erosion at Sungai Ayam

Photo 1: Accreting shoreline at southeast of Tg. Segenting (November 2014)

Photo 2: Eroding shoreline at Sungai Ayam river mouth (November 2014)

The entire shoreline at SR5 is eroding as shown in Figure 5. Total eroding area is 37.02% (179.17 hectare). Most critical eroded area is at MU5-3 about 19.76% (95.63 hectare) following by MU5-1 about 11.76% (56.89 hectare). As shown in photo 3 and 4 many mangroves are dying along the northwest and southeast of Sungai Punggor.

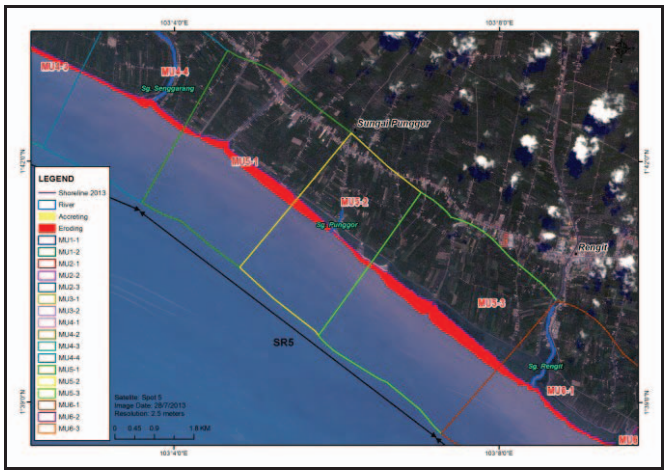

Figure 5: Critical shoreline erosion at Sungai Punggor

Photo 3: Eroding shoreline at northwest of Sungai Punggor (November 2014)

Photo 4: Eroding shoreline at southeast of Sungai Punggor (November 2014)

C. Impact of Sea Level Rise on Shoreline Changes

Sea level rise affected low lying areas inundated and causing the loss of surrounding activities. The area received the most impact is in the vicinity of the village at Sungai Koris (photo 5). Figure 6 shows the village affected with the sea level rise. The impact of continuous sea level rise causing shoreline erosion and saltwater intrusion in agriculture area and destroying coconut plantation near Padang Terbang (photo 6). Fieldwork showed that the coastal structures protecting the low-lying area have collapsed and lose its structural integrity. During high tide, salt water comes in and affects the growth of the coconut plant.

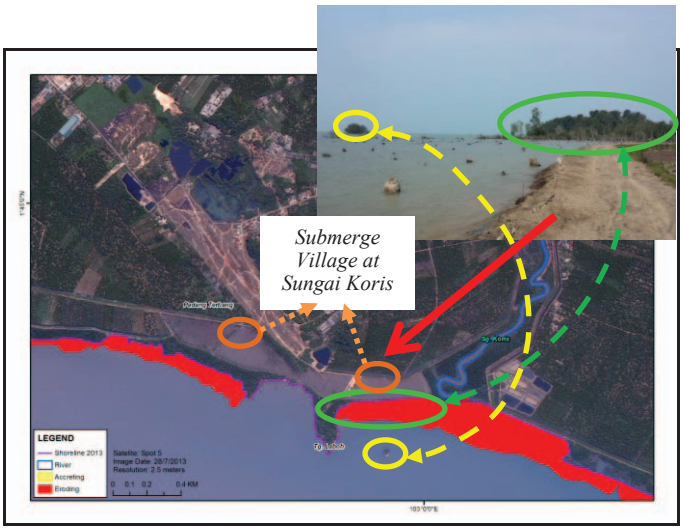

Figure 6: Areas sinking due to rising sea level

Photo 5: Coconut stump apper during low tide at Padang Terbang

Photo 6: Submerged area at Sungai Lurus

Rising sea levels caused shrinking mainland. It indirectly causes the ownership of the land or private land was affected. Sungai Lurus coastal areas have some areas of property rights that have been affected by the rise in sea level as shown in Figure 7.

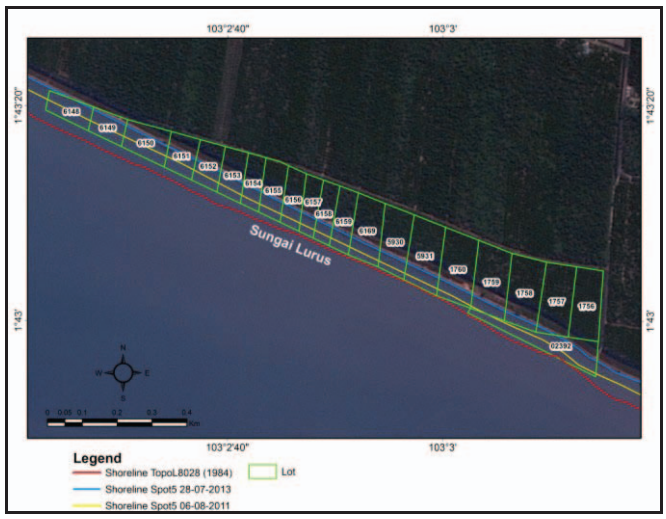

Figure 7: Land lots sink due to sea level rise

D. Sea level rise prediction

Sea level rise is one of the global warming effects. The contribution factors are the increasing of sea water temperature and the melting of iceberg. Wind speed and movement of seabed will influence the Sea current. The predictions of sea level rise for the year 2020 and 2040 along Batu Pahat near shore indicate the increasing of water level at several rivers namely at Sungai Ayam, Sungai Suloh Besar, Sungai Koris, Sungai Lurus, Sungai Senggarang, Sungai

Parit Botak, Sungai Tongkang and Sungai Rengit as shown in Figure 8 and 9. Total effected area for 2020 is 1,676.16 hectare and 1,875.93 hectare for 2040 as in Table 2.

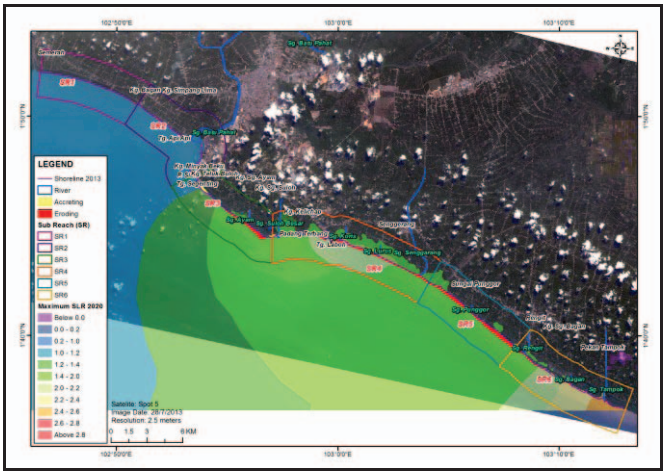

Figure 8: Sea Level Rise Prediction 2020

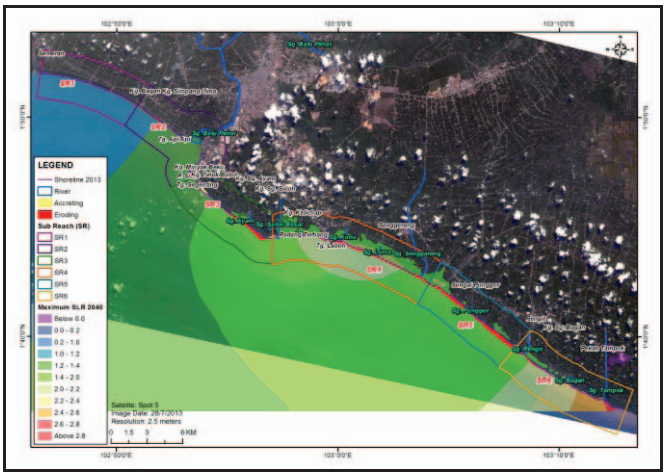

Figure 9: Sea Level Rise Prediction 2040

Table 2: Changes of affected area due to sea level rise for 2020 and 2040

SR	AREA (hectare)		Changes	
	2020	2040	Area (hectare)	Percentage
SR1	23.29	30.01	6.72	3.36
SR2	62.77	61.83	-0.93	-0.47
SR3	73.56	83.09	9.53	4.77
SR4	1,162.39	1,249.89	87.50	43.80
SR5	203.40	253.28	49.87	24.97
SR6	150.74	197.83	47.09	23.57
TOTAL	**1,676.16**	**1,875.93**	**199.77**	**100**

Some parts located near the shoreline have high risk of inundation, in particular during high tide [8-10]. Pictorial examples are shown in Photos 7 to 9. These events obviously have significant impacts on the structural integrity, human lives and possibility of the need for buildings retreat.


(a)


(b)

Photo 7: Inundation of salt water during high tide effected residential area at Sungai Ayam (a). Low tide condition at Kampung Sungai Ayam (b). Photo on November 2014.


(a)

(b)

Photo 8: Inundation of salt water during high tide at Minyak Beku Agrotourism (a) the revetment can be seen during low tide (b). Photo on November 2014.

(a)

(b)

Photo 9: The water level almost reached the top of the concrete sea wall at the Chong Long Gong temple during high tide (a) and the condition during low tide (b). Photo on November 2014.

IV. CONCLUSION

The continuous sea level rise will affect shoreline changes, environment and human activities along Batu Pahat shoreline. This has proved by the inundated sea water in some places, such as at Kampung Lapangan Terbang, Kampung Sungai Ayam, Minyak Beku and Kampung Serting during high tide event on 8 November 2014. These evidences are not only showing that the rise of sea level at the shoreline of Batu Pahat is critical and urgently need to be looked into, but also may provide a basis on the rise scale in the future.

ACKNOWLEDGMENT

The authors gratefully acknowledge the National Hydraulic Research Institute of Malaysia for sharing the satellite data Batu Pahat 2013 and projected sea level rise analysis 2020 and 2040. This work was supported by the Research Fund provided by Research University Grants (GUP-2014-038) and Chair of Climate Change UKM-YSD (ZF-2014-004).

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