Detection of mainland Kedah's shoreline changes (2013-2020); a case study

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Detection of mainland Kedah's shoreline changes (2013-2020); a case study

W M Wan-Afnizan[1,2], E H H Al-Qadami[2], M A M Razi[2*,3], N A Aminon[4], M Mahamud[4] and A Aziz[5]

[1]Geo-Structure Rehabilitation Centre (GSRC), Faculty of Civil Engineering & Built Environment, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia
[2]Department of Civil Engineering, Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia
[3]Eco Hydrology Technology Research Center (Eco-Hytech), Faculty of Civil Engineering & Built Environment, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia
[4]Department of Irrigation and Drainage Malaysia, Coastal Division, Kuala Lumpur, Malaysia
[5]IADA Kemasin Semerak, 16150 Kota Bharu, Kelantan, Malaysia
*Corresponding author: adib@uthm.edu.my

Abstract. Shoreline erosion and accretion are natural processes that involve the gradual change in the shape and position of coastlines due to the movement of water, sediment, and geological factors. These processes have significant implications for coastal environments, ecosystems, and human activities. Therefore, it is essential to frequently assess the shoreline changes for effective coastal management, sustainable development, and safeguarding valuable ecosystems. In the present study, shoreline condition along mainland Kedah (109 km) was investigated through remote sensing and geographical information system (GIS) techniques. The assessment was performed over the period of 7 years (2013 and 2020) by analysing the satellite images captured by Landsat-8 satellite Operational Land Imager (OLI) at 15 m resolution. Preprocessing was established by performing image geometric correction and registration. Next, the Support Vector Machines (SVMs) toolbox was used for image classification to define the water and non-water fields. Later, the shoreline was extracted from the classified images and overlaid in a geodetic base in ArcGIS software to detect shoreline changes. The results showed that the majority of mainland Kedah's shoreline did not experience extensive erosion or accretion at which 54% of the shoreline (58.8 km) was found to be stable. Erosion was observed at 6 locations with a total length of 10.1 km (9% of the total shoreline length) which was mainly concentrated in the non-protected areas. On the other hand, shoreline accretion was observed at 19 locations with a total length of 40.1 km (37% of the total length). It is worth highlighting that the erosion areas were concentrated in the southern part of the coastline, while the accretion areas were distributed between the middle part and the north side of mainland Kedah's shoreline.

1. Introduction

The shoreline change phenomenon is one of the most common issues that can occur in coastal areas [1]. Basically, coastline changes refer to the alterations in the shape, position, and characteristics of a coastline over time. These changes can be driven by natural processes, human activities, and a

combination of both [2]. Coastline changes have wide-ranging implications, including habitat loss, increased vulnerability to natural hazards, displacement of communities, and impacts on tourism and economic activities [3], [4]. The changes in the shoreline can occur in two forms, namely (i) erosion which refers to the gradual or rapid removal of sediment and land from the coastline due to the action of natural processes such as waves, currents, tides, and weathering [5], and (ii) accretion which refers to the natural process by which sediment, such as sand and gravel, accumulates along the coastline over time, resulting in the expansion of land areas or the buildup of beach and shoreline features [6]. Several factors lead to shoreline accretion such as sediment transport, littoral drift, river inputs, depositional environments, and vegetation [7]. Shoreline changes can be identified through the analysis of multispectral and multitemporal satellite imagery captured by satellites of varying resolutions, including low-, medium-, and high-resolution platforms like SPOT, Landsat, World View, and others. In the case of detecting shoreline changes, a number of researchers have utilized Landsat satellite imagery (including Landsat 7 and Landsat 8) as a means of analysis. Meanwhile, a significant portion of researchers have opted to employ the Digital Shoreline Analysis System (DSAS) for evaluating alterations in the shoreline within specific chosen regions [8].

The coastline of Malaysia stretches over 4,809 km, with over 1,300 km of its beaches experiencing erosion [9]. Daud et al. (2021) [10] and Abdul Maulud et al. (2022) [8] reported that erosion along the west coast of Peninsular Malaysia is notably aggravated by human interventions disrupting natural processes, including agricultural and aquacultural activities involving the construction of tidal gates, bunds, and channel dredging. To counteract this erosion, various strategies for coastal erosion mitigation have been adopted. Control of erosion along coastal areas can be achieved through either soft or hard engineering approaches. In Malaysia, typical coastal engineering structures employed include breakwaters, revetments, groins, seawalls, geo-tubes, and the Simplified Armor Unit-H (SAUH). A majority of these protective units have found application along the west coast of Peninsular Malaysia, yielding successful outcomes. Notably, they have been effectively implemented along a stretch of 1.5 km at Sungai Haji Dorani and Sungai Tegar in Selangor, serving to curtail erosion along the coastline [8].

In the present study, the changes along the mainland Kedah shoreline were investigated using remote sensing and geographical information system (GIS) techniques. The assessment was performed for the time range of 7 years (2013 to 2020) and it covers 109 km length of the shoreline starting from Kedah's border with Pulau Pinang (south) to Perlis (north). The used satellite images in this study were captured by Landsat-8 satellite Operational Land Imager (OLI) with 15 m resolution. The outcomes of the present study can help to have a general understanding of the changes on mainland Kedah's shoreline, as well as to help the local authorities in adopting proper mitigation measures to minimize the potential coastal areas' erosion or accretion.

2. Methodology

The present study was conducted to assess changes on the shoreline along Mainland Kedah's coastal area. The shoreline changes were evaluated between the years 2013 and 2020 using remote sensing and geographical information system (GIS) techniques as well as other applicable thematic maps for ground truthing purposes. The steps that were adopted to perform the present study includes, data collection, image pre-processing, image classification, accuracy assessment, image conversion, and shoreline extraction. A detailed description of these steps is presented in the following sections.

2.1. Study area

This study was conducted to investigate the shoreline condition of the mainland Kedah state shoreline which has a total length of 109 km extending from Kedah's border with Pulau Pinang (south) to Perlis (north) as shown in Figure 1. The study area was divided into 22 management units (MU) based on the natural coastal processes and land use. The MUs were labelled by using the district name and given number for example the MUs at Kuala Muda district were labelled by using the initial letter 'M' followed by cell number '1' followed by the MU number '1, 2, etc.'.

2.2. Data collection

Landsat-8 satellite Operational Land Imager (OLI) with 15 m resolution after pan-sharpening was used to extract coastline and water bodies giving it capabilities to provide reasonably good coverage of the coastline. The Landsat 8 satellite's Operational Land Imager (OLI) is a sophisticated remote sensing instrument designed to capture high-quality multispectral imagery of the Earth's surface. Landsat 8 is part of the Landsat program, which is a series of Earth observation satellites managed by NASA and the U.S. Geological Survey (USGS). These satellites have been crucial for monitoring and studying changes in the Earth's landscapes, ecosystems, and urban areas over time. The Operational Land Imager (OLI) on Landsat 8 is equipped with several bands that capture electromagnetic radiation across the visible, near-infrared, and shortwave infrared parts of the electromagnetic spectrum. Each band measures specific wavelengths of light, which allows scientists and researchers to analyse various features and characteristics of the Earth's surface. For mainland Kedah, two images were downloaded from https://glovis.usgs.gov/ in a radiometrically calibrated and geographically referenced form. Each Landsat image (OLI2013 and OLI2020) was obtained for Kedah Mainland dated 27th February 2013 and 10th December 2020 with tidal height of 2.1 m to observe the shoreline changes. These images were selected based on the atmospheric conditions, time of the year, tidal height and used in shoreline conditions assessment in the present study.

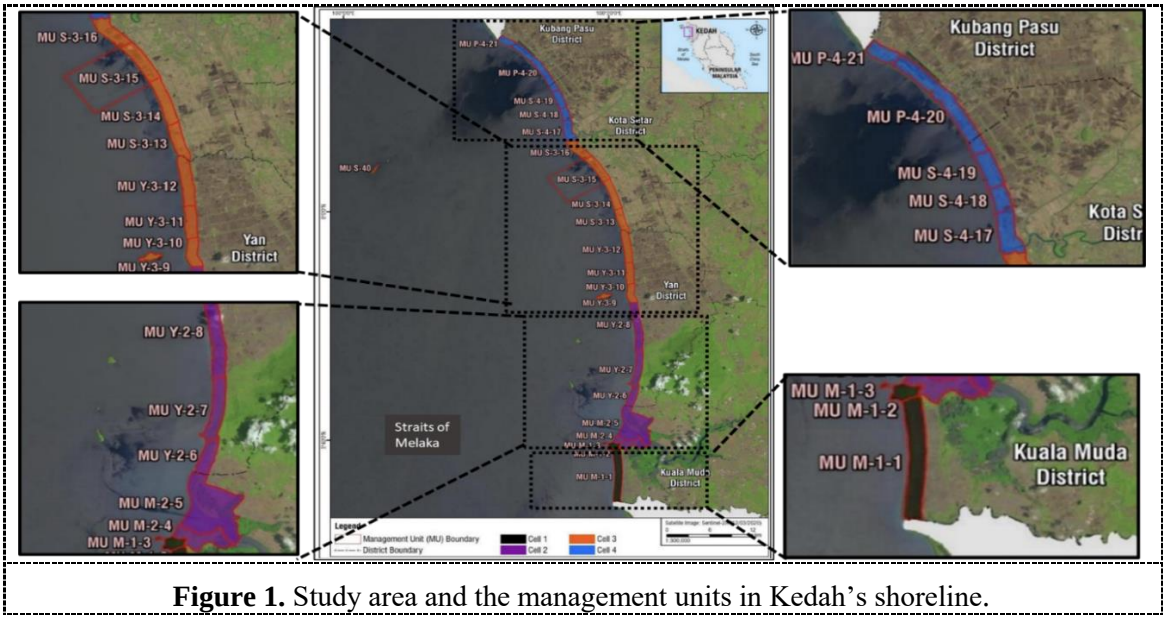

Figure 1. Study area and the management units in Kedah's shoreline.

2.3. Image processing and classification

The image pre-processing started by conducting the geometric correction and registration for the downloaded Landsat images. This was done by transforming image coordinates to geographic coordinates. The whole process, namely the rectification process, was repeated for several locations until the best transformation fit was established. The goal of rectification is to eliminate distortions caused by factors such as sensor geometry, terrain variations, and Earth's curvature so that the resulting image can be accurately compared, analysed, and integrated with other geographic data. Geometrically and radiometrically corrected images were then used to assess the shoreline change based on the combination of support vector machine classification (SVMs) and Geographical Information System (GIS).

Support Vector Machines (SVMs) toolbox was used to extract coastline from remote sensing images. Through this classification process, two classes were created and called "Water" and "Other-Fields". Later, the classified image accuracy was checked by calculating the KAPPA coefficient. The KAPPA coefficient is often used to evaluate the accuracy of land cover classifications or thematic maps produced

by different classification algorithms or by comparing classified images to ground truth data. The KAPPA coefficient considers both the agreement that would be expected by chance and the actual agreement observed between the observers or methods. It provides a more robust measure of agreement than simple percentage agreement, especially when dealing with imbalanced or skewed datasets.

2.4. Shoreline changes detection method

A post-classification comparison was applied when detecting Kedah's shoreline changes. Classified images were converted to vector layers by using the Raster to Vector module in ArcGIS 10.4 software. All shorelines extracted from classified images were overlaid and operated in a geodetic base in ArcGIS software to detect shoreline change. In the present study, the coastal area condition was categorized into three main categories, namely accreting, eroding, and stable zones. For further verifying the position of coastal conditions, the Landsat image and Google Earth engine were used hand-in-hand during the shoreline change detection processes.

3. Results and discussion

As previously mentioned, the investigated shoreline condition was classified into three different zones namely, stable, accreting, and eroding zones. Figure 2 shows the general overview of the shoreline condition of mainland Kedah at which the blue line represents the stable zones, while the green and red lines represent the accreting and eroding zones, respectively.

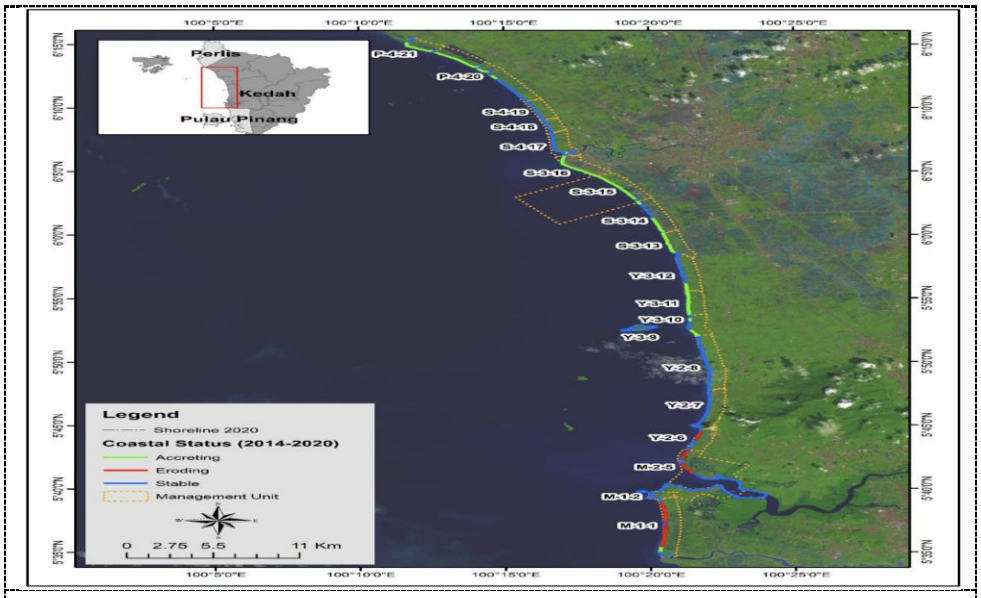

Figure 2. Shoreline condition on mainland Kedah.

The shoreline condition was assessed based on the collected images between the years 2013 and 2020. Overall, it can be seen that the mainland Kedah shoreline did not experience extensive erosion at which only 10.1 km suffered from erosion issues. This was due to the major enhancements along Kedah's shoreline by constructing rock revetment and rip raps to protect the coastal area. On the other hand, shoreline accretion was found to cover a longer stretch of the shoreline with a total length of 40.1 km. The remaining length of the shoreline Kedah's shoreline was found to be stable, the stable stretch covers 58.8 km of the shoreline's total length. According to the obtained results, a total of 6 stretches were observed to suffer from erosion along Kedah's shoreline with the highest rate of 27.3 m/year in MU M-2-5 (Pantai Rhu to Kg. Huma). On the other hand, a total of 19 stretches were found to suffer from accretion, where the highest average accretion rate was found to be 23.6 m/year in the vicinity of Kampung Sala (MU P-4-21). When comparing the present study findings with the National Coastal

Erosion Study (NCES) 2015, it can be noticed that there is a significant reduction in the number of eroded sites. This is due to implementing physical protection works, and coastal management plans and practices by the relevant authorities. The following sections discuss in detail the management units that were found to have unstable shorelines. Tables 1 summarizes the accreted and eroded locations along Kedah's shoreline.

Table 1. Summary of the accreted location along mainland Kedah's shoreline.

No.	MU ID	Location	Start		End		Length (km)	Rate (m/year)
			Latitude (°N)	Longitude (°E)	Latitude (°N)	Longitude (°E)		
1	M-1-1	Kg. Tepi Sungai to Kg. Kepala Jalan	5° 35' 27"	100° 20' 21"	5° 34' 57"	100° 20' 19"	0.9	6.8
2	Y-3-10	Kg. Kuala Dulang Kechil to Kg. Sungai Kering	5° 52' 33"	100° 21' 22"	5° 52' 4"	100° 21' 39"	1.1	7.5
3	Y-3-10	Kg. Sungai Tongkang to Kg. Sungai Tongkang	5° 53' 29"	100° 21' 25"	5° 53' 13"	100° 21' 23"	0.5	9.3
4	Y-3-11	Kg. Sungai Limau to Kg. Sungai Dedap	5° 56' 13"	100° 21' 15"	5° 53' 38"	100° 21' 25"	4.9	10.8
5	Y-3-12	North of MU Y-3-11	5° 53' 38"	100° 21' 25"	n.r.	n.r.	1.3	10.8
6	S-3-13	Kg. Kuala Sala to Kg. Kuala Kangkong	6° 00' 12"	100° 20' 28"	100°20'28"	100° 20' 51"	3.2	12.2
7	S-3-14	Jalan Kampung Sala	6° 01' 23"	100° 20' 6"	6° 00' 14"	100° 20' 28"	2.2	12.0
8	S-3-14	Kg. Sungai Papan to Kg. Lahar Pumpong	6° 2' 42"	100° 19' 36"	6° 02' 24"	100° 19' 41"	0.6	11.2
9	S-3-15	Kg. Lahar Pumpong to Kg. Sri Putra	6° 06' 15"	100° 17' 04"	6° 02' 45"	100° 19' 35"	9.1	21.2
10	S-3-16	Kg. Lahar Pumpong to Kg. Sri Putra	6° 02' 45"	100° 19' 35"	n.r.	n.r.	8.5	21.2
11	S-4-17	Jalan Marina Harbour	6° 06' 26"	100° 17' 03"	6° 06' 27"	100° 17' 09"	0.2	15.8
12	P-4-20	Kg. Jeruju	6° 12' 36"	100° 14' 32"	6° 12' 19"	100° 14' 43"	0.6	3.1
13	P-4-20	Jalan Seberang Kuala	6° 13' 08"	100° 14' 05"	6° 12' 50"	100° 14' 26"	0.9	6.9

Table 1. (Continued)

No.	MU ID	Location	Start		End		Length (km)	Rate (m/year)
			Latitude (°N)	Longitude (°E)	Latitude (°N)	Longitude (°E)		
14	P-4-20	Kg. Kuala Tunjang to Jalan Kampung Baru Tepi Laut	6° 14' 26"	100° 12' 38"	6° 13' 14"	100° 14' 04"	3.6	11.2
15	P-4-21	Jalan KampungKuala Kerpan	6° 15' 11"	100° 11' 44"	6° 14' 28"	100° 12' 36"	2.5	23.6
16	M-1-1	Kg. Masjid to Kg. Paya	5° 36' 57"	100° 20' 29"	5° 35' 27"	100° 20' 21"	2.8	6.8
17	M-1-1	Kg. Paya	5° 37' 12"	100° 20' 29"	5° 36' 59"	100° 20' 29"	0.4	5.1
18	M-1-1	Kg. Meriam to Kg. Yu	5° 38' 52"	100° 20' 22"	5° 37' 23"	100° 20' 29"	2.7	7.7
19	M-2-5	Pantai Rhu to Kg. Huma	5° 42' 01"	100° 21' 2"	5° 34' 57"	100° 21' 27"	1.7	27.3
20	M-2-5	Kg. Sungai Pial to Teluk Sg. Pier	5° 43' 05"	100° 21' 17"	5° 42' 22"	100° 21' 3"	1.4	11.7
21	Y-2-6	Kg. Singkir to Jln. Pantai Barat Kedah	5° 44' 26"	100° 21' 43"	5° 43' 53"	100° 21' 34"	1.1	6.2

n.r. not recorded.

3.1. MU M-1-1: Sungai Muda to Tanjung Palas Hari

Along the shoreline of MU M-1-1, shoreline accretion was observed along the stretch between Kg. Tepi Sungai south and Kg. Kepala Jalan north (around 0.9 km) with a yearly rate of 6.8 m/year as shown in Figure 3a. The mangrove vegetation was noticed to be repropagated fronting the coastal bund. On the other hand, shoreline erosion was observed in three locations which include (i) 2.8 km from Kg. Masjid to Kg. Paya with an erosion rate of 6.8 m/year, (ii) 0.4 km in Kg. Paya with an erosion rate of 5.1 m/year, and (iii) 2.7 km from Kg. Meriam to Kg. Yu with an erosion rate of 7.7 m/yea. The mangrove vegetation was noticed to be die-backed along the eroded shoreline.

3.2. MU M-2-5: Sungai Merbok to Kampung Sungai Pial

Along the shoreline of MU M-2-5, no accretion was observed along the whole stretch. However, shoreline erosion was noticed in 2 locations which include (i) 1.7 km between Pantai Rhu and Kg. Huma with erosion rate of 27.3 m/year, and (ii) 1.4 km between Kg. Sg Pial to Teluk Sungai with erosion rate of 11.7 m/year as shown in Figure 3b. The groynes that were present near Tanjung Dawai in 2003 were not detected in 2017 along with the receding sandy shoreline. The mangroves along the rest eroded shoreline have either thinned significantly or are non-existent.

3.3. MU Y-2-6: Kampung Sungai Pial to Tanjung Jaga

In Y-2-6 management unit, shoreline erosion was observed only in one location with a total length of about 1.1 km, while there are no eroded locations. The eroded location was extended between m Kg.

Singkir to Jln. Pantai Barat Kedah as shown in Figure 3c. The average yearly erosion rate was found to be 6.2 m/year. The width of the mangrove belt fronting the coastal bund was significantly affected.

3.4. MU Y-3-10: Kampung Sungai Sedaka to Kampung Kuala Sungai Limau

Along the shoreline of Y-3-10 management unit, two locations were observed to suffer from erosion which include, (i) 1.1 km from Kg. Kuala Dulang Kechil to Kg. Sungai Kering with erosion rate of 7.5 m/year, and (ii) 0.5 km in Kg. Sungai Tongkang with an erosion rate of 9.3 m/year as shown in Figure 3d.

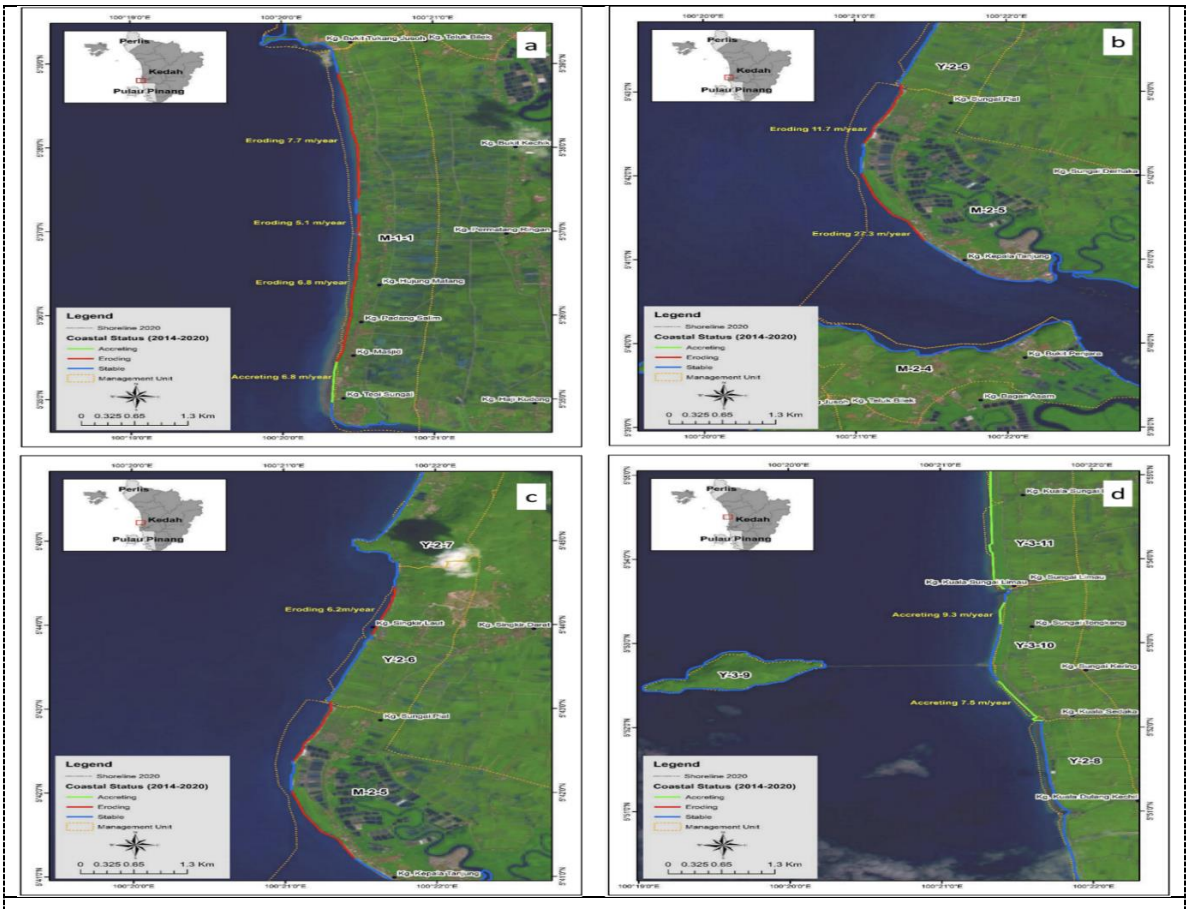

Figure 3. Shoreline conditions (a) MU M-1-1, (b) MU M-2-5, (c) MU Y-2-6, and (d) MU Y-3-10.

3.5. MU Y-3-11: Kampung Kuala Sungai Limau to Kampung Pisang

The whole shoreline stretch along Y-3-11 management was noticed to suffer from accretion starting from Kg. Sungai Limau and ending by Kg. Sungai as shown in Figure 4a. The total length of this MU is about 4.9 km and the accretion rate was found to be around 10.8 m/year. The mangrove vegetation was noticed to be repopulated on the seaward frontage of the shoreline.

3.6. MU Y-3-12: Kampung Pisang to Sungai Sala river mouth

In this management unit, shoreline erosion was not observed, while only one location was noticed to suffer from accretion which is located to the north of MU Y-3-11 as shown in Figure 4b. The total length of the affected area is around 1.3km and the rate of accretion was about 10.8 m/year. Similar to MU Y-3-11, The mangrove vegetation was noticed to be repopulated on the seaward frontage of the shoreline.

3.7. MU S-3-13: Sungai Sala river mouth to Kampung Kuala Kangkong

Most of the shoreline of MU S-3-13 was noticed to be suffering from accretion with an average yearly rate of 12.2 m/year. The total length that was affected was about 3.2 km which represents more the 90% of the MU shoreline length. The shoreline accretion was exactly observed between Kg. Kuala Sala to Kg. Kuala Kangkong as shown in Figure 4c.

3.8. MU S-3-14: Kampung Kuala Kangkong to Kampung Tebengau

Accretion was observed at two locations, on the north and south sides of the MU, while the middle part was noticed to be stable as shown in Figure 4d. The affected locations were (i) the vicinity of Jalan Kuala Sala with a total length of 2.2 km and average accretion rate of 12.0 m/year, and (ii) the shoreline stretch between Kg. Sungai Papan and Kg. Laharat Pumpong with a total length of 0.6 km and an average accretion rate of 11.2 m/year.

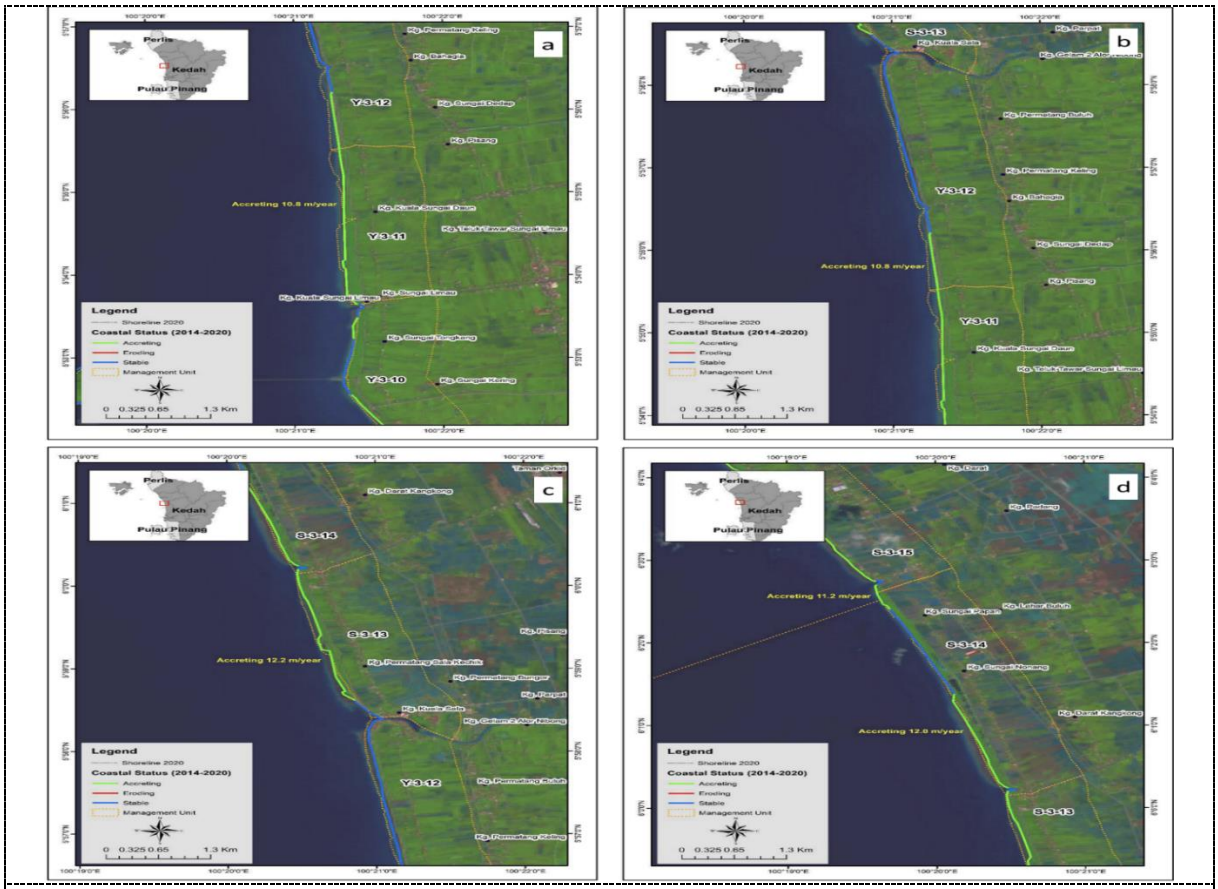

Figure 4. Shoreline conditions (a) MU Y-3-11, (b) MU Y-3-12, (c) MU S-3-13, and (d) MU S-3-14.

3.9. MU S-3-15: Kampung Tebengau to Kampung Tepi Laut

Figure 5a shows the shoreline condition along the S-3-15 management unit. It can be seen that almost the whole shoreline stretch was suffering from accretion. The largest accretion area was located at the north side of the MU with a total affected length of 8.5 km (from Kg. Lahar Pumpong to Kg. Sri Putra) with an average accretion rate of 21.3 m/year. A small area located at the south side of the MU with a total length of 0.4 km was accreting as well and the average accretion rate was found to be 11.2 m/year as shown in Figure 5a.

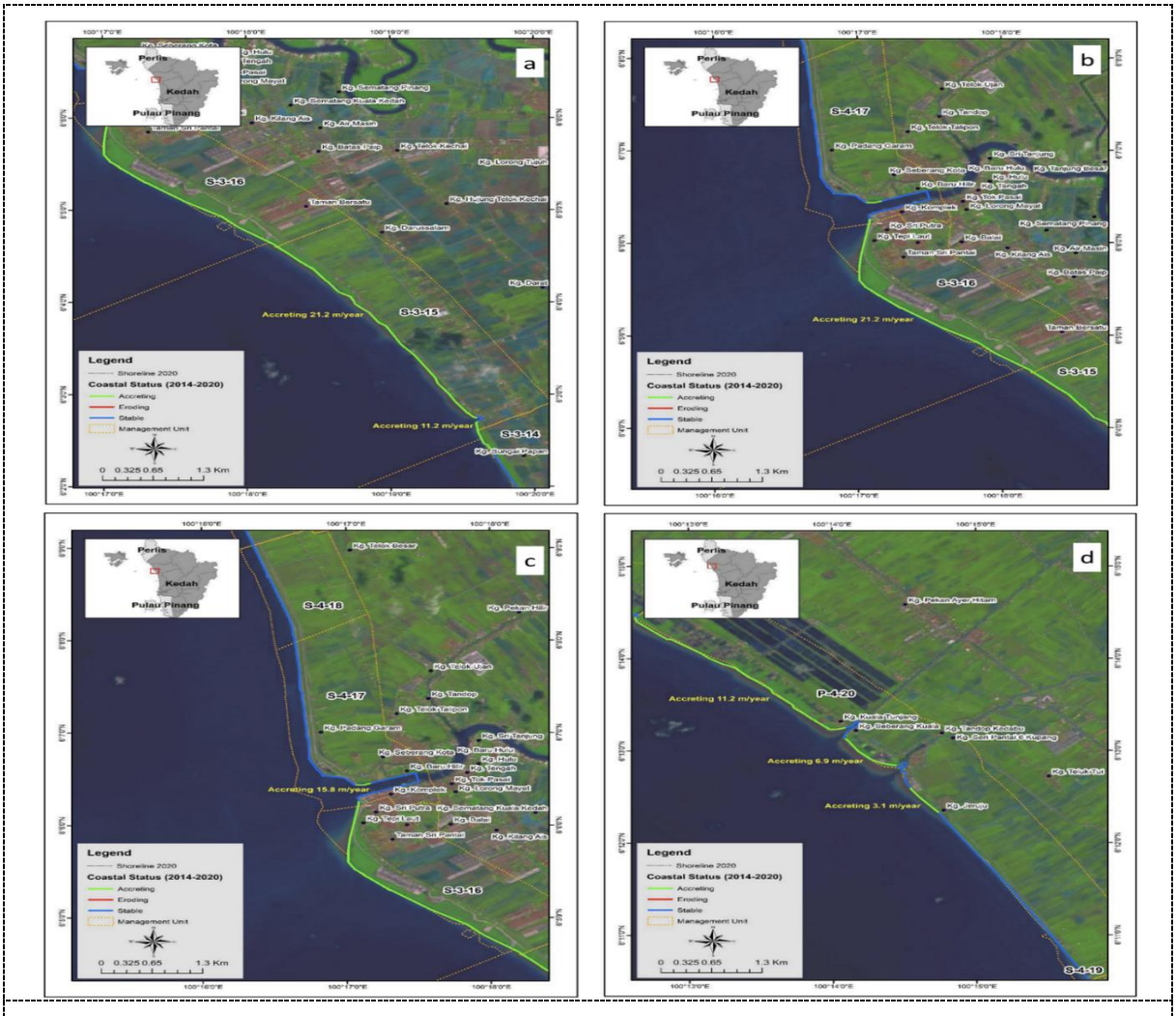

Figure 5. Shoreline conditions (a) MU S-3-15, (b) MU S-3-16, (c) MU S-4-17, and (d) MU P-4-20.

3.10. MU S-3-16: Kampung Tepi Laut to Kuala Kedah

Figure 5b shows the shoreline condition along the S-3-16 management unit. According to the presented figure, it can be clearly seen that the whole stretch of this MU is suffering from accretion. The total length of the shoreline is about 8.5 km, and the average rate of accretion was found to be 21.2 m/year.

3.11. MU S-4-17: Kuala Kedah to Kampung Permatang Bogak

Along the shoreline of the S-4-17 management unit, only a short stretch was noticed to be suffered from accretion with a total length of 0.2 km near Jalan Marina Harbour. The average yearly accretion rate was found to be around 15.8 m/year. The accretion in this location was specifically due to the regeneration of mangroves within the abandoned Kuala Kedah marina. The rest length of the shoreline in this MU was found to be stable and no erosion was noticed as shown in Figure 5c.

3.12. MU P-4-20: Kuala Kuar to Sungai Kerpan river mouth

Three locations were observed to suffer from accretion along the shoreline of this MU which include, (i) 0.6 km in the vicinity of Kg. Jeruju with an average accretion rate of 3.1 m/year, (ii) 0.9 km in the vicinity of Jalan Seberang Kuala with an average accretion rate of 6.9 m/year, and (iii) 3.6 km from Kg. Kuala Tunjang to Jalan Kampung Baru Tepi Laut with average accretion rate of 11.2 m/year as shown in Figure 5d.

4. Conclusion

The assessment of mainland Kedah's coastline condition (109 km) between 2013 and 2020 was performed based on the collected images from the Landsat-8 satellite Operational Land Imager (OLI) with resolution of 15 m. About 54% (58.8 km) of the total shoreline length was found to be stable. Middle and north side of the shoreline had accretion of 37% (approximately 40 km), while south side had erosion of 9%. A total of 19 locations were suffered from accretion with the highest rate of 23.6 m/year which found to be at Jalan Kampung Kuala Kerpan coastal area (MU P-4-21). The erosion issue was found in 6 locations with the highest rate of 27.3 m/year which was located at Pantai Rhu to Kg. Huma coastal area (MU M-2-5). In the accreted locations, mangrove vegetation was noticed to be repopulated on the seaward frontage of the shoreline, while in the eroded locations, the mangrove vegetation was thin significantly or are non-existent. Thus, it is recommended to adopt more strict strategies by the local authorities to monitor and protect Kedah's shoreline areas.

5. References

[1] Al Farrizi A, Taofiqurohman A and Subiyanto S 2020 Shoreline Change Analysis of Pontang Cape of Serang Regency of Banten Province *Omni-Akuatika* **16 (2)** 90–98
[2] Mohd F A, Maulud K N, Karim O A, Begum R A, Awang N A, Ahmad A, Azhary W A, Kamarudin M K, Jaafar M and Mohtar W H 2019 Comprehensive coastal vulnerability assessment and adaptation for Cherating-Pekan coast, Pahang, Malaysia *Ocean Coast. Manag.* **182** 104948
[3] Sajjad M, Li Y, Tang Z, Cao L and Liu X 2018 Assessing hazard vulnerability, habitat conservation, and restoration for the enhancement of mainland China's coastal resilience *Earth's Futur.* **6 (3)** 326–338
[4] Phillips M R and Jones A L 2006 Erosion and tourism infrastructure in the coastal zone: Problems, consequences and management *Tour. Manag.* **27 (3)** 517–524
[5] Foti G, Barbaro G, Barillà G C, Mancuso P and Puntorieri P 2022 Shoreline erosion due to anthropogenic pressure in Calabria (Italy) *Eur. J. Remote Sens.* **1** 1–21
[6] Young S S, Rao S and Dorey K 2021 Monitoring the erosion and accretion of a human-built living shoreline with drone technology *Environ. Challenges* **5** 100383
[7] Lawson S K, Udo K, Tanaka H and Bamunawala J 2023 Littoral Drift Impoundment at a Sandbar Breakwater: Two Case Studies along the Bight of Benin Coast (Gulf of Guinea, West Africa) *J. Mar. Sci. Eng.* **11 (9)** 1651
[8] Abdul Maulud K N, Selamat S N, Mohd F A, Md Noor N, Wan Mohd Jaafar W S, Kamarudin M K, Ariffin E H, Adnan N A and Ahmad A 2022 Assessment of Shoreline Changes for the Selangor Coast, Malaysia, Using the Digital Shoreline Analysis System Technique *Urban Sci.* **6 (4)** 71
[9] Ong J E 2021 Vulnerability of Malaysia to sea level change *Asia Pacific Network for Global Change Research Proceeding, Kobe, Japan*
[10] Daud S, Milow P and Zakaria R M 2021 Analysis of shoreline change trends and adaptation of Selangor Coastline, Using Landsat Satellite Data *J. Indian Soc. Remote Sens.* **49** 1869–1878

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