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Beach Morphodynamics and Evolution of Monsoon Dominated Coast in Selangor, Malaysia

Athiqah Nadhirah Manshah[1], Haris Abdul Rahim[1*], Raiz Razali[1], Nor Aizam Adnan[1], Fazly Amri Mohd[2], Yannie Anak Benson[3]

[1] *School of Geomatics Science and Natural Resources, Faculty of Built Environment, Universiti Technology MARA, 40450 Shah Alam, Selangor, Malaysia*

[2] *Studies of Surveying Science & Geomatics, Faculty of Built Environment, Universiti Teknologi MARA, 02600 Arau, Perlis, Malaysia*

[3] *Coastal & Oceanography Research Centre, National Water Research Institute of Malaysia (NAHRIM), 43300 Seri Kembangan, Selangor, Malaysia*

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ABSTRACT

Human-induced climate change has intensified coastal hazards globally, with shoreline erosion emerging as a critical challenge for monsoon-dominated coasts. Along the Selangor coast of Peninsular Malaysia, erosion processes are strongly influenced by Northeast Monsoon (NEM) wind and wave regimes, which govern sediment transport and shoreline stability. This study examines the geomorphological and morphodynamic characteristics of NEM-dominated beaches and their relationship with erosion and accretion dynamics along the Selangor coast. Five representative coastal sectors - Bagan Pasir, Pantai Jeram, Bagan Sungai Janggut, Pantai Kelanang, and Kg Batu Laut -were analysed using multi-temporal datasets for 2014, 2020, and 2023. Shoreline change and beach morphology were quantified through the integration of Land Satellites Program (LANDSAT) - derived shoreline extraction and conventional beach profiling to assess spatial and temporal variability and to validate remotely sensed observations. This approach enables the identification of short-term erosional and accretionary responses to seasonal monsoonal forcing. Results reveal marked spatial heterogeneity in erosion intensity, reflecting differences in coastal geomorphology, sediment availability, and exposure to monsoonal wave energy. The findings underscore the continued relevance of geomorphological controls in shaping erosion risk and associated socio-economic impacts. By updating earlier national assessments, this study provides an empirical basis for zone-specific coastal management and climate adaptation strategies along the Selangor coast.

[1*] Corresponding author. *E-mail address*: harisrahim@uitm.edu.my
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INTRODUCTION

The erosion of coastal areas is indeed a topic of great concern worldwide since at least 60% of sandy beaches across the globe are currently being eroded (Durgappa, 2018). Rocks, soils, and sands near the coast are worn down or carried away by the process of coastal erosion, which is brought on by local sea level rise, powerful wave action, and coastal flooding (Hammer-Klose et al., 2001). As a result of the effects of climate change, natural disasters such sea level rise, floods, landslides, coastal erosion, droughts, forest fires, and smog have become more frequent. The dynamic interactions between wave shoaling and breaking processes and bed response over a variety of time-space scales are referred to as beach morphodynamics (Pranzini et al., 2018). Additional processes, including tide and wind, and boundary conditions, like antecedent morphology, geology, sediment properties, and biota, make this interaction more complex. According to Abdul Maulud et al., 2022, the process of beach morphodynamic is altered because of the wave direction angle changing by 20° from southwest to northeast monsoon and bringing about a storm period. The shift in direction of the monsoonal winds has a major impact on the wave direction (Mirzaei et al., 2014).

Selangor coastal areas have been classified as sensitive to dangers that could cause a catastrophe by the National Coastal Erosion Study (NCES) conducted by the Malaysian government in 2016 (Abdul Maulud et al., 2022). The water level in areas with significant tidal ranges may change by 10 meters between high and low water, and the shoreline may shift laterally by several kilometres. The ecology of tidal flats depends on them being alternately flooded and exposed, which is crucial to biology (Hashim et al., 2013). The intertidal zone's exposed locations to erosion and deposition are of geological relevance. The prediction by 2030 is that more than 20,000 hectares of coastal areas will be affected by rising sea levels, and more than 123,000 hectares of saturated built-up areas face a tsunami risk. Therefore, all coastal areas must have strong sea defences to prevent coastal erosion, particularly in regions where development is taking place (Ehsan et al., 2019). Coastal hazards such as erosion, harmful algal blooms, big storms, flooding, tsunamis, and sea level rise are common in coastal areas. As for that, the aim for this study is to determine geomorphological characteristics of northeast monsoon-dominated beach in Selangor Coast and its relationship towards erosion and accretion and the objectives for this study are to quantify coastal erosion rate along Kuala Selangor shoreline and to analyse geomorphology factors and coastal erosion impacts (social economic) along Selangor Coast (Rameli et al., 2018).

METHODOLOGY

In Figure 1 shows the methodology used in this study. After all the data has been downloaded from United States Geological Survey (USGS). It needs to go through the preprocessing phase. So, in pre-processing phase. It consists of two methods which are layer stacking, and subset image. These methods are all in Earth Resources Data Analysis System (ERDAS) Imagine software (Mohd et al., 2019). In layer stacking, it is the process of combining multiple layers of data into a single layer. The layers can be of the same type or different types, such as raster or vector data (Selamat et al., 2017). By combining multiple layers, a more detailed and informative image can be created and can be used for analysis or visualisation. For subset images, it contains only the pixels that fall within the Area of Interest (AOI), and it can be used for a variety of purposes, such as reducing the file size of an image or focusing on a specific area of interest for analysis (Thieler et al., 1999). Next, the data processing will split into two parts which are beach erosion and slope estimation. It will undergo the digitisation part in ArcMap and erosion rate will be calculated once the digitisation is done. Under data analysis phase, it has relationship analysis between coastal slope and erosion rate.

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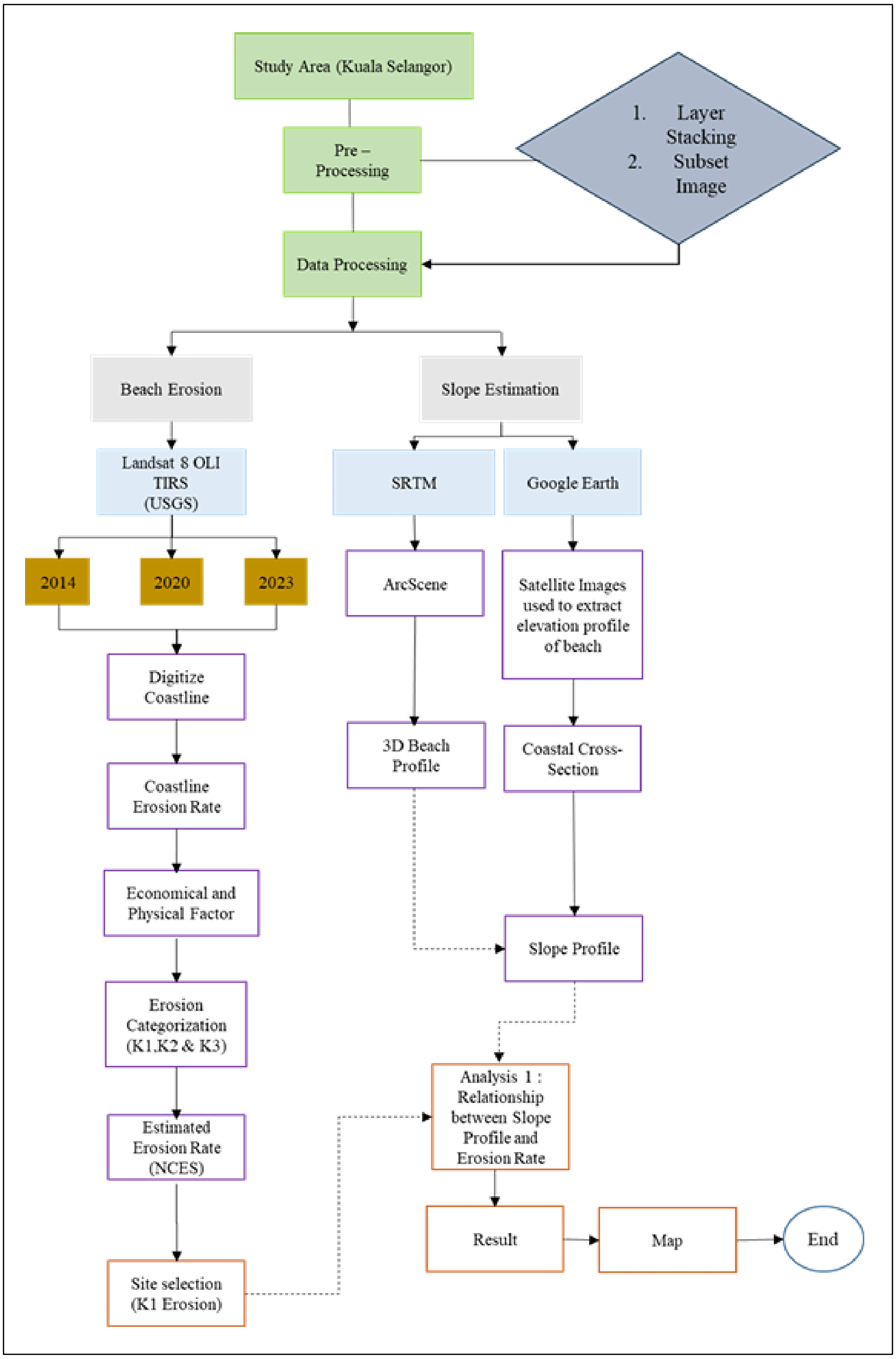

Fig. 1 Flowchart of Study

Source: Authors (2025)

Study Area

This study area will be conducted along Selangor coast which are Bagan Pasir, Pantai Jeram, Bagan Sungai Janggut, Pantai Kelanang, and Kg Batu Laut in Figure 2. This study monitored shoreline changes along five study areas, which are along the Selangor coast from Bagan Pasir to Kg Batu Laut, using secondary data, high spatial resolution imagery, and remote sensing and Geographic Information System (GIS) tools (McLaughlin et al., 2010). About 126 kilometres of shoreline have changed in total as stated in Table 1.

Table 1. Study Area

Zone	Study Area	From Latitude, Longitude	To Latitude, Longitude
1	Bagan Pasir	3° 26' 30.37" N 101° 7' 23.13" E	3° 23′ 55.91″ N 101° 10′ 12.14″ E
2	Pantai Jeram	3° 20' 14.69" N 101° 13' 44.15" E	3° 13′ 31.25″ N 101° 18′ 17.26″ E
3	Bagan Sungai Janggut	3° 13' 5.61" N 101° 18' 17.88" E	3° 10′ 19.79″ N 101° 18′ 17.26″ E
4	Pantai Kelanang	3° 9' 41.55" N 101° 18' 19.69" E	2° 47′ 18.56″ N 101° 24′ 43.19″ E
5	Kg Batu Laut	2° 46' 54.16" N 101° 24' 56.24" E	2° 43′ 41.16″ N 101° 27′ 20.45″ E

Source: Authors (2025)

Fig. 2 Study Area in Google Earth (2025)

Source: Authors (2025)

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Software

The software used in this study are ERDAS imagine, ArcMap, Google Earth Pro, ArcScene. For the ERDAS imagine, it will use for the layer stacking to combine all the satellite images become one image, haze reduction to get rid the cloud and the subset image to reduce the size of the satellite imagery. For ArcMap in Table 2, it will use for the digitising coastline in the first place and to produce map in the final stage. For ArcScene, it is a 3D viewer that allows you to view our GIS data in three dimensions.

Table 2. Data and Software

Item	Scope	Limitation
Software	Processing data includes ArcGIS, ArcScene and ERDAS Imagine.	The software depends on the data's compatibility.

Source: Authors (2025)

Secondary Data

LANDSAT images (Table 3) will be utilised in this study, compare it to remotely sensed data, and analyse how it connects to an existing erosion event. In this analysis, data from various temporal resolutions encompassing the coastline from Bagan Pasir to Kg Batu Laut were employed. The initial collection of data consists of LANDSAT pictures from 2014, 2020, and 2022. These data were required for this research to prepare the base map for digitising the shoreline and to compute the erosion and accretion rates from the digitised data.

Table 3. Satellite Data Acquisition

Satellite Sensor	Date of Acquisition	Time of Acquisition	Spatial Resolution (m)	Path/ Row	Tide (m) LW/HW	Agency
Landsat 8 OLI_TIRS	24/03/2014	03:28 PM	30	127 / 058	/	United States Geological Survey
	05/12/2020	03:28 PM			/	
	17/03/2023	03:28 PM			/	

Source: Authors (2025)

Coastline Digitisation

The image's scale was maintained about 1 to 1500 throughout the digitising process to prevent errors and achieve the highest level of accuracy. The digitised data were layered on top of one another to form the polygon of the area for the computation of accretion or erosion (Pendleton et al., 2010). The position of the line in reference to the sea was used to determine the area of accretion or erosion. If the earlier, digitally preserved line was near the sea, the coastal line was eroding, and vice versa (Pramanik et al., 2021). Figure 3 shows the line of digitisation of Bagan Pasir and Figure 4 below shows the all the digitisation of five locations along Kuala Selangor coastline.

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Fig. 3 Digitisation of Bagan Pasir

Source: Authors (2025)

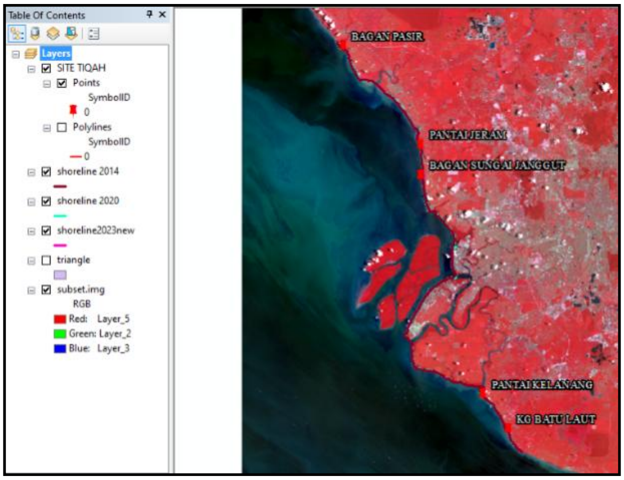

Fig. 4 All of the Digitisation

Source: Authors (2025)

NCES Scoring Parameter

In response to the growing critical problem of coastal erosion in various sections of the country, which threatens the livelihood and property of Malaysia's coastal communities, the Malaysian government commissioned the National Coastal Erosion Study (NCES) in 2015.

Calculation of Erosion Rate

The erosion and accretion rates were calculated using ArcGIS software. The area of erosion and accretion, as well as the range of data years used (2014 and 2020, 2020 and 2023, and 2014 and 2023), are

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crucial in calculating the rate of erosion and accretion. The following formula was used to calculate the rate of erosion and accretion based on the data collected Figure 5 (Eq.1):

$$\text{Erosion and Accretion Rates} = \frac{Area\ (meter)}{Range\ year}$$

Fig. 5 Erosion and Accretion Rate Formula

Source: National Coastal Erosion Study (2015)

Calculation Physical Parameter

The physical parameter rating based on physical erosion rates is shown in Table 4. Physical erosion is classified as 'High' when it surpasses 4 metres per year and as 'Low' when it is less than 1 metre per year. 'Medium' erosion rates are those ranging between 1 and 3.9 m/year. These criteria can be found on the official NCES, 2015 report (Ariffin, 2017).

Table 4. Scoring of Physical Parameter

Parameter	Description	Erosion Rate (m/year)	Physical Erosion Score
Rate of coastline retreat	Low	≤0.99	Actual erosion rate (m/year)
	Medium	1.00 to 1.99	2 points
		2.00 to 2.99	3 points
		3.00 to 3.99	4 points
	High	≥4.00	points

Source: National Coastal Erosion Study (2015)

Determining Erosion Category

The following processes must be followed in order to identify the erosion category for each erosion site. The constant value identified in NCES, 2015 report being published Figure 6 (Eq.2):

Step 1: Determine the scoring rate for the physical parameter related to the maximum average annual erosion rate analysed from satellite images.

Step 2: Determine the score for each of the economic parameter's components based on their economic significance.

Step 3: Compute the total score as follows:

$$\text{Total Score} = \text{Physical Parameter Score} \times \begin{pmatrix} 0.1 \times Land\ Use\ Rating \\ + \\ 0.4 \times Buildings\ and\ Establishment\ Rating \\ + \\ 0.3 \times Public\ Uitlities\ and\ Infrastructure\ Rating \\ + \\ 0.2 \times Public\ Facilities\ and\ Amenities\ Rating \end{pmatrix}$$

Fig. 6 Total Score of Coastal Vulnerability Index (CVI) Formula

Source: National Coastal Erosion Study (2015)

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Step 4: Arrange the eroded section of shoreline into Category 1, Category 2, or Category 3 depending on its Total Score (Table 5.)

Table 5. Scoring for Each Erosion Category

Erosion Category	Total Score Range
1 (Critical)	Greater than 12
2 (Significant)	Greater than 5 but lower or equal to 12
3 (Acceptable)	Lower than or equal to 5

Source: National Coastal Erosion Study (2015)

RESULTS AND DISCUSSIONS

This section will explain what have got while and after doing the calculations and analysis. It will discuss in further detail the processes that were followed in relation to what was outlined including coastal profile and erosion study of shoreline region in Kuala Selangor (Azhar et al., 2018). The data had been collected from the websites of the USGS for further erosion research and profiling (Hashmi et al., 2018). ERDAS Imagine and ArcGIS software can be used to determine accreted and eroded areas (Kantamaneni et al., 2018).

Summary of Erosion Rate

All of the parameters have been calculated in the previous chapter based on NCES, 2015 report. It indicates that the total score lower or equal to 5 will be called Acceptable or K3. K2 is called Significant which is the total score of more than 5 and less than 12. K1 is designated as a dangerous area due to its relatively dense human settlements and rapid retreat of critical public infrastructure. From the table below, clearly see that every year erosion length, area, and width increase. This means that erosion is still happening in both the long and short term.

Table 6. Summary for Erosion in Kuala Selangor Coasts from 2014 to 2020

Category	Total Length (m)	Total Area (ha)	Total Width (m)	Condition
K1	1211.266	4.704	154.449	Critical
K2	4017.74	10.609	563.010	Significant
K3	668.537	0.83	37.212	Acceptable

Source: Authors (2025)

As in the Table 6, for the year 2014 to 2020, the critical area is recorded is 4.704 hectare that been eroded along 1211.266 meter. for significant condition took up 10.609 hectare and 4017.74 meter. For acceptable condition, only 0.830 hectare and 668.537 meter. For the year 2020 to 2023 as shows in the Table 7, the critical area is recorded is 4.733 hectare that been eroded along 1284.34 meter. for significant condition took up 10.311 hectare and 2863.246 meter. For acceptable condition, only 0.128 hectare and 311.289 meter.

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For the year 2014 to 2023 in the Table 8 shows, the critical area is recorded is 3.693 hectare that been eroded along 783.216 meter. for significant condition took up 10.706 hectare and 3072.939 meter. For acceptable condition, only 4.312 hectare and 2529.520 meter.

Table 7. Summary for Erosion in Kuala Selangor Coasts from 2020 to 2023

Category	Total Length (m)	Total Area (ha)	Total Width (ha)	Condition
K1	1284.34	4.733	227.907	Critical
K2	2863.246	10.311	471.655	Significant
K3	311.289	0.128	10.542	Acceptable

Source: Authors (2025)

Table 8. Summary for Erosion in Kuala Selangor Coasts from 2014 to 2023

Category	Total Length (m)	Total Area (ha)	Total Width (ha)	Condition
K1	783.216	3.693	125.954	Critical
K2	3072.939	10.706	495.139	Significant
K3	2529.52	4.312	240.812	Acceptable

Source: Authors (2025)

NCES Erosion and Accretion Analysis

The permanent loss of land and habitat along the shore is also known as coastal erosion. There are seasonal monsoons that distinguish the condition of the coasts from typical weather. The erosion and accretion sites may be seen in five locations: Bagan Pasir, Pantai Jeram, Bagan Sungai Janggut, Pantai Kelanang, and Kg Batu Laut. The permanent loss of coastal land and ecosystems is known as coastal erosion. The five previously mentioned locations underwent coastal erosion, which was detrimental to the social, environmental, economic, and recreational interests along the coast.

Table 9. Erosion Zone (2014, 2020 and 2023) Based on The Erosion Rate (m/year).

Zone	Location	2014 - 2020 (6 years)			2020 - 2023 (3 years)			2014 - 2023 (9 years)		
		Length (m)	Width (m)	Erosion Rate (m/year)	Length (m)	Width (m)	Erosion Rate (m/year)	Length (m)	Width (m)	Erosion Rate (m/year)
1	Bagan Pasir	1584.237	227.979	37.997	1582.32	136.144	45.381	2164.862	287.971	31.997
2	Pantai Jeram	1716.602	174.759	29.127	499.390	71.086	23.695	400.587	35.95	3.944
3	Bagan Sungai Janggut	1625.379	74.708	12.451	1877.468	328.782	109.594	2721.185	353.69	39.299
4	Pantai Kelanang	2629.998	118.543	19.757	1749.743	114.488	38.163	2131.211	202.686	22.521
5	Kg Batu Laut	1312.686	178.183	29.697	822.514	48.365	16.122	74.301	10.047	1.116

Source: Authors (2025)

As mentioned in Table 9 above, the result shows that from 2014 to 2020, Pantai Jeram experienced the greatest eroded length of 1716.602 metres, while Bagan Sungai Janggut had the greatest eroded length of 1877.468 metres from 2020 to 20203. From 2014 to 2023, the largest erosion that occurred in the Kuala Selangor coastline is Bagan Sungai Janggut, with a length of 2721.185 metres.

In contrast, the 2020 to 2023 period exhibits a marked intensification of erosion in selected zones, particularly at Bagan Sungai Janggut (Zone 3), where the erosion rate escalated dramatically to 109.59 m/year, accompanied by a substantial increase in erosion width (≈329 m). This sharp acceleration over a shorter period strongly suggests the influence of episodic high-energy events, such as extreme monsoonal storms, altered sediment budgets, or the failure of natural or artificial coastal buffers. Similarly, Bagan Pasir (Zone 1) recorded an increased erosion rate of 45.38 m/year, despite a reduction in shoreline width, indicating rapid landward retreat concentrated over a narrower coastal strip. Conversely, Pantai Jeram (Zone 2) and Kg Batu Laut (Zone 5) showed reduced erosion rates during 2020 to 2023 (23.70 m/year and 16.12 m/year, respectively). This decline may reflect temporary sediment accretion, shoreline stabilisation measures, or a lull between erosive events rather than a long-term recovery. The relatively short, eroded lengths recorded in these zones during this period further reinforce the likelihood of localised or short-lived erosion processes.

When considering the cumulative 2014 to 2023 period, Bagan Sungai Janggut (Zone 3) emerges as the most critically affected zone, with the largest eroded length (≈2.72 km), widest erosion extent (≈354 m), and a high mean erosion rate (39.30 m/year). This indicates sustained and severe shoreline retreat over the long term. In contrast, Kg Batu Laut (Zone 5) and Pantai Jeram (Zone 2) exhibit very low cumulative erosion rates (≤4 m/year), despite higher short-term values earlier in the record, highlighting the non-uniform persistence of erosion across zones.

Erosion Categorisation

Previous studies have shown that waves during the northeast monsoon can cause erosion and sedimentation of coasts and sand ridges, raising coastal and inland water levels. The seasonal monsoon that hits the east coast from November to March accentuates this phenomenon and, if left unchecked, will exacerbate certain areas of Kuala Selangor (JPBD, 2012). Figure 7, Figure 8, and Figure 9 below shows the maps for year 2014 to 2023, 2020 to 2020 and 2014 to 2023 of erosion categorisation along Kuala Selangor coastline. Vulnerability is a combination of processes originating from environmental, physical and socioeconomic parameters that increase the risk of an individual or a group to the effect of hazards (Kumpulainen, 2006; Mahendra et al., 2011). The understanding of this study about water quality is to maintain the water quality and facilitate the management as actions can be taken by local authorities and other government agencies to maintain and improve the water quality and create boundaries and regulations that can bring back nature (Nasir et al., 2021).

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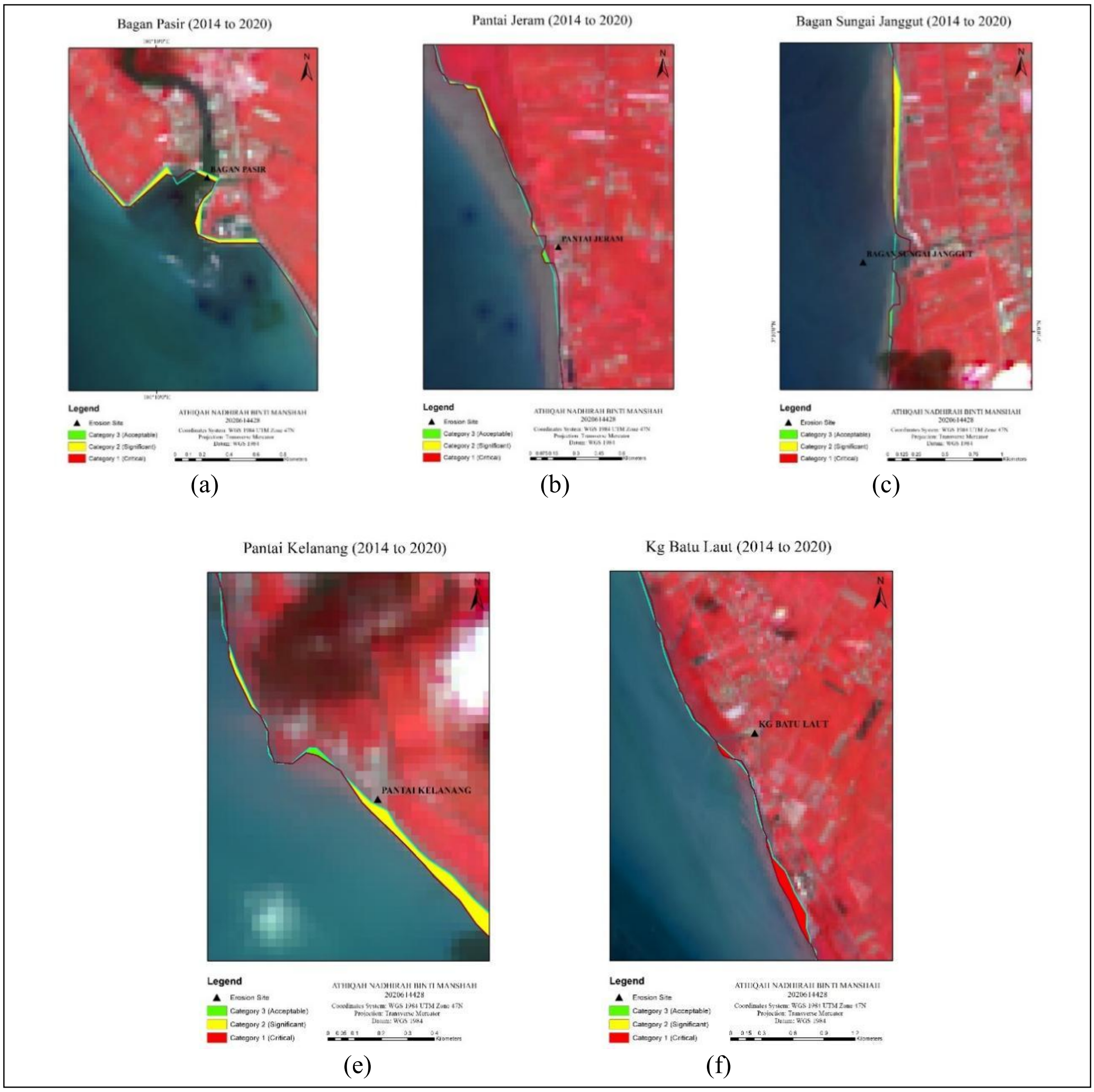


Fig.7 Map of Erosion in Years 2014 to 2020 (a) Bagan Pasir (b) Pantai Jeram (c) Bagan Sungai Janggut (d) Pantai Kelanang (e) Kg Batu Laut

Source: Authors (2025)

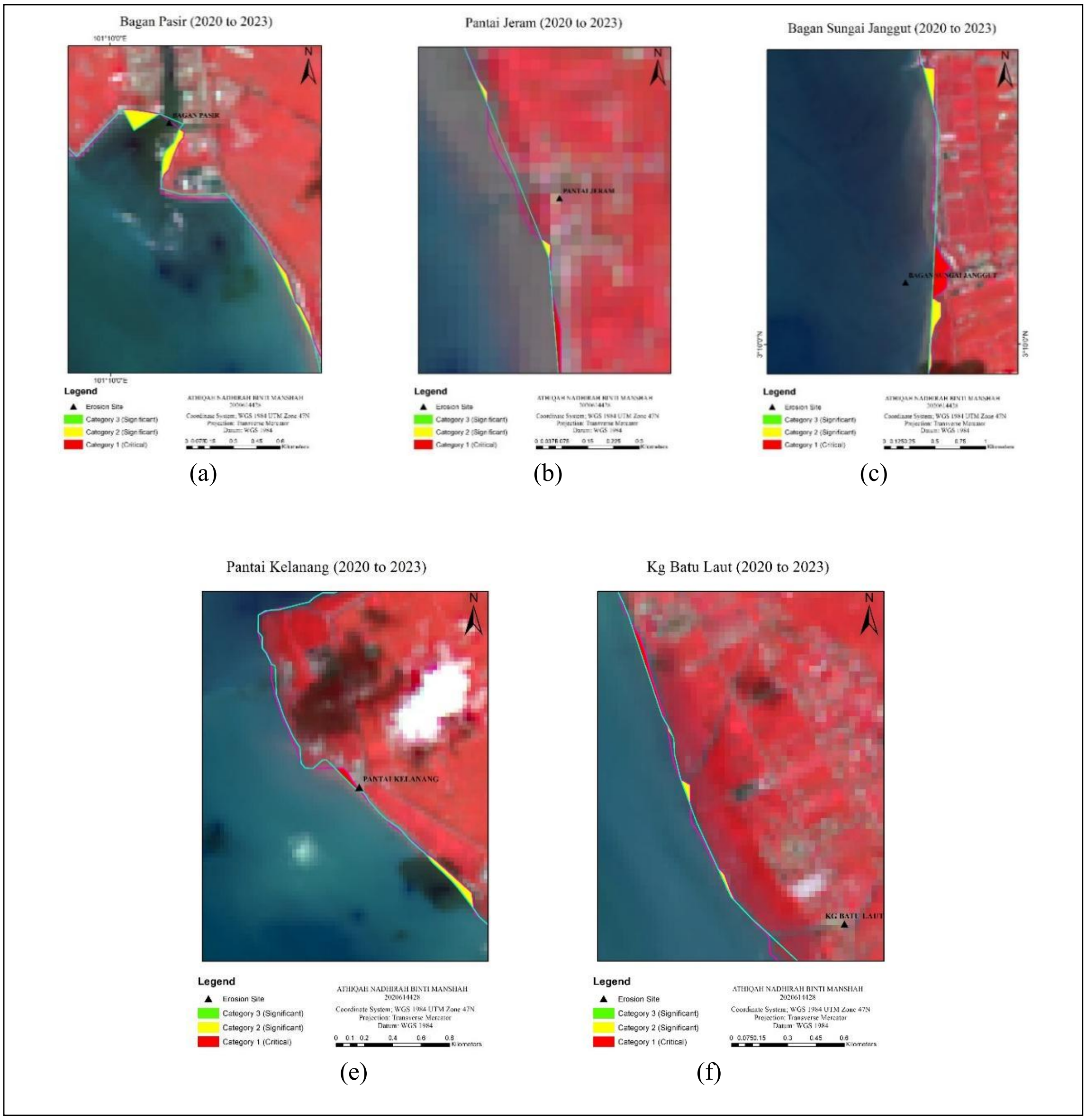


Fig.8 Map of Erosion in Years 2020 to 2023 (a) Bagan Pasir (b) Pantai Jeram (c) Bagan Sungai Janggut (d) Pantai Kelanang (e) Kg Batu Laut

Source: Authors (2025)

During the 2014 to 2020 period, erosion rates ranged from 12.45 m/year at Bagan Sungai Janggut (Zone 3) to 37.99 m/year at Bagan Pasir (Zone 1). Zones 1, 2, and 5 recorded relatively high erosion rates (>29 m/year), despite moderate shoreline widths, suggesting that these areas were already under chronic erosional stress. Pantai Kelanang (Zone 4), although exhibiting the longest eroded shoreline length (≈2.63 km), showed a comparatively moderate erosion rate (19.76 m/year), implying spatially extensive but less aggressive retreat.

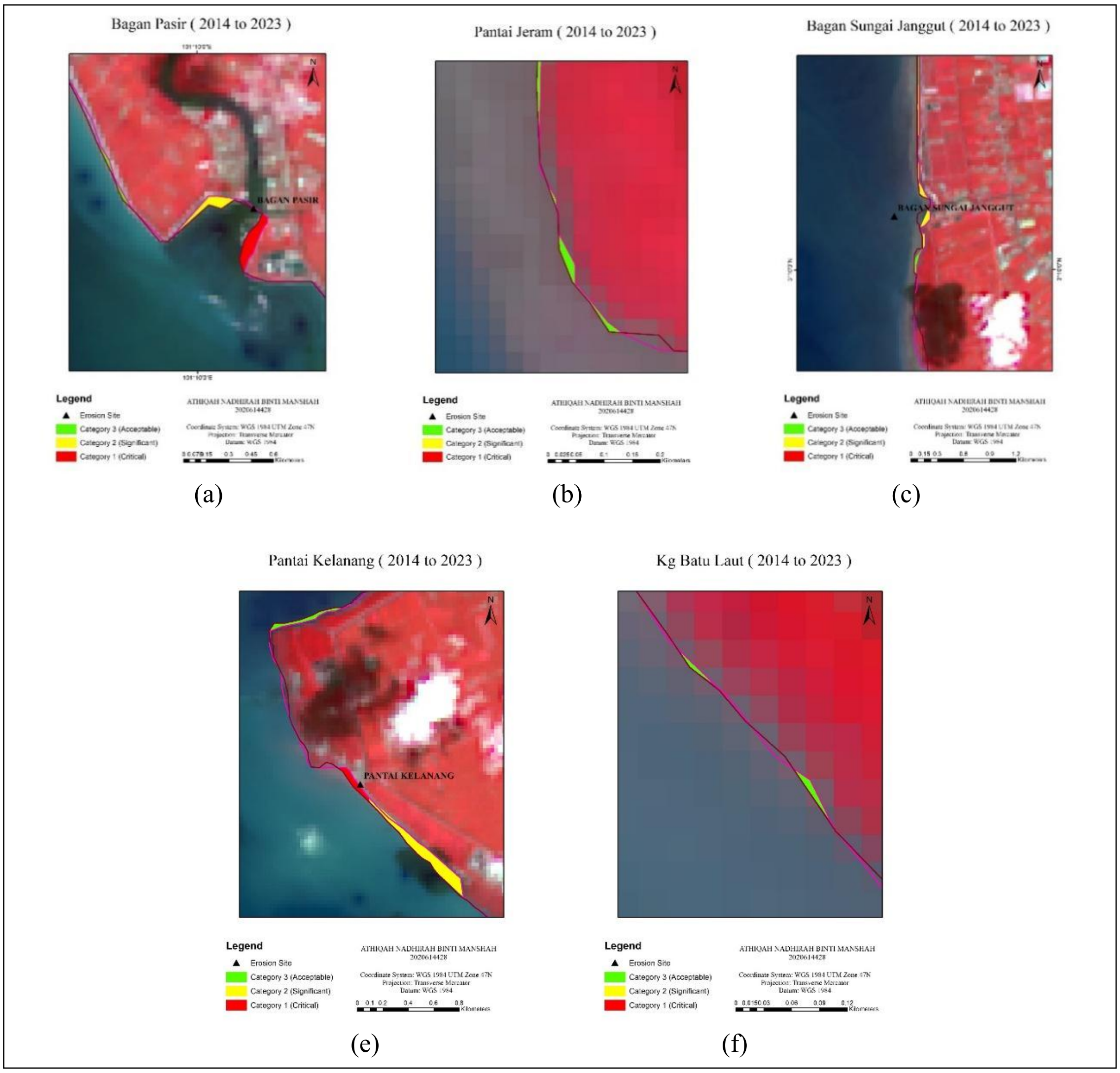


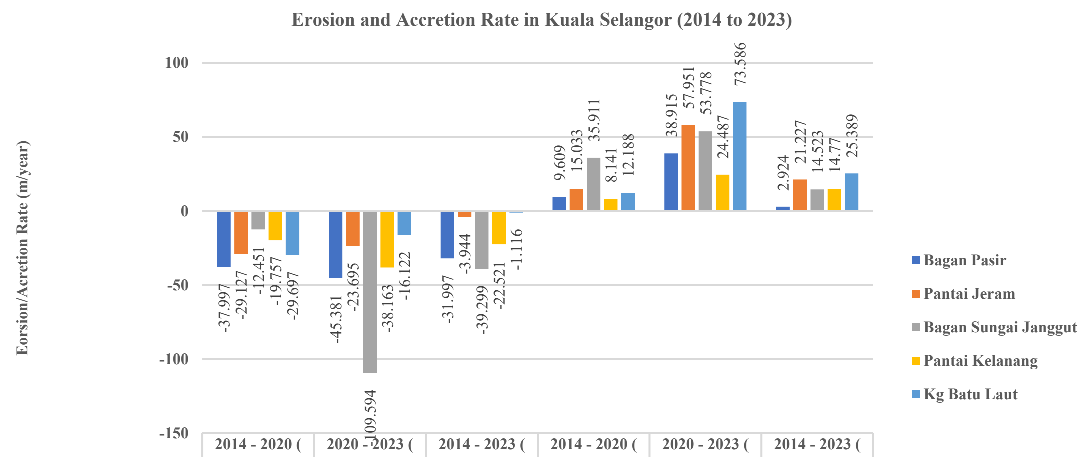
Fig. 9 Map of Erosion in Years 2014 to 2023 (a) Bagan Pasir (b) Pantai Jeram (c) Bagan Sungai Janggut (d) Pantai Kelanang (e) Kg Batu Laut

Source: Authors (2025)

Erosion and Accretion Rate

The highest rate of accretion in 2014 to 2020 is Bagan Sungai Janggut which is 39.299 m/year. As for the years 2020 to 2023, the highest rate of accretion is Kg Batu Laut with the rate 73.586 m/year. Years 2014 to 2023, Kg Batu Laut is the highest of accretion rate which is 25.389 m/year. Accretion is the process by which coastal sediments return to the visible part of the coast or foreshore after a flood event. Fig.10 shows the ranges value of coastal width for the highest of erosion in 2014 to 2020 is Bagan Pasir which is -37.997 m/year and for 2020 to 2023, the highest erosion went to Bagan Sungai Janggut which is -109.594 m/year. For 2014 to 2023, the highest eroded is Bagan Sungai Janggut which is take up to -39.299 m/year. The highest erosion rates are likely due to human activities such as construction and reclamation. The effects of coastal erosion have caused alarm and concern around the world (Ariffin et al., 2017). Coastal vulnerability such a concept that can be identifies people and places that are vulnerable to disturbances because of the coastal hazards. This was expected that the space technology will facilitate by exploitation of the developments of CVI and give some effective strategies for coastal management. Furthermore, coastal erosion are unavoidable and natural processes as coastal sediments are constantly being moved due to the effects of tides, storm surge, currents, winds, and waves. The coast is the area that separations the coastal land from the sea (Azhar et al., 2018).

The CVI is preferred in the study of coastal hazard because it prepared a predictive approach to any changes of coastal that occur through the facilities available in its statistical basis to classify coastlines based on the potential for change. However, through reviews are often performed to elaborate all applications of this advances technological, especially in exploitation of the space geodetic technology to determined and classified some of coastal information from some analytical approaches. Various parameters include ecological, spatial, and human characteristics are strong to influenced coastal erosion of vulnerability (Hamid et al., 2019). Therefore, the coastline be chosen along the beach of Kuala Terengganu as it is in K1 categorisation as stated in NCES, 2016 report. This area is exposed with extreme monsoonal activity for the past four decades. A relatively small increase in sea level could affect natural coastal systems (Din et al., 2019).



	2014 - 2020 (6 years)	2020 - 2023 (3 years)	2014 - 2023 (9 years)	2014 - 2020 (6 years)	2020 - 2023 (3 years)	2014 - 2023 (9 years)
Bagan Pasir	-37.997	-45.381	-31.997	9.609	38.915	2.924
Pantai Jeram	-29.127	-23.695	-3.944	15.033	57.951	21.227
Bagan Sungai Janggut	-12.451	-109.594	-39.299	35.911	53.778	14.523
Pantai Kelanang	-19.757	-38.163	-22.521	8.141	24.487	14.77
Kg Batu Laut	-29.697	-16.122	-1.116	12.188	73.586	25.389

Fig.10 Erosion and Accretion Rate in Kuala Selangor (m/year)

Source: Authors (2025)

CONCLUSION

This section will conclude after the study has been done through analysis and some calculations. The first to conclude is the aim of the study is to determine the geomorphological characteristics of the northeast monsoon dominated beach in Selangor coast and its relationship towards erosion and accretion. The study involves examining a beach profile and other relevant geomorphic features. Erosion refers to the loss of sediment from the beach, resulting in a receding shoreline, while accretion refers to the deposition of sediment, causing the beach to widen or grow (Malaysian Meteorological Department, MET 2023). Erosion refers to the loss of sediment from the beach, resulting in a receding shoreline, while accretion refers to the deposition of sediment, causing the beach to widen or grow. Understanding the geomorphological characteristics and erosion accretion dynamics of the beach can have practical implications for coastal management. The conclusions drawn from this study may provide valuable information for coastal planners, engineers, and decision-makers in terms of erosion control measures, shoreline protection, and sustainable beach management strategies. Daily activities such as harbour construction and sand dredging disrupt the continuity of sediment transport and thus accelerate coastline erosion (Yanalagaran & Ramli, 2018)

The analysis of shoreline erosion from 2014 to 2023 across five coastal zones reveals strong spatial and temporal variability in erosion behaviour. Erosion rates are not linear over time, indicating that short-term, high-energy events play a significant role alongside long-term coastal processes. During 2014 to 2020, erosion was already pronounced in Bagan Pasir (Zone 1), Pantai Jeram (Zone 2), and Kg Batu Laut (Zone 5), with rates approaching or exceeding 30 m/year, suggesting persistent erosional pressure. Pantai Kelanang (Zone 4) experienced the most extensive shoreline erosion spatially, but at moderate rates, while Bagan Sungai Janggut (Zone 3) showed comparatively lower erosion intensity during this period. In 2020 to 2023, erosion intensified sharply in Bagan Sungai Janggut (Zone 3) and Bagan Pasir (Zone 1), with Zone 3 recording an extreme erosion rate exceeding 100 m/year, indicative of episodic or event-driven shoreline retreat. Conversely, Zones 2 and 5 experienced reduced erosion rates, likely reflecting temporary stabilisation rather than long-term recovery. Over the cumulative 2014 to 2023 period, Bagan Sungai Janggut (Zone 3) emerges as the most critically eroded area in terms of length, width, and mean erosion rate, while Pantai Jeram (Zone 2) and Kg Batu Laut (Zone 5) show relatively low long-term average erosion despite earlier short-term impacts.

Coastal erosion in the study area is highly non-uniform and episodic, necessitating zone-specific management and monitoring, with priority intervention required for Zones 1 and 3. This study also to assess the social-economic impacts of coastal erosion along the Selangor Coast. The tourism industry is one of Selangor's top attractions and a source of revenue for the local population. Many hotels and resorts were constructed recently specifically for this purpose. However, erosion was eventually brought on by the construction of these facilities in coastal areas, which frequently altered the region's natural form and sediment movement. Erosion will result in the loss of sandy beaches, which will affect the tourism and recreation activities in coastal communities. The problem of coastal erosion has been noted to be more serious in areas that are most attractive for the development of tourism. Construction of these facilities in coastal areas, which frequently changed the region's natural structure and sediment movement, eventually caused erosion.

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CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

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AUTHORS' CONTRIBUTIONS

Athiqah Nadhirah carried out the research, wrote and revised the article. Haris Abdul Rahim conceptualised the central research idea and provided the theoretical framework. Nor Aizam Adnan and Fazly Amri Mohd designed the research, supervised research progress; Raiz Razali and Yannie Anak Benson anchored the review, revisions and approved the article submission.

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