MULTIDISCIPLINARY APPLIED RESEARCH AND INNOVATION
e-ISSN: 2773-4773

MARI

Vol. 6 No. 2 (2025) 119-126
https://publisher.uthm.edu.my/periodicals/index.php/mari

Coastal Erosion Hazard Map at Pantai Perpat and Pantai Punggur, Batu Pahat, Johor

Afif Altaf Mohd Ezuan'Izam, Muhammad Affendi Alias, Nur Farisha Mohd Fakarruddin, Suhaila Sahat*

Department of Civil Engineering, Centre for Diploma Studies,
Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600 Pagoh, Johor, MALAYSIA

*Corresponding Author: suhailasa@uthm.edu.my
DOI: https://doi.org/10.30880/mari.2025.06.02.014

Article Info

Received: 31 August 2024
Accepted: 31 December 2024
Available online: 20 February 2025

Keywords

Hazard, Coastal, Parameters, CVI, Erosion.

Abstract

Coastal erosion is a major problem in Malaysia, impacting the country's coastline and providing a variety of environmental, economic, and social difficulties. Several causes contribute to Malaysian coastal erosion, including changes in sea level and monsoons that occur in Malaysia. This leads to increased erosion and infrastructure damage, as well as other natural disasters such as floods and landslides. This research investigates the coastal erosion hazard map at the Pantai Punggur and Pantai Perpat coastlines in Batu Pahat, Johor. The aim is to produce a diagram mapping the beach profile and beach hazards around the two beaches. Google Earth Pro software was used to obtain data, and ArcGIS software was employed to analyze the study area for each parameter. Data was collected from a previous study, which provided essential information on geomorphology, shoreline change rate, coastal slope, relative sea level rate, and mean significant wave height.

1. Introduction

A natural phenomenon known as coastal erosion is brought about by the interaction of constructions and natural processes at beaches and oceans. The process by which material is removed from the shore by tidal currents and waves, causing the coastline to recede landward, is known as coastal erosion. Erosion along the coast is a constant result of both natural and human processes working together. Globally, the processes of erosion and accretion are always changing the coasts [1].

Peninsular Malaysia's 1,972 km of coastline faces the South China Sea to the east and the Straits of Malacca to the west, whereas East Malaysia's 2,837 km of coastline is significantly longer than that of the rest of the nation [2]. According to the National Coastal Erosion Study 1986, erosion poses a threat to over 30% of Malaysia's coastline, which is why the government launched an erosion management program. Remis Beach, Ayam Laut River, Suloh River, Koris River, Frozen Oil Village, and Segenting Kemeruk Village are a few examples from different districts. To alleviate coastal erosion and lower the risk of flooding in Johor, the government has planned to execute a number of projects. Certain scholars have examined the characteristics of the eroding coastline area's silt [3].

The coast of Selangor and Batu Pahat experienced severe coastal erosion recording the total eroded area of 1878.5 hectares and 415.47 hectares respectively [4]. Similarly, Johor's coastal flooding was causing an estimated RM 2.4 billion in economic losses and RM 0.35 billion in of infrastructure damage and causing sea level rise and loss of 180,000 hectares of agricultural land, 15% to 20% loss of mangroves along the coast [4]. It is clear that 85.84% of Batu Pahat are extremely experiencing erosion phenomena occurred only within 3 years from 2011 until 2013 [5]. The coastline of Batu Pahat has experienced severe erosion due to wave impact and sea level rise [6]. This study was conducted for the effects of sea level rise in the coastal zone of Batu Pahat, Johor.

Parameters that related to vulnerability in coastal erosion is geomorphology that affects of large bodies of water, such as seas and oceans, and big lakes. Meteorological and hydrological records have shown that the Kelantan River often overflows during the northeast (NE) monsoon season [7]. Shoreline change rates at Pahang in the eastern region of Peninsular Malaysia facing the South China Sea indicate how the coastline is shifting over time. The shoreline is frequently dynamic, as it involves erosion and accretion processes, as a result of the action of natural processes such as sea level rise, wave energy and sedimentation and human activity [8]. The coastal slope of a region can be influenced by lithology where steep slopes can reduce the impact of flood hazards and gentle slopes increase vulnerability to inundation. Based on their findings, coastal slope along the entire east coast of Peninsular Malaysia is rather gentle and is categorized as high to very high vulnerability [9]. Relative sea-level rise predicts significant changes in coastal areas, increasing the risk of erosion and flooding, particularly affecting sandy beaches in Kuala Terengganu. An increase in the rate of sea-level rise and range of potential impacts, including flood and coastal erosion, will likely affect the wide East Coast of Peninsular Malaysia and would cause serious disturbance for sandy beaches, particularly in Kuala Terengganu [10]. The average of the highest one-third of waves (33%) that occur in each period is termed as Significant Wave Height (SWH) [11]. SWH is one of the properties used to identify the energy of waves and is essential for the identification of coastal vulnerability.

This research aims to evaluate the coastal erosion hazard map at Pantai Perpat and Pantai Punggur near the Batu Pahat coastline. The objectives are to determine vulnerabilities and hazards related to coastal erosion, evaluate these parameters for both locations, and conduct a coastal erosion hazard assessment using the Coastal Vulnerability Index (CVI). The scope includes a preliminary survey of coastal residents and visitors to assess the importance and hazards at the sites, covering a 5km stretch of Johor's coastline. The study focuses on five parameters: geomorphology, shoreline change rates, coastal slope, relative sea level rate, and mean significant wave height. Secondary data from various Malaysian institutions will be used for risk analysis using the CVI in ArcGIS software.

2. Methodology

The purpose of this study is to assess the factors that contribute to coastal erosion in Pantai Perpat and Pantai Punggur. The parameters will be examined using the ArcGIS software's Coastal Vulnerable Index (CVI) model. The CVI model is used to assess the risks and vulnerabilities of coastal erosion in the research area. It also uses Google Earth. The objectives for this research are:

i. To determine vulnerabilities and hazards related to coastal erosion.
ii. To evaluate both parameters for Pantai Perpat and Pantai Punggur on coastal erosion hazard.
iii. To determine coastal erosion hazard assessment using the Coastal Vulnerability Index CVI.

The total distance for this study area is 10 kilometres of coastline with the inland distance to shoreline of 500 metres as shown in Fig. 1. The coastline starts at latitude 1°40'41.00"N, longitude 103° 6'32.71"E, and ends at latitude 1°41'8.61"N, longitude 103° 5'50.91"E. This study was carried out in Pantai Punggur and Pantai Perpat to assess five criteria involved in the occurrence of coastal erosion has been examined using the ArcGIS software's Coastal Vulnerable Index (CVI) model and Google Earth.

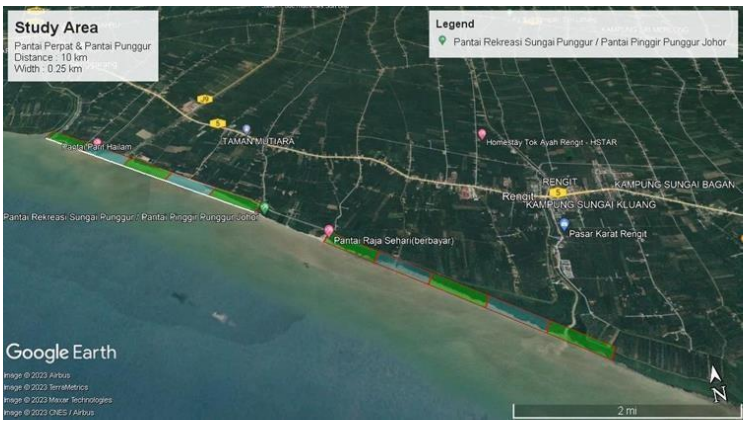


Fig. 1 *Study Area (source: Google Earth Pro)*

Multidisciplinary Applied Research and Innovation Vol. 6 No. 2 (2025) p. 119-126

The data involved in this study has been obtained from secondary data, which includes previous studies available on various websites, providing additional insights to support the research. A site visit to the study area was also conducted to gather current information regarding the coastal condition and its related parameters, such as geomorphology, coastal slope, and wave height.

2.1 Coastal Vulnerability Index

The Coastal Vulnerability Index (CVI) was calculated using five factors in this study which are geomorphology, coastline change rate, maximum current speed, tidal range, major wave height, and sea level rise based on Equation 1. As indicated in Table 1, the rating is on a linear scale from 1 (lowest risk) to 5 (highest risk).

Table 1 *Vulnerability Ranking [12]*

No	Variable	Ranking of coastal vulnerability				
		Very low	Low	Moderate	High	Very High
		1	2	3	4	5
1	Geomorphology	Rock y Coast	Composite of sand and rocks	Sand	Composite of clay and rock or sand	Mud Flats
2	Shoreline change rate (m/yr)	>+8	+3 to +7	-1 to +3	-5 to -1	< - 5
3	Maximum current speed (m/s)	0 – 0.2	0.2 > 0.4	0.4 – 0.6	0.6 – 0.8	0.8 - 1
4	Maximum tidal range (m)	>3.5	3 – 3.5	2.5 - 3	2 – 2.5	0
5	Significant wave height (m)	< 0.5	0.7 – 1.4	1.4 – 2.1	2.1 – 2.8	>5
6	Sea level rise (mm/yr)	<1.8	1.8 – 2.5	2.5 - 3	3 – 3.4	>3.4

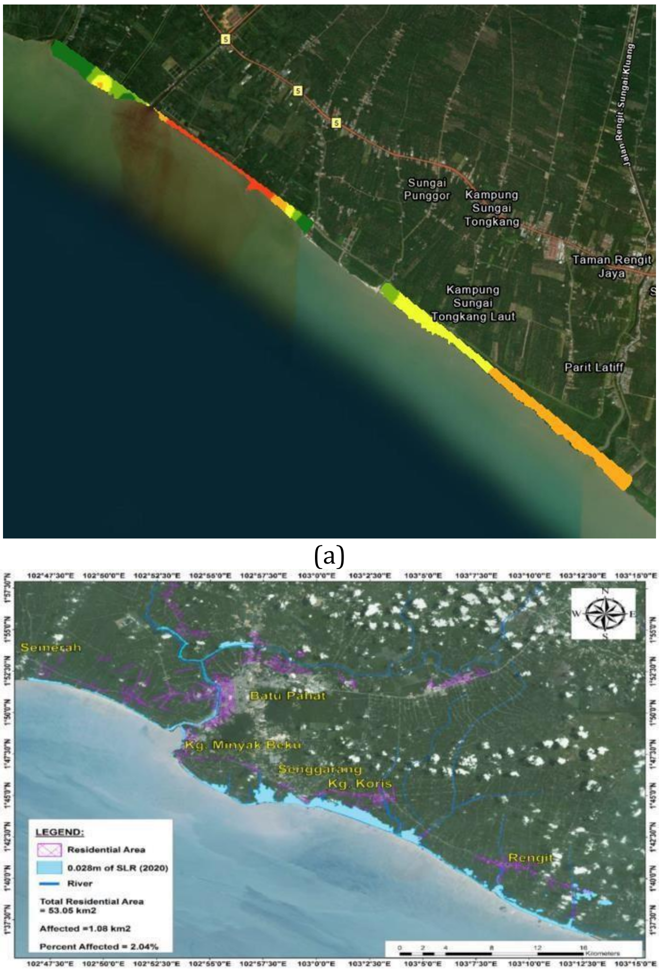
The variable geomorphology expresses the relative erodibility of various landform forms. A coastal susceptible score of 1 indicates the least danger of erodibility, such as a rocky shoreline, while a ranking of 5 indicates the greatest risk of erodibility to the coastline. Shoreline change rates are determined by collecting historical coastline data from reliable sources, including aerial pictures, satellite photography, topographic maps, and coastal surveys, over a lengthy period to capture long-term patterns and changes. Significant wave height is to identify the important wave heights along the research locations, a spectral wave simulation was built, and it showed that the higher the significant wave height, the more sensitive the shoreline is to erosion. Additionally, examining the research area's historical and anticipated sea-level rise patterns using data from tidal gauges, satellite altimetry, and global climate models helps understand the size and pace of sea level rise.

3. Results & Discussion

3.1.1 Geomorphology

Pantai Perpat and Pantai Punggur in Batu Pahat, Johor, have dynamic coastal geomorphology, with considerable erosion and sedimentary processes affected by seasonal monsoons. Both beaches feature sandy clay deposits with moisture content varying from 92% to 158% and organic content ranging from 8.41% to 20.9%, making them prone to erosion. UAV monitoring revealed significant shoreline changes at both locations, emphasizing the impact of natural and anthropogenic forces and assisting in the creation of effective coastal management methods.

The attached image Fig. 2(a) provides a visual representation of the geomorphological stability of Pantai Punggur and Pantai Perpat. The color-coded classification in Table 2 indicates varying levels of geomorphological stability, from low stability (Class 1) to extreme instability (Class 5), highlighting priority areas for intervention.



(a)

(b)

Fig. 2 *(a) Geomorphology for Pantai Punggur and Pantai Perpat, and (b) Sea Level Rise [14]*

Table 2 *Colour classes geomorphology for Pantai Punggur and Pantai Perpat*

Color	Upper Value	Range	Class Label
	≤ 2.231813	1.002 - 2.232	Low (Class 1)
	≤ 2.755336	2.233 - 2.755	Moderate (Class 2)
	≤ 2.978099	2.756 - 2.978	High (Class 3)
	≤ 3.501622	2.979 - 3.502	Very High (Class 4)
	≤ 4.731974	3.503 - 4.732	Extreme (Class 5)

3.1.2 Relative Sea Level Rate

A research team has conducted a thorough analysis of the rise in sea level at Pantai Punggur and Pantai Perpat in Batu Pahat, Johor. The results show that the coastline contour and sediment volume in these locations were greatly affected by the high tide event that occurred in November 2022. UAVs were used to gather the data, while Pix4D and Global Mapper software were used for analysis. 15% of Malaysia's coastline is eroding, according to the National Coastal Erosion Study 2015, which calls for structural protection. Malaysia's average yearly sea level rise has been measured at 0.67 to 0.74 mm [13].

Sea level increase is depicted in Fig. 2(b), "Sea Level Rate," from the Proceedings of the Tuanuku Ja'afar Conference (TJC) 2017 [14]. This highlights the urgent need for effective coastal management strategies to reduce potential damage and adapt to changing conditions. The dramatic alterations in coastal dynamics at Pantai Punggur and Pantai Perpat, due to sea level rise and monsoons, further underscore the importance of implementing efficient management techniques to protect residents and ensure sustainable coastal development.

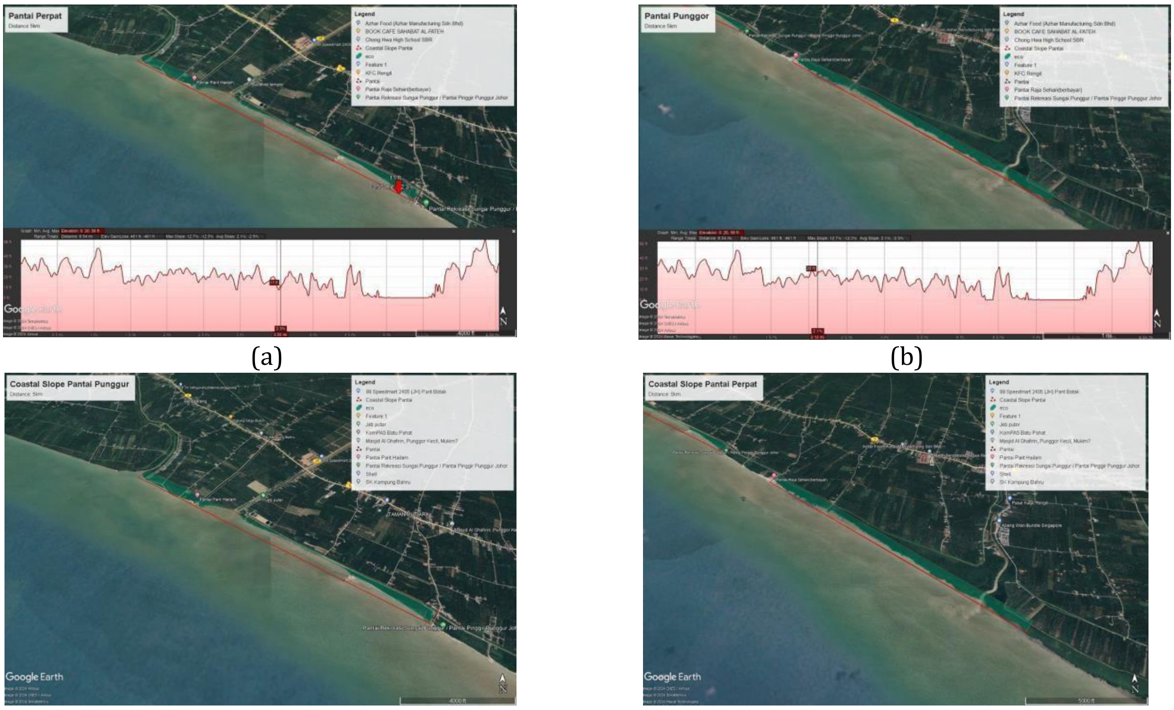
3.1.3 Shoreline Change Rate

Pantai Perpat has had significant coastline change rates, especially during the northeast monsoon season. UAV photogrammetry research has revealed substantial erosion and accretion patterns. During high monsoon seasons, the average rate of coastline change was between 0.5 and 1.0 meters per month. These fluctuations are principally driven by the tremendous hydrodynamic forces associated with monsoon winds and high tide events, resulting in significant sediment movement and shoreline reconfiguration [15]. Pantai Punggur, like Pantai Perpat, sees dynamic shoreline alterations. Monitoring efforts have revealed erosion rates ranging from 0.3 to 0.8 meters each month. UAV technology has played an important role in documenting these changes, providing precise insights into erosion patterns and assisting in identifying erosion-prone locations.

3.1.4 Mean Significant Wave Height

Pantai Perpat has variable significant wave heights due to seasonal fluctuations, particularly those caused by the northeast monsoon. During this time, the average significant wave height (SWH) is around 1.5 meters, with peaks reaching up to 2.0 meters during high tide and storm events.

At Pantai Punggur, the mean significant wave height is similarly influenced by seasonal monsoon winds, averaging around 1.4 meters, with peak values occasionally exceeding 1.8 meters during severe weather. This continuous wave activity contributes to the ongoing coastal erosion in the area. Monitoring wave heights is critical for developing effective coastal protection measures to prevent additional shoreline erosion and sediment displacement according to Fig. 3.



(a) (b) (c) (d)

Fig. 3 *Mean Significant Wave Height (a) Pantai Perpat; (b) Pantai Punggur; Coastal Slope (c) Pantai Punggur; (d) Pantai Perpat*

3.1.5 Coastal Slope

Fig. 3(c) coastal slope Pantai Punggur, and Fig. 3(d) coastal slope Pantai Perpat, illustrate the coastal slopes at Pantai Punggur and Pantai Perpat, which we retrieved from Google Earth and data from previous research. Slope and classification are among them. The mud flat in Pantai Punggur has a relatively gentle slope that ranges from 1:400 to 1:1000. The moisture content of soil samples taken in 2012 and 2013 ranged from 75.83% to 122.63%. Organic content ranged from 2.2% to 11.2% [16]. The sand component has a specific gravity that ranges from 1.1 to 1.85. The specific gravity of the marine clay is 2.62. The last term dealt with velocity setting. The Stokes equation was used to get the settling velocities. Samples of sand: 0.020 to 1.197 meters per second. Samples of clay: 3.23×10^{-5} m/s to 7.15×10^{-7} m/s [16].

3.2 Hazard Map

The Hazard Map in Fig. 4 is strategically crafted to assess wave height risks along specific coastal areas, particularly Pantai Punggur and Pantai Perpat. The legend classifies wave heights into five risk levels from "Very Low" to "Extreme" each distinguished by a colour gradient from green to red, highlighting the escalating potential hazards along the coastline. Colour transitions on the map from green to red are indicative of varying underwater topography or specific coastal configurations that may amplify wave heights, such as underwater ridges or coastline shapes that channel waves into concentrated areas. Areas marked in darker shades orange to red, point to regions that could experience "Very High" to "Extreme" wave heights, demanding particular attention from disaster management teams and local authorities. This hazard map is a vital resource, pivotal in fostering coastal resilience and safety through proactive planning and mitigating the impacts of coastal hazards.

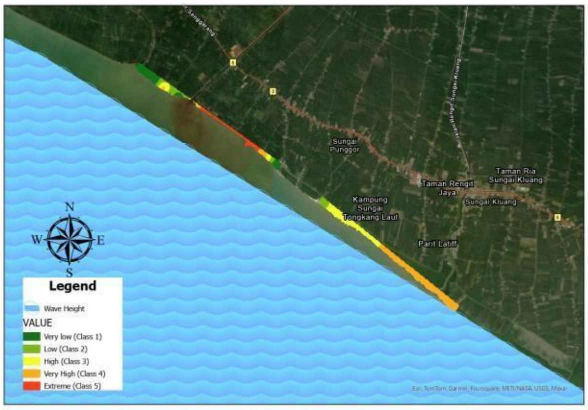


Fig. 4 *Hazard Map*

3.3 The Coastal Vulnerability Index for Pantai Perpat and Pantai Punggur

The Coastal Vulnerability Index (CVI) for Pantai Perpat and Pantai Punggur were calculated to determine their relative susceptibility. This approach required normalizing many critical factors, including slope, moisture content, organic content, average significant wave height, and peak significant wave height, against their respective maximum values. Pantai Perpat's slope was normalized to 1, with a slope ratio of 1:400 resulting in a dimensionless value of 0.0025. The moisture content of 92% was normalized to around 0.582, the organic content of 8.42% to around 0.403, and the average and peak significant wave heights of 1.5 meters and 2.0 meters were normalized to 0.75 and 1, respectively. Pantai Perpat's CVI was estimated to be 1.75 based on these adjusted results.

Pantai Punggur went through the same normalizing procedure. Additionally, the slope was normalized to one. Moisture and organic content, at 92% and 8.42%, were adjusted to 0.582 and 0.403, respectively. However, the important wave heights were somewhat different. Pantai Punggur's average significant wave height of 1.4 meters and peak wave height of 1.8 meters were normalized to 0.7 and 0.9, respectively. These adjusted results yielded a CVI of about 1.67 for Pantai Punggur, showing a somewhat lower coastal vulnerability than Pantai Perpat.

$$CVI = \sqrt{\frac{abcef}{6}} \tag{1}$$

Penerbit UTHM

Table 3 *Data Factors of Pantai Perpat and Pantai Punggur*

Factor	Pantai Perpat	Pantai Punggur
Geomorphology	Moisture content: 92% to 158%	Moisture content: 92% to 158%
Organic content (%)	8.42% to 20.9%	8.42% to 20.9%
Relative Sea Level Rate (mm/year)	0.67 to 0.74	0.67 to 0.74
Shoreline Change Rates (m)	0.5 to 1.0	0.3 to 0.8
Mean Significant Wave Height (m)	1.5	1.4

4. Conclusion

The investigation at Pantai Perpat and Pantai Punggur near the Batu Pahat coastline aimed to assess coastal erosion hazards and develop mitigation plans using the Coastal Vulnerability Index (CVI) and ArcGIS software. By thoroughly evaluating factors such as geomorphology, shoreline change rates, coastal slope, relative sea level rise, and significant wave height, the study pinpointed areas highly vulnerable to erosion. The results highlight the substantial influence of both natural and human activities on coastal erosion, underscoring the need for specific management strategies to address these impacts.

The CVI findings illustrate the disparities in coastal risk between the two sites. The Coastal Vulnerability Index (CVI) of Pantai Perpat has a CVI of 1.75, slightly higher than Pantai Punggur's 1.67. This suggests that Pantai Perpat is more susceptible to coastal risks such as erosion, sea-level rise, and wave action. This difference is mostly attributable to Pantai Perpat's greater average and peak significant wave heights. These findings are critical for coastal management and planning, indicating that Pantai Perpat may require more resources and preventive measures to reduce future coastal hazards.

In summary, the study of Pantai Perpat and Pantai Punggur highlights the urgent need for proactive coastal management practices. By identifying erosion risks and vulnerable areas, the research supports the development of informed strategies to protect coastal communities and infrastructure. Utilizing CVI and GIS technology is crucial for enhancing our understanding of coastal erosion dynamics and creating sustainable solutions for this significant environmental issue. Pantai Perpat's slightly higher vulnerability requires more focused coastal management efforts to mitigate potential impacts from natural coastal processes, ensuring adequate protection for both beaches in the future.

Acknowledgement

Authors are thankful to all persons, organizations, and sources who contributed directly or indirectly to the completion of this study especially Universiti Tun Hussein Onn Malaysia (UTHM). The authors would like to thank the Centre for Diploma Studies (CeDS), Universiti Tun Hussein Onn Malaysia for their support.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm their contribution to the paper as follows: ***study conception and design, data collection, and draft manuscript preparation:*** *Afif Altaf Bin Mohd Ezuan'Izam, Muhammad Affendi Bin Alias, Nur Farisha Binti Mohd Fakarruddin, Suhaila Binti Sahat. All authors reviewed the results and approved the final version of the manuscript.*

References

[1] T. Pang, X. Wang, R. A. Nawaz, G. Keefe, T. Adekanmbi, "*Coastal erosion and climate change: A review on coastal-change process and modeling,*" Ambio, vol. 52, no. 12, pp. 2034–2052, 2023.

[2] M. I. Siddiq, M. E. Daud, M. Kaamin, M. Mokhtar, A. S. Omar, N. A. Duong, "*Investigation of Pantai Punggur Coastal Erosion by using UAV Photogrammetry,*" International Journal of Nanoelectronics and Materials, vol. 15, pp. 61-69, Mac 2022.

[3] N. H. M. Dahlan, "*Flood Disasters at Housing Areas in Malaysia: A Planning Law Perspective,*" INSAF-The Journal of the Malaysian Bar, vol. 39, no. 2, pp. 263-290, 2022.

[4] S. Ehsan, R. A. Begum, N. G. M. Nor, K. N. A. Maulud, "*Current and potential impacts of sea level rise in the coastal areas of Malaysia*," IOP Conference Series, vol. 228, pp. 012023, 2019.

[5] K. N. A. Maulud, R. M. Rafar, "*Determination the impact of sea level rise to shoreline changes using GIS,*" International Conference on Space Science and Communication, pp. 352-357, August 2015.
[6] N. A. Awang, M. A. Hamid, "*Sea level rise in Malaysia. Sea level rise adaptation measures,*" Hydrolink, vol. 2, pp. 47-49, 2013.
[7] A. R. Abdul Hadi, M. R. A. Ghani, J. Talib, I. Nur Afiqah, "*Geomorphology and Hydrology of 2014 Kelantan Flood*," In ICIPEG 2016: Proceedings of the International Conference on Integrated Petroleum Engineering and Geosciences, pp. 655-668, 2017.
[8] F. A. Mohd, K. N. A. Maulud, O. A. Karim, R. A. Begum, F. Khan, W. S.W. M. Jaafar, S. M. S. Abdullah, M.E. B. Toriman, M. K. A. Kamarudin, M. B. Gasim, N. A. Wahab, "*An assessment of coastal vulnerability of Pahang's coast due to sea level rise,*" International Journal of Engineering & Technology, vol. 7, no. 3.14, pp. 176, 2018.
[9] E. H. Ariffin, M. J. Mathew, A. Roslee, A. Ismailluddin, L. S. Yun, A. B. Putra, et al., "*A multi-hazards coastal vulnerability index of the east coast of Peninsular*," International Journal of Disaster Risk Reduction, vol. 84, pp. 103484, Jan 2023.
[10] M. Bagheri, Z. Z. Ibrahim, S. Mansor, L. A. Manaf, N. Badarulzaman, N. Vaghefi, "*Shoreline change analysis and erosion prediction using historical data of Kuala Terengganu, Malaysia*," Environmental Earth Sciences, vol. 78, no. 15, 2019.
[11] J. A. Ferreira, C. G. Soares, "*Modelling distributions of significant wave height*," Coastal Engineering, vol. 40, no. 4, pp. 361-374, 2000.
[12] M. F. Mohamad, L. H. Lee, M. K. H. Samion, "*Coastal Vulnerability Assessment towards Sustainable Management of Peninsular Malaysia Coastline*," International Journal of Environmental Science and Development, vol. 5, no. 6, pp. 533–538, 2014.
[13] A. H. M. Rashidi, M. H. Jamal, M. Z. Hassan, S. S. M. Sendek, S. L. M. Sopie, M. R. A. Hamid, "*Coastal structures as beach Erosion Control and Sea level rise adaptation in Malaysia: a review*," Water, vol. 13, no. 13, pp. 1741, 2021.
[14] F. A. Mohd, K. A. Abdul Maulud, A. Y. Benson, M. R. Abdul Hamid, "*Assessing the impacts of the sea level rise at Batu Pahat, Johor,*" In Proceedings of The Tuanku Ja'afar Conference (TJC), vol. 2017, pp. 668-679, 2018.
[15] N. M. S. Sabri, "*Monitoring the dynamics of sedimentary load variations along coastal regions using UAVs after monsoon and high tide events at Pantai Punggur and Pantai Perpat, Batu Pahat, Johor*," Journal of Advanced Research in Applied Sciences and Engineering Technology, vol. 44, no. 2, pp. 35–51, 2024.
[16] N. M. Mokhtar, N. M. E. Daud, N. M. Kaamin, N. F. Hayazi, N. M. S. Sabri, N. N. B. Hamid, N. A. A. Kadir, N. N. A. M. Zain, "*Evaluation Coastal Volume Changes with UAV Photogrammetry: An Example in West Coast Malaysia*," Journal of Advanced Research in Applied Sciences and Engineering Technology, vol. 33, no. 2, pp. 67–75, 2023.