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# Short-Term Shoreline Evolution Mapping by using UAV

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**ABSTRACT**

The boundary separating land from the beachside is known as the coastline. Monitoring and analysing shorelines are crucial because it gives us a better understanding of shoreline changes and identifies beach conditions. Unmanned aerial vehicle (UAV) or drone usage has emerged as a beneficial technology in coastal engineering, notably in the study of shoreline evolutions, because it is more credible and more straightforward to use than the prior technologies. This study aims to gather coastal data, evaluate Pantai Punggur shorelines, and track shoreline changes using processed imagery. The "Pix4D Capture" application has been programmed with the flight planning route, and the drone takes pictures along the entire grid line provided. The data on shoreline evolutions were processed using the Pix4d Mapper and Global Mapper tools. Shoreline changes were tracked continuously from August 4th, 2020, through August 10th, 2021. According to the results, Pantai Punggur is undergoing erosion, as evidenced by the alterations in the shoreline that were apparent in less than a year.

## 1. Introduction

Coastal erosion is a growing concern in many parts of the world, including in Malaysia as stated in the previous study [1]. Monitoring and analyzing shoreline changes is crucial for understanding the effects of erosion and identifying beach conditions [2]. Unmanned aerial vehicle (UAV) technology, specifically drone usage, has emerged as a useful tool in coastal engineering, particularly in studying shoreline evolutions due to its credibility and ease of use [3]. However, despite the availability of such technology, there is a lack of comprehensive studies on shoreline changes in Malaysia, particularly in the Pantai Punggur area.

This study aims to gather coastal data, evaluate Pantai Punggur shorelines, and track shoreline changes using processed imagery. Pantai Punggur was selected as the study area due to its high vulnerability to erosion and lack of previous research on shoreline changes [4]. The choice was also

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based on statistical data that shows a significant increase in the rate of coastal erosion in the area in recent years [5]. By analyzing the shoreline changes in Pantai Punggur, this study aims to provide a better understanding of coastal erosion and to contribute to the development of more effective coastal management strategies in Malaysia [6].

The coastal areas are vulnerable to erosion during the monsoon season, resulting in damage to mangroves, plants, marine life, infrastructure, and people [9]. Coastal erosion occurs continuously due to natural and human influences such as land erosion and tidal removal of sediments from the beach or dunes [7]. Therefore, monitoring and analyzing shorelines are crucial to understand shoreline changes and identify beach conditions, particularly in areas prone to erosion.

The problem statement for this study is to gather coastal data, evaluate Pantai Punggur shorelines, and track shoreline changes using processed imagery. Pantai Punggur is located on the west coast of Peninsular Malaysia and is undergoing erosion, as evidenced by alterations in the shoreline apparent in less than a year. Therefore, there is a pressing need to collect data to understand the extent and rate of erosion and to identify potential mitigation strategies.

Pantai Punggur was chosen as the sample for this study based on statistical data and relevant research. According to previous studies, the coastal region is experiencing erosion, with estimates ranging from 1.8 to 5 meters per year. Additionally, based on the results of a shoreline mapping study conducted by the Department of Irrigation and Drainage Malaysia, the Pantai Punggur shoreline is eroding at a rate of approximately 3.7 meters per year. The high erosion rate, coupled with the importance of Pantai Punggur as a tourism destination and the presence of critical infrastructure, makes it a suitable case study for evaluating the effectiveness of drone-based coastal mapping techniques [8].

Coastal erosion is a significant environmental challenge that poses a threat to various human activities, including tourism, fisheries, and port operations [9]. The monsoon season exacerbates this problem, and the resulting land loss, infrastructure damage, and ecological harm could be devastating [10]. Remote sensing and aerial photogrammetry have traditionally been used to acquire coastal maps, but these techniques have limitations such as high costs, low resolution, and limited coverage areas [11].

Unmanned Aerial Vehicles (UAVs) offer a more practical and cost-effective solution for mapping coastal areas. This study focuses on the use of UAVs to gather coastal data and monitor shoreline changes in Pantai Punggur, Senggarang, Johor, on the west coast of Peninsular Malaysia. This paper aims to provide a methodology for gathering coastal data and analyzing shoreline changes, as well as to evaluate Pantai Punggur's shoreline characteristics and zoning parameters based on ground observations. The study will also compare the shoreline changes with existing guidelines from Malaysian authorities and other relevant standards. By using UAVs for mapping and monitoring coastal areas, hope to provide a valuable tool for stakeholders such as developers, local governments, engineers, and researchers to aid in decision-making regarding coastal erosion management [12].

Coastal erosion is a global challenge that has been a subject of research for many years. Several studies have been conducted on the impact of climate change on coastlines, highlighting the need for coastal management and erosion control measures [13]. Malaysia is no exception, and the country has witnessed significant coastal erosion in recent years. The coastline is a vital component of the country's economy, and as such, any adverse effects on it would have far-reaching consequences [14].

By conducting this study in Pantai Punggur, this study aims to contribute to the knowledge base on coastal erosion in Malaysia, and the findings will help stakeholders develop sustainable coastal management strategies [15]. Coastal erosion is a significant issue in Malaysia, with adverse effects on the economy, making it crucial to develop sustainable coastal management strategies. By using

UAVs for mapping and monitoring coastal areas, the study aims to provide a valuable tool for stakeholders such as developers, local governments, engineers, and researchers to aid in decision-making regarding coastal erosion management [16].

## 2. Methodology

The methodology used for this study involved the use of an unmanned aerial vehicle (UAV) to capture images of the coastal area in Pantai Punggur. The collected images were processed to generate a digital elevation model (DEM), which was used to identify different zones based on their elevation and slope characteristics. These zones were further analyzed to determine their susceptibility to erosion and potential impact on the surrounding environment. The entire process is depicted in the Fig. 1 below, which illustrates the step-by-step procedures involved in data collection and analysis.

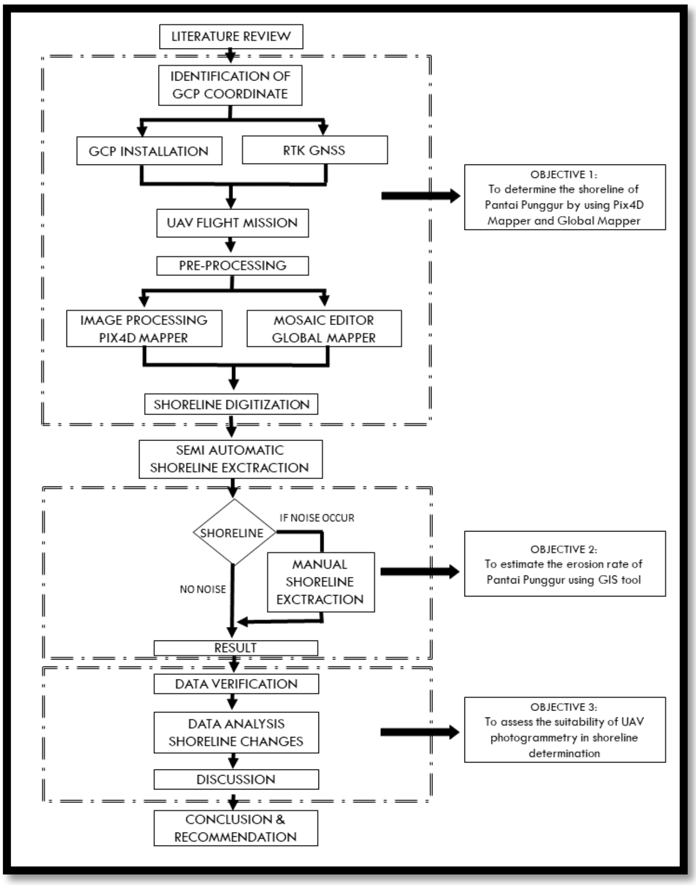

**Fig. 1.** The flowchart of research methodology

The zoning characteristic and parameter selection were based on ground observations and analysis of the study area's physical features. The four zones identified in this study were selected to represent different coastal characteristics in Pantai Punggur. For example, Zone A was selected because it has no revetment and is covered with mangrove trees, making it more vulnerable to erosion. Zone B was chosen because it has a seawall and is located near a bridge, which can affect the shoreline's stability. Zone C has a sandy beach, and Zone D is located near a river mouth, making it susceptible to sediment deposition.

Furthermore, the zoning parameters were selected based on a combination of established guidelines and the study area's specific characteristics. For instance, the width of each zone was selected based on the physical characteristics of the shoreline in each area and the recommended guidelines for similar areas. Additionally, the depth of each zone was determined by observing the water depth at each site during low and high tides. Overall, the zoning characteristics and parameters used in this study were carefully selected to ensure that they accurately represent the study area's unique features and provide useful insights into coastal erosion management.

The methodology of this study follows a systematic approach using a flowchart that begins with the identification and installation of Ground Control Points (GCPs) and the use of Real-Time Kinematic Global Navigation Satellite System (RTK GNSS) to obtain accurate coordinates. The UAV flight mission is then conducted to capture aerial images of the study area.

The pre-processing stage involves the use of Pix4D Mapper software to process the images and generate a Digital Surface Model (DSM) and an orthomosaic. The DSM and orthomosaic are then imported into Global Mapper for mosaic editing. Semi-automatic shoreline extraction is conducted using the Shoreline Digitization tool in Global Mapper. If noise is detected in the shoreline data, manual shoreline extraction is performed.

The resulting shoreline data is analyzed to identify shoreline changes over time. A discussion is then conducted on the implications of the findings, followed by the conclusion and recommendations for future research.

This methodology is highly detailed and follows a systematic approach to ensure the accuracy and reliability of the data. The use of GCPs and RTK GNSS ensures that the coordinates of the study area are precise. The use of Pix4D Mapper and Global Mapper for image processing and shoreline digitization provides a high level of accuracy in the data obtained. Overall, this methodology serves as a robust framework for conducting UAV-based coastal monitoring studies.

The primary method utilized in this study to gather information about coastal changes was aerial photogrammetry. As a result, several variables, such as the weather and tidal periods, affected the UAV's flight duration [17,18]. The depth of the low tide must be between 0.01 and 0.50 meters. Hence the following timetable was established. The data also demonstrates how the shoreline varies following the annual monsoon changes. The flight mission schedule from August 4th, 2020, to August 10th, 2021, is shown in Table 1.

**Table 1** Flight planning schedule

| Flight | Date | Tide Condition | Tide Level (m) |
|---|---|---|---|
| 1 | 04/08/2020 | Low tide | 0.26 m |
| 2 | 19/10/2020 | Low tide | 0.32 m |
| 3 | 15/12/2020 | Low tide | 0.19 m |
| 4 | 16/02/2021 | Low tide | 0.23 m |
| 5 | 03/03/2021 | Low tide | 0.24 m |
| 6 | 29/05/2021 | Low tide | 0.11 m |
| 7 | 12/06/2021 | Low tide | 0.29 m |
| 8 | 13/07/2021 | Low tide | 0.20 m |
| 9 | 10/08/2021 | Low tide | 0.25 m |

Pix4D Capture was used to complete the flying mission through a grid for 2D mapping. Aerial image collection started, and the drone flew along the gridline, taking pictures at a 50-meter height. The flight planning was planned according to a specific grid to collect aerial photographs covering the entire study area. As shown in Fig. 2, the flight route gridline for the flight planning route covers the whole region of Pantai Punggur, 233 m x 1368 m.

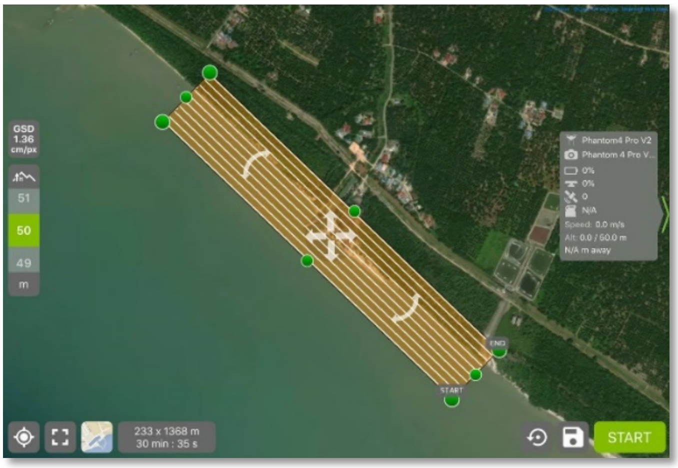

**Fig. 2.** The flight route gridline covers the whole region of Pantai Punggur

## *2.1 Model and Data*

The overlapped aerial pictures will then be combined and processed by the Pix4D Mapper to create the aerial map for Pantai Punggur [18]. The Pix4D Mapper uses three primary processes. The photos are first sorted and calibrated using aerial triangulation and bundle block adjustment [19,20]. The second procedure produced the densified point cloud and gave the model a 3D textured mesh, as depicted in Fig. 3. The Digital Surface Model and the orthomosaic map were created in the third step. After that, Global Mapper will be used to process the orthomosaic map so that the shoreline may be identified [21,22]. The Global Mapper produced the shoreline using the orthomosaic map's Normalized Difference Water Index (NDWI) layer.

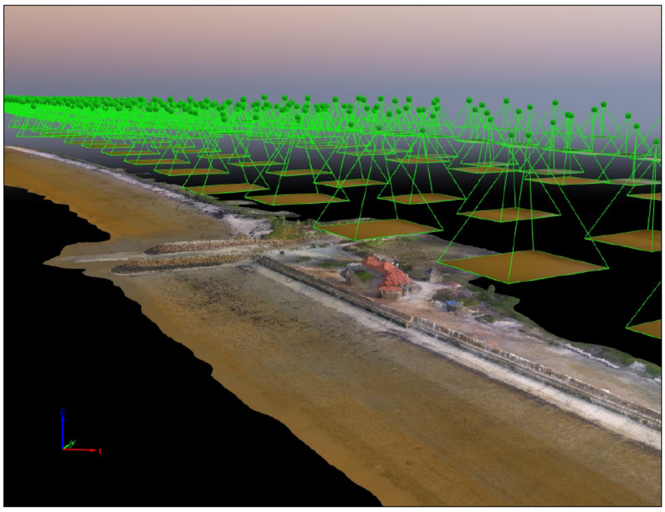

**Fig. 3.** Pantai Punggur mesh layer processed from Pix4D Mapper

The point cloud for each image that the UAV took is shown in Figure 3. A three-dimensional model image will be created by automatically assembling each of these images following their original placements. This point cloud verifies the accuracy of the GCP position and the model [23,24]. The calibration is used to produce orthomosaic photos that are accurate to each image in terms of latitude, longitude, and height. Any noise or errors in the model creation process can be removed by altering the point cloud.

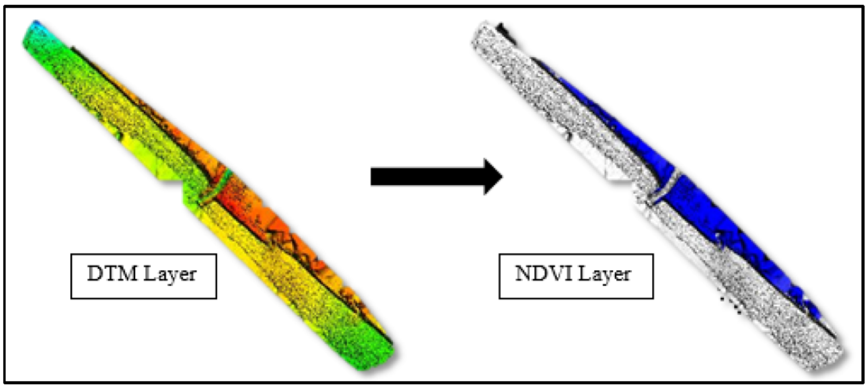

**Fig. 4.** NDWI Layer in Global Mapper to determine shoreline

Figure 4 shows the NDWI layer for the whole orthomosaic images. Figure 3 has two overlap layers: the orthomosaic layer and the NDWI layer. NDWI works as a filter that could present the orthomosaic features in land and water. This filter allows the process to differentiate the land and water features and be represented as the shoreline in the orthomosaic. The white line indicates zero metres of water level, also marked as the shoreline in the orthomosaic.

## 3. Results and Discussion

The research on shoreline changes in Pantai Punggur was conducted for one year, from the 4h of August 2020 to the 10th of August 2021. Based on the Global Mapper, each shoreline has a different coloured line representing the months that have been generated, as shown in Fig. 5.

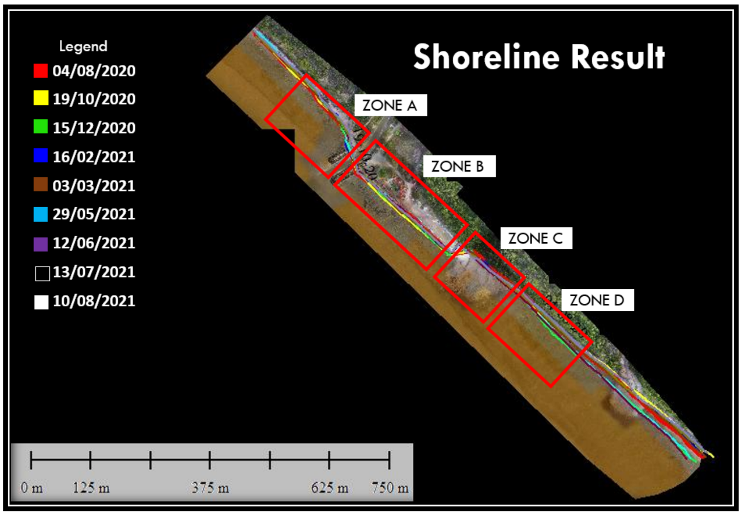

**Fig. 5.** Shoreline evolutions from August 2020 until August 2021

UAV-based remote sensing has reduced the gap in scale and resolution between ground observations and mapping images acquired from satellite sensors and conventional manned aircraft. For 2D and 3D analysis, the computer uses Digital Surface Model (DSM) and Point Cloud to ensure reliable geodata. Figure 4 shows an example of the orthophoto that was generated. The Pantai

Punggur orthophoto shows the coast alongside the mangrove forest. The coastline along the map is visible, and even small pebbles and small branches can be seen across the mapped region. Compared to the orthomosaic, the satellite datasets cannot produce the high resolution and precision of the generated orthophoto maps and 3D visualisations. The shoreline evolutions were analysed in four different zones, each with distinguished characteristics. The result of the shoreline changes is shown in Table 2.

**Table 2** The shoreline changes in Pantai Punggur from August 2020 to August 2021

| **Research period** | **Shoreline changes by zone (m)** | | | | | **Monsoon** |
|---|---|---|---|---|---|---|
| | **Zone A** | **Zone B** | | **Zone C** | **Zone D** | |
| | | **B1** | **B2** | | | |
| October 2020 | -2.8 | -4.5 | 5.9 | 4.2 | 3.8 | Southeast Monsoon |
| December 2020 | -3.3 | -0.3 | 5.7 | 5.1 | 8.7 | Northeast Monsoon |
| February 2021 | -8.1 | 1.2 | -3.2 | 1.0 | -0.9 | Northeast Monsoon |
| Mac 2021 | -1.6 | 0.7 | -2.8 | 1.8 | -0.3 | Transitional Monsoon |
| May 2021 | -5.9 | 1.4 | -0.6 | 4.4 | -5.7 | Transitional Monsoon |
| June 2021 | -7.3 | 2.0 | -0.4 | 5.2 | -6.7 | Southeast Monsoon |
| July 2021 | -6.9 | 2.0 | -1.2 | 2.7 | -2.1 | Southeast Monsoon |
| August 2021 | -7.1 | 1.4 | -0.7 | 2.6 | -5.2 | Southeast Monsoon |

### *3.1 Zone A Shoreline Changes*

Zone A is located on the left side of the Pantai Punggur area. The zone has no revetment or coastal structure in the area. A groin is placed between river streams flowing towards the open sea. Zone A is covered with mangrove trees. The shoreline positions are digitized from the groin area until the coverage of mangrove trees. The results of the shoreline changes are shown in Table 3.

**Table 3** The data of shoreline changes for Zone A

| **Transect ID** | **Shoreline changes Zone A (m)** |
|---|---|
| 107 | -5.16 |
| 108 | -3.72 |
| 109 | -2.96 |
| 110 | -2.12 |
| 111 | -1.87 |
| 112 | -1.64 |
| 113 | -1.63 |
| 114 | -2.34 |
| 115 | -2.83 |
| 116 | -3.90 |
| 117 | -3.71 |
| 118 | -2.22 |

The average changes for the shoreline changes in Zone A are -2.85 m. The maximum distance of shoreline changes is -5.16 m, and the minimum length of shoreline changes is -1.63 m. All of these changes reflected that “Zone A” experienced erosion. Figure 6 shows the shoreline in Zone A and the shoreline changes data in bar chart form.

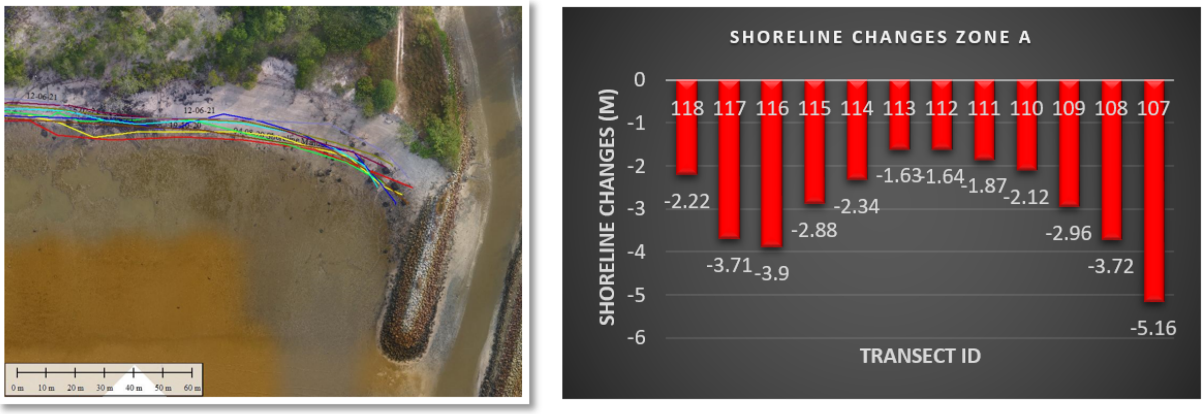

**Fig. 6.** The shoreline changes in Zone A

Zone A experienced erosion because no coastal structure or revetment was being developed in Zone A. The area is open to solid waves from the open seas. The soil and the mud condition also contribute to erosion as it needs to provide a suitable need for mangrove trees. The mangrove trees cannot sustain and did not grow big enough to retain the wave.

### *3.2 Zone B Shoreline Changes*

Zone B is located in the middle of the Pantai Punggur area. This zone has revetment and coastal structures along the shore. The coastal system is called the "Labuan Block". There is a restaurant building in the zone area. This zone also has become the main attraction for the public as for recreation area. The width of this zone is 260 m. The results of the shoreline changes are shown in Table 4.

**Table 4** The data of shoreline changes for Zone B

| Transect ID | Shoreline changes Zone B (m) |
|---|---|
| 76 | -0.50 |
| 77 | -0.90 |
| 78 | -1.10 |
| 79 | -0.80 |
| 80 | -1.00 |
| 81 | -1.60 |
| 82 | -1.60 |
| 83 | -1.50 |
| 84 | -2.00 |
| 85 | 0.13 |
| 86 | 0.11 |
| 87 | 0.17 |
| 88 | 1.12 |
| 89 | 1.57 |

The results of shoreline changes in Zone B can be divided into two parts. The first part is the shoreline changes from transect 85 to transect 96. The shoreline changes of the first part of Zone B show accretion condition. The average shoreline change in the first part of Zone B is 1.29 m. The maximum distance of shoreline changes is 2.59 m, and the minimum is 0.11 m.

The second part is the shoreline changes from transect 76 to transect 84. The shoreline changes of the second part of Zone B shows erosion condition. The average shoreline change in the first part of Zone B is -1.20 m. The maximum distance of shoreline changes is -2.00 m, and the minimum length of shoreline changes is -0.50 m. Figure 7 shows the shoreline in Zone B and the shoreline changes data in bar chart form.

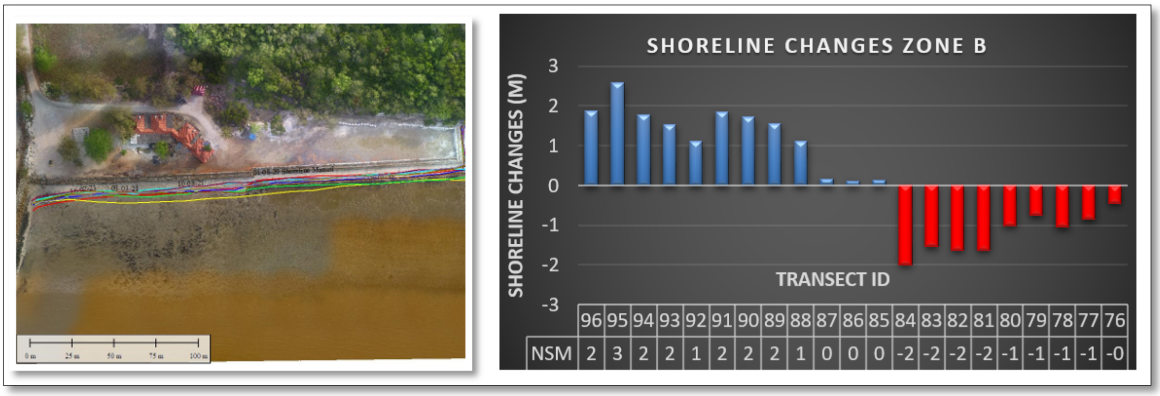

**Fig. 7.** The shoreline changes in Zone B

The first part of Zone B experienced accretion, but the second part of Zone B experienced accretion. This is because the first part has higher level elevations compared to the second part of Zone B. The conditions of the Labuan Block structure on the first part are in good condition as it does not move and can retain the wave coming from the open sea. However, the Labuan block in the second part is disturbed and cannot retain the wave.

### *3.3 Zone C Shoreline Changes*

Zone C is located on the right side of the Pantai Punggur area. The zone has no revetment or coastal structure in the area. Zone C is covered with mangrove trees. Zone C has sedimentary deposits from the small water stream outlet that flows towards the open sea. The results of the shoreline changes are shown in Table 5.

**Table 5** The data of shoreline changes for Zone C

| Transect ID | Shoreline changes Zone C (m) |
|---|---|
| 56 | 2.17 |
| 57 | 2.71 |
| 58 | 2.57 |
| 59 | 2.48 |
| 60 | 2.68 |
| 61 | 2.89 |
| 62 | 2.63 |
| 63 | 2.40 |
| 64 | 5.96 |
| 65 | 8.36 |
| 66 | 9.08 |
| 67 | 4.50 |

The average change for the shoreline changes in Zone C is 4.04 m. The maximum distance of shoreline changes is 9.08 m, and the minimum distance is 2.40 m. All of these changes reflected that Zone C experienced accretion. Figure 8 show the shoreline in Zone C, and the shoreline changes data in bar chart form.

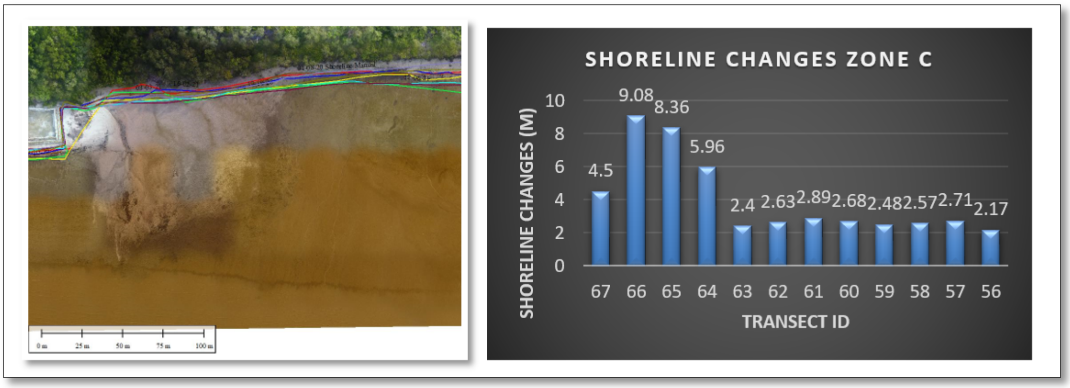

**Fig. 8.** The shoreline changes in Zone C

Zone C experienced accretion because a small water stream outlet flows towards the open sea. This stream carries sedimentary deposits towards the sea. The sand then accumulates over time and thus contributes to accretion.

### *3.4 Zone D Shoreline Changes*

Zone D is located on the right side of the Pantai Punggur area. The zone has no revetment or coastal structure in the area. Zone D is covered with mangrove trees. The width of Zone D is 300 m. The results of the shoreline changes are shown in Table 6.

**Table 6** The data of shoreline changes for Zone D

| **Transect ID** | **Shoreline changes Zone D (m)** |
|---|---|
| 30 | -5 |
| 31 | -4 |
| 32 | -4 |
| 33 | -4 |
| 34 | -4 |
| 35 | -3 |
| 36 | -3 |
| 37 | -3 |
| 38 | -3 |
| 39 | -3 |
| 40 | -4 |
| 41 | -4 |
| 42 | -4 |
| 43 | -4 |
| 44 | -5 |
| 45 | -6 |
| 46 | -6 |
| 47 | -5 |
| 48 | -4 |
| 49 | -3 |
| 50 | -2 |
| 51 | -1 |
| 52 | -1 |
| 53 | -1 |
| 54 | -0 |

The average changes for the shoreline changes in Zone D are -3.50 m. The maximum distance of shoreline changes is -6.19 m, and the minimum distance of shoreline changes is -0.34 m. All of these changes reflected that Zone D experienced erosion. Figure 9 shows the shoreline in Zone D and the shoreline changes data in bar chart form.

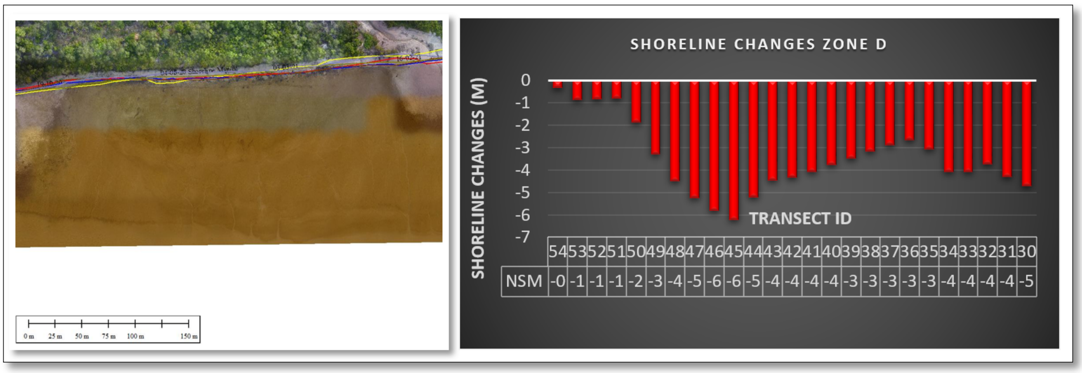

**Fig. 9.** The shoreline changes in Zone D

Zone D experienced erosion because no coastal structure or revetment is being developed in Zone D. The vegetation dunes are exposed towards the open wave. The soil of vegetation cannot withstand the open seawater as it takes the form of mud, causing it to be moved by the tide. The mangrove trees keep dying due to high water levels and strong waves.

## 4. Conclusions

The synthesis of shoreline data collected from Pantai Punggur provides valuable insights into the severity of coastal erosion in the area. The data indicates that erosion is not only affecting the coastline's position but also its width, highlighting the need for effective management strategies. Zoning and targeted approaches to coastal erosion management are essential to address the problem effectively. In comparison with relevant shoreline guidelines, the study revealed that existing guidelines are not comprehensive enough to account for Pantai Punggur's unique shoreline characteristics. A more site-specific approach is necessary to guide effective decision-making and management of coastal erosion in the area.

The study also highlights the potential of UAV technology for coastal mapping and monitoring. The use of Pix4D Mapper and Global Mapper to create high-resolution images of shoreline alterations data and maps using overlapping pictures technique can provide valuable information on changes in the coastline. Ground control points are essential for accurate orthomosaic mapping, and the study emphasizes their value in creating accurate maps. In conclusion, the study underscores the urgency of addressing coastal erosion in Pantai Punggur and highlights the potential of UAV-based coastal mapping and monitoring as a valuable tool for decision-makers. The study provides valuable insights into the need for site-specific approaches to coastal erosion management and emphasizes the importance of zoning and targeted management strategies.

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## References

[1] Ahmad, Anuar, Khairul Nizam Tahar, Wani Sofia Udin, Khairil Afendy Hashim, NorHadija Darwin, Mohd Hafis, Nurul Farhah Adul Hamid, Noor Aniqah Mohd Azhar, and Shahrul Mardhiah Azmi. "Digital aerial imagery of unmanned aerial vehicle for various applications." In *2013 IEEE International Conference on Control System, Computing and Engineering*, pp. 535-540. IEEE, 2013. https://doi.org/10.1109/ICCSCE.2013.6720023

[2] Ahn, Yushin, Bumshick Shin, and Kyu-Han Kim. "Shoreline change monitoring using high resolution digital photogrammetric technique." *Journal of Coastal Research* 79 (2017): 204-208. https://doi.org/10.2112/SI79-042.1

[3] Raid, Al-Tahir, Marcus Arthur, and Dexter Davis. "Low cost aerial mapping alternatives for natural disasters in the Caribbean." In *FIG Working Week*. 2011.

[4] Biesemans, Jan, Jurgen Everaerts, and Nicolas Lewyckyj. "PEGASUS: Remote sensing from a HALE-UAV." In *ASPRS annual convention*, vol. 1, pp. 53-56. 2005. https://doi.org/10.1007/3-540-27468-5_13

[5] Siddiq, Mohammad Ikhmal, Mohd Effendi Daud, Masiri Kaamin, Mardiha Mokhtar, Amin Shah Omar, and Nguyen Anh Duong. "Investigation of Pantai Punggur Coastal Erosion by using UAV Photogrammetry." *International Journal of Nanoelectronics & Materials* 15 (2022).

[6] Mokhtar, Mardiha, Mohd Effendi Daud, Masiri Kaamin, Muhamad Syamil Sabri, Fitrah Hayazi, Muhammad Hanif Hisham, Mohammad Ikhmal Siddiq, Mohamad Azim Mohammad Azmi, Nor Baizura Hamid, and Hafsa Mohammad Noor. "Beach Profile and Shoreline Sediment Properties at Eroded Area in Batu Pahat." *Construction Technologies and Architecture* 4 (2023): 127-137. https://doi.org/10.4028/p-ny3700

[7] Mokhtar, Mardiha, Mohd Effendi Daud, and Muhamad Syamil Sabri. "Effect Of Soil Shear Strength on Shoreline Changes at Batu Pahat Coastal Area." *Journal of Sustainable Underground Exploration* 2, no. 1 (2022): 9-19. https://doi.org/10.30880/jsue.2022.02.01.002

[8] Kaamin, Masiri, Mohd Effendi Daud, Mohd Erwan Sanik, Nor Farah Atiqah Ahmad, Mardiha Mokhtar, Norhayati Ngadiman, and Faeez Rizwan Yahya. "Mapping shoreline position using unmanned aerial vehicle." In *AIP Conference Proceedings*, vol. 2016, no. 1. AIP Publishing, 2018. https://doi.org/10.1063/1.5055465

[9] Lee, K. E. "Kesan Hakisan dan Kenaikan Paras Air Laut Di Batu Pahat (Impak kepada Komuniti Setempat)." Cetakan Pertama (2015).

[10] Lyddon, Charlotte E., Jennifer M. Brown, Nicoletta Leonardi, and Andrew J. Plater. "Increased coastal wave hazard generated by differential wind and wave direction in hyper-tidal estuaries." *Estuarine, Coastal and Shelf Science* 220 (2019): 131-141. https://doi.org/10.1016/j.ecss.2019.02.042

[11] Maged, Marghany, and Hashim Mazlan. "Different polarised topographic synthetic aperture radar (TOPSAR) bands for shoreline change mapping." *International Journal of Physical Sciences* 5, no. 12 (2010): 1883-1889. https://doi.org/10.1109/igarss.2011.6049937

[12] Rezaee, Meysam, Aliasghar Golshani, and Hosein Mousavizadegan. "A new methodology to analysis and predict shoreline changes due to human interventions (case study: Javad Al-Aemmeh port, Iran)." *International Journal of Maritime Technology* 12 (2019): 9-23. https://doi.org/10.29252/ijmt.12.9

[13] Mohamed Rashidi, Ahmad Hadi, Mohamad Hidayat Jamal, Mohamad Zaki Hassan, Siti Salihah Mohd Sendek, Syazana Lyana Mohd Sopie, and Mohd Radzi Abd Hamid. "Coastal structures as beach erosion control and sea level rise adaptation in Malaysia: A review." *Water* 13, no. 13 (2021): 1741. https://doi.org/10.3390/w13131741r

[14] El-Ashmawy, Nagwa. "Automatic determination of shoreline at maximum retreating." *The Egyptian Journal of Remote Sensing and Space Science* 22, no. 3 (2019): 247-252. https://doi.org/10.1016/j.ejrs.2019.07.001

[15] Everaerts, Jurgen. "*The use* of unmanned aerial vehicles (UAVs) for remote sensing and mapping." *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 37, no. 2008 (2008): 1187-1192. https://doi.org/10.1201/9780203888445.ch9

[16] Boak, Elizabeth H., and Ian L. Turner. *"*Shoreline definition and detection: a review.*"* *Journal of coastal research* 21, no. 4 (2005): 688-703. https://doi.org/10.2112/03-0071.1

[17] Łubczonek, Jacek, Małgorzata Łącka, and Grzegorz Zaniewicz. "Analysis of the accuracy of shoreline mapping in inland navigational charts (Inland ENC) using photogrammetric and sonar images." *Zeszyty Naukowe Akademii Morskiej w Szczecinie* 58 (130 (2019): 45-54. https://doi.org/10.1127/pfg/2016/0297

[18] Toure, Seynabou, Oumar Diop, Kidiyo Kpalma, and Amadou Seidou Maiga. "Shoreline detection using optical remote sensing: A review." *ISPRS International Journal of Geo-Information* 8, no. 2 (2019): 75. https://doi.org/10.3390/ijgi8020075

[19] Smith, Carter S., Morgan E. Rudd, Rachel K. Gittman, Emily C. Melvin, Virginia S. Patterson, Julianna J. Renzi, Emory H. Wellman, and Brian R. Silliman. "Coming to terms with living shorelines: a scoping review of novel restoration strategies for shoreline protection.*"* *Frontiers in Marine Science* 7 (2020): 434. https://doi.org/10.3389/fmars.2020.00434

[20] Baig, Mirza Razi Imam, Ishita Afreen Ahmad, Shahfahad, Mohammad Tayyab, and Atiqur Rahman. "Analysis of shoreline changes in Vishakhapatnam coastal tract of Andhra Pradesh, India: an application of digital shoreline analysis system (DSAS)." *Annals of GIS* 26, no. 4 (2020): 361-376. https://doi.org/10.1080/19475683.2020.1815839

[21] Nassar, Karim, Wael Elham Mahmod, Hassan Fath, Ali Masria, Kazuo Nadaoka, and Abdelazim Negm. "Shoreline change detection using DSAS technique: Case of North Sinai coast, Egypt." *Marine Georesources & Geotechnology* 37, no. 1 (2019): 81-95. https://doi.org/10.1080/1064119X.2018.1448912

[22] Ariffin, Bin, and Effi Helmy. "Effect of monsoons on beach morphodynamics in the East Coast of Peninsular Malaysia: Examples from Kuala Terengganu coast." PhD diss., Lorient, 2017. https://doi.org/10.1007/s11852-019-00703-0

[23] Ariffin, Effi Helmy, Mouncef Sedrati, Mohd Fadzil Akhir, Rosnan Yaacob, and Mohd Lokman Husain. "Open sandy beach morphology and morphodynamic as response to seasonal monsoon in Kuala Terengganu, Malaysia." *Journal of Coastal Research* 75 (2016): 1032-1036. https://doi.org/10.2112/SI75-207.1

[24] Kaamin, Masiri, Muhammad Amirul Fadzly Mohd Fadzil, Mohd Adib Mohammad Razi, Mohd Effendi Daud, Noorul Hudai Abdullah, Ahmad Hakimi Mat Nor, and Nor Farah Atiqah Ahmad. "The shoreline bathymetry assessment using unmanned aerial vehicle (UAV) photogrammetry." In *Journal of Physics: Conference Series*, vol. 1529, no. 3, p. 032109. IOP Publishing, 2020. https://doi.org/10.1088/1742-6596/1529/3/032109