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ANALYSIS OF THE COASTAL EROSION IN DUNGUN, TERENGGANU USING DIGITAL SHORELINE ANALYSIS SYSTEM (DSAS) AND ITS IMPACT ON THE COMMUNITY'S SOCIO-ECONOMIC

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ABSTRACT

Coastal erosion is defined as the long-term loss of habitats and land along the shore, resulting in changes to the coastline. Therefore, it is crucial to identify shoreline changes, particularly along the Dungun coast in Terengganu, as these changes have significant socio-economic impacts. This study aims to: (1) estimate the rate of shoreline changes between 2016 and 2020 using the Digital Shoreline Analysis System (DSAS) method, and (2) analyse the impact of these changes on coastal communities along the Dungun coast. In this analysis, the End Point Rate (EPR) method within the DSAS was selected based on its application in previous studies. Overall, the coastal areas are experiencing a greater rate of erosion than accretion. The average erosion rate is -1.79 m/year, with the highest rate recorded at Sura Beach at approximately -9.44 m/year (2016–2020). In contrast, the average accretion rate is 2.11 m/year, with the highest accretion observed at the mouth of Sungai Dungun, at about 9.62 m/year (2016–2020). These results highlight the serious implications of coastal erosion for populations living along the shore, including the loss of property and damage to infrastructure, which disrupts economic and community activities. Thus, this study provides valuable insights for authorities to develop effective *coastal erosion management strategies and emphasizes the need to raise awareness among coastal communities.*

Keywords: *Accretion, Coastal community, DSAS, Dungun coast, Erosion*

INTRODUCTION

The coastal zone is a complex ecosystem, comprising the land adjacent to the coastline where the sea and land intersect (Adnan et al., 2021). In many oceanic regions, it serves as a vital resource for physical processes, biodiversity, flood control, and recreation (Mohd et al., 2018). Coastal areas are under constant pressure due to a combination of natural processes and human activities (Sowmya et al., 2019). The coastline of Peninsular Malaysia is generally divided into two regions: the west coast, which borders the Malacca Strait, and the east coast, which faces the South China Sea.

Erosion has affected over 1,300 km of Malaysia's 4,809 km coastline, with nearly 29% experiencing erosion since 1984 (Mohd et al., 2018; Rashidi et al., 2021). The eastern coast of Peninsular Malaysia, including Kuala Terengganu, is influenced by two seasonal monsoons. Significant wave heights on this coast range from about 2 m during the northeast monsoon to 0.5–1 m during the southwest monsoon. Coastal erosion is primarily caused by the interaction of natural factors such as waves, currents, tides, and river flows (Ahmad et al., 2021). At present, coastal zones face increasing risks from both natural and anthropogenic sources, including rising sea levels, resource exploitation, and continued erosion (Nassar et al., 2019).

To monitor coastal areas, various studies and analyses have been conducted. Earlier research, such as that by Ariffin et al. (2016), applied traditional methods like beach profile surveys and wave modelling to investigate patterns of beach erosion and accretion. However, these approaches are time-consuming and involve extensive manual computation. Geospatial technologies now offer more efficient alternatives. Remote sensing and Geographic Information Systems (GIS) have been widely used to map coastal erosion trends. According to Ahmad et al. (2021), the Digital Shoreline Analysis System (DSAS) is a valuable tool for identifying shoreline changes and provides crucial insights into environmental transformations along the coast.

Despite these advancements, there is still limited research on erosion management systems in the Dungun–Kemaman area of Terengganu (Yaacob et al., 2018). Understanding coastal erosion is vital for stakeholders to better comprehend the dynamics of the coastal environment and mitigate its adverse impacts, including the loss of social, physical, and financial resources (Akhter et al., 2024). Coastal erosion significantly affects the socio-economic well-being of communities in Dungun, as local beaches serve as key sources of livelihood for residents. Therefore, stakeholders should implement targeted policies aligned with the Sustainable Development Goals (SDGs) to address coastal erosion (Karim, 2021; Roslee et al., 2022).

The main objectives of this study are: (1) to estimate the rate of shoreline change from 2016 to 2020 using the DSAS method, and (2) to analyse the impact of shoreline changes on coastal communities along the Dungun coast in Terengganu. In this context, DSAS is demonstrated as an effective tool for detecting and analysing shoreline changes.

STUDY AREA

This study was conducted along the coastal area of Dungun Beach, Terengganu, as illustrated in Figure 1. The study covered approximately 11.7 km of coastline, extending from coordinates (4°46'45.35"N, 103°25'37.41"E) at the northern end to (4°41'5.09"N, 103°26'48.86"E) at the southern end. The Dungun district spans an area of 2,735.04 km^2 and is home to approximately 185,300 citizens and 4,300 non-citizens. This study focused specifically on the sandy coastal areas located near the main road in Dungun.

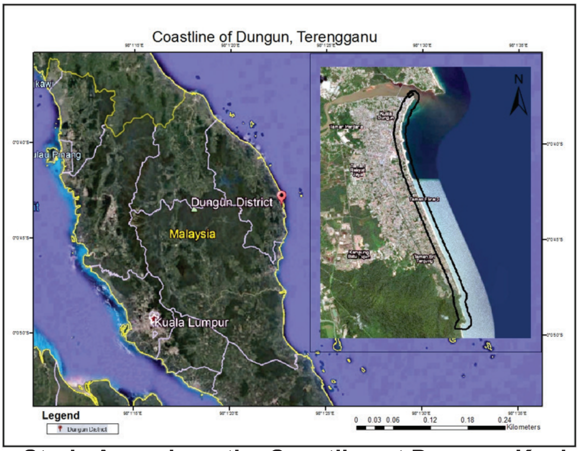


Figure 1. The Study Area along the Coastline at Dungun, Kuala Terengganu

Source: Author, 2025

RESEARCH METHODOLOGY

The research process is outlined in Figure 2 and consists of five main stages: study area selection, data acquisition, data processing, data analysis, and map production. In the data acquisition phase, Sentinel-2 satellite images from 2016 and 2020 were collected to digitize shoreline features along the coast of Dungun, Terengganu. Additionally, a questionnaire was administered to assess the impact of shoreline changes on the coastal community.

Data Acquisition

Two types of data were used in this study: satellite imagery and questionnaires. Satellite images of the study area from two different years were required to identify and evaluate shoreline changes. Questionnaires were also used to analyse the impact of these changes on the coastal community along the Dungun coast in Terengganu.

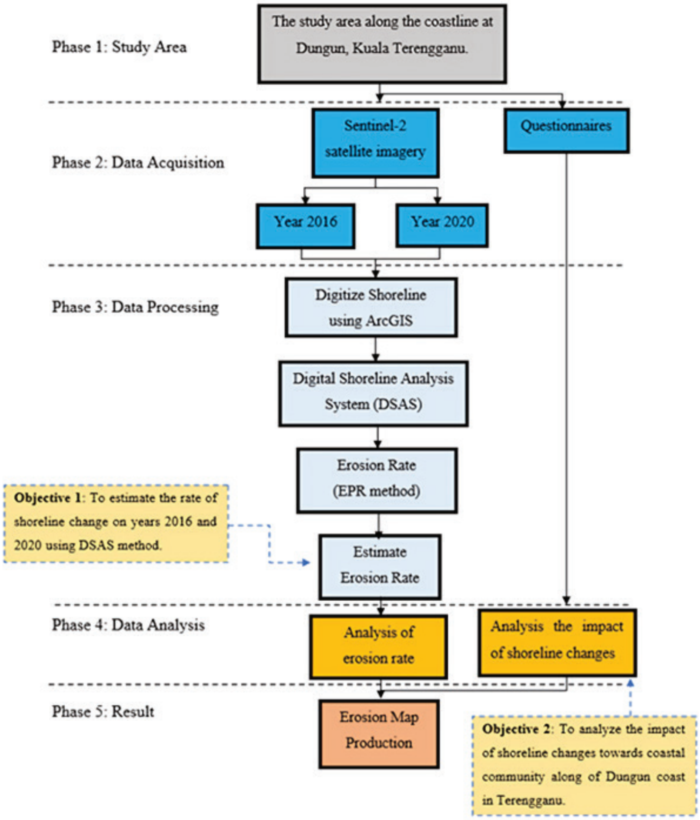


Figure 2. The methodology Phases of this Project

Source: Author, 2025

Satellite Imagery

The Sentinel-2 satellite images used in this study were taken in the months of April and August, as these months typically have less cloud cover, allowing for more accurate shoreline delineation. Sentinel-2 offers a spatial resolution of 10 meters. Most of the satellite data were obtained in .TIFF format and consist of raw imagery. Shoreline changes along the Dungun coast in Terengganu were comprehensively assessed over a four-year period (2016–2020) using the Digital Shoreline Analysis System (DSAS) to extract and analyse shoreline shifts. Table 1 provides detailed information about the satellite imagery used in this study.

Table 1. Data Image Information

No	Satellite image	Date	Sensor band	Spatial Resolution	Source
1.	Sentinel- 2	16th April 2016 and 18th Aug 2020	Red, Green, Blue and Near Infrared (4,3,2,8).	10 meters	Land Viewer

Source: Author, 2025

Questionnaires

The second data source for this study consists of questionnaires distributed via Google Forms. These questionnaires were designed to evaluate the effects of shoreline changes on the coastal community living near Dungun, Terengganu, in conjunction with the satellite data. This integration allows for cross-verification, enhancing the accuracy and reliability of the findings. The questionnaires were randomly distributed to members of the coastal community to gather local perspectives. They comprised multiple sections, including demographics, population impact, economic and social effects, impact on marine habitats, effects on fishermen, and impact on income. These sections were developed to comprehensively assess the effects of shoreline changes on the local community.

Coastline Digitizing

Pre-processing of raw satellite imagery is essential to obtain reliable and valid data, as it enables precise measurement and analysis of shoreline changes over time. One key procedure in the pre-processing stage is digitizing. Digitization is the process of converting geographic data by transforming image features into vector data (Dempsey, 2017). This technique allows raster data to be converted into vector form for analytical purposes, such as generating attribute tables. In this study, satellite images from the years 2016 and 2020 were digitized by creating distinct line features for each year. Shoreline attributes, including the year and shape length, were assigned to each digitized feature. A comparison of shoreline positions between 2016 and 2020 revealed a significant retreat in certain localized areas.

Digital Shoreline Analysis System (DSAS)

The rate of shoreline and beach changes over time can be effectively analysed using the Digital Shoreline Analysis System (DSAS). Prior to the development of DSAS, methods such as tacheometry and manual digitizing were commonly used to study coastal erosion. Muskananfola et al. (2020) highlighted that DSAS offers a precise approach for calculating shoreline change rates using historical coastal data. According to Siyal et al. (2022), many researchers have adopted GIS techniques for shoreline change analysis due to their high temporal resolution, cost-effectiveness, and spatial accuracy, making them superior to traditional field-based shoreline mapping methods.

Mondal et al. (2020), for instance, employed DSAS integrated with ArcGIS software to quantify and analyse coastal dynamics on Sagar Island over a 40-year period (1975–2015). Their findings emphasized the significance of DSAS as a scientific tool for measuring both temporal and spatial variations in shoreline change. Similarly, Zakwan et al. (2023) used DSAS to determine the rate of shoreline change along the Kelantan coast from 2013 to 2021. In that study, the End Point Rate (EPR) method was applied to calculate the rate of gradual shoreline alterations.

The DSAS approach enables precise shoreline positioning and provides reliable results for understanding erosion and accretion patterns. It involves four key phases: (1) shoreline preparation, (2) baseline creation, (3) transect generation, and (4) estimation of shoreline change rates (Kermani et al., 2016). This method allows for systematic and quantitative assessment of coastal changes over time.

Shoreline Changes Determination

Once the shoreline was identified, the next step was to detect changes over time. These changes were determined by comparing historical and recent shoreline positions. In this study, shoreline shifts were analysed by comparing data from the years 2016 and 2020, representing long-term coastal changes. The variation in shoreline position was assessed by identifying the intersection and displacement between shoreline lines from the two time periods. Measuring these changes is crucial for evaluating areas of erosion and accretion.

To perform this analysis, the Digital Shoreline Analysis System (DSAS) tool in ArcGIS was used. Several preparatory steps were required before executing the DSAS computation, including the preparation of shoreline data, definition of reference baselines, generation of transects, and shoreline change analysis.

Preparation of Shoreline and Baseline Dataset

The process begins with the collection of baseline and shoreline data to ensure the DSAS system functions correctly. All data must be prepared in the appropriate format and contain the necessary attribute information required by DSAS to enable accurate recognition and measurement of shoreline change rates. Shoreline data should be merged and stored in a personal geodatabase as a single feature class. Additionally, DSAS requires both shoreline and baseline data to use a projected coordinate system and be expressed in meter units. Each shoreline feature must also include a date attribute in the month/day/year format to facilitate accurate calculations of shoreline change rates.

Determination of Baselines and Transect Line for DSAS

For each shoreline time series, DSAS statistically applies the baseline method to estimate shoreline change rates. The baseline is a crucial component of the DSAS workflow, as it serves as the reference line from which all calculations begin. The user must define this baseline, which DSAS uses to automatically generate transect lines. The baseline should extend across the shoreline, and transects are generated perpendicular to it based on a user-defined spacing.

Several parameter settings must be specified during transect construction, including transect generation settings, shoreline computation parameters, and metadata configurations. The position of the baseline is critical during this process, as it determines the direction and extent of the transects—whether they project inland or seaward. The user must also define the transect length and the spacing between transects. In this study, the analysis produced a total of 114 transect lines, each spaced 100 metres apart.

Assessment of End Point Rate (EPR) Method

DSAS offers several calculation methods, each with its own specific functions and advantages. Shoreline changes are recorded for each transect and expressed in units of metres. According to Ahmad et al. (2021), the End Point Rate (EPR) method is recommended as the most suitable technique for estimating the rate of shoreline change, as it requires only two shoreline dates for computation.

The EPR approach provides a reliable means of calculating long-term shoreline change and is a convenient method for evaluating coastal dynamics (Immanuvel David et al., 2016). It is widely used due to its simplicity and effectiveness in generating results from just two shoreline datasets (Zambrano-Medina et al., 2023). Moreover, EPR is considered highly effective because it accounts for exact date differences, enabling precise calculations of shoreline and beach level changes over days, months, and years.

RESULTS AND ANALYSIS

This study has two main objectives: (1) to estimate the rate of shoreline change from 2016 to 2020 using the Digital Shoreline Analysis System (DSAS) method, and (2) to analyse the impact of shoreline changes on the coastal community along the Dungun coast in Terengganu. Areas of accretion and erosion were identified using the End Point Rate (EPR) method within the ArcGIS platform and DSAS tool, allowing for accurate calculation of erosion rates. In addition, questionnaires distributed in Dungun were used to assess and verify the effects of shoreline changes on local coastal communities.

Erosion Rate using EPR Method

This analysis utilised DSAS version 5.0, an ArcGIS extension, to compute the statistical details of coastline changes. The extension generates transect lines and measures shoreline shifts based on specific x and y coordinates. DSAS was developed to analyse historical shoreline changes by calculating the rate of change along each transect.

In this study, shoreline transect lines from 2016 to 2020 were used. A total of 114 transects were generated in Dungun, Terengganu, to evaluate coastal changes from a defined offshore baseline, using the earliest shoreline as a reference and placing transects at 100-metre intervals. Each transect extends up to 500 metres, ranging from Line 1 at Teluk Gadung to Line 114 at the Dungun River estuary.

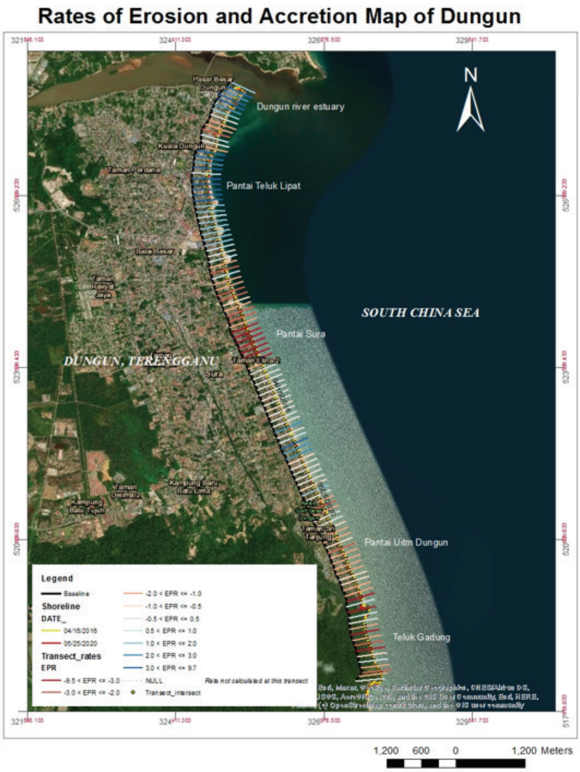
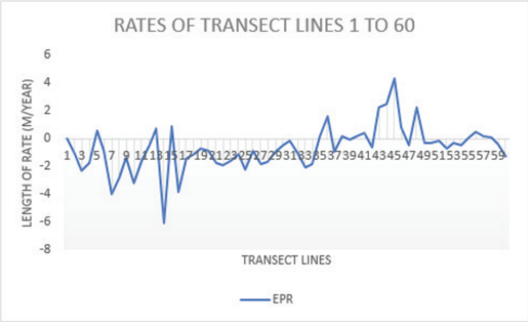


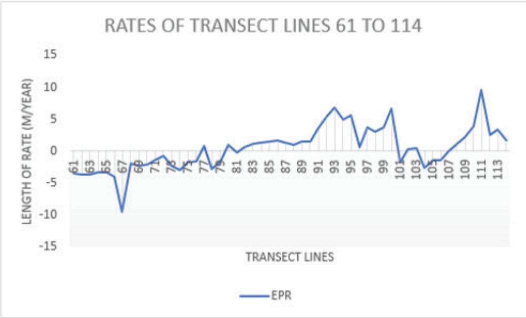
Figure 3. Rates of Erosion and Accretion Map

Source: Author, 2025

Figure 3 illustrates the erosion rates and a categorised accretion map used to determine End Point Rate (EPR) values at specific locations. The approach classifies shoreline changes into four erosion categories for negative (–) values, which are represented in red. A neutral grey bin indicates a value of zero, while four shades of blue represent positive (+) values, indicating deposition or accretion. The intensity of the colour increases with the magnitude of the change. Dashed grey lines denote areas with null values. To improve legibility and enhance classification accuracy, additional colour gradations and category divisions were applied.



(a)



(b)

Figure 4. Rates of transect lines 1-60 (a) and rates of transect lines 61-114 (b)

Table 2. Summary Result Transect Line based on EPR Techniques

	Min (m/year)	Transect ID (Min)	Average (m/year)	Max (m/year)	Transect ID (Max)	Statistically significant (%)	Total of Percent (%)	Total of Transect line
Erosion	-0.06	107	-1.79	-9.44	67	7.02 %	57.89 %	66
Accretion	0.04	01	2.11	9.62	111	10.53 %	42.11 %	48
Total								114

Source: Author, 2025

The rate of shoreline change was calculated using DSAS, with values obtained by applying the End Point Rate (EPR) method across 114 transects. This method refines shoreline position estimates over a four-year period (2016–2020), ensuring accurate assessment of coastline orientation. Figure 4(a) and Figure 4(b) illustrate the EPR results for Transects 1–60 and Transects 61–114, respectively. Transects 1–60 cover the area from Teluk Gadung to Pantai Sura, while Transects 61–114 extend from Pantai Teluk Lipat to the Dungun River estuary.

Significant erosion was observed near the UiTM Dungun Beach area at Pantai Sura, particularly along Transects 2–35 [Figure 4(a)] and Transects 61–79 [Figure 4(b)]. The littoral zone from Teluk Gadung to Pantai Sura exhibited widespread erosion. In total, 66 transects recorded erosion, representing 57.89% of all transects, with 7.02% showing statistically significant erosion. The lowest erosion rate was recorded at Transect 107 in Pantai Teluk Lipat (-0.06 m/year), while the average erosion rate across all transects was -1.79 m/year. The highest erosion rate occurred at Transect 67 in Pantai Sura, reaching -9.44 m/year. The analysis classified the coastal zone as a sandy littoral environment and confirmed that factors such as wind, ocean currents, tides, and seasonal monsoons significantly influence shoreline morphology—findings consistent with previous research. For instance, Mohd et al. (2018) noted erosion in the backshore area and the formation of wave-induced sand ridges during the northeast monsoon, driven by high wave energy.

In contrast, Figure 4(b) shows significant accretion between Transects 82–100 and 107–114. These accretional changes occurred near the Dungun River estuary and Pantai Teluk Lipat, reflecting substantial shoreline growth over the four-year period. Out of the 114 transects, 48 showed accretion (42.11%), with 10.53% classified as statistically significant. At Teluk Gadung, Figure 4(a) shows a minimum accretion rate of 0.04 m/year at Transect 1. The average accretion rate was calculated at 2.11 m/year. The highest accretion was recorded at Transect 111 near the Dungun River estuary (9.62 m/year), followed by Transect 93 at Pantai Teluk Lipat (6.89 m/year). Although Pantai Teluk Lipat was previously known for coastal erosion, it has shown considerable accretion. This observation aligns with reports from Berita Harian (2015), which stated that a beach reclamation project began in September 2016, extending three kilometres from the Dungun River estuary to Pantai Teluk Lipat, in collaboration with the Terengganu state and local authorities. Furthermore, mStar (2011) reported that powerful waves had previously eroded much of Teluk Lipat's coastline, resulting in the collapse and closure of a three-kilometre coastal road. The findings of this study indicate that the beach reclamation initiative has contributed to improved shoreline stability and supports sustainable coastal management in the region. These results fulfil the first objective of this study, which was to estimate the rate of shoreline change between 2016 and 2020 using the DSAS method.

The Effects of Coastal Erosion on The Socio-Economy of The Coastal Community

Respondents Demographic

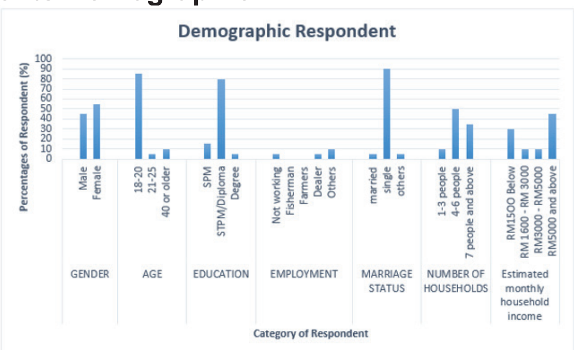


Figure 5. Respondent Demography

Source: Author, 2025

A total of 20 questionnaire responses were collected. As shown in Figure 5, the majority of respondents were between the ages of 18 and 20, with two respondents aged over 40. Of the total, 45% were male and 55% were female. In terms of occupation, 80% of respondents were students, 10% were employed, 5% were unemployed, and 5% were self-employed or identified as dealers. Regarding marital status, 90% of respondents were single, while 5% were married and another 5% were divorced.

As for household size, 52.6% of respondents reported living in households with 4–6 members, 36.8% in households with more than 7 members, and 10.5% in households with only 1–3 members. In terms of monthly household income, 47.4% reported an income of RM5000 and above, 31.6% earned less than RM1500, 10.5% earned between RM3000 and RM5000, and another 10.5% had a monthly income between RM1600 and RM3000.

In conclusion, as the majority of respondents were students, the findings may not fully represent the broader Dungun coastal population—particularly the working-age demographic, whose livelihoods are likely to be more directly affected by coastal erosion.

Impact on the Population in Coastal Areas

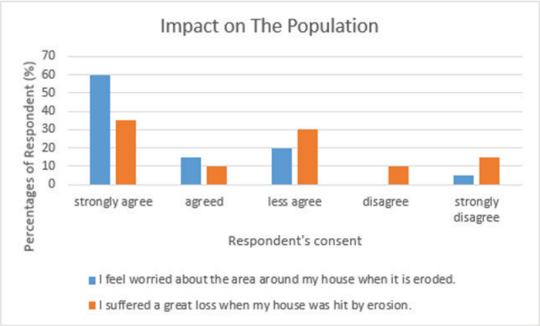


Figure 6. Impact on the Population in Coastal Areas
Source: Author, 2025

Figure 6 shows that 60% of respondents strongly agree that they feel worried when the area around their homes is affected by erosion. In contrast, only 5% strongly disagree with this concern. Regarding property damage caused by coastal erosion, 35% of respondents strongly agree that they have experienced significant losses, while 10% strongly disagree with this statement.

These findings indicate that the majority of respondents living in coastal areas are highly concerned about coastal erosion and have faced notable property damage as a result. Conversely, the small number of respondents who expressed little or no concern are likely residing further inland or in areas less vulnerable to coastal erosion. These results are consistent with other documented cases. For example, Figure 7 illustrates the severe erosion that occurred during high wave events in Tok Jembal and Teluk Lipat in 2011.

Figure 7. Erosion on (a) Teluk Lipat Dungun, (b) Tok Jembal Kuala Terengganu in December 2011

Source: Rahman et al.,(2020)

Economic and Social Impact

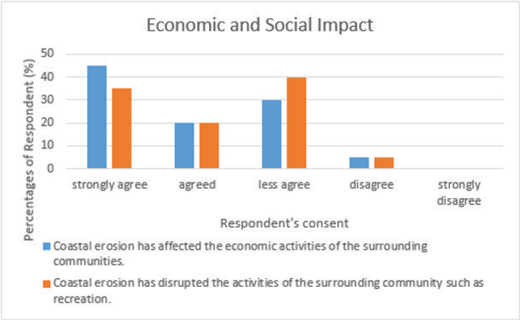


Figure 8. Economic and Social Impact

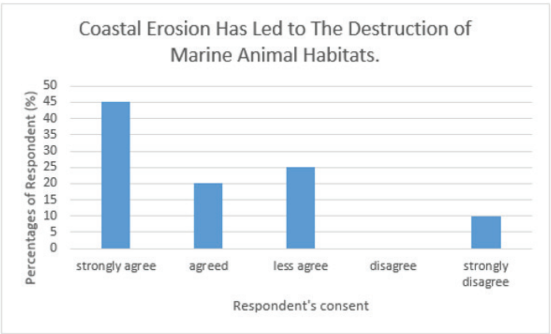
Source: Author, 2025

According to Figure 8, only 5% of respondents disagreed with the statement that coastal erosion affects the economic activities of the local community, while 45% strongly agreed. Additionally, 5% did not believe that coastal erosion has impacted local recreational activities. In contrast, 40% of respondents strongly agreed that coastal erosion has disrupted community life. These findings suggest that coastal erosion has significantly affected local activities, particularly tourism.

The majority of respondents indicated that coastal erosion has disrupted both economic and community activities along the coast. This is largely due to damage and property loss in several affected locations and structures. These findings are consistent with previous research highlighting the social, economic, and ecological consequences of coastal erosion.

Documented impacts include the loss of white sand beaches, prime arable land, and agricultural productivity, as well as the destruction of infrastructure such as hotels, roads, fish landing sites, and other coastal properties. These changes also contribute to the loss of employment opportunities in affected communities.

Impact on Marine Animal Habitat



Source: Author, 2025

Figure 9 shows that the lowest percentage of respondents (10%) strongly disagreed that coastal erosion leads to the loss of marine animal habitats. In contrast, the majority (45%) agreed that coastal erosion contributes to the destruction of these habitats. Overall, the findings indicate that coastal erosion is widely perceived to cause significant habitat loss for marine life.

These results suggest that most respondents recognize the detrimental impact of coastal erosion on marine biodiversity. In light of this, several recommendations are proposed, including the establishment of a marine and coastal planning authority, enhanced public education on the importance of the marine environment, and the implementation of stronger measures to protect coastal biodiversity and ecosystems.

Impact on Fisherman

Figure 10 shows that only 5% of respondents strongly disagreed with the statement that fish catches in the Dungun region have declined due to coastal changes. In contrast, 35% strongly agreed that coastal changes have contributed to a reduction in fish catches. Additionally, 10% of respondents strongly agreed that coastal changes have not made it difficult for fishermen to bring their catch ashore, while 40% of respondents expressed agreement that such difficulties do exist.

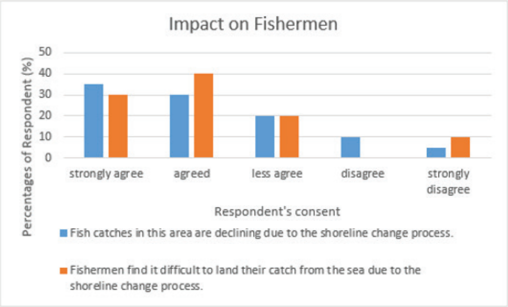


Figure 10. Impact on Fishermen

Source: Author, 2025

These findings suggest that the majority of respondents—particularly those involved in fishing—perceive a decline in fish catches as a result of coastal changes. Erosion has damaged or, in some cases, destroyed jetty structures, making it more difficult for fishermen to offload their catch onto land. These results are consistent with previous studies, which have reported a decline in fisheries productivity in coastal 'hotspot' areas such as lagoons, directly affecting the livelihoods of many fishing families.

Impact on Income

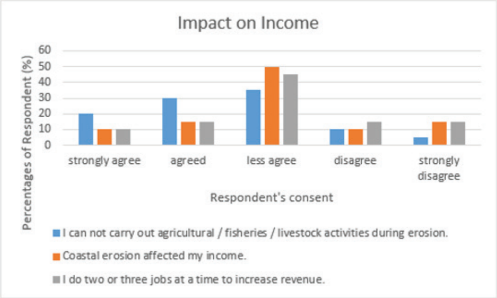


Figure 11. Impact on Income

Source: Author, 2025

Figure 11 illustrates the perceived impact of coastal erosion on respondents' income. For the first item, 5% of respondents strongly disagreed with the statement that activities such as agriculture, fisheries, and livestock rearing can still be carried out during periods of erosion. The second item shows equal responses (15%) for both strong agreement and strong disagreement regarding whether coastal erosion significantly impacts income, while the highest proportion—50%—disagreed with the statement. The third item indicates that only 10% strongly agreed with the need to hold two or three jobs to supplement income, whereas 45% disagreed with this notion.

In conclusion, the findings suggest that although activities such as agriculture, fishing, and livestock rearing can still continue, the income generated from these activities is likely reduced compared to pre-erosion levels. Overall, the impact of coastal erosion on income was not strongly reflected in the responses. This may be due to the demographic composition of the sample, which was predominantly made up of students, salaried workers, and small-scale traders. As such, the findings may not fully capture the perspectives of older individuals or those whose livelihoods are directly tied to coastal-based economic activities and who are likely more severely affected by erosion.

CONCLUSION

The rate of coastal erosion along the shoreline of Dungun, Terengganu, was determined using two Sentinel-2 satellite images from 2016 and 2020, with a spatial resolution of 10 metres. The study area extended from Teluk Gadung near the UiTM Dungun campus to the Dungun River estuary. Previous research (Ariffin et al., 2016; Mohd et al., 2018; Rosnan & Ariffin, 2010; Yaacob et al., 2018) has shown that coastal erosion is influenced by several factors, including the monsoon season, sea-level rise, high-energy storm waves, and sediment depletion. The findings of this study, based on the End Point Rate (EPR) method, indicate that the majority of beaches along the Dungun coast are undergoing erosion.

Using the short-term change rate category, the study revealed that 57.89% of the area experienced erosion, while 42.11% experienced accretion. It was also noted that shoreline reclamation efforts began in September 2016, starting at the Dungun River estuary and extending three kilometres to Pantai Teluk Lipat. However, severe wave activity had already caused widespread erosion in Teluk Lipat, including the collapse and closure of a three-kilometre coastal road in 2011. These findings highlight that coastal erosion is an ongoing phenomenon, and continuous monitoring is essential to track shoreline transitions over time.

In addition to shoreline analysis, this study also investigated the impacts of erosion on coastal communities through a questionnaire survey. The results indicate high levels of concern among residents due to recurring property damage and loss of assets. Based on these findings, it is recommended that responsible authorities implement structural protection measures—such as seawalls, dams, or breakwaters—to mitigate wave energy and control sediment movement. These efforts would help reduce the risk of further erosion along the Dungun coastline.

Furthermore, raising public awareness and conducting education programmes are vital to ensure that coastal communities are well-prepared to manage future coastal hazards. Such initiatives are crucial for effective planning and long-term coastal management, particularly in Terengganu, where the monsoon season frequently brings high tides and strong waves that intensify erosion risks.

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AUTHOR CONTRIBUTIONS

Writing original draft preparation are Muhammad Hafifi Amirul Mohammad Azizi and Najwa Imani Mohd Ali. Meanwhile, review and editing are Fazly Amri Mohd and Noorazwani Mohd Razi. All authors have read and agreed to the published version of of the manuscript

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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