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EROSION RATE ESTIMATION IN KUALA TERENGGANU COASTLINE FOR SUSTAINABLE COASTAL COMMUNITY

Haris Abdul Rahim[1], Nor Aizam Adnan[2], Fazly Amri Mohd[3] and Effi Helmy Ariffin[4]

[1,2]*School of Geomatics Science and Natural Resources,*
College of Built Environment,
UNIVERSITI TEKNOLOGI MARA, SHAH ALAM, MALAYSIA
[3]*School of Geomatics Science and Natural Resources,*
College of Built Environment,
UNIVERSITI TEKNOLOGI MARA, ARAU, PERLIS, MALAYSIA
[4]*Institute of Oceanography and Environment,*
UNIVERSITI MALAYSIA TERENGGANU, TERENGGANU, MALAYSIA

Abstract

Kuala Terengganu is located on the east coast of Peninsular Malaysia and its coastline has been attracting various economic activities such as tourism, agriculture, and food industries. However, studies regarding erosion management for the populated sustainable community in Terengganu remain lacking. The purpose of this study was to quantify coastal erosion using geospatial and statistical approaches. It involved the utilisation of high-resolution SPOT-5 satellite imagery and unmanned aerial vehicles (UAVs) to monitor the coastline changes along Kampung Batu Rakit to Pantai Tok Jembal in Kuala Terengganu. This study proves that the geospatial technique based on high-resolution UAV and SPOT-5 images is suitable for the determination and analysis of coastline erosion.

Keywords: Erosion, Geographic Information System, satellite image, SPOT-5

[1] Associate Professor at University Teknologi MARA: nor_aizam@uitm.edu.my

INTRODUCTION

Coast is defined as a stretch of land along the sea while coastline describes the boundary between water and land (Li & Damen, 2010). However, it is difficult to identify water level due to its dynamic nature. Coastline also can be defined as the product of natural processes, such as sea level change, waves, tides, and human activities, that happened within a large timescale (Stanchev et al., 2018). The coastal area produces various advantages and has become more important to human activities. As a result, the conversion of coastline areas for economic use becomes a common sight where numerous areas situated nearby the coast have been developed to accommodate tourism infrastructure and activities, such as airports, hotels, and resorts. While such development assists towards a boost in the economy, it also promotes land use conflicts and shoreline erosion. Apart from natural causes like water and wind, past studies suggest that the severity of shoreline erosion is dependent on several factors, including geomorphological properties and land use (Adnan et al., 2021; Muslim, Foody, & Atkinson, 2007).

The National Coastal Erosion Study (NCES) identified that 29% of Malaysia's coastline was in various stages of evacuation due to erosion (Abdul Maulud et al., 2022; Ghazali, 2006). In this regard, the main cause of coastal slope changes comes from the dynamic physical process within the area due to the change in sea level and human activities. The erosion rate is influenced by many factors, such as geomorphological characteristics, monsoon season, anthropogenic activity, and the coastal profile. Coastline is also a dynamic environment element with its important component changes being the sea level rise, shore protection, tidal inundation, land subsidence, and erosion sediment process (Muslim et al., 2011).

In response to the issue, researchers have highlighted the use of remote sensing and Geographic Information System (GIS) technology for mapping the pattern of coastal erosion (Saravanan et al., 2014; Abdul Maulud et al., 2022; Abdul Rahim et al., 2022). Nowadays, geospatial technique can be used to ease the production and preparation of coastal erosion and accretion along the coastline as well as reducing the time needed for such process. Remote sensing provides high-resolution data image systems like Worldview Data with 0.4 m resolution and SPOT with 1.5 m resolution. The advantage of using the geospatial technique lies on its ability to evaluate changes and the relationship between coastal slope and rate of coastline erosion. This highlights the prominence of utilizing the geospatial technique to classify and analyse coastal slopes, rates of erosion, and patterns within a research study area, particularly following its ability to conduct efficient surveys and digital mapping.

RESEARCH BACKGROUND

Coastline refers to the intersection between the land and water surface at a selected tidal elevation level (Adnan et al., 2021; Mohd et al., 2021). However,

the process of selecting water surface is difficult due to its dynamic environment and important component, such as sea level rise, erosion process, tidal, and land. The mean high and low water levels are also useful to specify the sea level rise based on the mean sea level. This study area is important for many economic activities, including the tourism, agriculture, food, ad fisheries industries. It also offers a huge contribution to the industrial economy at the state and country levels.

According to Ariffin et al. (2018), at least 60% of sand beach across the world is classified as coastal erosion areas. The global coastal erosion is mainly triggered by natural phenomena, such as wind and wave, that commonly occurred during monsoon season. Ultimately, coastal erosion can cause severe damage to nearby infrastructure like buildings, hotels, chalets, and roads. In the context of Malaysia, the local erosion problem mainly owes to the dynamic process, changes in sea level, and human activity (Chalabi et al., 2006). The NCES reported that 30% of Malaysian coastal areas are threatened by erosion (Ghazali, 2006). Furthermore, the National Coastal Vulnerability Index (NCVI) classifies coastline erosion into three categories: (1) shorelines that are currently in the state of erosion where shore-based facilities are in immediate danger of being damaged; (2) shorelines that are eroding at an alarming rate whereby public properties or valuable agricultural lands are threatened in the last 5 to 10 years; and (3) undeveloped coastlines that are subject to erosion but with only minor or no economic losses if left unchecked. Additionally, researchers indicated that Kampung Mengabang Telipot is one of the areas extremely affected by coastal erosion with approximately 65 residential are situated less than 5 meters from the danger zone (Husain, 2017; Razak, 2015).

Furthermore, the coastal erosion at Kuala Terengganu has been aggravating every year; however, studies regarding the erosion management system at Terengganu are still lacking (Ariffin et al., 2018). Hence, the application of unmanned aerial vehicles (UAVs), Geographic Information System (GIS), and remote sensing can assist in measuring and analysing this phenomenon to better understand the erosion problem. The geospatial technique has been widely used to monitor coastal erosion and accretion area. Such technique also reduces the time needed to obtain relevant data while having the capability of providing reliable quantitative output.

METHODOLOGY

This study involved the administration of 4-phases research that looked on the relationship assessment of erosion rate at Kuala Terengganu coastline using the geospatial technique. The research objective was achieved using data obtained from the ground, UAV image, and high-resolution SPOT-5 satellite imagery data. Figure 1 shows the flowchart of the methodology employed in this study. It began with Phase 1, which was the selection of the study area that was related to the

coastline changes in Kuala Terengganu. Phase 2 involved the acquisition of SPOT-5 satellite imagery data for the year 2014 from the Malaysian Space Agency (MYSA) as well as UAV image for the year 2018. This study quantified the erosion rate of coastline using the geospatial technique from these two images.

Phase 3 involved the calculation of erosion rate based on the NCES techniques (Adnan, Abdul Rahim, Mohd and Maulud, 2021; Adnan et al., 2021) for the quantification of physical and economic factors. Equation 1 was used to derive the erosion rate and categories (as shown in Table 1).

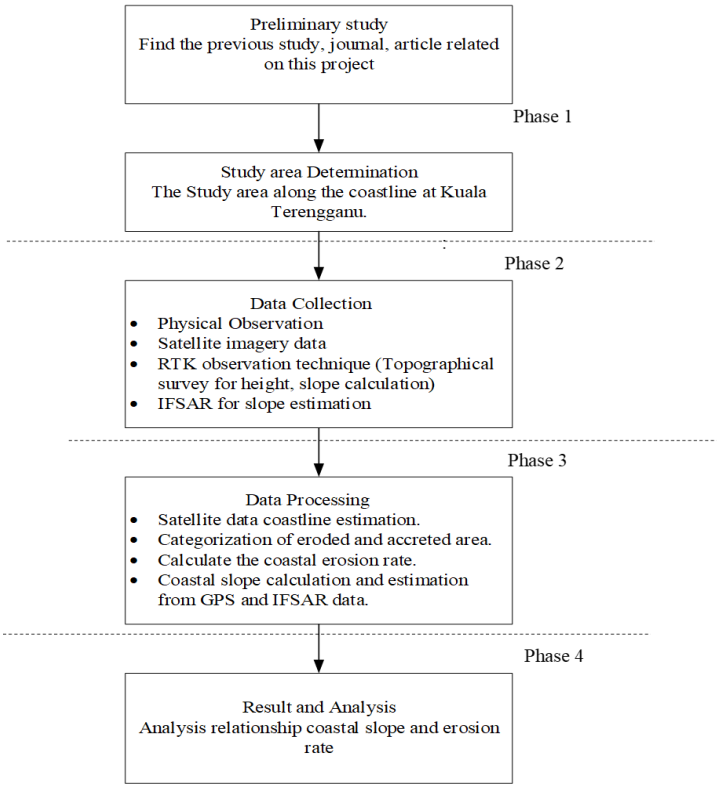

Figure 1: The flowchart of research methodology

The calculation of erosion rate is based on the NCES techniques (Adnan, Abdul Rahim, Mohd and Maulud, 2021; Adnan et al., 2021) which involves the quantification of physical and economic factors as in Phase 3. The Equation 1 below involved in order to derive erosion rate and categories. Meanwhile the erosion categories as shown in Table 1.

$$Total\ Score = Physical\ Parameter\ Score \times \left(\begin{array}{c} 0.1 \times Land\ Use\ Rating \\ + \\ 0.4 \times Buildings\ and\ Establishments\ Rating \\ + \\ 0.3 \times Public\ Utilities\ and\ Infrastructure\ Rating \\ + \\ 0.2 \times Public\ Facilities\ and\ Amenities\ Rating \end{array} \right) \quad \text{(Eq.1)}$$

Table 1: Erosion rate category according to NCES (2015)

Erosion Category	Description
K1 (Critical)	The rate of more than 4 m/year with generally fairly dense human settlement, with some commercial/industrial activities
K2 (Significant)	The rate of between more than 1 m/year but less than 4 m/year with generally sparsely-populated area
K3 (Acceptable)	The rate less than 1 m/year with generally no human settlement and minimal agricultural activities

RESULT AND DISCUSSIONS

The results of this study were generated based on on-site physical observation that was done between 4 and 5 February at Kuala Terengganu coast. The purpose of the observation was to identify the geomorphology characteristics that began from the coastal of Kampung Batu Rakit to Pantai Tok Jembal, with a distance of approximately 8.5 km. There were about 25 chainages collected along the coastline. Each control station was collected through five (5) series of observation lines with 5-meter intervals (Figure 2). The geomorphology of this coastal area was classified as sandy coast. The east coast facing the South China Sea, specifically Terengganu, experienced high wave energy during the Northeast Monsoon (Daud et al., 2016).

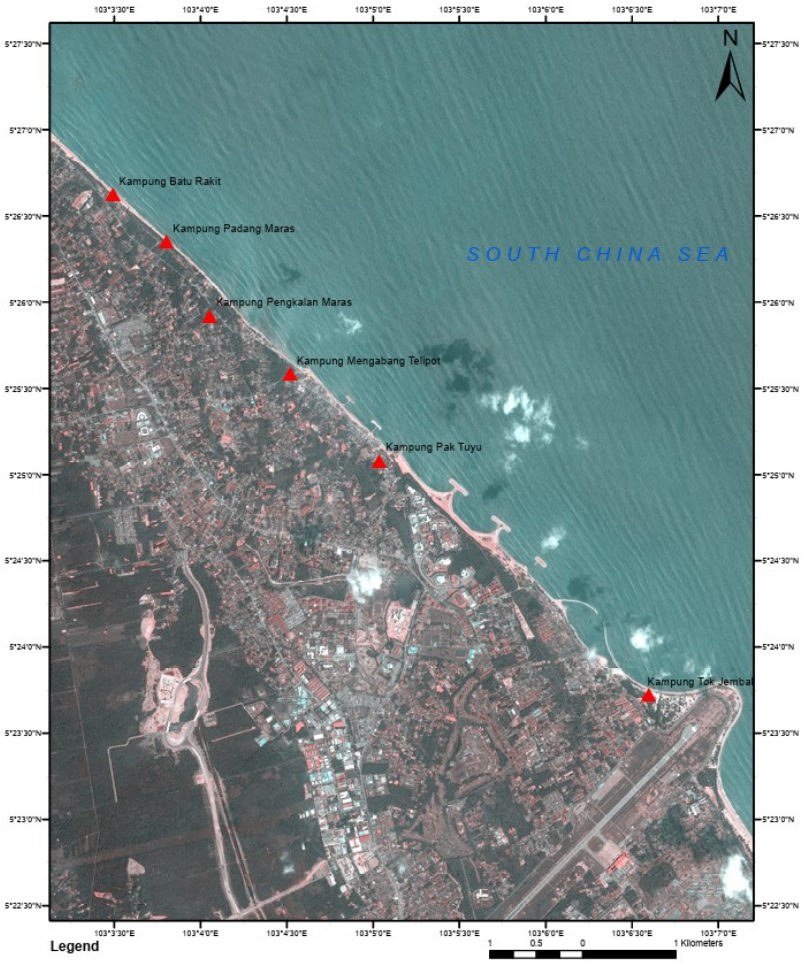

Figure 2: Location site observation from SPOT-5 (2014)

A study by Jones (2005) stated that the erosion rate caused by sea-level rise is increasing approximately 2.5 times higher for the next 100 years. For example, investigation on the sea-level rise at the shoreline of Klang, Selangor indicated that almost all existing village settlements at Pulau Ketam will be affected by a 0.53 m increase of maximum water level rise in 2100 (Mohamad et al., 2018).

However, it is important to note that coastal structures may have a localized impact on accretion or erosion changes, depending on shoreline trends (Romine et al., 2013; Ling et al., 2019). Table 2 shows the critical areas that were derived by coastal erosion, namely Pantai Tok Jembal, Kampung Pak Tuyu, Kampung Mengabang Telipot, Kampung Pengkalan Maras, Kampung Padang Maras, and Kampung Batu Rakit (Figure 2). The results revealed that Pantai Tok

Jembal has the largest erosion area that spans across 11.746 hectares with a length of 3387.397 m. Whereas, the smallest erosion area is located at Kampung Pak Tuyu with 0.118 hectares.

Table 2: Area derived from SPOT-5 2014 and UAV image 2018 based on the erosion table

No	Location	Coastline Length (m)	Area eroded (Hectare)
1	Pantai Tok Jembal	3387.397	11.746
2	Kampung Pak Tuyu	161.983	0.118
3	Kampung Mengabang Telipot	1453.857	3.4798
4	Kampung Pengkalan Maras	1161.521	0.5361
5	Kampung Padang Maras	798.387	0.2905
6	Kampung Batu Rakit	1231.819	0.6489

Table 3 summarises the area of erosion in Kuala Terengganu. The most critical area was K1, which contained 12 zones from a total of 33 erosion areas. This was categorised based on the total score of the NCES (2015) report, which consisted of three categories: critical, significant, and acceptable. The first category (critical) refers to erosion areas that will cause significant loss of property and land. In this study, the critical area comprised a total of 15.0829 hectares along the 4627.665 m coastline from Pantai Tok Jembal to Kampung Pengkalan Maras. An increase of 0.72 m is projected by the end of the century; hence, salinity contour will intrude further up to 9 km into the river as the deltas are low-lying areas (Pereira et al., 2019).

Our results also demonstrated the significance of K2, which comprised 9 areas, with a total score of more than 5 and less than 12. The K3 area, which consisted of 12 areas, was considered as an acceptable area with a total score of less than 5. However, the destruction of mangrove forests was observed along with the report of low awareness amongst the coastline community (Aisyah et al., 2015). Additionally, K3 recorded a total of 825.717 m² eroded area with a length of 258.419 m (Table 3).

Table 3: Summary for area of erosion in Kuala Terengganu

Classify	No	Coastline Length	Area (Sq. meter)	Condition Level
K1	(12)	4627.665	150829.886	Critical
K2	(9)	340.690	1214.996	Significant
K3	(12)	258.419	825.717	Acceptable

Figures 3 and 4 present the analysis of erosion length category as well as the erosion area (m^2) for the Terengganu coastal, respectively. As shown in Figure 3, K1 (critical category) had the highest number of categories with a length of 4627.665 m along the coast of Kuala Terengganu. The second highest category was recorded by K2 (significant category) with a length of 340.69 m, followed by K3 (acceptable category) with a length of 258.419 m. Tan et al. (2007) observed that breakwaters create a calmer water surface at the shoreward side. This proves that Terengganu is one of the states experiencing serious erosion on the East Coast of Malaysia. Therefore, it is crucial for stakeholders to take necessary mitigation and prevention actions against the problem. However, as the coast of Terengganu is a tourist attraction area, beach nourishment was conducted recently, which requires maintenance every three to five years. This technique is considered a "hold the line" strategy to maintain the recreational beach (Beaven et al., 2020).

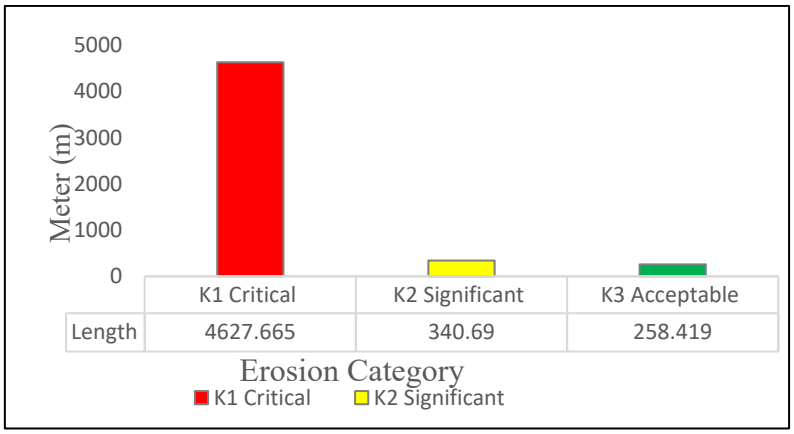

Figure 3: Erosion length of coastal Terengganu.

On the other hand, Figure 4 indicates that the K1 category contributed about 88.5% of the total erosion area 150829.89 m^2. The K2 category of erosion was approximately 1214.99 m^2, followed by the K3 category with a total area of 825.72 m^2.

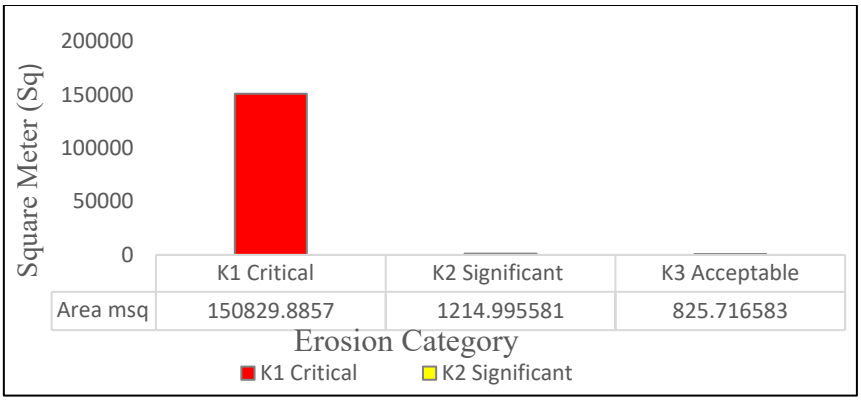

Figure 4: Erosion area (sq.) for Terengganu coastal

Figure 5 portrays that both Pantai Tok Jembal and Kampung Mengabang Teliput had a high value of erosion with rates ranging from -5.147 to -7.107 m/year. Most of the coastal areas were represented by sandy coast. Furthermore, the rate of erosion was highest due to anthropogenic activities, such as land reclamation and a new airport extension. Hence, the coastline changes in shape and size from year to year in response to the wave, current, tide, and monsoon season.

The second-highest erosion rate was recorded at Kampung Mengabang Teliput with -5.147 m/year. It showed that erosion or accretion occurred on the backshore and the sand ridges, which was caused by the higher level of waves during the Northeast Monsoon. Lee et al. (2012) discussed about the installation of geotextile-synthetic tubes for shoreline management at Teluk Kalong and Pantai Batu Buruk, Terengganu. Such mitigation measure was conducted along the coastline by constructing the water break. Meanwhile, Kampung Pengkalan Maras, Kampung Padang Maras, and Kampung Batu Rakit recorded an erosion rate of 1.063 to 1.384 m/year. This highlights mangroves as the most suitable vegetation species to minimise the effect of mighty tidal waves (Kathiresan et al., 2005). However, these areas are far from anthropogenic activities and mitigation measures must be conducted to maintain the coastline. Additionally, local participation is considered as an important key determinant for adaptation (Betzold et al., 2015).

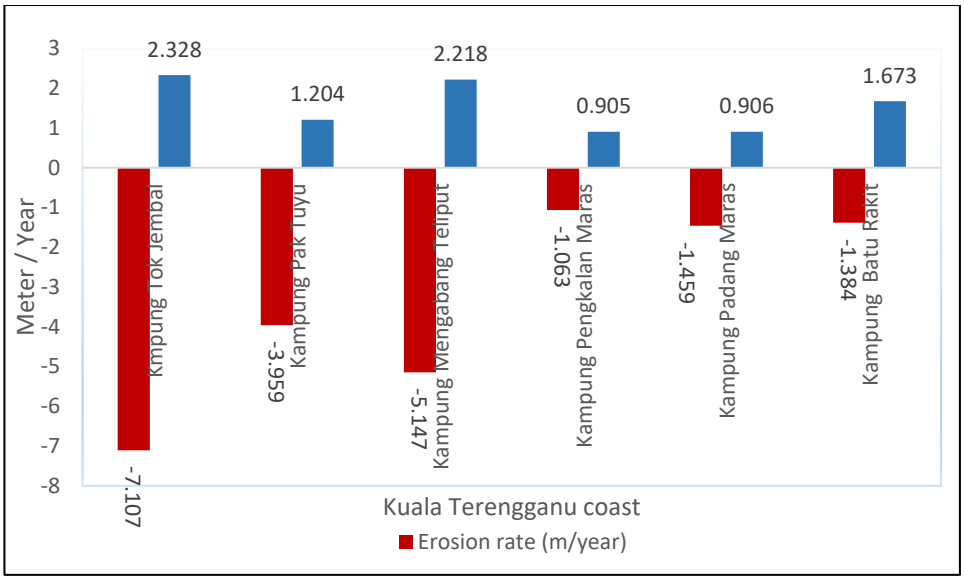

Figure 5: The area for the erosion and accretion (m/year) rate along identified Kuala Terengganu areas.

Moreover, the highest accretion rate was recorded at Pantai Tok Jembal with 2.328 m/year, followed by Kampung Mengabang Telipot with a slightly lower rate of 2.218 m/year. These areas have development activities occurring at its surrounding area. Accumulated sediment successfully stabilized the shoreline and provided a suitable condition for natural mangrove growth (Das et al., 2020). The on-site observation further revealed that local stakeholders have been taking their own actions and initiatives to mitigate erosion. It included a new mangrove rehabilitation using an ecoengineering coastal protection technique to restore the endangered mangroves. Lastly, Kampung Pengkalan Maras and Kampung Padang Maras showed the lowest accretion rate with less than 1 m/year. However, adverse physical and environmental impacts are expected at the adjacent shoreline and downdrift areas.

CONCLUSION

Anthropogenic factors or human activities such as land development and reclamation along the coast may have an impact towards the erosion rate and vertical coastal slope changes. Our results showed that the most critical area (K1) of erosion category in Kuala Terengganu consisted of 12 areas from the total number of 33 known areas. The highest critical erosion area was represented by Pantai Tok Jembal. Overall, this study revealed 15.0829 hectares of critical erosion areas that stretched along the 4627.665 m coastline from Pantai Tok Jembal to Kampung Pengkalan Maras. The energy from the waves is believed to

have directly washed the surface area of the beach and swept away the white medium sand, causing Kampung Batu Rakit to be the area with the lowest erosion. Shorter width and flat slope of the beach also make the erosion to become more aggressive with the weak waves hitting the shore. This study also proved the suitability of using satellite imagery data to estimate coastal erosion changes. Appropriate measures for the mitigation and prevention of coastal environment should be taken by the related authorities to maintain the livelihood and living sustainability of the coastal surrounding communities.

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