VOL 3, NO.2 (2023) 1-24
https://jagst.utm.my

JAGST
Journal of Advanced Geospatial Science & Technology

Coastal Vulnerability Index and Impact of Erosion Along Terengganu Coastline

Fatin Irdina Isa, Haris Abdul Rahim*, Nor Aizam Adnan, Fazly Amri Mohd
Schools of Geomatics Science and Natural Resources, College of Built Environment,
Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
*Corresponding author: harisrahim8@gmail.com

Abstract – Coastal erosion is a sensitive issue in Malaysia. This is because coastal erosion in Terengganu Malaysia's coastline is reliably exposed to dangers from the sea, bringing about beachfront disintegration and sea level rise. The nation is situated close to the equator in Southeast Asia, where its significant ports are arranged inside the worldwide sea and delivery courses. Straits of Malacca and the South China Sea encircled it, where the complete ocean region is two times the land region. Thus, these two unmistakable dangers antagonistically affected the physical, socioeconomic, and biodiversity along the coast. This study checked on chosen beachfront mitigation structures along the coastline of Malaysia as a wave-disintegration control and sea level rise variation considering the seaside executive's systems. This study is implemented in the state of Terengganu. The study aims to identify the changes in shorelines that are caused by coastal erosion in the years 2013, 2017 and 2021 using the Coastal Vulnerability Index (CVI) techniques from Pantai Rusila, Pantai Chendering, Pantai Batu Buruk, Pantai Seberang Takir and Pantai Menggabang Telipot at Terengganu. National Coastal Erosion Study (NCES) applies as a guideline to quantify erosion or accretion rates based on physical parameters. It can also identify the erosion area even from the social and economic outlined by NCES 2015.

Keywords – *Biodiversity, Coastal, Coastal Vulnerability Index, Erosion, National Coastal Erosion Study (NCES)*

Article History: Received 19 June 2023, Accepted 31 July 2023, Published 30 August 2023

How to cite: Isa, F. I., Rahim, H. A., Adnan, N. A. and Mohd, F. A. (2023). Coastal Vulnerability Index and Impact of Erosion Along Terengganu Coastline. Journal of Advanced Geospatial Science and Technology. 3(2), 1-24.

1.0 Introduction

Coastal erosion is the loss of long-term sediment to the coastal zones that have some impact by changing hydrodynamic patterns like wind, waves and current (Noujas et al., 2015; Prasad et al., 2014). The changing of the hydrodynamic can cause coastal erosion. These changes can affect the long-term stability of coastal zones. Even though anthropogenic activities mainly become erosion, the combination of climate change and natural forces can also contribute to the erosion cycle. In Malaysia, for instance, the monsoon season generates intense winds and waves, which can trigger coastal erosion (Jamal et al., 2021). Coastal erosion is a primary disaster that can affect the lives of coastal communities in Malaysia. It has an impact degree that ranges from moderate to severe, especially on the East Coast of Peninsular Malaysia. Depending on the eroded area, coastline retreats may have serious social, environmental and economic impacts (Bagheri et al., 2019).

Coastal areas are dynamic; many have multiple functions and are always at odds with human socioeconomic practices. Multi-functional coastal areas include recreation, residential, tourism, industry, agriculture, aquaculture and others (JPBD, 2012). Although they were known for giving a high risk to natural threats, start from a few coastal areas are usually considered resilient to these threats, and most of the threats are caused by climate change and human intervention. The effects of coastal erosion have caused alarm and concern worldwide (Ariffin et al., 2018). In addition to the natural disasters that can occur naturally in coastal areas, such as storms, coastal erosion can also be caused by human activities. This type of obstacle is usually built along the coast to prevent erosion. Although these barriers are meant to prevent coastal erosion, they often cause erosion. However, although these barriers are designed to control erosion, they have been shown to drive coastal erosion, especially in some cases.

Coastal vulnerability is a concept that can identify people and places that are vulnerable to disturbances because of coastal hazards. This was expected that space technology would facilitate by exploitation of the developments of the Coastal Vulnerability Index (CVI) and give some effective strategies for coastal management. Furthermore, coastal erosion is unavoidable and natural as coastal sediments constantly move due to tides, storm surges, currents, winds, and waves. Daily activities such as harbour construction and sand dredging disrupt the continuity of sediment transport and thus accelerate coastline erosion (Yanalagaran & Ramli, 2018).

The coast is the area separating the coastal land from the sea (Mohd Azharn et al., 2018). Hashim and Noor (2013) and Mohd et al. (2019) stated that most coastal areas on the east coast of

Peninsular Malaysia are going through a critical erosion process. However, an opposite phenomenon is observed in most areas on the West Coast of Peninsular Malaysia. Yanalagaran & Ramli (2018) discovered that the beaches on the East Coast of Peninsular Malaysia are directly exposed to the weather phenomenon during the northeast monsoon, where large, aggressive waves are capable of eroding the coastal zone (National Coastal Erosion Study, 2016).

Coastal erosion can be determined as dynamic areas influenced by land use and socioeconomic status. This study used the CVI technique to analyse the impact on the coastal zone and assess it through a tool measuring the relative coast vulnerability. This study can be conducted further to obtain coastal erosion using this technique on the diverse coastlines from Pantai Rusila to Pantai Menggabang Telipot, Terengganu. Mohd Azharn et al. (2018) investigated the shoreline changes caused by natural activities through the combined actions of waves, currents, tides and river flow, which often lead to a conflict in the process of coastal erosion. The changes related to human activities result from an uncontrolled increase in population and unplanned development in coastal areas especially.

The CVI is preferred in the study of coastal hazards because it prepares a predictive approach to any changes in the coast that occur through the facilities available in its statistical basis to classify coastlines based on the potential for change. However, thorough reviews are often performed to elaborate all applications of these technological advances, especially in exploiting the space geodetic technology to determine and classify some coastal information from analytical approaches. Various parameters, including ecological, spatial, and human characteristics, strongly influence coastal vulnerability erosion (Hamid et al., 2019). Therefore, the coastline along the beach of Kuala Terengganu has been chosen as it is in the K1 categorisation as stated in National Coastal Erosion Study (NCES) 2016 report. This area has been exposed to extreme monsoonal activity for the past four decades. A relatively small increase in sea level could affect natural coastal systems (Din et al., 2019).

2.0 Materials and Methods

The research of the study areas is around the East Coast of Peninsular Malaysia along the Kuala Terengganu coastline (Figure 1), about 33 km in length. The study area faces the South China Sea, which is heavily influenced by Northeast Monsoon, which lasts from November to March. The Northeast Monsoon brings heavy rain, especially to the states on the East Coast of Peninsular

Malaysia, west of Sarawak and east of Sabah. At the same time, the Southwest Monsoon relatively shows drier weather (METMalaysia, 2023). The study focuses on Kuala Terengganu's coastline from Pantai Rusila, Pantai Chendering, Pantai Batu Buruk, Pantai Seberang Takir, and Pantai Menggabang Telipot. The coordinate for the sites is from 5˚ 14' 40.2" N, 103˚ 11' 16.08" E to 5˚ 25' 37.2" N, 103˚ 04' 31.08" E along the shoreline in Kuala Terengganu. The Northeast Monsoon season is Malaysia's primary rainy season, especially in East Coast states. The monsoon weather system that forms together with cold air flows from Siberia produces heavy rain that often causes large floods in the East Coast states of Kelantan, Terengganu, Pahang and East Johor, as well as the state of Sarawak and Sabah in East Malaysia. In the present day, Geospatial technology, which includes Geographical Information System (GIS) and satellite Remote Sensing, is used to store, extract, analyse and map shoreline changes (Selamat et al., 2017).

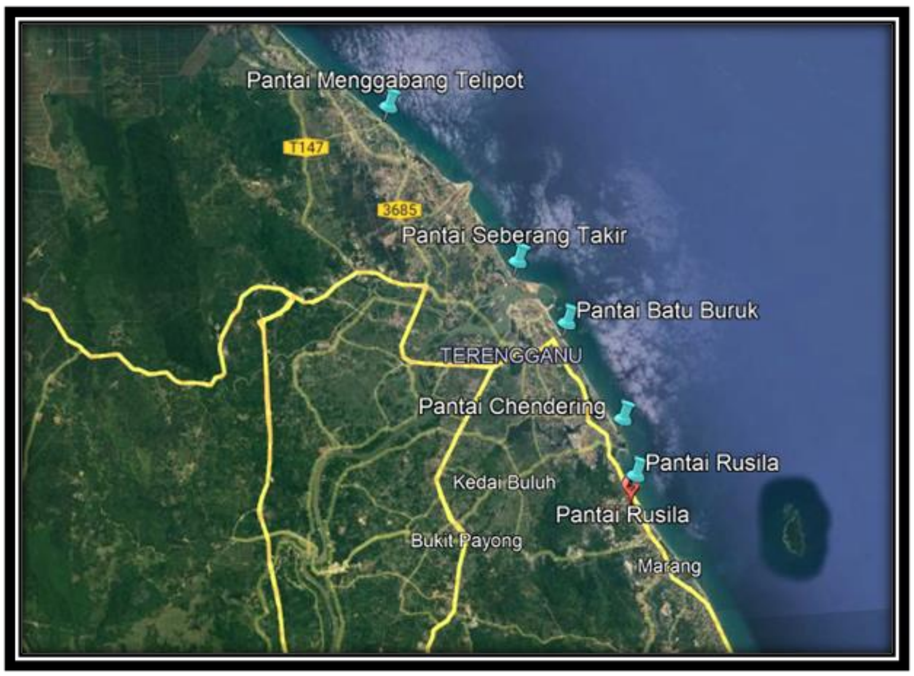


Figure 1. Study Area: Pantai Rusila to Pantai Menggabang Telipot, Terengganu

Coastlines are one of the most dynamic environments on Earth. Among the various effects of climate change, the regional rise in sea level raises the direct impact on inundation and potential habitat loss (Pramanik et al., 2020). This environment was produced by natural processes containing high-level, episodic events, for example, storm surges, flooding, storm waves, and daily modes of wind, big waves, and tidal conditions, which one of the long-term operations and drive massive risk of the shoreline that produce erosion and accretion. Vulnerability is a combination of processes originating from environmental, physical and socioeconomic parameters that increase the risk of an individual or a group to the effect of hazards (Mahendra et al., 2011; Kumpulainen, 2006). The Earth's climate cycle exhibits the sequencing and clustering of storm events and various seasonal, interannual, and decadal oscillations. The processes can be classified as superimposed on an accelerating climate change background referring to human activities. All these climate signals can consist of and produce the cycles and trends that will tend a cause shift in the plan view shape and coastline position. The understanding of this study about water quality is to maintain the water quality and facilitate the management as actions can be taken by local authorities and other government agencies to maintain and improve the water quality and create boundaries and regulations that can bring back nature (Nasir et al., 2021).

Digitising the waterline from the satellite images, deriving the boundary between the ocean and the terrestrial coverage was defined for the coastline for every one of the observation periods. Thus, for each map produced, it was possible to define a momentaneous of the coastline position. The Kuala Terengganu coastline was determined to be relatively straight, about 30 km, which refers to an orientation of about 315° and facing the South China Sea. The mean annual temperature lies in the range of 25.6–33.8 °C. The prevailing winds are south-westerly and north-easterly, showing a seasonal wind regime to the southwest and northeast monsoons. This has been carried out in many studies showing that the monsoon period refers to rainfall distribution (Ariffin et al., 2018). In Kuala Terengganu, the average high frequency of rainfall from November to March was 830 mm (METMalaysia, 2023).

2.1 Flow Chart of CVI

The CVI is intended to describe the distinctive beachfront segments' overall weakness regarding environmental change's potential impacts. McLaughlin and Cooper (2010) state that physical coastal characteristics, wave forcing, and socioeconomic factors contribute to overall vulnerability. This interaction might have different results; for instance, it can expand levels of immersion, speed up seaside disintegration, and change wave conditions. This multi-disciplinary parameter represents a diverse data type that is complex to assemble for coastal vulnerability assessment. Most of the parameters simplify to measure coast vulnerability globally. CVI will eventually assist coastal communities in mitigating coastal threats in future urban development (Hamid et al., 2019).

Therefore, it must be guided by acknowledging appropriate data to be used at a spatial resolution of interest, the geomorphology and hydrodynamics of the area concerned. The first rules of the CVI methodology, typically utilised for comparative evaluations along the seacoasts facilitating an impressive flowing reach, were reconsidered considering the litho-morphodynamical elements of this miniature flowing low-lying region. Hammar-Klose and Thieler (2001) ranked six (6) physical variables on a linear scale from 1-5 in order of increasing vulnerability due to sea-level rise. In other words, 1 represents the lowest risk, and 5 illustrates the highest risk. Chosen models were coordinated into the CVI estimation in two varieties (Figure 2). The index allows the six (6) physical variables to be related in a quantifiable manner. Once each section of the coastline is assigned a risk value based on each specific data variable, the coastal vulnerability index is calculated as the square root of the geometric mean or the square root of the product of the ranked variables divided by the total number of variables.

2.2 Data Acquisition

Data acquisition depends on the six boundaries in this investigation of the seaside weakness file (CVI): geomorphology, shoreline change rate, coastal slope, mean tide range, mean significant wave height and sea-level rise. This information is gained from distinction sources that should be gathered and interacted with using various procedures. The same area's remote sensing data with different years uses Landsat data imageries. Two boundaries were extricated from remote detecting information: geomorphology and coastline change rate for the CVI assessment. Fieldwork was done to determine whether the seaside region's geomorphology is sloppy, rough, sandy or other. Furthermore, different information that should be utilised in this study, including ocean level change, giant wave stature and tide range, got from the National Hydraulic Research Institute of

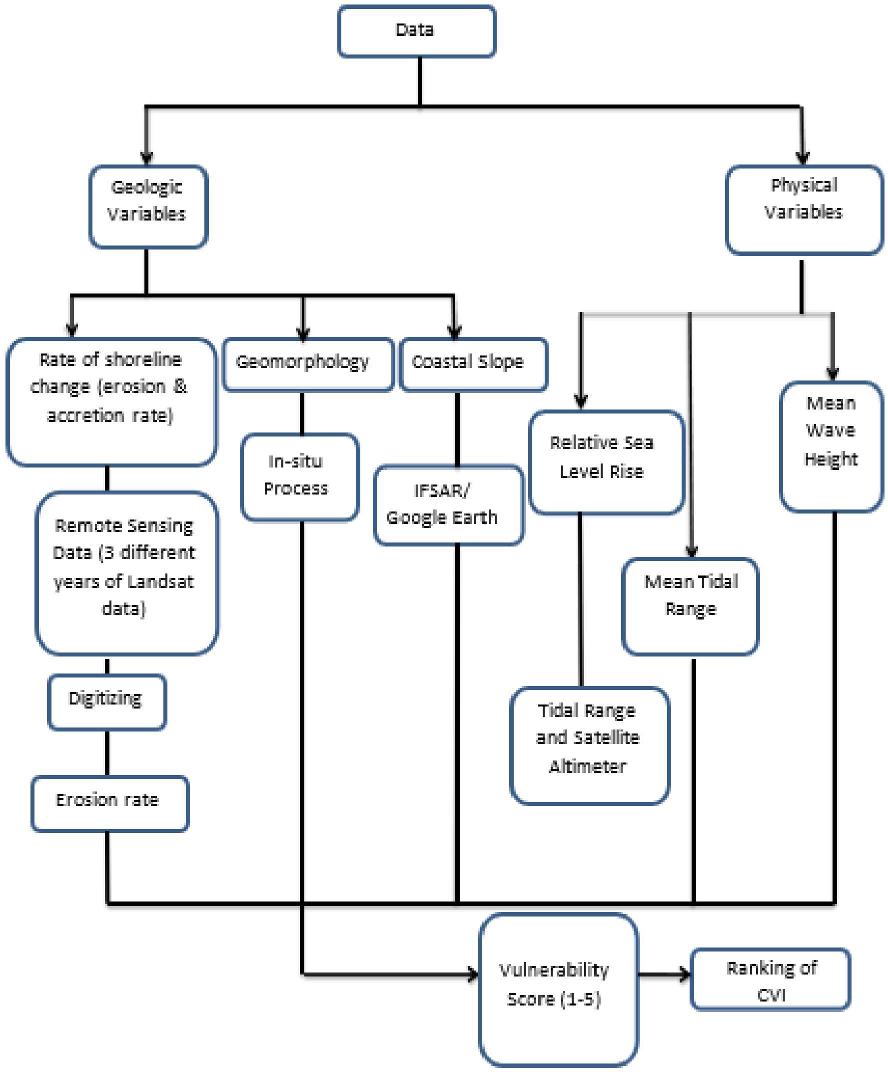


Figure 2. Flowchart of CVI ranking

Malaysia (NAHRIM). All the data obtained will be combined for the CVI value assessment used for the analysis.

2.3 Data Processing

The rate of the coastal changes the description and characteristics of landforms and surface features of a coastal area. The geomorphology variables selected will express the relative erodibility of different features and landforms in the study site. The geologic material alludes to the rock that makes up any rough bluff and wave-cut stage. This characteristic is significant as various stones show different erodibility levels. Pendleton et al. (2010) investigate CVI along the coast of the Northern Gulf of Mexico, ranking the following primary six (6) physical variables from previously published data sources (from the year 1985-2009), much like Thieler and Hammar-Klose (1999). However, the result of the coastal vulnerability index percentile at five chosen beaches relates the six (6) factors: Geomorphology, Mean Tidal Range, Sea Level Rise, Erosion, Wave Height and Coastal Slope(%). Besides, the erosion categorisation of NCES 2015 is being issued by the Department of Irrigation and Drainage (DID) Malaysia, which comprises three categories (K1, K2 and K3). Using as many variables as possible for coastal vulnerability assessment is not necessarily

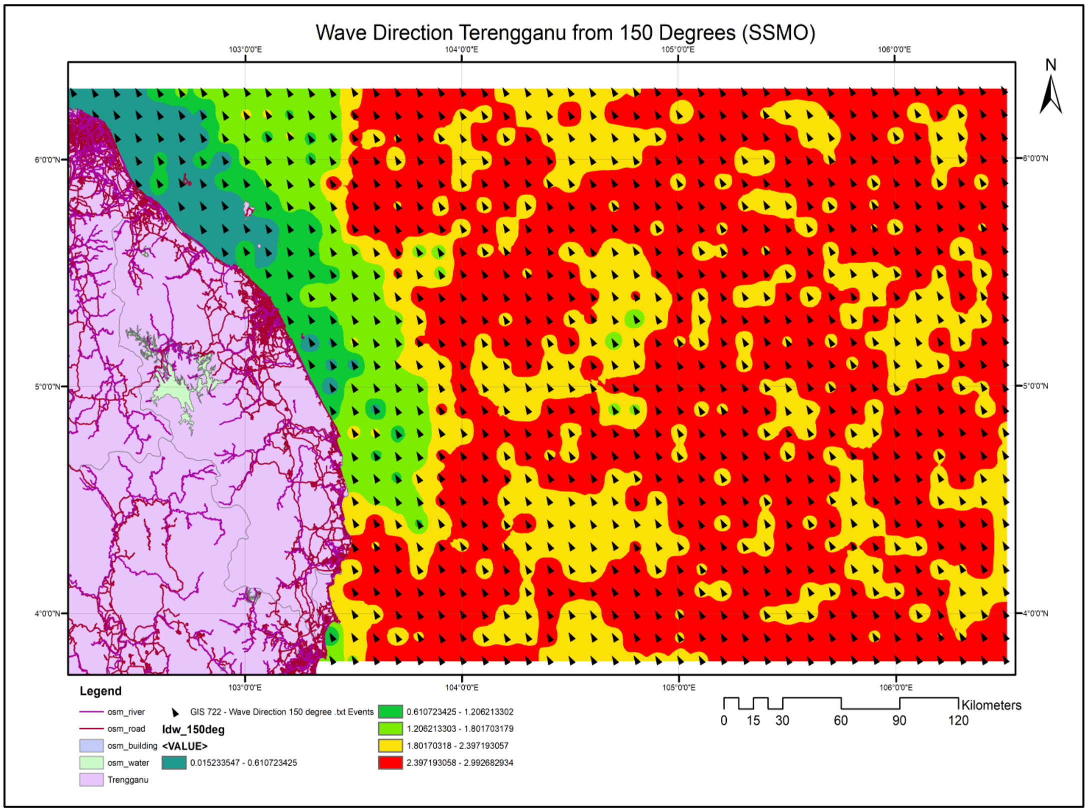


Figure 3. Wave height value based on different directions (150˚) along Kuala Terengganu

true since using many variables indicates a risky correlation among the data (McLaughlin and Cooper, 2010).

2.3.1 Geomorphology of Coastal Changes

Geomorphology is the description and characteristics of landforms and surface features of a coastal area. The geomorphology variables selected will express the relative erodibility of different features and landforms in the study site. The geologic material alludes to the rock that makes up any rough bluff and wave-cut stage. This characteristic is significant as various stones show different erodibility levels. However, Kantamaneni et al. (2018) assess coastal vulnerability by combining physical and economic indices. Solid and gigantic rocks, for example, meddling molten rocks, are more impervious to disintegration than most sedimentary rocks. Rocks that show joint shortcoming planes and bedding are more defenceless to the deterioration interaction. The geomorphology of the shoreline will be decided by going to the site, and perceptions of each area will be made. The image underneath shows a portion of the geomorphology on the Terengganu waterfront region. Socioeconomic variables tend to be cultural bias to the vulnerability index since socioeconomic variables are difficult to quantify (McLaughlin and Cooper, 2010).

2.3.2 Mean Significant Wave Height

Several directions are involved in the wave height data, which are 0°, 30°, 60°, 90°, 120°, 150°, 180°, and 330°. Microsoft Excel calculates all the mean wave heights based on the different angles. The mean wave height in every area is not the same because it will consider the natural characteristic and can be made characteristic. For example, some areas will be naturally sheltered by the archipelagic island and can be made as the breakwater. Field measurements were carried out to gather coastal data positions, which are used to determine shoreline changes (Mohd Azharn et al., 2018). Shoreline change studies have been done using remote sensing and Geographic Information System (GIS) techniques in several studies at different periods in the recent past (Din Hashmi & Ahmad, 2018). Shoreline changes in coastal areas are easily detected and computed using geospatial techniques and automatic calculations by the extended tool of ArcGIS. Further, the wave action and alongshore currents are responsible for the accretion and erosion of coasts (Nasir et al., 2019). The coast, subjected to accretion, will be considered less vulnerable than erosion trend areas as they move towards the ocean, adding land areas. Still, the erosion trend increases the risk of population exposure to coastal hazards.

2.3.3 Mean Tidal Range

With more extensive tidal ranges, storm wave attacks will likely spread out over a greater vertical range, causing less cumulative erosion (Thieler & Hammer-Klose, 1999). Tidal information obtained from the various tide stations at the respective sites was used to determine the mean tidal range and to interpret sea level changes. Tidal levels at Terengganu are defined using the empirical formula for semidiurnal harmonic constants to determine the mean tidal range at the Terengganu area. The mean value of each tidal level station is defined and calculated in Microsoft Excel. The mean tidal range for the study area at Terengganu coastal can generally be described by tidal records based on the two tide stations.

2.3.4 Relative Sea-Level Rise

Relative or observed sea level is the sea level close to the land. Relative sea level rise has a wide range of effects on coastal processes. A rise in relative sea level allows waves to break closer to the shore, increasing the load and stresses on coastal resources. Increasing water depths can also affect the progress of tides and surges.

2.3.5 Erosion in Coast

Erosion rates (m/year) of each management unit (MU) are aggregated separately because they represent different information about the physical temperament of each MU. However, it must be known that a shoreline's physicality, regardless of its rigidity or weakness, is always vulnerable to man-made threats, such as expanding urban settlements, facilities, and tourism economies.

2.3.6 CVI Ranking Value

The recognisable proof of physical variables reasonable for a specific beachfront coastal area dependent on its exceptional seaside trademark might impact the seaside weakness evaluation. Mohd et al. (2018) use the mean to distinguish actual factors appropriate for Terengganu's coast to foster CVI. Six (6) physical characteristics have been recognised to evaluate the CVI: geomorphology, seaside slant, coastline change rate, critical wave stature, flowing reach, relative ocean level rate, and land use. In Malaysia, CVI assessment is commonly regarded to assess coastal vulnerability along the coast of Malaysia. Mohamad et al. (2014) develop a CVI along the coast of Peninsular Malaysia. Identifying physical variables suitable for a specific coastal area based on its unique coastal characteristic may impact the coastal vulnerability assessment. Mohd et al. (2018) study aims to identify physical variables suitable for Pahang's coast to develop CVI. An extensive CVI was acquired by incorporating the differential weighted position upsides of the factors. Rameli & Jaafar (2018) posited that changes in coastal areas, or more precisely, the changes in the shoreline, are also strongly influenced by the effects of sea level rise as a result of global climate change.

Table 1. CVI Percentile (Mohd et al., 2018)

Category	Percentile
VERY LOW	$\leq 20^{th}$ percentile
LOW	20^{th} percentile $\leq$ CVI $\leq 40^{th}$ percentile
MODERATE	40^{th} percentile $\leq$ CVI $\leq 60^{th}$ percentile
HIGH	60^{th} percentile $\leq$ CVI $\leq 80^{th}$ percentile
VERY HIGH	$\geq 80^{th}$ percentile

3.0 Results and Discussions

This study employs the parameter database compiled by Thieler and Hammer-Klose (1999) with the alterations by DID Malaysia and Mohamad et al. (2014), considering the relative sea level of Peninsular Malaysia. The CVI index is ranked from 1 to 5 according to Table 2, based on a variable's potential contribution to physical changes on the coast. The mangrove habitats along the coastline, which help dissipate wave energy, have been destroyed, resulting in rapid coastal erosion (Ehsan et al., 2019). Since the study area is in the Peninsular Malaysian Sea, there are adjustments to the original ranking parameters in the Thieler and Hammar-Klose (1999) index. The parameters were altered according to the temperaments of Malaysia's geomorphology, relative sea level change (m/year), shoreline erosion (m/year), tidal range (m), wave height (m) and coastal slope(%). Geospatial technology is a tool that allows end users to generate, monitor, analyse and manipulate data per their needs (Ahmad et al., 2021).

Table 2. CVI equation based on five categories of vulnerability (Mohd et al., 2018)

CVI	Very Low	Low	Moderate	High	Very High
Variable	**1**	**2**	**3**	**4**	**5**
Morphology	Rocky shores, high cliffs	Cliffs of average height, sand, and rocks composite	Low cliffs, alluvial plains, sand	Shores with pebbles, clay and sand composite, lagoons	Mudflats, sandy shores
Shoreline change (m/yr)	>8.0	3.0-7.0	-1.0-3.0	-5.0- -1.0	<-5.0
Coastal slope (%)	>20	7.0-20	4.0-7.0	2.5-4	<2.5
Sea level change (m/yr)	<0.24	0.25-0.30	0.31-0.40	0.41-0.50	>0.51
Wave height (m)	<0.8	0.9-1.3	1.4-1.8	1.9-2.3	>2.4
Tidal range (m)	<0.5	0.5-1.0	1.0-1.5	1.5-2.0	>2.0

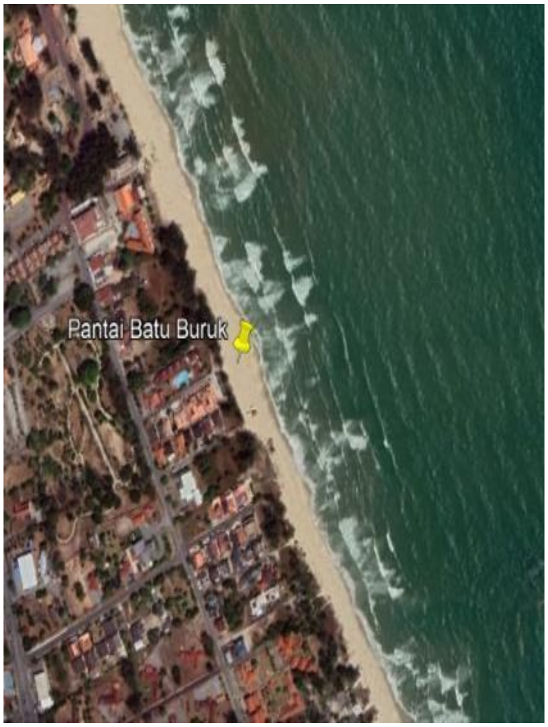
The result and analysis of this study revolve around the information on segregated management units, their geomorphology and geological materials, shoreline horizontal displacement, trends of sea level, tidal ranges, and wave heights. Their analysis will be presented either in tables or graphs.

3.1 Coastal Changes at Terengganu

As previously mentioned in the research, the dissociation between one MU to another makes the information more manageable; hence the vulnerability of different localities can be assessed. Hashim and Noor (2013) pointed out that the mangrove bands along the coastline, which dissipate wave energy, have been demolished, resulting in rapid coastal erosion. The DID refers to the MU of the location on the Terengganu coastline. The area is divided according to features on the coastline, such as rivers, ports, and others. The MU at Terengganu is divided into five sections but only focuses on MU3 and MU5. Table 3 shows the management units and their locations in the Kuala Terengganu area. Site visits were conducted on June 2022 to prove the current land use in the area. GPS and an anemometer were used to determine wind speed and mark the location coordinates. Later the data are tabulated into respected features in specific MUs.

Table 3. The Coastal Features in MUs and their locations along the Terengganu coast

Management Units (MUs)	Location
MU1  	Pantai Menggabang Telipot Coordinates: 5° 25’ 37 “N, 103° 4’ 31” E Facilities: - Masjid Mengabang Telipot Homestay - Kerabu Anak Jantan Rice Stall Temperature: 30°C (Ventusky) Date: 1 June 2022, 2.00 pm Geomorphology: Yellow – sandy coast
MU2  	Pantai Seberang Takir Coordinates: 5° 21' 3.3"N, 103°7' 57"E Facilities: - Waldan Homestay Pantai Kuala Terengganu - Klinik Desa Seberang Takir Temperature: 31°C (Ventusky) Date: 1 June 2022, 2.00 pm Geomorphology: White – sandy coast

MU3  	Pantai Batu Buruk Coordinates: 5°19’8.76"N, 103° 9’ 27"E Facilities & Activities: - Sultanah Nur Zahirah Hospital - A&W restaurant, KFC - Riding an ATV - Horseback riding & horse – drawn carriage rides Temperature: 30°C (Ventusky) Date: 1 June 2022, 2.00 pm Geomorphology: Sandy coast
MU4  	Pantai Chendering Coordinates: 5°16’18"N, 103°10’57"E Facilities: - Anis Homestay - Surau Pantai Pandak - Warung ZM Ict Temperature: 30°C (Ventusky) Date: 1 June 2022, 2.00 pm Geomorphology: Sandy coast

MU5  	Pantai Rusila Coordinates: 5°14’40"N, 103°11’16"E Facilities: - Hotel Seri Malaysia Marang - Medan Jaya Mosque Temperature: 30°C (Ventusky) Date: 1 June 2022, 2.00 pm Geomorphology: Sandy coast

3.2 CVI Mapping

From the geomorphological information of the Terengganu shoreline area, it was found that 2 out of 5 areas, MU1 and MU3, fall under moderate vulnerability. Most of the area consists of sand, which made it not so easy or difficult to be affected and caused it to be in intermediate condition. Nutrients such as nitrate, ammonia and phosphate are being used as a benchmark for indicating the water quality of estuaries and whether the water bodies can maintain their designated uses (Nasir et al., 2019). This area is less vulnerable than the landform consisting of mud flats and the composite of clay and rock. The site with moderate vulnerability also tends to be a tourist area for tourists because it has smooth sand and is suitable for leisure activities like the Pantai Batu Buruk area (Table 4).

Table 4. The geomorphology description of Kuala Terengganu coastline

No.	Location	Type Of Geomorphology	Geologic Physical	Vulnerability Index
1.	Pantai Rusila	The beach has a parallel wave movement and height. The strength of the wave is high. Most of the beach areas are not developed. Have a forested beach.	The beach sand is smooth and grey in colour. Sedimentation from the river brings silt; waves bring sand to the sea.	3
2.	Pantai Chendering	The fortress had protected the beach. There are a lot of activities.	The beach sand is a little bit smooth and rocky.	2
3.	Pantai Batu Buruk	The beach has a parallel wave movement and height. The strength of the wave is medium. The beach is polluted with animal faeces.	The beach sand is smooth and arranged in order while a little bit course at the Legend Holiday area.	3
4.	Pantai Seberang Takir	The beach is developed as a recreation area for the local and oversea tourist.	The beach has a parallel wave movement. The beach also has a rocky cliff.	1
5.	Pantai Menggabang Telipot	The beach is developed as a recreation area for local and oversea tourist.	The beach sand is a little bit smooth and rocky.	1

For the low vulnerability ranking, it has 1 out of 5 areas, Pantai Chendering. This area is known as a port area because economic and business activities take part, and normal civilians are restricted from accessing this area. The beach's possibility to erode or be affected is less since the fortress can minimise the wave impact that hits the beach (Pramanik et al., 2021). Lastly, for a very low vulnerability ranking, it has 2 out of 5 areas: Pantai Seberang Takir and Pantai Menggabang Telipot. It is poor in vulnerability because the beach has a rocky cliff. The rocky cliff is resistant to weathering and erosion and is usually formed by rock. One of the factors that help the wave's frequency to be strong is the help of wind. The stronger the wind, the stronger the wave in the area.

Table 5 below is the final CVI inventory that summarises the CVI scoring and vulnerability category of each MU at the Terengganu coastal area. After all the management units were segmented according to their vulnerability ranksfor each specific variable, the coastal vulnerability index (CVI) for each area unit was calculated by using the CVI formula (Equation 1) below (Mohd et al., 2018).

$$Coastal\ Vulnerability\ Index\ (CVI) = \sqrt{\frac{a * b * c * d * e * f}{6}}$$

(Equation 1)

where,

a: geomorphology factor

b: rate of erosion (m/year)

c: coastal slope (%)

d: rate of relative sea level rise

e: mean significant wave height

f: mean tidal range

To determine the CVI categories for all units, their CVI scores were then implemented into percentile values from statistical analysis (Table 1). They were then divided into quartile ranges for the five vulnerability categories (Mohd et al., 2018). Table 5 is the final CVI inventory summarising each MU's CVI scoring and vulnerability category at the Kuala Terengganu coastal area.

Table 5. The result of CVI at Kuala Terengganu

PVI		PARAMETER						RANKING OF CVI	PERCENTILE OF CVI	CATEGORY
	LOCATION	GEOMORPHOLOGY	MEAN TIDAL RANGE	RATE OF SLR	RATE OF EROSION AND ACCREATION	HEIGHT WAVE	COASTAL SLOPE			
1	Pantai Rusila	3	2	3	4	2	4	9.798	19.444	HIGH
2	Pantai Chendering	2	2	3	5	2	3	7.746	19.444	HIGH
3	Pantai Batu Buruk	3	2	3	5	3	3	11.619	25.000	VERY HIGH
4	Pantai Seberang Takir	1	2	3	5	2	3	5.477	22.222	HIGH
5	Pantai Menggabang Telipot	1	2	3	5	2	3	5.477	25.000	VERY HIGH

Using the ArcMap, the map of CVI was generated (Figure 4). The map displayed all the parameters involved in the CVI process and the result of the CVI according to the MU area to know which tends to have a low or high score of CVI. The map can also be used as a reference for the authority for coastal management.

3.3 NCES 2015 Coastal Erosion Categorization

Individuals generally witness seaside disintegration because of human activities. It is because it is continuously found in the broad communications or before one's own eyes that people do exercises that can dissolve the coast, for example, digging exercises, ocean recovery, ocean sand mining, deforestation of mangrove marshes and development that disturb the equilibrium of waterfront structures. Notwithstanding, waterfront disintegration happens because of nature. For instance, the inescapable regular activity between powers of nature that connect on the coast like waves, wind, flows, and tides. Terengganu turns into the review region to examine the coastline changes given the NCES 2015 for five beaches or Management Unit (MU).

Based on economic and physical scores, physical parameters were used to analyse the differences that occurred on the shoreline in five coastal areas of Terengganu by erosion category. Table 6 shows the scoring of physical parameters based on NCES 2015 in five coastal areas based on a type of satellite data, namely Landsat 8/9.

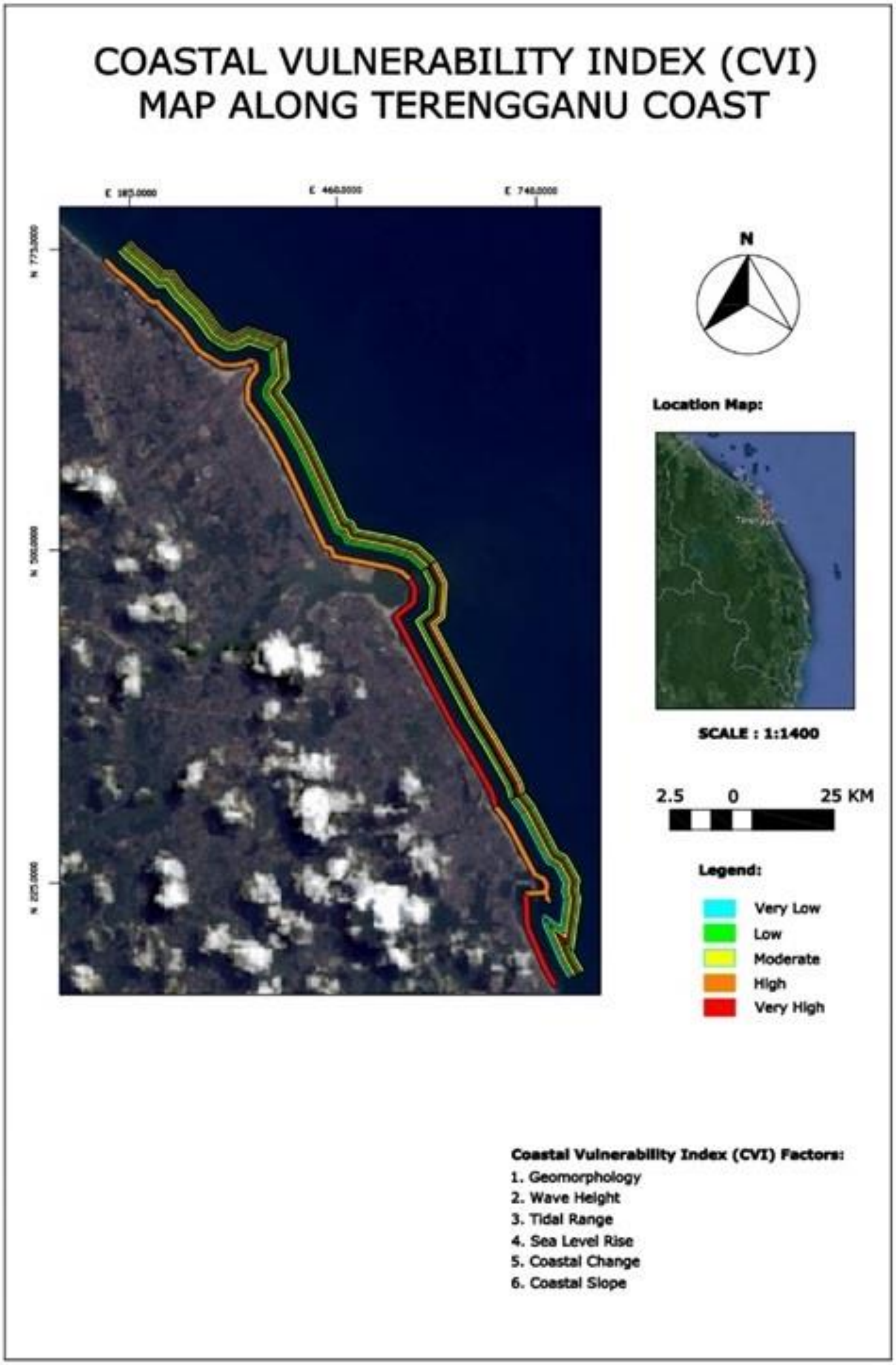


Figure 4. CVI Map Along Terengganu Coast

Table 6. The rate of the physical and economic score by using Landsat 8/9

Management Unit (MU)	Length	Erosion Rate	Physical Erosion Score	Land Use	Buildings	Utilities	Facilities	Economic Score	Total Score	Description Category
1	3557.88	6.79	5	3	3	3	2	2.8	14.00	K1 (Critical)
		9.67	5	3	3	3	4	3.2	16.00	K1 (Critical)
		2.37	3	3	3	3	4	3.2	9.60	K2 (Significant)
2	4000.83	2.45	3	2	4	4	4	3.8	11.40	K2 (Significant)
		11.38	5	3	4	4	3	3.6	18.00	K1 (Critical)
		1.45	2	1	1	4	3	2.3	4.60	K2 (Significant)
3	3842.82	0.41	1	4	3	4	3	3.4	3.40	K3 (Acceptable)
		0.86	1	3	3	4	4	3.5	3.50	K3 (Acceptable)
		1.61	2	3	4	3	4	3.6	7.20	K2 (Significant)
4	5228.59	5.757	5	3	2	3	1	2.2	11.00	K1 (Critical)
		6.016	5	3	2	3	1	2.2	11.00	K1 (Critical)
		0.666	1	1	1	1	1	1.0	1.00	K3 (Acceptable)
		2.439	3	2	1	1	1	1.1	3.30	K2 (Significant)
5	6725.30	0.517	1	3	2	2	2	2.1	2.10	K3 (Acceptable)
		1.889	2	3	2	2	2	2.1	4.20	K2 (Significant)
		3.458	4	3	3	3	2	2.8	11.20	K2 (Significant)
		5.738	5	4	4	4	3	3.8	19.00	K1 (Critical)
		1.845	2	3	3	3	2	2.1	4.20	K3 (Acceptable)
		3.564	4	3	3	3	2	2.8	11.20	K2 (Significant)
		0.687	1	3	2	3	2	2.4	2.40	K3 (Acceptable)
		2.235	3	3	2	3	2	2.4	7.20	K2 (Significant)
		2.546	3	3	3	3	2	2.4	7.20	K2 (Significant)
		4.243	5	3	3	3	3	3.0	15.00	K1 (Critical)
		0.801	1	3	3	3	2	2.8	2.80	K3 (Acceptable)
		1.567	2	3	3	3	2	2.8	5.60	K2 (Significant)
		5.751	5	4	4	4	3	3.8	19.00	K1 (Critical)

4.0 Conclusion and Recommendations

The CVI study shows that the Terengganu coastal area is mainly exposed to the high coastal vulnerability index score ranking. The awareness of sea level rise is essential to overcome the natural phenomena that will cause loss of life, change of ecosystem, loss of work and others. This also can assist or be a reference for the department or agency responsible for managing, planning and maintaining the coastal environment to be consistent and in good condition.

In this study, the geomorphology rates for Pantai Rusila, Pantai Chendering, Pantai Batu Buruk, Pantai Seberang Takir and Pantai Menggabang Telipot at Terengganu for the years 2013, 2017, 2021 have been determined. The coastal erosion has been quantified using the Coastal Vulnerability Index (CVI) technique for Pantai Rusila, Pantai Chendering, Pantai Batu Buruk, Pantai Seberang Takir and Pantai Menggabang Telipot at Terengganu for the years of 2013, 2017, 2021. The northern area of the Terengganu coast is more likely to be exposed to the high-ranking score of CVI due to its location near the Terengganu coastal area.

The coastal vulnerability index (CVI) assessment can be improved by adding the social, economic and other components that can make the result more beneficial for coastal management planning and give awareness to the public about the importance of preserving the coastal environment. The satellite image data can also be improved by using the WorldView or GeoEye satellites with a very high spatial resolution of 0.46 m and DEM data from Lidar observations which can map terrain at 0.3 m resolution. Furthermore, the CVI assessment can be implemented by using both Unmanned Aerial Vehicle (UAV) and satellite images so that a comparison of the best output and techniques can be conducted.

Acknowledgement

We want to express our sincere gratitude to all the individuals and organisations that have contributed to the publication of this research paper.

References

Ahmad, H., Maulud, K. N. A., Karim, O. A., & Mohd, F. A. (2021). Assessment of erosion and hazard in the coastal areas of Selangor. *Geogr. Malays. J. Soc. Space*, *17*, 14-30.

Ariffin, E.H. Effect of MonsoonsonBeachMorphodynamicsintheEastCoastofPeninsularMalaysia. UniversiteBretagneLoire, France. 2017. Available online: https://www.researchgate.net/publication/320563984_Effect_of_Monsoons_on_Beach_Morphodynamics_in_the_East_Coast_of_Peninsular_Malaysia_Examples_from_Kuala_Terengganu_coast

Bagheri, M., Zaiton Ibrahim, Z., Bin Mansor, S., Abd Manaf, L., Badarulzaman, N., & Vaghefi, N. (2019). Shoreline change analysis and erosion prediction using historical data of Kuala Terengganu, Malaysia. Environmental Earth Sciences, 78(15). https://doi.org/10.1007/s12665-019-8459-x

Din Hashmi, S. G. M., & Ahmad, S. R. (2018). GIS-Based analysis and modeling of coastline erosion and accretion along the coast of Sindh Pakistan. Journal of Coastal Zone Management, 21(1), 1–7. https://doi.org/10.4172/2473-3350.1000455

Din, A. H. M., Zulkifli, N. A., Hamden, M. H., & Aris, W. A. W. 2019. Sea level trend over Malaysian seas from multi mission satellite altimetry and vertical land motion corrected tidal data. Advances in Space Research, 63(11), 3452–3472.

https://doi.org/10.1016/j.asr.2019.02.022

Ehsan, S., Ara Begum, R., Ghani Md Nor, N., & Nizam Abdul Maulud, K. (2019). Current and potential impacts of sea level rise in the coastal areas of Malaysia. IOP Conference Series: Earth and Environmental Science, 228(1). https://doi.org/10.1088/1755-1315/228/1/012023

Hamid, A. I. A., Din, A. H. M., Yusof, N., Abdullah, N. M., Omar, A. H., & Abdul Khanan, M. F. (2019). COASTAL VULNERABILITY INDEX DEVELOPMENT: A REVIEW. International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences.

Hammar-Klose, E. S. and Thieler, E. R., 2001. Coastal vulnerability to sea-level rise: a preliminary database for the US Atlantic, Pacific and Gulf of Mexico coasts. US Geological Survey, Coastal and Marine Geology https://pubs.usgs.gov/dds/dds68/htmldocs/project.htm

Hashim, A. M., & Noor, N. D. M. (2013). Performance evaluation of innovative concrete armor unit for coastal protection structure. BEIAC 2013 - 2013 IEEE Business Engineering and Industrial Applications Colloquium, 673–678. https://doi.org/10.1109/BEIAC.2013.6560215

Hashim, A. M., & Noor, N. D. M. (2013). Performance evaluation of innovative concrete armor unit for coastal protection structure. BEIAC 2013 - 2013 IEEE Business Engineering and Industrial Applications Colloquium, 673–678. https://doi.org/10.1109/BEIAC.2013.6560215

JPBD, 2012. Garis Panduan Perancangan Pemuliharaan dan Pembangunan KSAS – Kawasan Persisiran Pantai. Kuala Lumpur: Jabatan Perancangan Bandar dan Desa Semenanjung Malaysia.

Kantamaneni, K., Phillips, M., Thomas, T., & Jenkins, R. 2018. Assessing coastal vulnerability: Development of a combined physical and economic index. Ocean and Coastal Management, 158 (April 2017), http://doi.org/10.1016/j.ocecoaman.2018.03.039

Kumpulainen, S. (2006). Vulnerability concepts in hazard and risk assessment. Natural and technologi cal hazards and risks affecting the spatial development of European Regions. Geological Survey of Finland, Special Paper, 42, 65–74.

Mahendra, R. S., Mohanty, P. C., Bisoyi, H., Kumar, T. S., & Nayak, S. (2011). Assessment and management of coastal multi-hazard vulnerability along the Cuddalore–Villupuram, East Coast of India using geospatial techniques. Ocean and Coastal Management, 54, 302–311.

https://doi.org/10.1016/j.oceco aman.2010.12.008.

Malaysian Meteorological Department (2023). Weather Phenomenon in Malaysia, Monsoon by Ministry of Natural Resources, Environment & Climate Change. METMalaysia - Weather Phenomena

McLaughlin, S. and Cooper, J. A. G., 2010. A multi-scale coastal vulnerability index: A tool for coastal managers? Environmental Hazards 9 (2010) Page no. 233-248.

Mohamad, M. F., Lee, L. H., Kamarul, M., & Samion, H., 2014. Coastal Vulnerability Assessment Towards Sustainable Management of Peninsular Malaysia Coastline, 5(6). http://doi.org/10.7763/IJESD.2014.V5.540

Mohamed Rashidi, A. H., Jamal, M. H., Hassan, M. Z., Mohd Sendek, S. S., Mohd Sopie, S. L., & Abd Hamid, M. R. (2021). Coastal structures as beach erosion control and sea level rise adaptation in Malaysia: A review. Water, 13(13), 1741.

Mohd Azharn, M., Nizam Abdul Maulud, K., Norsakinah Selamat, S., Firoz Khan, M., Jaafar, O., Shafrina Wan Mohd Jaafar, W., Mastura Syed Abdullah, S., Ekhwan Toriman, M., Khairul Amri Kamarudin, M., Barzani Gasim, M., & Juahir, H. (2018). Impact of Shoreline changes to the coastal development. International Journal of Engineering & Technology, 7(3.14), 191. https://doi.org/10.14419/ijet.v7i3.14.16883

Mohd, F. A., Abdul Maulud, K. N., Karim, O. A., Begum, R. A., Awang, N. A., Ahmad, A., Wan Mohamed Azhary, W. A. H., Kamarudin, M. K. A., Jaafar, M., & Wan Mohtar, W. H. M. (2019). Comprehensive coastal vulnerability assessment and adaptation for Cherating-Pekan coast, Pahang, Malaysia. Ocean and Coastal Management, 182(February). https://doi.org/10.1016/j.ocecoaman.2019.104948

Nasir, F. A. M., Suratman, S., & Le, D. Q. (2019). Distribution and Behavior of Nutrients in Besut River Estuary, Terengganu, Malaysian Journal https://doi.org/10.17576/mjas-2019-2306-15.

Nasir, N. A. M., & Yaakub, N. (2021). Study on Marine Water Quality Parameters in Keluang Kecil River Estuary at Bukit Keluang, Terengganu. *Journal Of Agrobiotechnology*, *12*(1S), 140-149.

National Coastal Erosion Study. (2016). Jabatan Pengairan dan Saliran. Seminar Pemumian. Februari 2016.

Pendleton, B. E. A., Barras, J. A., Williams, S. J., Twichell, D. C., & Survey, U. S. G. (2010). Coastal Vulnerability Assessment of the Northern Gulf of Mexico to Sea-Level Rise and

Coastal Change.

Pramanik, M. K., Dash, P., & Behal, D. (2021). Improving outcomes for socioeconomic variables with coastal vulnerability index under significant sea-level rise: an approach from Mumbai coasts. Environment, Development and Sustainability, 1-35.

Pramanik, M., Diwakar, A., Dash, P., Szabo, S., & Pal, I. (2020). Conservation planning of cash crops species (Garcinia gummi-gutta) under current and future climate in the Western Ghats India. Environment, Development and Sustainability. https://doi.org/10.1007/s10668-020-00819-6.

Prasad, D.H.; Kumar, N.D. Coastal Erosion Studies—A Review. Int. J. Geosci. 2014, 5, 341–345.

Rameli, N. L. F., & Jaafar, M. (2018). Detecting coastline changes use GIS geospatial techniques in Island Carey- Morib Coast, Selangor, Malaysia. International Journal of the Malay World and Civilisation (Jurnal Antarabangsa Alam Dan Tamadun Melayu), 6(2), 17–22.

Selamat, S. N., Abdul Maulud, K. N., Jaafar, O., & Ahmad, H. (2017). Extraction of shoreline changes in Selangor coastal area using GIS and remote sensing techniques. Journal of Physics: Conference Series, 852(1). https://doi.org/10.1088/1742-6596/852/1/012031

Thieler, E.R., and Hammar-Klose, E.S., 1999, National assessment of coastal vulnerability to future sea-level rise: Preliminary results for the U.S. Atlantic Coast: U.S. Geological Survey, Open-File Report 99-593, 1 sheet, accessed at: http://pubs.usgs.gov/of/1999/of99-593/.

Wong, P.P. Where have all the beaches gone? Singap. J. Trop. Geogr. 2003, 24, 111–132.

Yanalagaran, R., & Ramli, N. I. (2018). Assessment of coastal erosion related to wind characteristics in peninsular Malaysia. Journal of Engineering Science and Technology, 13(11), 3677–3690.