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Research Article

Analysis of coastal vulnerability of Rangsang Island due to climate changes

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Abstract: Rangsang Island is home to more than 48,000 residents. Climate change has been a critical issue to the Island and threatened the existence of the inhabitants. This study is proposed to identify the zone of the coastal area of Rangsang Island which is vulnerable to climate change. By mapping coastal vulnerability index (CVI) of the island, it is expected to be a reference of local government in planning their spatial management. The method of this study was by a direct survey for collecting data of geomorphology, beach elevation, sea level rise, tidal fluctuation, significant wave height, and changes in the coastline. To determine CVI, each parameter is divided into 5 categories and given a value level: 1 for very not vulnerable, 2 for not vulnerable, 3 for moderate, 4 for vulnerable, and 5 for very vulnerable. The results show that most villages on the island are classified as highly vulnerable to climate change, namely 9 villages. Even 2 villages are threatened very high risk because the village has CVI more than 12.5. Only 6 villages whose territory has moderate vulnerability index. Vulnerability level of coastal Rangsang Island is strongly influenced by geomorphological variable and coastal elevation. In addition, the variable coastline changes and sea level rise also contributed to the vulnerability index of the Island.

Keywords: *climate changes, coastal vulnerability index, geomorphology, Rangsang Island*

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Introduction

The impact of climate change on human life almost covers all aspects of human life and the environment. Climate change can trigger a number of natural hazards in the marine and coastal ecosystem. Working Group I of the Intergovernmental Panel on Climate Change (WG1IPCC) have been identified and reviewed climate change effects as follows: 1) rising of seawater temperature, 2) increasing in frequency and intensity of number of extreme weathers, 3) changes in the pattern of natural climate variability which creates further danger in the form of changes in rainfall patterns, river flows, winds and ocean currents, and 4) sea level rise (Hadad, 2010).

Rangsang Island is one of a habitable island in the Meranti Islands Regency, Riau Province, which is directly facing the Malacca Strait waters. The coastline of Rangsang Island has a significant role and inseparable part of national sovereignty because the boundaries of the Country's waters are measured based on the island position. The Island is home for more than 48,000 people (BPS, 2018). Most of the residents occupied north coast of the island.

Various methods of assessing coastal vulnerability can be conducted with an index-based approach. One of the common methods to assess the level of physical vulnerability caused by climate change is Coastal Vulnerability Index (CVI) method (Ramieri et al., 2011). This method is robust to obtain the empirical character of the coast and give a map of the vulnerable zone to prevent natural disaster due to climate change (Kumar et al., 2010; Kumar and Kunte, 2012).

This research was proposed to determine the zone of the coastal area of Rangsang Island which is susceptible to climate change, especially in the north region which is the centered of the population activities. Zoning of the CVI of Rangsang Island is expected to be a reference in the spatial plan for managing coastal areas in Riau Province.

Materials and Methods

This research was carried out on the northern coast of Rangsang Island in Kepulauan Meranti Regency, Riau Province (Figure 1) using data on sea level rise trends from 1993 to 2018, Landsat image data in 1998 and 2018, land use data, significant wave height from 1998 to 2018, average tidal range from 1998 to 2018 and Digital Elevation Model (DEM) of Rangsang Island. Data analysis was processed by using various GIS software to obtain the model of CVI. The visualization technique of coastal vulnerability was applied along the coast of Rangsang Island by dividing the location into several cells and by buffering 1 km to the sea and 1 km to the land. It will keep the area model from erroneous simulation (Nash and Hartnett, 2014). Then, the buffer was cut based on village administration boundary to produce several polygons of cell data. This cell will be used to visualize the results of the CVI of Rangsang Island.

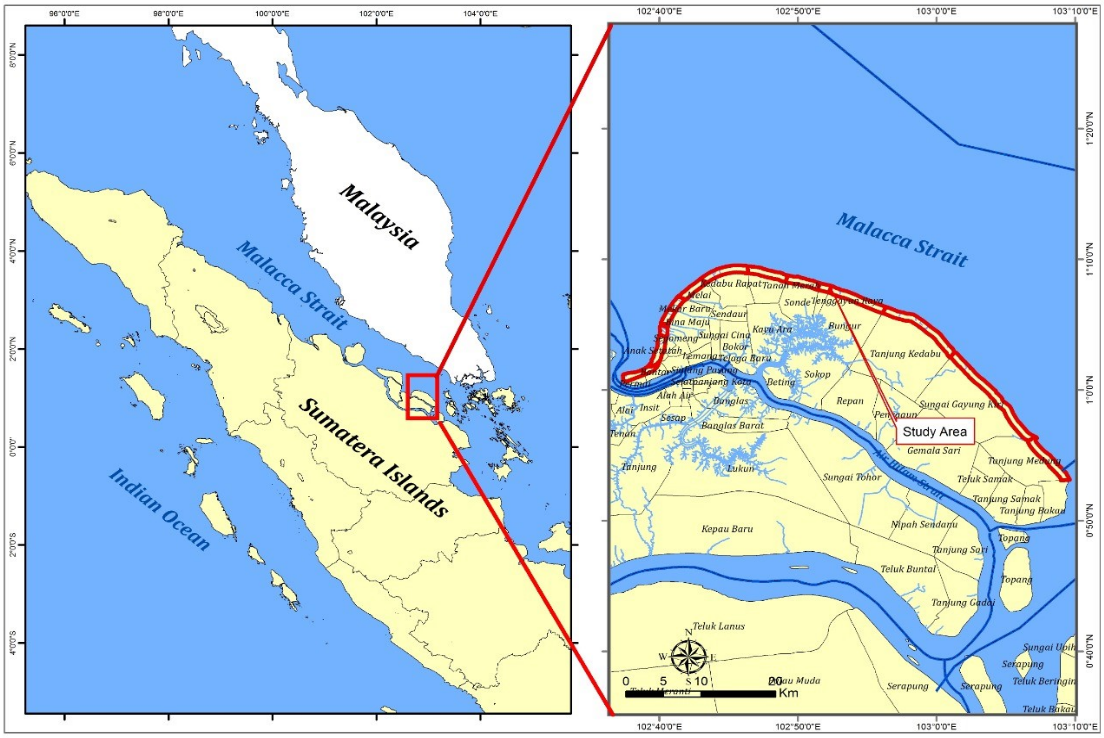


Figure 1. Research Location.

Assessing the vulnerability with the CVI matrix is based on the parameters influencing the vulnerable conditions of the coast, due to climate change. The matrix uses six parameters for the assessment as shown in Table 1.

According to Gornitz (1991) and Thieler and Hammar-Klose (1999), calculation of the vulnerability index is obtained through multiplying each variable and divided them by the number of variables, and then take a square root preceded calculation as shown below:

$$CVI = \sqrt{\frac{a \times b \times c \times d \times e \times f}{6}}$$

where $a, b, c, d, e,$ and f are geomorphology, beach elevation, sea level rise, tidal fluctuation, significant wave height, and changes in coastline respectively. The classification of coastal vulnerabilities ranks were divided into five categories as given in Table 2.

Table 1. Variable of coastal risk.

Variable	Vulnerability Rank				
	Very Low 1	Low 2	Moderate 3	High 4	Very high risk 5
Geomorphology	Rocky, cliffed Coasts, Fiords, Fiards	Medium Cliff, Indented coasts	Low cliffs, Glacial drift, Salt marsh, Coral Reefs, Mangrove	Beaches, Estuary, Lagoon, Alluvial plains	Urban residence, Barrier beaches, Beaches (sand), Mudflats, Deltas
Relief/elevation (m)	≥30.1	20.1—30.0	10.1—20.0	5.1—10.0	0—5.0
Shoreline displacement(m/tahun)	≥2.1	2.0—1.0	-1.0—+1.0	-1.0 — -2.0	≤-2.0
Tidal range (m)	≤0.99	1.0—1.9	2.0—4.0	4.1—6.0	≥6.1
Wave height (m)	0-2.9	3.0—4.9	5.0—5.9	6.0—6.9	≥7.0
Relative sea level (mm/year)	≤-1.1	-1.0—0.99	1.0—2.0	2.1—4.0	≥4.1

Source: Gornitz (1991).

Table 2. CVI categories.

CVI value	Rank
<3.5	Very low
>3.5-5.5	Low
>5.5-8.5	Moderate
>8.5-12.5	High
>12.5	Very high risk

Results and Discussion

Geography of Rangsang Island

Rangsang Island is one of the administrative regions of Kepulauan Meranti Regency in Indonesia. Rangsang Island has an area of 913.16 km² which consists of three sub-districts, namely Rangsang District, West Rangsang District, and Rangsang Pesisir District. Relief of the island is dominated by a slope of 0 - 3%, with an average height of about 1-6.4 m above sea level. The climate in Rangsang Island generally has maximum air temperatures ranging from 25-32°C. Dry season happens between February and August and wet season falls from September to January. Average rainfall in 2017 ranges from 16 - 70 mm per year.

Wind movement

In general, the movements of the wind are relatively low in the research locations. The highest wind speed was 5.8 knots (2.9 m/s) which was recorded in January and the lowest was 3.8 knots (1.9 m/s). During the West Season (West Muson), most winds are usually from the North and Northeast, while the East Muson is dominated by winds blowing from the South and East as shown from the wind pattern in Figure 2.

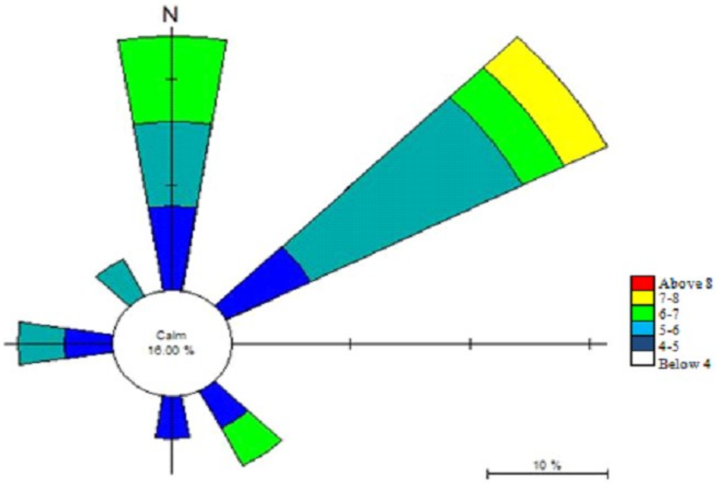
Tidal fluctuation

The water tides of Riau Province are mainly influenced by tidal conditions in the waters of the Malacca Strait. The tidal propagation to the Malacca Strait originates at the Andaman Sea from the Northeast and the South China Sea from the Southeast (Wrytki, 1961 and Pariwono, 1989). The tides from the Andaman Sea is usually a semidiurnal tidal type while mixed type comes from the South-eastern part of the Malacca Strait. The tidal waves coming from the Andaman Sea first propagate to the Malacca Strait compared to the propagation from the South China Sea.

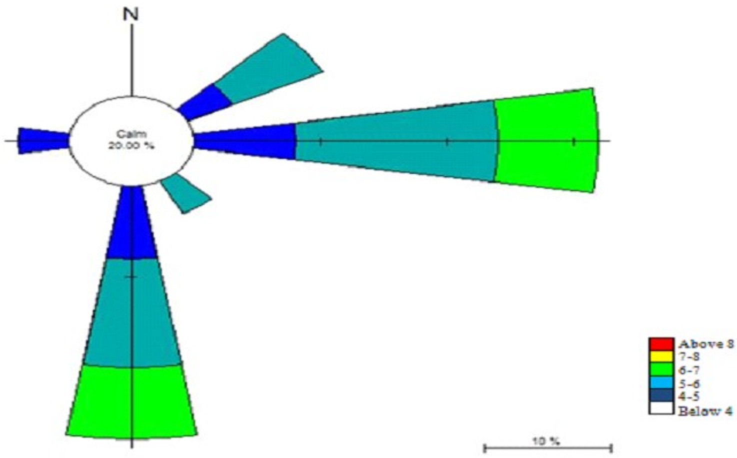
The tidal range in Rangsang Island is around 0.9 - 3.7m. The tidal type on the coast of Rangsang Island and its surroundings tends to a double daily tide, i.e. twice high and low tides with different heights. This tide will have an influence on local environmental conditions. Where at low tide, the depth will be low and vice versa.

Wave propagation

The main driver of waves at sea is the wind, so that wave conditions are very dependent on local wind conditions (Purba and Pranowo, 2015). In the Malacca Strait, the waves were physically influenced mostly by the Indian Ocean rather than of South China Sea. This is because the gap that connects the Malacca Strait with the Indian Ocean is wider than the gap that connects to the South China Sea. The wave height in the study location is relatively ranged from 0 to 0.50 m (Figures 4 and 5).



West season



East season

Figure 2. Windrose in the west and east season.
(Source: Sta. Met. Kelas I Sultan Syarif Kasim II – Pekanbaru).

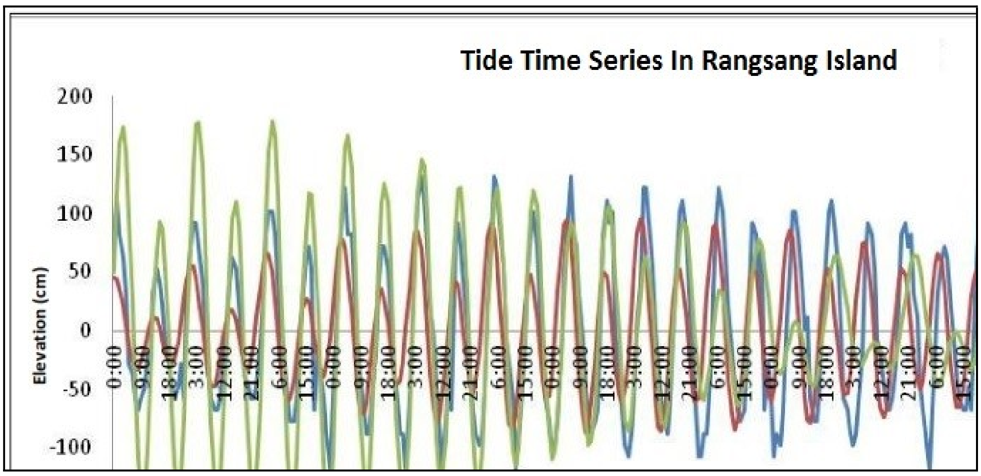


Figure 3. Pattern of tidal range in the area.

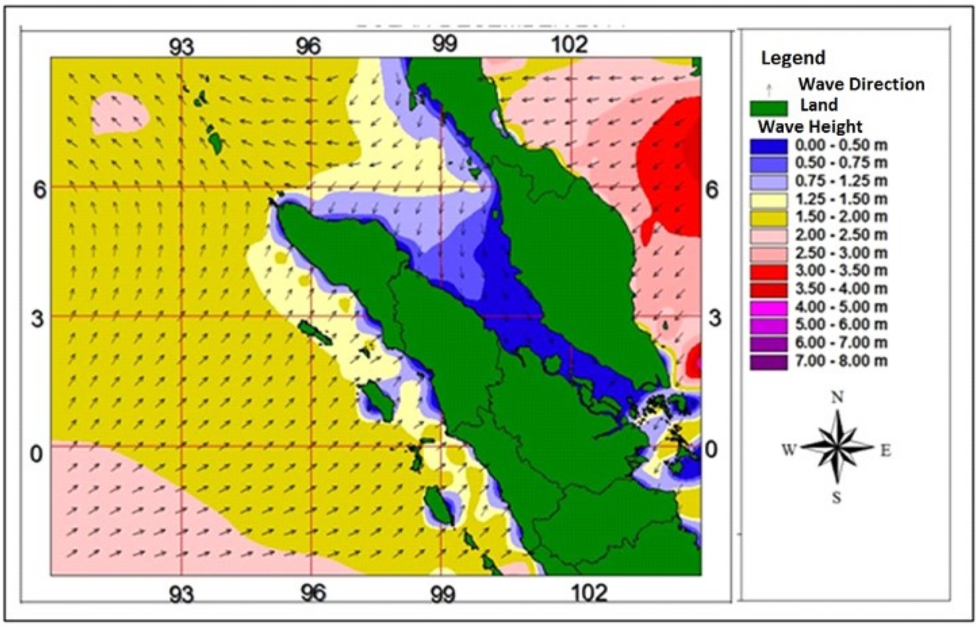


Figure 4. Direction and wave high in west season.

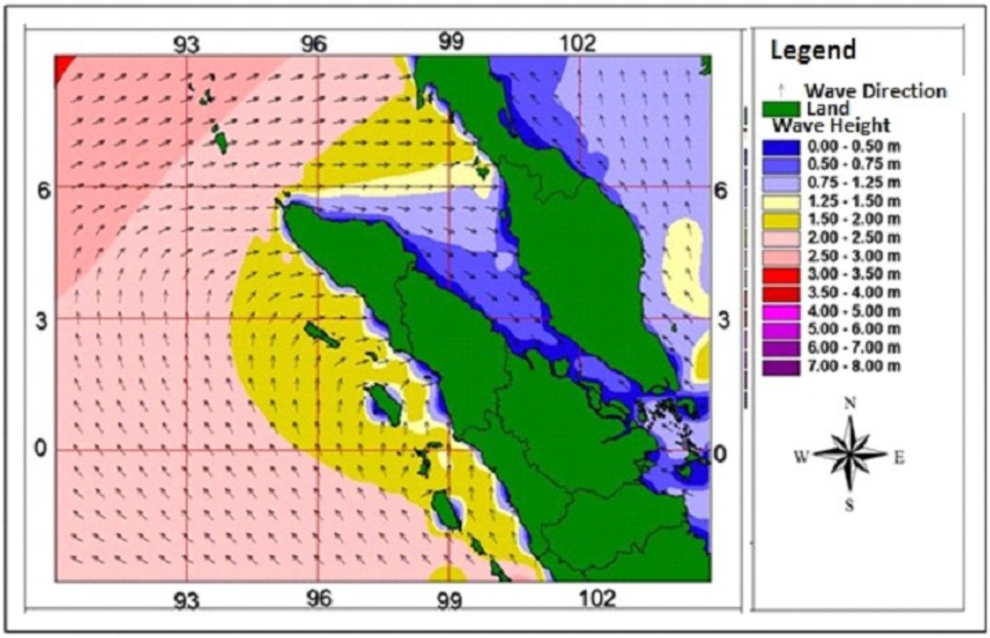


Figure 5. Direction and wave high in east season.

Ocean current

Indonesian waters are generally influenced by monsoons which will experience twice a year reversely (Wyrtky, 1961). Based on the surface flow data obtained from PODAAC (2018), it is known that the average current velocity in the waters of Malacca Strait or East of Riau Province ranges from 0.50 to 1.70 m / sec when west season (Figure 6), and 0.50 to 2.90 m / sec at east season (Figure 7).

The pattern of ocean currents movement in 2018 can be said that the movement of surface ocean currents in west season generally flows from the South China Sea to Indonesian waters. This is because the wind direction in the Indonesian region generally comes from the west (west season wind). The current velocity from the

Malacca Strait in the eastern season is increasing to 2.90 m / s which continuously moves out towards the South China Sea. The mainstream that moves in the east season has a higher rate when compared to the west season as reporter by Gordon and Susanto (2003) and Sprintall et al. (2009) that the highest transport rate occurs in the eastern season (June-August), while the lowest trajectory occurs in the western season (December-February).

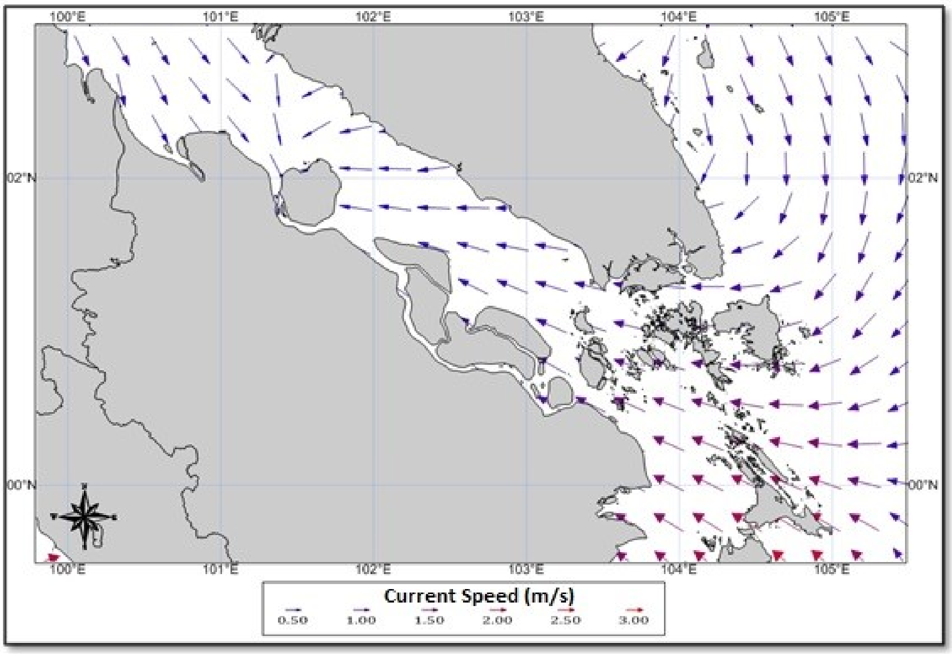


Figure 6. Current speed in west season.

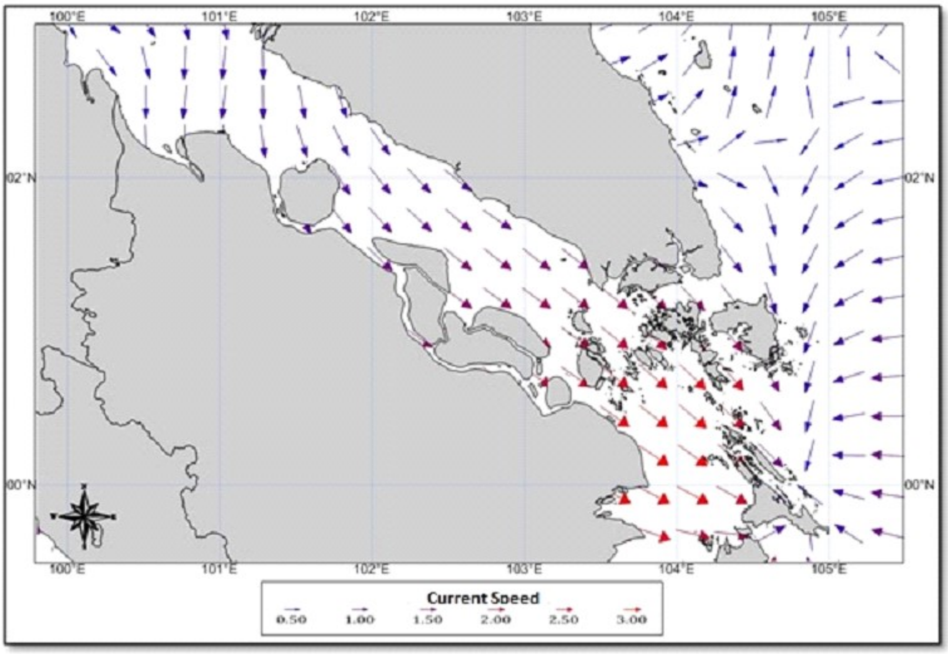


Figure 7. Current speed in east season.

Ocean current

Considering the results from the calculation of Coastal Vulnerability Index for each parameter, a coastal vulnerability class was obtained for each parameter, as shown in Table 2. Upon careful evaluation of the physical variables in the coastal area of Pulau Rangsang, the following three levels of vulnerability were obtained, namely moderate, vulnerable and very vulnerable. The areas with moderate level are villages of Segomeng, Bina Maju, Mekar Baru, Melai and Kedabu Rapat. Coastal zone of these villages had CVI within the range of 5.5 to 8.5. The most influential vulnerability variables in these five villages are beach elevation, coastal geomorphology and rise in sea level.

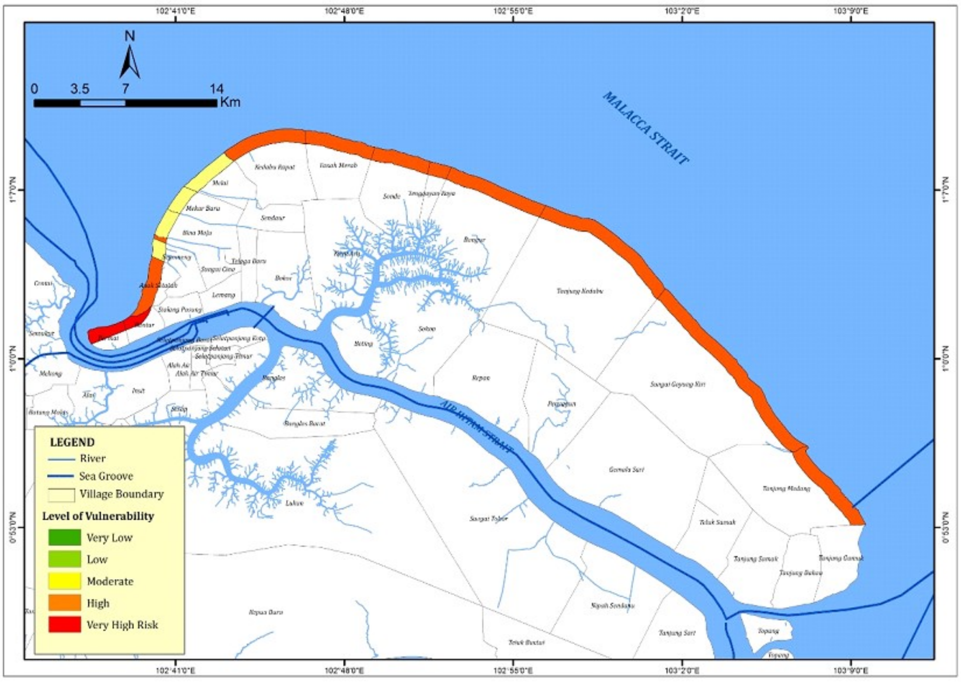


Figure 8. Map of CVI of Rangsang Island.

Table 3. Physical variable values and CVI of villages on the coast of Rangsang Island.

Village	CL	CE	WH	SLR	TF	GM	CVI
Permai	5	4	1	4	3	5	14.14
Bantar	5	5	1	4	3	4	14.14
Anak Setatah	3	4	1	4	3	5	10.95
Segomeng	1	5	1	4	3	5	7.07
Sungai Cina	3	4	1	4	3	5	10.95
Bina Maju	1	5	1	4	3	5	7.07
Mekar Baru	1	5	1	4	3	5	7.07
Melai	1	5	1	3	3	5	6.12
Kedabu Rapat	3	4	1	3	3	4	8.49
Tanah Merah	5	4	1	3	3	4	10.95
Sonde	5	4	1	3	3	4	10.95
Tenggayun Raya	5	5	1	3	3	4	12.25
Bungur	4	5	1	3	3	4	10.95
Tanjung Kedabu	3	5	1	3	3	5	10.61
Sungai Gayung Kiri	5	5	1	3	3	4	12.25
Tanjung Medang	5	4	1	3	3	5	12.25

Note: CL: Coastline, CE: Coastal elevation, WH: Significant wave height, SLR: Sea level rise, TF: Tidal fluctuation, GM: Geomorphology, CVI: *Coastal Vulnerability Index.*

Regions with a high level of vulnerability include Anak Setatah, Sungai Cina, Tanah Merah, Sonde, Tenggayun Raya, Bungur, Tanjung Kedabu, Sungai Gayung Kiri, and Tanjung Medang. Also, the research areas with very high-risk level status are Permai and Bantar villages. Variables that greatly affect the areas with a high level of vulnerability are coastal elevation, geomorphology, rise in sea level and coastline change.

The coastline changes experienced along the coast of Pulau Rangsang are mainly caused by the differences in the characteristics and natural factors of the coast. The condition of the coast on is semi-open to the dynamics of the waters, influenced by the waves and currents from Malacca Strait. The regions without mangrove vegetation are influenced directly by the waves from Malacca Strait, a process that accelerates abrasion. According to Halim et al. (2016), the abrasion process is also reinforced by the presence of anthropogenic factors which are human activities such as landfilling or reclamation for the purpose of settlements, tourism, building ports, and the construction of coastal protectors.

Conclusion

Based on the vulnerability evaluation of the coastal zone of Pulau Rangsang with the CVI matrix, the vulnerability levels of these coastal areas due to climate change are categorized into moderate, vulnerable and very high risk. The total study areas are 16 villages of which the 5 classified as moderate are Segomeng, Bina Maju, Mekar Baru, Melai, and Kedabu Rapat villages; 9 villages are classified as high vulnerable and these are Anak Anak Setatah Village, Sungai Cina, Tanah Merah, Sonde, Tenggayun Raya, Bungur, Tanjung Kedabu, Sungai Gayung Kiri, and Tanjung Medang, while 2 villages, Permai and Bantar are classified as very high risk. In general, geomorphological and beach elevation variables greatly influence these levels of vulnerability in these coastal regions. Aside from these two variables, coastline changes and rise in sea level contributed to the final assessment of the vulnerability of the coastal area of Pulau Rangsang.

Acknowledgement

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