

RESEARCH ARTICLE

COASTAL HAZARD RISK AND SOCIO-ECONOMIC IMPLICATIONS OF RISING SEA LEVELS IN PAHANG AND SELANGOR

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ABSTRACT

The rising sea level due to climate change poses a critical threat to Malaysia's coastal regions, impacting both the physical environment and socio-economic stability. This study assesses the vulnerability of the Pahang and Selangor coastlines by integrating physical and socio-economic data through a combination of qualitative and quantitative methods. A Coastal Vulnerability Index (CVI) was developed using six key parameters: geomorphology, coastal slope, shoreline change rate, mean tidal range, wave height, and rate of sea level rise (SLR). Concurrently, a socio-economic survey was conducted to evaluate community awareness, preparedness, and adaptation strategies toward SLR. The CVI results indicate that 9 out of 14 management units along the Pahang and Selangor coastlines exhibit high to very high vulnerability. The findings reveal that areas with extensive sandy and muddy shorelines, low coastal slopes, and high erosion rates are particularly at risk. Additionally, socio-economic data highlight a concerning lack of awareness and preparedness among coastal communities, despite evidence of shoreline retreat and economic losses. This study underscores the urgent need for targeted coastal management strategies that integrate both physical risk assessments and community-based adaptation measures. The results provide a scientific foundation for policymakers to enhance coastal resilience and sustainable development in Malaysia's coastal regions.

KEYWORDS

Coastal Vulnerability, Sea Level Rise, Socio-Economic Impact, Malaysia, Coastal Management

1. INTRODUCTION

The rise in sea levels due to climate change has become a critical environmental concern, particularly for low-lying coastal regions. SLR is a significant threat to coastal stability, leading to increased erosion, flooding, Malaysia, with its extensive coastline along the South China Sea and the Strait of Malacca, faces heightened risks associated with SLR. Pahang's eastern coastline, exposed to monsoonal influences, experiences greater wave energy, contributing to severe erosion and inundation. In contrast, Selangor's western coastline, characterized by extensive mudflats and mangrove ecosystems, is less exposed to high-energy waves but remains susceptible to flooding and saltwater intrusion (Ismail et al., 2018; 2022). The combination of these physical factors and increasing human activities exacerbates coastal vulnerability in both regions.

habitat loss, infrastructure damage, and socio-economic consequences (Nicholls & Cazenave, 2010). These impacts disrupt communities dependent on coastal resources, forcing adaptation strategies to mitigate long-term risks (IPCC, 2023).

Existing research on coastal vulnerability in Malaysia primarily focuses on

physical assessments, such as shoreline changes and erosion rates (Mohd et al., 2019; Bagheri et al., 2021). However, fewer studies integrate socio-economic impacts, including community awareness, perception, and adaptation strategies. Given that local communities play a crucial role in responding to climate-induced changes, understanding their knowledge and preparedness is vital for effective coastal management (Islam et al., 2021). The CVI is a widely used tool for assessing physical susceptibility to SLR, while socio-economic surveys provide critical insights into how communities perceive and respond to these environmental threats (Vousdoukas et al., 2016).

This study aims to assess the combined physical and socio-economic vulnerability of coastal communities in Pahang and Selangor. By integrating geospatial analysis with qualitative and quantitative survey methods, this research evaluates the extent of coastal changes and community adaptation strategies. The findings provide crucial insights into the vulnerabilities of different coastal regions and contribute to developing targeted adaptation and mitigation strategies. Through this interdisciplinary approach, the study seeks to bridge the gap between environmental risk assessment and socio-economic resilience planning, ultimately supporting sustainable coastal management efforts in Malaysia.

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2. MATERIAL AND METHODS

2.1 Data Collection

This study was conducted in three phases. The first phase involved preliminary data collection, including coastal vulnerability assessment and a pilot study on questionnaire comprehension. The second phase focused on data collection through beach profiling and community surveys on SLR impacts. The final phase analyzed satellite imagery and field data to generate a CVI for Pahang and Selangor, along with socio-economic impact assessments. The study area comprised two components: the CVI, covering 14 management units (MUs) along the coastlines, delineated by river mouths; and socio-economic surveys, conducted in five selected areas in Pahang (Cherating, Beserah, Tanjung Lumpur, Pekan, Rompin) and Selangor (Sabak Bernam, Kuala Selangor, Klang, Kuala Langat, Sepang), categorized by district boundaries. The geographical scope of the study is illustrated in Figure 1, which presents the mapped study area, including the designated management units along the Pahang and Selangor coastlines.

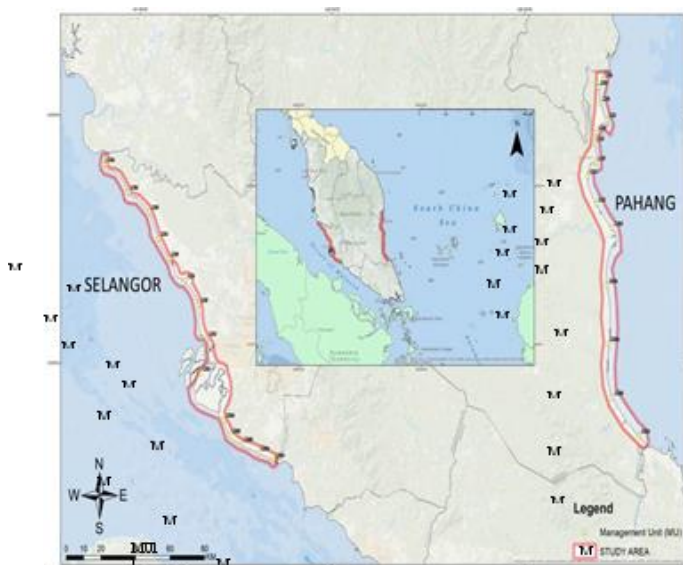


Figure 1: A schematic flowchart of coastal vulnerability assessment.

2.2 Data Collection for CVI

CVI was calculated using six parameters: geomorphology, shoreline change rate, coastal slope, SLR, wave height, and tidal range, following (Vousdoukas et al., 2016). Data collection involved field measurements (Total Station, GPS), satellite imagery (2010 and 2020), tide gauges, and wave modeling. Vulnerability ratings were assigned, and the CVI was computed by the square root of the product of these ranked parameters divided by their total number.

The CVI formula (Pendleton et al. 2010) used for calculation was:

$$CCI = \sqrt{(a * b * c * d * e * f) / 6}$$

where: a = Geomorphology, b = Coastal slope, c = Shoreline change rate, d = Sea level rise, e = Mean significant wave height, f = Mean tidal range

Each parameter was ranked from 1 (least vulnerable) to 5 (most vulnerable) using natural break classification across 14 Management Units (MUs) in Pahang and Selangor. This classification identified areas at very low to very high risk, effectively illustrating the potential impacts of future SLR and coastal changes. Figure 2 summarizes the coastal vulnerability assessment and adaptation strategies for Pahang.

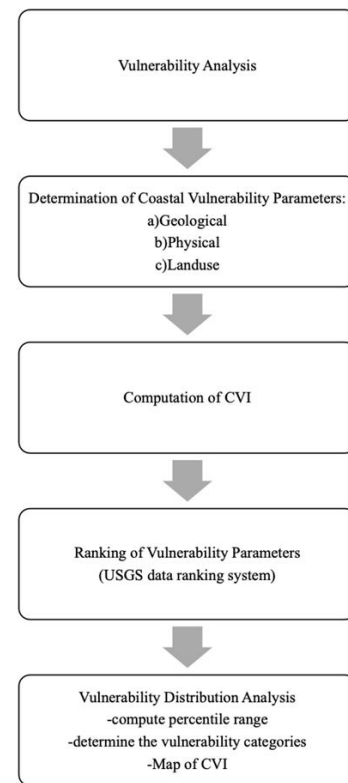


Figure 2: A schematic flowchart of coastal vulnerability assessment.

2.3 Data Collection for Socioeconomic survey

A structured survey questionnaire was employed for primary data collection, effective for addressing research inquiries (Hanafiah et al., 2021). It assessed coastal community knowledge, awareness, preparedness, and adaptability regarding climate change and SLR, structured into four sections: (1) socioeconomic characteristics, (2) knowledge about SLR and climate change, (3) perception and awareness via a 5-point Likert scale, and (4) preparedness, adaptation strategies, and economic impacts. Purposive sampling targeted 500 respondents from affected coastal areas in Pahang and Selangor, selected based on Yamane's (1973) formula. Data analysis included descriptive statistics, factor analysis, reliability tests, and ANOVA. Figure 3 outlines the survey methodology.

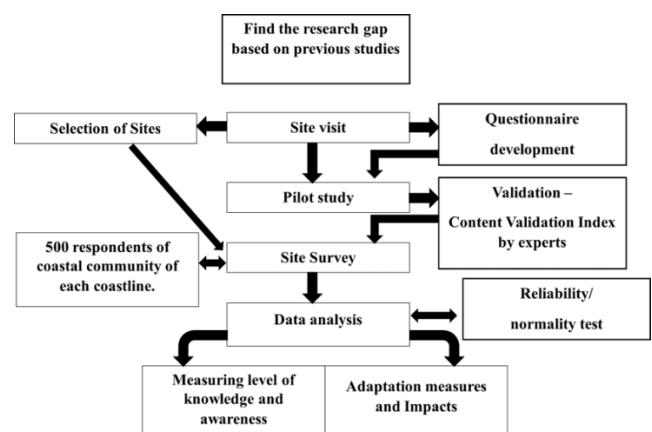


Figure 3: Schematic flowchart of measuring community awareness and adaptation.

3. RESULTS AND DISCUSSION

This study employs the CVI alongside a socioeconomic survey. The results start with CVI computation and mapping, followed by descriptive socioeconomic analyses, including factor analysis, reliability testing, and basic statistics.

3.1 Coastal Vulnerability Index in Pahang and Selangor

The CVI assessment (Tables 1 and 2) revealed distinct vulnerability patterns along the coastlines of Pahang and Selangor. In Pahang, most coastal segments were classified as highly vulnerable, including prominent areas such as Pantai Cherating, Tg Cherating, Balok, and Nenasi. Certain locations, specifically Kuala Pahang and Kuala Rompin, exhibited very high vulnerability levels, primarily driven by high erosion rates, gentle coastal slopes, and geomorphological factors. Moderate vulnerability was recorded at Kg Beserah and Hulu Tering, while notably, Pelabuhan Kuantan was identified with very low vulnerability due to favorable geomorphological and erosional characteristics.

In Selangor, the coastline generally displayed high to very high vulnerability. Areas such as Sg Nibong, Tanjung Karang, Pulau Indah, and Morib were categorized as very highly vulnerable, reflecting significant susceptibility from coastal slope, erosion rates, and geomorphology. Other coastal segments, including Pantai Jeram and Pantai Bagan Lalang, were also marked as highly vulnerable. Conversely, Port Klang emerged as an area of low vulnerability, attributed to stable geomorphology and lower erosion rates. These differences highlight the critical need for targeted and location-specific coastal management interventions to effectively address vulnerabilities across the region.

Table 1: CVI table of Pahang coastline										
MU	Location	Geomorphology	Coastal Slope	Rate of Erosion and Accretion	Mean Tidal Range	Mean Wave Height	Rate of SLR	CVI	Percentile (%)	Vulnerability
MU1	Tjg Cherating	3	3	3	4	3	3	14.70	72.22	High
MU2	Pantai Cherating	3	3	3	4	3	3	14.70	72.22	High
MU3	Sg Ular	3	3	3	4	3	3	14.70	72.22	High
MU4	Pelabuhan Kuantan	1	3	1	4	3	3	4.24	2.78	Very Low
MU5	Balok	3	3	3	4	3	3	14.70	72.22	High
MU6	Kg Beserah	3	4	3	3	3	3	12.70	41.67	Moderate
MU7	Teluk Cempedak	3	3	3	4	3	3	14.70	72.22	High
MU8	Kg Kempadang	3	3	3	4	3	3	14.70	72.22	High
MU9	Sg Penor	5	3	3	4	3	3	13.41	40.05	Moderate
MU10	Kuala Pahang	4	3	3	4	3	3	18.97	91.67	Very High
MU11	Hulu Tering	3	3	3	4	3	3	12.72	41.67	Moderate
MU12	Nenasi	4	3	3	4	3	3	18.97	97.22	Very High
MU13	Kuala Rompin	5	3	3	4	3	3	18.97	72.22	High
MU14	Endau	4	3	2	3	3	3	12.22	40.05	Moderate

3.2 Coastal Condition of Pahang and Selangor

The coastal conditions observed in Pahang and Selangor strongly correlate with their respective vulnerability profiles (Section 3.1). Pahang's coastline, which represents the eastern coast of Peninsular Malaysia, holds significant socio-economic and environmental importance (Koshy et al., 2019). Nevertheless, approximately 46.3% (125.4 km) of this coastline experiences active erosion driven by monsoonal waves and sediment

disruptions from port developments (Unit Perancang Ekonomi, 1985; Wong, 2003; Amirul et al., 2019). While northern segments such as Pantai Cherating to Kempadang benefit from coastal protection measures like rock revetments, breakwaters, groynes, and beach nourishment, the southern region, notably Kuala Pahang and Kuala Rompin, remains highly vulnerable, aligning closely with the very high vulnerability ratings highlighted in the CVI assessment (Williams et al., 2018; Islam et al., 2022).

Table 2: CVI table of Selangor coastline										
MU	Location	Geomorphology	Coastal Slope	Rate of Erosion and Accretion	Mean Tidal Range	Mean Wave Height	Rate of SLR	CVI	Percentile (%)	Vulnerability
MU1	-	5	5	2	4	2	3	-	-	High
MU2	-	4	4	3	4	2	3	-	-	High
MU3	-	4	5	4	4	2	3	-	-	Very High
MU4	-	5	3	4	4	2	3	-	-	High
MU5	-	5	5	3	4	2	3	-	-	Very High
MU6	-	5	3	3	4	2	3	-	-	Moderate
MU7	-	4	3	5	4	2	3	-	-	High
MU8	-	2	3	3	4	2	3	-	-	Low
MU9	-	5	4	4	4	2	3	-	-	Very High
MU10	-	5	4	4	4	2	3	-	-	Very High
MU11	-	4	3	3	4	2	3	-	-	Moderate
MU12	-	4	3	3	4	2	3	-	-	Moderate
MU13	-	4	3	4	4	2	3	-	-	Moderate
MU14	-	5	4	3	4	2	3	-	-	High

Similarly, Selangor's western coastline primarily consists of muddy substrates supporting extensive mangrove ecosystems that naturally reduce erosion (Ahmad et al., 2021; Mustapa et al., 2015; Md Hashim and Mohd Jani, 2019; Remli et al., 2023). Although mangroves serve as natural barriers along approximately 72% of the west coast, degradation, especially around Pulau Indah, has intensified erosion, increasing

vulnerability as identified in the CVI analysis (Ghazali, 2006). Areas around Carey Island and Port Klang exhibit significant erosion influenced by mangrove loss and wave impacts from heavy maritime traffic, reflecting their high to very high CVI rankings (Md Hashim et al., 2019; Rameli and Jaafar, 2015). This correlation underscores the urgent need for targeted coastal management strategies that address specific physical and

ecological challenges in these vulnerable regions.

3.3 Survey analysis for Socioeconomic in Pahang and Selangor

3.3.1 Socioeconomic Characteristic

This study analyzes the socioeconomic factors influencing community adaptation and awareness regarding coastal hazards in Pahang and Selangor, based on a survey of 500 respondents (Figure 4). Most respondents were male (Pahang 55%; Selangor 62%), predominantly Malay (Pahang 97%; Selangor 84%), and primarily aged 19–44 (Pahang 50%; Selangor 49%). A significant portion had resided in their communities for over 30 years (Pahang 42%; Selangor 40%). Educational attainment was predominantly secondary level (Pahang 63%; Selangor 43%). The average monthly income typically ranged from RM1001–RM2000 (Pahang 43%; Selangor 35%), exceeding Malaysia's poverty line of RM720 (Shaffril et al., 2017; 2020).

Occupationally, respondents primarily identified with local community roles (Pahang 52%; Selangor 32%), fisheries or aquaculture (Pahang 23%; Selangor 30%), and tourism-related activities (Pahang 14%; Selangor 17%). Awareness of sea-level rise was relatively high in both states (Pahang 66%; Selangor 76%), highlighting the critical role of continuous education and community engagement in climate adaptation strategies.

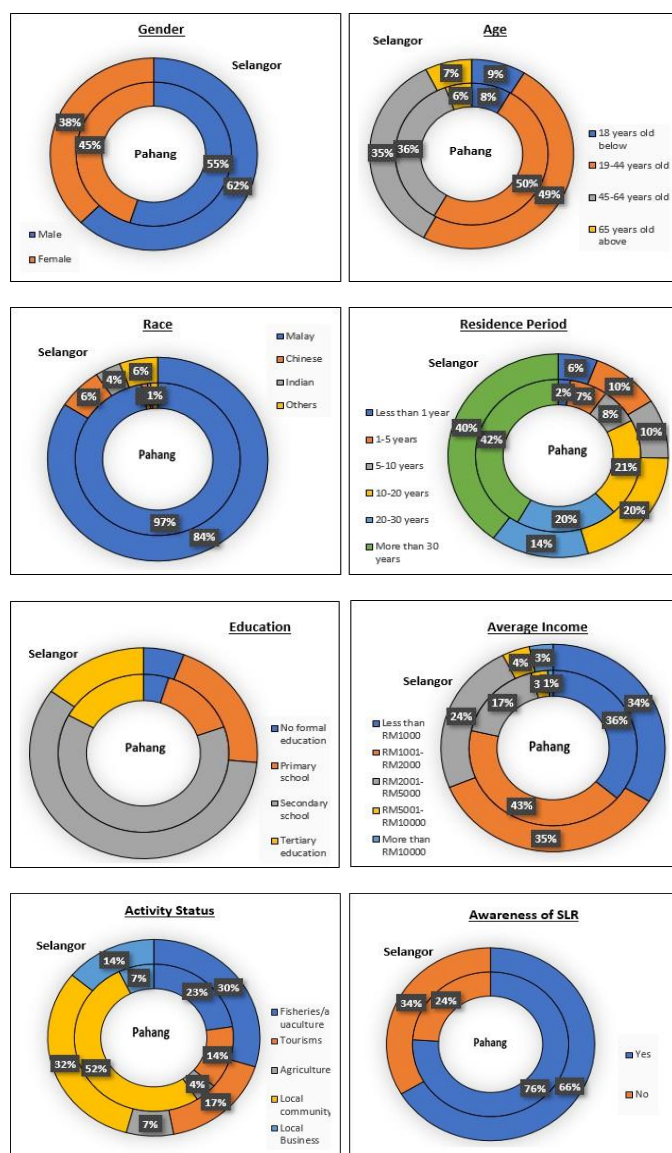


Figure 4: Percentage of socioeconomic characteristic for Pahang and Selangor community

3.3.2 Analysis Of Knowledge And Awareness Of The Communities

Principal Component Analysis with varimax rotation identified two primary domains from 12 statements assessing community awareness (Table 3). In Pahang, the dominant component accounted for 26.74% of the

variance (eigenvalue: 3.476), with highest awareness regarding the impact of global temperature increases on sea-level rise and weather changes (factor loading: 0.811). Similarly, in Selangor, the primary component explained 41.21% of variance (eigenvalue: 5.357), with the highest factor loading (0.868) related to the awareness of global temperature-induced weather and sea-level changes. Reliability tests showed strong consistency with Cronbach's Alpha values of 0.811 (Pahang) and 0.862 (Selangor).

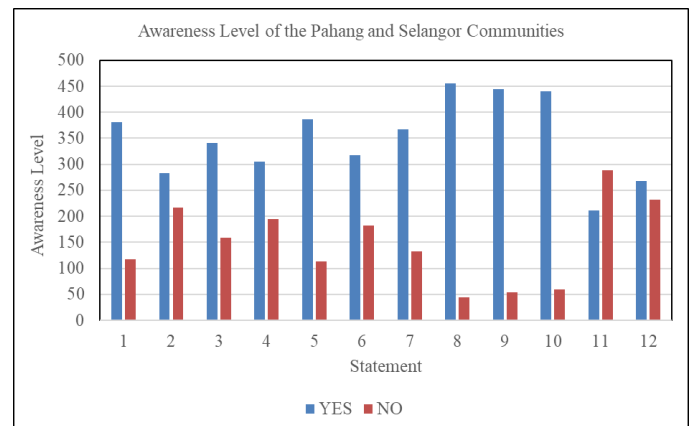


Figure 5: Awareness of the communities based on the statements.

Table 3: Statement For Awareness Of The Communities.	
Statements	
1	Do you know about sea level rise?
2	Do you know the cause of sea level rise?
3	The rise in global temperatures is causing significant weather changes.
4	The rise in sea level is caused by an increase in global temperature that is higher than normal.
5	Tides affect sea level rise.
6	The rise in global temperatures causes the ice at the poles to melt and raise sea levels.
7	The increase in global temperature is caused by human activities and uncontrolled development.
8	Rising sea levels will cause low-lying areas to be flooded.
9	Sea level rise will cause coastal erosion.
10	The rise in sea level causes coastal communities to be affected.
11	Sea level rise does not cause coastal areas changes.
12	Sea level rise does not depend on the monsoon season.

Figure 5 illustrates the community awareness responses, highlighting substantial awareness across statements related to sea-level rise causes and impacts. The statement data is at Table 3. A majority clearly understood the relationship between global temperature increases, polar ice melting, and subsequent coastal effects. Notably, statements concerning the direct impacts of sea-level rise on coastal changes and monsoon dependency revealed uncertainty among respondents, indicating areas where awareness and education initiatives could be strengthened.

3.3.3 Analysis Of Impact And Adaptation Of The Communities

Principal Component Analysis identified two key segments (Table 4): adaptation strategies and impacts. Adaptation accounted for approximately 31% of variance in Pahang and 30% in Selangor. The primary adaptation measures included building coastal forts (Pahang 40.2%, Selangor 39.2%), relocating to higher ground (Pahang 40.0%, Selangor 35.4%), and modifying buildings (Pahang 11.8%, Selangor 13.6%). Most respondents in Pahang (67.2%) reported preparedness for rising sea levels, compared to fewer in Selangor (46.8%). Information on sea-level rise warnings was mainly obtained through news sources, social media, and fellow villagers.

Table 4: Descriptive analysis results for impact and adaptation of the community on sea level rise (N=100)

No	Statements	Pahang		Selangor	
Adaptation					
1	What actions do you take if you are affected by sea level rise and erosion?				
	Move to higher ground	200	40.0%	177	35.4%
	Plant more mangrove trees	39	7.8%	59	11.8%
	Build coastal forts	201	40.2%	196	39.2%
	Modifying building construction to adapt to sea water changes	59	11.8%	68	13.6%
2	Are you preparing for rising sea levels?				
	Yes	336	67.2%	234	46.8%
	No	164	32.8%	266	53.2%
3	Where do you find information about warnings about sea level rise?				
	News	156	31.2%	125	25.0%
	Social media	153	30.6%	149	29.8%
	Villagers	143	28.6%	119	23.8%
	None	48	9.6%	107	21.4%
4	In your opinion, what are the appropriate coastal barriers to use in your area to reduce erosion caused by rising sea levels?				
	Revetment	200	40.0%	222	44.4%
	Gabion	76	15.2%	47	9.4%
	Breakwater	73	14.6%	30	6.0%
	Groyne	14	2.8%	4	0.8%
	Seawall	93	18.6%	94	18.8%
	Mangrove	38	7.6%	102	20.4%
Impacts					
1	Are you affected by sea level rise or erosion?				
	Yes	240	48.0%	272	54.4%
	No	260	52.0%	228	45.6%
2	Based on the options below you are affected in terms of?				
	Daily activities	275	55.0%	309	61.8%
	Assets	37	7.4%	63	12.6%
	Business	38	7.6%	61	12.2%
	Infrastructure	52	10.4%	22	4.4%
	Maintenance cost	73	14.6%	45	9.0%
3	How much damage do you estimate?				
	No damage cost	276	55.2%	309	61.8%
	Less than RM500	37	7.4%	53	10.6%
	RM500 – RM999	58	11.6%	36	7.2%
	More than RM1000	63	12.6%	50	10.0%
	More than RM10,000	30	6.0%	24	4.8%
	More than RM100,000	11	2.2%	28	5.6%

Regarding suitable coastal barriers, revetments were most preferred (Pahang 40.0%, Selangor 44.4%), followed by seawalls (Pahang 18.6%, Selangor 18.8%) and mangroves (Selangor 20.4%). For impacts, Selangor respondents reported higher disruption to daily activities (61.8%) and greater impact on assets (12.6%) and businesses (12.2%) compared to Pahang. While most respondents indicated no significant financial damages, a minority estimated damages exceeding RM1000, with some reporting substantial losses over RM100,000.

4. CONCLUSION

This study assessed the combined physical and socio-economic vulnerability of coastal communities in Pahang and Selangor by integrating geospatial analysis and survey-based approaches. Using a CVI, the research identified moderate to very high levels of vulnerability across both

coastlines, particularly in the northern and southern regions of Pahang and central and northern areas of Selangor. Survey analysis highlighted significant gaps in community awareness and preparedness, emphasizing the importance of enhancing local understanding of sea-level rise and its socio-economic impacts. By connecting environmental risk assessments with socio-economic resilience strategies, this interdisciplinary study provides essential insights for developing targeted, effective, and sustainable coastal management practices. Collaborative stakeholder engagement is critical in mitigating risks and building resilient coastal communities in Malaysia.

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