COASTAL HAZARD VULNERABILITY ASSESSMENT ALONG THE COAST OF PRANBURI – SAM ROI YOT, PRACHUAP KHIRI KHAN PROVINCE

Miss Somruedee Kawlomlerd

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การประเมินความเปราะบางชายฝั่งทะเลต่อภัยพิบัติธรรมชาติ บริเวณชายฝั่งทะเลปราณบุรี-สามร้อยยอด จังหวัดประจวบคีรีขันธ์

น.ส.สมฤดี ขาวล้ำเลิศ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
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Thesis Title	COASTAL HAZARD VULNERABILITY ASSESSMENT ALONG THE COAST OF PRANBURI – SAM ROI YOT, PRACHUAP KHIRI KHAN PROVINCE
By	Miss Somruedee Kawlomlerd
Field of Study	Earth Sciences
Thesis Advisor	Assistant Professor SUMET PHANTUWONGRAJ, Ph.D.

Accepted by the FACULTY OF SCIENCE, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Science

-- Dean of the FACULTY OF SCIENCE

(Professor POLKIT SANGVANICH, Ph.D.)

THESIS COMMITTEE

-- Chairman

(Professor SRILERT CHOTPANTARAT, Ph.D.)

-- Thesis Advisor

(Assistant Professor SUMET PHANTUWONGRAJ, Ph.D.)

-- Examiner

(Professor MONTRI CHOOWONG, Ph.D.)

-- External Examiner

(Assistant Professor Anukul Buranapratheprat, Ph.D.)

สมฤดี ขาวล้ำเลิศ : การประเมินความเปราะบางชายฝั่งทะเลต่อภัยพิบัติธรรมชาติ บริเวณชายฝั่งทะเลปราณบุรี-สามร้อยยอด จังหวัดประจวบคีรีขันธ์. (COASTAL HAZARD VULNERABILITY ASSESSMENT ALONG THE COAST OF PRANBURI – SAM ROI YOT, PRACHUAP KHIRI KHAN PROVINCE) อ.ที่ปรึกษาหลัก : ผศ. ดร.สุเมธ พันธุวงค์ราช

พื้นที่ชายฝั่งปราณบุรี-สามร้อยยอด ประกอบด้วยลักษณะทางธรณีวิทยาชายฝั่งหลายรูปแบบ ซึ่งเป็นสถานที่สำคัญได้แก่ แหล่งทรัพยากรธรรมชาติ, สถานที่ท่องเที่ยว และพื้นที่เศรษฐกิจ ทั้งยังเป็นพื้นที่ที่มีการใช้ประโยชน์ที่ดินหลายประเภท เช่น เกษตรกรรม พื้นที่อนุรักษ์ ที่อยู่อาศัย โรงแรมและรีสอร์ทต่างๆ โดยพื้นที่ชายฝั่งนี้เป็นบริเวณที่มีโอกาสได้รับผลกระทบจากภัยธรรมชาติที่สร้างความเสียหายต่อระบบนิเวศชายฝั่ง รวมทั้งความเป็นอยู่ของชุมชน งานวิจัยนี้มีวัตถุประสงค์เพื่อประเมินความเสียหายทางกายภาพที่เกิดจากภัยธรรมชาติ โดยใช้การวิเคราะห์ปัจจัยที่เกี่ยวข้องตามวงล้อภัยพิบัติ (Coastal Hazard Wheel: CHW) และประเมินความเปราะบางของชายฝั่งโดยใช้ดัชนีความเปราะบางของชายฝั่ง (Coastal Vulnerability Index: CVI) และกระบวนการลำดับชั้นเชิงวิเคราะห์ (Analytic Hierarchy Process: AHP) รวมทั้งการวิเคราะห์การใช้ประโยชน์ที่ดินตามแนวชายฝั่งเพื่อทราบประเภทการใช้ประโยชน์ที่ดินที่อยู่ในระดับความเปราะบางสูง จากผลการวิเคราะห์ด้วยวิธี CHW พบว่าในพื้นที่ศึกษามีความรุนแรงจากภัยน้ำท่วมโดยคลื่นพายุซัดฝั่งในระดับสูงมาก ซึ่งครอบคลุมพื้นที่ส่วนใหญ่คำนวณระยะทางได้ 27 กิโลเมตร คิดเป็นร้อยละ 73 ของพื้นที่ และรองลงมาเป็นภัยการกัดเซาะชายฝั่งในระดับสูง คำนวณระยะทางได้ 21 กิโลเมตร คิดเป็นร้อยละ 55 ของพื้นที่ ต่อมาเป็นผลการประเมินความเปราะบางของชายฝั่งด้วยวิธี CVI พบว่าความเปราะบางระดับสูงมาก แสดงค่าอย่างเห็นได้ชัดในบริเวณชายฝั่งทางตอนใต้ของพื้นที่ศึกษา คำนวณระยะทางได้ 9 กิโลเมตร คิดเป็นร้อยละ 24 ของพื้นที่ และผลการประเมินจากกระบวนการ CVI ร่วมกับ AHP พบว่าความเปราะบางในระดับสูงมากนั้นมีระยะทางลดลงเป็นร้อยละ 20 ของพื้นที่ และยังพบการเปลี่ยนแปลงของระดับความเปราะบางอย่างเห็นได้ชัดจากการประเมินด้วยวิธีนี้ สำหรับเกณฑ์ที่ทำให้เกิดความแตกต่างของระดับความเปราะบางได้แก่ ความลาดชันชายฝั่ง ลักษณะธรณีสัณฐานวิทยา และการเปลี่ยนแปลงของแนวชายฝั่ง สำหรับผลการวิเคราะห์การใช้ประโยชน์ที่ดินระยะ 1 กิโลเมตรจากชายฝั่ง มีพื้นที่รวมประมาณ 33 ตารางกิโลเมตร พบว่าการใช้ประโยชน์ที่ดินประเภทเกษตรกรรมมีพื้นที่ส่วนใหญ่อยู่ในระดับความเปราะบางสูงมากร้อยละ 47 ของพื้นที่ และการใช้ประโยชน์ที่ดินประเภทเมืองร้อยละ 24 ของพื้นที่ ซึ่งอยู่ในพื้นที่มีโอกาสที่จะได้รับผลกระทบมากที่สุดเมื่อเกิดเหตุการณ์ภัยธรรมชาติ เนื่องจากมีการขยายตัวเพิ่มขึ้นอย่างต่อเนื่องโดยเฉพาะบริเวณชายหาดที่เป็นแหล่งท่องเที่ยวสำคัญ

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Somruedee Kawlomlerd : COASTAL HAZARD VULNERABILITY ASSESSMENT ALONG THE COAST OF PRANBURI – SAM ROI YOT, PRACHUAP KHIRI KHAN PROVINCE. Advisor: Asst. Prof. SUMET PHANTUWONGRAJ, Ph.D.

Pranburi - Sam Roi Yot coastal area consists of various coastal landforms such as rocky coasts, beaches, mangroves, and estuaries. These include several important places such as natural resources, tourist attractions, and significant economic areas of the province. In addition, there are a broad range of land use in this region, including agriculture, conservation, residence, hotels, and resorts. However, this coastal area is vulnerable to natural disasters, which can damage the local ecosystem and population. The objective of this study is to assess the physical damage from coastal hazards by using the Coastal Hazard Wheel (CHW) approach and also to estimate the coastal vulnerability by using the Coastal Vulnerability Index (CVI) and the Analytic Hierarchy Process (AHP). Moreover, land use analysis was also performed to identify the land use type in the high vulnerability zone. The result of the physical damage assessment by CHW method found that most of the study area exhibited a storm surge-flooding hazard at a very high level of 27 km long (73 percent of the total length of the study area). Subsequently, coastal erosion is the second substantial hazard in this area, a distance of 21 km (55 percent of the total area). The result of the coastal vulnerability assessment by CVI method found that a very high level is located at the southern part of the study area, which has a length of 9 km (24 percent of the total area). In terms of CVI combined with AHP approach, it was discovered that the vulnerability class, particularly a very high level, was reduced in distance to 20% of the study area. The parameters that have significant influence include a coastal slope, geomorphology and shoreline change rate. Finally, from the land use analysis, within 1 km from the coastline, agricultural land use occupied the most areas at a very high vulnerability level, 47 percent, followed by urban land use, 24 percent. This urban zone will be the most affected area by natural disasters as it continues to expand, especially in the beach area, a major tourist attraction.

Field of Study:	Earth Sciences	Student's Signature ....
Academic Year:	2022	Advisor's Signature ....

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CHAPTER 1 INTRODUCTION

1.1 Background

The coastal environments around the world are experiencing the effects of climate change by sea-level rise and coastal erosion. The latest climate change projections indicate since 1950, natural disaster events around the world have been continuously extreme, and sea levels will rise and increase in the global oceans (The Intergovernmental Panel on Climate Change, 2022). Therefore, the climate change situation causes natural disasters, especially coastal erosion and storm surges, However, the coast has a variety of utilization, such as tourist attractions and economic resources, all are impacted by the above reason, which impacts the ecosystem and human livelihood.

Currently, coastal vulnerability assessment has developed methodologies and approaches to assess and manage coastal hazards. Ramieri et al. (2011) explained "principles used to assess coastal vulnerability namely (1) index and indicator-based methods, (2) GIS-based decision support systems, and (3) dynamic computer models" that are developed for different purposes and different requirements for data and expertise. Studying various research in the past found several researchers have assessed and modified the Coastal Vulnerability Index (CVI) for different coastal environments. Sheik Mujabar and Chandrasekar (2011) studied geological and physical variables and used the CVI index to map vulnerability in southern coastal Tamil Nadu of India. The result of this study found natural and human activity coastal processes both cause vulnerability. In addition, data within this assessment showed significant variability at different spatial scales. Bagdanavičiūtė et al. (2015) proposed a set of indicators of coastal vulnerability that characterize relatively low-lying coastal segments with negligible tidal range but affected by substantial storm surges driven by atmospheric factors. The study area is the coast of Lithuania in the south-eastern Baltic Sea. Assessment CVI combined with Analytical Hierarchical Process (AHP). The results of this assessment provide further insights into coastal vulnerability and yield more consistent results in the study area. Denner et al. (2015) presented CVI that can be developed and implemented according to the researcher's objectives. They adjusted this index for simplicity of use in an estuarine environment. As a result, showed that the method can be adapted to the local or regional coastal environment and the most critical physical parameters affecting vulnerability along this shoreline were coastal slope and beach width. Mohd et al. (2019) evaluated the CVI for the Cherating-Pekan coast, Pahang, Malaysia. Using six criteria of physical and geological, namely morphology, coastal slope, rate of erosion and accretion, mean significant wave height, mean tidal range, and rate of sea-level rise. These criteria are comprehensive coastal vulnerability assessments. Hoque et al. (2019) developed the index by using eight indicators from remote sensing and GIS tools to develop an index within a spatial analysis environment comprehensive and quantified the degree of vulnerability of the eastern coastal region of Bangladesh. As a result, this assessment of CVI can help planning and development strategies in vulnerable coastal regions to protect resources from coastal hazards.

Besides, the research of Rosendahl Appelquist and Balstrøm (2014); Rosendahl Appelquist and Balstrom (2015); Rosendahl Appelquist and Halsnæs (2015) suggested Coastal Hazard Wheel (CHW) a new methodology for coastal multi-hazard assessment covers all coastal perils under damage from ecosystem disruption, gradual inundation, saltwater intrusion, erosion, and flooding. The result of the assessment CHW was another approach for evaluating researcher vulnerability to develop a coastal vulnerability map and support comprehensive local to-regional coastal management, but the study should be repeated in other areas for quality results. Also, Rosendahl Appelquist (2016) proposed the main manual for start provides a brief introduction to how to use the CHW to support coastal assessment and consideration of relevant indicators.

The literature review about coastal hazard assessment mainly assessed coastal areas at the regional level and little was studied in the same area of the whole index. We are interested to assess physical damage using the classification of physical indicators according to CHW. In addition, to assess coastal vulnerability by using the Coastal vulnerability index (CVI) and the analytic hierarchy process (AHP) along the coast of Pranburi - Sam Roi Yot Prachuap Khiri Khan province because this area consists of coastal landforms such as rocky coast, beach, mangroves, and estuary which has diverse land use whether agriculture, conservation area, residence, hotels, and resorts. Moreover, the coast is affected by natural disasters that cause damage to the coastal ecosystem, society, and economy. The expected result of this study is to suggest maps showing the coastal hazard intensities and estimate land use affected by the disaster for management and planning in the study area.

1.2 Research Objectives

To assess physical damage from natural disasters

To assess coastal vulnerability to natural disasters

1.3 Scope of Study

In this study, the physical damage assessment will assess coastal hazards under the damage from ecosystem disruption, gradual inundation, saltwater intrusion, erosion, and flooding. In addition, the physical damage was focused on the terrain or coastal area that can be affected by those natural hazards.

Coastal vulnerability assessment will assess based on physical indicators of the terrain, including geomorphology, coastal slope, coastline change rate, significant wave height, tide range, and underwater slope. Geo-informatics tools will be used in this assessment to develop coastal vulnerability maps to support local coastal management. The vulnerability assessment is based only on damage to coastal areas and does not include damage to buildings or structures.

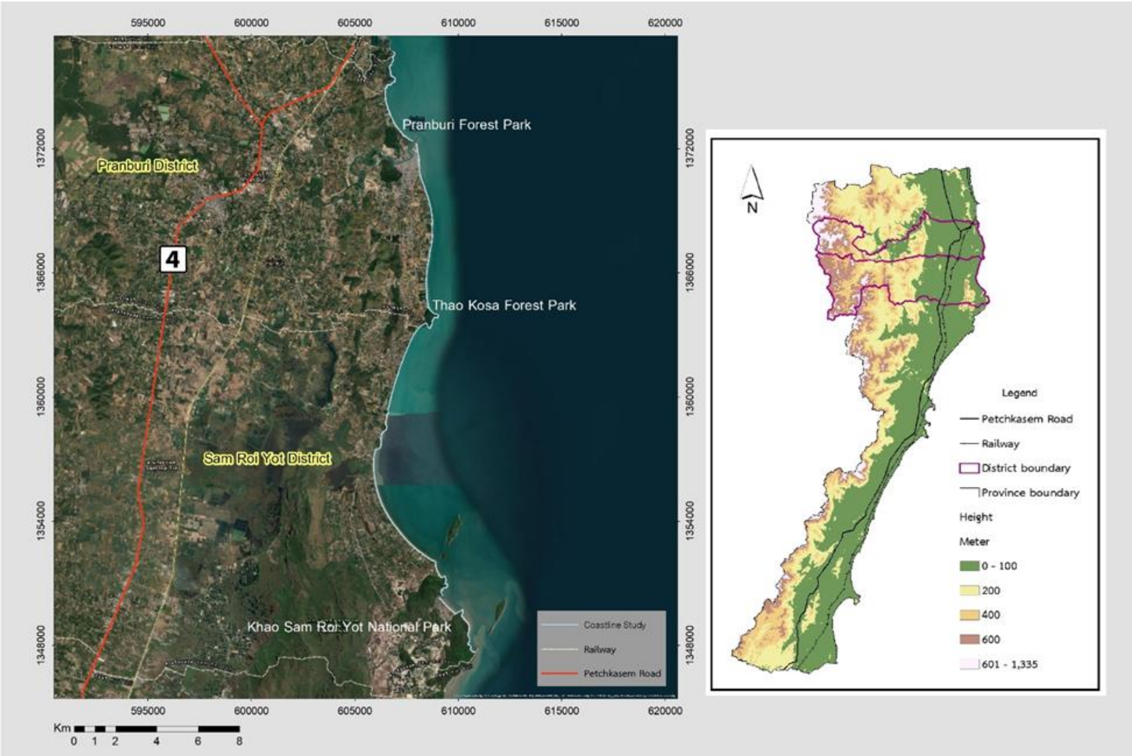


Figure 1. The study area along the coastline of Pranburi and Sam Roi Yod, the total distance is 31 kilometers.

1.4 Benefit

The physical damage caused by natural disasters and a map of the vulnerability of the coastline.

1.5 Hypothesis

The damage intensity from natural hazards in the coastal area varies from place to place and depends mainly on topographic conditions. The geomorphology and topography of the coast also have varying degrees of influence on coastal vulnerability.

CHAPTER 2 LITERATURE REVIEW

2.1 Coastal Vulnerability

Coastal vulnerability is defined as the state of a coastline that is likely to suffer negative impacts. It encompasses concepts and elements from a variety of factors including the susceptibility or tendency to be damaged by natural disasters as well as the capacity or adaptive potential of coastal areas (Office Of Natural Resources and Environmental Policy and Planning, 2016). Noor and Abdul Maulud (2022) explained the degree of vulnerability is determined by resilience and resistance to disasters. The susceptibility depends on the specifics of different coastal environments. For example, rocky coastal shorelines are characterized by low vulnerability due to the rock composition having a higher resistance than silt or sandy silt which has a low resistance to erosion and erosion.

Figure 2. Coastal characteristics became more vulnerable when sea levels rise and storm frequency increases (Noor & Abdul Maulud, 2022).

2.2 Climate Change

Climate change is long-term changes in weather patterns in one area that persist for a decade or more, possibly due to several reasons. One of them is caused by Global warming from increasing concentrations of greenhouse gases in the atmosphere related to human activities (Green Network, 2021). Rising sea levels are one of the most important signs of climate change (Noor & Abdul Maulud, 2022). The latest climate change projections indicate that by 2100 sea levels will rise by at least 18 centimeters and by a maximum of 59 centimeters in the global oceans (The Intergovernmental Panel on Climate Change, 2007). The effects of climate change are expected to cause coastal erosion, damage homes and infrastructure, and damage coastal ecosystems such as mangrove forests and coral reefs (Ghosh & Mistri, 2021). Moreover, multiple economic and social impacts include loss of economic value. Land and coastal habitat loss increase flood risks to humans and infrastructure (Noor & Abdul Maulud, 2022).

2.3 Coastal Hazard Wheel

The Coastal Hazard Wheel is another tool for assessment to assist coastal planners of global climate change. Which gathers the main "geo- biophysical parameters determining the characteristics of coastal systems" (Rosendahl Appelquist & Balstrøm, 2014). The CHW framework is based on a specially designed coastal classification system containing 113 typical coastal environments, includes geological parameters that characterize coastal systems. It aims to cover all coastal areas worldwide. Coastal geological models are fundamental and add the physical main dynamical parameters and processes in coastal environments (Rosendahl Appelquist & Balstrom, 2015). The coast classification starts from the inside of the wheel until the outermost wheel included six geo-biophysical classification circles, five hazard circles, and the coastal classification codes (Figure 3).

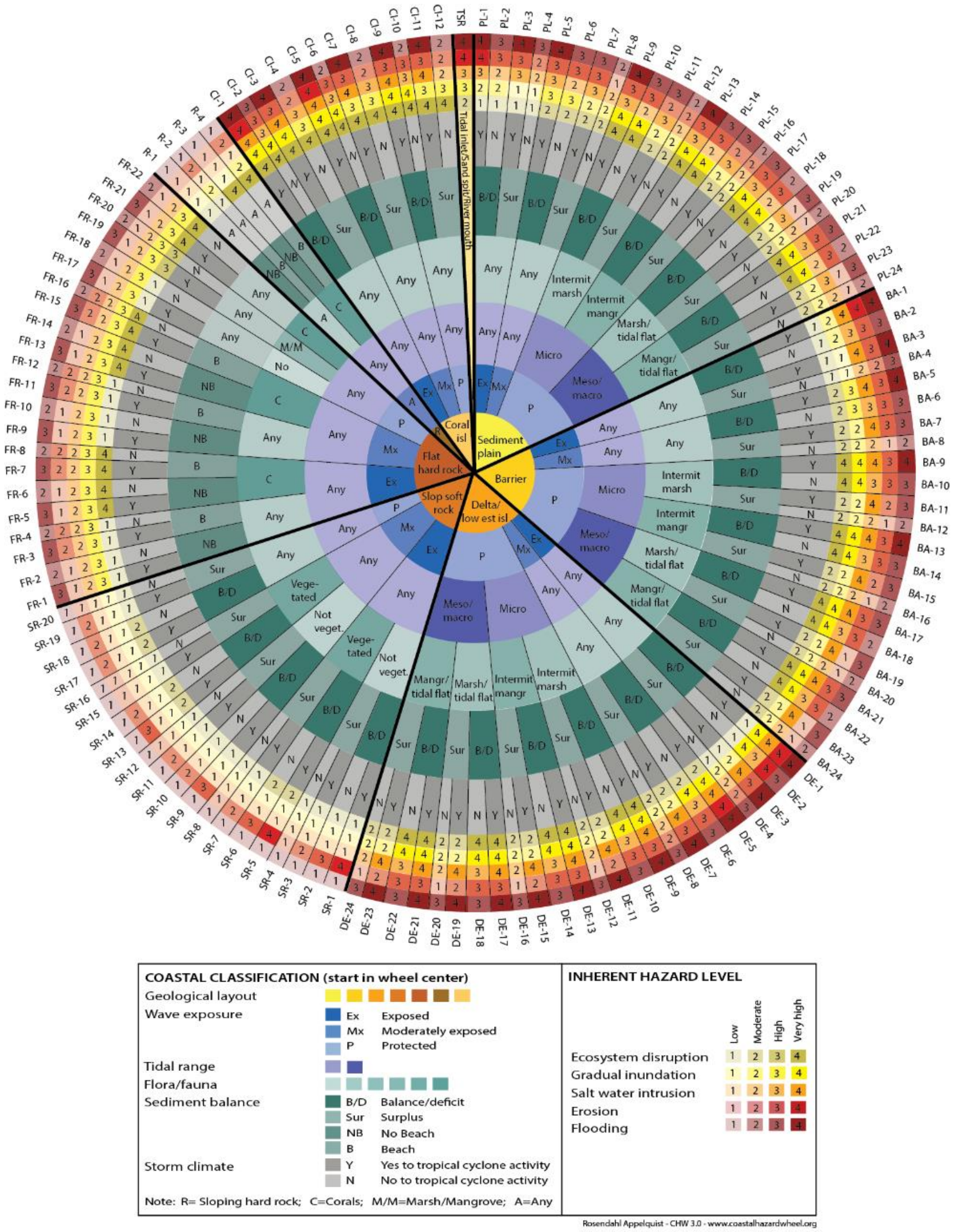


Figure 3 The Coastal Hazard Wheel was developed for coastal multi-hazard assessment from natural disasters. (Rosendahl Appelquist, 2016).

The research of Rosendahl Appelquist and Balstrom (2015) proposed the CHW for coastal multi-hazard assessment in the state of Karnataka, India. The result of the assessment found the most common types are the sloping soft rock coasts, SR-5 and SR-17, followed by the sloping hard rock coast HR-1 (Table 1). Table 2 shows 61 percent of Karnataka's coastline has a high or very high inherent hazard of erosion, making erosion the most prevalent coastal hazard.

Table 1. The top 10 most common coastal types of Karnataka's coastline (Rosendahl Appelquist & Balstrom, 2015).

Coastal type	Length (km)	Percent of coastline
Sloping soft rock 5 (SR-5)	146	23
Sloping soft rock 5 (SR-17)	118	18
Hard rock 1 (HR-1)	100	16
Tidal inlet/Sand spit/River mouth (TSR)	84	13
Coastal plain 13 (CP-13)	58	9
Delta 13 (DE-13)	49	8
Barrier 13 (BA-13)	16	3
Coastal plain 1 (CP-1)	14	2
Delta 15 (DE-15)	13	2
Barrier 1 (BA-1)	12	2

Table 2. The distribution of hazard levels in percent for Karnataka's coastline (Rosendahl Appelquist & Balstrom, 2015).

Hazards/Hazard level	Low	Moderate	High	Very high
Ecosystem disruption	24	56	0	19
Gradual inundation	61	6	13	19
Saltwater intrusion	61	0	25	14
Erosion	16	24	21	40
Flooding	61	0	0	39

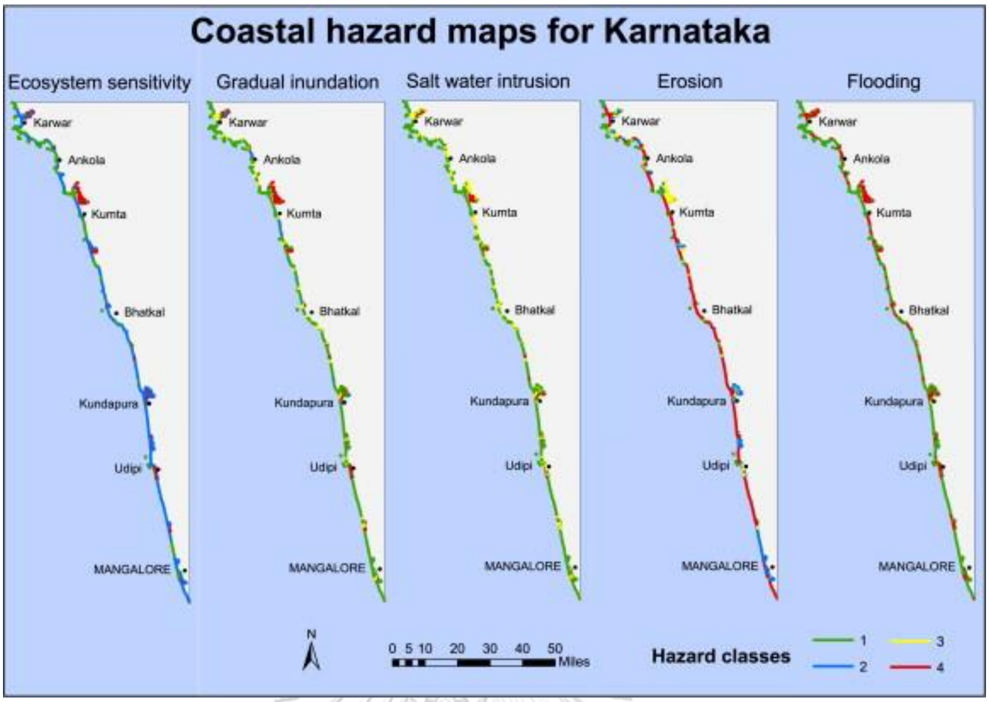


Figure 4. Map of coastal hazards for Karnataka showing the intensity of natural disasters (Rosendahl Appelquist & Balstrom, 2015).

2.4 Coastal Vulnerability Index

The Coastal Vulnerability Index (CVI) is widely used in coastal vulnerability assessment using data from geomorphology and physical characteristics. However, there is no unique approach to be adopted and existing ones can supply different information (Koroglu et al., 2019). The physical characteristics of the coastal system were related to the coastal vulnerability in a quantifiable manner. The indicators that were used in comprehensive assessments, namely geomorphology coastal slope, rate of erosion and accretion, mean significant wave height, mean tidal range, and rate of sea-level rise (Mohd et al., 2019; Sheik Mujabar & Chandrasekar, 2011). The rank for each variable was into five vulnerability rankings i.e., very low, low, moderate, high, and very high (Table 3-4).

Table 3. Vulnerability ranking of CVI variables (Sheik Mujabar & Chandrasekar, 2011).

Variables	Very low	Low	Moderate	High	Very high
Geomorphology	Rocky cliffs	Medium cliffs	Low cliffs, Alluvial plains	Cobble beaches, Estuary	Sand beaches, Salt marsh, Mud flats
Shoreline change rate (m/y)	>3.0	1.0–3.0	-1.0–1.0	-1.0–3.0	<-3.0
Coastal slope (deg)	>4.5	4.0–4.5	3.5–4.0	3.0–3.5	<3
Relative sea-level change (mm/y)	<1.8	1.8–2.5	2.5–3.0	3.0–3.4	>3.4
Mean wave height (m)	<0.30	0.30–0.60	0.60–0.90	0.90–1.20	>1.20
Mean tide range (m)	>6.0	4.0–6.0	2.0–4.0	1.0–2.0	<1.0

Table 4. Vulnerability ranking of CVI variables (Mohd et al., 2019).

Variables	Very low	Low	Moderate	High	Very high
Geomorphology	Rocky cliffs	Composite Of sand and rocks	Sand	Composite Of clay and sand	Muddy flat area
Slope Coastal (%)	>4.8	4.7–3.6	3.5–2.4	2.3–1.2	<1.1
Rate of Erosion and Accretion (m/y)	>2.0 (Accretion)	1.9–1.0 (Accretion)	0.9 – -0.9 (STable)	-1.0 – -1.9 (Erosion)	<2.0 (Erosion)
Rate of SLR (m/y)	<0.24	0.25–0.30	0.31–0.40	0.41–0.50	>0.50
Mean Significant wave height (m)	<0.8	0.9–1.3	1.4–1.8	1.9–2.3	>2.4
Mean Tide range (m)	<0.5	0.5–1.0	1.0–1.5	1.5–2.0	>2.0

The research of Bagdanavičiūtė et al. (2015) proposed indicators to characterize relatively low-lying coastal segments with negligible tidal range but affected by substantial storm surges. Using the seven variables i.e., historical shoreline change rate, beach width, beach height, beach sediments, underwater slope, sand bars, and mean significant wave height (Table 5). The assessment was performed following two scenarios (I) all criteria contribute equally, (II) each criterion may have a different contribution to the coastal vulnerability by an analytical hierarchical process (AHP) (Table 5).

Furthermore, Denner et al. (2015) proposed indicators of physical vulnerability focused on estuarine location. The five variables i.e., beach width, dune width, distance to 20 m isobaths (replace with a parameter for coastal slope calculation and rating. Finally, the distance of vegetation behind the back beach, and percentage of the outcrop. The rank for each variable was into four vulnerability rankings: very low, low, moderate, and high (Table 6).

Table 5. Vulnerability ranking of CVI variables (Bagdanavičiūtė et al., 2015).

Variables		Very low	Low	Moderate	High	Very high
Geologic	(a) historical shoreline changes rate (m/yr)	>1	0.3–1	-0.3–0.3	-0.3– -1.0	<-1.0
	(b) Beach width (m)	>60	40–60	30–40	20–30	<20
	(c) Beach height (m)	>4	3–4	2–3	1–2	<1
	(d) Beach sediments (m)	Sand/pebble/ till/boulders	Sand/ gravel/ pebble	Sand/gravelly sand/sand with gravel	Sand	Sand/ Peat/ Sapropel
	(e) Underwater slope (tanα)	>0.0005	0.0005–0.001	0.001–0.008 0.001–0.005	0.008–0.01 0.005–0.01	>0.01
	(f) Sand bars (underwater slope)	>4	3	2	1	0
Physical process	(g)Mean significant wave height (m)	<0.5	0.5–0.6	0.6–0.7	0.7–0.8	>0.8

Table 6. Physical vulnerability indicators and parameter ratings of level of vulnerability (Denner et al., 2015).

Variables	Very low	Low	Moderate	High
Beach width	>150 m	100–150 m	50–100 m	<50 m
Dune width	>150 m	50–150 m	25–50 m	<25 m
Distance to 20 m isobath	>4 km	2–4 km	1–2 km	<1 km
Distance of vegetation behind the back beach	>600 m	200–600 m	100–200 m	100 m
Percentage Outcrop	<50%	20–50%	10–20%	<10%

The research of Hoque et al. (2019) assessed coastal vulnerability using geospatial techniques along the eastern coast of Bangladesh. The eight variables i.e., elevation, coastal slope, geomorphology, storm surge height, bathymetry, shoreline change rate, sea level rise, and tide range (Table 7).

Table 7. Vulnerability ranking of CVI variables (Hoque et al., 2019).

Variables	Very low	Low	Moderate	High	Very high
Elevation (m)	>6	>4–6	>2–4	>1–2	<1
Coastal slope (%)	>1.2	1.20–0.90	0.90–0.60	0.60–0.30	<0.30
Geomorphology	Rocky coast	Medium rocky coast, Inundated coast, Agriculture and saltpan	Low cliff, Alluvial plains	Sand beaches, Estuary, Lagoon, Vegetated coast (other than mangroves), Artificial structures	Barrier beaches, Salt marsh, Mud flats, Mangrove, Coral reefs
Storm surge height (m)	<0	0–3	3–6	6–9	>9
Bathymetry (m)	>-4	-3 – -4	-2 – -3	-1 – -2	>-1
Shoreline change rate (m/y)	>6	6–2	2 – -2	-2 – -6	<-6
Sea level rise (mm/y)	<1	>1–2	>2–3	>3–4	>4
Tide range (m)	>6	4–6	2–4	1–2	<1

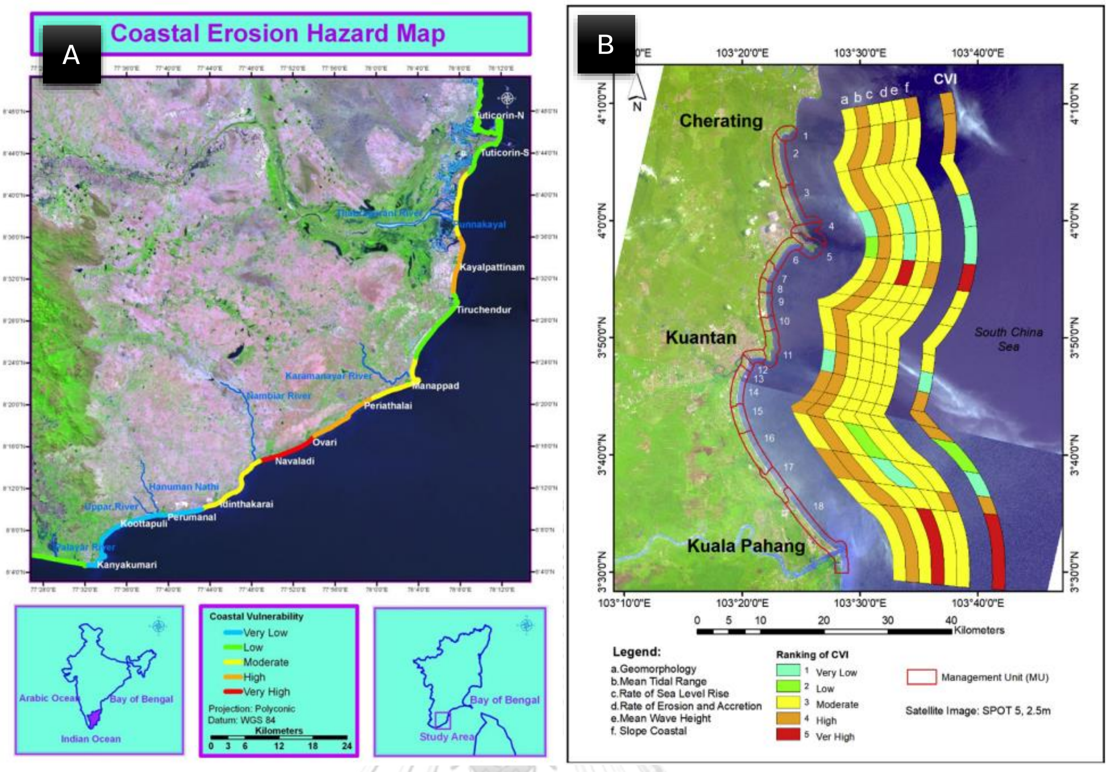
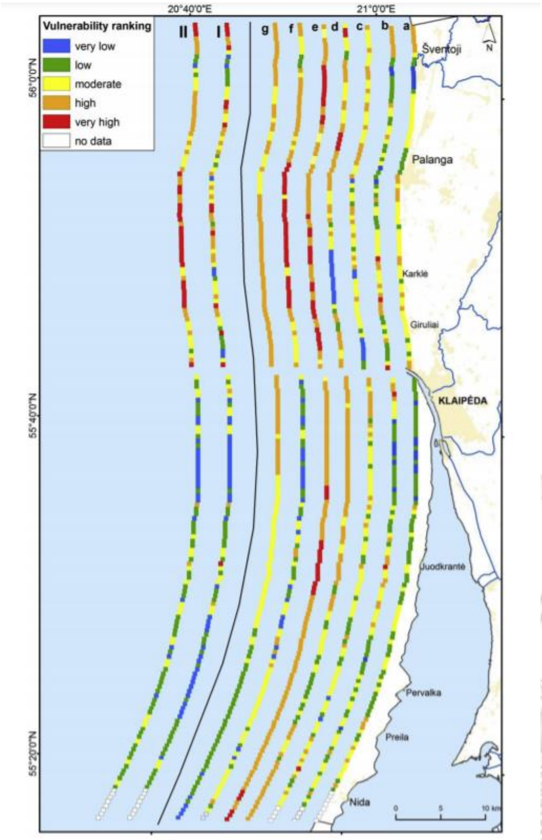


Figure 5. (A) Coastal erosion hazard map showing the coastal vulnerability level of Sheik Mujabar and Chandrasekar (2011) and (B) Coastal vulnerability map illustrating the coastal vulnerability level of Mohd et al. (2019).



Values of coastal vulnerability index for vulnerability levels.

Vulnerability class	CVI	Length (km) of coastal sectors	CVI_w	Length (km) of coastal sectors
Very high	34.0–45.3	6	3.67–4.35	13.5
High	25.7–34.0	10	3.23–3.66	15
Moderate	18.1–25.7	21	2.80–3.22	20
Low	12.1–18.1	29.5	2.54–2.80	26.5
Very low	3.7–12.1	18.5	1.89–2.53	10

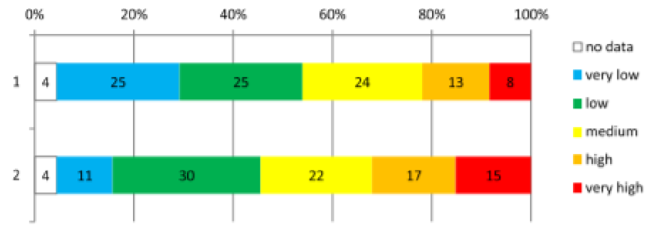


Figure 6. Vulnerability map and length of the shoreline (%) in each vulnerability class according to scenarios I and II of Bagdanavičiūtė et al. (2015).

Figure 7. Coastal vulnerability map illustrating the shoreline vulnerability rates superimposed of Denner et al. (2015).

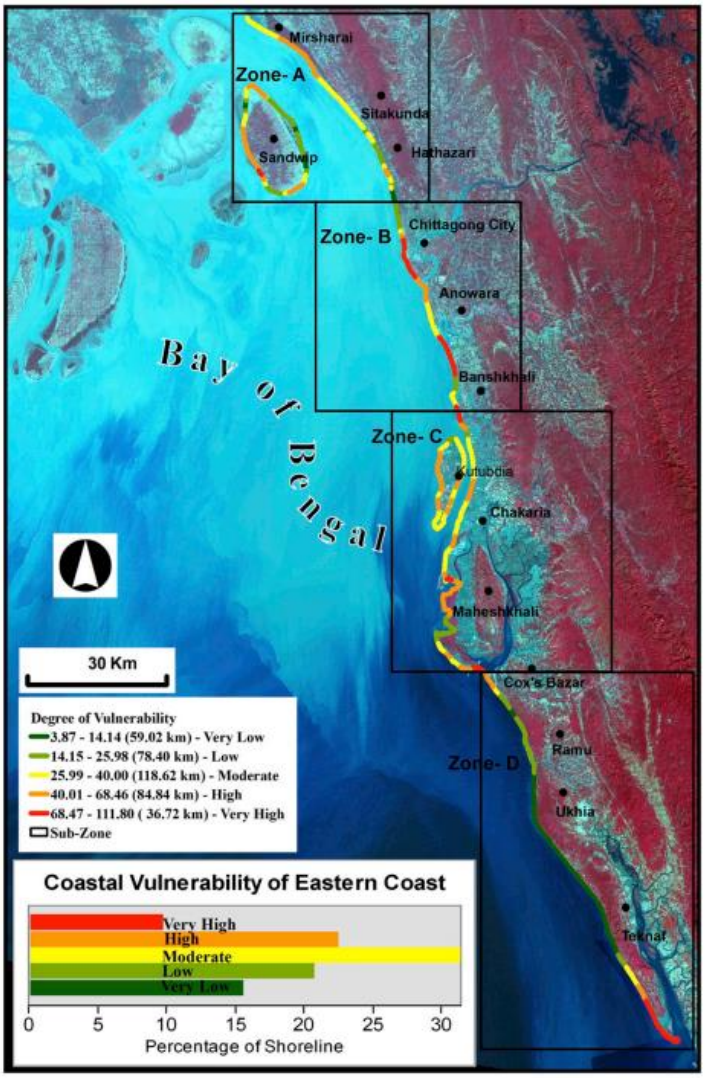


Figure 8. Coastal vulnerability map showing coastal vulnerability levels in the eastern coast of Bangladesh (Hoque et al., 2019).

CHAPTER 3 METHODOLOGY

3.1 Coastal Hazard Wheel (CHW)

3.1.1 Creating a Coastline

Creating the coastline with satellite imagery from Google Earth Pro traces the coastline along the vegetation and beaches. This was determined by the visually observable physical properties of the coast. Then, open data in ArcGIS program to create a geodatabase for assessment.

Figure 9. An example of the creation of a coastline tracking in the study area.

Connect each polyline using the merge tool in the editor panel. Next, use the dissolve tool for create a new single coastline. Then, add a new field at the attribute Table to fill in the details of the Hazard Code. Start editor by the split tool for classification. Begin from the center of the wheel through the outside by identifying the geological layout, wave exposure, tidal range, flora/fauna, sediment balance, and storm climate (Figure 3).

3.1.2 Determination of Criteria from CHW

The hazard assessment was conducted to use data according to Rosendahl Appelquist (2016) that is available in the main manual CHW framework paper including a description determined of each variable and inherent hazard level.

1) Geological layout based on classification of geomorphologies which includes sediment plain, barrier, delta/low estuary island, sloping soft rock coast, flat hard rock coast, sloping hard rock coast, coral island, and tidal inlet/sand split/river mouth as follow Table 8.

Table 8. Key characteristics of the different geological layout categories.

	Low-lying coast	**Sloping coast**
Sedimentary/soft rock material	Sedimentary plain Barrier Delta/low estuary/island Tidal inlet/sand spit/river mouth	Sloping soft rock coast
Hard rock material	Flat hard rock coast	Sloping hard rock coast
Mixed	Coral island	

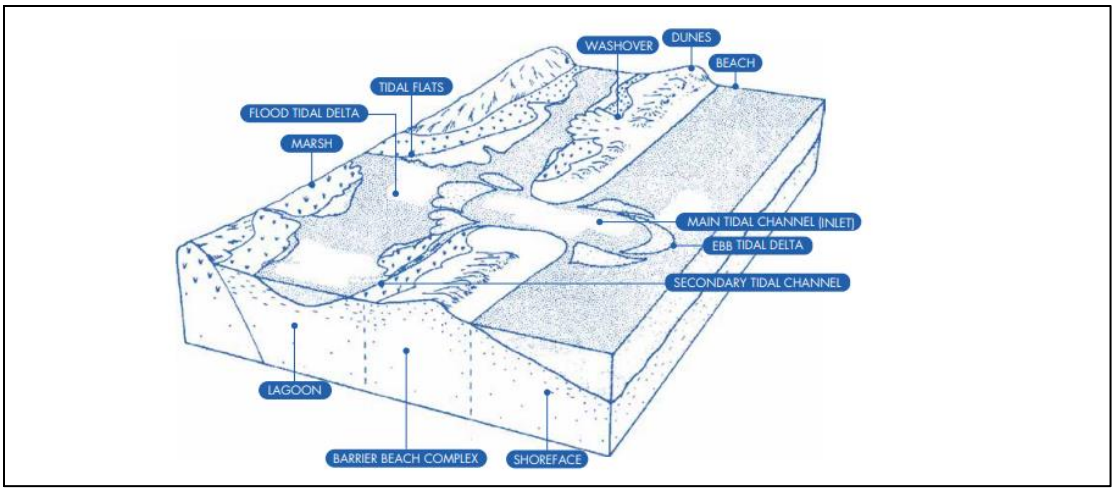


Figure 10. Assessment of coastal geological layout by considering the barrier system, the outer beach environment, and the environment behind the barrier (Rosendahl Appelquist, 2016).

2) Wave exposure is based on the map of global wave environments. The sites are located in “West coast swell”, “East coast swell” and “Trade/monsoon influences” which are classified as swell wave climates, while the remaining types are classified as non-swell wave climates (Figure 11). Then assess specific coastal conditions for wave exposure classifications as follow Table 9.

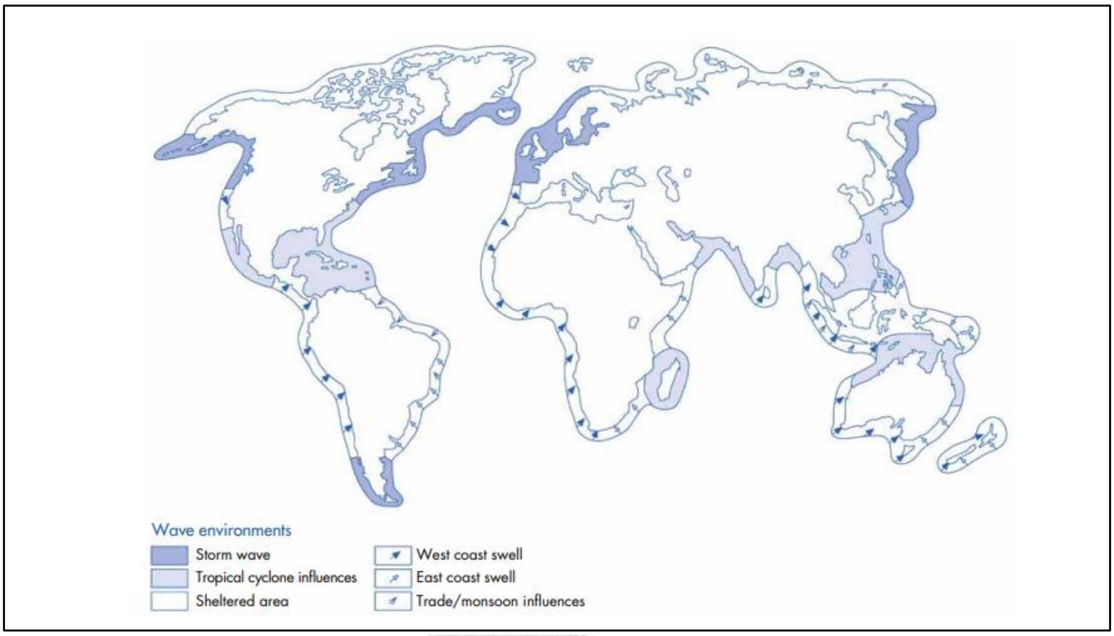


Figure 11. Classification of wave exposure in the study area based on a map of global wave environments (Rosendahl Appelquist, 2016).

Table 9. Wave exposure classification for the CHW system.

General wave climate	Waterbody size (fetch length)	Specific coastal conditions	CHW classification
Swell wave climate (West coast swell, East coast swell, Trade monsoon influences)	Any	Extreme swell (West coast swell south of 30°S)	Exposed
		Swell	Moderate exposed
		Back-barrier, inner waters, inner estuary, fjord	Protected
Non-swell wave climate (Storm wave, Tropical cyclone influences, Sheltered area)	>100 km	Stronger on-shore winds	Exposed
		Weak on-shore winds	Moderate exposed
	10-100 km	Stronger on-shore winds	Moderate exposed
		Weak on-shore winds	Protected
	< 10 km	Any	Protected

3) Tidal range based on a map over global tidal environments. The classification of coastlines can be grouped into various tidal environments based on tidal range and a generally used classification system operates with three main categories micro-tidal, meso-tidal, and macro-tidal.

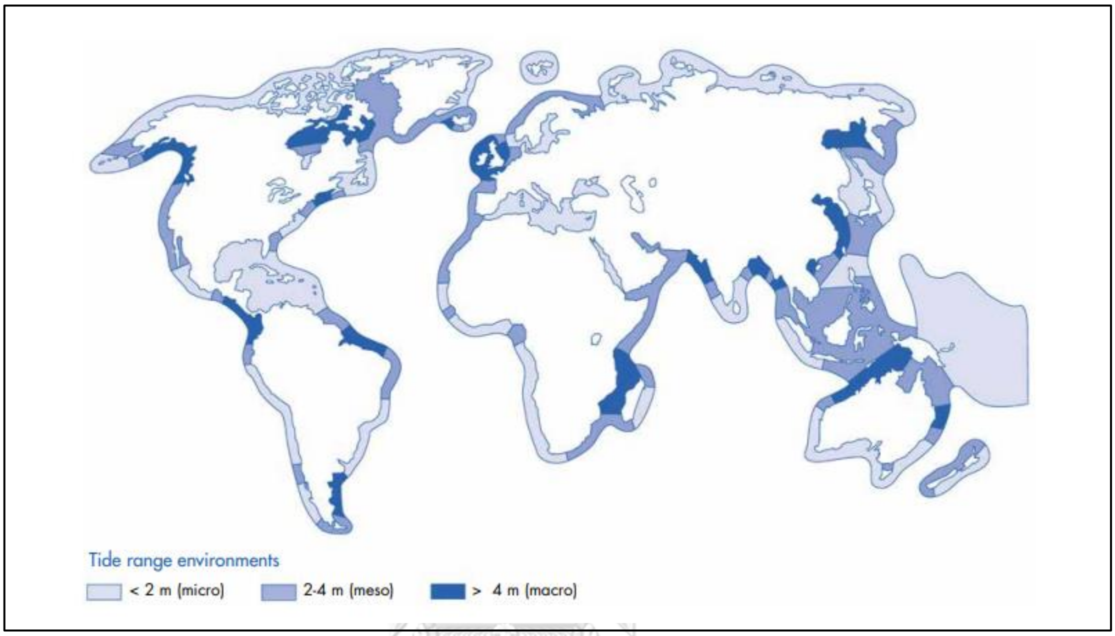


Figure 12. Classification of tidal range in the study area based on a map of global tidal environments (Rosendahl Appelquist, 2016).

4) Flora/fauna based on classification by Google Earth's satellite images for observing the vegetation characteristics of the coastal area include marsh, mangrove, vegetated, not vegetated categories, and Corals

5) Sediment balance can observe by Google Earth's satellite images and Google Earth’s timeline function. The sediment balance section includes the two main categories balance/deficit and surplus for sedimentary/soft rock. The two special categories no beach and beach apply to the hard rock coastlines (Figure 13).

Figure 13. Example comparison of sediment balance from Google Earth's timeline function.

6) Storm climate classification areas are indicated to be under tropical cyclones and outside these areas based on the map of global wave environments (Figure 11).

3.2 Coastal Vulnerability Index (CVI)

3.2.1 Determining assessment criteria

Descriptions of the criterion for coastal vulnerability assessment in the study area according to several research reference studies as follows:

Table 10 Descriptions of the criteria for coastal vulnerability assessment

criteria	Descriptions	Reference
Geomorphology	The geomorphology as a result of surface changes in the Holocene period, such as beaches, muddy beaches, mangrove forests, rocky shores, river mouths, etc. will affect the severity of disasters that are not equal	Mohd et al. (2019)
Coastal slope	The coastal slope measure distance from the inclination angle of the coastline to the mean sea level line. Different slopes will affect the severity of coastal unequal disasters.	Mujabar & Chandrasekar (2011)
Coastal shoreline change rate	Changes caused by erosion and deposition of coastal sediments. Measure changes in coastline comparisons from past and present aerial and satellite imagery.	Bagdanavičiūtė et al. (2015)
Mean significant wave height	One-third of the highest wave height average during a period of 12 hours	Mohd et al. (2019)
Mean tidal range	Vertical variation of the tide calculated from the average annual tidal range from the predicted tide sequence Table.	Mohd et al. (2019)
Rate of sea level rise	The rate of sea level rise is the result of climate change which has increased the average global temperature. affecting global sea level changes.	(Hoque et al., 2019)
Underwater slope	Underwater measure distance from the slope of the coastline to a depth of 20 m, different slopes will affect the severity of coastal disasters.	Palmer et al. (2011)

1) The different of characteristics geomorphology when natural disasters occur along the coast such as sea level rise, and storm surge. These responses and resistance to hazard vulnerability are not equal. The rocky coastal areas have low vulnerability because rocks are more resistant than silt or sandy sediments that are high vulnerability to erosion and flooding. The geomorphology in the study area was determined by imagery from Google Earth satellites and evaluated the vulnerability of this criteria according to Mohd et al. (2019).

2) Coastal slope is relative to the intensity of the wave energy. low slope coasts are evenly smooth and may have high vulnerability due to the smoothness of the area caused when a storm surge hits the coastline be the cause of flooding and erosion to the beach area or intrusiveness on the area behind the beach wide area. It affects more than areas with high slopes. The coastal slope in the study area is considered based on surveys and data collection by beach profile and evaluated the vulnerability of this criteria according to Sheik Mujabar and Chandrasekar (2011).

3) Coastal shoreline change rate is a change of erosion or sediment deposition that occurred from natural disasters such as sea level rise and storm surges. The differentiation between geomorphology and coastal structures whose responses to hazard vulnerability are not equal. This can be measured by a comparison of aerial photographs or satellite imagery conducted to measure the rate of erosion and sediment deposition from the past compared to the present. The study area was determined from the marine and coastal resources information Prachuap Khiri Khan Province report (Department of Marine and Coastal Resources, 2018) and evaluated the vulnerability of these criteria according to Bagdanavičiūtė et al. (2015).

4) Wave is the main hydrodynamic energy of the coast which increased along the height. When the wave surfs the coast causes erosion, storm surge, and sediment deposition. The coast that has an average wave height of one-third of the highest wave height average during a period of 12 hours consistently high expect to get coastal has a high vulnerability. The mean significant wave height in the study area used data from the research of Kompor et al. (2018) and evaluated the vulnerability of this criteria according to Mohd et al. (2019).

5) Mean tidal range is relative to natural disasters. The coasts have an average tide range of high because this has a high vulnerability effect than the tide range is low. The mean tidal range in the study area used data from Hydrographic Department, Royal Thai Navy, and evaluated the vulnerability of this criteria according to Mohd et al. (2019).

6) The rate of sea level rise occurred by global climate change. The change in the mean sea level measured by tide-gauge stations is called relative sea level change. The coasts have a rate of change in sea level that is high expecting a high hazard vulnerability. The rate of sea level rise in the study area used data from the research of Sojisuporn et al. (2013) and evaluated the vulnerability of this criteria according to Hoque et al. (2019).

7) Underwater slope relative to the movement towards the coast of the wave. When the wave crashed against the seabed caused the strength of the wave that hit the coastline. The different distances result in different hazard levels. The underwater slope in the study area was measured from the pouring angle of the shoreline to a depth of 20 m. This area used the underwater depth data obtained from the survey of the Hydrographic Department, Royal Thai Navy, and it was created into the GIS database by Geo-Informatics and Space Technology Development Agency (Public Organization) (2017) and evaluated the vulnerability of these criteria according to Denner et al. (2015).

Table 11. The ranking of coastal vulnerability in the study area.

Parameter	**Coastal Vulnerability Ranking**				
	Very low 1	**Low 2**	**Moderate 3**	**High 4**	**Very high 5**
Geomorphology	Rocky Cliff	Composite of sand and rocks	Sand	Composite of clay and sand	Muddy flat area
Coastal slope (deg)	> 4.5	4 – 4.5	3.5 – 4	3 – 3.5	< 3
Coastal shoreline change (m/y)	>1	0.3 – 1	-0.3 – 0.3	-0.3 – -1	>- 1
Mean significant wave height (m)	<0.8	0.9 – 1.3	1.4 – 1.8	1.9 – 2.3	>2.4
Mean tidal range (m)	< 0.5	0.5 – 1.0	1.0 – 1.5	1.5 – 2.0	> 2.0
Rate of sea level rise (mm/y)	< 1	> 1 – 2	> 2 – 3	> 3 – 4	> 4
Underwater slope (km)	>4	4 – 3	3 – 2	2 – 1	<1

3.2.2 Update land use land cover compare satellite imagery

Land use and land cover in 2019 (Department of Land Development, 2019) Determination distance from the coast 1 km by buffer tool. Then, proceed to adjust data with the editor tool in the ArcMap program while editing, it compares along with satellite imagery from Landsat 9 in 2021 and Google Earth Pro (Figure 14).

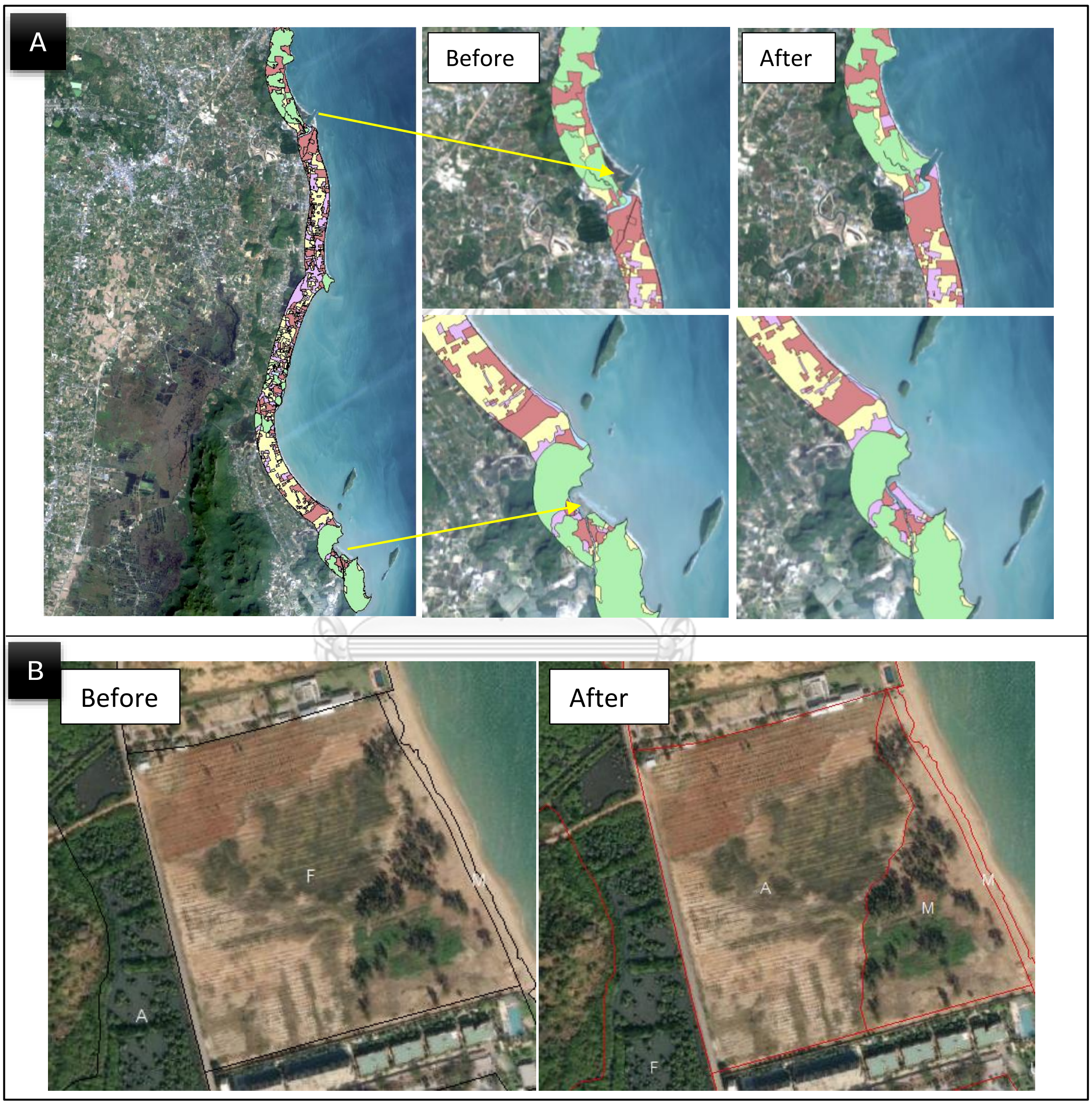


Figure 14. (A) Example update land use data with satellite imagery from Landsat 9, (B) Example editor land use data with satellite imagery from Google Earth Pro.

Field data collection is coastal data collection in the study area consist of surveying and conducting beach profile preparation from the survey of 9 study points divided by beach cell system and different coastal structures. However, it proceeds to measure the beach level with a Total Station camera of 6 study points because 3 study points have available information from the study in the past (Figure 15). In addition, surveying the coastal structure and validating the translation of satellite imagery (Figure 17).

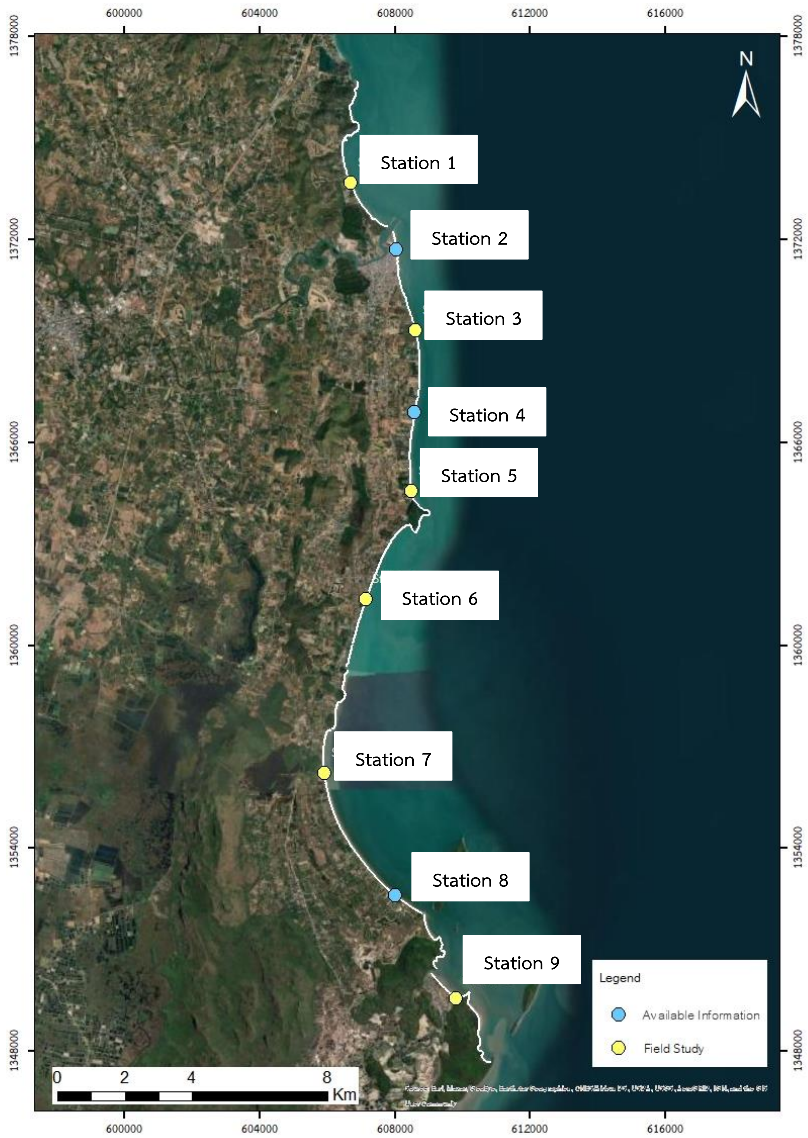


Figure 15. A map of the location field data collection showed an overview station measurement of the coastline.

Table 12. Location of field data collection.

Study point	coordinates		Date collection data
Station 1	606712 E	1373681 N	21 May 2022
Station 3	608626 E	1369314 N	
Station 5	608509 E	1364571 N	
Station 6	607058 E	1361371 N	
Station 7	605940 E	1356230 N	
Station 9	609828 E	1349573 N	

1) Beach profile is the coastal measurement of the terrain in the direction perpendicular to the coast. Coastal elevation relative to mean tide water level (MTWL) and beach width were measured in the field. A horizontal distance from the coastline or seawall to the mean tide water level is a beach width used in this study. Then, the coastal slope was calculated (degrees = $\tan^{-1}$:coastal elevation/beach width). The survey is conducted to use a Total Station camera to measure the distance from the coastline to sea level. Using the time of lowest water referent from a table of highest and lowest water levels of 2022, Hua-Hin station, Prachuap Khiri Khan Province (Table 13).

Table 13. Water level prediction Table from station Hua-Hin (Hydrographic Department, 2022)

Date	Time	Height of sea level (m)
20 May 2022	13:37 p.m.	0.04
	22:33 p.m.	2.85
21 May 2022	14:29 p.m.	0.12
	23:31 p.m.	2.80

Figure 16. Coastal measurement conducts by Total Station camera.

2) Validation of the interpretation of satellite imagery from Google Earth and surveying coastal structures in the study area.

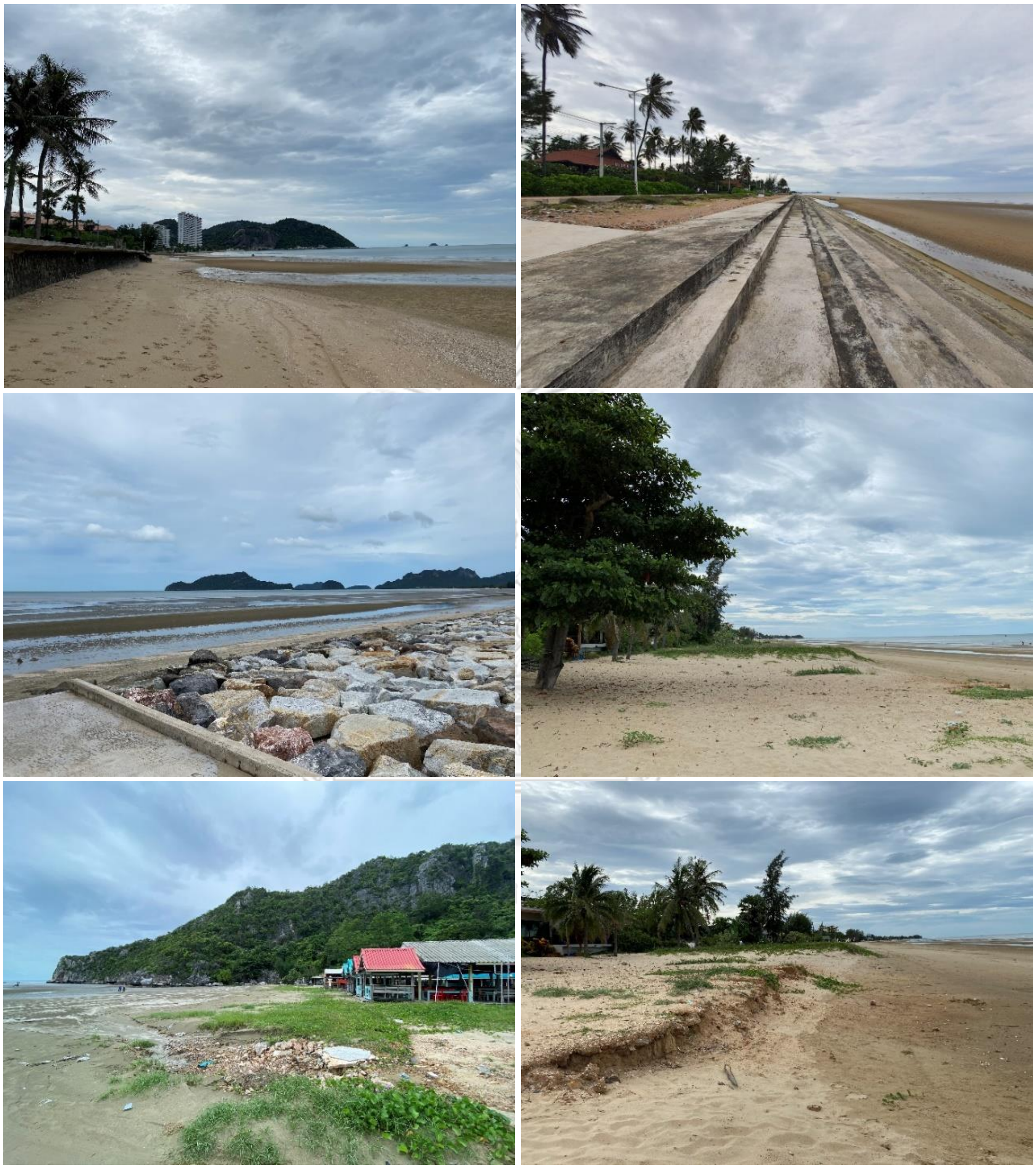


Figure 17. Validation of the coastline traced from the interpretation of satellite imagery by Google Earth Pro, and surveying coastal structures in the study area.

3.2.4 Analysis Hierarchy Process (AHP)

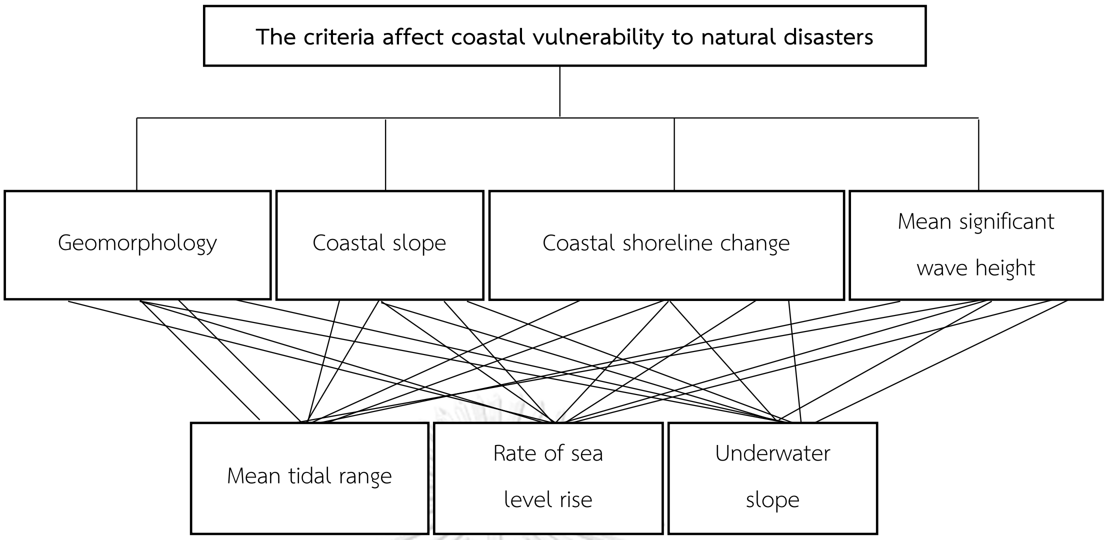


Figure 18 Structure of criteria affects coastal vulnerability to natural disasters

1) Experts weighting each pairwise of criteria. For example, Questionary: If you consider geomorphology criteria more important coastal slope criteria than most in coastal vulnerability assessment to natural disasters Mark ✘ the number 9 in the geomorphology on the left-hand side.

Geomorphology	X	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Coastal Slope
	Left more important									Right more important								

2) Comparisons between each pairwise of criteria to determine the priority weighting. Determination of a number instead of values to find the comparative significance of each sub-garden. The fundamental scale employs numbers 1–9 according to Table 14.

Table 14. The fundamental scale of Comparison between each pairwise of criteria (Saaty, 1990).

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one over another
5	Essential or strong importance	Experience and judgment strongly favor one over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate value between the two adjacent judgments	When compromise is needed

Comparison pairwise under the object of assessment that how much does that factor in comparison with other factors affect the higher factor. Creating a matrix Table according to Table 15.

Table 15. Creating a matrix Table used to display the sum of vertical rows.

Criteria	Factor 1	Factor 2	Factor 3
Factor 1	1	a_{12}	a_{1n}
Factor 2	a_{21}	1	a_{2n}
Factor 3	a_{n1}	a_{n2}	1
Vertical Total	x	y	z

a_{12} is the priority weighting of factor 1 when comparing factor 2 under the objective of assessment and a_{21} is reciprocal (a_{21} = 1/ a_{12}) which under decision criteria factor 1 compares with factor 2 to other factors in the horizontal row of factor 1. The comparison continues until all rows.

3) Weighting analysis after experts were weighted, which shows in numbers. Then, takes numbers comparison to find priority weight in the hierarchical analysis performed at each level from top to bottom according to Table 16.

Table 16. Computation of hierarchical analysis.

Criteria	Factor 1	Factor 1	Factor 1	Horizontal Total	Weighting
Factor 1	1/x	a_{12}/y	a_{12}/z	A	S_1=A/3
Factor 2	a_{21}/x	1/y	a_{2n}/z	B	S_2=B/3
Factor 3	a_{n1}/x	a_{n2}/y	1/z	C	S_3=C/3
Vertical Total	1	1	1	3	1

4) Consideration of the computation of reason for weighting (C.R) which conducts a comparison of all the determining criteria. First, the weight of each criterion is multiplied by the weighting of experts which is the horizontal row (Table 17). Second, take the sum of each row and divide the weight of the row. Then, take the sum of the horizontal total divided number of criteria. The Result equal number of determined criteria called Eigenvalues (L).

Table 17. Computation of Eigenvalues (L).

Criteria	Factor 1	Factor 2	Factor 3	Weight
Factor 1	1	a_{12}	a_{1n}	S_1
Factor 2	a_{21}	1	a_{2n}	S_2
Factor 3	a_{n1}	a_{n2}	1	S_3

Factor 1	$= ((1x\ S_1) + (a_{12}x\ S_2) + (a_{1n}x\ S_3))/\ S_1 = XX$	Eigenvalues= (XX+YY+ZZ)/3
Factor 2	$= ((a_{21}x\ S_1) + (1x\ S_2) + (a_{2n}\ x\ S_3))/\ S_2 = YY$	
Factor 3	$= ((a_{n1}x\ S_1) + (a_{n2}x\ S_2) + (1x\ S_3))/\ S_3 = ZZ$	
Total	XX+YY+ZZ	

5) Consideration of the computation of Consistency Index (C.I.) conducts the weight of each criterion multiplied by the weight of the vertical priority row. Then, the average in the horizontal row gets a multiplication Table for calculated C.I. as follows: *formula 1* and Consistency Ratio (C.R) which conducts a comparison C.I. from matrix Table with Random Consistency Index (R.I) as follows: *formula 2*

$$C.I. = \frac{(L-n)}{(n-1)} \qquad (1)$$

n = *Number of criteria*

$$C.R. = \frac{C.I}{R.I} \qquad (2)$$

$C.R.$ = *Consistency Ratio*

$C.I.$ = *Consistency Index*

$R.I.$ = *Random Ratio*

6) Random Consistency Index (R.I) which is reciprocal matrix sampling using the fundamental scale between 1–9 for the average of R.I as follows Table 18.

Table 18. Random Consistency Index (R.I) (Taherdoost, 2017).

N	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	0.58	0.90	1.12	1.24	1.32	1.40	1.45	1.49	1.51	1.54	1.56	1.57	1.58

If C.R. is less than or equal to 0.10 considered acceptable. If more than 0.10 is considered unacceptable repeat the comparison weighting of criteria until C.R. is considered acceptable.

3.2.5 Approach assessment and formula

Computation of coastal vulnerability assessment was divided into 2 approaches according to Bagdanavičiūtė et al. (2015) First, all criteria are assumed to contribute equally to the coastal vulnerability calculate to *formula 3*. Second, each criterion may be of different importance to coastal vulnerability calculate to *formula 4*.

$$CVI = \sqrt{\frac{a \cdot b \cdot c \cdot d \cdot e \cdot f \cdot g}{7}} \qquad (3)$$

a = *Geomorphology*

b =*Coastal slope*

c =*Coastal shoreline change*

d =*Mean significant wave height*

e =*Mean tidal range*

f =*Rate of sea level rise*

g =*Underwater slope*

$$CVI_w = \sum_{j=1}^{n} Wj \cdot Vij \qquad (4)$$

Wj = *The weight of criterion j*

Vij = *The vulnerability score of area I under criterion j*

n = *The total number of criteria*

3.2.6 The Coastal vulnerability classifications

1) Export attribute Table from ArcMap program to create a Table of data in Excel. Then, calculate the percentile values 0.2, 0.4, 0.6, and 0.8 (20%, 40%, 60%, 80%) respectively (Figure 19).

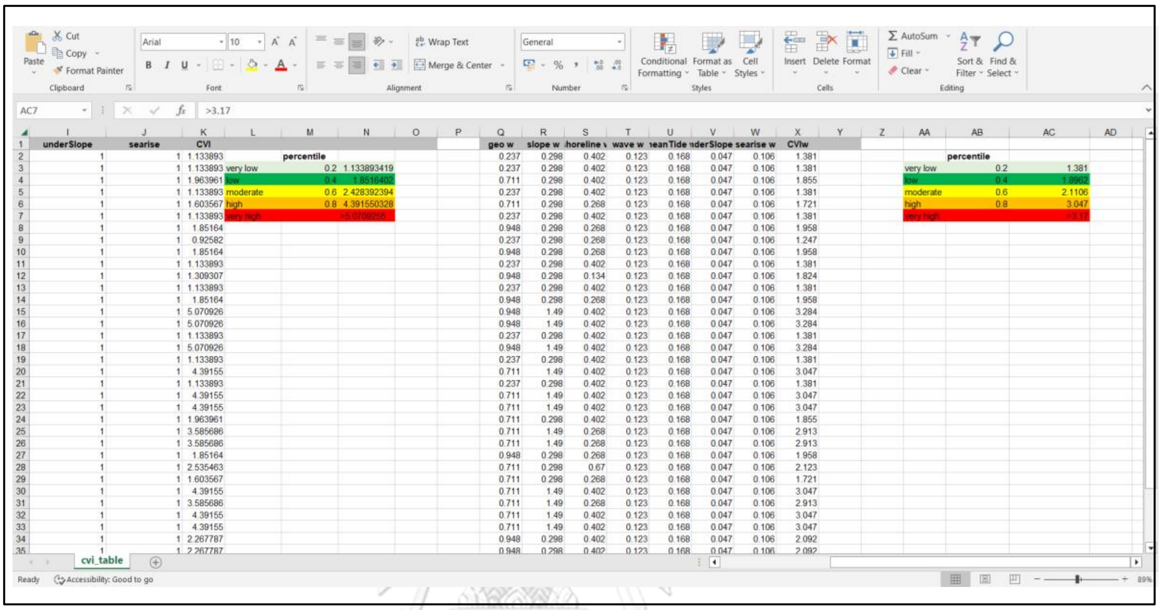


Figure 19. Attribute Table and computation of the percentile in Excel.

2) Classifications the percentile values according to Table 19 in the ArcMap program to classify the percentile values 0.2, 0.4, 0.6, and 0.8 respectively for coastal vulnerability ranking classifies into 5 severities including very low, low, moderate, high, and very high (Figure 20).

Table 19. The score distribution range of percentile classifications.

order	Percentile of CVI	Percentile of CVI_w	Vulnerability
1	0 -1.339	1.37-1.504	Very low
2	1.339-1.852	1.504-2.019	Low
3	1.852-2.428	2.019-2.234	Moderate
4	2.248-4.392	2.234-3.170	High
5	4.392-5.071	3.170-3.407	Very high

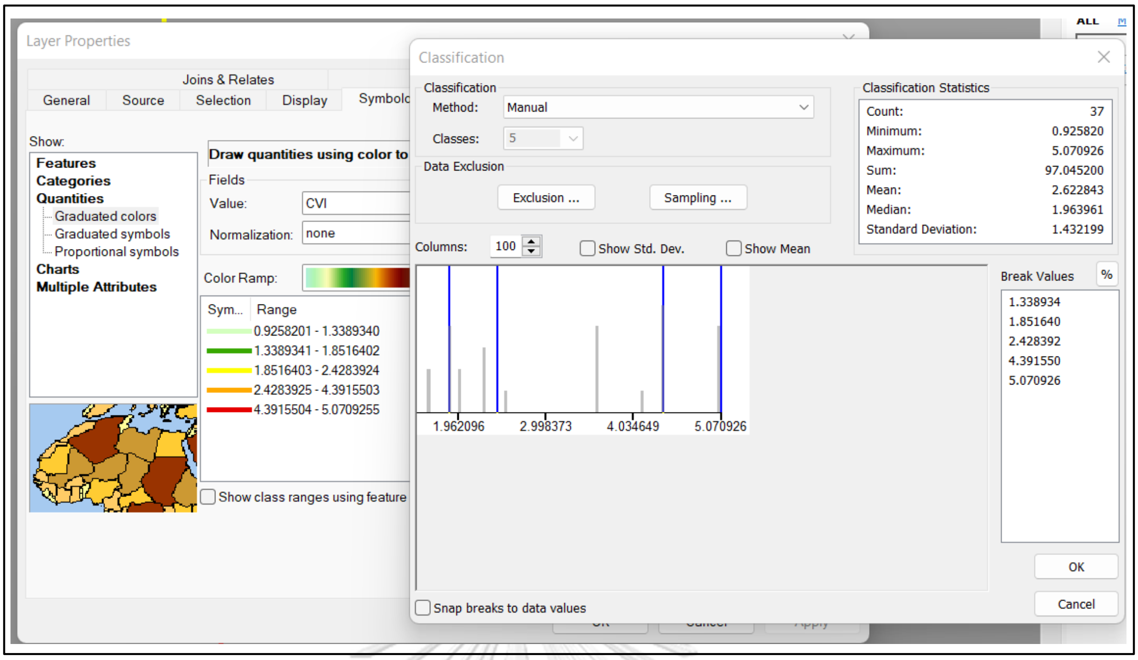


Figure 20. Example of classifications of the percentile in ArcMap program.

3.3 Land Use Land Cover Analysis

The analysis of land use measures the distance is 1 km from the coastline to estimate what categories of land use are in each hazard vulnerability.

3.3.1 Feature to raster and creating fishnet grid

1) Performs the conversion of a line of CVI features into raster format with a cell size of 1000 m. In part CVI_w, proceed with this method, but change the field to the value of CVI_w.

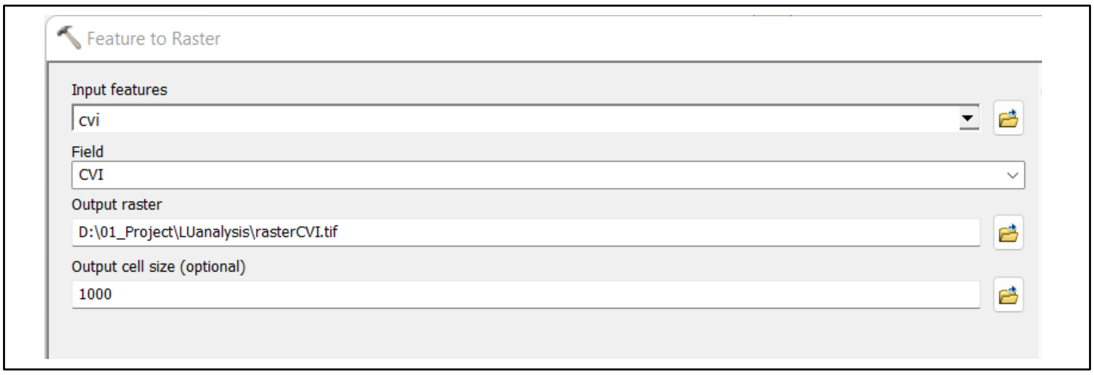


Figure 21. Converting a line of CVI feature to raster with a cell size of 1000 pixels in ArcMap Program.

2) Converting a line conversion from raster format back to vector format.

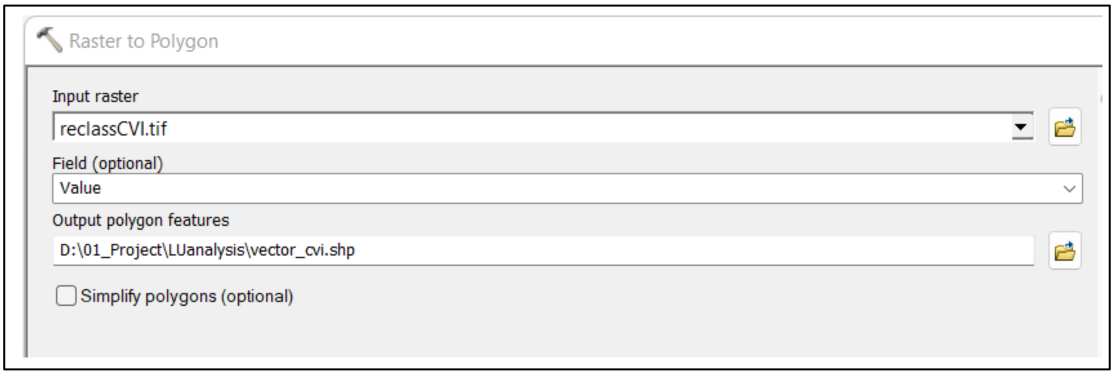


Figure 22. Setting a line of CVI raster to polygon in ArcMap Program.

3) Creating a fishnet grid of 1x1 km from the converted vector format. Then, setting cell size width and height of 1000, the geometry type chooses polygon.

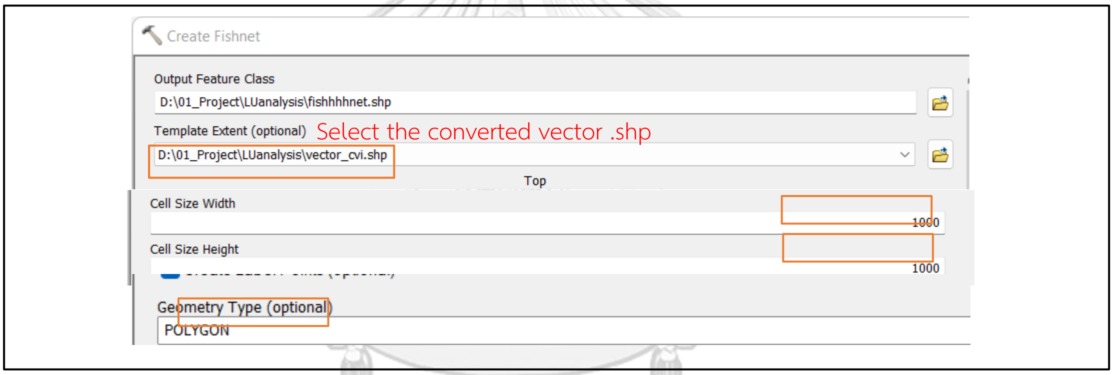


Figure 23. Setting polygon of CVI created fishnet grid of 1x1 km.

3.3.2 Overlay land use with coastal vulnerability lines

1) Add data for both line features to overlay with land use data. In this method conduct one line at a time for cutting the polygon on each line.

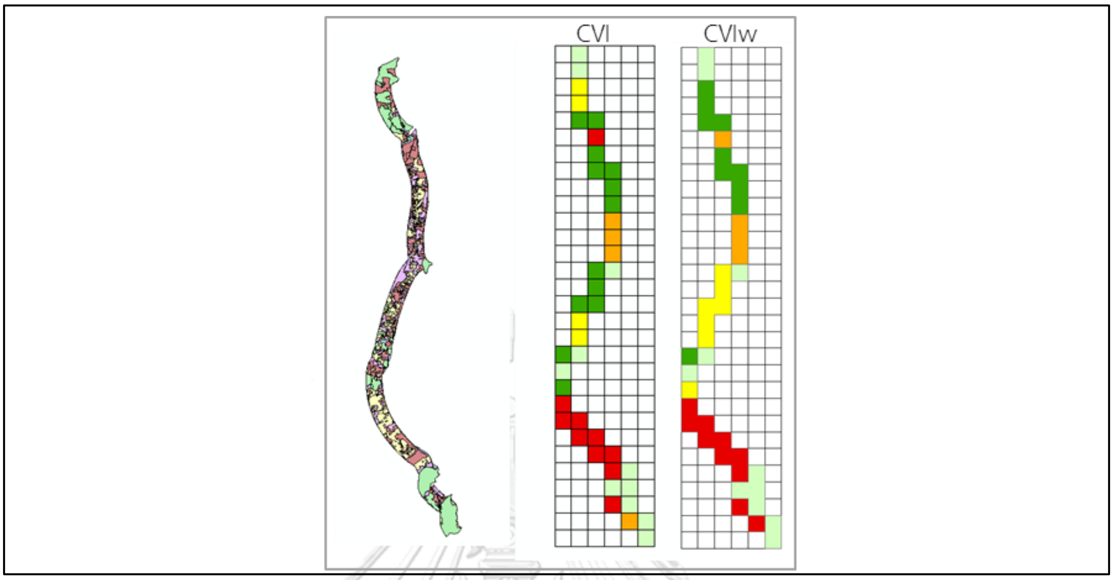


Figure 24. land use data overlay with fishnet grid of 1x1 km of CVI and CVI_w, which overlay one data at a time.

2) Editing data to cut the polygon along the grid cell in each vulnerability. In this method conduct one line at a time for cutting the polygon on each line. Then, calculate the area for each type of land use.

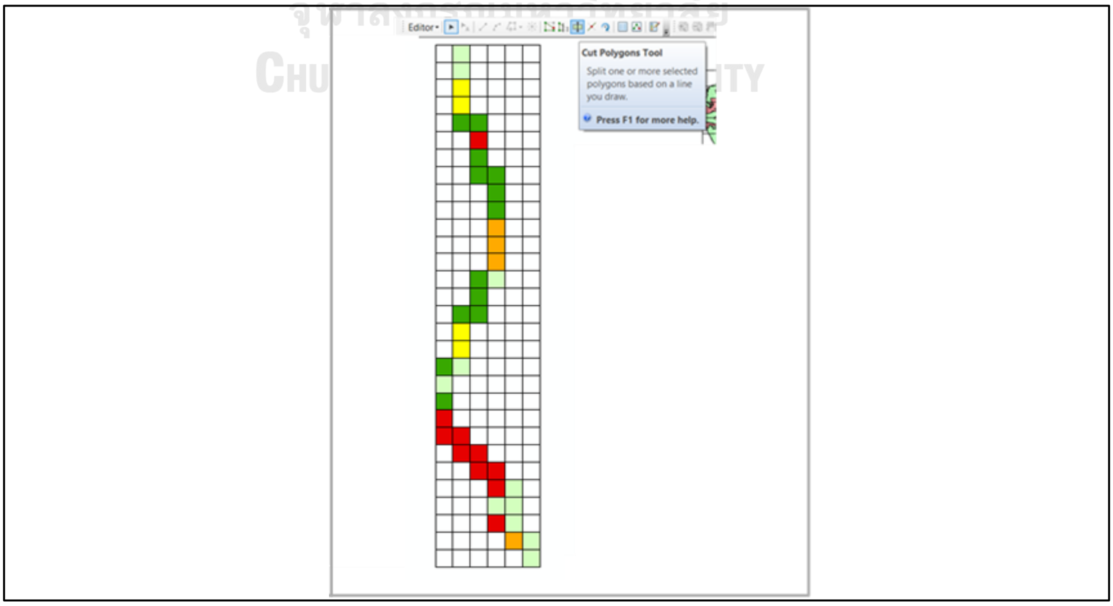


Figure 25. Editor tool for cutting the polygon along the grid cell in each vulnerability level.

CHAPTER 4 RESULT

4.1 Coastal Hazard Wheel

4.1.1 Coastal classifications

The classification of coastal types by CHW revealed in Table 20 that the total length of the coastline was 37.31 km. Sediment plain, Pl-5 type occupied 56 percent of the overall length, or 20.82 km, followed by sloping hard rock coast, R-1 type at 8.08 km (21%). The last two types are tidal inlets/sand spits/river mouths, TSR type, which is 6.61 km (18%), and sloping hard rock coast, R-2 type, which is 1.8 km (5%).

Table 20. The coast types and code CHW for the assessment of inherent hazards level in the study area.

Variable	**Coastal types**				**Total (km)**
	R-1	**R-2**	**PL-5**	**TSR**	
Geological layout	Sloping hard rock coast	Sloping hard rock coast	Sediment plain	Tidal inlet/Sand split/River mount	
Wave exposure	Any	Any	Moderate exposed	-	
Tidal range	Any	Any	Any	-	
Flora/Fauna	Any	Any	Any	-	
Sediment balance	No Beach	Balance/Deficit	Balance/Deficit	-	
Storm climate	Any	Any	Yes	-	
Code CHW					
Flooding	1	1	4	4	
Erosion	1	2	3	4	
Saltwater intrusion	1	1	3	3	
Gradual inundation	1	2	3	3	
Ecosystem disruption	1	1	2	2	
Length (km)	8.08	1.80	20.82	6.61	37.31
Percent of length	21	5	56	18	100

4.1.2 Coastal hazard levels

The coastal hazard levels map (Figure 26) showed the coastal types and multi-natural hazard levels in the study area. The flood (storm surge) hazard is very high throughout most of the area, except for the coastal types of sloping hard rock coast (R-1, R-2) that present a low hazard level. For erosion hazard, a tidal/sand split/river mount (TSR) has a very high intensity level, while a sediment plain (Pl-5) has a high intensity level. In addition, the hazards of saltwater intrusion and gradual inundation (sea-level rise) resulted in a high intensity level for both TSR and Pl-5 coastal types. Lastly, the hazard of ecosystem disruption was shown as moderate in TSR and Pl-5 coastal types.

The assessment of the coastal multi-hazard level of the study area revealed that a very high intensity level of flooding hazard extended almost the entire 27 km length of the study area. Subsequently, an erosion hazard with a high intensity yields the greatest distance, 21 km. For Saltwater intrusion and gradual inundation hazard, a high intensity level is present in most of the area, which is 27 km long. Finally, the hazard level of ecosystem disruption in the study area was determined to be moderate intensity (27 km) as shown in Table 21.

Table 21. The coastal hazard level in the study area.

Hazard levels	**Length (km)**				
	Flooding	Erosion	Saltwater intrusion	Gradual inundation	Ecosystem disruption
Low	10	8	10	8	10
Moderate	0	2	0	2	27
High	0	21	27	27	0
Very high	27	7	0	0	0

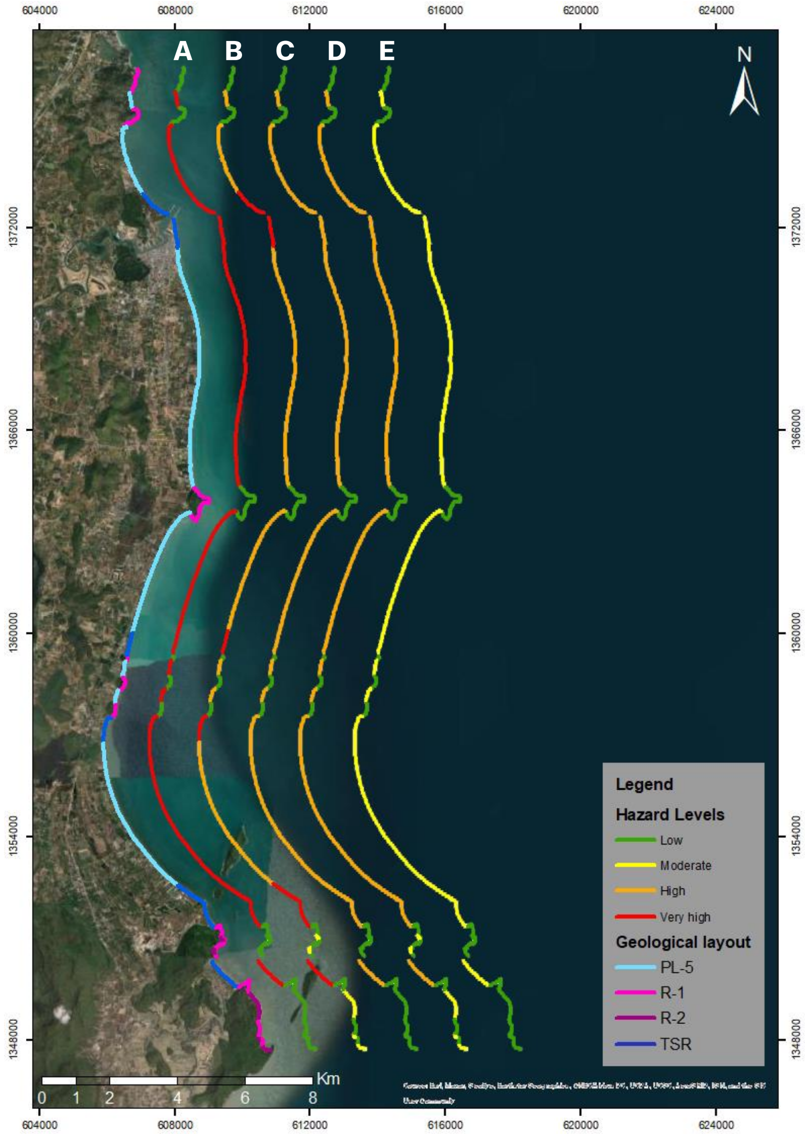


Figure 26. Coastal hazard levels map showed the coastal types and multi-natural hazard levels in the study area including the hazards of flooding (A), erosion (B), saltwater intrusion (C), gradual inundation (D), and ecosystem disruption (E).

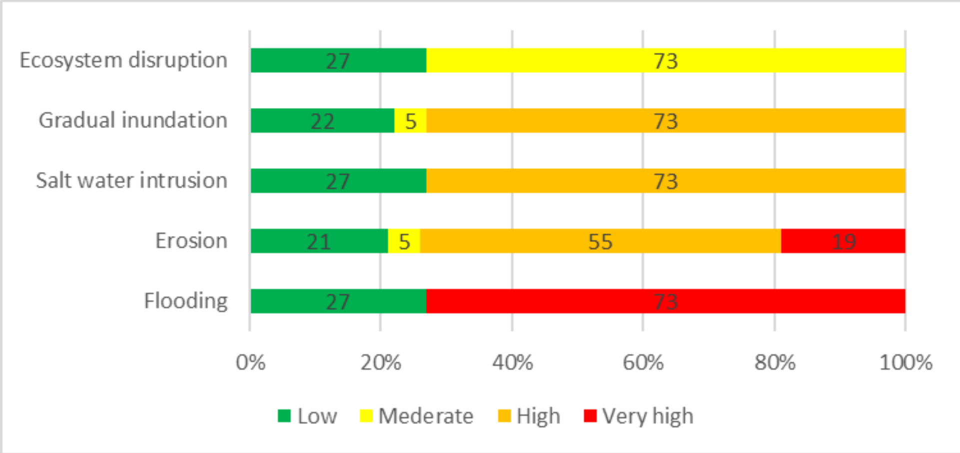


Figure 27. The distribution of hazard levels in the study area (percent of length).

Figure 27 depicts a distribution of multi-natural hazard levels in the study area, revealing that flooding hazard is primarily distributed at a very high intensity level by 73% of the area, followed by erosion hazard, which is primarily distributed at a high intensity level by 55%. Furthermore, saltwater intrusion and gradual inundation hazards were represented at a high intensity level in 73% of the area. In comparison, ecosystem disruption was distributed at a moderate intensity level in 73% of the area.

4.2 Beach Profile

The survey was conducted using a Total Station camera to create a coastal slope and charts to compare coastal topography in the study area from a total of 6 study points and 3 study points were used the beach data that had been studied before was used for the analysis.

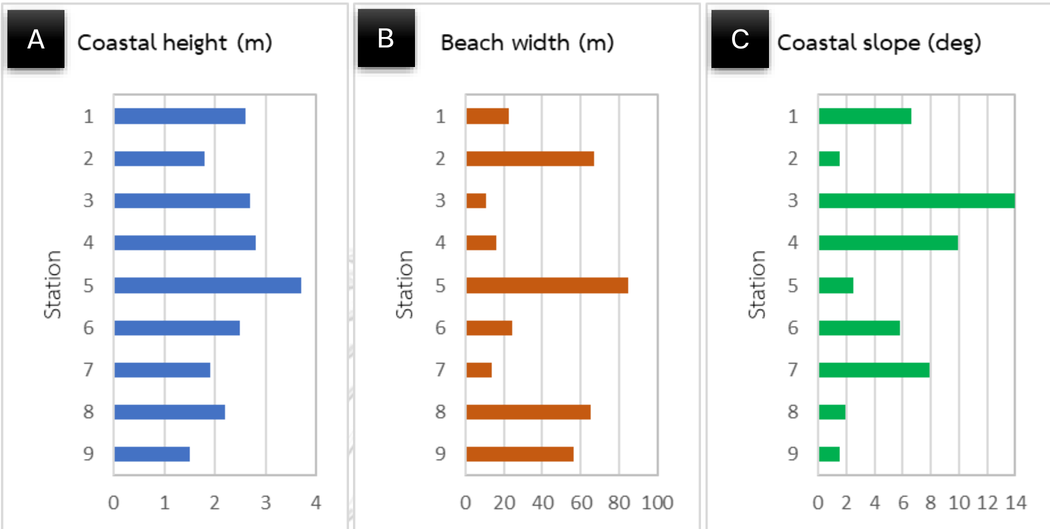


Figure 28. Chart of the result coastal measurement in the study area including (A) coastal height, (B) beach width, and (C) coastal slope.

Figure 28 showed the coastal height in each station. Station 5 had a highest was 3.7 m and station 9 had the lowest height 1.5 m. In addition, beach widths in the study area were noticeably different including the beach which had a width of more than 50 m and a width lower than 50 m. Moreover, coastal slopes included a coastline that had a slope of more than 6 deg, a coastline that had a slope between 2-6 degrees, and a coastline that had a slope lower than 2 degrees.

4.2.1 Station 1: Ban Tao Bungalow.

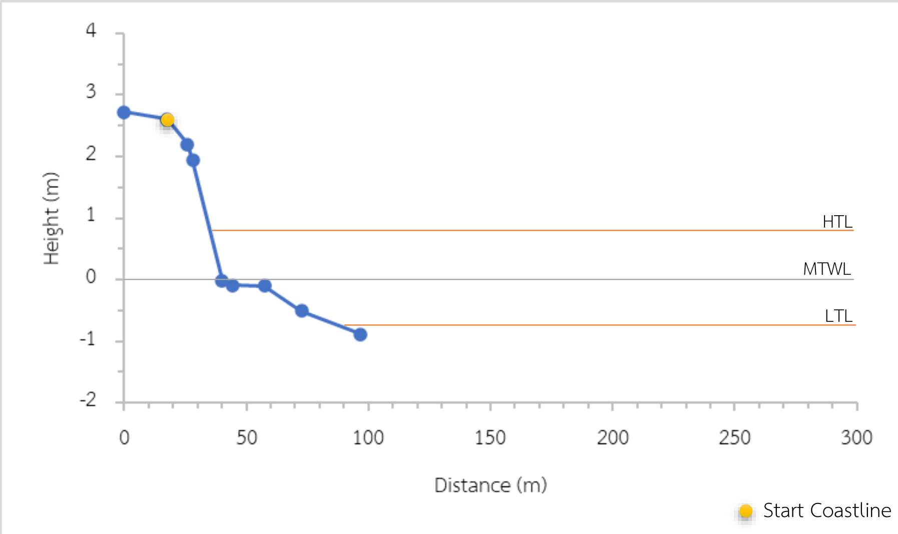


Figure 29. Graph of Beach profile Station 1 showing the coastline relative to mean tide water level (MTWL), high tide level (HTL), and low tide level (LTL).

Figure 30. Pictures of the coast at Station 1, a private seawall was found at the coast.

Station 1 was at the north of entire study area which located in Khao Tao Beach, Pranburi district. The beach height is 2.6 meters, and width of 22.4 meters. The coastal slope is 6.64 degrees.

4.2.2 Station 3: Pattawia Resort

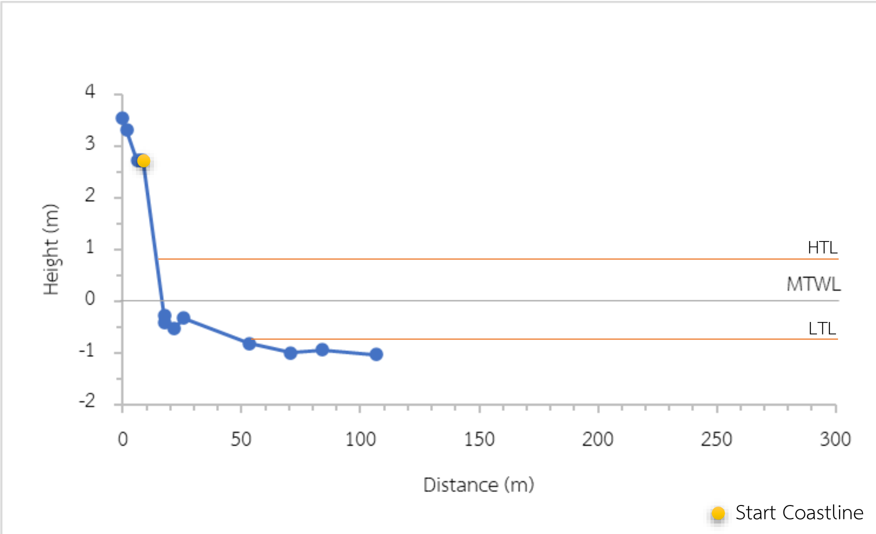


Figure 31. Graph of Beach profile Station 3 showing the coastline relative to mean tide water level (MTWL), high tide level (HTL), and low tide level (LTL).

Figure 32. Pictures of the coast at Station 3, a stepped seawall covered the coast made by the government.

Station 3 is located in Laem Ket beach in Pranburi district found a coastal structure namely a seawall. The beach height of 2.7 meters, and width of 10.96 meters were characterized in this area. The coastal slope is 13.96 degrees.

4.2.3 Station 5: Sea Mountain Resort

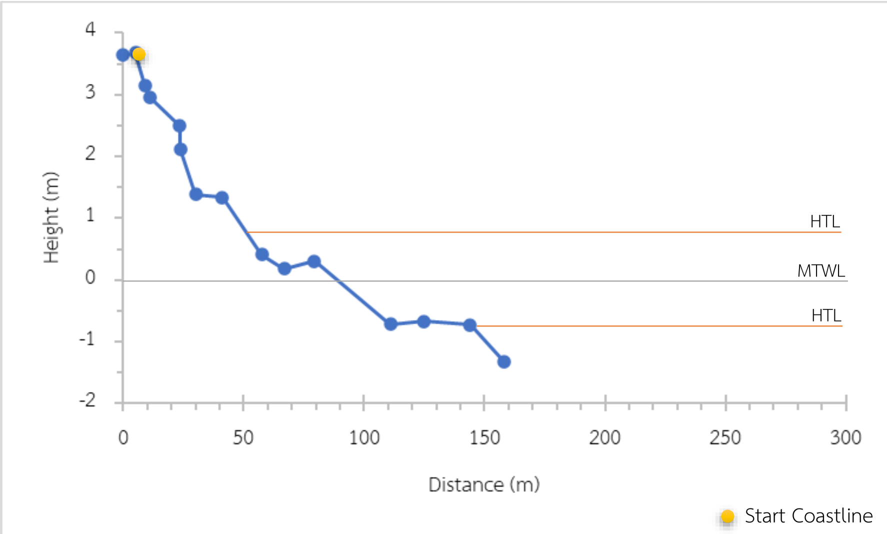


Figure 33. Graph of Beach profile Station 5 showing the coastline relative to mean tide water level (MTWL), high tide level (HTL), and low tide level (LTL).

Figure 34. Pictures of the coast at Station 5, the topography is a wide beach area with a gentle slope.

Station 5 is located near Thao Kosa Forest Park in Pranburi district. The beach height of 3.7 meters, and width of 84.75 meters were recognized. The coastal slope is 2.48 degrees.

4.2.4 Station 6: Baanmai Resort

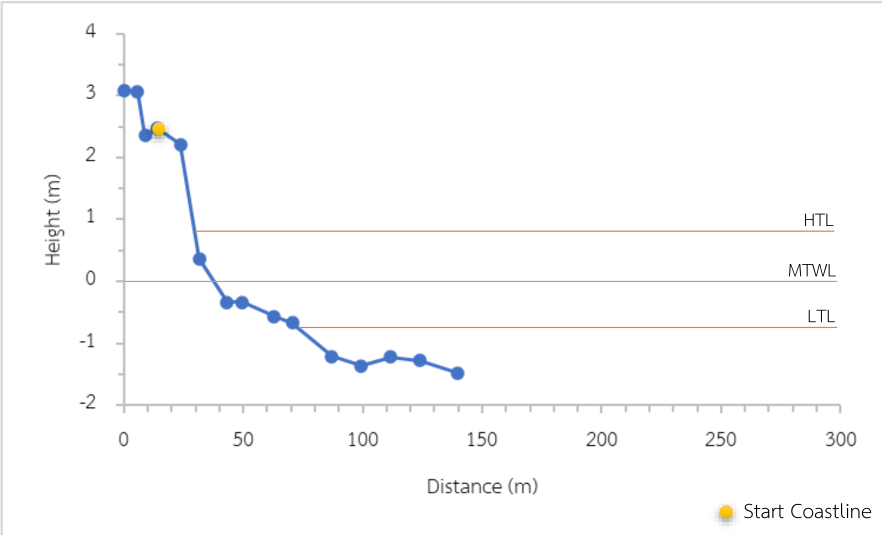


Figure 35. Graph of Beach profile Station 6 showing the coastline relative to mean tide water level (MTWL), high tide level (HTL), and low tide level (LTL).

Figure 36. Pictures of the coast at Station 6, a riprap revetment was found at the coast.

Station 6 is located in Khao Kalok bay, Pranburi district. There was a coastal structure namely revetment. The beach height of 2.5 meters, and width of 24.24 meters were found here. The coastal slope is 5.84 degrees.

4.2.5 Station 7: Villa Marinee

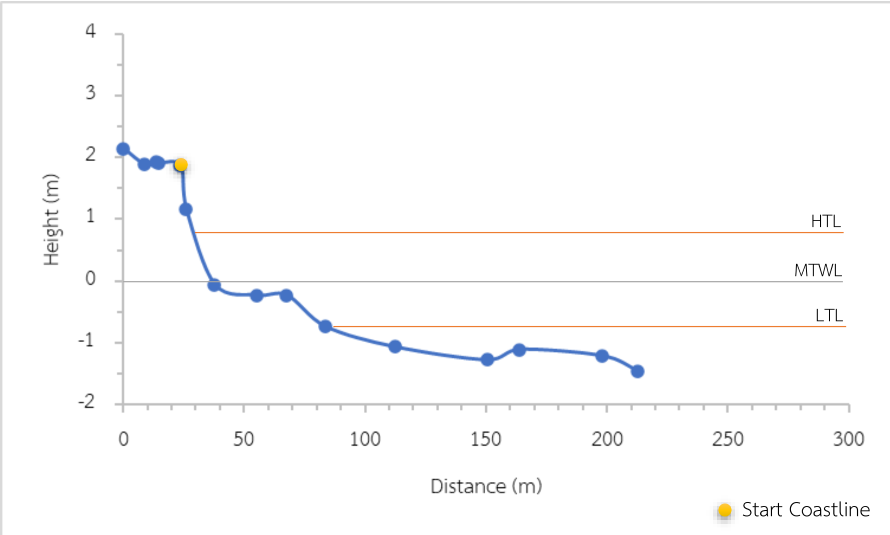


Figure 37. Graph of Beach profile Station 7 showing the coastline relative to mean tide water level (MTWL), high tide level (HTL), and low tide level (LTL).

Figure 38. Pictures of the coast at Station 7, a riprap revetment and seawall were found at the coast.

Station 7 is located in Nong Khao Niew Beach, Sam Rod Yot district found a coastal structure namely revetment. The beach height of 1.9 meters, and width of 13.39 meters were measured. The coastal slope is 7.95 degrees.

4.2.6 Station 9: Bang Pu Beach

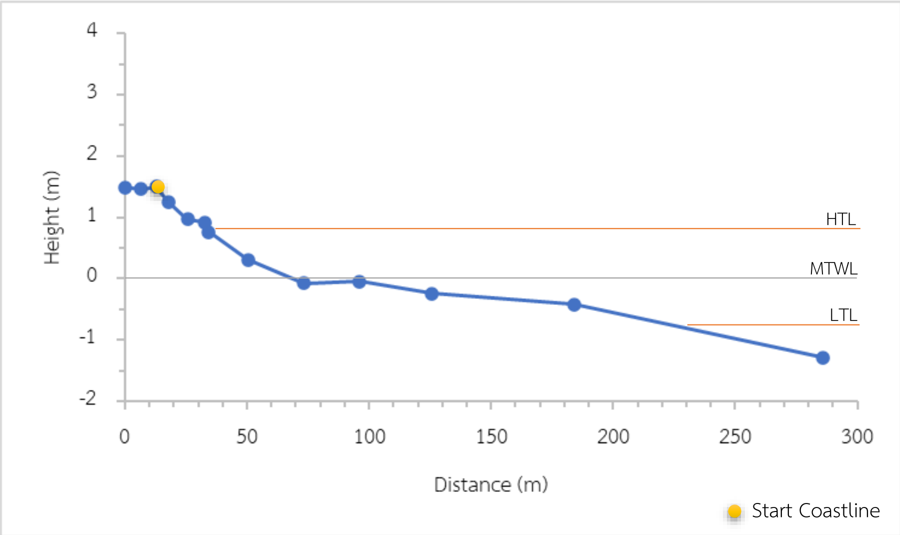


Figure 39. Graph of Beach profile Station 9 showing the coastline relative to mean tide water level (MTWL), high tide level (HTL), and low tide level (LTL).

Figure 40. Pictures of the coast at Station 9, The coastline is a flat area without coastal protection structure.

Station 9 is located in Bang Pu Beach, Sam Rod Yot district. There was a beach height of 1.5 meters, a beach width of 56.28 meters, and a coastal slope of 1.53 degrees.

4.3 The Vulnerability of Criterion.

The ranking of coastal vulnerability in this study was compiled from relevant research and referenced to a comprehensive assessment of coastal vulnerability. Figure 41 showed the criterion for coastal vulnerability assessment included seven criteria as follows:

A) Geomorphology found three types namely rocky coasts, beaches (sand), and beaches (composite of clay and sand). The vulnerability assessment corresponds to very low, moderate, and high levels respectively.

B) Coastal slope measured from the beach profile showed two vulnerability levels namely very low and very high. The most coastal slope value was found where the coastal structure namely seawall and revetment, is presented. The low coastal slope value was found on the non-structural coast.

C) Coastal shoreline change was determined by the marine and coastal resources information Prachuap Khiri Khan Province report (Department of Marine and Coastal Resources, 2018). Moreover, to update data by Satellite image from Google Earth. The changes found were moderate erosion area, equilibrium area, and coastal structure area so the vulnerability assessment corresponds to low, moderate, and very high levels respectively.

D) This the study area used the average significant wave height during the northeast monsoon season of 0.50 m from station Prachuap Khiri Khan Province according to Kompor et al. (2018). Therefore, the vulnerability assessment was classified as a very low level throughout the study area.

E) Mean tidal range in the study area used data from Hydrographic Department, Royal Thai Navy. There was a value of 1-1.1 m, so the vulnerability assessment corresponds to a moderate level throughout the study area.

F) Rate of sea level rise used data according to Sojisuporn et al. (2013). There was a value of 1.4 mm/y from the annual MSL during 1982-2004 at six tide-gauge stations along the western side of the Gulf of Thailand. Therefore, the vulnerability assessment corresponds to a very low level throughout the study area.

G) Underwater slope was a value of 4.6 km measured from the pouring angle of the shoreline to a depth of 20 m. Using the underwater depth data obtained from the survey of the Hydrographic Department, Royal Thai Navy and created it into the GIS database by GISTDA. Therefore, the vulnerability assessment corresponds to a very low level throughout the study area.

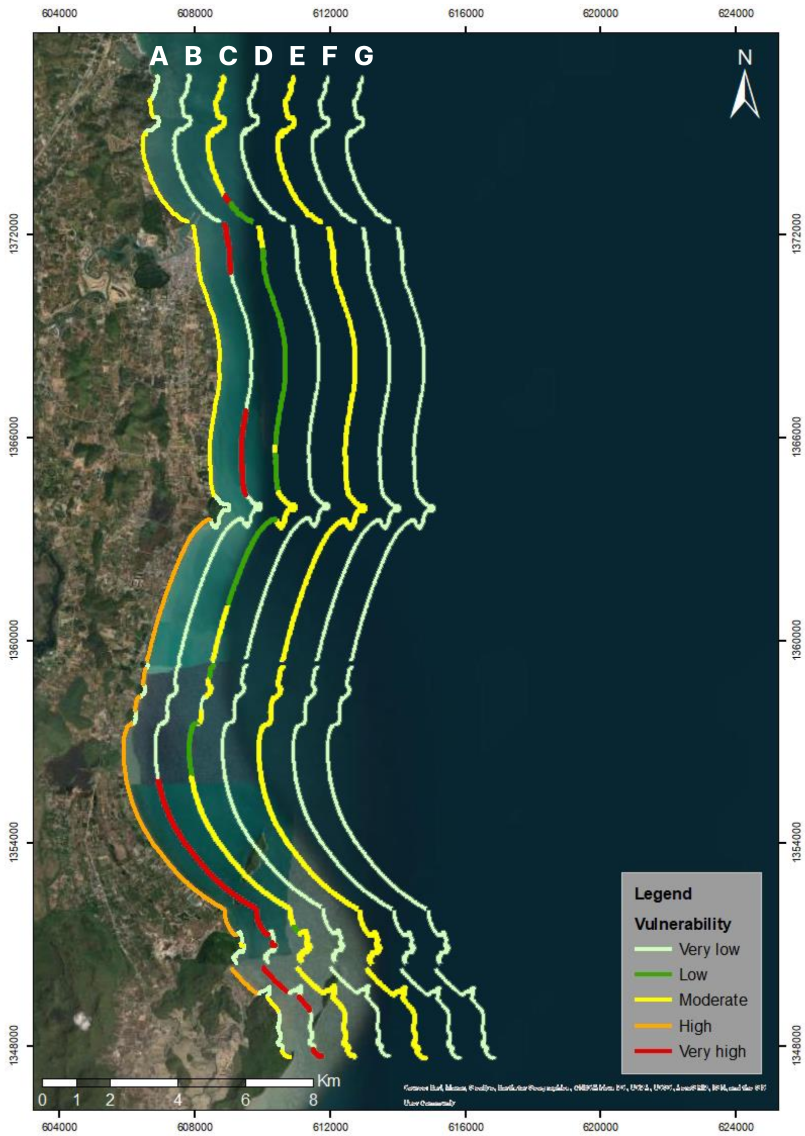


Figure 41. The vulnerability of each criterion in the study area including geomorphology (A), coastal slope (B), coastal shoreline change (C), mean significant wave height (D), mean tidal range (E), Rate of sea level rise (F) and underwater slope (G).

4.4 The Result of The Weighting Criterion

The result of the weighting criterion used in this assessment was collected from a total of 4 expert questionnaires. Then, it is taken into an average to prioritize. According to Table 22, a coastal slope criterion obtained the number one most score for priority of vulnerable for this assessment while geomorphology obtained a score second rank, coastal shoreline change was third and other criteria respectively.

Table 22. The weighting of criteria.

Criteria	Expert 1		Expert 2		Expert 3		Expert 4		Combined	
	Weight	Rank	Weight	Rank	Weight	Rank	Weight	Rank	Weight	Rank
Geomorphology	0.419	1	0.090	4	0.388	1	0.049	7	0.237	2
Coastal slope	0.234	2	0.401	1	0.242	2	0.316	1	0.298	1
Coastal shoreline change	0.147	3	0.024	7	0.153	3	0.210	2	0.134	3
Mean significant wave height	0.094	4	0.151	3	0.100	4	0.146	3	0.123	4
Mean tidal range	0.052	5	0.048	6	0.057	5	0.065	5	0.056	6
Rate of sea level rise	0.033	6	0.243	2	0.023	7	0.126	4	0.106	5
Underwater	0.021	7	0.043	5	0.036	6	0.088	6	0.047	7
Consistency ratio	0.097		0.065		0.096		0.024			

4.5 Coastal Vulnerability Index

Figure 42 showed the CVI value was calculated as the square root of the whole factor divided by the total number of criteria (Formula 3). Table 23, found the study area was distributed coastal vulnerability across five levels which calculated lengths of very low, low, moderate, and high levels of 8.7, 10.8, 4.8, and 3.9 km equal to 23,29,11,13 percent respectively. However, the most prominent was a very high level which a calculated length of 9 km equal to 24 percent found in the most southern part of the study area.

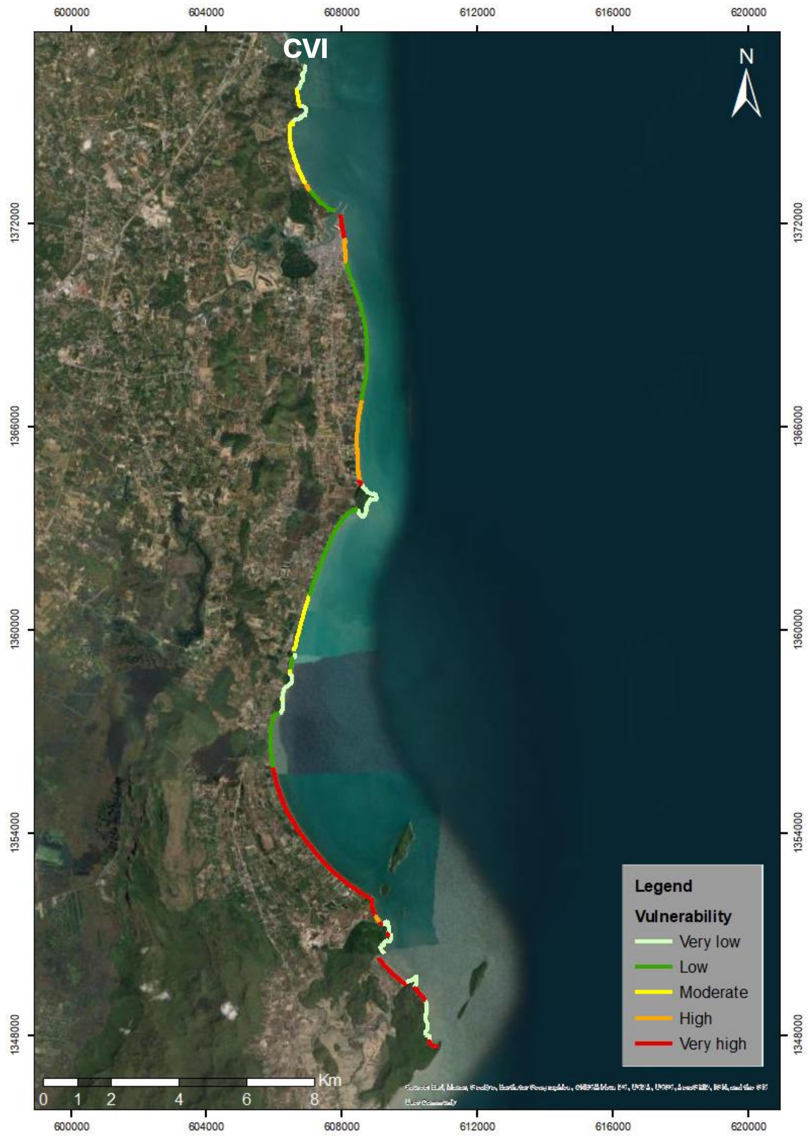


Figure 42. The coastal vulnerability map by CVI method.

Figure 43 showed the CVI_w value used by the AHP process to calculate the relative importance of each priority of the weighting criterion multiplied by the criterion's vulnerability score (Formula 4). The result found in the study area is distributed coastal vulnerability across five levels which calculated lengths of very low, low, moderate, and high levels of 8.7, 8.6, 7, 5.6 km equal to 23,23,19,15 percent respectively. The very high level which was calculated length of 7.4 km equal to 20 percent still found in the most southern part of the study area.

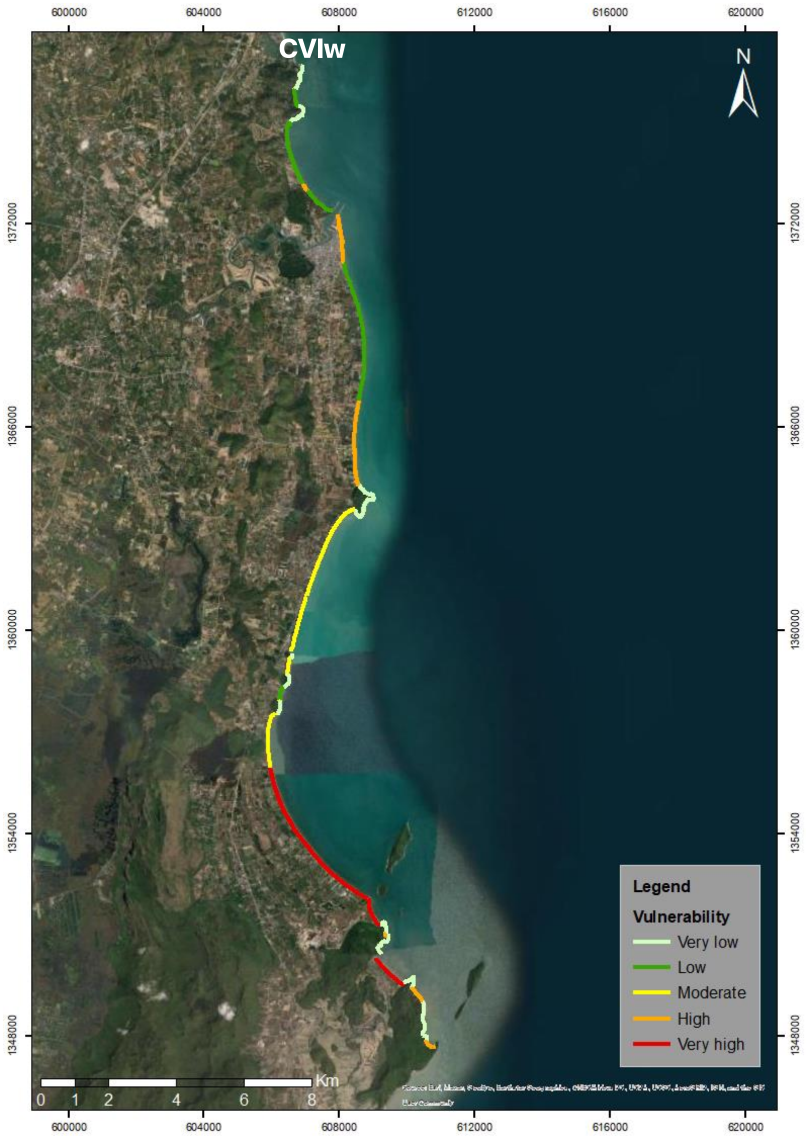


Figure 43. The coastal vulnerability map by CVI_w method.

Table 23. The coastal vulnerability in the study area.

Vulnerability Rank	Length of CVI (km)	Percentage	Length of CVI_w (km)	Percentage
Very low	9.2	24	8.7	23
Low	10.4	28	8.6	23
Moderate	4.8	13	7.0	19
High	3.9	11	5.6	15
Very high	9.1	24	7.4	20
Total	37.3	100	37.3	100

4.6 Land Use Land Cover Analysis

Checking and updating land use data was carried out by comparing land use data with satellite imagery. The result was adjusted to 204 polygons. It was calculated the changing area was equal to 1.31 km^2. Table 23, found the forest type decreased by 0.08 km^2, followed by an agricultural type of 0.18 km^2. In addition, it was found the urban type increased by 0.27 km^2 and other miscellaneous land found that there was the most increase of 0.17 km^2, while the water body type had not changed (Table 24).

Table 24. The updated land use data in the study area.

LU Types	LU2019 (km^2)	LU2022 (km^2)
Agriculture	9.51	9.33
Forest	9.03	8.95
Rangeland/Marsh and Swamp/Other miscellaneous lands	5.61	5.78
Urban	8.02	8.29
Waterbody	0.59	0.59
Total	32.76	32.94

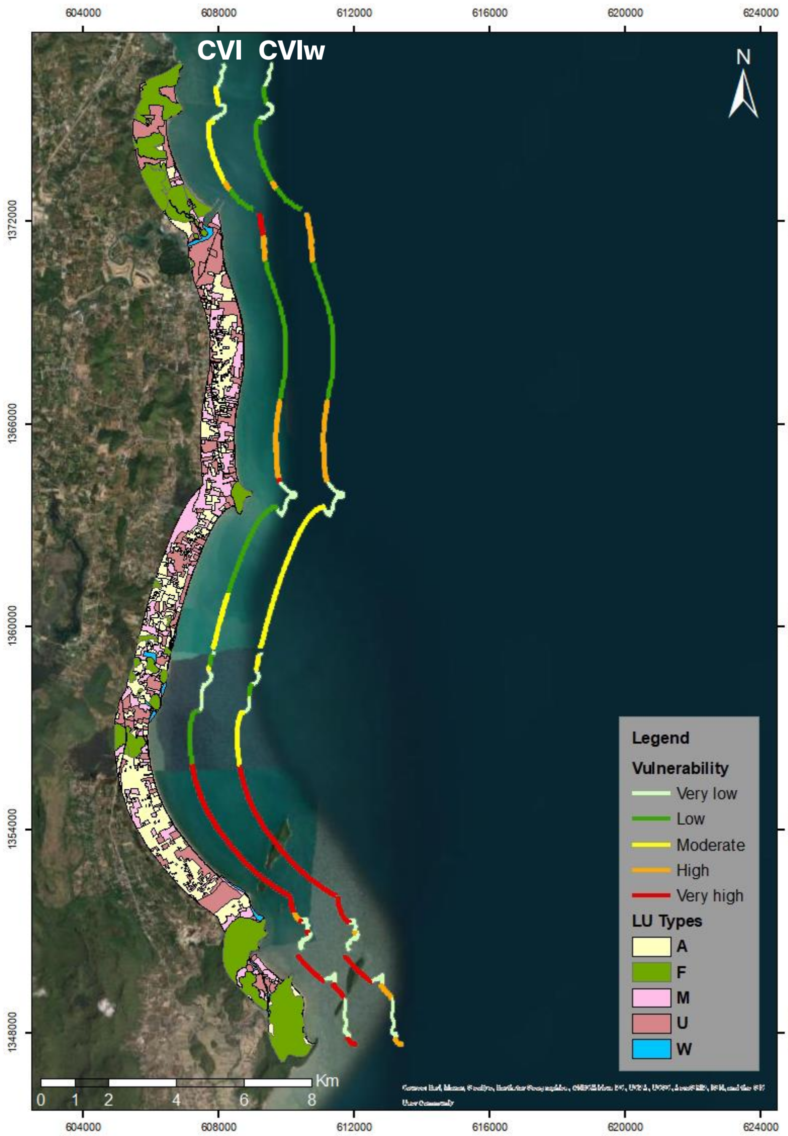


Figure 44 The coastal vulnerability levels overlay with land use.

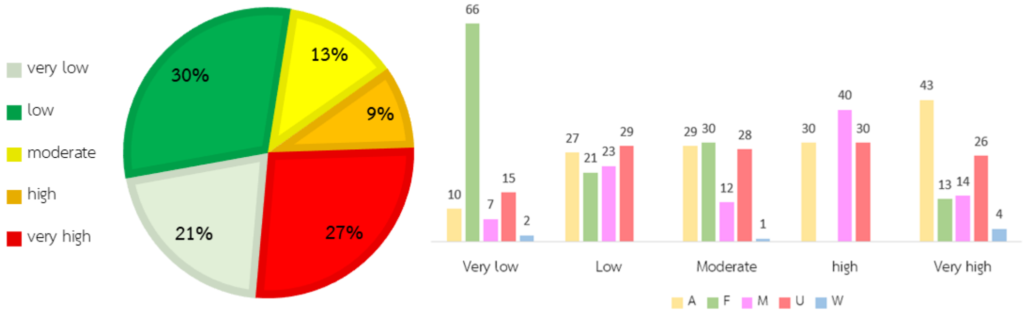


Figure 45 The pie chart of CVI vulnerability levels and a graph of land use type at each level.

Figure 45 of the pie chart shows the percent of vulnerability in each CVI level. It found the low level had the most common in the study area, followed by the very high level. In addition, the types of land use at a very high level found the agriculture type had the most area equal to 43 percent, the urban type had area equal to 26 percent respectively. The forest type mainly had a very low level equal to 66 percent.

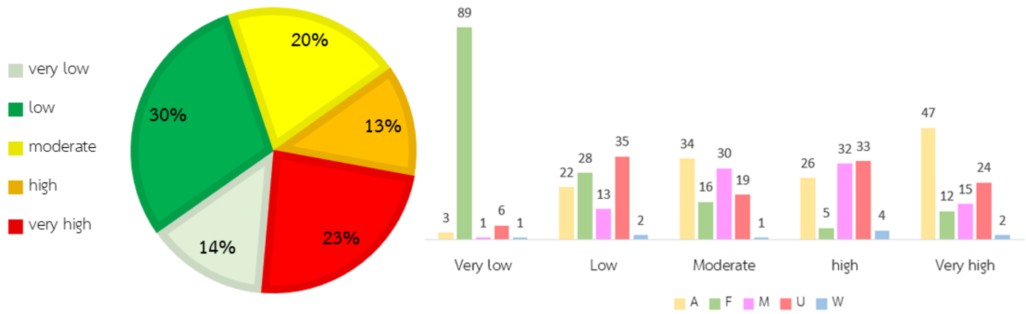


Figure 46 The pie chart of CVI_w vulnerability levels and a graph of land use type at each level

Figure 46 of the pie chart shows each CVIw level found type of land use. Which found the low level had the most common. However, the very high level had decreased areas while high and moderate levels had increased in the study area. The forest type had a very low level equal to 89 percent. The agriculture type was distributed at all levels but most areas in a very high level equal to 47 percent, and the urban type had a low level equal to 35 percent.

CHAPTER 5 DISCUSSION

5.1 Assessment of Coastal Hazard Intensity by CHW

Coastal Hazard Wheel (CHW) a new methodology for coastal multi-hazard assessment covers all coastal perils under damage from ecosystem disruption, gradual inundation, saltwater intrusion, erosion, and flooding (Rosendahl Appelquist & Balstrom, 2015; Rosendahl Appelquist & Balstrøm, 2014; Rosendahl Appelquist & Halsnæs, 2015) CHW is another approach for evaluating researcher vulnerability current to develop a coastal vulnerability map (Rosendahl Appelquist, 2016).

The result of this assessment supports the above reasons for simple methodology and determining hazard profile. The intensity of each hazard on the map in Figure 26 showed an assessment that found coastal hazards had high intensity in all the perils except ecosystem disruption. Especially, flooding and erosion hazards due to geological characterization, it was found that the general characteristics of the study area were sediment plain (PL-5), tidal inlets/sand spits/river mouths (TSR), and sloping hard rock coast (R-1, R-2). The topography of the study area is a slope from the high mountains in the west, and the longest slope down to the east is the Gulf of Thailand, causing important rivers to flow out into the sea, such as Paknam Pranburi, Pak Nam Bang Pu (Khao Sam Roi Yot National Park) includes wetlands and many small streams. As a result, the determining of coastal hazard levels. It was found common coast type Pl-5 in the study area accounted for 56 percent of the distance and it was indicated as a moderate wave exposure indicator according to the map of global wave environments (Rosendahl Appelquist, 2016). In addition, it was indicated as a storm climate under tropical cyclones. These caused the intensity of flooding hazards to have very high levels, as well as erosion hazards being determined to have high levels.

In R-1 part was due to the rock composition consisting of igneous, sedimentary, or metamorphic rock and elevation. Thus, the intensity was low levels while R-2 was an erosion of a rocky shoreline occurring sediment accumulation is found as a beach along a slope of hard rock, causing the intensity of the erosion threat to have moderate levels. Finally, TSR was identified as a special coast type and sensitive to natural disasters including those influenced by the tide caused the intensity of flooding and erosion hazards to have very high levels. However, some river mouths in the study area are so small that could rather be considered streams or canals than river mouths (Figure 47). Although CHW determines a distance to both sides out the estuary of 1 km, this coast is not influenced by high tidal inlets and there are lower levels than defined in CHW (Rosendahl Appelquist & Balstrom, 2015). Therefore, the assessment in further should determine the appropriate distance for the micro-estuary environment. Although CHW is able to identify hazards along the coast, it cannot reliably detect the extent of vulnerability in inland areas (Paul & Das, 2021). As a consequence, data availability and accuracy requirements are relatively low when assess on a local scale.

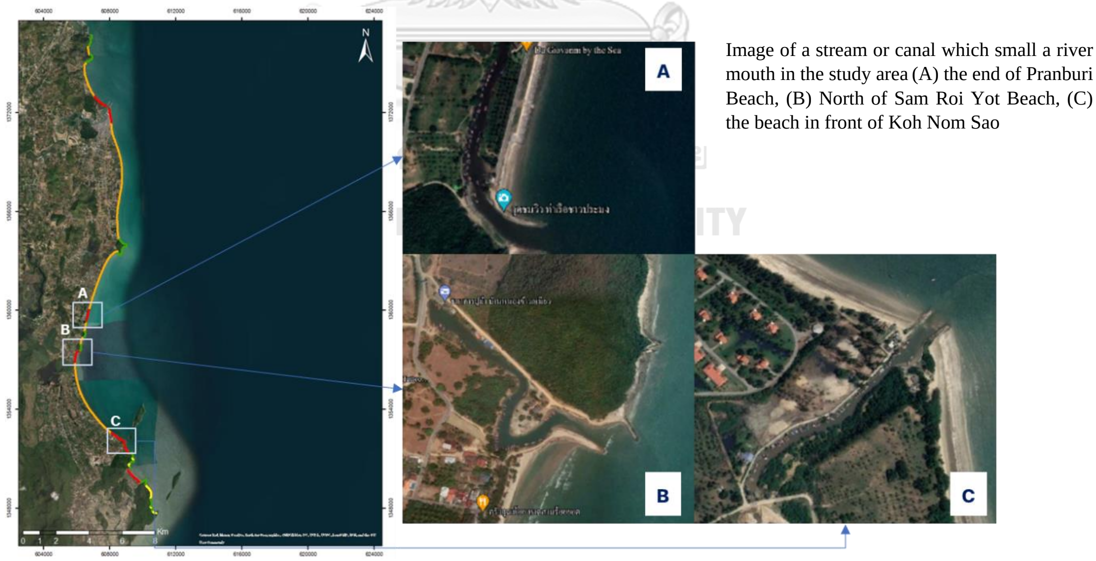


Figure 47. Map of erosion hazard levels showing a stream or canal in the study area.

This study found that the coastal structure was another important indicator of coastal change by comparing it with the marine and coastal resources information Prachuap Khiri Khan Province report in 2017 (Department of Marine and Coastal Resources, 2017). It was found that the hazard assessment results of erosion were inconsistent due to considerations of coastal structures, while CHW cannot consider changes in the coast outside of natural events (Figure 48). Likewise, another limitation from the intensity of saltwater intrusion hazards was found to be inflated in intensity due to it was mainly determined indicator from the geological layout. Therefore, other influential indicators of coastal change such as porosity, permeability, erodibility of coastal materials, beach height, beach width, coast slope, and beach sediments, should be added to the assessment as additional parameters (Paul & Das, 2021) to cover indicators related to coastal vulnerability and more accurate assessment results.

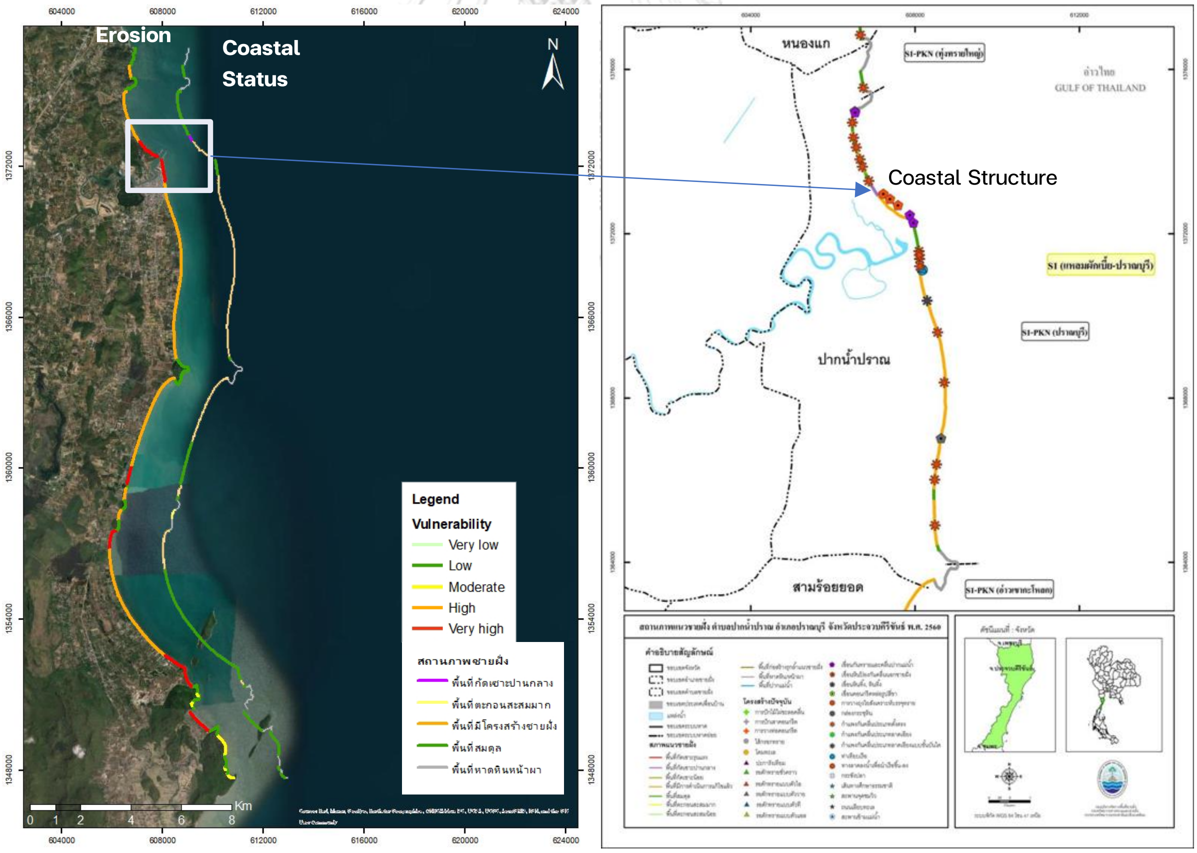


Figure 48. Map of erosion hazard levels compared with the marine and coastal resources information Prachuap Khiri Khan Province reported in 2017.

5.2 Assessment of Coastal Hazard Vulnerability

The Coastal Vulnerability Index (CVI) can be modified to adjust indicators in accordance with different coastal environments (Bagdanavičiūtė et al., 2015; Denner et al., 2015; Hoque et al., 2019; Ramieri et al., 2011; Sheik Mujabar & Chandrasekar, 2011). Comprehensive indicators in coastal vulnerability assessment includes geomorphology, coastal slope, rate of erosion and accretion, mean significant wave height, mean tidal range, and rate of sea-level rise (Mohd et al., 2019). These are basic coastal vulnerability assessment criteria. Geomorphology is related to the intensity of erosion. In addition, the rate of erosion is an indicator of vulnerability to coastal processes related to the energy of the waves, which is another factor that affects the intensity of erosion (Gornitz. V, 1991).

The results of this study correspond with the above reason. It was found that determining the appropriate indicators for the study area offers results consistent with coastal environments. In terms of the CVI method, according to the first approach, all criteria are assumed to contribute equally to the coastal vulnerability. It was found that areas with very high vulnerability are commonly located in the area of sand or sand composite of clay geomorphology type with coastal slopes of less than 3 degrees. The coastal shoreline change rate also characterizes as equilibrium with values of erosion and deposition in the range of 0.3 m/y. The high vulnerability zone also shows the same geomorphology class and coastal slope. However, the rate of coastal change differs in areas with coastal structures such as breakwaters, rock embankments, and seawalls. These have a lower vulnerability than the equilibrium region. In addition, it was found that areas with moderate, low, and very low vulnerability are mainly situated in the geomorphology class of rocky coasts or sand with more than 6 degrees coastal slopes. The coastal shoreline change rate is also present as equilibrium region or coastal structures.

In CVI_w method part, the weighting scores were prioritized from the criteria clearly and transparently by integrating independent expert opinions. And to reduce the bias of comparing coastal vulnerability according to each criterion, which may be of different importance to coastal vulnerability (Bagdanavičiūtė et al., 2015). As a result, the criteria that are important for the assessment of coastal vulnerability in this study include (1) coastal slope, (2) geomorphology, and (3) coastal shoreline change rate. These have markedly increased or decreased levels of vulnerability. In particular, the coastline south of the study area showed a very high level of vulnerability when assessed under the first approach. Figure 49 showed both areas have a slope of less than 3 degrees, and the coastal shoreline change rate is the same in the equilibrium region. However, the geomorphology class is different, where A is a sandy composite of clay with a very high vulnerability level, and B is a sandy beach with a high vulnerability level. When multiplying the weighted scores in the evaluation, the vulnerability level was reduced due to the weighting of the geomorphology criterion. This clearly shows the priorities of vulnerability indicators in the study area.

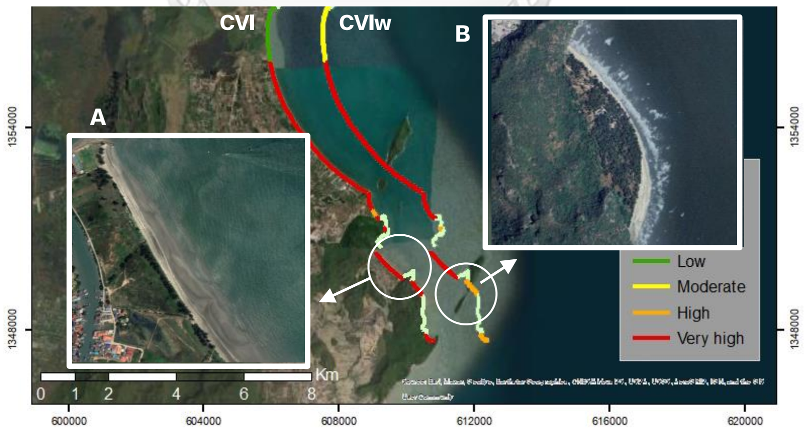


Figure 49. Example of the difference in vulnerability levels when weighting the geomorphology criterion.

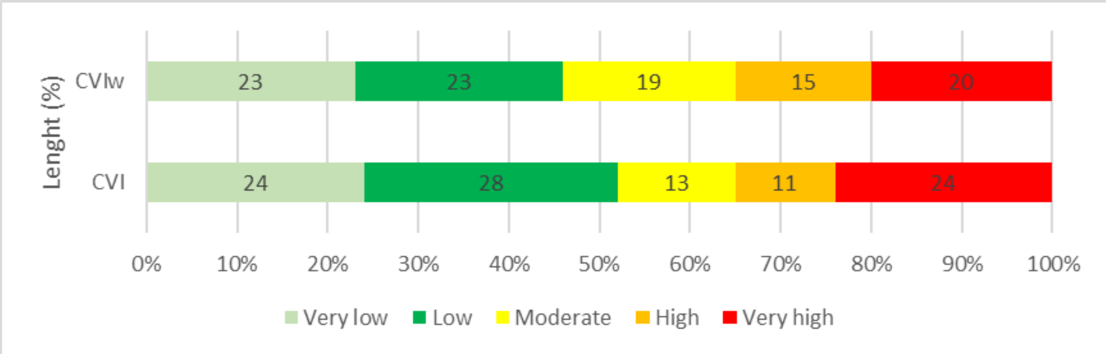


Figure 50. The distribution of the coastal vulnerability levels in the study area.

Figure 50 shows the distribution of the vulnerability levels of both methods. It was found that at very low levels the distances were similar, while moderate and high levels increased approximately 4 – 5 percent within the CVI_w method. In addition, a very high level the distance was decreased to 20 percent by CVI_w method.

Summary of the CVI assessment from this study, the result of CVI_w is recommended for use in coastal management and planning. Because, given the importance of each criterion that affects vulnerability, CVI_w method has more consistent results in the study area than CVI. The limitation of this assessment is that some threshold values are dynamic. Therefore, most of the values used are those obtained from statistics or spatial interpolation. This may cause discrepancies in the assessment results, especially the coastal slope values obtained from field data collection. However, some areas are unable to collect field data because they are in private or restricted areas. Thus, the estimation values are based on spatial interpolation from neighboring beaches. However, it is recommended that the next assessment should collect detailed information on the criteria used and update the information regularly in order to obtain the most actual value. Another limitation of this assessment is that the expert weights are difficult to calculate for the Consistency Index (C.I.) because the evaluation form mainly uses the discretion of highly individual experts. Therefore, there are conflicting opinions, and the number of experts involved should be increased to reduce the degree of bias in comparing the criteria used in the assessment.

5.3 Difference of Coastal Hazard Assessment by CHW Method and CVI Index

Several research methods and approaches are currently being developed for the assessment and management of coastal hazards. One of the more continually evolving methods is CVI, an assessment that considers relevant indicators in different coastal environments. It also applies to many factors related to coastal vulnerability (Bagdanavičiūtė et al., 2015; Denner et al., 2015; Hoque et al., 2019; Mohd et al., 2019; Ramieri et al., 2011; Sheik Mujabar & Chandrasekar, 2011) Another new assessment methodology CHW was developed to simplify the procedure for coastal vulnerability assessment, focusing on identifying situations of natural disaster severity as a starting tool for coastal vulnerability assessment for areas with limited information such as developing countries (Micallef et al., 2018; Paul & Das, 2021; Rosendahl Appelquist & Balstrom, 2015; Rosendahl Appelquist & Balstrøm, 2014; Rosendahl Appelquist & Halsnæs, 2015).

The results from both approaches found consistency in geological indicators at very high vulnerability in the southern part of the study area. The common geological characteristics were the sandy composite of clay with low erosion resistance, especially in tidal-affected estuaries. On the other hand, at a very low - low vulnerability, most of the geological characteristics were characterized as rocky coasts. The rock composition is more resistant to erosion than sand. Moreover, it has a high slope and low vulnerability. The difference in results between the two assessment methods is due to the different information details. The CHW is designed to consider indicators from the wheel setting in the framework. In contrast, the CVI contains more detailed information on study areas, such as coastal slope, coastal shoreline change rate, etc. These offered the CVI approach with a more consistent vulnerability degree dispersed across all levels in the study area. However, there are limitations to using complex detailed information and often mistakes in the regular collection, and it involves a long time to prepare the data.

In conclusion, both assessment methods have different advantages and limitations. The assessment selection depends on the objectives and limitations of data in the coastal area. Therefore, in the next assessment, it is recommended that a combination of applications of both methods be utilized to adjust vulnerability levels or improve relevant indicators depending on the coastal environment. Moreover, the CHW assessment can consider additional indicators from the CVI, which may be better and provide more consistent results.

5.4 Land Use Land Cover Analysis

Land use analysis along the coastline was performed to estimate the categories of land use in each coastal vulnerability zone. The land use along the coastline has continued to increase because the increasing population led to the expansion of the city. In a less populated area, it may not be as affected or stressed by the environment as in a more populated area. This could increase the risk of damage caused by disasters. (S. McLaughlin et al., 2002) The limitless settlements along the coast will increase pressure, leading to coastal vulnerability (Kantamaneni, 2016a).

The analysis of land use changes in the study area found that the urban type increased the most, and most of them were in high to very-high vulnerability areas. It is also a large community that spreads along the coastline and is often located near the beach, which is the area's main attraction (Figure 51). Subsequently, the agricultural land use matched with the miscellaneous land use, which is typically represented as vacant land after harvest or the preparation for next planting. In addition, most forest types were found in very low vulnerability area due to the geological setting of the rocky coasts. However, forests located near river mouths are identified as highly vulnerable areas. The limitation of this analysis still lacks detailed information about economic information on the value of the area. Therefore, it is recommended that further studies should include economic variables because the change in socioeconomic whether land use or transportation, can affect coastal vulnerability more rapidly than physical processes (Duriyapong & Nakhapakorn, 2011). These will enhance the analysis results for management and budget to produce more precise preventive measure.

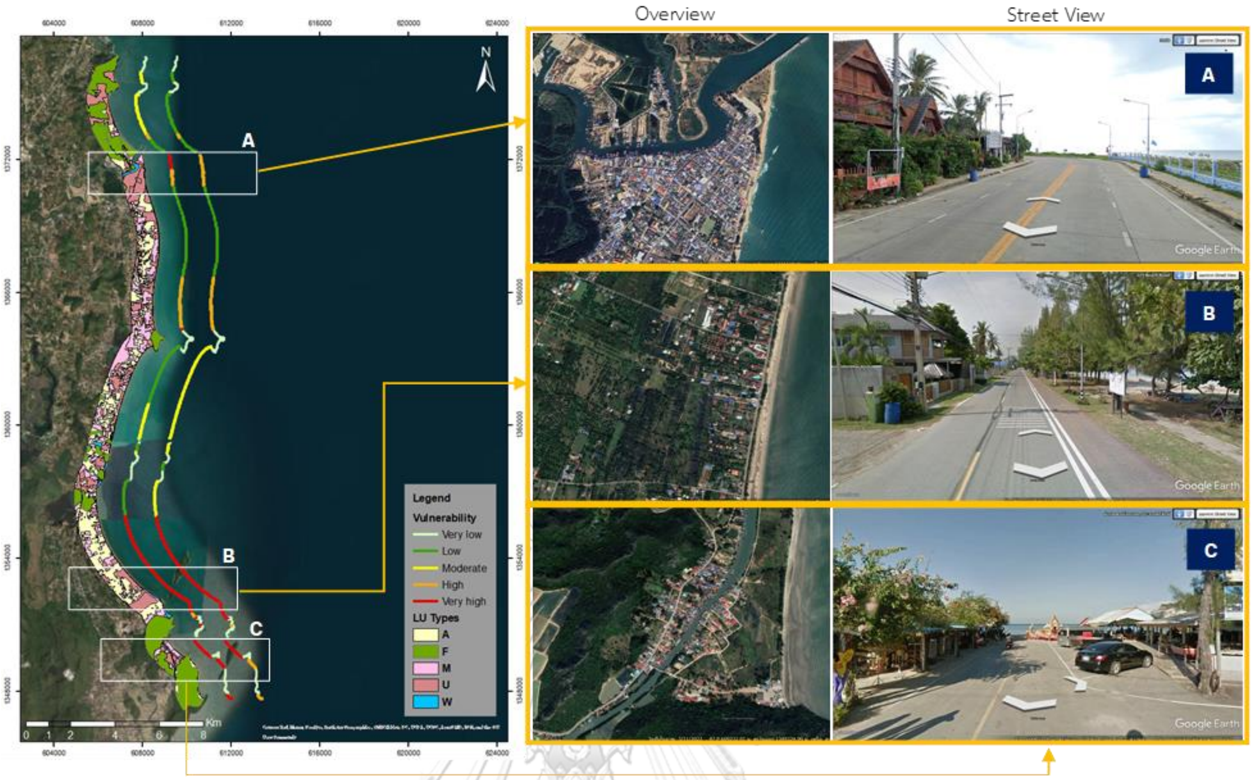


Figure 51. The coastal vulnerability levels overlay with land use. For example, pictures of the area at a very high level: (A) north of Pranburi Beach, (B) Sam Roi Yot Beach, and (C) Bang Pu Beach.

5.5 Application for Coastal Hazard Management

The assessment result from this study is recommended to use in cases where the coastal condition in the study area has not changed from this assessment. If a coastline undergoes new construction of coastal structures or new beach improvements such as beach nourishment and sea walls. In that case, the implementation should reassess the coastal vulnerability because these changes affect the parameters used in the assessment and cause the assessment results to be inconsistent with actual coastline conditions. Therefore, the physical data from the parameter used in this study should be updated to make an assessment result consistent with the actual environment. The credibility of the assessment results is based on the use of comprehensive indicators on coastal environments as well as the examination of relevant literature review. Finally, relevant agencies can use the findings of this study in coastal management, planning, and public relations to provide people in the coastal area with knowledge and understanding in order to prepare for and deal with natural disasters that may occur in a timely manner, as well as to issue policies to promote effective prevention in the future.

CHAPTER 6 CONCLUSION

Coastal hazard and vulnerability assessments were performed along the coast of Pranburi - Sam Roi Yot, Prachuap Khiri Khan province. The objective of this study includes (i) assessing physical damage from natural disasters and (ii) assessing coastal vulnerability to natural disasters. Firstly, to assess the physical damage from coastal hazards using the classification of physical indicators following the Coastal Hazard Wheel (CHW). The results showed that sediment plain (PL-5) and tidal inlets/sand spits/river mouths (TSR) were identified as the coast types with the highest severity of the danger and that covered most of the research area's distance. These are classified as susceptible coastlines due to characteristics of geological sandy sediments, which have a low resistance to erosion. Moreover, in the estuary area affected by tide, the vulnerability degree is categorized as high to very high due to the rapid topography change from natural hazard events in this area.

Secondly, to assess coastal vulnerability by the CVI index with the AHP process, it was found that the important indicators to this coastal vulnerability assessment include (1) coastal slope, (2) geomorphology, and (3) coastal shoreline change rate. As a result of the prioritization of the criteria from the AHP, it is evident that each criterion affects vulnerability, leading to more consistent results in the study area. In addition, the results of both methods were consistent in the geological indicators at a very high level: sand sediments with low erosion resistance. In contrast, low vulnerability is predominant in rocky coastal areas due to a more resistance to rock erosion and a high slope topography. In addition, the land use assessment of each level of coastal vulnerability determined that the urban type is most vulnerable to natural hazards as it continues to expand, particularly since the beach is a popular tourist destination.

In summary of this study, CHW and CVI have distinct advantages and disadvantages. The decision to investigate depends on the intended use and limits of coastal data in the study area. Therefore, using both approaches may be preferable and yield more consistent results. Moreover, including economic and social variables in the assessment will improve the result analysis for management and budget in addressing problems and developing more precise preventative measures. Finally, natural disasters can occur at any time and cannot be avoided. Coastal management requires technology and knowledge in multiple disciplines, such as ecology, sociology, environmental science, geology, etc. Regarding disaster warnings and policy of coastal zoning according to the intensity of hazard that will occur, planning and education coupled with coastal research will increase safety and reduce the loss of life and property of the people understanding the sustainable use of shared coastal resources.

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APPENDICES

APPENDIX A: Data of Coastal Measurement

Table 25. Data of coastal measurement at Station 1.

Date	coordinates	Study point	Distance from a reference point (m)	Elevation above mean tide level (m)
21 May 2022	606712 E 1373681 N	0	0	2.7204
		1	17.5918	2.6075
		2	25.8295	2.2024
		3	28.1206	1.9324
		4	40.1134	-0.0152
		5	44.4983	-0.0923
		6	57.5224	-0.0989
		7	72.5808	-0.5055
		8	96.7833	-0.8855

Table 26. Data of coastal measurement at Station 3.

Date	coordinates	Study point	Distance from a reference point (m)	Elevation above mean tide level (m)
21 May 2022	608626 E 1369314 N	0	0	3.5506
		1	1.6469	3.3076
		2	6.0392	2.7241
		3	7.4095	2.7345
		4	8.3812	2.7273
		5	17.5036	-0.2812
		6	17.602	-0.4229
		7	21.3828	-0.5364
		8	25.6122	-0.3295
		9	53.2179	-0.8222
		10	70.6331	-0.9983
		11	83.9690	-0.9470
		12	106.4681	-1.0344

Table 27. Data of coastal measurement at Station 5.

Date	coordinates	Study point	Distance from a reference point (m)	Elevation above mean tide level (m)
21 May 2022	608509 E 1364571 N	0	0	3.6348
		1	5.252	3.6768
		2	9.1101	3.1503
		3	-0.8530	2.9486
		4	11.2825	2.4949
		5	23.7133	2.1208
		6	30.1500	1.3877
		7	41.0230	1.3342
		8	57.5542	0.4102
		9	66.8380	0.1826
		10	79.3796	0.3084
		11	111.0620	-0.7140
		12	124.8870	-0.6668
		13	144.1125	-0.7230
		14	158.3075	-1.3322

Table 28. Data of coastal measurement at Station 6.

Date	coordinates	Study point	Distance from a reference point (m)	Elevation above mean tide level (m)
21 May 2022	607058 E 1361371 N	0	0	3.0840
		1	5.6373	3.0613
		2	8.8274	2.3533
		3	13.7635	2.4781
		4	23.7064	2.2134
		5	31.5968	0.3631
		6	43.2223	-0.3366
		7	49.4541	-0.3366
		8	62.735	-0.5643
		9	70.4582	-0.6665
		10	86.9748	-1.2117
		11	99.2874	-1.3651
		12	111.6728	-1.2238
		13	124.0518	-1.2779
		14	139.5176	-1.4800

Table 29. Data of coastal measurement at Station 7.

Date	coordinates	Study point	Distance from a reference point (m)	Elevation above mean tide level (m)
21 May 2022	605940 E 1356230 N	0	0	2.1491
		1	8.9826	1.8851
		2	13.5719	1.9261
		3	14.7308	1.9133
		4	23.6087	1.8703
		5	26.0532	1.1557
		6	37.7846	-0.0594
		7	55.3229	-0.2318
		8	67.6437	-0.2318
		9	83.5764	-0.7385
		10	112.2052	-1.0681
		11	150.4906	-1.2788
		12	163.9922	-1.1098
		13	198.1118	-1.2138
		14	212.8508	-1.4594

Table 30. Data of coastal measurement at Station 9.

Date	coordinates	Study point	Distance from a reference point (m)	Elevation above mean tide level (m)
21 May 2022	609828 E 1349573 N	0	0	1.49365
		1	6.5705	1.45835
		2	12.7213	1.50345
		3	17.8464	1.24305
		4	25.6918	0.96545
		5	32.758	0.91505
		6	34.1837	0.75875
		7	50.2673	0.30825
		8	73.3274	-0.07765
		9	96.1709	-0.04705
		10	125.7361	-0.24065
		11	183.9202	-0.42225
		12	285.664	-1.28875

APPENDIX B: Data of Coastal Hazard Assessment

Table 31. Intensity score by CHW.

FID	Geological	code	Flooding	Erosion	Salt water	Gradual_in	Eco-dis
1	Sloping hard rock coast	R-1	1	1	1	1	1
2	Sediment plain	PL-5	4	3	3	3	2
3	Sloping hard rock coast	R-1	1	1	1	1	1
4	Sediment plain	PL-5	4	3	3	3	2
5	Tidal inlet/sand spit/river mouth	TSR	4	4	3	3	2
6	Sediment plain	PL-5	4	3	3	3	2
7	Sloping hard rock coast	R-1	1	1	1	1	1
8	Sediment plain	PL-5	4	3	3	3	2
9	Tidal inlet/sand spit/river mouth	TSR	4	4	3	3	2
10	Sloping hard rock coast	R-1	1	1	1	1	1
11	Sediment plain	PL-5	4	3	3	3	2
12	Sloping hard rock coast	R-1	1	1	1	1	1
13	Sediment plain	PL-5	4	3	3	3	2
14	Sloping hard rock coast	R-1	1	1	1	1	1
15	Tidal inlet/sand spit/river mouth	TSR	4	4	3	3	2
16	Sediment plain	PL-5	4	3	3	3	2
17	Tidal inlet/sand spit/river mouth	TSR	4	4	3	3	2
18	Sloping hard rock coast	R-1	1	1	1	1	1
19	Tidal inlet/sand spit/river mouth	TSR	4	4	3	3	2
20	Sloping hard rock coast	R-1	1	1	1	1	1
21	Sediment plain	PL-5	4	3	3	3	2
22	Sloping hard rock coast	R-2	1	2	1	2	1

Table 32. Vulnerability score by CVI.

FID	geo	slope	shoreline	wave	meanTide	underSlope	searise	CVI
0	1	1	3	1	3	1	1	1.133893
1	1	1	3	1	3	1	1	1.133893
2	3	1	3	1	3	1	1	1.963961
3	1	1	3	1	3	1	1	1.133893
4	3	1	2	1	3	1	1	1.603567
5	1	1	3	1	3	1	1	1.133893
6	4	1	2	1	3	1	1	1.85164
7	1	1	2	1	3	1	1	0.92582
8	4	1	2	1	3	1	1	1.85164
9	1	1	3	1	3	1	1	1.133893
10	4	1	1	1	3	1	1	1.309307
11	1	1	3	1	3	1	1	1.133893
12	4	1	2	1	3	1	1	1.85164
13	4	5	3	1	3	1	1	5.070926
14	4	5	3	1	3	1	1	5.070926
15	1	1	3	1	3	1	1	1.133893
16	4	5	3	1	3	1	1	5.070926
17	1	1	3	1	3	1	1	1.133893
18	3	5	3	1	3	1	1	4.39155
19	1	1	3	1	3	1	1	1.133893
20	3	5	3	1	3	1	1	4.39155
21	3	5	3	1	3	1	1	4.39155
22	3	1	3	1	3	1	1	1.963961
23	3	5	2	1	3	1	1	3.585686
24	3	5	2	1	3	1	1	3.585686
25	4	1	2	1	3	1	1	1.85164
26	3	1	5	1	3	1	1	2.535463
27	3	1	2	1	3	1	1	1.603567
28	3	5	3	1	3	1	1	4.39155
29	3	5	2	1	3	1	1	3.585686
30	3	5	2	1	3	1	1	3.585686
31	3	5	3	1	3	1	1	4.39155
32	4	1	3	1	3	1	1	2.267787
33	4	1	3	1	3	1	1	2.267787
34	4	1	3	1	3	1	1	2.267787
35	4	5	2	1	3	1	1	4.140393
36	4	5	3	1	3	1	1	5.070926

Table 33. Vulnerability score by CVI_w.

FID	geo w	slope w	shoreline w	wave w	meanTide w	underSlope w	searise w	CVIw
0	0.237	0.298	0.402	0.123	0.168	0.047	0.106	1.381
1	0.237	0.298	0.402	0.123	0.168	0.047	0.106	1.381
2	0.711	0.298	0.402	0.123	0.168	0.047	0.106	1.855
3	0.237	0.298	0.402	0.123	0.168	0.047	0.106	1.381
4	0.711	0.298	0.268	0.123	0.168	0.047	0.106	1.721
5	0.237	0.298	0.402	0.123	0.168	0.047	0.106	1.381
6	0.948	0.298	0.268	0.123	0.168	0.047	0.106	1.958
7	0.237	0.298	0.268	0.123	0.168	0.047	0.106	1.247
8	0.948	0.298	0.268	0.123	0.168	0.047	0.106	1.958
9	0.237	0.298	0.402	0.123	0.168	0.047	0.106	1.381
10	0.948	0.298	0.134	0.123	0.168	0.047	0.106	1.824
11	0.237	0.298	0.402	0.123	0.168	0.047	0.106	1.381
12	0.948	0.298	0.268	0.123	0.168	0.047	0.106	1.958
13	0.948	1.49	0.402	0.123	0.168	0.047	0.106	3.284
14	0.948	1.49	0.402	0.123	0.168	0.047	0.106	3.284
15	0.237	0.298	0.402	0.123	0.168	0.047	0.106	1.381
16	0.948	1.49	0.402	0.123	0.168	0.047	0.106	3.284
17	0.237	0.298	0.402	0.123	0.168	0.047	0.106	1.381
18	0.711	1.49	0.402	0.123	0.168	0.047	0.106	3.047
19	0.237	0.298	0.402	0.123	0.168	0.047	0.106	1.381
20	0.711	1.49	0.402	0.123	0.168	0.047	0.106	3.047
21	0.711	1.49	0.402	0.123	0.168	0.047	0.106	3.047
22	0.711	0.298	0.402	0.123	0.168	0.047	0.106	1.855
23	0.711	1.49	0.268	0.123	0.168	0.047	0.106	2.913
24	0.711	1.49	0.268	0.123	0.168	0.047	0.106	2.913
25	0.948	0.298	0.268	0.123	0.168	0.047	0.106	1.958
26	0.711	0.298	0.67	0.123	0.168	0.047	0.106	2.123
27	0.711	0.298	0.268	0.123	0.168	0.047	0.106	1.721
28	0.711	1.49	0.402	0.123	0.168	0.047	0.106	3.047
29	0.711	1.49	0.268	0.123	0.168	0.047	0.106	2.913
30	0.711	1.49	0.268	0.123	0.168	0.047	0.106	2.913
31	0.711	1.49	0.402	0.123	0.168	0.047	0.106	3.047
32	0.948	0.298	0.402	0.123	0.168	0.047	0.106	2.092
33	0.948	0.298	0.402	0.123	0.168	0.047	0.106	2.092
34	0.948	0.298	0.402	0.123	0.168	0.047	0.106	2.092
35	0.948	1.49	0.268	0.123	0.168	0.047	0.106	3.15
36	0.948	1.49	0.402	0.123	0.168	0.047	0.106	3.284

APPENDIX C: Questionnaire Example for Expert

เรียน ท่านผู้เชี่ยวชาญ

เกณฑ์การประเมินความเปราะบางชายฝั่งทะเลต่อภัยพิบัติทางธรรมชาติ ถูกรวบรวมจากการศึกษางานวิจัยการประเมินความเปราะบางของชายฝั่ง ซึ่งเกณฑ์การพิจารณาเหล่านี้จะถูกใช้ในการหาค่าน้ำหนักในแต่ละเกณฑ์ เพื่อใช้ในการพิจารณาความเปราะบางของชายฝั่งจากปัจจัยทางกายภาพของพื้นที่ศึกษา ในการพิจารณาน้ำหนักนั้นจะใช้วิธีการพิจารณาลำดับชั้นเชิงวิเคราะห์ (Analytic Hierarchy Process: AHP) โดยพิจารณาทีละคู่ว่าประเด็นใดมีความสำคัญมากกว่ากัน โดยทำเครื่องหมาย × บนตัวเลขซึ่งมีระดับความพึงพอใจดังนี้

1	2	3	4	5	6	7	8	9
มีความสำคัญเท่ากัน	มี ความสำคัญ มากกว่า น้อยที่สุด	มี ความสำคัญ มากกว่า น้อย	มี ความสำคัญ มากกว่า น้อยถึงปานกลาง	มี ความสำคัญ มากกว่าปานกลาง	มีความสำคัญ มากกว่าปานกลาง ค่อนข้างมาก	มีความสำคัญ มากกว่า ค่อนข้างมาก	มี ความสำคัญ มากกว่ามาก	มี ความสำคัญ มากกว่ามาก ที่สุด

ตัวอย่าง

หากท่านพิจารณาว่าเกณฑ์ ลักษณะธรณีสัณฐานชายฝั่ง มีความสำคัญมากกว่า ความลาดชันของชายฝั่ง มากกว่ามากที่สุด ในการประเมินความเปราะบางของชายฝั่งต่อภัยพิบัติทางธรรมชาติ ให้ทำเครื่องหมายลงบน × หมายเลข 9 ที่อยู่ในเกณฑ์ลักษณะธรณีสัณฐานชายฝั่งทางด้านซ้ายมือ ดังภาพ

เกณฑ์ลักษณะธรณีสัณฐานชายฝั่ง	☒	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	เกณฑ์ความลาดชันของชายฝั่ง
	ด้านนี้สำคัญมากกว่า																ด้านนี้สำคัญมากกว่า	

ส่วนที่ 2 การพิจารณาค่าคะแนนเปรียบเทียบ เกณฑ์ในการประเมินความเปราะบางชายฝั่งทะเลต่อภัยพิบัติทางธรรมชาติ

ลักษณะธรณีสัณฐานชายฝั่ง	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความลาดชันของชายฝั่ง
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	อัตราการเปลี่ยนแปลงแนวชายฝั่ง
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสูงของคลื่นนัยสำคัญ
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ค่าพิสัยน้ำขึ้น-น้ำลง
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	การเพิ่มขึ้นของระดับน้ำทะเล
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความลาดชันพื้นท้องทะเล
ความลาดชันของชายฝั่ง	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	อัตราการเปลี่ยนแปลงแนวชายฝั่ง
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสูงของคลื่นนัยสำคัญ
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ค่าพิสัยน้ำขึ้น-น้ำลง
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	การเพิ่มขึ้นของระดับน้ำทะเล
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความลาดชันพื้นท้องทะเล
อัตราการเปลี่ยนแปลงแนวชายฝั่ง	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความสูงของคลื่นนัยสำคัญ
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ค่าพิสัยน้ำขึ้น-น้ำลง
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	การเพิ่มขึ้นของระดับน้ำทะเล
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความลาดชันพื้นท้องทะเล
ความสูงของคลื่นนัยสำคัญ	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ค่าพิสัยน้ำขึ้น-น้ำลง
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	การเพิ่มขึ้นของระดับน้ำทะเล
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความลาดชันพื้นท้องทะเล
ค่าพิสัยน้ำขึ้น-น้ำลง	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	การเพิ่มขึ้นของระดับน้ำทะเล
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความลาดชันพื้นท้องทะเล
การเพิ่มขึ้นของระดับน้ำทะเล	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ความลาดชันพื้นท้องทะเล

Figure 52. Questionnaire example for expert.

VITA

NAME	Somruedee Kawlomlerd
DATE OF BIRTH	1 July 1996
PLACE OF BIRTH	Rayong Thailand
INSTITUTIONS ATTENDED	Kasetsart University (B.Sc)
HOME ADDRESS	40, Moo 1, Tambon Huaithapmon, Amphoe Khaochamao, Rayong 21110