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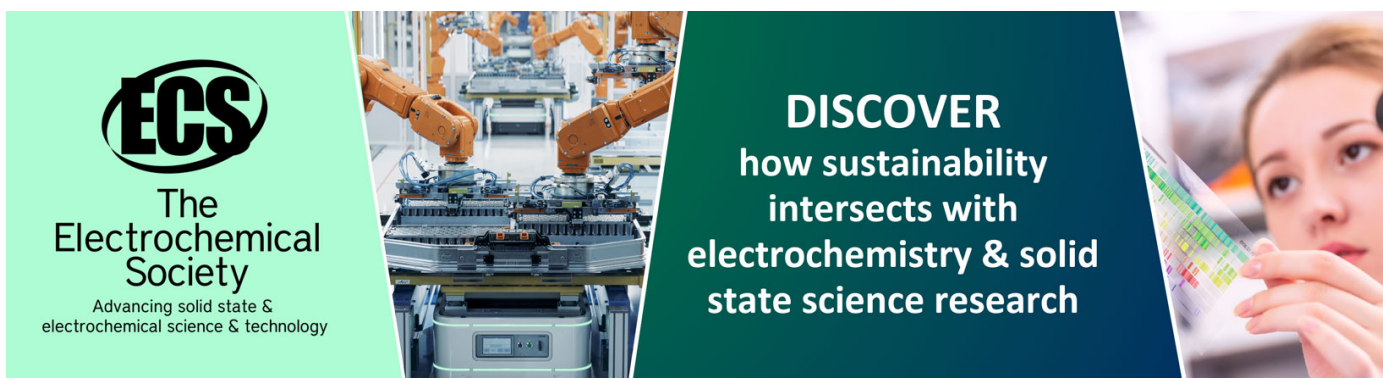
Assessment of coastal vulnerability to sea level rise: a case study of Prachuap Khiri Khan, Thailand

To cite this article: Pattakorn Nidhinarangkoon and Sompratana Ritphring 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **326** 012005

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Assessment of coastal vulnerability to sea level rise: a case study of Prachuap Khiri Khan, Thailand

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Abstract. The coastal zone of Thailand will get the effect from the eustatic sea level rise due to climate change. It is necessary to protect the coastal area from it. Therefore, coastal vulnerability index (CVI) was chosen to be a tool to identify the vulnerability of coastal zone in Prachuap Khiri Khan which is the study area. The physical and socioeconomic variables for CVI in this study were a coastal slope, rate of shoreline changes, geomorphology, signification wave height, tidal range, sea level changes, population density, coastal structure and land use. The CVI values was classified in 5 classes of vulnerabilities in the format of the coastal vulnerability map. The results presented that most of the coastal area in Prachuap Khiri Khan had very low to moderate vulnerability to sea level rise. It can be the preliminary analysis to develop the coastal management for this area in the future.

1. Introduction

Coastal zones are the plentiful ecosystems that provide many benefits to human. Coastal zones are the dynamic areas that have changed by increasing populations and the development activities including the industry. According to the report from Intergovernmental Panel for Climate Change (IPCC) [1], global sea level is rising in this century due to climate change. From the previous study, it indicated that sea level has risen in the Gulf of Thailand and Andaman sea average rate of 6.5 mm/yr [2]. Moreover, the projected beach loss in Thailand from the future sea level rise may reach a maximum of 71.8% or 39.77 km² [3]. Prachuap Khiri Khan was selected to the study area because this province has the longest coastline in Thailand. Many tourist attraction, two of the royal palace and famous beaches such as Huahin beach and Suan-son beaches located in Prachuap Khiri Khan. Moreover, there are several beachfront hotels and communities along the coastline. Therefore, it is necessary to plan the countermeasure and protect the coasts from the impacts of sea level rise.

Coastal vulnerability assessment is a spatial tool to identify the susceptible of the coast from the hazard. Coastal vulnerability index (CVI) was first developed for assessing the susceptibility to erosion of the coast in the United States from sea level rise [4]. There are many studies about coastal vulnerability assessment in Thailand which have different variables. In this study, CVI was considered by physical, economic and social parameters which were a coastal slope, rate of shoreline changes, geomorphology, signification wave height, tidal range, sea level changes, population density, coastal structure and land use.

The main purposes of this study were to develop the coastal vulnerability index for sea level rise to identify the vulnerability of coastal zone in Prachuap Khiri Khan and to analyze the coastal vulnerability index presented as the coastal vulnerability map.

2. Study area

Prachuap Khiri Khan is the province in the western part of Thailand which located on the Gulf of



Thailand (Figure 1). It has 22 coastal sub-districts with 246.83 km lengths of coastline that are 178.27 km lengths of sandy beaches (Figure 2), 8.86 km lengths of sandy mud beaches, 1.85 km lengths of muddy beaches, 0.89 km lengths of rocky beaches, 55.13 km lengths of headlands and 1.83 km lengths of river mouths. There are 3.72 km lengths of shoreline with low-rate of erosion (0-1 m/yr), 0.22 km lengths of moderate-rate of erosion (1-5 m/yr) and 0.55 km lengths of high-rate of erosion (1-5 m/yr) [5]. Prachuap Khiri Khan got the effect of south-west monsoon in the rainy season (May-October) and north-east monsoon from China that made this area becomes cooler in the winter season (October-February).



Figure 1. Study area



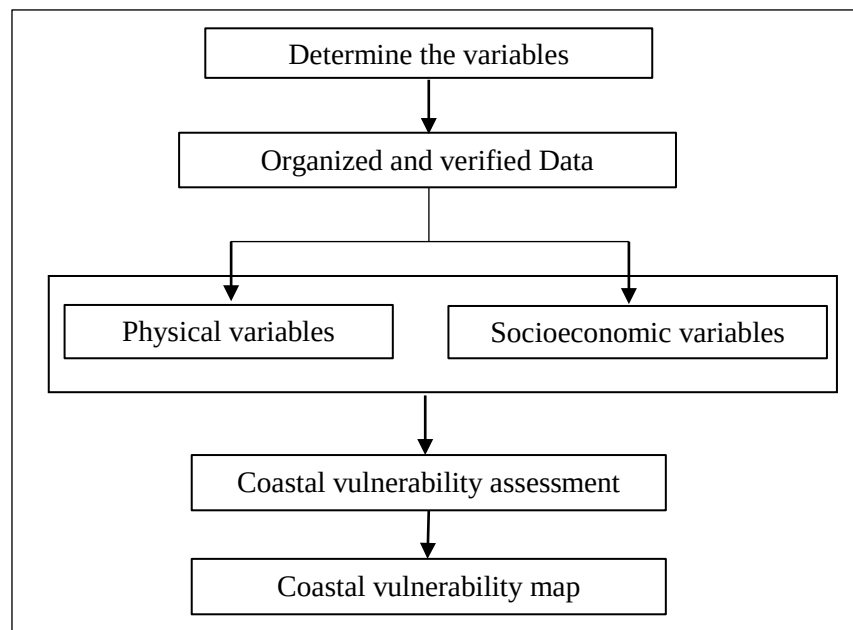
Figure 2. Beaches in Prachuap Khiri Khan

3. Methodology

This study aims to analyze the coastal vulnerability index by considering the physical and socioeconomic variables (Table 1) before divides the data in the ranges as in Table 2. The coastal vulnerability index (CVI) was calculated by the square root of product mean [6] which was used in many research as in equation (1) and shows the results as a coastal vulnerability map. The method of this study is shown in Figure 3.

$$CVI = \sqrt{\frac{a*b*c*d*e*f*g*h*i}{n}} \quad (1)$$

Where a = coastal slope, b = shoreline changes, c = geomorphology, d = signification wave height, e = tidal range, f = sea level changes, g = population density, h = coastal structure, i = land use and n = number of variables

**Figure 3.** Research methodology**Table 1.** Variables used in this study.

Variables	Sources
Coastal slope	Digital Elevation Model ASTER GDEM1 ARCSEC (30 meters) in Shuttle Radar Topography Mission (SRTM) https://gdex.cr.usgs.gov/gdex/
Shoreline changes	Department of Marine and Coastal Resources Thailand
Geomorphology	Department of Marine and Coastal Resources Thailand
Signification wave height	Thai Meteorological Department
Tidal range	Department of Marine and Hydrographics Department, Royal Thai Navy
Sea level changes	Vongvisessomjai (2006), Sommat and Itthi (2007), Supat (2007), Khongwat (2008), Ritphring (2011), Kirapat and Sompratana (2012) Kirapat (2017)
Population density	The bureau of registration administration, Department of Provincial Administration
Coastal structure	Department of Marine and Coastal Resources Thailand, Department of Marine and Department of Public Works and Town & Country Planning
Land use	Department of land development

Table 2. Coastal vulnerability index classification

	Order of coastal vulnerability index				
	Very Low	Low	Moderate	High	Very High
	1	2	3	4	5
Coastal slope (%)	> 12.0	9.0 - 12.0	6.0 - 9.0	3.0 - 6.0	< 3.0
Rate of shoreline changes (m/yr)	< 1 m/yr erosion and > 1 m/yr accretion	-	1 – 5 m/yr erosion	-	> 5 m/yr erosion
Geomorphology	Rocky cliffed coast	Rocky beach, indented coasts	Sandy beach, Alluvial plains	Sandy mud beach, estuary, lagoon	Muddy beach, Mangrove/ Swamp forest
Signification wave height (m)	-	-	0.406	-	-
Tidal range (m)	1.08 – 1.17	1.17 – 1.26	1.26 – 1.35	1.35 – 1.44	1.44 – 1.53
Sea level changes (mm/yr)	5 - 6.54	6.54 – 8.08	8.08 – 9.62	9.62 – 11.16	11.16 – 12.7
Population density (person/km ²)	38 – 318.4	318.4 – 598.8	598.8 – 879.2	879.2 – 1159.6	1159.6 - 1440
Coastal structure	Present	-	In the progress	-	Absent
Land use	Open space, Swamp forest, Pond	Conserved forest, Beach Forest, Mangrove, Pine forest, Grassland, Grove	Agriculture, Aquaculture, Salt pan, Mine	Tourists attraction, Roads, Miscellaneous area	Royal area, Community area, Industrial zone, Government bureau, Business quarter, Religious place, School, Hospital, Historical monuments

4. Results and discussions

4.1 Coastal vulnerability to sea level rise in Prachuap Khiri Khan

As shown in Figure 4, the coastal vulnerability index had the minimum values as 1.82 and maximum values as 136.93. Therefore, the CVI values in this study were separated in 5 class intervals as very low (1-28.4), low (28.4-55.8), moderate (55.8-83.2), high (83.2-110.6) and very high (110.6-138).

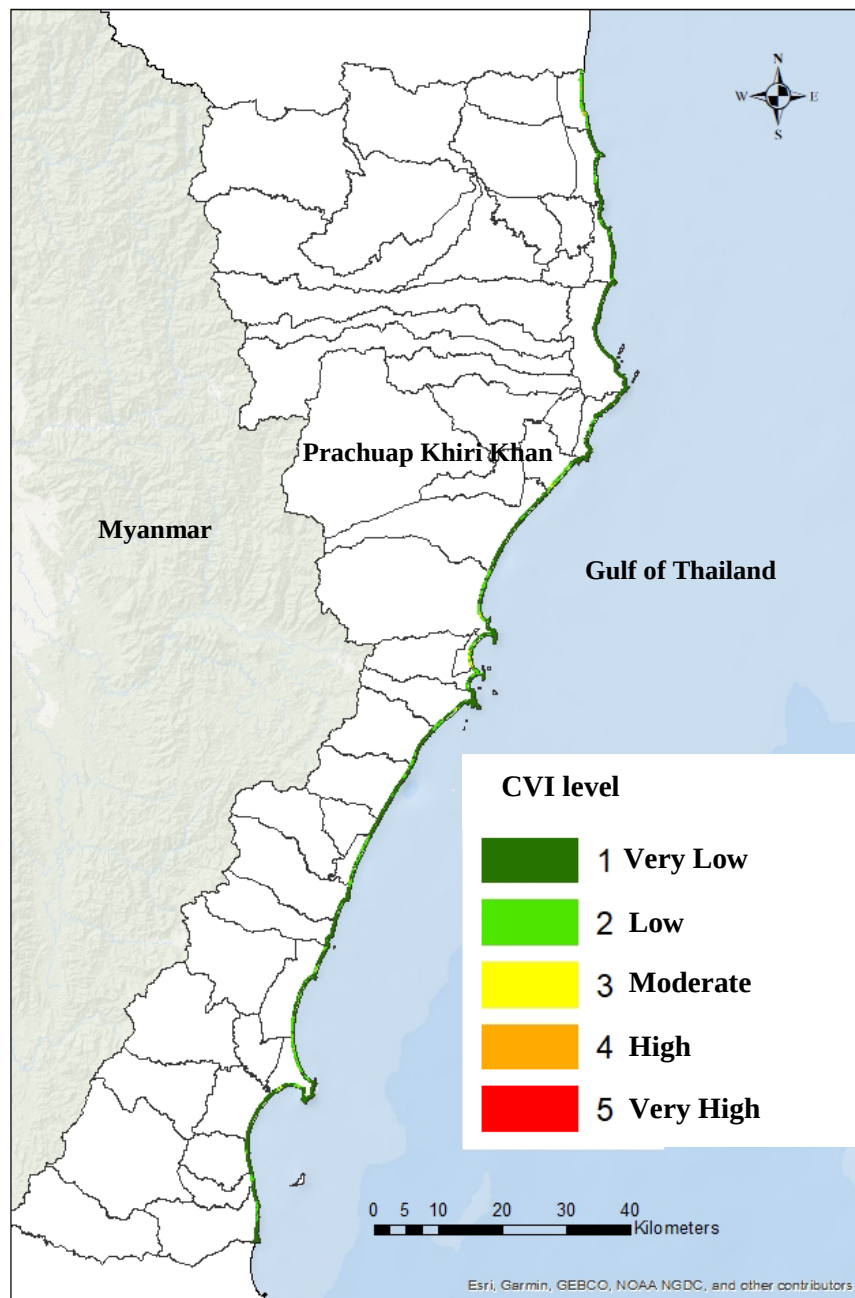


Figure 4. Coastal vulnerability map

4.2 Percentage of vulnerable area in Prachuap Khiri Khan

Prachuap Khiri Khan has 116.04 km² of coastal area which consists of 84.39 km² or 72.72 percentage of very low vulnerability area, 29.87 km² or 25.74 percentage of low vulnerability area, 1.53 km² or 1.32 percentage of moderate vulnerability area, 0.21 km² or 0.18 percentage of high vulnerability area and 0.04 km² or 0.03 percentage of very high vulnerability area (Figure 5). Most of the coastal areas in Prachuap Khiri Khan had very low to moderate vulnerability to sea level rise because there are the coastal structures placed in these areas with a very low rate of erosion, high coastal slope, low of the population density and the open space kind of land use. As can be seen in Figure 6, the area of very high vulnerability was located in Prachuap Khiri Khan sub-district which has the communities with

very high population density. It located behind the famous tourist attraction which is Thammikaram temple on Chong-krajok mountain. Moreover, there is the government bureau located on the flatland with no coastal structure. Then, these factors led to the very high vulnerability.

Percentage of vulnerable areas in Prachuap Khiri Khan

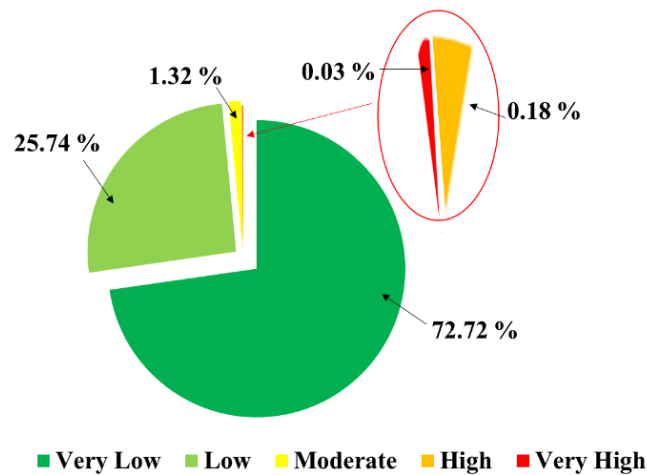


Figure 5. Represent the percentage of vulnerable area in Prachuap Khiri Khan



Figure 6. The very high vulnerability area in Prachuap Khiri Khan sub-district

5. Conclusions and recommendations

The coastal vulnerability index was chosen to be the tool for analyzing the coastal vulnerability to sea level rise in Prachuap Khiri Khan. In this study, the physical and socioeconomic variables were determined as a coastal slope, the rate of shoreline changes, geomorphology, signification wave height, tidal range, sea level changes, population density, coastal structure and land use. The CVI values were separated in 5 class intervals as very low (1-28.4), low (28.4-55.8), moderate (55.8-83.2), high (83.2-110.6) and very high (110.6-138). There were 72.72 percentage of very low vulnerability area, 25.74 percentage of low vulnerability area, 1.32 percentage of moderate vulnerability area, 0.18

percentage of high vulnerability area and 0.03 percentage of very high vulnerability of the total area of coastal zone in Prachuap Khiri Khan.

Most of the coastal zones in Prachuap Khiri Khan had very low to moderate vulnerability to sea level rise. The variables leading to low vulnerability were the rate of erosion, coastal slope, land use, population density and coastal structure. The coastal structure and land use were the important variables for analyzing the coastal vulnerability because the coastal structure affected the rate of erosion and the land use was directly related to the population density.

This study is the preliminary analysis of the coastal vulnerability index for this study area due to the limitation of the data that affected the accuracy and precision of some variables. Therefore, the accuracy of coastal vulnerability assessment can be improved by developing the coastal vulnerability index and updating the data of variables or determining other variables in the future study. However, the preliminary planning and countermeasure can be applied from the result of this study in the management of the coastal zone in Prachuap Khiri Khan.

6. References

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Acknowledgements

This research was supported by Advancing Co-Design of Integrated Strategies with Adaptation to Climate Change in Thailand Project (ADAP-T). The authors would like to express grateful thanks to Department of Marine and Coastal Resources Thailand, Meteorological Department of Thailand, Department of Marine and Hydrographics Department, Royal Thai Navy for the data information.