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Assessing Coastal Composite Vulnerability Indices on Seasonal Change in Phetchaburi, Thailand

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Abstract

The aims of this study were to apply the Geo-information technology for coastal vulnerability assessment of Phetchaburi coast, which depended on seasonal changed (by influence of Southwest monsoon and Northeast monsoon). The assessment uses a coastal vulnerability index (CVI), consists of a physical environment vulnerability index (PVI) and the socio-economic vulnerability index (SVI) with 9 variables; coastal slope, mean tidal ranges, average wave height, rates of coastal erosion, population density, land use, built-up, transportation and coastal protection measures. The results showed, the different during monsoon had an indecisive difference effect on mean tidal ranges, average wave height, and changes in the coastline. However, the monsoon had effected to sand sediment of the beach. That increased in the Southwest monsoon and decreased in the Northeast monsoon. The level of vulnerability of the coastal area was shown by a map of CVI, with high coastal vulnerability areas having a size of 4.6 square kilometers (10.89% of the coastal surveillance area), mainly in Pak-Thale, Bang-Keaw and Chao-Samran. The moderate and the low coastal vulnerability areas have size of 31.29 square kilometers and 6.97 square kilometers, respectively. The variables that influence the vulnerability are land use, slope, erosion rate and population density.

Keywords: coastal vulnerability; seasonal change; Phetchaburi coast; GIS

1. Introduction

Climate change caused by global warming results in high risks to severe and frequent natural disasters (IPCC, 2012). In addition to, the development leads to the deterioration of natural resources and the cumulative long shore sediments. All of this speeds up the process of erosion and flooding along the coast (McFadden *et al*., 2007). The erosion causes Thailand's coast to lose 16,760 Rai or 26.816 km^2 (Department of Marine and Coastal Resources: DMCR, 2009). The prediction in the next 40-100 years, the sea level will be a meter higher, which will impact 2 million Rai or 3,200 km^2 (Office of Natural Resources and Environmental Policy and Planning: ONEP, 2009). Phetchaburi is one coastal province of Thailand which has abundant natural resources. They are seen as crisis areas that require active surveillance (DMCR, 2011). The solution of the erosion problem needs the study of a natural process occurring in monsoon season because the Oceanography as the main factor of coastline changed (Armah, 2011).

Therefore, in order to implement effective coastal area management, it is important to study coastal vulnerability assessment (CVA) and focus on the change in coastal areas, which will lead to the analysis of actual vulnerability of the areas. Moreover, it is crucial to support the planning and decision-making of the development which may cause some adverse effects. By doing this, the solution both long-term and short-term to the problem of coastal erosion would become more effective.

2. Materials and Methods

This study has applied to use Geographic Information System (GIS) and remote sensing for assessing coastal vulnerability in Phetchaburi, includes 13 sub-districts adjacent to shoreline which covers shoreline about 91.2 kilometers (Fig. 1). To study shoreline changing during 2001-2011 has been focused on the impact of season change, includes two periods: the Southwest monsoon (May-September) and the Northeast monsoon (October-February). The coastal vulnerable index has been developed and adapted to be proper to characteristic and data collecting of each area. Then, this study adapted from Clauio (2005), used socio-economic aspects to be factors to assessed coastal vulnerability with physical environment, applied from Thieler and Hammar-Klose (2000), McLauglin *et al*. (2002) and Cutter (2008). The variation consists of coastal slope, mean tidal range, mean wave height, erosion rate, population density, land use, type of built-up, transportation and coastal protection measures.

2.1. Data organization and verification

The formats of collected data are spatial data and non-spatial data. Spatial data refers to satellite images and topography map that are verified by using GPS data of field surveys. Non-spatial data had no specific location in space such as population, and protection measures. The whole data have implemented to organize in order to ready and be available in GIS analysis.

2.2. Data classification and processing

After data verification, the study has classified data into each class. It has also applied the level of coastal vulnerability and weighting of each variable. Moreover, they use the weight from the research of Duriyapong and Nakhapakorn (2011) and ONEP (2003) due to the weight from experts in Thailand, which has a understanding of the physical and socio-economy as well. The classification details are as follow in Table 1.

All data have been evaluated by the overlay technique (Fig. 2) and the score of each variable would be incorporated into the Physical Environment Vulnerability Index: PVI and the Socio-Economic Vulnerability Index: SVI by using this equation as follow. When $X(PV)_i$ is the score of physical environment vulnerability index and $W(PV)_i$ is the weighting of physical environment vulnerability index as well. $X(SV)_i$ is the score of socio-economic vulnerability index and $W(SV)_i$ is the weighting of socio-economic vulnerability index (Adapted from Clauio, 2005).

$$CVI = \frac{PVI + SVI}{\text{Number of Indices}}$$

$$PVI = \frac{\sum X_{(PV)i} W_{(PV)i}}{\sum W_{(PV)i}}$$

$$SVI = \frac{\sum X_{(SV)i} W_{(SV)i}}{\sum W(SV)_i}$$

3. Results

3.1. Coastal Vulnerability Assessment (CVA)

CVA use application GIS to indicate CVI from 2 indices, there are PVI and SVI. The results of PVI factors are as follow: 1) Coastal Slope - There are several areas in upper zone from Bang Tabun to Hat Chao Samran that slope is below than 0.025% that has very high PVI. On the contrary, slope of most of lower zone is higher than 0.070%, this area has very low PVI. 2) Mean Tide Range - At Ban-Laem station and Hua-Hin station (Fig. 3), the results are in the same trend and mean tidal ranges of both monsoons are

Table 1. Classification of vulnerability variables

Variable	Level of coastal vulnerability					Weight
	Very low 1	Low 2	Moderate 3	High 4	Very High 5	
Coastal Slope (%)	> 0.200	0.200 - 0.070	0.070 - 0.040	0.040 - 0.025	< 0.025	0.35
Mean Tide Range (m)	> 6.00	4.10 - 6.00	2.00 - 4.00	1.00 - 1.90	< 1.00	0.11
Mean Wave Height (m)	< 0.55	0.55 - 0.85	0.85 - 1.05	1.05 - 1.25	> 1.25	0.29
Erosion Rate (m/yr)	< 1.0	1.0 - 1.9	2.0 - 2.9	3.0 - 3.9	> 4.0	0.25
Population Density	1 - 100	101- 200	201 - 400	401 - 600	> 600	0.24
Landuse	Abandoned area, Swamp, Water bodies	Grass, Scrub	Forest, Mangrove forest	Agriculture, Aquaculture, Salt-farm	Town, Factory Commercia, Tourist zone	0.42
Built-up	Absent	-	Essentiality place	-	Culture heritage	0.27
Transportation	Absent	-	Street	-	Main road, Railway	0.07
Coastal Protection Measure	No erosion	-	Erosion; Present measure	-	Erosion; Without measure	0.10

Source: Adapted from Thieler and Hammar-Klose (1999), McLaughlin, McKenna and Cooper (2002), Cutter (2008), Duriyapong and Nakhapakorn (2011) and ONEP (2003)

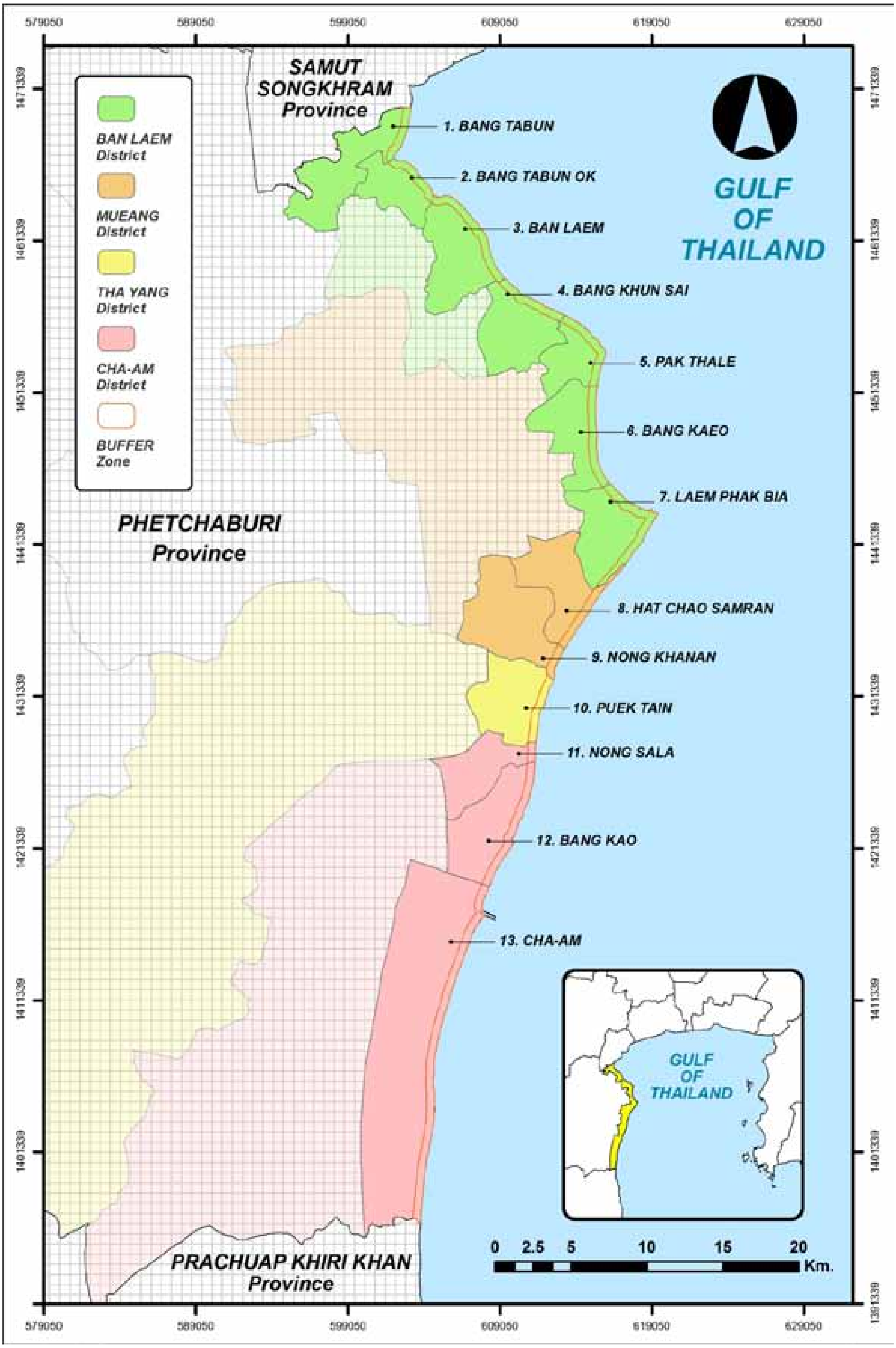


Figure 1. Study area

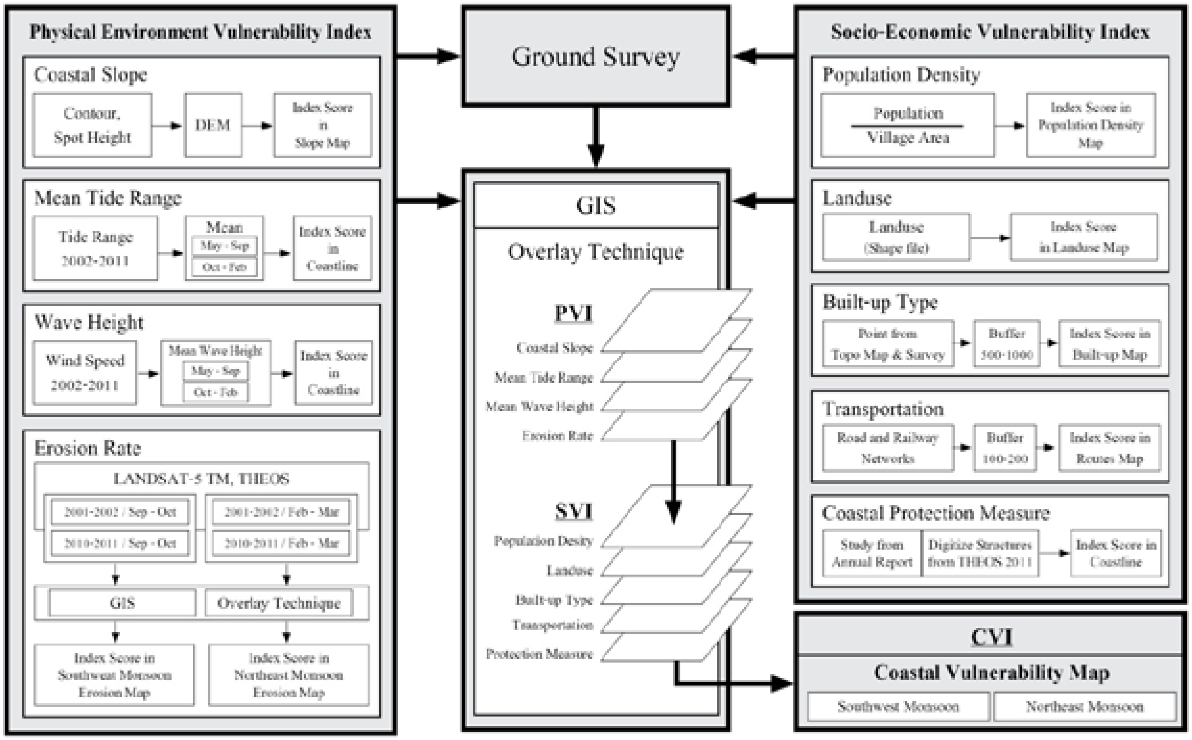


Figure 2. Step of coastal vulnerability assessment

similarly. Upper zone is defined moderate PVI and Lower zone is defined as high PVI. 3) Mean Wave Height - It is calculated from wind speed data to monthly mean wave height from Phetchaburi meteorological station during 2001-2011 (Fig. 4), Mean wave height of both monsoons is similarly and defined low PVI. 4) Erosion rate - The result of coastline analysis by DSAS is erosion rate of both monsoons, which is similar and can be defined PVI as in Fig 5. It respectively indicates that upper zone, most is mud flat and mangrove forest, there are not any changes in each monsoon while the lower zone, most is the sandy beaches, has changes in each monsoon obviously. The Southwest monsoon contributes to accumulate sandy sediments onshore and the Northeast monsoon play a role in blowing sandy sediments to offshore.

As the vulnerability maps in each monsoon are similarly because the vulnerability scores of 3 factors which are supposed to be reflected factor to variance vulnerability of each monsoons, mean tide range, mean wave height and erosion rate, are classified in the same vulnerability level. For this reason the map of physical environment vulnerability of each monsoon shows the same results as Fig. 6(a). High vulnerability area has

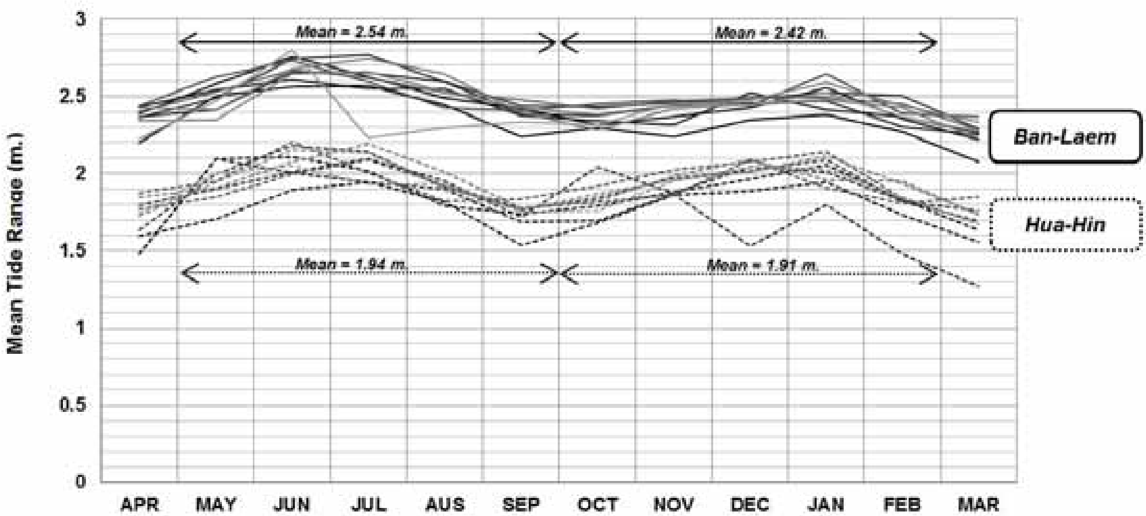


Figure 3. Graph of the monthly average tidal range, 2001-2011

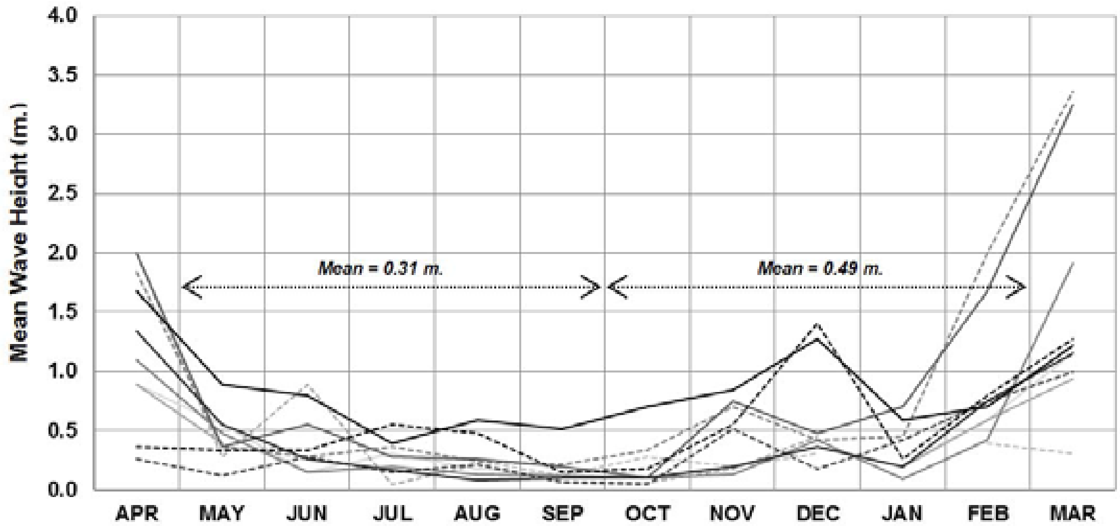


Figure 4. Graph of the monthly average wave height, 2001-2012

total area 2.53 square kilometers (km^3), most area is in Pak Thale, Bang Kao and Hat Chao Samran.

The results of SVI factors as follow: 1) Population density-Coastal area which have high vulnerability are fishery community at Ban-Laem and tourist attraction areas at Hat-Chao-Samran and Cha-am beach. 2) Landuse-52.8% of study area is agricultural area and high vulnerability, community area has 16.78%. In the upper zone, it located canal side or river to the mouth of river. While the lower zone, it located near the beach. 3) Type of Built-up-high vulnerability is the Mrigadayavan Palace in Cha-am and there are 39 religious places in every sub-district 4) Transportation-There is 5 kilometers concrete road along the beach leads to high vulnerability because it blocks sediment that cannot move to the beach (ONEP, 2003). 5) Coastal Protection Measure-The area has high vulnerability is Pak-Thale because problems still occurs continually. Though related sector did the map for built up protective infrastructure, it lacks of budget for doing concrete plan. The result can show as a map of SVI as Fig. 6(b). The high vulnerability total area is 8.5 and most area is in Laem-Pak-Bia.

CVI using GIS program for mapping from PVI and SVI by overlaying method and mapping coastal vulnerability of each monsoons, index of PVI in each monsoons are the same level, therefore, maps are shown in the same format as Fig. 6(c). High coastal vulnerability has total area 4.68 square kilometers. It's 10.89% of the coastal surveillance area that buffered offshore to the ground 500 meters.

3.2. Verifying coastal vulnerability assessment

The results will be verified by field survey that focuses on coastal surveillance area and have high of PVI and CVI. The results are corresponding to reality in area as following: The upper zone coast at Pak-Thale (Fig. 7(a)) that intense eroded and high of PVI because of low slope and no mangrove forest or protection structures, but it is aquaculture, moderate of SVI. This affect to its CVI is same level as community area of Bang-Kaeo coast (Fig. 7(b), (c)), it has SVI higher, and they are different from Laem-Pakbia coast (Fig. 7(d)), it has low PVI and SVI because it has mangrove forest to protect the erosion and there are not communities. The lower zone coast at Hat-Chao-Samran (Fig. 8(c)), it has very high of SVI because of tourist attraction areas, community area, high population density, which has religious place and road near the beach.

4. Discussions and Conclusion

4.1. The sediment balance in the beach system

Although Phetchaburi coastal characteristics are different, the upper area from Bang-Tabun estuary to Laem-Luang beach that are mud beach has occurred from river sediment. The lower areas are sand beach that followed from geological structure. However, the study from satellite image and survey in study area, sand sediment swept into the upper area. It has impacted to mangrove degradation because the ecosystem of mangrove forest changed (Sinsakul *et al.*, 2002). Therefore, the term of sediment balance or beach balance is considering. Sediments are moved from one to replace another that lost sediment (Pornpinatepong *et al.*, 2001). It could be observe that sand sediment from the lower area is swept to the upper area. Since, the sediments have been lack in the upper area. The causes may be effect from dam construction or sand dredging on canals or estuaries.

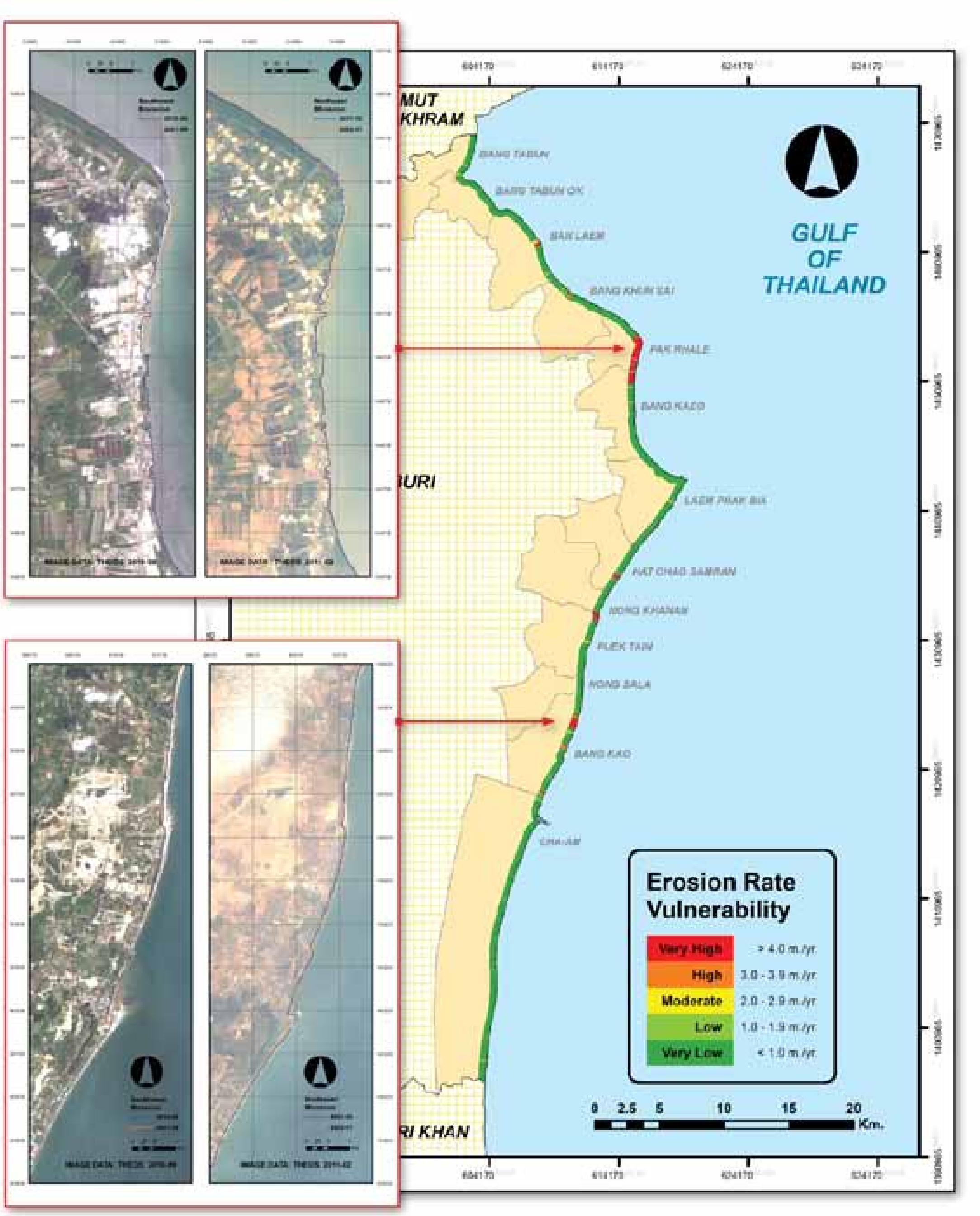
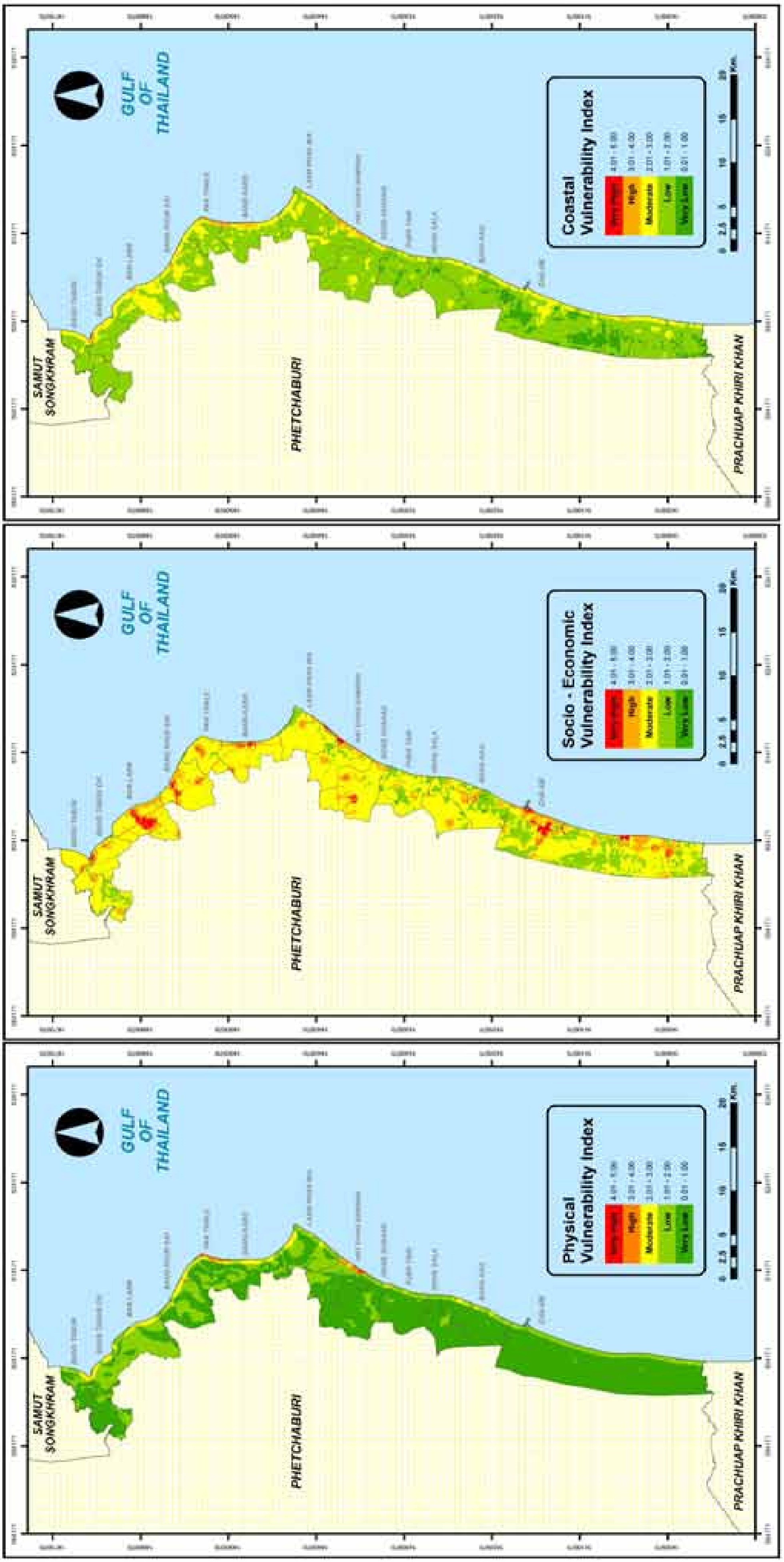


Figure 5. Map of the erosion rate vulnerability



(c) Map of CVI

(b) Map of SVI

(a) Map of PVI

Figure 6. Map of vulnerability index

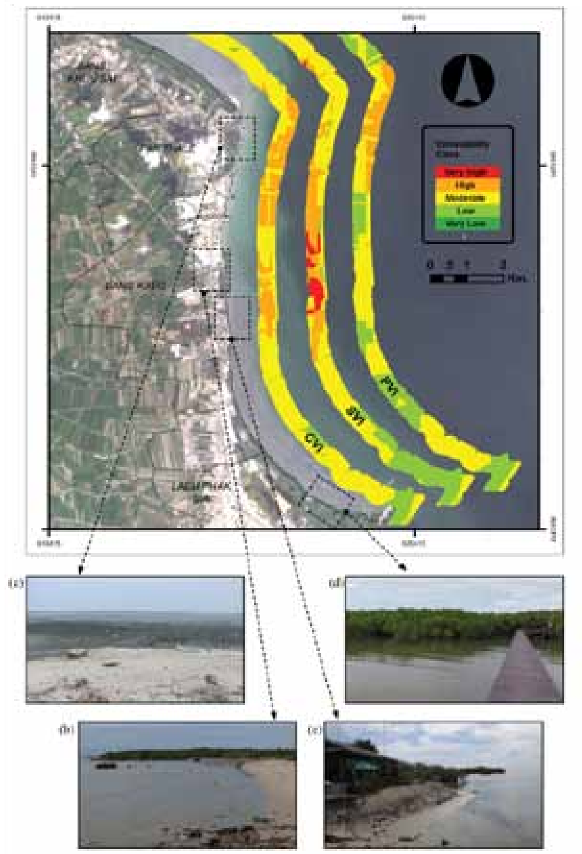


Figure 7. Ground survey in upper zone coast

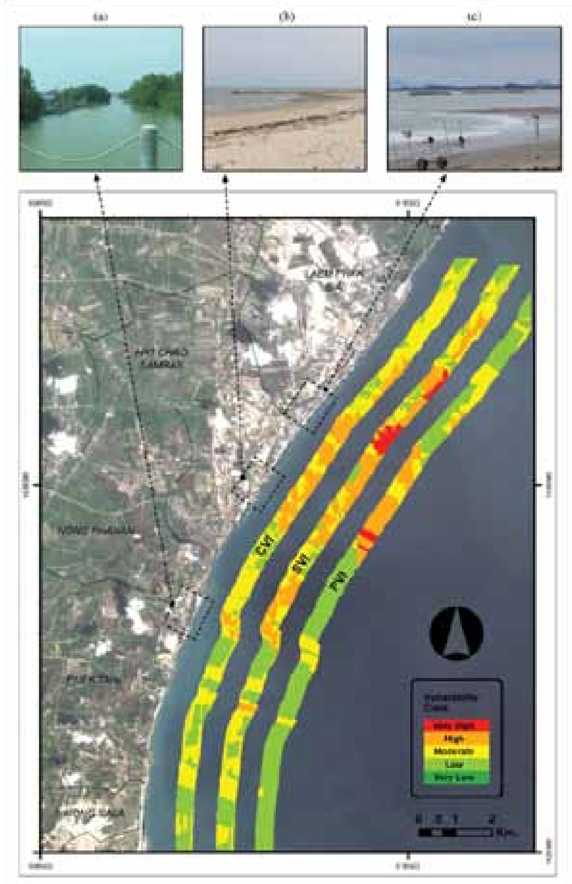


Figure 8. Ground survey in lower zone coast

4.2. Impact of engineering structures along the coast

In this study coastal erosion is high at Pak-Thale sub-district. The result has been compared with the report of Phetchaburi coastal erosion in 1967-1995 by Department of Mineral Resources (ONEP, 2003). From the report recorded that coastal erosion at Pak-Thale sub-district was moderate. The erosion rate was 1-5 meters per year, that less than the rate of coastal erosion Bang-Kaew sub-district, more than 10 meters per year. But this study has found coastal areas of the Pak-Thale sub-district, which above the rock revetment of Bang-Kaew sub-district. There were high erosion problem that increased 10.19 meters per year. It has shown the engineering structures, built for protecting coastal erosion affect to coastal areas above those structures, have been intensified eroded (Pornpinatepong *et al*., 2001). Including the building extending to the sea such as the harbor, and breakwater, the coastal had been eroded above the building. Moreover, breakwaters that built near the coastline for stabilization affect to loss sand sediment in front of them because of no sediment to accumulate on the beach.

4.3. The importance of socio-economic factors

From the coastal vulnerability assessment (CVA) that considered factors including the physical environment and the social economy. There has shown that the rate of coastal erosion has been very high which occurred from arising of influence of nature, unnecessary to very high level of the coastal vulnerability index (CVI). For example, Pakthale district found severely eroded but coastal areas had coastal vulnerability equal with coastal areas in Chaosamran that are not found the erosion. Because of, Pakthale district had aquaculture and less population. The people were affected and damaged by coastal erosion that were less than Chaosamran district, which was a community, touring area, high population density, a place of culture, and beach road. The both of coastal areas had similar in level of importance in management and prevention. They were show the important factor of social and economic to assess with environmental factors. The results of the assessment were reality and suitable to use as supporting data in coastal area management.

Although, the assessment of vulnerable coastal areas (CVA) was not show in worth of damage or expected in the future. Besides, the selection of the data was collected that helped easily to plan a budget and coastal area management. Demonstration in the accuracy of the image at each point of the vulnerable coastal areas as well. The information in a map was not complicated. It was easier to communicate with the community and relevant agencies informed of the level of vulnerability of the area that approach to participate in preparing to deal with the problem. The both of coastal areas had similar in level of importance in management and prevention. They were show the important factor of social-economic to assess with environmental factors.

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References

Armah AF. GIS-based assessment of short term shoreline change in the coastal erosion-sensitive zone of Accra, Ghana. Research Journal of Environmental Sciences 2011; 5(7): 643-54.

Clauio FS. Climate change, sea-level rise and coastal natural hazard: A GIS-based vulnerability assessment, state of Pará, Brazil. Journal of Coastal Conservation 2005; 11(1): 53-66.

Cutter SL. A framework for measuring coastal hazard resilience in New Jersey communities. The Urban Coast Institute. Columbia. 2008.

Department of Marine and Coastal Resources, Ministry of Natural Resources and Environment. The state of marine and coastal Thailand 2009. Thaiphum Publishing., Bangkok, Thailand. 2009; 57-67.

Department of Marine and Coastal Resources, Ministry of Natural Resources and Environment. Coastal erosion management in Thailand. Documents of the international symposium on coastal erosion. at Rama Gardens Hotel Bangkok: 27 - 29 April 2011.

Duriyapong F, Nakhapakorn K. Coastal vulnerability assessment: a case study of Samut Sakhon coastal zone. Songklanakarin Journal of Science and Technology 2011; 33(4): 469-76.

Intergovernmental Panel on Climate Change: IPCC. Summary for policymakers. *In:* Managing the risks of extreme event and disasters to advance climate change adaptation (*Eds:* Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Edi KL, Mastrandrea MD, Mach KJ, Plattner GK, Allen SK, Tinor M, Midgley PM). A special report of working groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press. Cambridge, UK. 2012; 3-21.

McFadden L, Penning-Rowsell E, Nicholls RJ. Setting the parameters: A framework for developing cross-cutting perspectives of vulnerability for coastal zone management. Managing Coastal Vulnerability. Elsevier, Oxford, UK. 2007; 262.

McLaughlin S, McKenna J, Cooper JAG. Socio-economic data in coastal vulnerability indices: constraints and opportunities. Journal of Coastal Research 2002; Special Issue 36: 487-97.

Office of Natural Resources and Environmental Policy and Planning, Ministry of Natural Resources and Environment. Final report: Master plan for solutions of coastal erosion at Phetchaburi estuary to Pranburi estuary. Asian Institute of Technology and Southeast Asia Technology Co., Ltd. 2003.

Office of Natural Resources and Environmental Policy and Planning, Ministry of Natural Resources and Environment. Final report: The study analyzes the impact of rising sea levels on coastal land use in Thailand. Thammasart University Research and Consultancy Institute. 2009.

Pornpinatepong S, Pornpinatepong K, Korathinthakom S, Surangsriratha D. Sand beach: depletion of natural heritage. Thai universities for public policy project: Case study of use value and conservation of the beach. Prince of Songkla University. Songkla. Graphicnext. 2011.

Sinsakul S, Tiyapairat S, Chaimanee N, Aramprayoon A. The changing coastal area at the gulf seacoast of Thailand. (Technical Report). Department of Mineral Resources, 2002; 173.

Thieler ER, Hammar-Klose ES. National assessment of coastal vulnerability to sea-level rise: Preliminary results for the U.S. Gulf of Mexico coast [homepage on the Internet]. U.S.: U.S. Geological Survey; 2000 [cited 2012 May 10]. Available from: http://pubs.usgs.gov/of/2000/of00-179.

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