Assessment the Vulnerability of Environmental and Natural Resources in Coastal Area, Prachuap Khiri Khan Province, Thailand

การประเมินความเปราะบางของทรัพยากรธรรมชาติและสิ่งแวดล้อม บริเวณพื้นที่ชายฝั่ง จังหวัดประจวบคีรีขันธ์ ประเทศไทย

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ABSTRACT

The purpose of this research was to analyze the vulnerability of the environment and natural resources in the coastal area of Prachuap Khiri Khan Province (8 Districts and 23 Sub-districts) by examining Environmental Vulnerability Index (EVI) and apply Geographic Information System (GIS) for analyses and to map the environment and the natural resources in the vulnerable areas. Thirteen factors for analyses were area size, drought periods, precipitation, population density, population growth rate, vertical relief, coastal erosion, preserved and conserved area, sea surface temperature, coastal aquaculture area, water use, the rate of deforestation and mangrove forest, and solid waste disposal. The overall results revealed that EVI values of the areas were ranged 2.01 – 4.00, which implied that the conditions of environment and natural resources were moderately vulnerable, and the area with the highest EVI was Prachuap Khiri Khan Sub-district (5.04).

บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อประเมินความเปราะบางของทรัพยากรธรรมชาติและสิ่งแวดล้อม ในพื้นที่ชายฝั่ง จ.ประจวบคีรีขันธ์ (8 อำเภอ 23 ตำบล) โดยพิจารณาปัจจัยจากดัชนีความเปราะบางด้านสิ่งแวดล้อม (Environmental Vulnerability Index: EVI) ประกอบกับประยุกต์ระบบสารสนเทศภูมิศาสตร์เพื่อวิเคราะห์และจัดทำแผนที่แสดงพื้นที่เปราะบางทางสิ่งแวดล้อม ปัจจัยที่นำมาวิเคราะห์มีทั้งสิ้น 13 ปัจจัย ได้แก่ ขนาดพื้นที่ ภาวะความแห้งแล้ง ปริมาณฝน ความหนาแน่นประชากร อัตราการเพิ่มประชากร ความสูงต่ำของพื้นที่ การกัดเซาะชายฝั่ง พื้นที่เขตอนุรักษ์ ระดับอุณหภูมิผิวน้ำทะเล พื้นที่การเพาะเลี้ยงชายฝั่ง การใช้น้ำ อัตราการลดลงของพื้นที่ป่าบกและป่าชายเลน และขยะมูลฝอย พบว่า ภาพรวมของพื้นที่มีค่า EVI ระหว่าง 2.01 – 4.00 จัดอยู่ในเกณฑ์ที่มีความเปราะบางระดับปานกลาง พื้นที่ที่มีความเปราะบางสูงสุด คือ ตำบลประจวบคีรีขันธ์ (EVI = 5.04).

Key Words: Environmental vulnerability index, Geographic information system, Prachuap Khiri Khan

คำสำคัญ: ดัชนีความเปราะบางด้านสิ่งแวดล้อม ระบบสารสนเทศภูมิศาสตร์ ประจวบคีรีขันธ์

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Introduction

Environment and natural resources are complicated systems. Developing countries during the past 30 years have met with serious issues on their management. Problems surged are caused by countless reasons including; population rise, rapid economic growth, intensive agricultural and industrial pollution. Moreover, technology adoption might less likely fit for production use. Technological advancement could have affected natural resources which might lead to degradation and restriction for further environmental development. The environmental issues are extremely severe due to excessive and in appropriate means until it cannot accommodate or adjust to recover to its original system (Sunthud, 1996).

Prachuap Khiri Khan Province is located in the central of Thailand and adjacent to the Gulf of Thailand on latitude of 12° 31' N - 11° 24' N and on a longitude of 99° 09' E - 100° 00' E (Prachuap Khiri Khan Provincial Governor's Office, 2009). This area is key to economy, society, and culture because of its variety of resources and lucrative to tourism. Therefore, there are high risks of resources' wastes if there is poor planning for the environmental management for future.

From the above effects could lead to vulnerability of environmental and natural resources. The vulnerability is a term used in describing negative situations the areas are now facing. could lead to vulnerability of environmental and natural resources. The vulnerability is a term used in describing negative situations the areas are now facing. The effect of changes bring forth pressure became risks. The areas are helpless to move away from the situations or to handle risks (Adger *et al*, 2001).

In this study, the researcher considered the vulnerability of environment and natural resources of areas by using the Environmental Vulnerability Index (EVI), developed by the South Pacific Applied Geoscience Commission (SOPAC), the United Nations Environment Programme (UNEP), and their partners (Kaly *et al*., 2005). This index consists of three sub-indices including intrinsic resilience (IRI), environmental degradation (EDI), and risk exposure (REI). These sub-indices reflects the characteristics or the environmental conditions in various ways because it depending on the areas, human activities, and natural disasters. Another reason is the period of time that makes risk and vulnerability happen in the areas.

The objective of this study was to assess the environmental vulnerability in the area and to map the vulnerable areas by using Geographic Information System (GIS).

Materials and Methods

1. Scope of Studied area

The site covered the coastal areas in Prachuap Khiri Khan Province including 8 District 23 Sub-district of Hua Hin Sub-district, Nong Khae, Pak Nam Pran, Khao Daeng, Kui Nuea, Bo Nok, Ao Noi, Prachuap Khiri Khan, Ko Lak, Khlong Wan, Huai Sai, Huai Yang, Saeng Arun, Thap Sakae, Na Hu Kwang, Ang Thong, Thong Chai, Mae Ramphueng, Phong Prasat, Bang Saphan, Pak Phraek, Sai Thong, and Sam Roi Yot Sub-district.

2. Data Collection and Factors Identification

Since 1999, SOPAC was studied and developed the Environmental Vulnerability Index: EVI (Kaly *et al*., 2005). In addition, CHARM (Coastal Habitats and Resources Management Project) was applied thirty-three factors of EVI and methods to map

the vulnerability and quality status of Phang Nga Bay and Ban Don Bay in Southern Thailand (Coastal Habitats and Resources Management Project: CHARM, 2005).

Therefore, the researcher selected factors based on CHARM (Coastal Habitats and Resources Management Project), because they were studied and applied them in Thailand.

The selected 13 factors including Spatial Data and Non-Spatial Data and gathering from the government agencies such as document, recorded statistics, and relevant researches, in order to create a database and to analyze the vulnerability of environmental and natural resources in coastal area. (Table 1)

Table 1 Factors identification in the studied site

Sub-Index	Name	Description	Unit	Period of Study	Source
IRI	area size	Total of land area in each zone (land area only)	Km^2	Present	Department of Provincial Administration
IRI	Vertical relief	Range of altitude. (the highest – the lowest point in each zone)	Meter	Topographic maps, 1:50,000 scale in L7018 series	The Royal Thai Survey Department
IRI	Coastal Erosion	Percentage of coastal erosion in each zone.	%	Satellite images from LANDSAT 5 TM in year 1989, 1999 and 2009	Geo-Informatics and Space Technology Development Agency (Public Organization) (GISTDA)
EDI	Preserved and conserved	Percentage of reserved area and protected area in each zone.	%	Present	- Department of National Park, Wildlife and Plant Conservation - Royal Forest Department - Department of Marine and Coastal Resources - Pollution Control Department
EDI	Coastal aquaculture area	Area of aquaculture farms in each zone.	Rai	Present	Land Development Department
EDI	Water use	Average annual water used over the last 5 years.	Cubic meter / Km^2 / year	During 2007 – 2011	- Department of Provincial Administration - Department of Environmental Quality Promotion
REI	Drought periods	Number of days over last 5 years, with rainfall less than 20% by average in each month for the last 30 years.	Number of months	During 1982 – 2011	Thai Meteorological Department

Table 1 Factors identification in the studied site (cont.)

Sub-Index	Name	Description	Unit	Period of Study	Source
REI	Wet periods	Number of months over last 5 years, with rainfall more than 20% by average in each month for the last 30 years.	Number of months	During 1982 – 2011	Thai Meteorological Department
REI	Population density	Total of human population density in the current year.	No. / Km^2	2011	Department of Provincial Administration
REI	population growth rate	Percentage of population growth rate, by average over the last 5 years.	%	During 2007 – 2011	Department of Provincial Administration
REI	Sea Surface Temperature	Occurrence of sea surface temperature deviated more than 0.25°C	Number of occurrences	During 2006 – 2011	National Oceanic and Atmospheric Administration (NOAA)
REI	Rate of Deforestation and Mangrove forest	Net percentage of land area changed by removal of natural vegetation in over the last 5 years.	%	During 2001 – 2011	- Land Development Department - Department of Marine and Coastal Resources
REI	Solid Waste Disposal	Average of Solid waste over the last 5 years.	Ton / Km^2 / year	During 2007 – 2011	- Department of Provincial Administration - Department of Environmental Quality Promotion

Source: Coastal Habitats and Resources Management Project: CHARM, 2005

3. Determining the weight of each factor.

The Sub-district Administrative Organization (SAO) judged and determines the weight of each factor and gave the relative importance of the 13 factors by using multi-criteria analysis or MCA. The scales of importance were ranged from 1-equal importance to 9-extreme importance (Saaty, T. L., 2008). After ranging, the level of importance were calculated and organized into three levels based on standard deviation (S.D.) and mean value. (Table 2)

Table 2 Ranking the level of importance

Level	Calculation Method	Interpretation
1	> Mean + S.D.	Less Important
2	Mean – S.D. to Mean + S.D.	Equally Important
3	< Mean – S.D.	More Important

4. Analysis of the Environmental Vulnerability Index (EVI)

The EVI analyses included three factors of intrinsic resilience (IRI), three factors of environmental degradation (EDI), and seven factors of risk exposure (REI). The indices were rated on a scale of 1 – 7, with 1-least vulnerable (most resilient) to

7-least resilient (Coastal Habitats and Resources Management Project: CHARM, 2005). Therefore the EVI could be calculated as follows.

$$\textbf{IRI} = \frac{Sc_1Wt_1 + Sc_2Wt_2 + Sc_3Wt_3}{Wt_1 + Wt_2 + Wt_3} \quad \ldots(1)$$

$$\textbf{EDI} = \frac{Sc_4Wt_4 + Sc_5Wt_5 + Sc_6Wt_6}{Wt_4 + Wt_5 + Wt_6} \quad \ldots(2)$$

$$\textbf{REI} = \frac{Sc_7Wt_7 + Sc_8Wt_8 + \ldots + Sc_{13}Wt_{13}}{Wt_7 + Wt_8 + \ldots + Wt_{13}} \quad \ldots(3)$$

After their combination, the final EVI equation was as below.

$$\textbf{EVI} = \frac{Sc_1Wt_1 + Sc_2Wt_2 + \ldots + Sc_{13}Wt_{13}}{Wt_1 + Wt_2 + \ldots + Wt_{13}} \quad \ldots(4)$$

Whereas

Sc_n = the score of each factor

Wt_n = weighting of each factor by SAO

EVI = Environmental vulnerability value

IRI = Intrinsic resilience value

EDI = Environmental degradation value

REI = Risk exposure value

The values of IRI, EDI, REI, and EVI could, form the result of the equations, be separated into three ranges and their intensity were presented in low, moderate, and high levels. (Table 3)

Table 3 Values of IRI, EDI, REI, and EVI.

Level Score / Index	≤ 2.00	2.01 – 4.00	> 4.00
IRI	Low sensibility to damages.	Moderate sensibility to damages.	High sensibility to damages.
EDI	High resistance to damages.	Moderate resistance to damages.	Low resistance to damages.
REI	Low risk	Moderate risk	High risk
EVI	Low vulnerability, more stable	Moderate vulnerability	High vulnerability, least stable

Source: Coastal Habitats and Resources Management Project: CHARM, 2005

5. GIS Application.

From this analysis, the result will presented by using GIS technique to map the vulnerability in the areas based on the following equations.

$$IRI = R_1W_1 + R_2W_2 + R_3W_3 \quad \ldots(1)$$

$$EDI = R_4W_4 + R_5W_5 + R_6W_6 \quad \ldots(2)$$

$$REI = R_7W_7 + R_8W_8 + R_9W_9 + R_{10}W_{10} + R_{11}W_{11} + R_{12}W_{12} + R_{13}W_{13} \quad \ldots(3)$$

Three sub-indices would be combined and displayed the value of the environmental vulnerability as follows.

$$EVI = (R_1W_1) + (R_2W_2) + (R_3W_3) + \ldots + (R_{13}W_{13}) \quad \ldots(4)$$

When

(R_nW_n) = Parameter and weighting system of each factor

Results and discussion

Based on the analysis of the data collected, the overall environmental vulnerability index (EVI) of the studied areas were ranged from 2.01 – 4.00, which implied the state of environment and natural resources were moderately vulnerable. The intrinsic resilience index (IRI) was greater than 4.00, which implied that the areas had high sensibility to damages. The risk exposure index (REI) was 2.01 – 4.00, which implied that the risk exposure of environment and natural resources was moderately. The environmental degradation index (EDI) ranged from 2.01 – 4.00 implied that the areas had moderate resilience to

damages, i.e. moderate damages occurred. Results were shown in Figure 1 – 4.

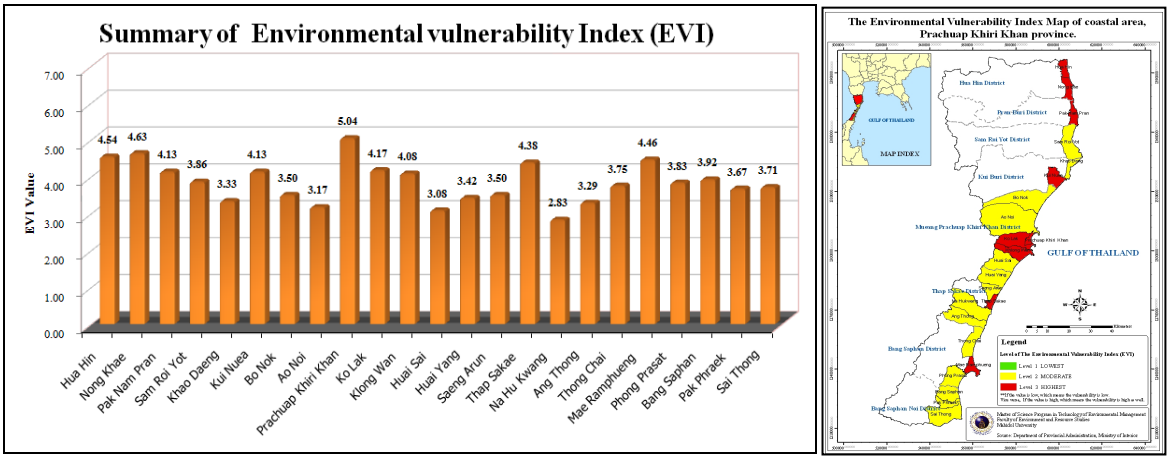

Figure 1 Illustration of environmental vulnerability index (EVI).

From **Figure 1**, the overall environmental vulnerability was moderate (EVI ranged from 2.01 – 4.00). The areas with moderate EVI values were found in 14 Sub-districts and the highest EVI values were in 9 Sub- districts. The highest EVI value was in Prachuap Khiri Khan Sub-district (EVI = 5.04) and the lowest EVI was in Na Hu Kwang Sub-district (EVI = 2.83). The environmental issues involved coastal erosion, wet periods, sea surface temperature, and preserved and conserved.

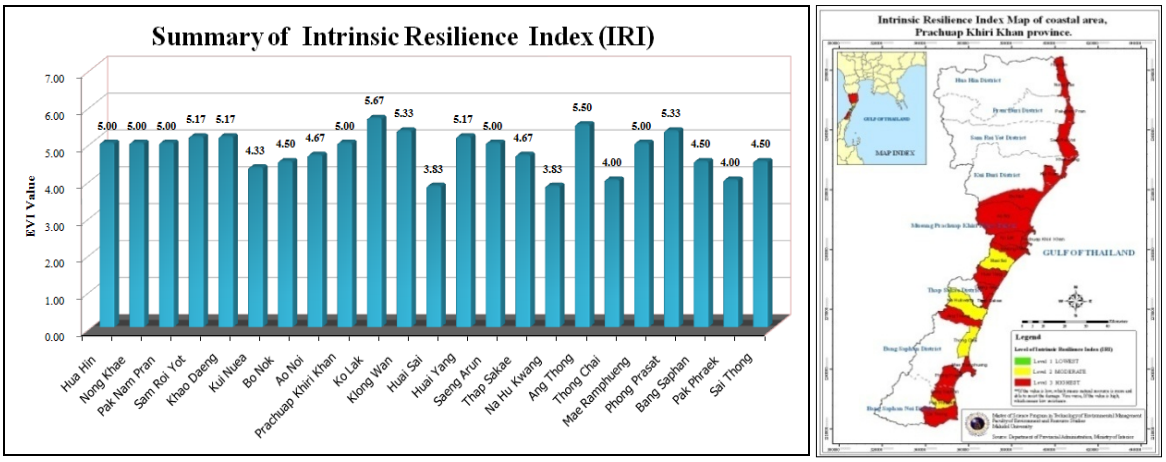

Figure 2 Illustration of Intrinsic Resilience Index (IRI)

From **Figure 2**, the intrinsic resilience by overall had high sensibility to damages (IRI was greater than 4.00). The areas with high IRI values were found in 19 Sub-districts and the moderate IRI values were found in 4 Sub-districts. The highest IRI value was in Ko Lak Sub-district (IRI = 5.67), and the lowest IRI value was in Huai Sai Sub-district (IRI = 3.83) and in Ang Thong Sub-district (IRI = 3.83). These areas were mostly affected by coastal erosion and limitations of area size which caused a significant impact in natural resource uses.

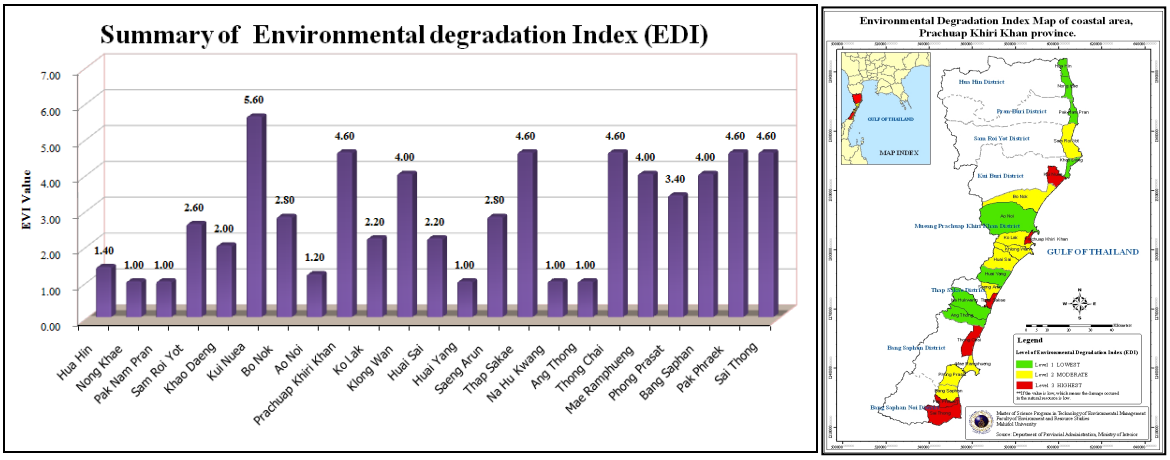

Figure 3 Illustration of Environmental Degradation Index (EDI)

From **Figure 3**, the state of environmental degradation had moderate resistance to damages (EDI ranged from 2.01 – 4.00). The highest EDI was found in 6 Sub-districts. The moderate IRI value was found in 9 Sub-districts, and the low EDI value was found in 8 Sub-districts, respectively. The highest EDI value was in Kui Nuea Sub-district (EDI = 5.60), and the lowest EDI value was in Nong Khae (EDI = 1.00), Pak Nam Pran (EDI = 1.00), Huai Yang (EDI = 1.00), Na Hu Kwang (EDI = 1.00), and Ang Thong Sub-districts (EDI = 1.00), respectively. Relevant agencies should be focused on the preserved and conserved areas and the coastal aquaculture areas.

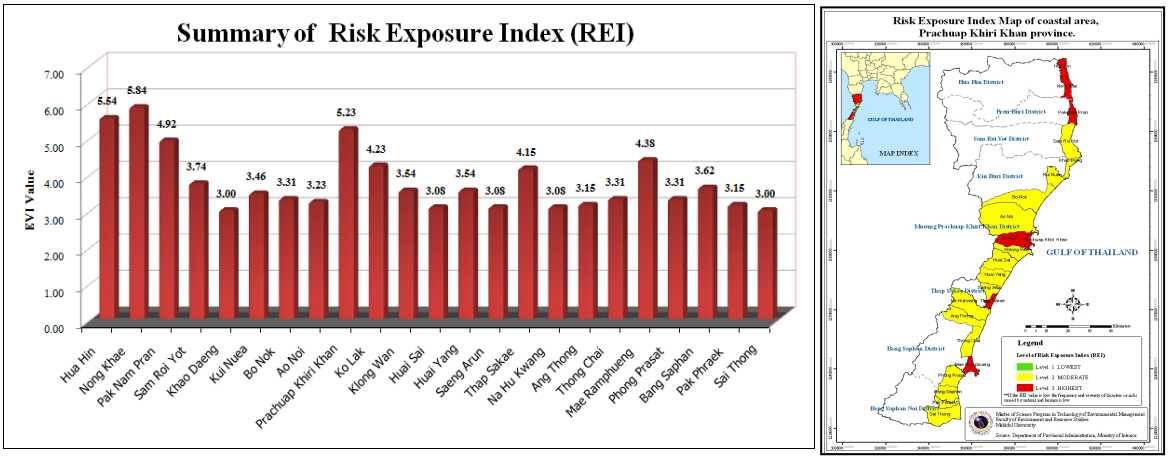

Figure 4 Illustration of Risk Exposure Index (REI)

From **Figure 4**, the risk exposure by overall was moderate (IRI ranged from2.01 – 4.00). The highest REI value was found in 7 Sub-districts and the moderate IRI value was found in 16 Sub-districts. The highest REI value was in Nong Khae Sub-district (REI = 5.84), and the lowest REI value was in Khao Daeng Sub-district (REI = 3.00) and in Sai Thong Sub-district (REI = 3.00). The issues of sea surface temperature should be reflected because they could cause the coral bleaching phenomenon as well as flooding prevention due to wet period factor. However, the problems of population density and population growth rate should be focused as well.

Conclusions

The overall values of environmental and natural resources vulnerability was moderate (EVI ranged from 2.01 - 4.00), which were corresponded with the Project of vulnerability mapping and quality status of Phang Nga Bay and Ban Don Bay in Southern Thailand (Coastal Habitats and Resources Management Project: CHARM, 2005) because these areas were located in coastal zone and with variety of physical characteristics. For example, the sea, the beach, forests and community life were not only popular in the country but also popular in global. However, the lucrative tourism may impact the natural systems due to human activities such as solid waste disposal, population density, population growth rate and natural disasters like coastal erosion, high rate of deforestation and mangrove forest, etc.

The assessment of natural resources and environmental vulnerability in the area provided us what factors caused the damage in the area in order to appropriately determine adapted strategies.

This study has assessed only 13 factors of environmental vulnerability index (EVI). In future there should be more factors associated with the area, which would be useful to the government agencies or departments involved in order to plan sustainable resource management.

However, the estimation of environmental and natural resources vulnerability might be changed by periods of time or situations, the assessment is therefore necessary to be continued in monitoring the status of the resources and guidelines for sustainable uses.

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