USING REMOTE SENSING DATA FOR CALCULATING THE COASTAL EROSION IN SOUTHERN THAILAND

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ABSTRACT:

There has been long-term observation of coastal erosion in Koh Kho Khao , Ban Nam Khem, Phang Nga province, in Thailand, which was affected by a tsunami on December 26, 2004. The disaster, as is well known, caused the loss of lives and property. This area is recognized as one of the best tourist areas in Thailand. The objective of the research was to identify the coastal changes to the island, Koh Kho Khao. The Geographic Information System and Remote Sensing were used. Five- time periods were used, in which aerial photographs and satellite images were taken, with the aerial photographs taken in February, 2002. IKONOS images were taken on December 29, 2004, and Quick Bird images were dated the 23rd of February, 2009. Worldview-2 images were dated the 6th of December, 2012, while the Pleiades images were dated January 8, 2016. The coastlines were compared using the overlay technique. Coastal erosion and coastal deposition during consecutive years were calculated. The results showed that the tsunami in 2004 caused coastal erosion in the area, as coastal changes during those years were found. Additionally, natural adaptation was found after 14 years at the middle and upper parts of the island. Severe coastal erosion of the lower part of the island has been continuously found, with an erosion rate between 2002 and 2004 (2-year period), 2004 and 2009 (5-year period), 2009 and 2012 (3-year period), and 2012 and 2016 (4-year period) of 22.44, 9.96, 19.63, and 12.34 meters per year respectively. In addition the erosion rate between 2002 and 2016 (14-year period) was 100.97 meters per year. It was also found that the seawall was the main factor in the coastal erosion in the lower part of the island because it was recognized that the coastline was sharply cut along the seawall. It is recommended that the lower part of the island be declared a special observation area in order to prevent further coastal erosion.

1. INTRODUCTION

Coastal areas are important for economic, social, and environmental reasons. Various uses of coastal zones, including tourism and recreation activities, fisheries and aquaculture, community activities, ports, industries, and water transportation, can cause changes in coastal areas. Serious socio-economic problems may arise with erosion and the loss of beaches (Clark, 1996). Coastal change means changes in physical characteristics of the coast due to the erosion of coastal areas and the accumulation of sediment (Sinsakul et al., 2003). Climate change can also aggravate the deterioration of natural resources and the environment. Nowadays, the erosion of the coast is more frequent and more severe.

Tsunami waves are waves that originate in the deep sea which often appear after a large earthquake underwater and intensified by volcanic eruptions, landslides, land subsidence, or when large meteorites fall into the sea. A tsunami can destroy coastal areas, causing loss of life and property. Tsunami waves cannot be predicted a long time in advance but there can be short-term warnings of them. On the 26th of December, 2004, a 9.0 scale earthquake occurred in the northwest part of Sumatra, Indonesia that caused a tsunami, one of the most serious geological events in world history. This event wreaked havoc for many countries in the Indian Ocean and the Andaman Sea areas, including Indonesia, Malaysia, Sri Lanka, Myanmar, Bangladesh, India, the Maldives, Somalia, Kenya, and Thailand. This event caused more than 250,000 deaths, 500,000 injuries, and more than 2 million people were left homeless.

The coastal provinces in the Andaman areas of Thailand were affected, including Krabi, Phuket, Trang, Phang Nga, Ranong, and Satun. More than 5,219 local people and foreigners died, 3,498 people disappeared, and 8,457 were injured. In addition, a great amount of the natural resources in the areas and the tourism industry were affected (Department of Mineral Resources, 2006). The impact of the tsunami caused severe and extensive coastal changes in Koh Kho Khao (Pantanahiran, 2014). Natural disasters in Thailand have tended to be more frequent and more violent in recent years due to climate changes, and this has affected the economic development of the country as well as the way of life of the people.

This research studied the physical changes in the coastal areas mentioned above by using aerial photographs and satellite images. The coastlines were compared in order to calculate the erosion and deposition in the areas. A Geographic Information Systems (GIS) was used to analyse the data. A GIS refers to a collection of computer hardware, software, and geographic data for capturing, storing, updating, manipulating, analysing, and displaying all forms of geographically-referenced information (Kennedy, 2001).

Remote sensing on the other hand is the acquisition of information concerning an object or phenomenon without making physical contact with the object and thus is in contrast to on-site observation, especially the earth. Remote sensing is used in numerous fields, including geography, land surveying, and most of the earth science disciplines.

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The objective of the research was to identify the coastal changes to the island, Koh Kho Khao in Takua Pa District, Phang Nga Province. The study area was divided into 3 parts: the upper area, the middle area, and the lower area (Figure 1).

1.1 Description of study area

The study area was located in Koh Kho Khoa (island), Ban Nam Khem sub-district, Takua Pa district, Phang Nga province, in the Andaman sea in southwest Thailand. The area is nearly flat, and the elevation is about two meters above mean sea level (MSL). The area of the island is approximately 6,328.33 ha (Figure 1). The land use has been classified as coastal zone (22.32 ha), upland crops (271.41 ha), orchards (605.78 ha), paddy rice (33.68 ha), upland forests (1,968.14 ha), shrubs (697.76), mangrove forests (2,341.19 ha), wetlands (199.18 ha), and unclassified (83.26 ha). Additionally, the climate has been classified as tropical monsoon. Takua Pa District is fully influenced by the northeast monsoons from January to April during the summer season and the southwest monsoons from May to December during the rainy season. The island is also well-known as a touristic area (Figure 1).

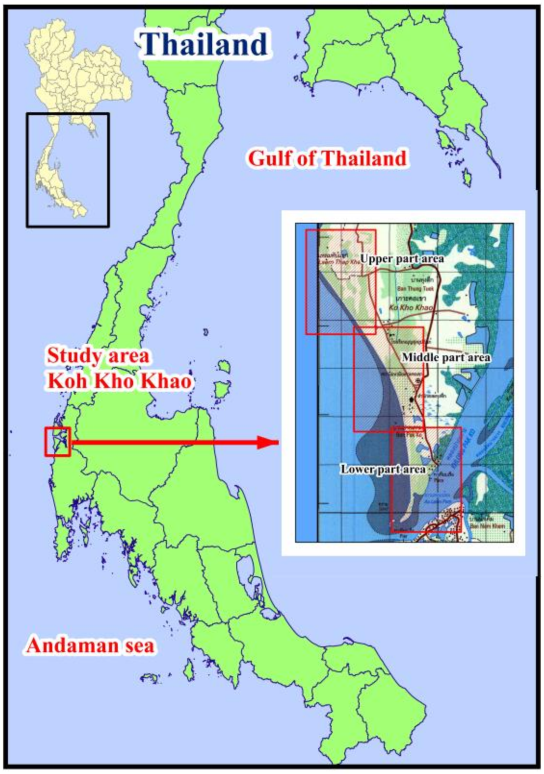

Figure 1. Study area

2. MATERIAL & METHODS

2.1 Data input and analysis

Remote sensing technology (RS) and the geographic information system were used as the analytical tools, and the ArcGIS software was used. The Universal Transverse Mercator (UTM) coordinate system was used as a standard coordinate system. The coastlines in the study refer to the beach ridges or slope changes that could be detected on the digital orthophotographs. The erosion and deposition/accretion of the coastal zone were detected by using the overlay technique between two sets of coastal lines (Pantanahiran, Weesakul, and Thaicharoen, 2008; Pantanahiran, 2014)

The remotely-sensed data in the study area were selected, including data before and after the tsunami on December 26th, 2004. The data were collected over time. The aerial photographs (scale 1:25000) taken in February 2002 represent the coastal area before the Tsunami. Then, satellite images after the tsunami were collected (Table 1). The IKONOS imagery (4-meter resolution) was taken on December 29, 2004. The QuickBird imagery (1-meter resolution) was taken on February 23, 2009, and the Worldview-2 imagery (1.8-meter resolution) was taken on December 6, 2012. The Pleiades imagery (0.5-meter resolution) was taken on the 8th of January, 2016, (Table 1). Those data were registered by using the appropriate geographic points of reference (ground control point). As such, the data could be completely overlaid and represent the same location.

Events	Type of data	Scale/ Resolution (m)	Date
Before tsunami	Aerial photographs	1:25000	February 2002
Three days after tsunami	IKONOS	4	29 December 2004
Five years after tsunami	QuickBird	1	23 February 2009
Eight years after tsunami	Worldview-2	1.8	6 December 2012
Twelve years after tsunami	Pleiades	0.5	8 January 2016

Table 1 Data used for coastal erosion.

The coastlines were digitized from the aerial photographs and satellite images representing the situation of the coastal area. The erosion and deposition of the coastal area were detected by using the overlay technique between two coastlines at different time periods. The comparison of the erosion and deposition was calculated using the coastlines between 2002 and 2004, the coastlines between 2004 and 20122, the coastlines between the years 20122 and 2012, the coastlines between the years 2012 and 2016, and the coastlines between 2002 and 2016.

Further, the beach erosion or deposition areas were calculated. The beach erosion indicates the retreat of the coastlines landward, and the deposition or accretion indicates the seaward deposition of the sand. It is reasonable to assume that the area means the product of its length and its width, and the erosion (width) may be calculated by the area divided by the erosion length along the shoreline. Then, the erosion and the rate of erosion were calculated (Pantanahiran, Weesakul, and Thaicharoen, 2008) and (ONEP 2003) using the following equations:

$$x = \frac{a}{l} \quad (1)$$

$$y = \frac{x}{t} \quad (2)$$

where x = beach erosion (m)
a = erosion area (m2)
l = distance of erosion along the coastline (m)
y = average erosion rate (m/y)
t = *comparing years (years).*

The calculated result of the erosion or deposition rate was classified into three main groups: the erosion coast, the deposition coast, and the stable coast (Pantanahiran, 2014) and (Sinsakul et al., 2003). The severe erosion means the rates of change are greater than -5 meters per year (m/y). The moderate erosion means the rated of change between -1 to -5 (m/y). The high deposition and medium deposition mean the rates of change which are greater than +5, and +1 to +5 m/y, respectively. The stable coast shows low erosion or low deposition, where the rates of change are equal and less than 1 m/y (Table 2).

Status	Degree of coastal change	Average erosion rate (m/y)
Erosion	Severe erosion	> -5
	Moderate erosion	-5 to -1
	Low erosion (stable coast)	< -1
Deposition	High deposition	> +5
	Medium deposition	+1 to +5
	Low deposition (stable coast)	< +1

Table 2. The rate of coastal change

3. RESULTS AND DISCUSSION

3.1 Comparison of the coastline length

The length of the five coastlines including 2002, 2004, 2009, 2012, and 2016, was measured and compared. The coastline in 2002 showed the longest distance (8,361.48 m), followed by 2004 (7,792.38 m), 2012 (7,420.27 m), and 2016 (7,199.63 m). According to the data limitations of the images for the year 2009, which covered only the middle and lower parts of the study area, then the analysis of the year 2009 would cover based on available data. The length of the coastlines between the consecutive years was then compared and it was found that the changes in the coastline in the upper and middle parts were less severe than in the lower part of the island. The changes of the coastal length between 2002 and 2016 (1,161.85 m) showed the highest difference, higher than the coastline changes between 2002 and 2012 (941.21 m), 2002 and 2004 (569.10 m), and 2012 and 2016 (220.64 m). This indicated that there was a change in the coastline of the island during the study period.

3.2 The rate of coastal change

The rate of change in the study area showed that five locations of severe erosion were found between 2002 and 2004 (Figure 2). Between 2004-2009, it was found that eight locations of erosion were found, including one location with severe erosion and seven locations of moderate erosion. Ten locations of deposition were found, including two locations of high deposition, six locations of medium deposition, and two locations of low deposition (Figure 2). Between 2009 and 2012, it was found that five locations of erosion were found, including one location with severe erosion, three locations with moderate erosion, and one location with low erosion. Six locations of deposition were found, including two locations with high deposition, three locations with medium deposition, and one location with deposition (Figure 2). Between 2012 and 2016, seven locations of erosion were found, including one location with severe erosion, five locations with moderate erosion, and one location with low erosion. Eight locations of deposition were found, including seven locations with medium deposition and one with deposition (Figure 2).

3.3 The areas of coastal change between 2002 and 2016

The comparison of coastal changes between 2002 and 2004 showed that coastal erosion covering an area of 25.85 ha. Five locations were classified as severe erosion and covering an area of 25.76 ha. One location was classifies as low erosion and covering an area of 0.08 ha (Table 3 and Figure 2)

Year	Degree of erosion	Area (ha)
2002-2004	Severe	25.77
	Low	0.08
2004-2009	Severe	6.12
	Moderate	1.17
	Low	0.01
2009-2012	Severe	5.61
	Moderate	1.34
2012-2016	Severe	4.27
	Moderate	1.54
	Low	0.02

Table 3. Coastal erosion between 2002 and 2016

A comparison of the coastal changes during 2004 and 2009 showed that one location of severe coastal erosion was found, which covered an area of 6.12 ha. Seven locations with a moderate level of coastal erosion were found, which covered the area of 1.17 ha (Table 3 and Figure 2). In addition, two locations with low deposition covering an area of 2.91 ha were found, and six locations of medium deposition covering an area of 2.90 ha were found. Two locations with high deposition covering an area of 5.14 ha were found (Table 4 and Figure 2).

A comparison of the coastal changes between 2009 and 2012 showed that one location of severe erosion covering an area of 5.61 ha was found. Three locations of moderate erosion covering an area of 1.34 ha were found, and one location with low erosion covering an area of 0.01 ha was found (Table 3 and Figure 2). In addition, two locations with high deposition covering an area of 1.55 ha were found; and three locations with medium deposition covering an area of 1.20 ha were found. One location with low deposition covering an area of 0.02 ha was found (Table 4 and Figure 2).

Comparison of the coastal changes between 2012 and 2016 showed that one location with severe erosion covering an area of 4.27 ha was found, and five locations with moderate erosion covering an area of 1.54 ha were found. One location with low erosion covering an area of 0.02 ha was found (Table 3 and Figure 2). In addition, seven locations with medium deposition covering an area of 4.37 ha were found; and one location with low deposition covering an area of 0.04 ha was found (Table 4 and Figure 2).

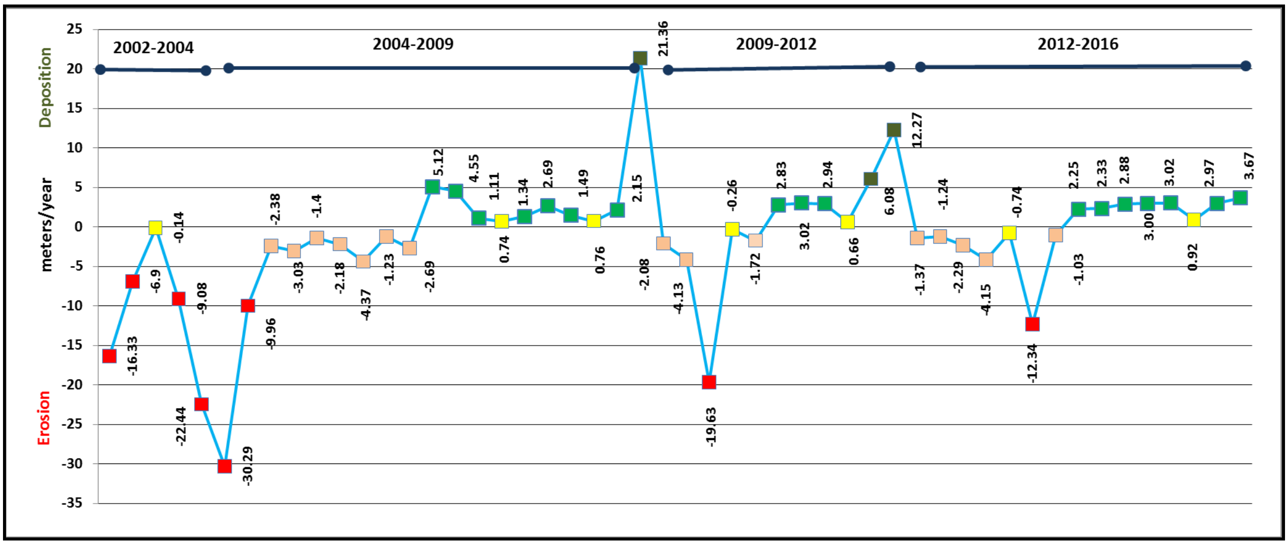

Figure 2. The rate of coastal change between 2002 and 2016

Year	Degree of deposition	Area (ha)
2004-2009	High	5.14
	Medium	2.91
	Low	0.03
2009-2012	High	1.55
	Medium	1.20
	Low	0.02
2012-2016	Medium	4.37
	Low	0.04

Table 4. Coastal deposition between 2002 and 2016

However, a comparison of the coastline changes between 2002 and 2016 for the 14-year period showed that one location with severe erosion covering an area of 28.14 ha was found. Three locations with moderate coastal erosion covering an area of 9.25 ha were found, and one location with low erosion covering an area of 0.07 ha was found. In addition, two locations with medium deposition covering an area of 6.27 ha were found, with one location with low deposition covering an area of 0.12 ha being found (Table 5 and Figure 2).

Degree of change	Erosion/ Deposition area (ha)	Rate of Change (m/y)
Severe	28.14	100.97
Moderate	8.21	36.48
Moderate	0.25	16.42
Moderate	0.79	15.55
Low erosion	0.07	4.98
Medium	6.21	26.37
Medium	0.05	14.71
Low deposition	0.12	13.9

Table 5. Coastal changes between 2002 and 2016

3.4 The risk areas in Ko Kho Khao

The erosion risk areas between 2002 and 2016 were evaluated and it was found that severe coastal erosion occurred in 2004. Then, natural adaptation demonstrated an important role in this area between 2004 and 2016, with the upper and middle parts of the area not showing the effect of severe erosion. In contrast,

the lower part of the island , especially the tip of the island , indicated severe erosion throughout the 14-year study period..

It indicated that there were other factors that caused the severe erosion. The study indicated that the coastal erosion was probably affected by the breakwater or seawall. It was found that the erosion areas between 2002 and 2004 exhibited a maximum erosion of 13.48 ha and higher than the erosion between 2004 and 2009 (6.12 ha), 2009 and 2012 (5.61 ha), and 2012 and 2019 (4.27 ha). The rate of erosion between 2002 and 2004 was 22.44 meters per year because of the tsunami phenomena. In addition, the rate of erosion between 2004 and 2009, 2009 and 2012, and 2012 and 2016 was 9.96, 19.63, and 12.34 meters per year, respectively (Table 6 and Figure 3).

It should be concluded that the first period of erosion from the tsunami disaster was in 2004. After that the erosion areas deceased because of natural recovery and adaptation. However, the tip at the lower part of the island was still found to have continuous severe erosion (Figure 3). The rate of erosion was 30.29 meters per year (2002-2004), 19.63 meters per year (2009-2012), and 12.34 meters per year (2012-2019).

Year	Year	Erosion area (ha)	Coastal length (m)	Rate of erosion (m/y)
2002-2016	14	28.14	2,787.01	100.97
2002-2004	2	13.48	3,004.36	22.44
2004-2009	5	6.12	1,228.88	9.96
2009-2012	3	5.61	952.21	19.63
2012-2016	4	4.27	865.58	12.34

Table 6. The coastal changes at lower part of island between 2002 and 2016

This research and previous research were compared, and the prediction of the study of Pantanahiran (2014) showed that the lower part of the island should have disappeared from erosion in 2015 (Figure 4), with the rate of erosion of 30 meters per year. However, the present study showed that some areas still remained as severe erosion was still active. This indicated that natural adaption plays a major role in this area; however, these areas are still in critical condition (Figure 5).

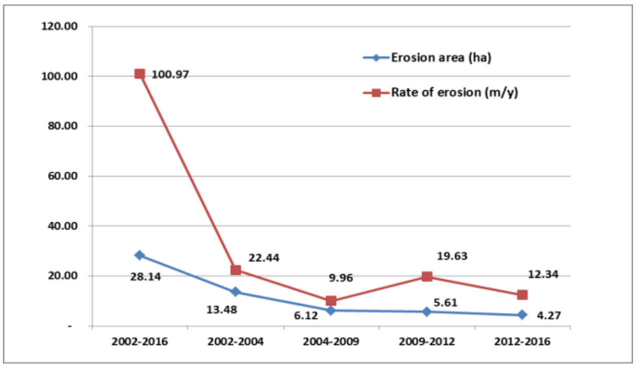

Figure 3. The coastal changes in the lower part of the island between 2002 and 2016

4. CONCLUSION

The results showed that the tsunami in 2004 caused coastal erosion in the area, as coastal changes during those years were found. However, natural adaptation was found after 14 years in the middle and upper parts of the island. Aerial photographs, IKONOS imagery, QuickBird imagery the Worldview-2 imagery, and Pleiades imagery were used. These remote sensing data were very useful tool for the coastal change. Severe coastal erosion in the lower part of the island has been continuously found, and it was also found that the seawall might be the main factor in the coastal erosion after tsunami occurrence. It is recommended that the lower part of the island be declared a special observation area in order to prevent further coastal erosion.

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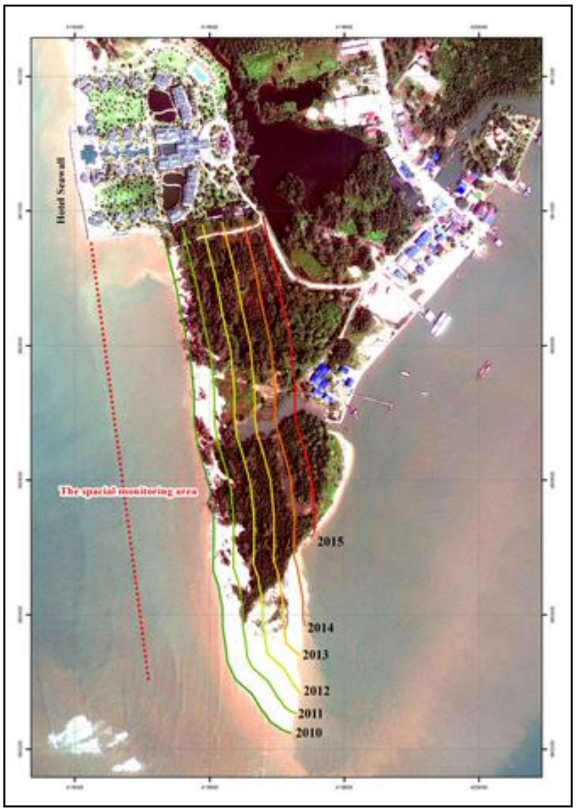

Figure 4. The prediction of previous study of Koh Kho Khao (Pantanahiran 2014)

Figure 5. The severe erosion of Koh Kho Khao and the special monitoring area

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