Monitoring Coastal Change after the Tsunami in Thailand

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Abstract. The tsunami on December 26, 2004 caused widespread devastation along the coast of Thailand, especially in Ban Nam Khem, Phang Nga province. This disaster claimed more than 941 lives, with 502 other people missing when the storm surge caught the residents of this area. The coastal geomorphology was impacted by this disaster. The objectives of the research were to study the effect of the tsunami on coastal change and the recovery of coastal areas. Six time-series datasets of aerial photographs and satellite images from 2002, 2004, 2005, 2006, 2009, and 2010 were compared using the Geographic Information System (GIS). The results showed the effect of the tsunami on the buildings in the area. Fifty-eight point sixty-three percent of the buildings in the urban area were destroyed by the tsunami and constructions was raised to 103.60% and 197.12% between 2004 and 2010, thus indicating the recovery of the local community. Geomorphological change in Ko Kho Khao (the island) was found after the tsunami disaster, including coastal erosion and coastal deposition. The balance of nature played a major role in controlling the erosion and deposition. The coastal deposits were the highest in 2005; however, deposition was not found in 2004. The erosion rate from 2002-2003 was the highest (48.10 meter per year) and higher than 2003-2004 (39.03 meters per year), 2004-2009 (15.64 meters per year) and 2009-2010 (29.49 meters per year). The coastal area was more severe eroded than the estuary area, and severe coastal erosion caused the loss of coastal area, approximately 0.28 ha. Severe coastal erosion has been repeatedly found since 2005 in the lower part of the area, and hard structures such as concrete seawalls might have been affected by coastal erosion. In addition, extrapolation of coastal erosion at the rate of 30 meters per year showed that the lower part of Ko Kho Khao should disappear in 2015.

1. Introduction
A tsunami is a series of water waves generated by such disturbance as earthquakes, volcanic eruptions, and explosions near the sea surface [1]. The tsunami on Sunday, 26 December 2004 resulted in an earthquake with a magnitude of Mw 9.0 in the deep sea in the northwest area of Sumatra Island, Indonesia. The damages occurred to many countries around the Indian Ocean and the Andaman Sea. This disaster was one of the most serious events in the history of humanity. Thailand was affected by the tsunami on December 26, 2004, affecting the six provinces of Ranong, Phang Nga, Phuket, Krabi, Trang, and Satun. It was found that an estimated 5,395 people died, 2,932 people were lost, and 8,457 people were injured [2]. The damage was estimated to be worth US$49,944,309 [3]. Ban Nam Khem, in Phang Nga province, was affected by the tsunami. This disaster claimed more than 941 lives, with another 502 people missing [4]. The objective of the research was to study the effect of the tsunami on coastal change and the recovery of coastal areas.
2. Materials and Methods

2.1. Description of study area
The study area was Ban Nam Khem, in Phang Nga province, a coastal area in Thailand (see figure 1), which was severely affected by the tsunami. It is located on the west coast of the southern part of the country and is connected to the Andaman Sea. The climate in the area is classified as tropical monsoon, and the summer season is from January to April and is influenced by the northeast monsoons; the rainy season is from May to December and is influenced by the southwest monsoons.

![Figure 1](image_url)

**Figure 1.** Study area: The study area covers two parts where the estuary links Koh Kho Khao island in the northern part and the mainland in the southern part. The elevation of the areas is about 2 meters above mean sea level. The area is nearly flat.

2.2. Data input and analysis
Geo-technology, including the Geographic Information System (GIS) and remote sensing were used as the analytical tools. The ArcGIS software was used. The erosion and deposition/accretion of the coastal zone were detected by using the overlay technique between two sets of the coastlines during the following periods [5].

The remotely sensed data in the study area were selected, including data before and after the tsunami on December 26, 2004. The aerial photographs taken in February 2002 represent the coastal area before the tsunami. Two periods of IKONOS imagery taken on December 29, 2004 and December 24, 2005 show the effects of the tsunami after three days and one year, respectively. The QuickBird imagery taken on February 23, 2009 shows the effect of the tsunami about two years. Two high-resolution satellite images from Google Earth taken on February 28, 2006 and on December 22, 2010 show the effect of the tsunami about two and six years, respectively.

The coastline was delineated on the beach ridge or the slope change that could be detected on the remotely-sensed data. They were digitized from the aerial photographs and satellite images representing the situation of the coastal area. The erosion and deposition/accretion of the coastal zone were detected by using the overlay technique between two coastlines during the following periods. The beach erosion or deposition areas were calculated, and the beach erosion indicates the retreat of the coastlines landward. The deposition or accretion indicates the seaward deposition of the sand. It is reasonable to assume that the area is 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 by the following equations [5, 6]:

\[
\text{Beach Erosion (m)} = \frac{\text{Erosion area (m}^2)}{\text{Distance of erosion along the coastline (m)}} \quad (1)
\]
Average erosion rate (m/yr) = \frac{\text{Beach erosion (m)}}{\text{Comparing years (yr)}} \quad (2)

The result of the erosion or deposition rate was classified into three main groups; namely, the erosion coast, the deposition coast, and the stable coast [7]. The calculated rate of change was used to classify the situation of the coast. **Severe Erosion** and **Moderate Erosion** mean the rates of change which are greater than -5 and -1 to -5 meters per year (m/yr), respectively. **High Deposition** and **Medium Deposition** mean the rates of change which are greater than +5 and +1 to +5 m/yr, respectively. The stable coast shows **Low Erosion** or **Low Deposition**, where the rates of change are equal and less than 1 m/yr (see table 1).

| Coastal status | Degree of coastal change | Average erosion rate (m/yr) |
|----------------|--------------------------|----------------------------|
| 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                   |

Source: Adapted from Sinsakul et al., 2003 The Technical Report: The coastal change of Andaman sea Department of Geology Bangkok Thailand.

3. The Results

3.1 The impact of the tsunami on Ban Nam Khem

The numbers of buildings were compared between before the tsunami and after the tsunami, including 2004, 2005, 2006, and 2010. It was found that the 672 units of buildings in Ban Nam Khem before the disaster were documented. When the tsunami occurred on 26 December 2004, 278 units of buildings remained. This showed that 58.63% of the construction was destroyed by the tsunami. However, the remaining structures could not be used for living. In addition, the buildings increased from 278 units to 566 units (103.60%) in 2006 (two years after the tsunami) and 826 units (197.12%) in 2010 (six years after the tsunami). This implies that local people moved back to the area after two years, indicating the recovery of the local community.

3.2. Coastal Change after the tsunami in Ban Nam Khem

The effect of the tsunami on 26 December 2004 on Ko Kho Khao (island) was studied. The shorelines of six-time periods from aerial photographs and satellite images were compared, including 2002, 2004, 2005, 2006, 2009, and 2010. Two areas were selected: the beaches of Ko Kho Khao which are connected to the Andaman Sea, and the estuary. Those areas are sensitive to change and the erosion process affects the use of the areas. It was found that the tsunami massively impacted the physiography of Ko Kho Khao (see figure 2).

The beach erosion between 2002-2004 showed the maximum erosion areas (10.97 Ha) and higher than the erosion area between 2005-2006 (9.50 Ha), 2006-2009 (4.14 Ha), and 2009-2010 (3.87 Ha) (see table 2). Coastal erosion between 2004-2005 was not found. However, the highest deposition area was between 2004-2005 (7.54 Ha) and higher than the deposition area between 2009-2010 (2.67 Ha), 2006-2009 (1.05 Ha), and 2005-2006 (0.15 Ha). Coastal deposition between 2002-2004 was not detected (see table 2).

The coastlines from 2002 and 2004 were compared. Two locations of erosion were found and the degree of change was classified as **Severe Erosion**, where the erosion rate was 48.10 and 13.16 meters per year (see table 2; figure 2a, 2b). The total erosion area was approximately 10.97 Ha.
Deposition was only found during 2004-2005 (see table 2; figure 2b, 2c). The total deposition area was approximately 7.54 Ha. The deposition rate was 26.22 meters per year, where the degree of change was classified as High Deposition.

Four locations of erosion and one location of deposition were found between 2005-2006 (see table 2; figure 2c, 2d). The total erosion area was approximately 9.46 Ha. The erosion rates were 40.83, 39.03, 10.70 and 9.12 meters per year, respectively. Those degrees of change were classified as Severe Erosion. The total deposition area was approximately 0.15 Ha. The rate of deposition was 91.25 meters per year and the degree of change was classified as High Deposition.

Three locations of erosion and two locations of deposition areas were found between 2006-2009 (see table 2; figure 2d, 2e). The total erosion area was approximately 3.88 Ha. The erosion rate was
15.64 meters per year, where the degree change was classified as *Severe Erosion*. The other two erosion rates were 4.82 and 2.93 meters per year. Those degrees of change were classified as *Moderate Erosion*. The total deposition area was approximately 0.94 Ha. The rate of deposition was 35.06 meters per year and the degree of change was classified as *High Deposition*. The rate of deposition was 4.57 meters per year and the degree of change was classified as *Medium Deposition*.

Three locations of erosion and four locations of deposition were found between 2009-2010 (see table 2; figure 2e, 2f). The total area of erosion was approximately 3.87 Ha. The erosion rates were 29.49 and 25.86 and 3.87 meters per year, where the degree of erosion was classified as *Severe Erosion* and *Moderate Erosion*. The deposition area was approximately 2.14 Ha. The rates of deposition were 20.60, 12.94, 9.11, and 5.46 meters per year, and the degree of deposition was classified as *High Deposition*.

### 3.3 Prediction of the erosion of Ko Kho Khao for the future

The extrapolation or future projection of beach erosion at Ko Kho Khao in the future was studied. The highest value of severe erosion rates in the same location between 2002-2004, 2004-2005, 2005-2006, 2006-2009, and 2009-2010 were selected, including 48.10, 39.03, 15.64, and 29.49 meters per year.

### Table 2. Beach erosion and sand deposition

| Location          | Area (Ha) | Area (m$^2$) | Beach length (m) | Erosion and deposition rate (m/yr) | Degree of coastal change |
|-------------------|-----------|--------------|------------------|-----------------------------------|-------------------------|
| **Comparison between 2002-2004** |           |              |                  |                                   |                         |
| Erosion-1         | 5.46      | 54,594.75    | 2,074.96         | 13.16                             | *Severe Erosion*        |
| Erosion-2         | 5.51      | 55,131.50    | 573.11           | 48.10                             | *Severe Erosion*        |
| **Comparison between 2004-2005** |           |              |                  |                                   |                         |
| Deposit-1         | 7.54      | 75419.81     | 2876.05          | 26.22                             | *High Deposition*       |
| **Comparison between 2005-2006** |           |              |                  |                                   |                         |
| Erosion-1         | 5.61      | 56119.52     | 1437.75          | 39.03                             | *Severe Erosion*        |
| Erosion-2         | 3.54      | 35376.77     | 866.54           | 40.83                             | *Severe Erosion*        |
| Erosion-3         | 0.21      | 2114.67      | 231.77           | 9.12                              | *Severe Erosion*        |
| Erosion-4         | 0.09      | 944.62       | 88.29            | 10.70                             | *Severe Erosion*        |
| Deposit-1         | 0.15      | 1492.18      | 16.35            | 91.25                             | *High Deposition*       |
| **Comparison between 2006-2009** |           |              |                  |                                   |                         |
| Erosion-1         | 3.46      | 34554.89     | 736.53           | 15.64                             | *Severe Erosion*        |
| Erosion-2         | 0.31      | 3149.70      | 358.17           | 2.93                              | *Moderate Erosion*      |
| Erosion-3         | 0.11      | 1137.92      | 78.71            | 4.82                              | *Moderate Erosion*      |
| Deposit-1         | 0.74      | 7388.59      | 70.24            | 35.06                             | *High Deposition*       |
| Deposit-2         | 0.20      | 1959.02      | 142.92           | 4.57                              | *Medium Deposition*     |
| **Comparison between 2009-2010** |           |              |                  |                                   |                         |
| Erosion-1         | 3.46      | 34582.96     | 639.77           | 29.49                             | *Severe Erosion*        |
| Erosion-2         | 0.23      | 2301.89      | 48.56            | 25.86                             | *Severe Erosion*        |
| Erosion-3         | 0.18      | 1820.28      | 256.52           | 3.87                              | *Moderate Erosion*      |
| Deposit-1         | 0.11      | 1086.22      | 108.62           | 5.46                              | *High Deposition*       |
| Deposit-2         | 0.36      | 3559.39      | 213.18           | 9.11                              | *High Deposition*       |
| Deposit-3         | 1.07      | 10702.71     | 283.39           | 20.60                             | *High Deposition*       |
| Deposit-4         | 1.07      | 10740.72     | 452.73           | 12.94                             | *High Deposition*       |
(see figure 2f). Then, the estimated average of erosion rate at 30 meters per year was selected to extrapolate the future erosion. The erosion of 30, 60, 90, 120, and 150 meters from the shoreline in 2011, 2012, 2013, 2014, and 2015 was found. Consequently, parts of Ko Kho Khao will finally be disappeared (see figure 2f). This area should be classified as an area sensitive to erosion, and it should be carefully monitored for erosion protection in the future.

4. Summary
The impact of the tsunami on 26 December 2004 had a significant effect on the coastal area, with the massive erosion. In addition, a number of buildings were destroyed after the tsunami. However, the number of buildings can be seen to have increased approximately two years after the tsunami, suggesting that local people moved back to the area after two years. It also indicated the recovery of the local community.

Severe erosion was found in this area because of the tsunami and then high deposition occurred one year later. Later, the coastal erosion and deposition processes were introduced due to natural adaptation. Importantly, the coastal erosion process showed a more dominant phenomenon than the coastal deposition process. It was also found that the coastal erosion occurs currently more frequently than in the past. In addition, the hard structure, such as the concrete seawall, might have been affected by coastal erosion.

Regarding the extrapolation or future projection of beach erosion, erosion of 30, 60, 90, 120, and 150 meters from the shoreline in the years 2011, 2012, 2013, 2014, and 2015 was found. Consequently, the area-tip of Ko Kho Khao will finally disappear. This area should be classified as sensitive to erosion, and it should be carefully observed for erosion protection in the future.

5. References
[1] Clark R 1996 Coastal zone management CRC Press Inc Boca Raton Florida USA pp 459
[2] GISTDA 2004 Using Geoinformatics to monitor the Tsunami area in Thailand Ministry of Science and Technology
[3] http://www.oecd.org/insurance/insurance/43726127.pdf
[4] Department of Mineral Resources 2006 Survey study to restore and develop coastal areas Ban Nam Khem Takua Pa Phang Nga province Ministry of Natural Resources and Environment. Bangkok
[5] Pantanahiran W, Weesakul S and Thaicharoen C 2008 Monitoring the coastal change in Thailand using GIS technology In Proceeding of the 7th International Conference of Asia GIS 2008 Pusan Republic of Korea
[6] ONEP 2003 Mater Plan Study for Coastal Erosion Alleviation from Pethchaburi River Mouth to Pranburi River Mouth Bangkok Thailand (in Thai)
[7] Sinsakul S, et al 2003 The Technical Report: The coastal change of Andaman sea Department of Geology Bangkok Thailand (in Thai)

Acknowledgements
This project was carried out using a grant from the Thai government. The author is grateful to GISTDA and Google Earth for providing the remotely-sensed data. The author also would like to extend his appreciation to the Strategic Wisdom and Research Institute, the Graduate School and the Faculty of Social Science, Srinakharinwirot University, for their support and encouragement.