

Coastline Change at Koh Tao Island, Thailand

Cherdvong Saengsupavanich

Abstract—Human utilizes coastal resources as well as deteriorates them. Coastal tourism may degrade the environment if poorly managed. This research investigated the shoreline change at Koa Toa Island, one of the most famous tourist destinations. Aerial photographs and satellite images from three different periods were collected and analyzed. The results showed that the noticeable shoreline change before and after the tourism on the island had expanded. Between 1995 and 2002 when the tourism on Koh Toa Island was not intensive, sediment deposition occurred along most of the coastline. However, after the tourism had grown during 2002 to 2015, the coast evidently experienced less deposition and more erosion. The erosion resulted from less land-based sediment being provided to the littoral system. If the coastline of Koh Toa Island is not carefully sustained, the tourism will disappear along with the beautiful beach.

Keywords—Coastal erosion, coastal tourism, Koh Toa Island, Thailand, coastal engineering and management.

I. INTRODUCTION

COASTAL zone is a valuable natural resource [1], [2]. It enhances the country in various ways, including promoting tourism activities, sustaining human livelihood, maintaining biodiversity as well as ecosystem [3]. However, the coast is also a fragile place which can be easily degraded. Human utilizes the coast as well as deteriorates it [4]. Development puts the coast in danger. Tourism is one of the major driving forces that jeopardize coastal stability [5], [6]. Coastal erosion is one of the main negative impacts created by the coastal tourism. For examples, buildings and roads reduce sediment supply to the shoreline. Piers and other coastal structures such as groins, revetments, as well as breakwaters interrupt coastal alongshore sediment transport, inducing coastal erosion. Thus, the poorly planned coastal development may result in more losses than gains. This research focuses on the coastline change on Koh Tao Island, Thailand, as it is an illustration of how the coastline responded to the tourism. Lessons learnt from this case study may raise awareness of other countries to prepare more suitable plans when developing the island.

A. Background on Koh Tao Island

Koh Tao Island is located in the Gulf of Thailand (Fig. 1). It covers an area of 21 km². It is about 74 km from the main land and is one of the most famous tourist destinations in Thailand. The number of tourists has been increasing from 441,823 in 2008 to 978,788 in 2014 (Table I) [7]. Its tourism attractions include white sandy beach, peaceful environment, and

amazing reef diving. In the past during 1933-1947, Koh Tao Island was used to detain political prisoners. In the early 1980s, a group of backpackers who stayed on a nearby island had discovered Koh Tao Island. At that time, there were approximately 400 people on the island. In the mid-1980s, recreational scuba divers began to explore coral reefs around Koh Tao Island. A few years later, a lot of tourism facilities were constructed to accommodate the expanding tourism business [8]. This altered the primitive remote island into the island with modern infrastructures. Such transformation inevitably affected coastal characteristic, particularly sediment supply in littoral system.

TABLE I
NUMBER OF TOURISTS VISITING KOH TAO ISLAND FROM 2008-2014

Year	2014	2013	2012	2011	2010	2009	2008
Number of tourists	978,788	906,763	403,782	246,360	246,602	310,615	441,823

The west side of Koh Tao Island is where tourism infrastructures, shopping area as well as restaurants are located. Piers and buildings are abundant (Fig. 2). However, this area also has a beautiful sandy beach which may be affected by tourism-generated pressure. The study, therefore, selected the west part of the island for the analysis since it was a good representative of how the shoreline responded to the tourism stress.

A. Coastal Characteristics of Koh Tao Island

The study began with collecting site-specific physical data along the west side of Koh Tao island such as bathymetry, wind, and wave characteristics. A bathymetric survey was undertaken in April 2015 based on the UTM zone 47 system. It was found that the depth of the ocean within 500 m from the shoreline was less than 5 m below mean sea level (-5.0 m MSL). Further away from the shoreline, the depth increased abruptly to -40 m MSL (Fig. 3). The studied coastline is bordered by 2 headlands. Therefore, coastal sediment transport is confined within these headlands. In other words, the sediment moves along the coast northwards and southwards seasonally.

Wind data recorded during 1994-2014 at the nearest weather station was gathered. Later on, wave climate was synthesized from the wind data by applying a JONSWAP method. It was found that, along the west side of the island, the waves mainly came from the west and west-southwest directions (Fig. 4). Normally, the offshore significant wave height (Hs) was less than 2 m but the height could be greater than 2.5 m during storm periods. Over a 50-year return period, the Hs was estimated to be 3.37 m.

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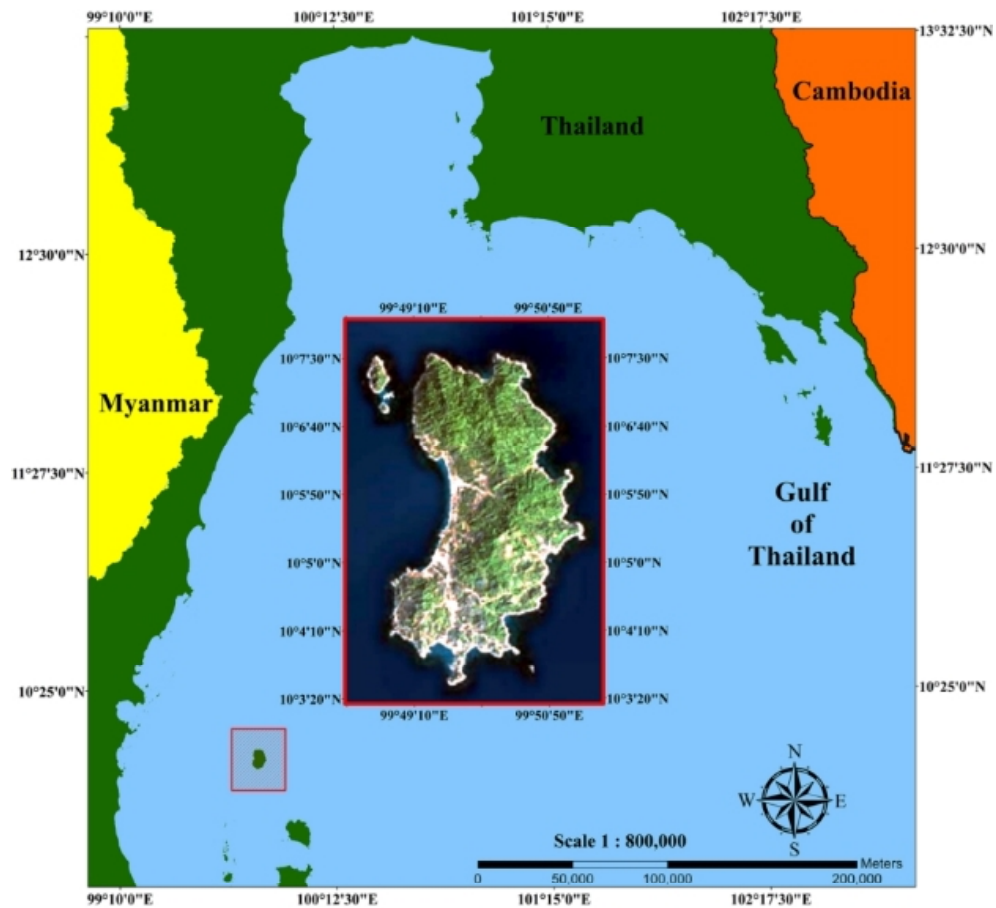


Fig. 1 Koh Toa Island



Fig. 2 Current situation at the west side of Koh Tao Island

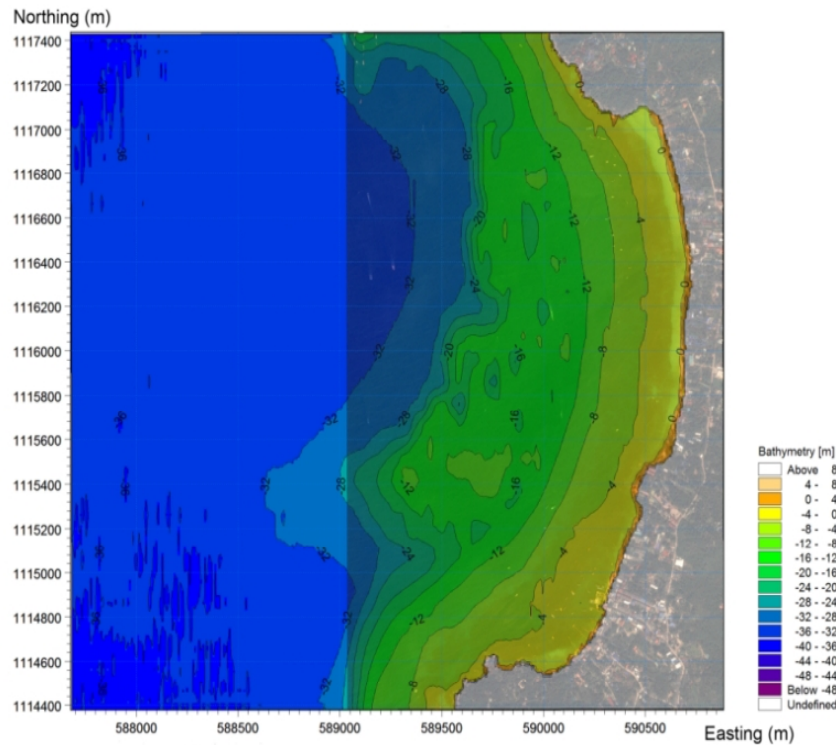


Fig. 3 A bathymetric map along the west side of Koh Tao Island (overlaid on a satellite image)

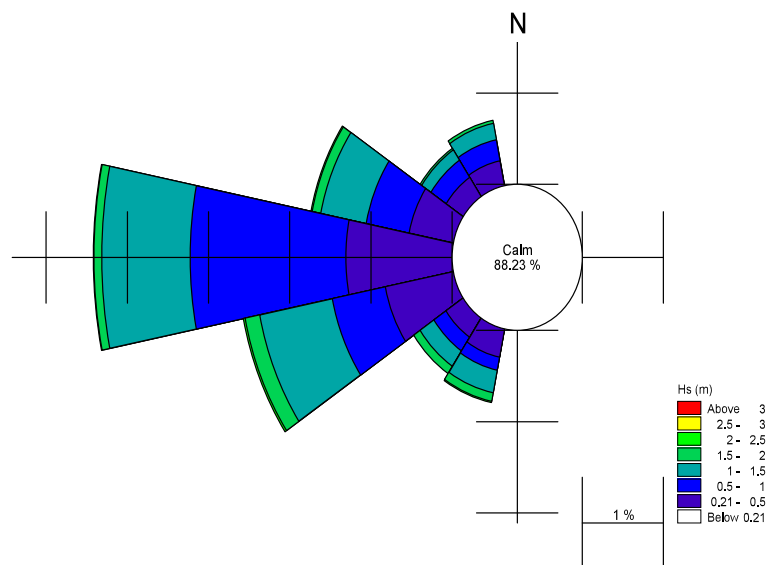


Fig. 4 Annual wave rose along the west side of Koh Toa Island

II. METHODOLOGY

In order to investigate the shoreline change, the author spent his great effort to gather historical aerial photographs and satellite images from the responsible governmental departments. The satellite images were also extracted from Google Earth. Since Koh Toa Island is far from the mainland, there were only a few images available. Three images

captured in 1995, 2002, and 2015 were collected (Figs. 5-7). After a successful acquisition of the images, the author began the analysis. All images were rectified and geo-referenced. The shorelines from different years were digitized and adjusted for the tide at the time the images were being captured [9]. The ArcGIS software package was used for the related analysis.

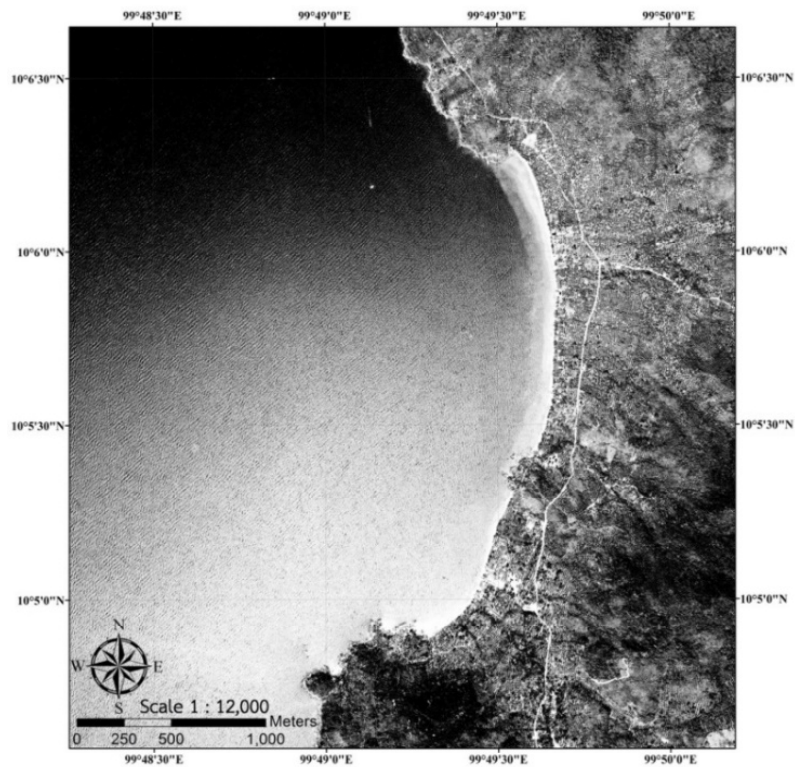


Fig. 5 An aerial photograph of Koh Toa Island in 1995

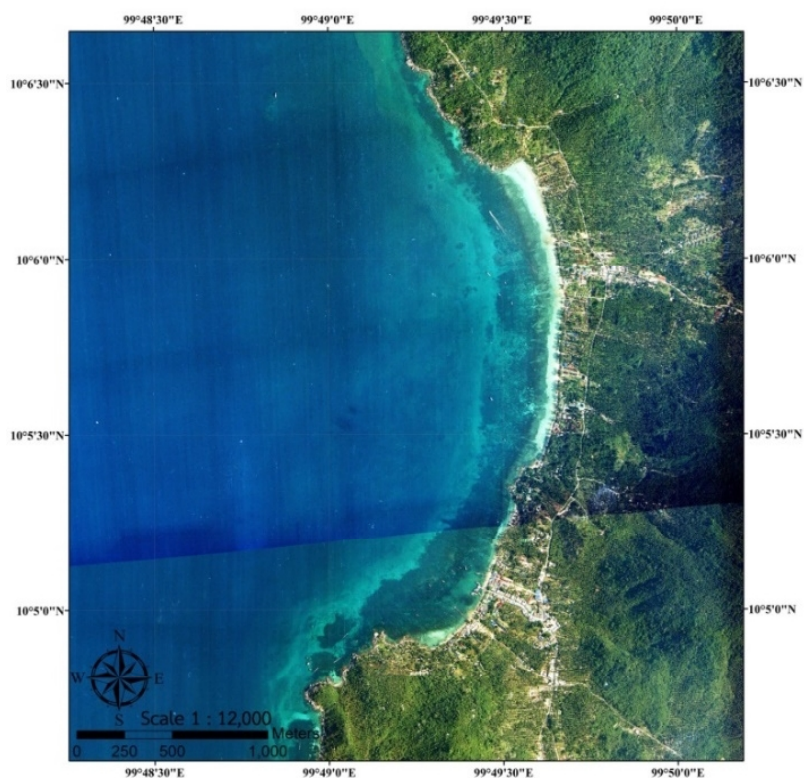


Fig. 6 An aerial photograph of Koh Toa Island in 2002

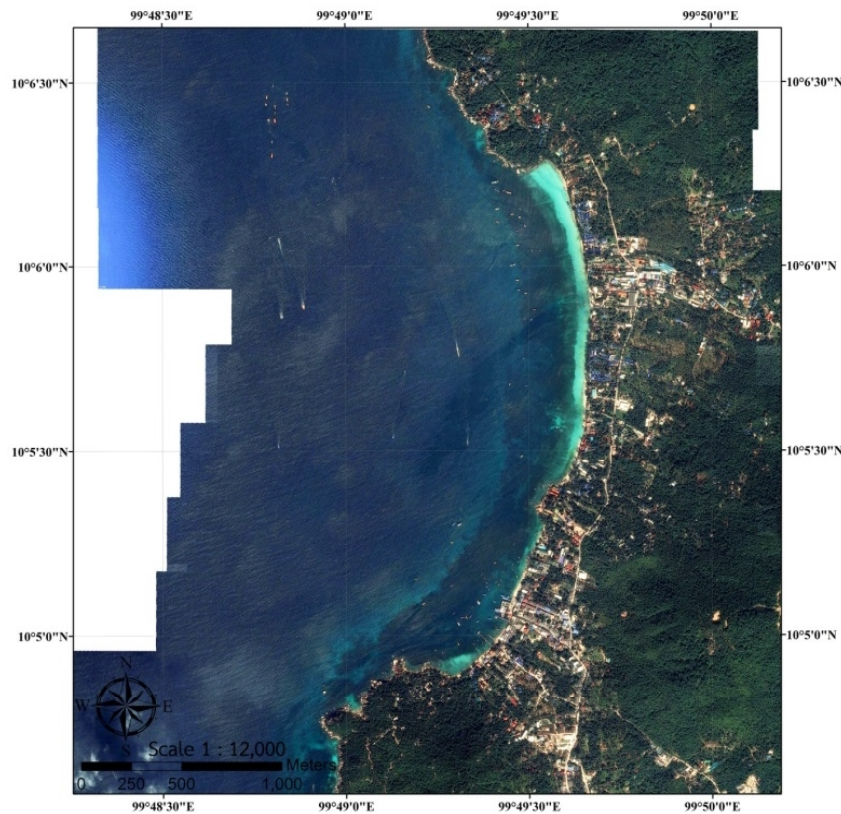


Fig. 7 A Google Earth satellite image of Koh Toa Island in 2015

III. RESULTS

The article divides the results into two parts. The first section presents the shoreline change between 1995 and 2002, while the second part is the change that happened between 2002 and 2015.

A. The Shoreline Change between 1995 and 2002

Between 1995 and 2002 when tourism on Koh Toa Island was not intensive, the west coast of the island exhibited accretion. Sediment deposition occurred along most of the coastline. The sedimentation was obvious along the southern part of the bay (Station 0+000 to Station 1+000). The shoreline accreted with the magnitude of approximately 1 m/yr. However, there was a certain area that experienced coastal erosion (Station 1+600 to Station 2+000) but the magnitude of the erosion was less than 0.34 m/yr. At the northernmost part of the bay, the deposition was apparent due to the net alongshore sediment transport that moved the sediment northwards (Fig. 8 and Table II).

TABLE II
SHORELINE CHANGE ALONG THE WEST COAST OF KOH TOA ISLAND
BETWEEN 1995 AND 2002

Shoreline change between 1995 and 2002				
Station	Eroded area (m ²)	Deposited area (m ²)	Erosion rate (m/yr)	Deposition rate (m/yr)
0+000 to 0+200	0.00	+184.85	0.00	+0.13
0+200 to 0+400	-88.15	+774.15	-0.06	+0.55
0+400 to 0+600	0.00	+1,425.43	0.00	+1.02
0+600 to 0+800	0.00	+747.52	0.00	+0.53
0+800 to 1+000	-54.30	+622.98	-0.04	+0.44
1+000 to 1+200	0.00	0.00	0.00	0.00
1+200 to 1+400	-171.21	+134.82	-0.12	+0.10
1+400 to 1+600	-28.68	+148.74	-0.02	+0.11
1+600 to 1+800	-287.16	+32.82	-0.21	+0.02
1+800 to 2+000	-384.59	0.00	-0.27	0.00
2+000 to 2+200	-481.46	0.00	-0.34	0.00
2+200 to 2+400	-32.10	+155.34	-0.02	+0.11
2+400 to 2+600	0.00	+706.79	0.00	+0.50
2+600 to 2+800	0.00	+2,062.18	0.00	+1.47
Total	-1,527.66	+6,995.64		

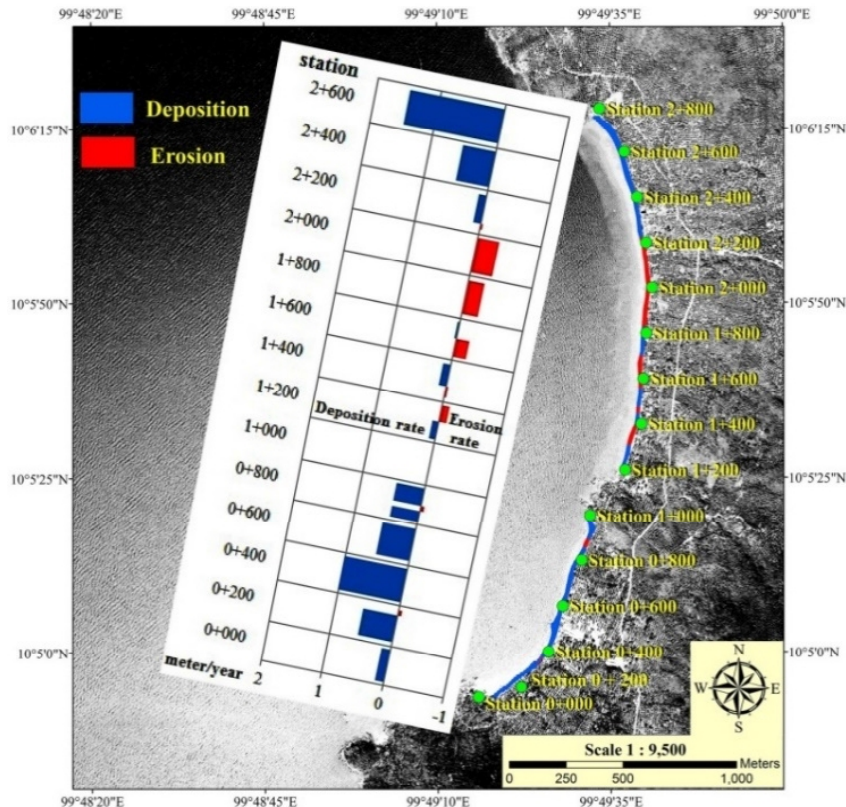


Fig. 8 Shoreline change along the west coast of Koh Toa Island between 1995 and 2002

TABLE III
SHORELINE CHANGE ALONG THE WEST COAST OF KOH TOA ISLAND
BETWEEN 2002 AND 2015

Shoreline change between 2002 and 2015				
Station	Eroded area (m ²)	Deposited area (m ²)	Erosion rate (m/yr)	Deposition rate (m/yr)
0+000 to 0+200	-304.69	0.00	-0.12	0.00
0+200 to 0+400	-246.76	+714.94	-0.09	+0.27
0+400 to 0+600	0.00	+1,377.01	0.00	+0.53
0+600 to 0+800	-609.31	+494.78	-0.23	+0.19
0+800 to 1+000	0.00	+733.17	0.00	+0.28
1+000 to 1+200	0.00	0.00	0.00	0.00
1+200 to 1+400	-1,033.35	0.00	-0.40	0.00
1+400 to 1+600	-1,058.47	0.00	-0.41	0.00
1+600 to 1+800	-472.78	+21.03	-0.18	+0.02
1+800 to 2+000	-235.37	+118.29	-0.09	+0.05
2+000 to 2+200	0.00	+1,019.23	0.00	+0.39
2+200 to 2+400	0.00	+689.32	0.00	+0.27
2+400 to 2+600	0.00	+1,104.73	0.00	+0.42
2+600 to 2+800	0.00	+1,746.25	0.00	+0.67
Total	-3,960.74	+8,018.74		

B. The Shoreline Change between 2002 and 2015

Between 2002 and 2015, Koh Toa Island accommodated more tourists. The fast-growing number of visitors demanded additional infrastructures to be constructed. In 2015, the west coast of the island was crowded with buildings and roads (Fig. 7), compared to the abundant tree-covered land in 2002 (Fig. 6). The paved land resulted in less land-based sediment being

discharged into the littoral system. For example, a runoff might carry a large amount of sediment load into the ocean if the land surface was soil. However, the concrete-paved surface did not provide such the sediment to the sea during the runoff. When there was less sediment input to the littoral system, the coastal erosion tended to happen [10]. This theory was the explanation why the west coast of the island suffered from the erosion after 2002.

Along the southern part of the bay (Station 0+000 to Station 1+000), the shoreline responded more negatively to the coastal development. During 1995 to 2002, the deposition occurred with the magnitude of about 1.02 m/yr, but during 2002 to 2015, the shoreline along the southern part of the bay appeared to be eroded with the magnitude of 0.23 m/yr. It can also be noticed that although some deposition still happened along the southern part of the bay, the accretion magnitude dropped from 1 m/yr (Fig. 8 and Table II) to less than 0.53 m/yr (Fig. 9 and Table III).

IV. DISCUSSION

Coastal tourism brought not only prosperity but also environmental degradation to Koh Toa Island. It was a trade-off that needs to be managed carefully. Between 1995 and 2002, the west coast of Koh Toa Island accreted. After the tourism had grown during 2002 to 2015, the coast noticeably experienced less deposition and more erosion. In the past when the land was not paved by concrete and the buildings

were absent, runoff carried sediment to the coast. A large quantity of the sediment resulted in coastal accretion, beautifying the beach and in turn attracting the tourists. However, the expanding tourism demanded more man-made infrastructures. The coast received less sediment since the land

surface had been transformed into concrete, resulting in the coastal erosion. If the coastline is continuously being eroded, there will be less and less tourism. Eventually, the island will lose both its environment and its tourists.

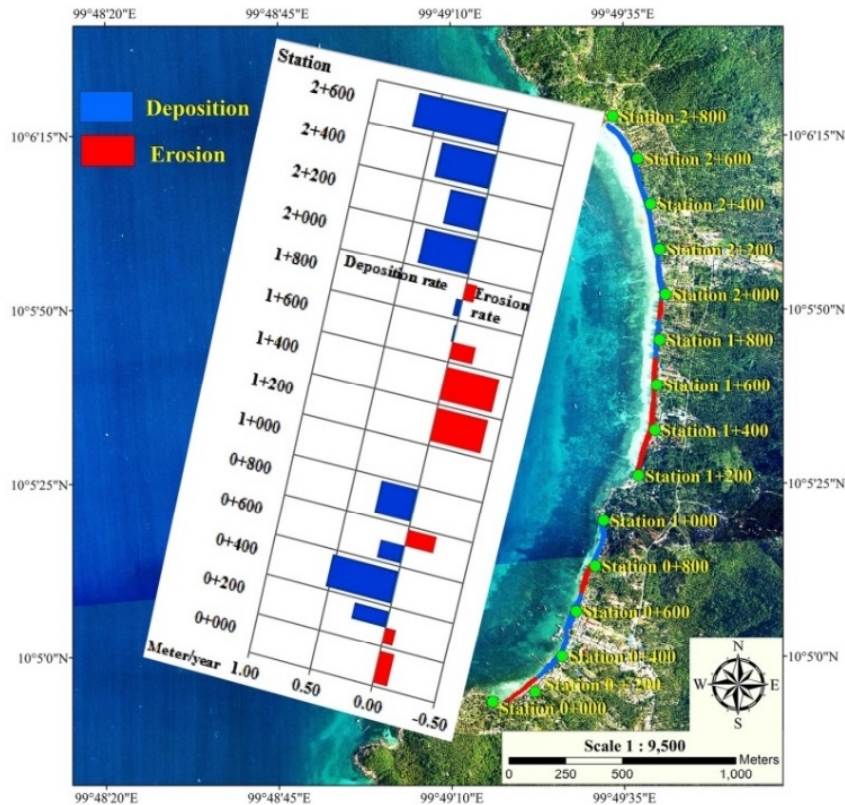


Fig. 9 Shoreline change along the west coast of Koh Toa Island between 2002 and 2015

The eroded beach can be restored by various options. Beach nourishment is one of the most promising alternatives. As can be seen from the result, the northernmost part of the bay has continuously deposited. Dominant waves from the west and the west-southwest move the sediment northwards. Therefore, the sediment accumulated at the upper part of the bay is the same as the sediment elsewhere in the bay. Grain size, shape, and color are similar. Excavating the sediment from the northernmost area and placing it on the eroded zone can restore the beach without any significant environmental impact and construction costs.

V.CONCLUSION

This research investigated the shoreline response along the west of Koh Toa Island. The fast-growing tourism activities have put the pressure on the island's coastal environment. Aerial photographs and satellite images were collected to investigate the shoreline change between 1995 and 2015. It was found that the west coast of the island, where there were a lot of infrastructures, responded negatively to the tourism developments. The shoreline in the past prior to 2002, when

there were not intense tourism activities, exhibited coastal deposition. After the coastal area was transformed into buildings and roads, the shoreline began to deposit less and erode more. Less land-based sediment was provided to the coast due to more land being converted to concrete pavements. If no mitigation measure is undertaken, the beach will continue to erode. Eventually, Koh Toa Island will lose both its beautiful beach and its tourists.

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