Shoreline change analysis through images from camera monitoring on Nha Trang Coast, Vietnam

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Abstract

Over the past 5 years, anomalous erosion has been occurred on Nha Trang Coast, Khanh Hoa province, Vietnam. The erosion of several hundred meters sandy beach leads to beach loss in several months. The trends in shoreline change both erosion and accretion have been analyzed through extracted continuous images from camera monitoring system. The shift of shoreline, which was observed from mid-2013 to the first five months of 2014, was related to wave conditions. High waves induced by the northeast monsoon have caused the significant retreat of shoreline from the end of September 2013 to the beginning of February 2014. Sandy beach was eroded severely when shoreline reached to sea dyke; the concave shape of the beach was formed. On the other hand, the advance of shoreline can be observed in the remaining time series due to the fact that calm waves were dominant during these periods. The quantitative analysis of shoreline evolution at various longshore positions is also shown in this study.

1. Introduction

Vietnam has 3260 km in length of the coastline from the north to the south. It plays a vital role in social-economic activities of the country. However, in recent years, coastal erosion and accretion have become anomalous and widespread in the coastal zone of Vietnam. At the south central region, Nha Trang coast is also no exception.

Nha Trang city is one of the most popular destinations in Vietnam's tourism map with a wonderful bay that has been known as one of the most beautiful bays in the world. Nha Trang coast is located in the central area of this city. The location of this coast is shown in Fig. 1.

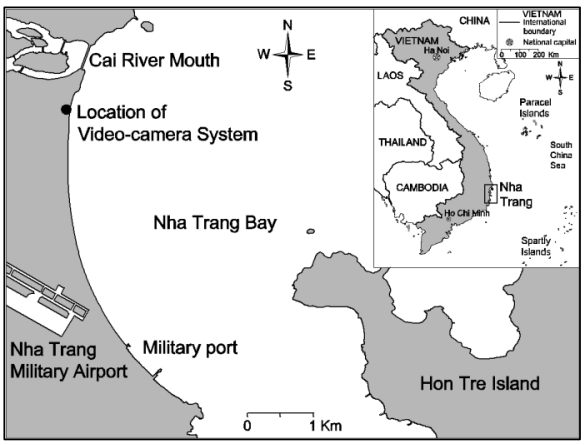

Fig.1　Location map of Nha Trang coast

In the north of Nha Trang coast, Cai River was considered as the principal source of the sediment to the coast (Inman et al., 1973, Szczuci ñ ski et al., 2005). In 2009, the embankment along the Cai River mouth was constructed as an important infrastructure for the disaster prevention project of this province. However, after this embankment was constructed, erosion on the part of sandy beach has been observed. On the right side of the Cai River mouth embankment, the protrusion of beachside hotel which is playing a role similar to a groin at coastal area, can be considered as one of the reasons of erosion in this area (Viet et al., 2014). The erosion of sandy beach causes significant negative impacts on the coastal environment or the increase of the costs of disaster mitigation. Finding methods to reduce erosion are necessary for the community interest. In order to find sustainable solutions about this matter, one of the important steps is to get more insight about the evolution of shoreline positions. Through a coastal surveillance system by video-camera technique, the changes of shoreline on Nha Trang coast were extracted based on analyzing images from this system.

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2. Study area and data collection

Nha Trang coast with 4.3km in length is located in the southeast coastline of Vietnam with about 450km to the north of Ho Chi Minh city. This coast is limited by the Cai River mouth with the protrusion of the hotel as a groin in the north and a breakwater of the military port in the south (Fig. 1). The existence of many islands including Hontre island, the largest island on the southeast of the coast, can be seen as obstacles to the wind and waves impacting on Nha Trang coast. The study area has a tropical monsoon climate with two monsoon seasons per year; the northeast monsoon and the east-southeast monsoon.

This study focuses on a part of Nha Trang coast, which is located approximately 350 m to the southwest of the Cai River mouth as can seen in Fig. 2. It is also the area on the right side of hotel which occurs the most serious erosion on Nha Trang beach. Along the beach, the local government constructed sea dyke to stop the intrusion of sea water.

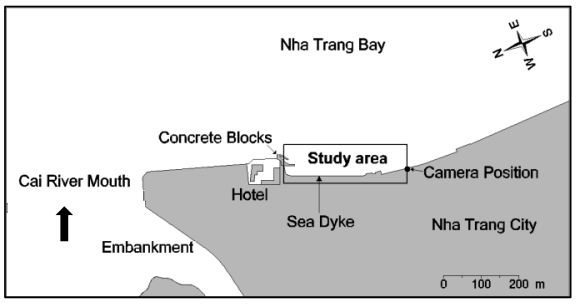

Fig.2 Study area

In order to describe the change of shoreline positions, video-camera system has been used. Recently, camera monitoring technique for shoreline observation, is commonly applied (Almar et al., 2012). This technique differs from the traditional aerial-photo of a single photograph analysis because the video system allows the use of continuous sequence images. Through protocol research project "Study on hydrodynamic regime and sediment transport in estuarine and coastal zones of Nha Trang bay, Khanh Hoa province" supported by Ministry of Science and Technology (MOST), Vietnam and Institute of Research and Development (IRD), France, a camera monitoring system with two cameras was installed in May 2013 (Viet et al., 2014). The first camera has been used for shoreline observation in the northern area of Nha Trang Coast (near the Cai River mouth) and the second one has been applied for the south area (Fig. 3). Images from the northern camera were used for this study.

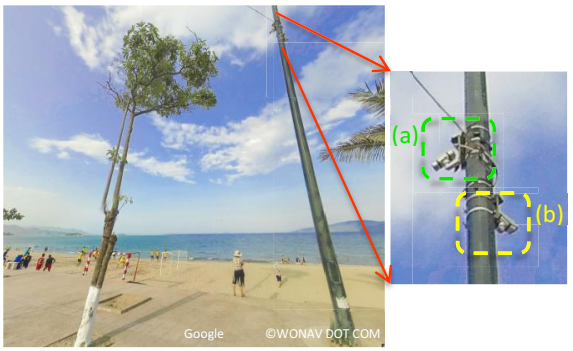

Fig. 3 Camera position, (a) Northern camera, (b) Southern camera (Background photograph is Google Street View image taken in June 2014)

From 26th May 2013 to 31st May 2014, the video-camera system captured images in every second from 06:00am to 05:15pm every day. All images taken in each 15 minutes interval were combined to make time-averaged images (Fig. 4). So, there were about 46 time-averaged images every day. In order to ignore the influence of sea level change on the selected images, the tidal level, which was collected at the nearest hydro-meteorological station, was calculated with respect to mean sea level in many years.

Fig. 4 Time-averaged image from video-camera system

This study utilizes time-averaged images at the time when the tidal level was 0. A set 98 time-averaged images of 98 days during the period of this study was used to extract shoreline.

All collected time-averaged images were rectified into World Geodetic System 1984 (WGS84) based on 12 Ground Control Points that were selected along sea dyke to have approximately the same elevation. The point, which has coordinates 303958.65 m E and 1355572.95 m N on WGS84 (dated February 01st, 2014), is selected as the initial shoreline position (x=0). Besides, x-axis and y-axis were performed based on sea dyke, the positive direction of y-axis is seaward as seen in Fig. 5. From rectified images, shoreline positions $y_s(x, t)$ were detected in every 5m and then corrected with sea level.

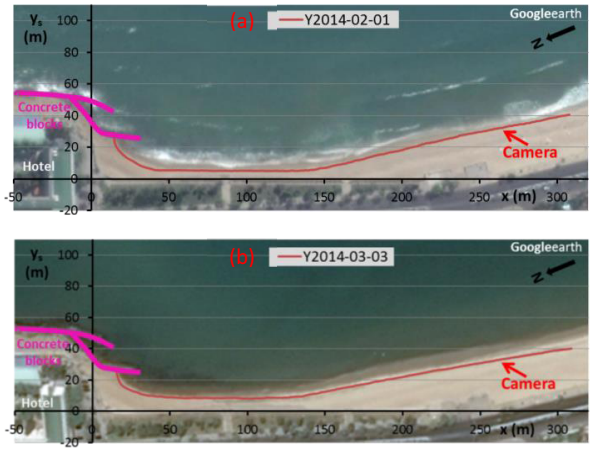

Fig. 5 Comparison between shoreline positions from camera images analysis and Google Earth images

On this coast, two aerial photographs were collected from Google Earth image during the period of this study. The comparison of extracted shoreline positions from camera images and the Google Earth images can be seen in Fig. 5. The detected shoreline on February 01st, 2014 (Fig. 5a) and on March 03rd, 2014 (Fig. 5b) have good agreement with shoreline which can be observed from the Google Earth images on the same days.

3. Results and discussion

The shift of about 310 m in length of shoreline every two months is shown in Figure 6. Besides, the study area was divided into four regions (Fig. 6), from the left side (region 1) to the right side (region 4). In this area, the protrusion of beachside hotel and concrete blocks (pink solid-line) plays a role similar to a groin at this coastal area.

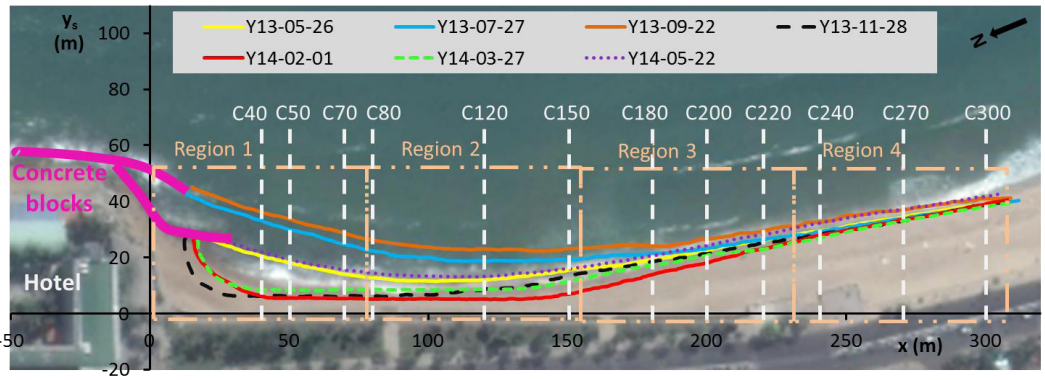

Fig. 6 Shoreline change on Nha Trang coast from May 26th, 2013 to May 31st, 2014 (Back ground photograph is Google Earth image taken on February 01st, 2014)

In the overview, the retreat of shoreline formed the concave shape from November 2013 to February 2014. And from May to September 2013 and from March to May 2014, shoreline advanced. Beach erosion and deposition can be observed clearly along the first 180m in length of coastline on the right side of hotel.

Besides, shoreline positions in May 2014 (purple dotted-line) are similar to that in May 2013 (yellow solid-line).

From the extracted shoreline positions in one year, the overall trend of the shoreline evolution on Nha Trang coast in 3D manner is shown in Fig. 7.

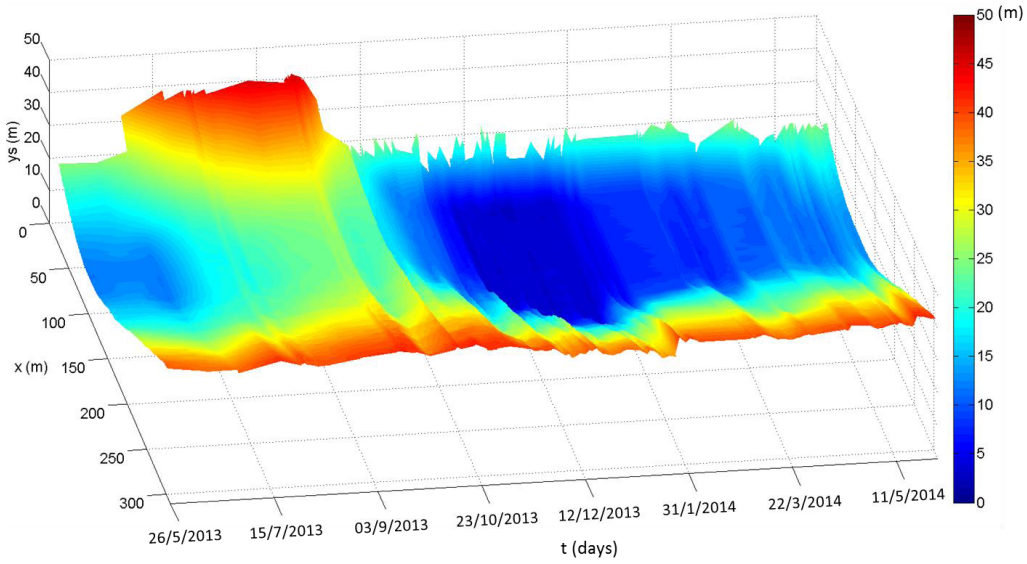

Fig. 7 Shoreline positions $y_s(x, t)$ in 3D manner

In Fig. 7, it is clear that the beach on the close side of the hotel (x = 0 – 150 m) has more significant erosion than the beach on the far side (x = 250 – 300m). Another interesting point is the seasonal variation of shoreline can be observed. The period of the retreat or the advance of shoreline is mentioned above as in Fig. 6. Looking at the detail of Fig. 7, the deposition can be most clearly observed from the beginning of July to September 2013. In contrast, the most erosion occurred during November 2013 to January in the next year.

The relationship between behavior of shoreline and wave conditions is shown in Table 1. With the climate characteristics in the south central region of Vietnam as well as at Nha Trang coast, the high waves and the calm waves are dominant during winter monsoon (northeast monsoon) and summer monsoon (east-southeast monsoon), respectively (Nagai et al., 1998, Almar et al., 2014, Viet et al., 2014).

Table 1 The shift of shoreline in the study area

Time	2013	2014	Wave conditions
January		☒ ✧	High waves (Northeast monsoon)
February		☒ ✧	
March		■	Calm waves (East – Southeast monsoon)
April		■	
May	■	■	
June	■		
July	■		
August	■		
September	■		
October	☒		High waves (Northeast monsoon)
November	☒ ✧		
December	☒ ✧		

■ Shoreline advance
☒ Shoreline retreat up to sea dyke
✧ Sandy beach disappear in front of sea dyke

Furthermore, this area is frequently affected by typhoons that often occur from October until January, hence this also contributes to the increase of wave-height during this period. It can be considered that the erosion or deposition of sandy beach in front of sea dyke is related to the change of wave-height and wave direction.

The northeast monsoon waves with high waves have caused the severe erosion of sandy coast in front of sea dyke on Nha Trang coast. The sandy beach in this area disappeared. Only from the end of September to October, although high waves induced by the northeast monsoon or typhoons can be observed, the amplitude of beach erosion increased gradually during this period and sandy beach was still remained in front of sea dyke.

The east – southeast monsoon with medium wind speed is generally expected to begin around March and fade away by the end of September. Besides, the islands which are located in the southeast of Nha Trang Bay can be considered as obstacles to the wind and waves as mentioned above in Fig. 1. So, calm waves can be observed. The beach was accreted in the same period.

The detailed view about the temporal variation of shoreline positions at some longshore positions is shown in Fig. 8. In 2013, during non-monsoon period of this study, from May 26th 2013 to the beginning of September, shoreline advanced in all regions. Especially, in region 1 and region 2, shoreline advanced about more than 10m (Fig. 8a, b) while the slight advance of shoreline was about 4m in region 3 (Fig. 8c).

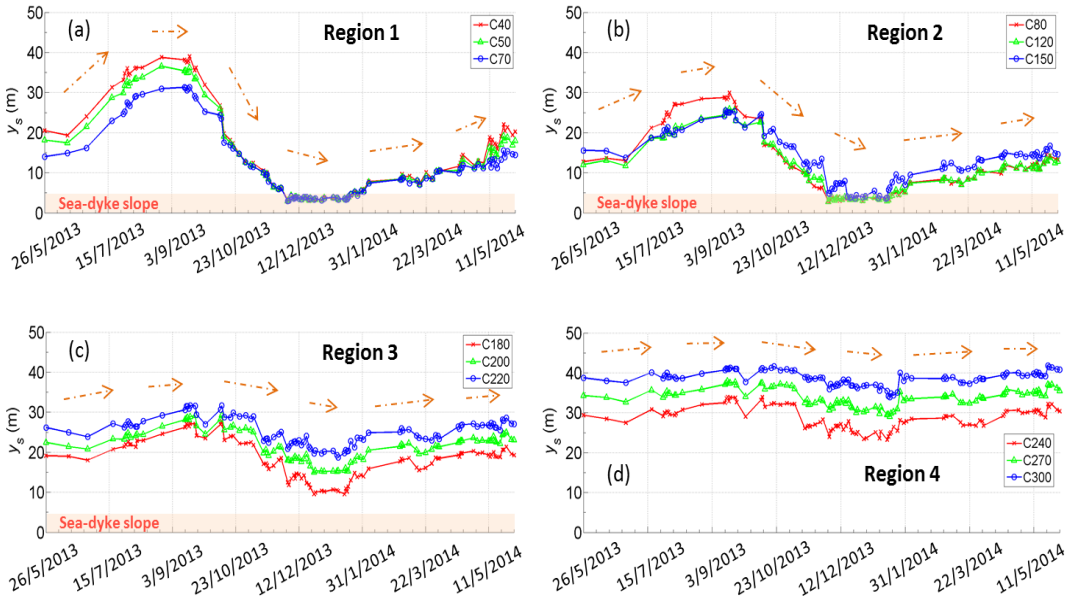

Fig. 8 Temporal variation of shoreline positions

However, the opposite trend can be observed from October to December, when Northeast monsoon waves occurred (Viet et al., 2014), shoreline positions retreated remarkably to sea dyke with about 30m in region 1 (Fig. 8a), 20m in region 2 (Fig. 8b) and about 7m in region 3 (Fig. 8c). It can be said that the erosion occurred, and it was concentrated in region 1 and region 2 that were adjacent to the hotel and the concrete blocks.

A glance at the Fig. 8 describes that the width of sea dyke is about 5m from the seawall to the farthest seaward positions of sea-dyke slope. The line of y_s=0 is the positions of seawall. These structures help to prevent overtopping by sea water. Thus, after shoreline retreated up to sea dyke in the beginning of December 2013, shoreline positions were stable in the next 2 months (Fig. 8a, b, c) before seeing a gradual

advance of shoreline. Generally the distance between the seawall and shoreline positions was about 3m - 5m in region 1 and region 2 during this period.

In 2014, from February to May, the shoreline recovered more than 6 m in both region 1 and region 2 (Fig. 8a, b) and about 3m in region 3 (Fig. 8c). Referring to the Fig. 8d, the stability of almost shoreline positions in region 4 during the period of this study can be observed.

4. Conclusion

In this study, through a video-camera monitoring system on Nha Trang coast, time-averaged images have been extracted to analyze the continuous change of shoreline. The shoreline in the study area appears to be especially sensitive to climate fluctuations. Under the influence of the northeast monsoon over the coastal areas of Nha Trang, the retreat of shoreline is induced by the high waves, the concave shape is formed as well as a part of sandy beach with more than 180m in length disappear in a long time, about 4 months. Besides, the most severe erosion is occurring in the area near the hotel. The recovery of shoreline is followed by an extended period of shoreline retreat, it is most common during east-southeast monsoon when the waves are comparatively calm. These detailed values in one year of shoreline change could be applied for estimation of longshore sediment transport in the future.

Acknowledgment

This study is supported by the protocol project "Study on hydrodynamic regime and sediment transport in estuarine and coastal zones of Nha Trang bay, Khanh Hoa province", under the co-operation between Ministry of Science and Technology (MOST), Vietnam and Institute of Research and Development (IRD), France. We wish to express our deep appreciation to Thuyloi University, Vietnam for their kindness in the provision images from camera monitoring.

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