Shoreline change and impacts of coastal protection structures on Da Rang River mouth and adjacent coast, south central of Vietnam

Nguyen Trong Hiep[1], Hitoshi Tanaka[2], Nguyen Xuan Tinh[3], Nguyen Trung Viet[4]

Abstract

Da Rang River mouth, Phu Yen, Vietnam is a representative coastal area of Vietnam where recently was observed a significant change on the morphology change. The morphology change was resulted by either natural and human influences. Since 2016, several coastal constructions (jetties, groins, breakwaters) had been implemented to stabilize the mouth area and the morphology of the river mouth is now very different from it in the last decade. This study, by satellite image analysis, provides the last decadal shoreline change in the entire Phu Yen coast from Ganh Ba Seacliff to Da Nong River mouth. The severe erosion can be found in region B where the old sand spits were both eroded in the mouth and pushed into the river channel after the typhoon in 2017. The morphology of the Da Rang river mouth been recently stabilized by new coastal structures constructed since 2018.

Keywords: Da Rang River mouth, Phu Yen Coast, coastal constructions, shoreline erosion.

1. INTRODUCTION

River mouths, estuaries or coastal regions in general are considered the centralized regions for socio-economic development in almost all countries in the globe. The studies regarding coastal processes, mechanism and potential coastal morphological change have been conducted broadly in the world in favour of coastal management, sustainable development, coastal protection and countermeasures against catastrophes.

Vietnam is one of a few countries in the world having a long coastline along the country. This brings a great deal of advantages for the development of many aspects such as economics, tourism, etc. However, the responsibility of preserving the coastline stability by which affected overwhelmingly natural change and nowadays mankind is also vital challenge. In recent years, many areas in Vietnam, particularly in central region, have reported on the erosion occurring severely. Cua Dai and Nha Trang are two coastal regions have had deep concern about coastal changes for several years lately. Viet et al. (2014) presented the erosion of sandy beach on the right side of the Cai River mouth, Nha Trang City associated to the difference of wave conditions in monsoon and non-monsoon periods. The study also discussed the influence of protrusive hotel similar to a groin that blocks the alongshore transport drift. Further analyses on the evolution of Nha Trang Coast utilizing shoreline dataset extracted from time-average images of video-camera monitoring system, were discussed in Thanh et al. (2015). Tanaka et al. (2017) investigated severe retreat of shoreline of the sandy beach on the left side of Cua Dai River mouth, Hoi An City, central Vietnam. In addition, Nagasawa et al. (2016) discussed the reduction of sediment supply from Thu Bon River basin to Cua Dai River mouth due to construction of dam reservoirs as well as excessive dredge of sand and gravel along the river channels. Noshi et al. (2015) investigated changes of coastal morphology associated with the elongation of a sandspit and longshore sediment accumulation at the jetty in Phan Rang City, south central Vietnam.

(1) Graduate Student, Department of Civil and Environmental Engineering, Tohoku University, 6-6-06 Aoba, Sendai 980-8579, Japan
(2) Professor, Department of Civil and Environmental Engineering, Tohoku University, 6-6-06 Aoba, Sendai 980-8579, Japan
(3) Assistant Professor, Department of Civil and Environmental Engineering, Tohoku University, 6-6-06 Aoba, Sendai, 980-8579, Japan
(4) Professor, Department of Civil Engineering, Thuyloi University, Hanoi, Vietnam

Similar to the coastal zones mentioned above, Darang River mouth and the adjacent coasts experienced notable morphology and coastal changes induced by both natural and human effects. Hoang et al. (2015) claimed the existence of the sand terrace in front of the river mouth created by floods contributing mainly the sediment on both sides of the entrance. Hiep et al. (2020) explains the migration of the river mouth before the sand mining in 2015 by mathematical solution of one-line model. In addition, Hiep et al. (2018) mentioned the severe erosion of the sand spits of Darang River mouth after Typhoon in 2017. Since 2016, multiple coastal constructions (jetties, groins, breakwaters) had been implemented to stabilize the mouth area and the morphology of the river mouth is now very different from it in the last decade. This study, by using shoreline analysis, provides the recent morphology change in the Da Rang River mouth and its adjacent coast over last decade.

2. STUDY AREA

The region including Da Rang River mouth and adjacent coasts in Phu Yen, Vietnam is one of the biggest coastal area in the south-central coast of Vietnam. Da Rang River mouth is located in Tuy Hoa City, Phu Yen Province, south central Vietnam. Figure 1 shows the location of the study area. Da Rang River mouth is the estuary of Ba River and known as the longest river in the centre of Vietnam with the length of 374 km, and total basin area of 13,900 km^2. The left coast of Da Rang River mouth extends from the mouth entrance to the Ganh Ba Seacliff, while the right coast is from the mouth to Da Nong River mouth (Figure 1). This mouth area is usually affected by typhoons during the rainy season which extends from September to December. The typhoon causes heavy rainfall resulting in floods which widens the river mouth. This river mouth is deemed to be one of the most important area contributing to the development of Phu Yen Province. The mouth area is now the shelter and harbour for more than 900 small and big fishing boats and vessels. Da Rang Opening is also an active and dynamic area that the severe deposition or erosion often occurs in the river mouth. In 2015, The deposition was so severe that hundreds of ships were unable to enter or exit, raising concerns about navigation clearance. As a result, several sand mining events were held to alleviate the problem. After 2015, consecutive coastal protection constructions were implemented in mouth area. These constructions had the objectives to prevent the erosions on the adjacent local coasts on both sides of river mouth.

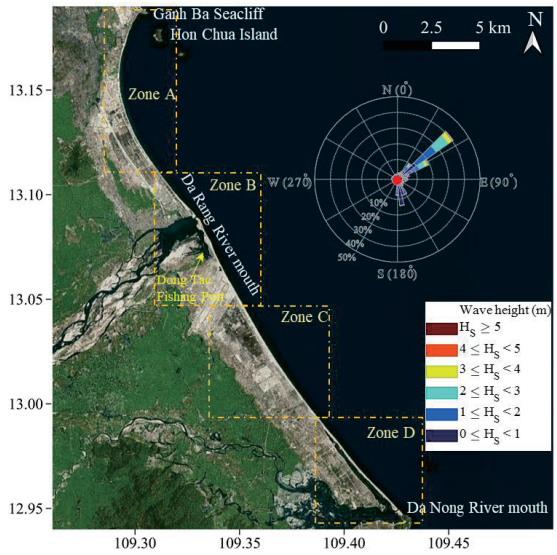

Figure 1. Phu Yen Coast and Da Rang River mouth

Regarding hydrodynamic conditions, the diurnal tide of Tonkin Gulf is the main tidal cycle having an effect on Da Rang River mouth. During the spring tide, the maximum that tidal range can reach is about 1.7 m and the minimum is nearly 0.5 m during the neap tide. The fresh water river discharge depends mainly on the rainfall and flood regimes of the entire basin. In flood season, river discharge can increase up to 2100 m^3/s and the annual river discharge is about 275 m^3/s. Similar to other coastal regions in central Vietnam, incident waves are mainly dominant at the northeast direction during monsoon season. Wave height is smaller dung non-monsoon season as the northeast wind becomes less dominant. The wave rose from the offshore wave data from WAVEWATCH III from 2006-2016 shows the dominance of northeast monsoon drives the wave condition Phu Yen Coast (Figure 1)

3. MATERIALS AND METHODS

The Landsat Imagery retrieved from the U.S Geological Survey (USGS) database from 2013 to 2021 is utilized as the main dataset for this study. The dataset is a combination of images taken from different satellite missions, Landsat 7 (EMT+), Landsat 8 (OLI), and Sentinel-2 (MSI). Some images obtained from Google Earth data base system were also collected for this study

Since Landsat Images are TOA images (Top-of-Atmosphere), all data must be pre-processed in order to extract the best quality of the image. Acquired images are then required to go through a pre-processing stage that involves cloud masking, pan sharpening and down-sampling. The pre-processing techniques followed the same process introduced by Vos et al. (2019). Landsat data from USGS assesses the cloud cover of each image by computing the percentage of cloud pixels on the image. Some images contain large parts covered by clouds which are difficult to perform the shoreline detection. The cloud masking stage is optional but necessary for discarding all images that are unable to analysis. In this study, a threshold is set for evaluating cloud percentage of each image. The value of cloud cover of any image exceeding this threshold is excluded from the data. The resolution of Landsat 7,8 images can be enhanced to be optimal by merging high-resolution panchromatic and lower resolution multispectral imagery due to the availability of panchromatic band in these images (Tu et al, 2001). The resolution can be enhanced from 30 m to 15 m per pixel. On the other hand, the resolution of Sentinal-2 is 10 m.

For shoreline detection, firstly, the separation between water and land zones in the image is implemented using the modified normalized water index (MNDWI) expressed as follows

$$MNDWI = \frac{SWIR1 - G}{SWIR1 + G} \tag{1}$$

Where: SWIR1 is pixel intensity in short-wave infrared band and G is the green band. The range of value is between -1 and 1. The shoreline is then detected by using K-mean clustering method. In this study, the effect of tidal level at different capturing is not considered since the local beach slope is quite steep ($\approx$ 0.1) and the possible error position error is likely smaller than the resolution of the image. The total error in shoreline is considered to be equal to the resolution of image as 10 m.

The Shoreline change rate is obtained by applying the linear regression rate to all data sets of shoreline position as follows

$$y = at + b \tag{2}$$

where a is slope of regression line (shoreline change rate); b is a constant.

4. RESULTS AND DISCUSSIONS

4.1 Overall shoreline change rate in Phu Yen Coast

Due to the different behaviours of shoreline change in different areas, the entire Phu Yen Coast is divided into 4 sub-zones (A, B, C and D) from north to south. Zone B is the regions representing for the Da Rang River mouth (Figure 1).

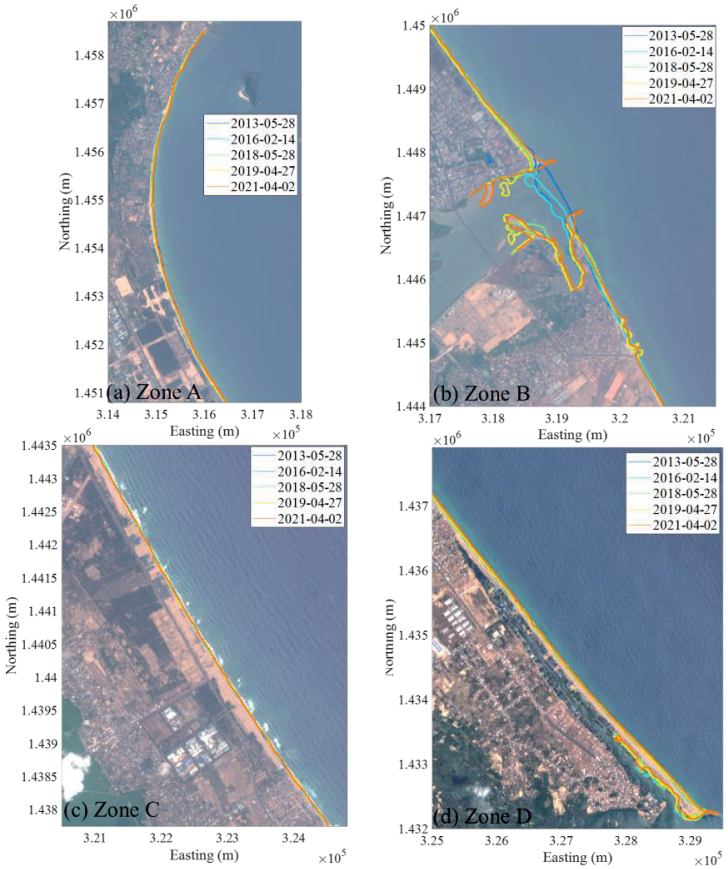

Figure 2. Shoreline position change in each zone

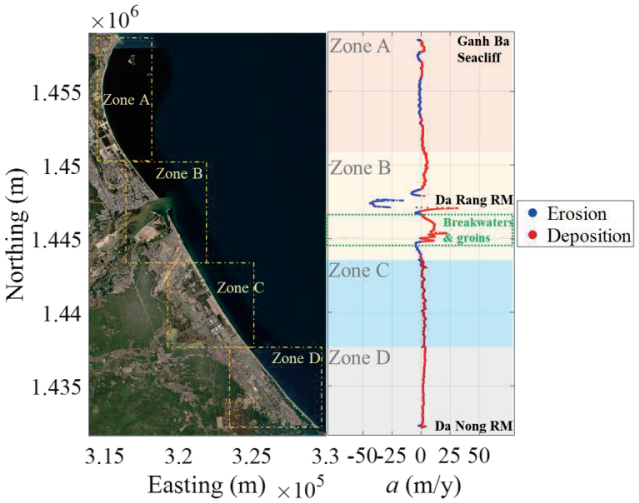

Figure 3. Shoreline change rate (2013~2021)

The shoreline change of Phu Yen Coast are shown in Figures 2 and 3. The shoreline changes in Zone A, B, D shows no significant change since these areas are almost straight sandy beaches. The small deposition can be found the Ganh Ba Seacliff and Da Nong River mouth. In the Da Nong River mouth, due to the construction of the jetty in the past, the sand spit of this river mouth is similar to the restricted spit which it can not elongate. The remarkable changes are found in Zone B where Da Rang River mouth is located. The severe erosion spot with the change rate approximately 40 m/*y* was the position of the sand spit. As seen in Figure, the elongated sand spit was gradually eroded until it was disappeared after the Typhoon in 2017. The deposition on the southern coast of Da Rang River mouth was due to the construction of breakwaters and groins in this area from 2016. The highest deposition rate is at the position of jetty after constructed in 2019. The sand accumulation is also detected at the locations of breakwaters and groins. The deposition was resulted from the formation of tombolo.

4.2 Morphology change in Da Rang River mouth (Zone B)

According to Hiep et al. (2018, 2020), after the constructions of detached breakwaters and groins on southern coast, and riprap on the northern coast at the river mouth, the sand spits were eroded severely until they were disappeared caused by the Molave Typhoon in 2017. Figure 4 shows that the sediment from sand spits was actually over-washed and pushed into the river mouth by extremely high waves to form two sediment strips attached on the embankment inside the river mouth. The natural subsequent recovery of the sand spits at the old locations were not observed after typhoon due to the coastal infrastructures on both sides of the river mouth preventing the alongshore drift to transport sediment to the mouth (Hiep et al, 2018). Due to the intensity of storm waves, the detach breakwaters and groins were also destroyed partly by the typhoon in 2017. To stabilized the morphology in the river mouth, the local government continued to constructed 5 more breakwaters beyond the position of the groins and 2 jetties on both sides of the river mouth. After the completion of the new coastal structures, the formation of tombolo at the new breakwaters and the deposition at the position of two jetties were observed.

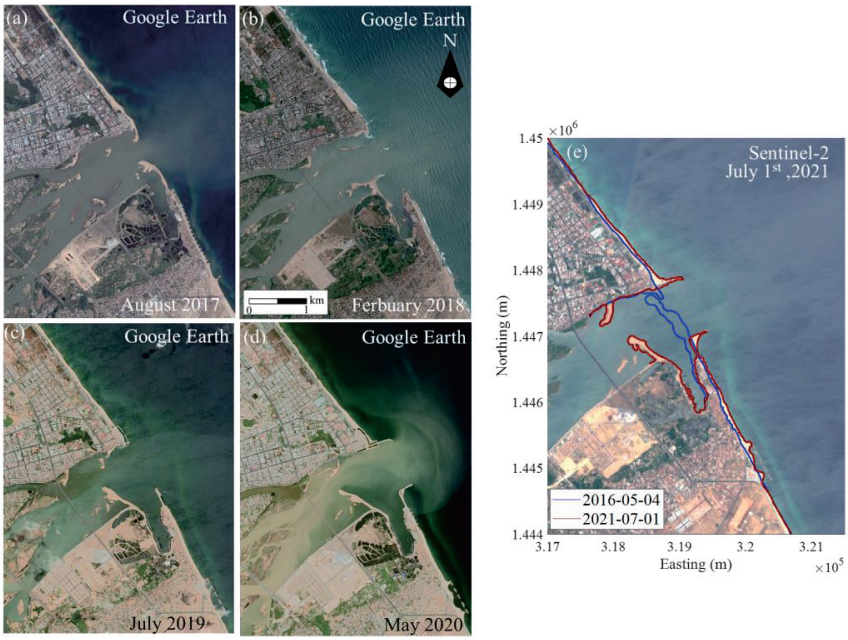

Figure 4. Sand spit in Da Rang River mouh before and after the Molave Typhoon in 2017 (Zone B)

The current morphology of mouth entrance can improve the flushing behaviour of the river during flood events. However, the wide opening can result to wave intrusion propagating inside the river mouth. This can trigger erosion inside the river and possible complicated cross-shore sediment transport induced by high and storm waves, especially inside the Dong Tac Fishing port where diffracted wave can propagate inside the port. The formation of subaqueous channel-spit was also discussed in several river mouth after the construction of jetties caused by the tidal transport current induced by ebb flows (Hein et al., 2019). Therefore, the detailed sediment transport inside the river must require further monitoring in the river mouth and thorough analysis in the near future.

5. CONCLUSIONS

The shoreline evolution of Phu Yen Coast and Da Rang River mouth in recent years is investigated by the satetllite image analysis. Significant change of shoreline from 2013 to 2021 was detected at the location of Da Rang River mouth where the sand spits was dissapeared at the mouth entrance and pushed inside the channel after the historic typhoon in 2017. The morphology of the river mouth been recently stabilzed by new coastal structures constructed since 2018. The opening of the river mouth and new construction of jetties requires further analyses in the future since wave-induced sediment transport inside the river mouth can be more complicated when waves can propagate further upstream.

REFERENCES

Hein, C.J, Fallon, A.R., Rosen,P., Hoagland, P., Georgiou, I.Y., FitzGerald, D.M., Morris, M., Baker, S., Marino, G.B. and Fitzsimons, G. (2019). “Shoreline Dynamics Along a Developed River Mouth Barrier Island: Multi-Decadal Cycles of Erosion and Event-Driven Mitigation”. Front Earth Science, 7:103.

Hiep, N. T., Tanaka, H., Tinh, N.T. and Viet, N.T. (2018). “Recent morphology changes at Da Rang River mouth, Phu Yen, Vietnam”. Tohoku Journal of Natural Disaster Science, 55, 79-84.

Hiep, N.T., Tanaka, H., Viet, N.T., Tinh, N.X. and Hoa, T.D. (2020). “Modelling river mouth evolution under migration process”. Journal of Japan Society of Civil Engineers (Applied Mech.), Ser. A2, Vol. 76(2).

Hoang, C.V., Tanaka, H., Viet, T.N. and Binh, H.T.L. (2015). “Analysis of shoreline erosion at the Da Rang River mouth, south central Vietnam”. Proceeding of Vietnam – Japan Workshop on Estuaries, Coasts and Rivers, September 2015, Hoian, Vietnam, VJWECR 2015, 60-68.

Nagasawa, T., Thuy, M.T.T, Viet, T.N. and Tanaka, H. (2018). “Analysis of shoreline change in Cua Dai beach by using Empirical Orthogonal Function”. Coastal Engineering Journal, 60(4), 548-565.

Noshi, Y., Uda, T., Kobayashi, A. and Miyahara, S. (2015). “Beach changes observed in Phan Rang City in southeast Vietnam”. Proceedings of the 8th International Conference on Asian and Pacific Coasts.

Tanaka, H., Hoang, V. C., and Viet, N. T. (2017). “Investigation of morphological change at the Cua Dai River mouth through satellite image analysis”. Proceedings of the 35th International Conference on Coastal Engineering, 35(1).

Thanh T. M., Tanaka H., Viet N. T., Mitobe Y., and Hoang V. C. (2015). “Evaluation of longshore sediment transport on Nha Trang Coast considering influence of northeast monsoon waves”. Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering), 71(2), I_1681-I_1686.

Tu, T.M., Su, S., hu, C., Shyu, H. and Huang, P.S. (2001). “A new look at IHS-like image fusion methods”. Information Fusion, 2, 177–186.

Viet, N, T., Duc, N, V., Hoang, V, C., Tanaka, H., Uu, D.V., Tung, T, T., Lefebvre, J, P. and Almar, R. (2014) Investigation of erosion mechanism on Nha Trang coast, Vietnam. Proceedings of the 19th Congress of the Asia and Pacific Division of the International Association of Hydraulic Engineering and Research.

Vos, K., Harley, M. D., Splinter, K. D., Simmons, J. A., and Turner, I. L. (2019). “Sub-annual to multi-decadal shoreline variability from publicly available satellite imagery”. Coastal Engineering. 150, 160–174.