Observation of sand spit development at Cua Lo River mouth, Central Vietnam

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Abstract: The development of a sand spit at Cua Lo River mouth in Central Vietnam is causing complex beach morphological change and affecting the local people activities. Satellite images were used to observe the migration of this sand spit. Shoreline positions extracted from Landsat images show that the sand spit has shifted 1.7 km from 1973 to 2016. As a result, the protrusion of this sand spit is causing beach erosion on the downdrift side. In addition, long-term sediment deposition rate on the sand spit evaluated based on temporal variation of the sand spit's area is 0.16×10^6 m^3/y.

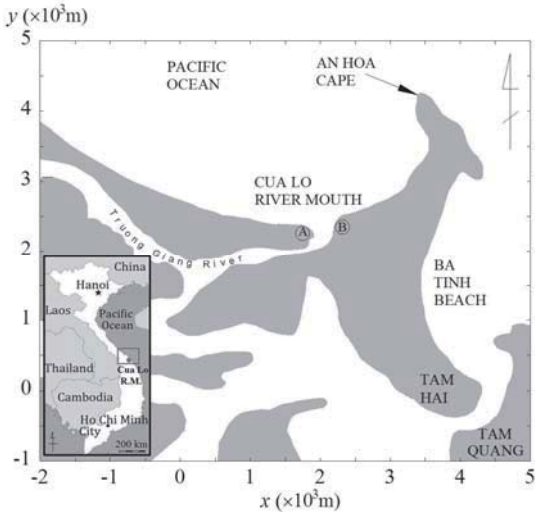

Figure 1. Study area

1. Introduction

Cua Lo River mouth locates in Central Vietnam, which is about 650 km southward from the Capital Hanoi (Figure 1). Beach morphological change at this river mouth is happening with the development of sand spit on one side and erosion of the opposite side (Figure 2). This problem is getting attention of local authorities as well as scientists since it is affecting the local people activities such as aquaculture and tourism. Although problem at Cua Lo River mouth has been stated, there are still few studies about this issue. Binh (2014) studied the geomorphic conditions at Cua Lo River mouth and concluded that shoreline retreat at this location is mainly caused by wave activities in the northeast monsoon season. Cong et al. (2016) made analysis to investigate the erosion and deposition mechanism at Cua Lo River mouth using

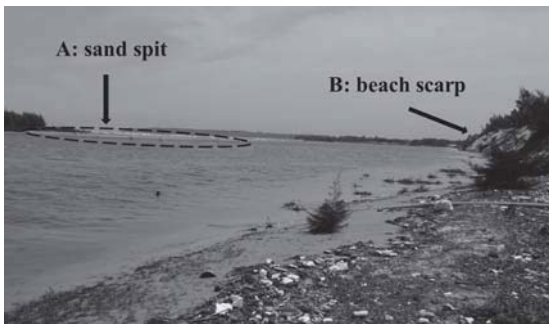

Figure 2. Beach morphological change at Cua Lo River mouth (Point A and B are specified in Figure 1)

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CERC formula and numerical model.

The development of the sand spit, which is important to understand and predict morphological change at inlet system (Tung et al., 2009), has not been studied at Cua Lo River mouth. Therefore, this study will focus on the movement of the sand spit at Cua Lo River mouth using sequential aerial photographs from 1973 to 2016.

2. Study area and data collection

This study focuses mainly on an area around the sand spit on the left of Cua Lo River mouth as shown in Figure 3. Truong Giang River is 70 km long, which is actually a branch of Thu Bon River running along the coastline from the northwest (the whole map of Truong Giang River can be seen in Tanaka et al., 2016).

Landsat images from 1973 to 2016 were utilized to observe the movement of the sand spit at Cua Lo River mouth as can be seen in Figure 3. Those images are rectified to the same coordinate system in the World Geodetic System 84 (WGS-84) with the coordinates of the origin are 246,998.99 E and 1,712,461.66 N. The baseline is set at 90 degrees counter clockwise from the north. Extracted shoreline positions from rectified photos are not corrected to tidal levels since the maximum difference of shoreline positions due to tidal effect is still

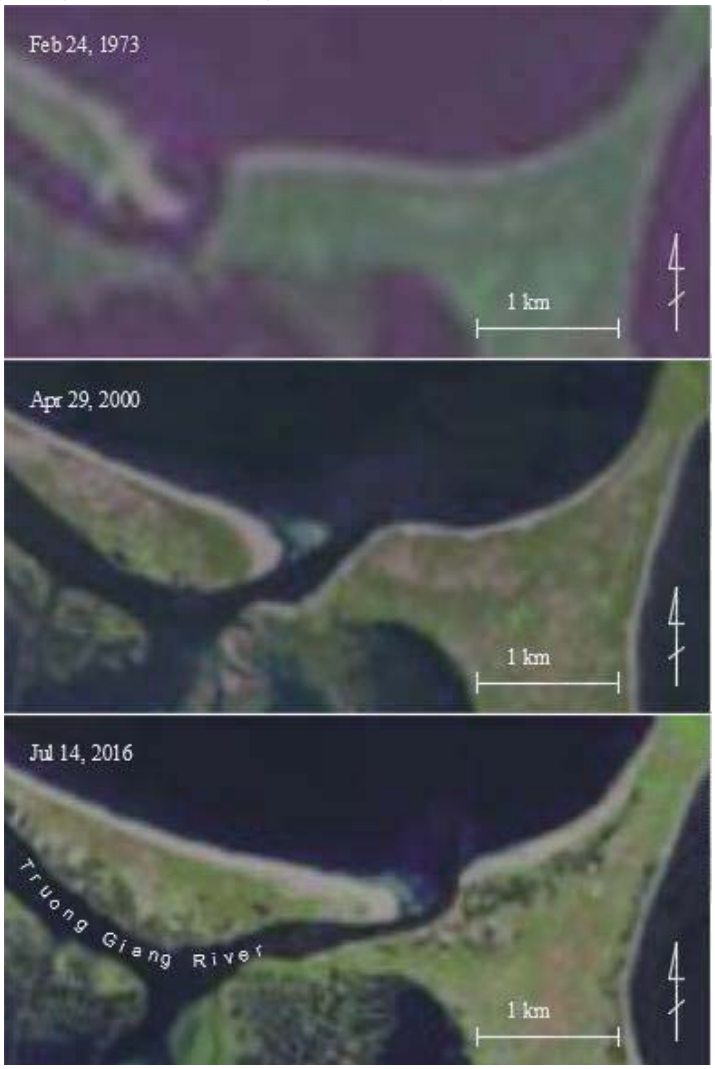

Figure 3. Typical Landsat images show the migration of the sand spit

smaller than 1 pixel of the Landsat image (usually from 25 m to 40 m per pixel).

3. Results and discussion

3.1. Migration of the sand spit

The migration of the sand spit can be seen clearly in Figure 3. The migration process has led to the disappearance of the beach on the right hand side of Cua Lo River mouth as well as the eastward shifting of this river mouth. To quantitatively investigate the migration of the sand spit, shoreline positions of several years during the surveying period are plotted in Figure 4 to show the migration of the sand spit. As can be seen from the figure, the sand spit has extended approximate to 1.7 km to the east in 43 years.

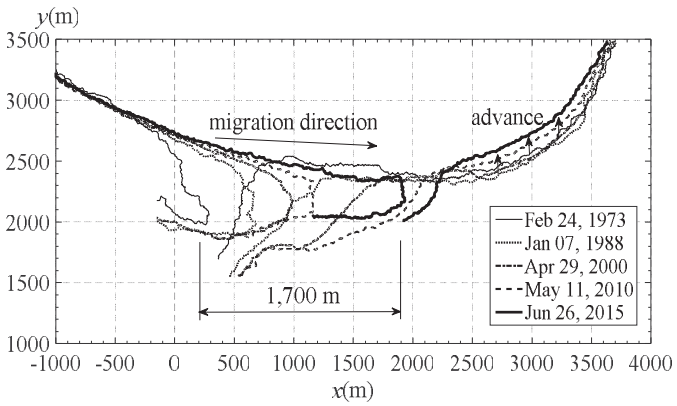

Figure 4. Shoreline positions of several years

The development of sand spit at Cua Lo River mouth is simmilar to the Inlet Migration Spit Breaching Model introduced by FitzGerald at el. (2000) as in Figure 5. In their report, they stated that during the migration process, longshore sediment transport adds sand predominantly to updrift side of the river mouth which inturn results in the erosion of the downdrift side and causes the shifting of the river mouth. FitzGerald at el. (2000) also discussed about the formation of a new inlet besed on the

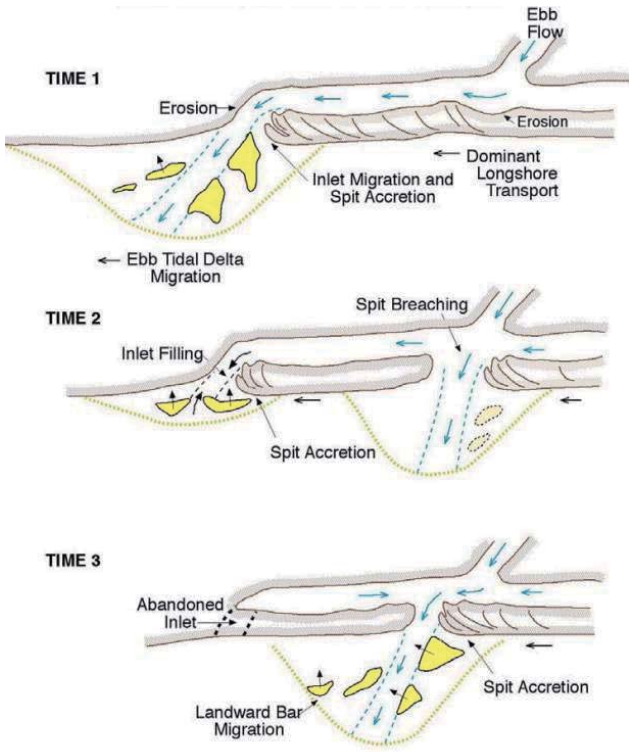

Figure 5. Migration and spit breaching model (FitzGerald et al., 2000)

breaching of the sand spit at a location updrift of the sand spit where the tidal prism is easily accessed (Figure 5). In their model, the ebb flow from the river impinges on the backbarrier side of the spit to reduce the width of the spit and determines the favourable location for breaching.

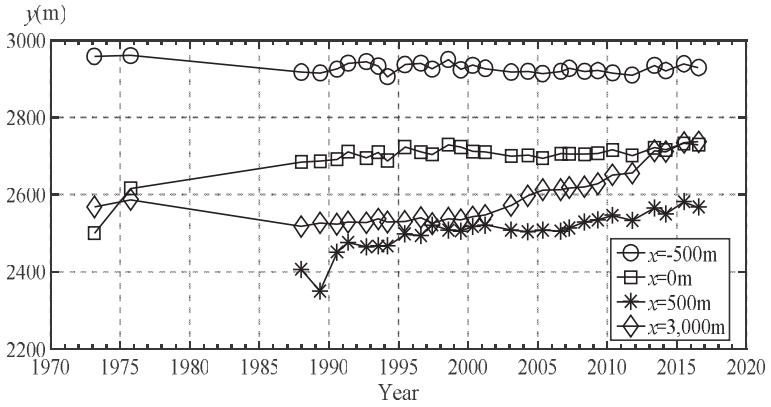

Figure 6. Temporal variations of shoreline positions at some positions

However, in case of Cua Lo River mouth as can be seen in Figure 1, Truong Giang River runs along the coast line which indicates that the effect of the river flow on the sand spit to erode the back side of the sand spit can be neglected. As a result, the tip of the spit will develop and entrench into the right side of the river mouth without any breaching. Finally, Cua Lo River mouth will be closed and Truong Giang River will discharge to the ocean through the inlet between Tam Hai and Tam Quang villages. This argument can be confirmed by the composition of the An Hoa Cape, which mainly consists of basalt (Binh, 2014) and will impede further migarion of the sand spit.

3.2. Temporal variation of shoreline positions at some positions along the coastline.

Temporal variations of shoreline positions at x=-500 m, 0 m, 500 m and 3,000 m along the coastlines are shown in Figure 6. According to the figure, among four observing locations, there is only one location where the shoreline position remained stable from 1973 to 2016. Shoreline advance at x=3,000m together with the erosion of beach on the right side of Cua Lo River mouth indicates that sediment in this area is moving predominantly to the east. This moving direction of sediment well agrees with the development direction of the sand spit.

3.3. Long-term sediment deposition on the sand spit.

Figure 7 defines the sand spit's area, A (m^2), which will be used to calculate the long-term sediment deposition on the sand spit of Cua Lo River mouth. The estimation of long-term sediment deposition is based on a theory, which was introduced by Tanaka et al. (2006).

With regard to the determination of the sand spit's area, a fixed boundary on the left side of the sand spit must be determined since the sand spit is developing to

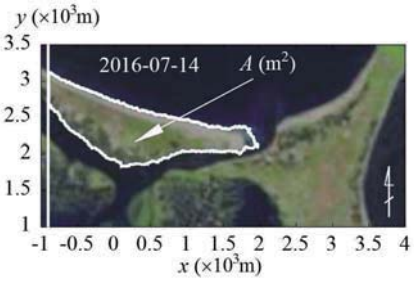

Figure 7. Area of the sand spit

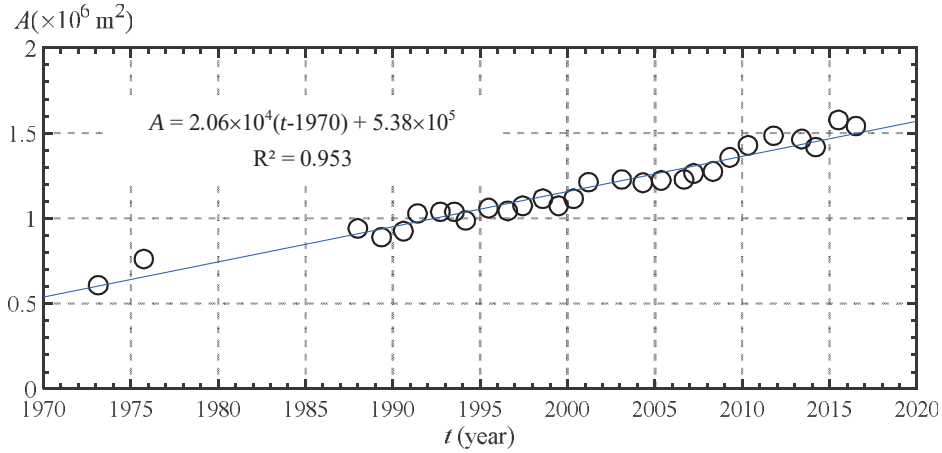

Figure 8. Temporal variation of the sand spit's area

the right. According to Figure 4 and Figure 6, there is almost no change of shoreline position over the surveying period at $x \leq$-500 m. Therefore, a vertical line will be set at x=-900 m as a demarcation on the left to calculate the area of the sand spit.

After calculating all the areas of the sand spit from 1973 to 2016, these values are plotted in Figure 8. Using linear regression method, temporal variation of the sand spit's area shows a developing trend at a speed of 2.06×10^4 m^2/y as in Eq. (1):

$$A = 2.06\times10^4\left(t-1970\right)+5.38\times10^5 \quad (1)$$

Where t: time.

From the values of the spit's area change rate, the long-term sediment deposition rate can be calculated as follows (Tanaka et al., 2006):

$$Q = \left(D_B + D_C\right)\frac{\Delta A}{\Delta t} \quad (2)$$

In which, Q: long-term sediment deposition rate, D_B: berm height, D_C: depth of closure, $\Delta A/\Delta t$ indicates the area change rate of the sand spit. Values of D_B and D_C can be taken as 2 m and 6 m, respectively, from Cua Dai Beach (Duy et al., 2016), which is located on the same coastline and about 50 km to the northwest from Cua Lo River mouth. Using Eq. (2), the long-term sediment deposition on the sand spit can be estimated as 0.16×10^6 m^3/y.

4. Conclusions

The development of the sand spit on the left of Cua Lo River mouth has been studied using satellite images from 1973 to 2016. The analyzing results show that the sand spit has been elongated about 1.7 km by the sediment deposition during the survey period. As prediction, this sand spit will entrench to the rocky beach at An Hoa Cape and Truong Giang River will enter the ocean through another inlet between

Tam Hai and Tam Quang villages. Finally, long-term sediment deposition on the sand spit is estimated at the rate of 0.16×10^6 m^3/y.

5. References

Binh T.V. (2014). Study on geomorphic conditions for beach environment management in Quang Nam Province. *Master thesis, VNU University of Science, Vietnam,* 131p (in Vietnamese).

Cong M.V., Anh N.Q.D., Hieu B.Q. and Giang H.T.L. (2016). Analysis of coastal erosion and sedimentation issues in vicinity of Cua Lo River mouth, Quang Nam Province. *Proceedings of the Vietnam-Japan Workshop on Estuaries, Coasts, and Rivers 2016*, pp. 60-70.

Duy D.V., Tanaka H., Mitobe Y., Hoang V.C. and Viet N.T. (2016). Study on river mouth delta formation and recent beach erosion on Cua Dai Beach, Vietnam. *Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering)*, Vol.72(2), pp. I_1657-I_1662 (in Japanese).

FitzGerald D.M., Kraus N.C. and Hands E.B. (2001). Natural mechanism of sediment bypassing at tidal inlets. *ERDC/CHL CHETN-IV-30, U.S. Army Engineer Research and Development Center, Vicksburg, MS*, 10p.

Tanaka H., Duy D.V. and Viet N.T. (2016). Shoreline change in a wide area on both sides of the Cua Dai River mouth, Vietnam. *Proceedings of the Vietnam-Japan Workshop on Estuaries, Coasts, and Rivers 2016*, pp. 13-22.

Tanaka H., Takahashi G., Matsutomi H. and Izumi N. (2006). Application of old maps for studying long-term shoreline change. *Proceedings of 30th International Conference on Coastal Engineering*, pp. 4022-4034.

Tung T.T., Walstra D.J.R., Graaff J. van de and Stive M.J.F. (2009). Morphological modeling of tidal inlet migration and closure. *Journal of Coastal Research*, SI 56 (Proceedings of the 10th International Coastal Symposium), pp. 1080-1084.