

Sand spit morphological change of An Hai and Le Thinh inlets, Phu Yen Province, Central Vietnam.

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1. Introduction

Tuy An is one of the most beautiful coastal districts in Phu Yen province in the central of Vietnam. This place has many scenic spots such as O Loan lagoon, the Sea cliff of stone plates and Cu Lao Mai Nha island. There is a long beautiful sand spit of 6 km length from Le Thinh and An Hai tidal inlets (as shown in Figure 1). These two tidal inlets are very important to maintain the O Loan lagoon water environment conditions which are vital for the aquaculture activities such as shrimp ponds in this area. This is a rather special and typical form of morphology along the coastline in Central Vietnam (Eriksson & Persson, 2014; Tanaka et al., 2018)



Figure 1. Location of the sand spit and An Hai and Le Thinh Inlets

Along O Loan lagoon through An Hai and Le Thinh inlets, local aquaculture activities have been developing significantly, which is conducive to the increase of revenues and profits to the local residents. However, it also negatively affects the living environment of the local people. The zone of the O Loan lagoon (with a total water surface area of 1,570 *ha*) to the end of the tidal channel of the local aquaculture industry has been developing strongly in the last 20 years. The shrimp ponds protecting methods are illustrated in the Figure 2. As can be seen in the Figure 2a, to protect the sand spit from the effect of waves and currents, citizens have grown trees on the right sand spit while in the inside side of the sand spit, a series of shrimp pond banks have been built. These make the northern part of spit sand from Le Thinh inlet to An Hai inlet be protected. Thus, it hardly occurs the breaching at the northern part of sand spit under the influence of natural factors.

Figures 2a and 2b show the beginning and the ending of the northern part of the sand spit with the viewing point from An Hai and from Le Thinh inlets, respectively. These photos were taken during the field trip on December 25th, 2018. Standing from the south side of An Hai inlet and looking up to the north and standing from the position of Le Thinh inlet and looking back to the south, it is very clear to observe

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the height of sand spit which is relatively high and being protected by the casuarina cultivation. The inside part of sand spit is protected by the shrimp pond banks reinforced by concrete structures or bamboo types (as shown in Figures 2c, 2d). These types of reinforcement solutions are built by the locality along the sides of tidal channel using their funds. In order to take advantage and expand the aquaculture space, the people have organized themselves to build the embankment and gradually encroached on tidal channel, which reduces the area of the tidal channel.

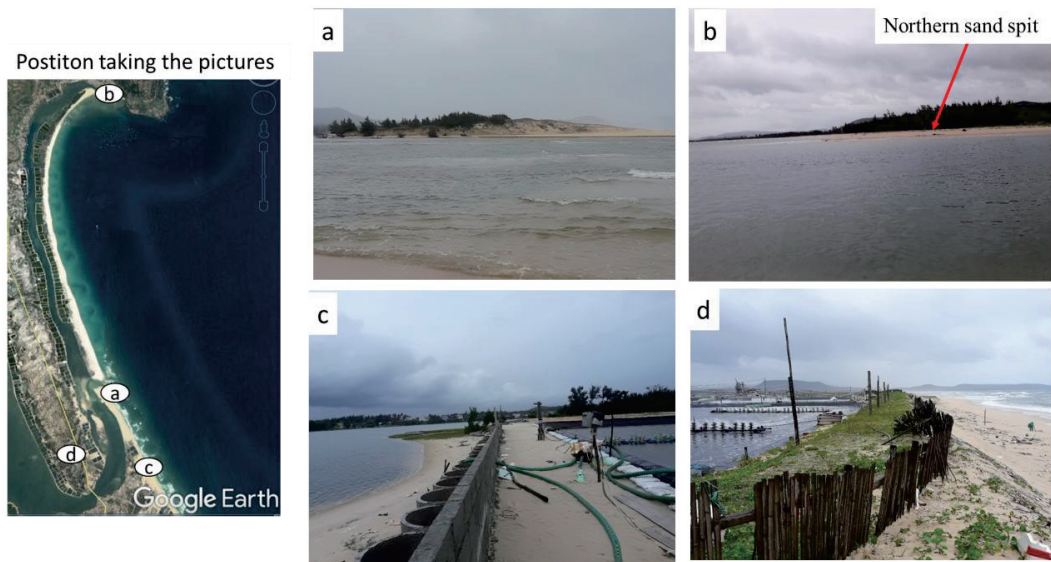


Figure 2. Sand spit, breaching and shrimp ponds protection.

The main objectives of this study are to investigate the sand spit morphological changes of An Hai and Le Thinh inlets as well as the breaching mechanisms at An Hai area. The analyzed results have been indicated that the sand spit breaching occurred at a lower dune elevation and usually following by a big flood event.

2. Data Collection and Research Methodology

In this study, the authors apply the remote sensing image method that has been carried out by Pradjoko & Tanaka, 2011; Tanaka, Hoang, & Nguyen, 2017 for An Hai and Le Thinh inlets in Phu Yen province. Being considered as the data set used in this study, beside the photos taken during the field trips, Landsat images from 1988 to 2018 (Figure 3) and Google images from 2009 to 2018 (Figure 4) were utilized. Those images are rectified to the same coordinate system in the World Geodetic System 84 (WGS-84) with the coordinates of the origin of 312895,40E and 1474664,56N. The baseline is set at 160 degrees counter clockwise from the North. In this study, tidal correction was not performed since the maximum difference between shoreline positions before and after tidal correction is still smaller than the resolution of Landsat images. Spatial moving average was applied to reduce the effect of big scatter in shoreline positions due to the low resolution of the Landsat images.

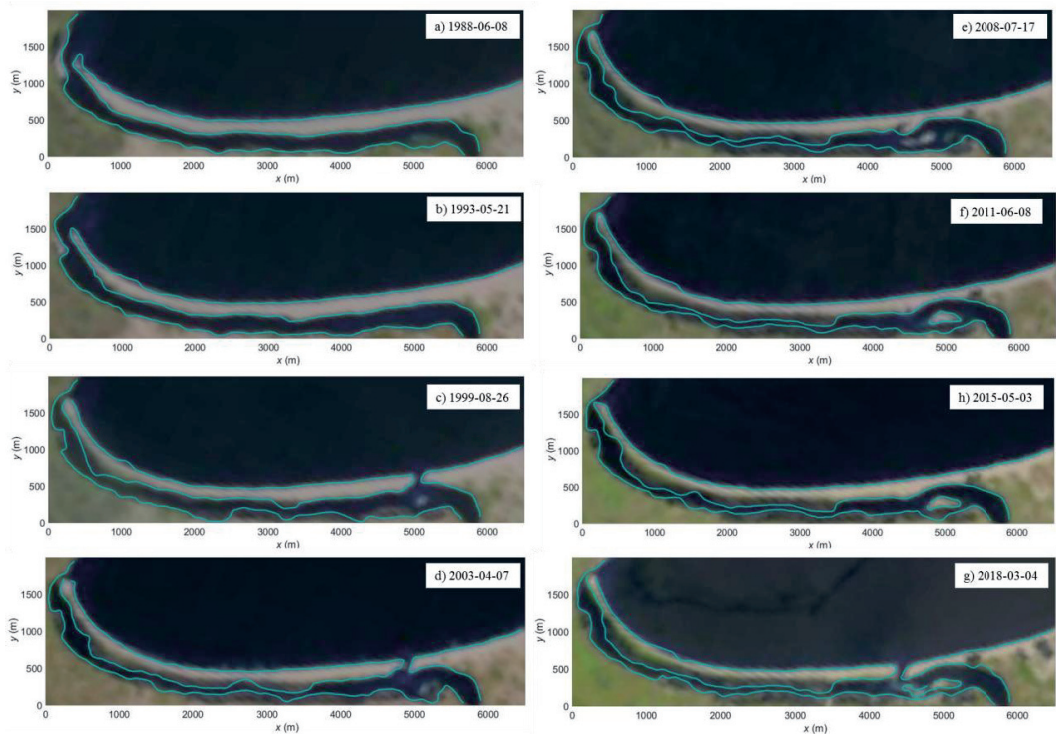


Figure 3. Analysis the shoreline changes of sand spits by using the Landsat images

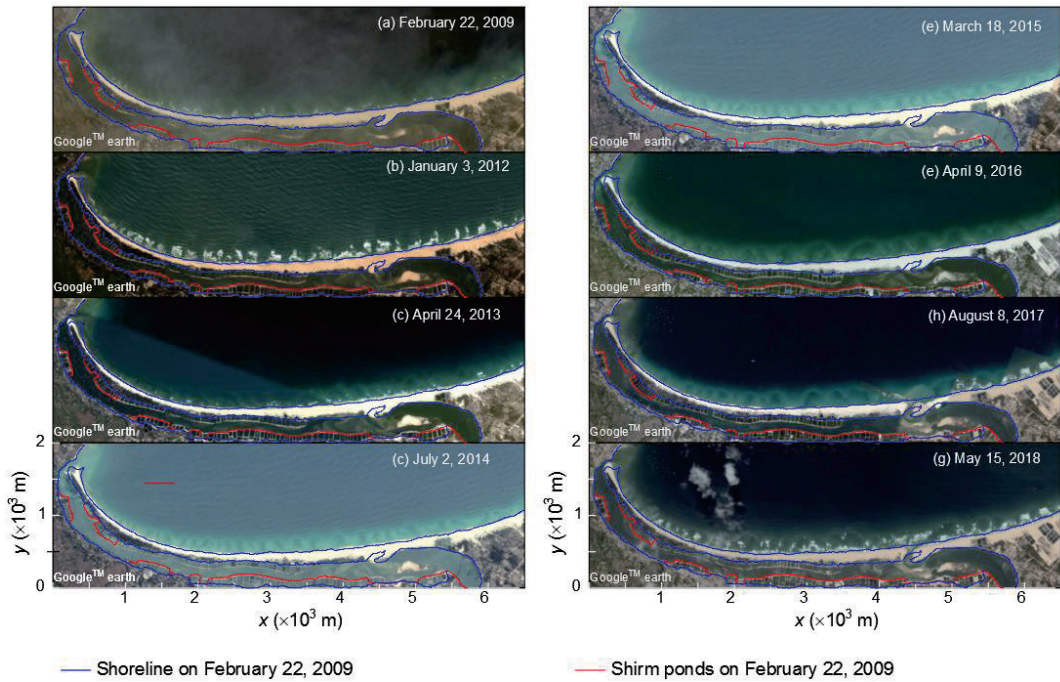


Figure 4. Analysis the shoreline changes of sand spits in Tuy An by using GG images

3. Results and discussion

In order to determine the increase in the area of shrimp ponds and the decrease in the area of the tidal channels over time, along with the observation of the width reduction phenomenon of Le Thinh inlet and the fluctuation of An Hai breaching over time, the authors have developed the basic definition in analyzing the extracted results of shoreline lines as shown in Figure 5.

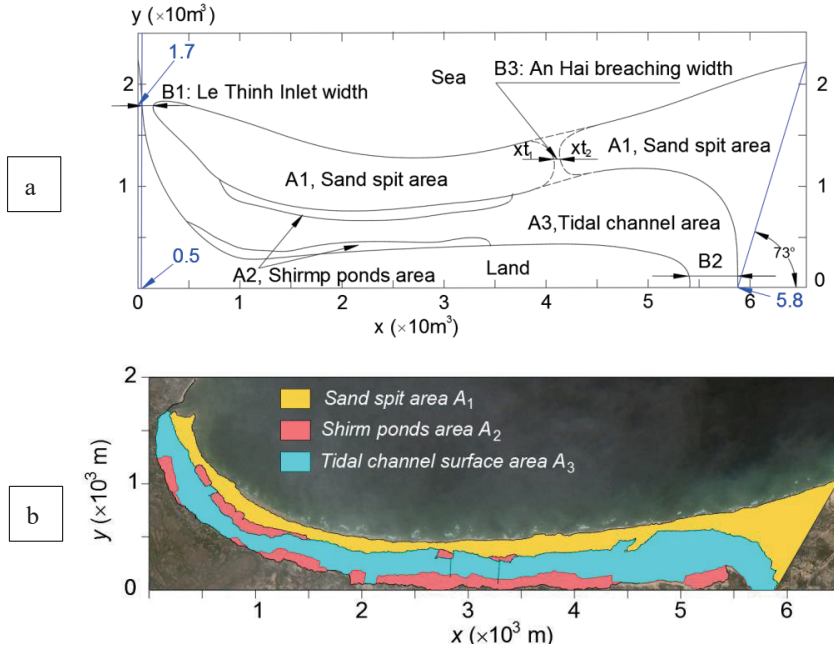


Figure 5. Definition of the analyzed parameters of the sand spit (a) and tidal channel areas at Tuy An (b) in which: A_1 : sand spit area; A_2 : shrimp ponds area and A_3 : tidal inlet channel; B1: Le Thinh inlet width and B3: An Hai breaching width

Figure 6 represents the results of the analysis the B1, B3 parameters by using stateliness images in relation with the water level at Ha Bang hydrological station. Le Thinh inlet width, B1, tends to slightly decline from the analysis of both Satellite and Google images. It is easy to identify that the cause is due to the effect of diffraction wave and stream sediment transport. Based on the hydrological data of Cai river at Ha Bang station, it is noticeable that when big floods appeared on the Cai River, the breaching phenomenon occurred in the years of 1988, 1999, 2005, and 2010. Based on this hydrological data, it is also possible to see the relative correlation between the flow of the Cai River and the declining trend of Le Thinh Inlet width B1. One of the main causes of the breaching phenomenon in the An Hai Inlet area can be resulted from the impact of the local people. The activities can be mentioned such as reinforcing the spit sand locations along the tidal channel, expanding the aquaculture area by constructing the shores of shrimp ponds, encroaching on tidal channel surface area. When large flooding reaches tidal channel combined with the decline of the open surface of the tidal channel, the possibility of flood drainage through Le Thinh Inlet tends to decrease in width. As the result, the breaching phenomenon will occur. It can be seen that

the breaching of sand spit is influenced by large rivers.

During the period from 1988 to 2017, An Hai inlet were completely deposited for 3 times. The first period lasted for 10 years from 1989 to 1999; the second period was from 2007-2010 and the latest period was from 2011 to 2015.

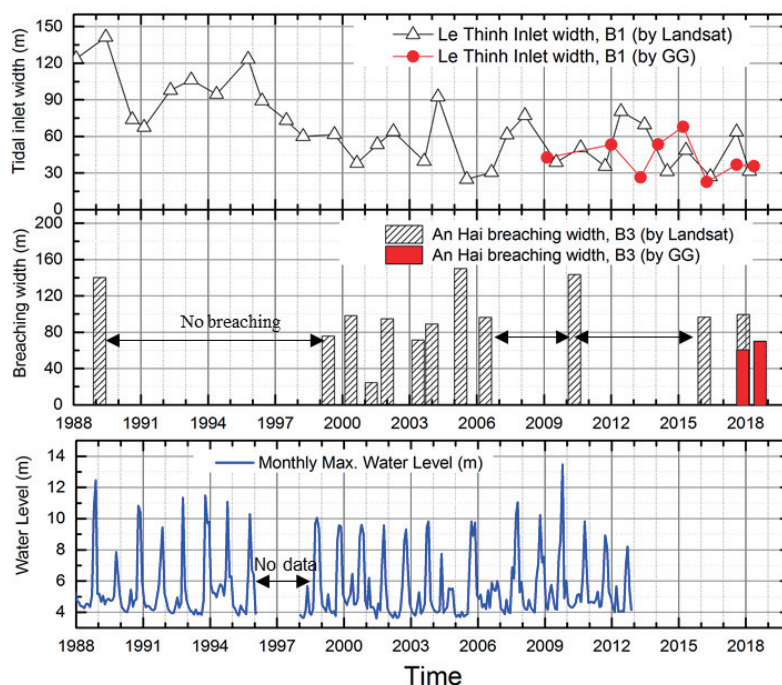


Figure 6. The relation between B1, B3 and the monthly max. water level at Ha Bang hydrological station.

To analyze in detail the cause of the breaching of sand spit, the authors correlated the variation of sand spit area and the tidal channel surface area based on the results analysis using the Google images with high resolution. Because the size of shrimp ponds along the two banks of the tidal channel is relatively small and the resolution of Landsat images is not good enough to do these analyzes.

There is a declining trend of tidal water area within 10 years from 2009 to 2018 due to construction of fishery embankments from 170×10^4 to $90 \times 10^4 m^2$. At the same time, the throat width of Le Thinh Inlet is very small, fluctuated from 20 m to 60 m. This indicates that in order to maintain the volume of water in O Loan lagoon, the depth of Le Thinh Inlet must be deeper.

During the period from 2000 to 2006, the breaching phenomenon of An Hai inlet appeared constantly although the monthly maximum water level during this period was not too high. During the fieldwork, through interviews with the local residents, it was found that in the southern sand spit where closes to the location of An Hai Port, the people have transported a lot of sand at the breaching position of sand spit during this period to fill up the banks of shrimp ponds. This activity decreased the height of sand spit in comparison with its original level. Therefore, although the flood water level during this period was not so high, the overflow through breaching positions for a long duration is completely explained.

As can be seen in Figure 8, the results of GG image analysis showed the reduction of the tidal channel water surface area from 2009 to 2018 along with a sudden decline in the area of sand spit in 2015, which can be observed by the breaching phenomenon of sand spit in this year.

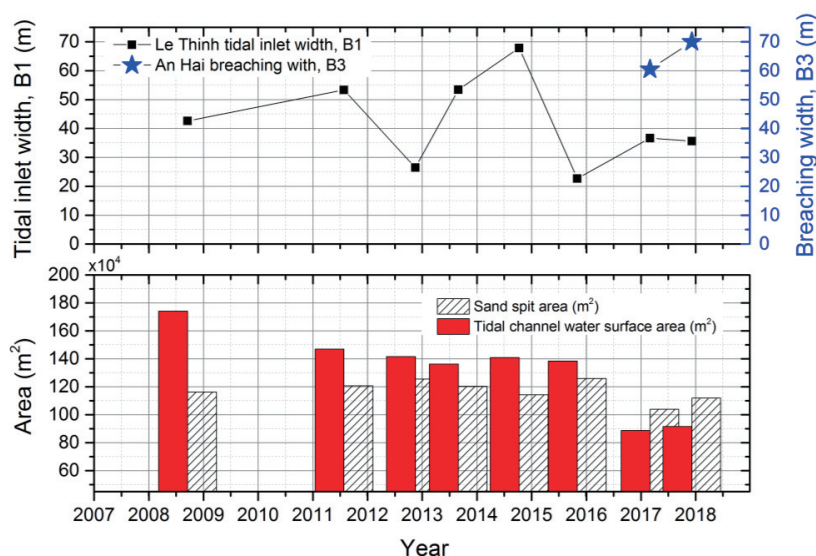


Figure 7. The relations of sand spit area, the tidal channel water surface area and the width of inlets

4. Conclusions

In short, sand spit morphological change of An Hai and Le Thinh inlets in Phu Yen province in the central of Vietnam has been figured out using satellite images in the last 30 years. Based on the analysis results, the breaching phenomenon of An Hai inlet and narrowing phenomenon of Le Thinh's inlet not only greatly depends on the flood flow regime but it is also being affected by the activities of the local people.

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