Shoreline change analysis using Sentinel-2A imagery data in Ben Tre, Vietnam

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ABSTRACT

In recent years, the process of erosion/accretion has become increasingly intense in coastal areas. With the advantage of low cost and large coverage, remote sensing and GIS have been widely applied in research and assessment of coastal erosion/ accretion in coastal estuaries. In this study, Sentinel-2A satellite images are used to extract the shoreline in Ben Tre province coast. Firstly, the obtained images are preprocessed and the SWIR band was enhanced in resolution. Subsequently, the boundary between land and water is determined by a two-step process: MNDWI ratio imaging and interactive thresholding. Finally, the DSAS statistics has also provided a detailed view of the change of shoreline at three periods (2016, 2018 and 2020). The study results show that from 2016 to 2021, The coast of Ben Tre province has the same phenomenon of erosion and accretion, but the trend of accretion is more dominant than erosion. The accretion phenomenon is concentrated in the area of Ba Lai estuary and coastal area of Thoi Thuan (Binh Dai). Erosion occurs strongly in the coastal areas of Bao Thuan, An Thuy (Ba Tri) and Thua Duc (Binh Dai).

1. INTRODUCTION

Nowadays, many sections of the coastline in Vietnam have been significantly changed due to the influence of climate change (Trí et al., 2018). In the coastal area of Ben Tre province, there are 20 places where strong erosion and accretion occurs with a total length of about 56 km (Thanh, 2020). Therefore, monitoring the coast morphology is practical, which contributes in limiting the damage to people and the economy.

The shoreline change is the basic geological change in the coastal area, which includes both the process of erosion and accretion (Sheik, 2011). Besides field survey data sources, multi-temporal remote sensing images are being widely applied in studying coastline morphology. Based on the spectral reflectance of land and water, the optical images provide a simple way to extract shorelines (Ouma et al., 2006; Sekovski et al., 2014)

There are many methods for coastline extraction, such as: edge detection algorithms (Paravolidakis et al., 2016), object-oriented multi-scale segmentation method (Ge et al., 2014), threshold segmentation method (Zoran et al., 2007), modified normalized water indexes (Du et al., 2016; McFeeters, 1996; Xu, 2006)… In this study, The modified normalized difference water index (MNDWI) and threshold segmentation method are used to extract coastline information from sentinel-2A image. In addition, The Digital Shoreline Analysis System (DSAS) used to analyze the position change of the shoreline from 2016 to 2020.

2. STUDY AREA

The studied coastal area is located in Ba tri and Binh Dai district of Ben Tre province, which its length is approximately 49 kilometers. Located in the Mekong Delta area of Vietnam, its geographical coordinate has the range of the longitude ($106^0$37'14"E – $106^0$45'26"E) and latitude ($9^0$58'08"N – $10^0$10'50"N). Figure 1 depicts the research area.

The research area has a Tropical monsoon climate, with two primary wind directions: the Northeast Monsoon (December to April) and the Southwest Monsoon (May to November). The average annual temperature is between 26°C and 27°C and the annual average rainfall ranges from 1,250 to 1,500 millimeters. The tidal range oscillates with the highest value of 3.5 m during the day (Hung, 2019). This coastal area is invested to develop marine economic sectors, especially aquaculture. In recent years, the phenomenon of accretionary erosion has affected people's lives and economic activities.

Figure 1. Map of the study area

3. DATA AND METHODS

3.1 Data

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The image data is obtained free of charge from the United States Geological Survey (USGS) with UTM/WGS84 projection. Sentinel-2A carries an innovative wide swath high-resolution multispectral imager (MSI) with 13 spectral bands, of which four 10 m visible and near-infrared (NIR) bands, 20 m short wave infrared (SWIR). Wind direction should be considered during data collection in order to minimize tidal influence on multi-temporal shoreline change analysis. For that reason, the Sentinel-2A images are collected between March and April, when the Northeast Monsoon is active. Information about the collected

image data is described in the Table 1.

Table 1. Characteristics of Sentinel-2A product used in this study.

Date	Acq. GMT (HHMM)
04 March 2016	10 :06
24 March 2018	10 :05
7 April 2021	10 :05

3.2. Methods

The implementation method includes the steps as shown in Figure 2.

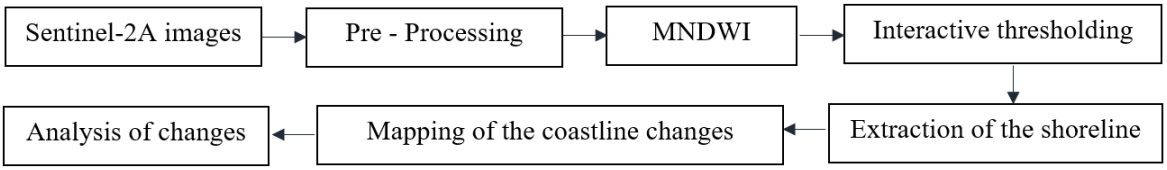

Figure 2. Processing workflow

3.2.1. *Pre–Processing*

All collected Sentinel-2A Level-1C satellite images are atmospherically corrected through the Sen2cor tool in SNAP, which is intended to remove haze and thin cirrus clouds. The result of this process is a Level-2A Bottom-Of-Atmosphere (BOA) reflectance product. The geographic coordinate system is the World Geodetic System 84 (WGS 84) and the selected projection is UTM zone 48 North. For a resolution compatible with Green and NIR bands, the pan-sharpening is applied using Resample to increase the resolution of the SWIR band from 20 m to 10 m.

3.2.2. *Extraction of the shoreline*

In this study, the shoreline information is extracted from Multi-Temporal Sentinel-2 Data using the spectral water index MNDWI. The MDNWI is calculated from the Green and Shortwave-Infrared (SWIR) bands to clarify the boundary between land and water. The MNDWI is expressed as follows (McFeeters, 1996):

$$MNDWI = (Green - SWIR)/(Green + SWIR)$$

An optimal histogram thresholding is chosen as 0.2575 in this case, which is used to create binary images from MNDWI images. The coastline is extracted as the boundary line between land and water. In order to evaluate the accuracy of the extracted coastlines, the shoreline results are overlayed on the Google Earth image with the corresponding time intervals. In this study, the tidal correction is ignored for the following reasons: the image acquisition time in years was similar (March and April), the largest tidal range during the day is 3.5m (Hung, 2019) and the resolution of Sentinel-2 image is 10m.

3.2.3. *Shoreline change assessment*

The DSAS tool is used to calculate the shoreline change in the study area over the period 2016-2018 and 2018-2021. The following steps are used to calculate DSAS parameters: determine the baseline and shoreline, build perpendicular lines, and calculate the

coastline rate. The net shoreline movement (NSM) and endpoint rate method (EPR) are used to analyze the erosion/accretion trend of the coastline.

4. RESULTS AND DISCUSSION

Period 2016-2018: The results of analysis of coastline changes show that the accretion trend clearly prevails in the study area (Figure 3). The average accretion rate in Ba Tri and Binh Dai districts is 12 m/year and 9 m/year, respectively. However, erosion still occurs in some locations in the study area. In Ba Tri district, erosion occurs in Bao Thuan and An Thuy areas with an average erosion rate of 1.5 m/year, of which the highest erosion rate is 39 m/year. This observation is consistent with statistics, which show that a high tide in February 2017 caused a 50m landslide in coastal Bao Thuan (Hien, 2017). In Binh Dai district, erosion occurs in the Dai estuary (Thua Duc) with an erosion rate of 4 m/year.

Figure 3. The shoreline extraction result for the period 2016-2018

Figure 4. The shoreline extraction result for the period 2018-2021

Period 2018-2021: The results of analysis of shoreline changes show that there are alternating between erosion and accretion trends in the study area, but in general, the accretion trend still prevails (Figure 4). In Ba Tri District, the coastline has a similar rate of erosion and accretion. DSAS analysis results show that the average accretion rate is 5 m/year and the average erosion rate is 4 m/year. The place where the most obvious erosion occurs is in the Ham Luong estuary (An Thuy) and Con Nhan (Bao Thuan) area with the maximum erosion length of 17 m/year. In Binh Dai district, the accretion trend prevails with an accretion rate of 7 m/year, which is concentrated in the Ba Lai estuary (Thoi Thuan) and a section of the Thua Duc coast. Besides, erosion continues to occur the Dai estuary (Thua

Duc) with an erosion rate of 5 m/year, which is an increase compared to the period 2016-2018.

5. CONCLUSION

The results of the analysis of shoreline changes over two periods show that the accretion trend prevailed in the change of coastline morphology in Ben Tre province. Besides, the research results show that the trend of erosion is increasing in both districts, in which the strongest erosion is in Bao Thuan, An Thuy (Ba Tri district) and Thua Duc (Binh Dai). These analysis results are consistent with the survey results of the Ben Tre Provincial Irrigation Sub-Department, which indicated that these areas are the severe coastal erosion sites of Ben Tre Province (Minh đãm, 2019). The analysis of factors affecting the trend of erosion and accretion in the coastal area of Ben Tre province will be carried out in further research.

The research results indicate that the method of extracting coastline information by MNDWI ratio imaging and interactive thresholding can be suitable for rapid assessment of shoreline changes in a large area. Sentinel-2A satellite images are useful data in supporting the monitoring of coastline changes that contribute to making reasonable plans for erosion and accretion in coastal areas.

6. REFERENCES

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