



ASSESSING THE SHORELINE CHANGES IN TRA VINH PROVINCE USING MULTI-TEMPORAL REMOTE SENSING DATA

Tran Ha Phuong^{1,*}, Hoang Phi Phung^{2,4}, Nguyen Thanh Hung³, Hoang Cong Tri³

¹*Ho Chi Minh City Institute of Resources Geography, VAST, 01 Mac Dinh Chi Street, District 1, Ho Chi Minh City*

²*HCMC Space Technology Application Center, Vietnam National Space Center, 268A Nam Ky Khoi Nghia St, Dist.3, Ho Chi Minh City*

³*Representative office VAST, 01 Mac Dinh Chi street, District 1, Ho Chi Minh City*

⁴*Graduate University of Science and Technology (GUST), VAST, 18 Hoang Quoc Viet, Cau Giay Dist., Ha Noi City*

*Email: thphuong@hcmig.vast.vn

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Abstract. The erosion – deposition of shoreline is not only a natural phenomenon, but also influenced by human activities. In recent decades, these changes occur more frequently with changes in the shape of shoreline, the changes in area of coastal mangroves as well as loss of productive land. In the trend of sea level rise, a study on changes of estuaries is necessary, in order to preserve and develop the mangroves, disposition, production planning infrastructure and civil works, etc. By using multi – temporal remote sensing from 1989 to 2015 and techniques appropriate digital image processing, the changes of erosion – deposition in shoreline are determined and contributed to clarify of erosion – deposition rules of the Mekong Delta. The results show that the shoreline of Tra Vinh province has changed over the years. This change is concentrated in some points such as: erosion occurs strongly in Hiep Thanh, Long Thanh and Dan Thanh communes with erosion rate can reach to 13 - 15 m per year. In addition, the deposition occurs mainly in communes such as My Long Nam commune, the first half of Truong Long Hoa and the area of Dong Hai and Long Vinh communes. The shoreline forecast for 2015 and 2017 is made for the entire shoreline of Tra Vinh province. The forecasted results show the trend of coastal deposition and erosion in the coming years, especially in the shoreline areas with strong changes as mentioned above. The phenomenon of erosion is predicted in the communes of Hiep Thanh, Long Hoa and Dan Thanh in the following years.

Keywords: the erosion – deposition of shore line, shoreline changes, remote sensing, climate change, sea level rise.

Classification numbers: 3.5.1; 3.5.2; 3.8.3

1. INTRODUCTION

In the context of global climate change, the Mekong Delta is one of the most affected areas, especially coastal areas including Tra Vinh province. At the present, Tra Vinh is one of the provinces having serious shoreline landslide of the Mekong Delta and the increasing complication of the erosion which concentrates on the shoreline areas of Duyen Hai district. In the past ten years, more than 30 hectares of the agricultural land and protection forests have been washed away to the sea and a dyke over 3 kilometers long has been destroyed, which threat the lives of dozens of households. Therefore, monitoring and forecasting the trend of the shoreline changes in Tra Vinh province in particular and the Mekong Delta in general is an urgent target.

There are a number of diverse methods of monitoring the process of shoreline landslides. These methods include conventional approaches such as field survey methods combined with measuring instruments, or shoreline surveying using a GPS receiver. Although the above traditional methods get high precision, there are also many problems when carrying out over a large area as well as forecasting the trend of the shoreline changes over time. Currently, the shoreline can be determined on a wide - scale from aerial imagery, satellite imagery with remote sensing approach. However, previous studies which used remote sensing techniques or forecasting calculations just show the degree of erosion or deposition with the average rate in a certain time period. With approaching the multi-temporal remote sensing data sources, it is possible to perform shoreline assessment and analysis directly, using GIS tools to calculate the trends and forecast shoreline changes in terms of location in the future.

A perfect definition of coastline in remote sensing is that it coincides with the physical interface of land and water [1]. Although this definition is apparently simple in fact a challenge to apply. In fact, the location of the coast change continuously over time, due to the movement of sand along the banks of mud and the coast and especially due to the nature of the sea level in coastal boundaries (e.g., tidal wave, groundwater, storm, flow, etc.). The location of the shoreline and change of position of the boundary over time and are important factors for coastal scientists, engineers, and managers [2]. Both shoreline management and engineering design require information about where the shoreline, its location in the past, and its location are predicted in the future.

To analyze change and coastal trends, there should be a definition of coastline. Due to the dynamics of this boundary, the definition chosen must consider the coast in both temporal and spatial sense and must take into account the dependence of this change on the time scale in which it is being studied [3, 4] For practical purposes, the specific definition chosen is often of lesser importance than the possibility of quantifying the selected coastline relative to the land-water boundary. One challenge is to develop a powerful enough and repeatable technique to allow for the detection of selected “*shoreline*” features in available data sources, and different identification techniques depending on the source of the data and definition of the selected coast.

Coastal shoreline change according to one or more factors, may be forms, climate or geology in nature. Location of the shoreline geometry depends on the interaction between the waves, tides, flow, hurricanes, tectonics and physical process, causing the two processes are mostly eroded (retreat to the mainland) and sedimentation (extension of the land through accretion) [5, 6]. The reviews about the changes in the position of the coastline have proved crucial in the overall understanding of the dynamics of the coastal regions and the morphological process dynamics promoting change. The coast was vulnerable due to changes caused by rising sea levels, climate change [7, 8]. The change whether short or long term about the location or the geometry of the coast is very important in the understanding of coastal dynamics and management of coastal areas [9]. Therefore, the quantitative analysis of changes in different time periods is critical in getting out and setting up the processes of erosion and accretion, identifying dangerous areas, and for coastal management and intervention [10, 11].

The position of the coastline and the position of this boundary change over time are important factors for engineers, scientists and coastal managers [3]. The relief agencies and management also depends on that information to facilitate the development of effective measures to prevent, mitigate or disaster management. All technical designs and management of sustainable coast require information about where the coastline, the location of it was in the past and its position is expected in the future. This information is required in the design to protect the coast, to adjust and balance the input data of the digital model [12].

Remote sensing data to help replace field surveys help save costs and give an overview. Some studies using satellite data proved its effectiveness in understanding the various coastal processes [13, 14]. Remote sensing technology has the ability to provide information on a large area on the basis of repeated, and therefore, it is very useful in the identification and monitoring of various coastal features. A series of model number [12] and methods have been proposed to detect the changing coastline and also to model the changes mathematically. In many cases, the parameters such as the wave disturbance, the impact of frequency, the variation in the propagation direction and the other wave change are also calculated and solutions are built. The second method is through statistical models as the authors [15, 16] using the tool DSAS analysis coastline and calculates the speed of erosion and multiples convergence. In addition, the group authors Lam Dao Nguyen et al. [17, 18] using regression weighted inverse time. In this study used regression model uses data Landsat images from 1989 - 2011 to the forecast for 2015 and 2017 and assess the accuracy of the predictions with the extracted from remote sensing images.

2. DATA AND STUDY METHODS

2.1. Study areas

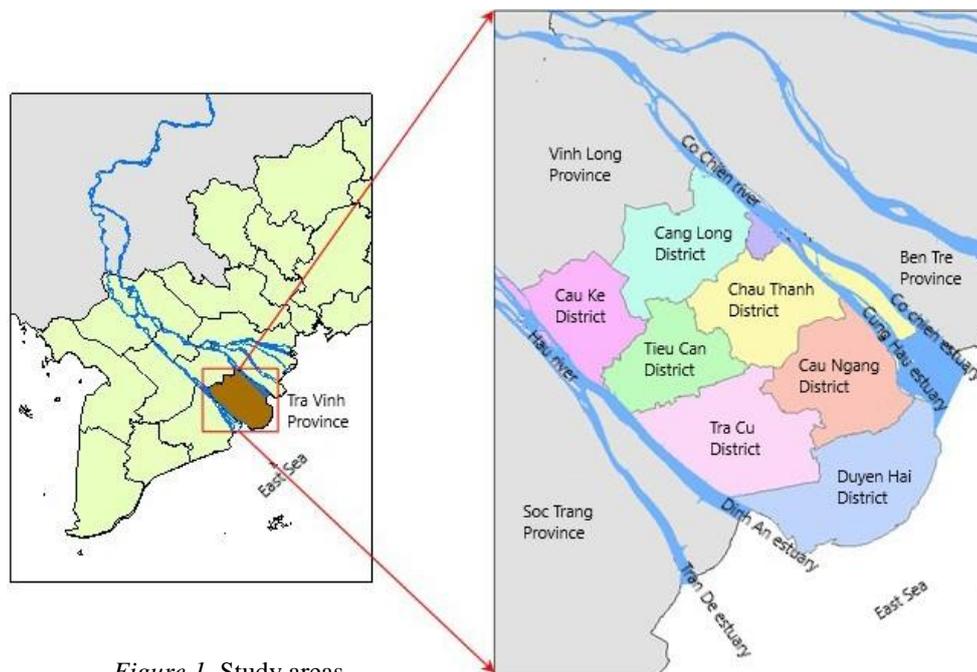


Figure 1. Study areas.

Study areas are limited with the shoreline areas of Tra Vinh province (including some communes such as My Long Nam, Hiep Thanh, Truong Long Hoa, Dan Thanh, Dong Hai, Long Vinh) (Figure 1).

2.2. Used data

Used data in the study determined, assessed and predicted the trend of shoreline changes in Tra Vinh province including multi-temporal remote sensing images and topographic maps. Satellite imagery data (Table 1) are adjusted according to the VN-2000 National Coordinate System.

Table 1. Data types and features of remote sensing images used in the study.

Satellite imagery	Path/row	Acquired on	Resolution (m)
LANDSAT5 TM	125/053	16/01/1989	30
LANDSAT4 TM	125/053	21/02/1996	30
LANDSAT5 TM	125/053	27/02/2004	30
LANDSAT5 TM	125/053	03/02/2007	30
LANDSAT7 ETM ⁺	125/053	05/06/2008	30
LANDSAT5 TM	125/053	09/12/2009	30
LANDSAT7 ETM ⁺	125/053	19/02/2010	30
LANDSAT7 ETM ⁺	125/053	10/03/2011	30
LANDSAT 8 OLI	125/053	09/02/2015	30
LANDSAT 8 OLI	125/053	14/02/2017	30

2.3. Methods

The conducted stages as in the map of Figure 2.

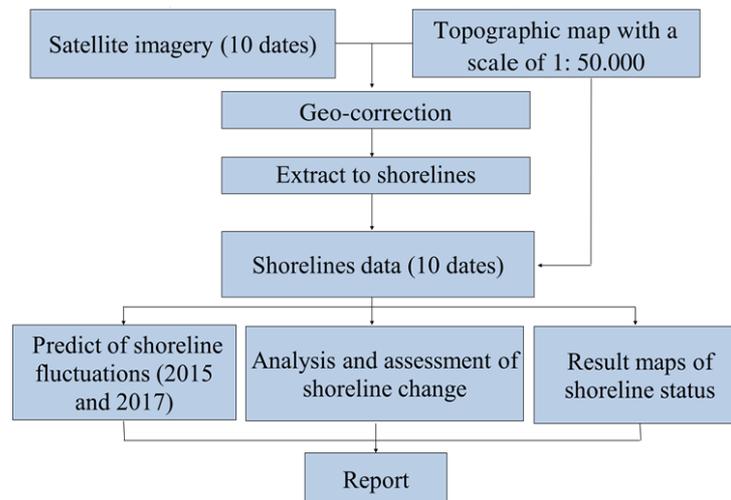


Figure 2. Diagram of steps taken.

2.3.1. The construction of GIS database

GIS database consists of basic and shorelines database in shapefile style (*.shp) of the software ArcView – ESRI (Environmental Systems Research Institute – the U.S.A). Data background and data dictionary are composed to use for constructing GIS data. Database is built basing on topographic maps which includes data types of traffic and hydrology systems. Shorelines data is extracted from remote sensing imagery.

2.3.2. The correction of geometric imagery

In order to determine the changes of shorelines over time, the data is moved to the same coordinate system. There are 26 controlled points which evenly distributed in the selected image for shaping geometry. Correction errors for all pixels images are within the allowable limit (less than 1 pixel). Then, the shoreline data will be moved to the VN-2000 coordinate system, the 105 degree central meridian using the ArcInfo Workstation tool in ArcGIS software, combined with the Geotool 1.5 software from the Ministry of Natural Resources and Environment.

2.3.3. Shortline dertermination method

So as to detach the shoreline information for optical image, the near infrared spectrum channel (Infrared) shows the most obvious differences in land-water-vegetation. In addition, to distinguish water surface objects and sludge banks, shortwave infrared spectrum channels and green channels are also used for shoreline extraction [19, 20]. The topic uses the semi-automatic extraction method to extract the shoreline and uses the threshold method for NDVI image to determine the coastline covered by salt-marsh forests where the shoreline is defined as plant boundary), and the areas of non-salt-marsh forests use the threshold ratio value for the green channel and the shortwave infrared channel.

2.3.4. Regression analysis method to predict shoreline flutuations

Regression analysis is to find out the specific expression for the correlation between two random variables X and Y. That mathematical expression is called the regression function. This topic uses weighted linear regression to predict since the time-varying shoreline changes are almost linearly related. Simultaneously, we are concerned about recent shoreline changes, so we use the w_i weight which being in inverse ratio to the square of the time duration given by [21] [17]. Therefore, the predicted shoreline will reflect the rate of shoreline changes in recent years better

$$w_i = \frac{S_w}{(t_{pred} - t_i)^2} \quad (1)$$

in which: S_w given by:

$$S_w = \sum_{i=1}^n (t_{pred} - t_i)^2 \quad (2)$$

t_{pred} : the point of time for predicting; t_i : The point of time corresponding to the extracted shoreline data.

Weighted linear regression

Supposing that there are two random variables X, Y and two corresponding random denominators $W_x = (x_1, \dots, x_n)$, $W_y = (y_1, \dots, y_n)$. The linear regression function of Y for X is given by the following expression:

$$y = f(x) = ax + b \quad (3)$$

where: a, b are constants.

We have (x_i, y_i) , $(i = 1, 2, \dots, n)$ are n experimental points. According to the principle of the least squares method, we have to minimize the square of the vertical distance between the experimental points (x_i, y_i) with the corresponding points $(x_i, ax_i + b)$ on the line:

$$E(a, b) = \sum_{i=1}^n w_i (ax_i + b - y_i)^2 \longrightarrow \min \quad (4)$$

The quantity E (a, b) is a function (with consequent derivatives) of a and b (x_i, y_i are constants), so it gets an extreme point when:

$$\frac{\partial E(a, b)}{\partial a} = 0 \quad (5)$$

and

$$\frac{\partial E(a, b)}{\partial b} = 0 \quad (6)$$

Because of $\frac{\partial^2 E(a, b)}{\partial a^2} > 0$ and $\frac{\partial^2 E(a, b)}{\partial b^2} > 0$, the conditions (5) and (6) are sufficient to minimize E(a,b)

$$\frac{\partial E(a, b)}{\partial a} = \sum_{i=1}^n 2w_i (ax_i + b - y_i)(x_i) = 2 \sum_{i=1}^n ax_i^2 w_i + bx_i w_i - x_i y_i w_i \quad (7)$$

and:

$$\frac{\partial E(a, b)}{\partial b} = \sum_{i=1}^n 2(ax_i + b - y_i)w_i = 2 \sum_{i=1}^n (ax_i w_i + bw_i - y_i w_i) \quad (8)$$

Replace (7) và (8) on (5) và (6); and rearrange the coefficients that lead to the following system of equations:

$$\begin{cases} \left(\sum_{i=1}^n x_i^2 w_i \right) a + \left(\sum_{i=1}^n x_i w_i \right) b = \sum_{i=1}^n x_i y_i w_i \\ \left(\sum_{i=1}^n x_i w_i \right) a + \left(\sum_{i=1}^n w_i \right) b = \sum_{i=1}^n y_i w_i \end{cases} \quad (9)$$

Answer the system of equations (9) we find the coefficients a and b of weighted linear regression equation (3). This method has been tested through [17, 18]. The process of data processing on forecasting shoreline fluctuations Figure 3.

- Remote sensing imagery data after extracting from the shoreline saved in the shapefile format (*.shp), using ArcGIS to transfer into Personal Geodatabase data with the baseline and shoreline
- Use Digital Shoreline Analysis System (DSAS) of the AcrGIS software [1] to initialize baselines (lines perpendicular to the baselines separated by a certain distance on the baselines). From the baseline, we can output data for the location of the cross sections and the intersection of the cross-sections with the shorelines as *.dbf file.
- Convert *.dbf file to *.txt file.

- Use Matlab to calculate linear regression , locate the predicted shoreline and output the predicted shoreline shapefile and standard error areas.
- Show the results of the predicted shoreline in AcrGIS software.

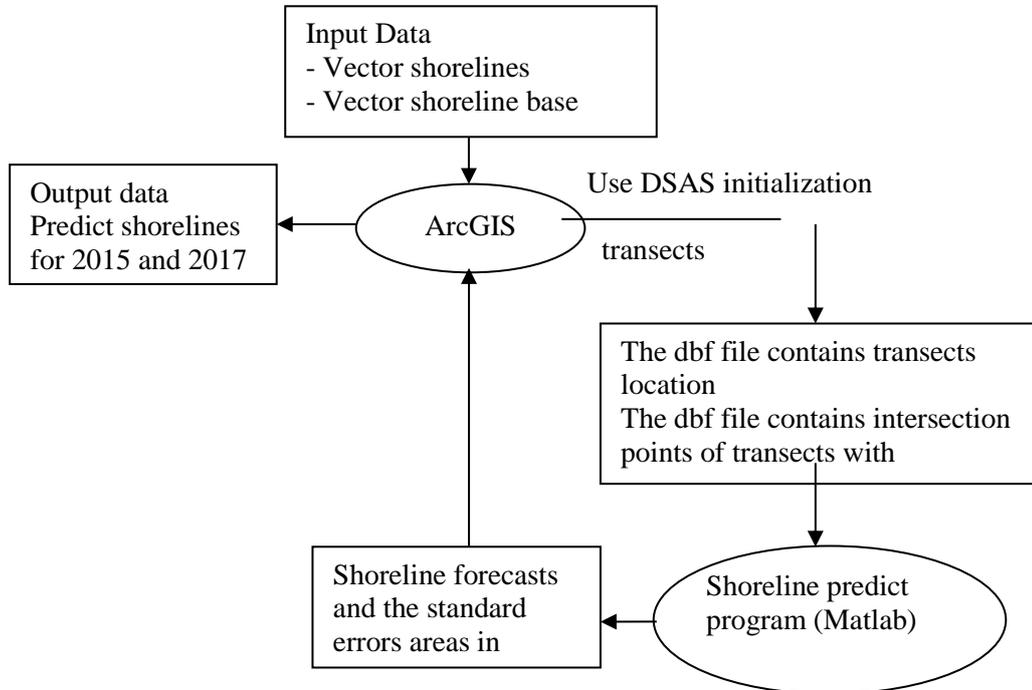


Figure 3. Diagram of data processing to use for shoreline forecasts.

3. RESULTS

3.1. Result of the shoreline process from 1989 to 2011

Coastal erosion and accretion are very complex natural phenomena happening in space, time and also an interactive consequences of many factors (nature and human). Tra Vinh is a regular salt-water area with a number of rivers and canals leading into the sea, creating a great advantage in aquaculture and developing saline forests. However, landslide phenomenon has been occurring at a higher rate in recent years, which created significant impacts to coastal people by breaking up the dykes and sweeping away a large area of salt-marsh forests and aquaculture.

Research areas are divided into 6 shoreline areas which need to be concerned from 1989 to 2011 (Figure 4). Among of these, the typical coastal areas of erosion and accretion are the area number 2 (Hiep Thanh commune, Duyen Hai district) and the area number 5 (Dong Hai commune, Duyen Hai district).

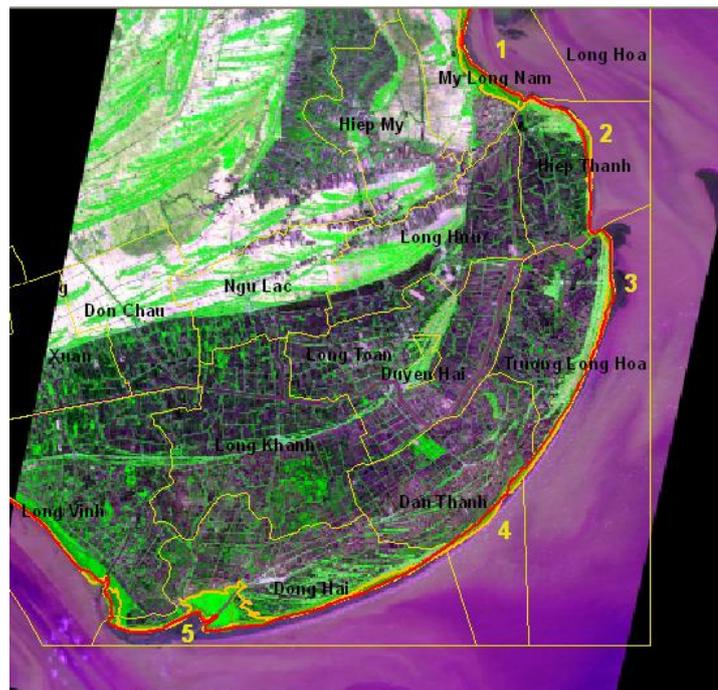


Figure 4. Accretion and erosion areas on the coast of Tra Vinh province.

3.2. Results of shoreline forecast for the year of 2015 and 2017

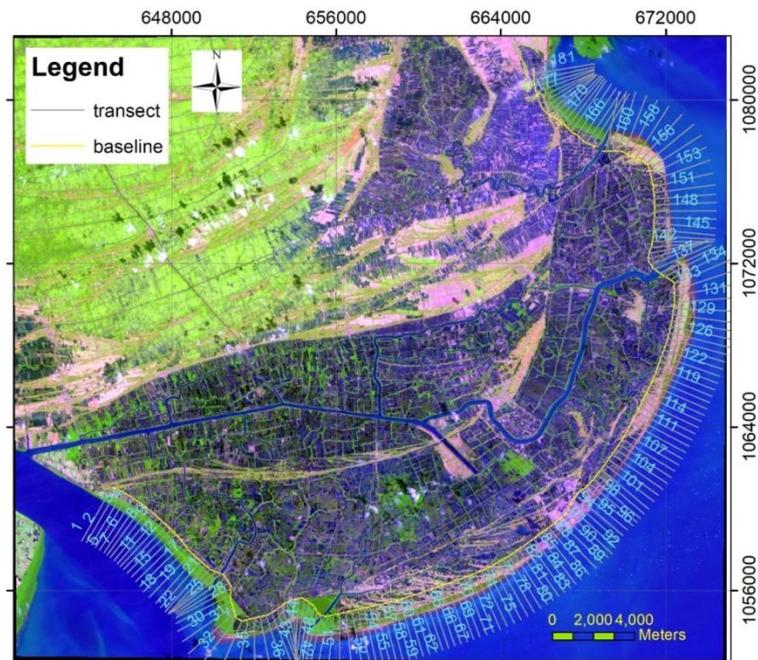


Figure 5. Transects are created from the baseline of Tra Vinh province. (Landsat imagery in 2015).

Table 2. Weights of years used for forecasting shoreline of Tra Vinh province.

Points of time	Weights in 2015	Weights in 2017
16/01/1989	0.005	0.015
21/02/1996	0.009	0.025
27/02/2004	0.029	0.058
03/02/2007	0.052	0.088
05/06/2008	0.073	0.108
09/12/2009	0.124	0.143
19/02/2010	0.134	0.149
10/03/2011	0.218	0.187

In order to use for predicting the shoreline in the future of Tra Vinh province, the baseline is created. The baseline is the boundary of shoreline buffer zone in 2011, using the method of weighted linear regression to predict the shoreline in the future (2015 and 2020). The entire coastline of Tra Vinh province has 181 cross sections derived from the baseline by using the DSAS extension tool of ArcGIS software (Figure 5).

Basing on the shoreline data in 1989, 1996, 2004, 2007, 2008, 2009, 2010, 2011, the shoreline in the future is predicted by the eighted linear regression method given by a formula (1) (Table 2)

Forecast results:

- > 0: accretion
- < 0: erosion

Correlated coefficients of the regression equation are also taken into account. Cross sections with a correlated coefficient of less than 0.5 indicate that the shoreline change but do not comply with the linear rule. It often occurs on less-changing shorelines or the shorelines which suddenly and locally change.

Since the shoreline of Tra Vinh province is relatively stable over the years, it is only focused on analyzing, showing the predicted shoreline in areas where fluctuations (erosion, accretion) occur much and we mentioned it in the section 3.1.

3.3. Accessing the result of shoreline forecasts in 2015 and 2017

In order to serve for assessing the results of coastal forecasts in 2015 and 2017 in the entire coastal area of Tra Vinh, 181 cross sections derived from the shoreline were used. The entire coastal area of Tra Vinh province has 181 cross sections derived from the shoreline. The 2015 shoreline will be compared to shoreline extracted from the Landsat 8 OLI image. 09/02/2015, the 2017 shoreline is compared with the shoreline extracted from the image of Landsat 8 OLI 14/02/2017.

After running the shoreline model with shoreline data from the 1989- 2011 data for the years 2015 and 2017, the degree of erosion and accretion of the forecast shoreline for the years 2015 and 2017 was shown in Figure 6 and compared to the last shoreline in 2011. Forecasted

results show that erosion (negative) and accretion (positive) areas in the coastal area of Tra Vinh province, and the level of erosion and accretion forecast in 2017 is higher than 2015. In addition, the model calculates the coefficient of correlation (α) of the regression model shown in Figure 8. In this coefficient the meanings are as follows: (a) $\alpha > 0.8$: the extent of shoreline change in this section will follow the linear model in recent times, (b) $0.5 < \alpha < 0.8$ the extent of shoreline change in these cuttings will change near the tissue. linear t (c) $\alpha < 0.5$: Shoreline change in this cross section is almost nonlinear, the coastline of this area is not much altered or the coastline is complex (erosion and accretion are complex, when looking at satellite data, there are years of erosion, there are years of accretion are alternating). Results for the 2015 and 2017 shoreline comparisons with shoreline from Landsat 8 OLI 09/02/2015 and 14/02/2017 (Figure 7). Figure 7 shows the differences between the predicted shoreline and the actual shoreline in most sections are less than 2 pixels (60 m) of the Landsat image. However, the results also show that there is a high degree of deviation in the region near the estuary (cuttings 31-37, 42-44, 134 - 142) complex shoreline developments. Also, the deviation of 2017 higher than 2015 indicates that the further the forecast results, the lower the accuracy. Briefly, the shoreline results provide good results with an accuracy of fewer than 2 pixels, but the model results in lower accuracy for the region near the estuary.

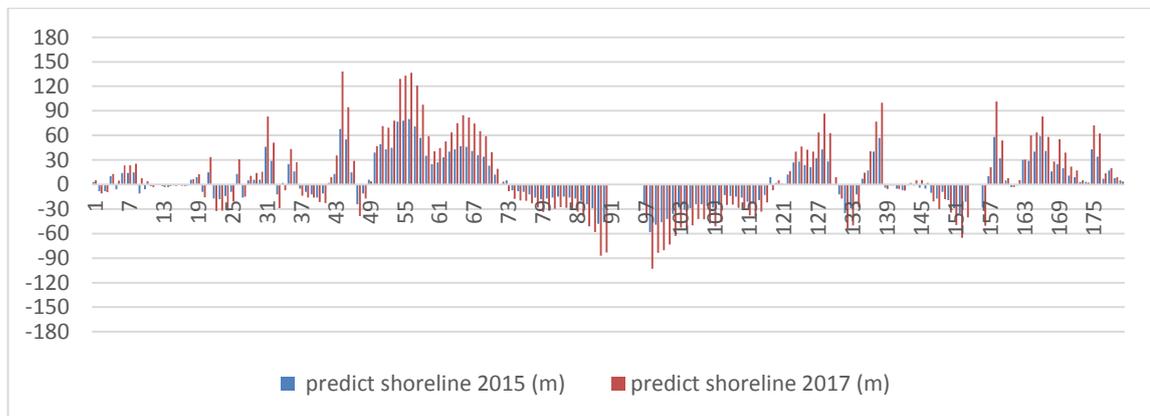


Figure 6. Estimation of erosion and accretion of the 2015 and 2017 shoreline versus the last shoreline of 2011.

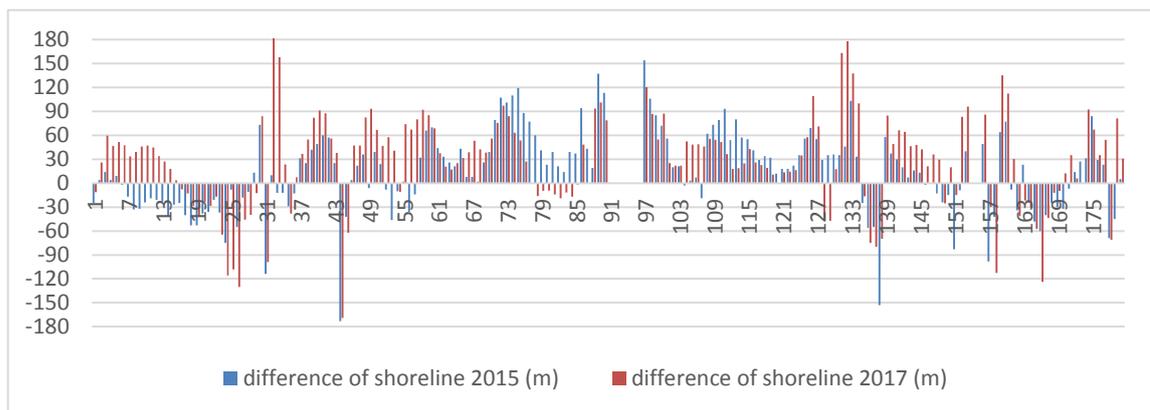


Figure 7. The difference between the projected shoreline two 2015 and 2017 compared to the actual shoreline of 09/02/2015 and 02/14/2017 respectively day.

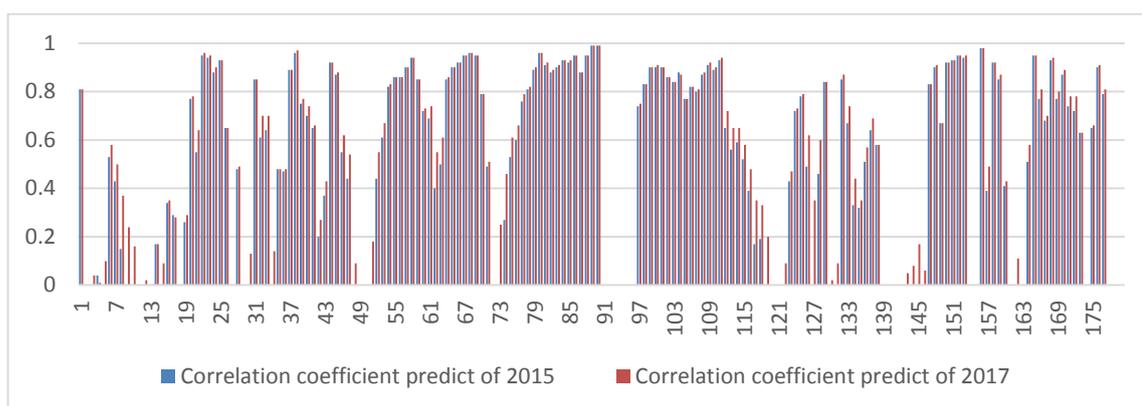


Figure 8. Description of the regression coefficients of 181 horizontal surfaces of the two forecast cases in 2015 and 2017.

4. CONCLUSION

The present study used remote sensing technology to examine and analyze the shift in shoreline in Tra Vinh province through various particular points in time between 1989 and 2011. The research also applied linear regression approach to predict trends of shoreline changes in 2015 and 2017.

The results of the study showed that Tra Vinh coastlines have fluctuated over years in the research period from 1989 to 2011. This movement involved the following features. The coastal erosion occurred severely at some communes like Hiep Thanh, Truong Long Hoa and Dan Thanh at the rate of erosion from 13 to 15 meters per year, while the shoreline deposition was mainly experienced at such communes as My Long Nam, part of Truong Long Hoa, Dong Hai and Long Vinh. The prediction of Tra Vinh shoreline features for the year of 2015 and 2017 was also made in this study. The result indicated that there occurred both the erosion and the deposition of the coastline in the next years, especially in the areas whose shoreline might experience high variability mentioned above. The erosion was predicted to happen at Hiep Thanh, Truong Long Hoa and Dan Thanh Commune.

The result of the shoreline assessment for the year of 2015 was figured out by comparing that of the shoreline extracted from OLI 09/02/2015 with the standard derivation of 53 meters. This indicated the accuracy in the shoreline evaluation for the year of 2015 in the data obtained from 1989 to 2011 with the standard derivation of less than 2 pixels. The prediction also achieved the similar result for the shoreline in 2017 with the standard derivation of approximately 67.0 meters. In order for the result to obtain a higher degree of accuracy, it is necessary to have photogrammetrical data with higher resolution.

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