MONITORING SHORELINE CHANGES OF THE TIEN AND HAU RIVERS USING MULTI-TEMPORAL LANDSAT DATA

Nguyen Huu Long[1], Nguyen Van Cam[2], Nguyen Van Trung[3], Le Thi Thu Ha[3]

[1]Dong Thap University, 783, Pham Huu Lau street, Ward 6, Cao Lanh City, Dong Thap, Viet Nam
Email: nhlong@dthu.edu.vn
[2]NN Construction Consulting Company, 458, National Road 30, Cao Lanh City, Dong Thap, Viet Nam
Email: camcantho@gmail.com
[3]University of Mining and Geology, 18 Vien street, Duc Thang Ward, Bac Tu Liem Ward, Hanoi City, Vietnam
Email: nguyenvantrung@humg.edu.vn

ABSTRACT

The shorelines are influenced by geological activities such as uplift, lower, faults, erosion, deposition and sand bar movement. Other causes are by the sea level rise, increased rainfall, sedimentary from river basin, and human activities for building dam, raising aquaculture and cutting Melaleuca forests. Monitoring of shoreline changes, thus, are necessary in climate change context in the Tien and Hau rivers located at An Giang and Dong Thap provinces. Multi-temporal Landsat TM, ETM+ and OLI data acquired on 1992, 2003, and 2015 are used for this purpose. Band rationing methods were applied to the threshold technique for the shoreline extraction. The changes of shoreline are estimated from special profiles established perpendicular to shoreline. Positive values represented deposition to the water surface and negative values erosion. The results of monitoring will be able to indicate the shoreline changes from 1992 to 2015 in the Tien and Hau rivers deltas.

1. INTRODUCTION

Tien and Hau river deltas located at An Giang and Dong Thap provinces are the lower Mekong river delta being one of the largest wetland ecosystems in Southeast Asia. They flow to sea with nine estuaries (Figure 1). The shoreline changes due to erosion, deposition depend on dynamic river generated by river's flow (Sreenivasulu, 2016). Tien and Hau rivers are one of the largest rivers in the southern of Vietnam. It rises from upper Mekong river and Tonle Sap lake to forms a great delta before entering into the East sea of Vietnam at the nine estuaries. Tien and Hau river deltas located from $10^{0}05'$ to $10^{0}55'$ north latitude and from $105^{0}15'$ to $105^{0}55'$ east longitude is flat and wide area. These deltas are about 2400 km^2, and belong to An Giang and Dong Thap provinces.

The coastal zone is influenced by various factors including modern tectonic (uplift, lower structure; fault), sea level rise, rainfall change, sediment increase from rivers, and man-made (digging ditches, building dams, reclamation for agriculture and pisciculture, mangrove planting) (Mills, 2005). The shoreline is defined as the boundary between land and a water surface (Elizabeth, 2005). Monitoring coastal morphological change, shoreline change and land use change is particularly concerned because they are affected by hydrology regime, geology, climate and vegetation factors (Annibale, 2006).

Traditional shoreline maps for small areas are constructed by using conventional field surveying methods (Dinh, 2010). Drawback of this method is that its application only is used for small area, high cost, and depending on the weather condition. Therefore, the popular approach used in the several recent decades to delineate the shoreline is analytical stereo photogrammetry using tide-coordinated controlled by kinematic GPS techniques (NOAA 1997) for aerial photography. This approach is difficult to apply for various periods in large area. In recent years, thus, remote sensing technique plays an important role for monitoring and mapping coastal areas (Kasetsart, 2005; Avinash, 2010). The shorelines extracted from satellite images depend on water lines and several other conditions (Lan, 2013).

Variations of shorelines position can be observed in long-term, cyclical, random time due to specific events (Annibale, 2006). Determination of shoreline change due to sea level rise is mentioned by several authors (Chen, 1998; Anniba, 2006; Ryu, 2008). Principle of this method is based on the distinction between spectral reflectance of soil surface and that of water surface in the delta. Red, NIR bands are additionally used for distinguishing vegetation from water surface in the deltas covered by vegetation. Therefore, application of single band, false color combination allows visual interpretation of shorelines or uses image transformation based on the calculations between spectral bands. This aims to obtain high efficiency for determining the coastlines (Ryu, 2002; Alesheikh, 2007; Liu, 2004; Lee, 1990).

The study is to select the extraction technique for the shorelines using satellite data. We use a method modified from (Alesheikh, 2007) for gathering the shorelines. Monitoring the shoreline change is performed by comparing the shorelines extracted from satellite images. Thus, multi-temporal satellite images must be chosen the same sensor and satellite types, season, flow regime in order to avoid the errors affecting the precision of shoreline. Three Landsat data with TM, ETM+ and OLI sensors acquired at the same the season and the tidal level are selected in this study.

2. STUDY AREA AND DATA PREPARATION

2.1 Study Area

The Tien and Hau river deltas cover the area of Thanh Binh, Cho Moi, Cao Lanh, Lấp Vò, và Sa Đéc with a plain delta, banks and river-bed. The study area has one link river between the Tien and Hau river (Figure 1) in which shorelines are rapidly changes due to various natural and man-made effects.

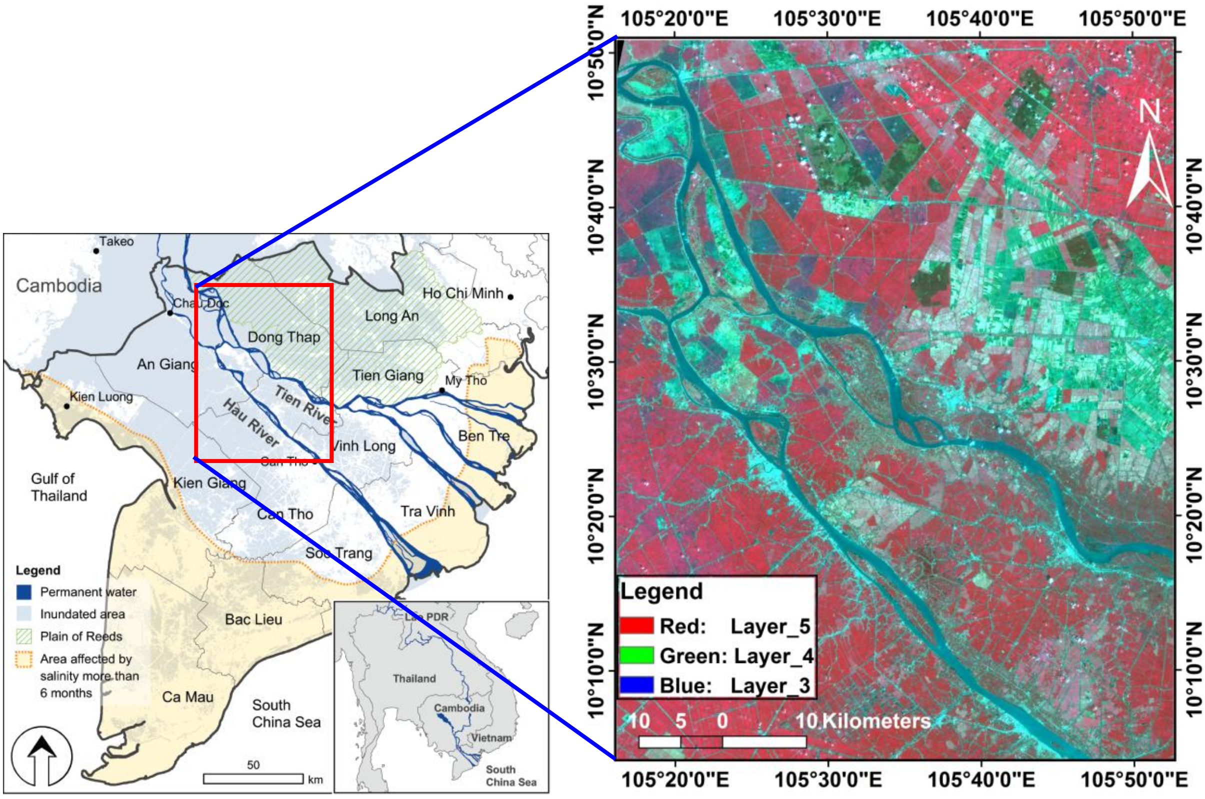


Figure 1. Tien and Hau river deltas. (Source: Mira, 2008) and Landsat-8 OLI data acquired on Jan. 24, 2015 (RGB=543).

2.2 Data Preparation

Maps and satellite images are necessary for this research. To prepare those data, we was supported topographic map at scale 1/50000 built in 2002 from Center of Surveying and Map Data (COSAMD). Statistical data of direction and speed of river flow along the shoreline was provided by Institute of Marine Geology and Geophysis (IMGG).

Satellite images used for extracting coastline includes: Landsat TM, ETM+ and OLI images. The following Table 1 shows the details of satellite images data and acquisition times.

Table 1. Landsat data and acquisition times.

Sensor	Parth/Row	Date (dd/mm/yyyy)	Local time	Spatial resolution (m)
TM	125/053	25/01/1992	9h38'	30
ETM+	125/053	15/01/2003	10h02'	30
OLI	125/053	24/01/2015	10h14'	30

3. METHODOLOGY

In order to complete the tasks, a series of remote sensing and GIS-based methods were implemented, such as image preprocessing, image analysis, change analysis on vector data in GIS,. An overall flowchart of the experimental method is shown in Figure 2.

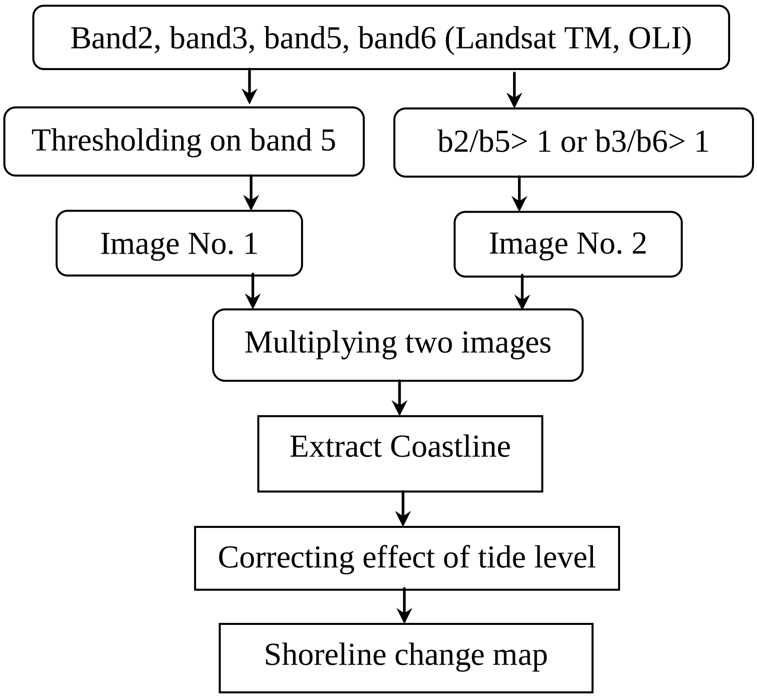


Figure 2. Experimental flow chart (modified from Alesheikh, 2007).

3.1 Images Pre-processing

All Landsat data were atmosphere corrected to obtain the surface reflectance (level 2 products). Then, these Landsat data were geo-coded to the UTM projection with 30m resolution, and are subset by using the boundary of the study area. This subset images then enhance the quality in order to highlight the shoreline by edge filtering technique shown in Figure 3.

3.2 Shoreline Detection

Since the shoreline is the line of contact between river and land (Elizabeth, 2005), as the river level varies, this boundary varies and therefore it is difficult to exactly identify its position (Annibale, 2006). Extraction shoreline using satellite image depends on waterline and several other conditions. Variations in shoreline position can be: long-term, cyclical, random, due to specific events (Annibale, 2006).

There are several methods for deriving shoreline position from remote sensing data. The shorelines can be interpreted and digitized by eye. In addition, the images can be classified into land and river area by identifying a threshold value for a single spectral band. Besides, an edge detecting filter or segmentation algorithm can be applied to determine the shorelines from the images (Kevin, 1999). Since the reflectance of water is nearly equal to zero in reflective infrared bands, and reflectance of absolute majority of land covers is greater than water (A.A. Alesheikh 2007). Therefore, shorelines are extracted from a single band image. For instance, band 5 of Landsat TM or ETM+ sensors can separate land and water features, but in the transition zone between land and water is influenced by mixed pixels and moisture regimes between land and water. If the reflectance values are sliced to two discrete zones, they can be depicted water (low values) and land (higher values) (Alesheikh, 2007). However, this method is difficult to find the exact value, as any threshold value will be exact on some area, not all.

This study used the band rationing method that is rationing between band 2 and band 5 for Landsat-5 TM or Landsat-7 ETM+, between band 3 and band 6 for Landsat-8 OLI. In this method, water and land area can be separated clearly. Generally, the ratio band2/band5 is greater than one for water and less than one for land in large areas of coastal zone (Pritam, 2010). Ratio images was calculated histogram and defined threshold by changing the value step by step with leap 0.01 until distinguishing the most clearly between water and land. Rationing image was sliced and converted to shape file by ENVI 5.2 software. Then, shape file was edited, removed small objects and generate map for shoreline positions are processed using ArcGIS 10.2 software shown in Figure 4.

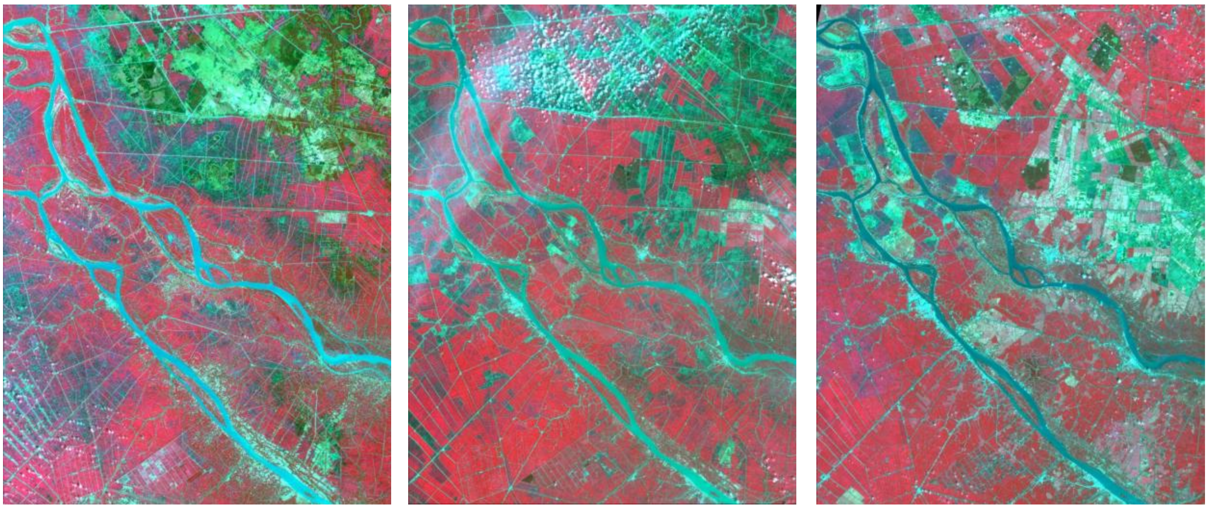
4. RESULTS AND DISCUSSIONS

From the shorelines in 1992, 2003, and 2015 extracted from Landsat data, we can clearly define that shorelines of study area varies very complicated with different shape, magnitude and trend. So it was divided six zones with the different characteristic as A, B, C, D, E and F (Figure 5). Zone A and B were located at the lower of Tien river, they were erosion area. Zone C located in the upper of the Tien river is the top of isle between two branch of river and shorelines are strongly influenced by river flow. This area includes deposition, erosion and sandbar movement. Zone D was located in the isle of the Hau river, in zone D the erosion occurs very fast. Zone E is the junction between the Tien and Hau rivers in which the flow change direction and speed. Zone F is where the Tien river is split into two branches. To determine the shoreline changes for six zone A, B, C, D, E and F, six cross-sections location (AA, BB, CC, DD, EE and FF) shown in Figure 5b are selected along to Tien and Hau rivers in which the deposition and erosion happen powerful.

The shorelines extracted from three acquires times of Landsat data are superimposed by using GIS tool in ArcGIS software in order to generate the shoreline change map as shown in Figure 5a. It can be seen that the shorelines of Tien and Hau rivers are almost no change. However, the shorelines located in the change flow of rivers vary over time. Particular, the shorelines of Tien river changes a lot due to curved flow. This is reason for chosing the cross-sections along-shore in the Tien river. Since the shorelines of small islands between two branches of river are complex due to sandbar movement, a cross-section is arranged to monitoring those changes.

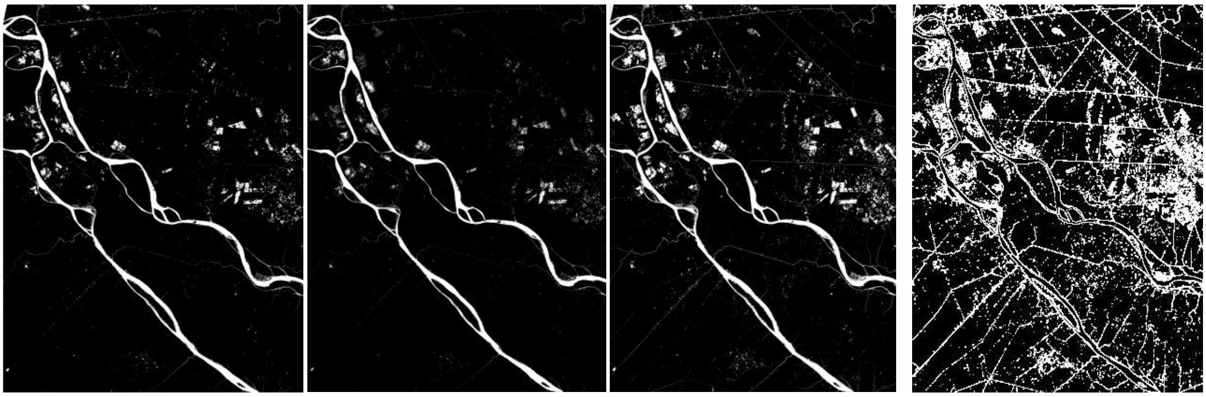
In order to calculate the shoreline changes, six cross-sections are measured and plotted in the Tien and Hau rivers for analyzing the shoreline change during 23 years (Figure 6). Six profiles are represented as six colors including red, green, blue, black, violet, and brown. The shoreline change in 1992 is considered as zero value (no change). This means that shoreline in 1992 are set as base coastline. Another shoreline is compared with shoreline in 1992 to measure the difference between both coastlines. If the value change is positive, this means that the shoreline occurs the erosion. Whereas the value change is negative, this corresponds with the deposition process.

According to the results shown in the Figure 6, a increase of shoreline change in cross-section BB is about 165 m and 265 m from 1992 to 2003 and from 2003 to 2015, respectively. The maximum change value is approximately 430 m compared with the base shoreline in 1992. However, the shoreline change in cross-section EE decreases about 223 m in 2003, and decreases about 380 m in 2015 compared with the base shoreline in 1992. The largest change value is approximately 562 m between 2003 and 2015 due to the flow change at the turning corner of Tien river. In the cross-section FF, the shoreline change values are decreases gradually about 147 m and 147 m over the time of 2003 and 2015, respectively. It is a increase of 220 m in 2003, and increase of 362 m in 2015 for profile DD located located in the isle of the Hau river due to erosion of sandbar.



(a) **(b)** **(c)**

Figure 3. Three Landsat data of Tien and Hau river deltas acquired on: (a) Jan. 25, 1992; (b) Jan. 15, 2003 và (c) Jan. 24, 2015.



a)Threshold of band5 b)band 3/band 6>1 c)binary image d)vector of shorelines

Figure 4. Extract shorelines from Landsat-8 OLI in study area acquired on 24 Jan. 2015.

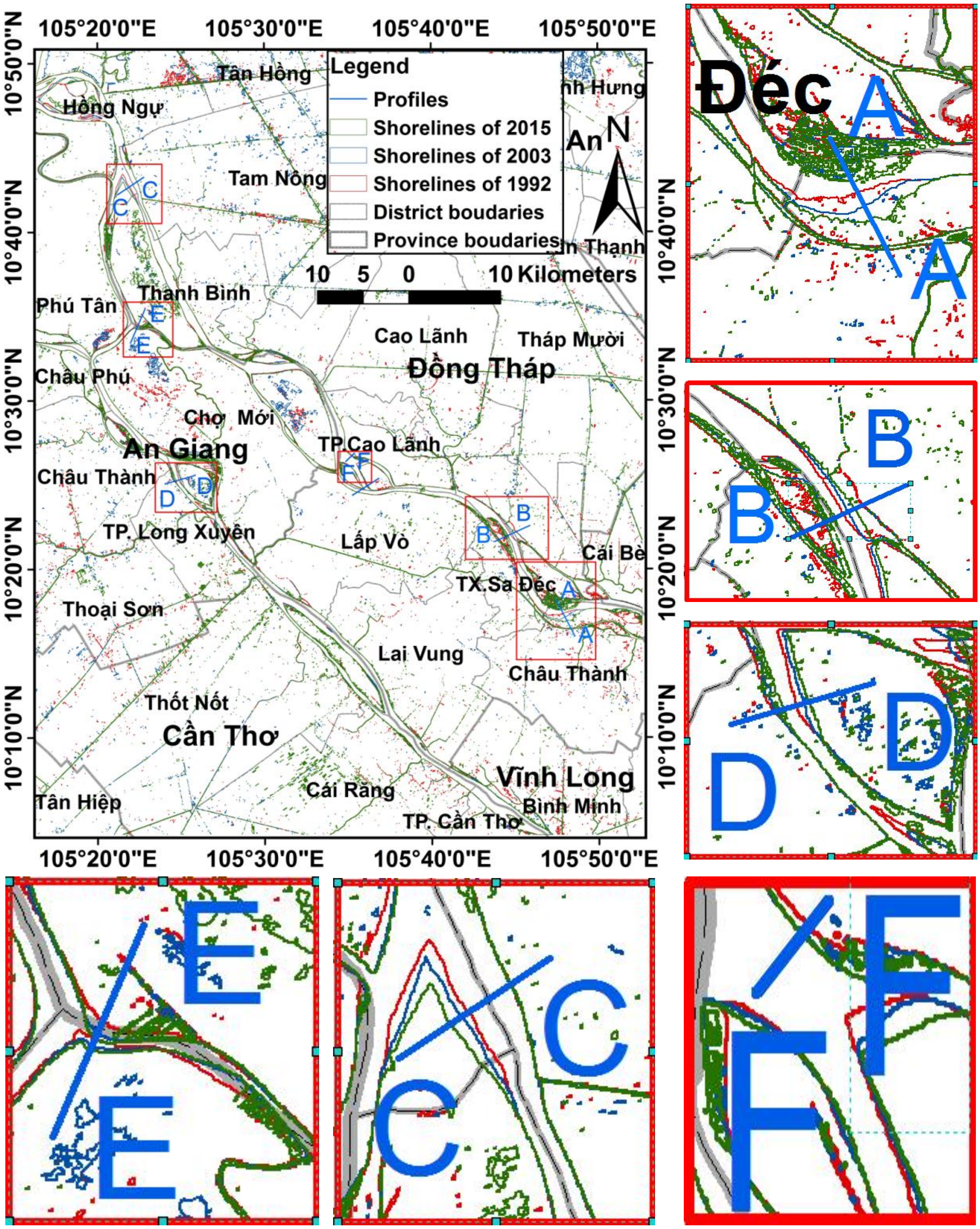


Figure 5. (a) Shorelines change map and (b) Zoom of six cross-section profiles located at Tien and Hau rivers.

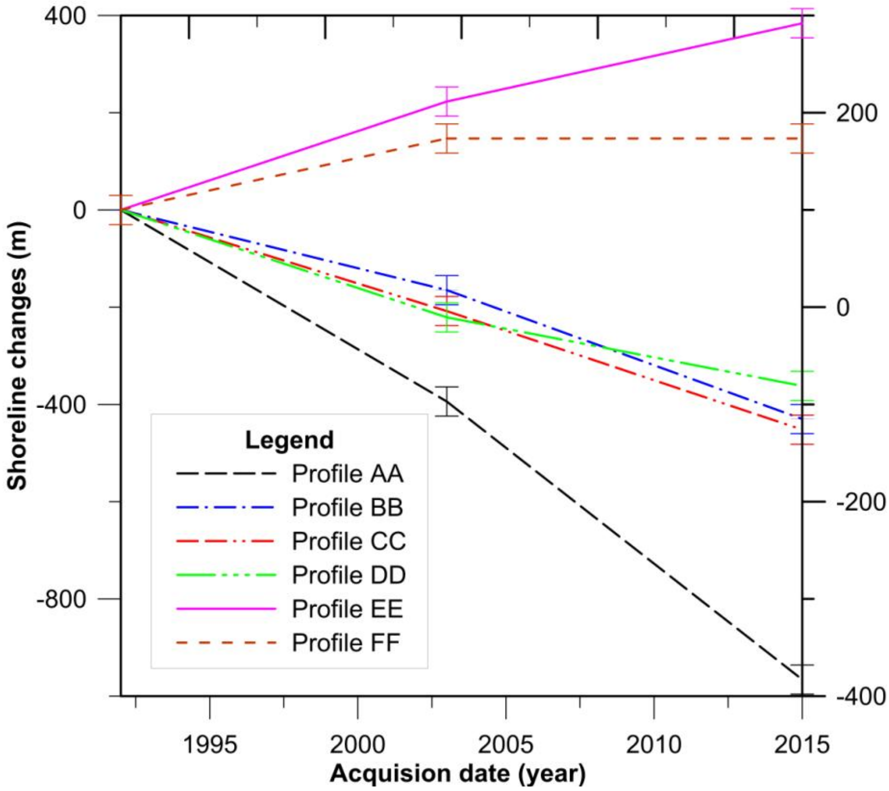


Figure 6. Six cross-sections of coastline change.

5. CONCLUSIONS

In this study, the three Landsat data in the period 1992-2015 were used to extract the shorelines in the Tien and Hau rivers, Vietnam. Those shorelines were superimposed by using GIS tool for analyzing their change during 23 years. Six cross-sections were selected in the the Tien and Hau rivers to provide the shoreline change values. Based on those shoreline change values, it can be concluded that the shoreline change of Tien river is the erosion process. Particularly, in period 1992-2003 and 2003-2015 the largest change value is about 394 m and 562 m for cross-section AA. The maximum change value is approximately 452 m for cross-section CC, and 430 m for cross-section BB. However, there was a deposition process occurs in the coastline indicated by the negative change value. In those cross-sections, the change values were about -223 m and -157 m in the period 1992-2003 and 2003-2015 for cross-section EE. Conclusively, the deposition or erosion occurrence depends on curved or straight shape of rivers.

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