Science on Natural Resources and Environment **33** (2020) 62-70

Science on Natural Resources and Environment
Journal homepage: tapchikhtnmt.hunre.edu.vn

APPLICATION OF REMOTE SENSING AND GIS TO DETERMINE THE RIVERBANK CHANGES IN AN GIANG PROVINCE

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Received 03 November 2020; Accepted 16 December 2020

Abstract

The paper presents an overview of the changes in the Hau river bank, An Giang province. The results have shown that some locations on the river were seriously eroding with the strong speed at the communes: Hoa Binh and Hoa An (Cho Moi district), Binh Thanh (Chau Thanh district), Binh Thuy (Chau Phu district), Chau Phong (Tan Chau district). The shoreline in the study period includes the years: 1995, 2000, 2005, 2015, 2020, which were selected and built by using Landsat satellite images. During the study period, the total erosion area was 585.5 ha, mainly concentrated in Cho Moi district and Long Xuyen city.

Keywords: Hau River; An Giang; Riverbank changes; Remote sensing.

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1. Introduction

Shoreline change (erosion, accretion), an inevitable phenomenon that takes place in the development process, directly impacts people's lives due to many reasons such as topographical characteristics, geology, impacts of upstream factors, anthropogenic activities. The Mekong Delta (MRD) is a fledgling plain that formed about 7000 years ago, filled by alluvium from the Mekong River and coastal silt flows from the north of the East Sea. The erosion phenomenon in the Mekong Delta has happened for many decades. Especially in the past 10 years, the erosion phenomenon has occurred seriously. The rate of erosion is increasing day by day. The Mekong Delta currently has 562 erosion points with a total length of over 786 km, of which the Hau River has 90 erosion points with a total length of 183 km [4].

An Giang is one of the provinces affected by serious riverbank erosion along the Tien and Hau rivers. The Hau river is composed mainly of clay and alluvium, making the river bank very sensitive to exogenous processes such as sedimentation and erosion. There was an emergency of erosion on Hau river bank, where the river goes through Chau Phong commune, Tan Chau town [3]. Therefore, monitoring changes in the Hau river over time is essential, to provide timely information, as a basis for appropriate management policies and directions. By assessing the speed and determining the locations of erosion on the Hau river bank, we aim to limit the lowest level of damage, ensure the safety of people's lives as well as the economic development process along the Hau's banks.

Nowadays, the development of remote sensing technology plays an important role in monitoring natural disasters such as erosion, floods, and saline intrusion [3]. For example, the study on monitoring the erosion of the Mekong Delta using remote sensing and GIS was conducted by Anthony et al (2015) or evaluated the changes in the coast of the Medjerda-Tunisia Delta in the period 1972 - 2013 was conducted by Mourad Louati et al (2014). Remote sensing imagery allows objective and cyclical evaluation to monitor and detect full spatial and temporal variations of river systems. In recent years, remote sensing technology has also been applied quite popularly in Vietnam. Remote sensing images are used to classify water surfaces from multispectral data sets, then overlapped to identify the change of shoreline. For instance, Nguyen Van Trung and Nguyen Van Khanh (2016) monitored shoreline changes using multispectral LANDSAT satellite images in Cua Dai, Thu Bon river. Pham Phuong Thao et al (2011) have used remote sensing and GIS to monitor and calculate shoreline changes in Phan Thiet area. Studies of applying remote sensing to monitor the changes of river bank shape have gradually met the increasing need to assess the shoreline changes in space and time. This study applied remote sensing and GIS methods to determine the shoreline variation in An Giang province (Fig. 1).

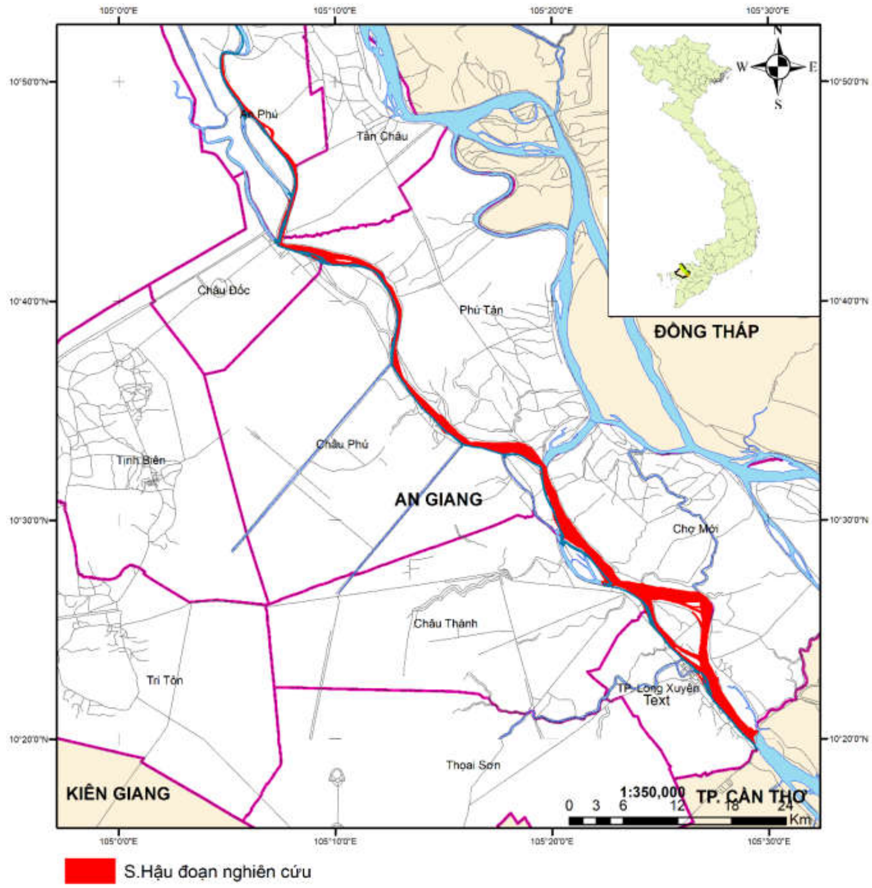


Figure 1: Map of the study area

2. Material and methodology

2.1. Material

- Administrative map layer along the Hau river branch used to limit the study area and map background.

- Map layers: river, stream and traffic network;

- Statistical data related to riverbank erosion and deposition in the study area.

- The satellite imagery is used to extract the shorelines including Landsat 5TM, 7 ETM + and Landsat 8 OLI and TIRs. Data have been provided by the U.S. Geological Survey (USGS) at http://glovis.usgs.gov/. Images are selected when the level of cloud cover is low, normally from September to December, coinciding with the flood season on the river, which is also about the time riverbank fluctuating the most in the year. The results of calculation and analysis of the regional shoreline changes indicated the flood season and its changes over time. The Landsat data used in the study are detailed in Tab. 1.

Table 1. LANDSAT satellite image data used for research

No.	Satellite	Path/row	Year	Date	Resolution
1	Landsat 5 TM	125 053	1990	03/11	30
2		126 053		25/10	30
3		125 053	1995	16/10	30
4		126 053		08/11	30
5	Landsat 7 ETM+	125 053	2000	27/9	30 - 15
6		126 053		18/9	30 - 15

No.	Satellite	Path/row	Year	Date	Resolution
7	Landsat 5 TM	125 053	2005	12/11	30
8		126 053		19/11	30
7		125 053	2010	09/10	30
8		126 053		16/10	30
9	Landsat 8 OLI and TIRs	125 053	2015	26/12	30 - 15
10		126 053		17/12	30 - 15
11		125 053	2020	02/9	30 - 15
12		126 053		09/9	30 - 15

2.2. Methodology

Traditional methods of monitoring shoreline changes often involve field measurements and estimation of the change. These methods are often very costly and time consuming. Remote sensing technology provides a more effective tool to monitor and detect erosion areas. This study to solve the problem in the direction of applying remote sensing and GIS tools to calculate and determine the shoreline changes. The calculation of the changes in the river bank is shown in Fig. 2:

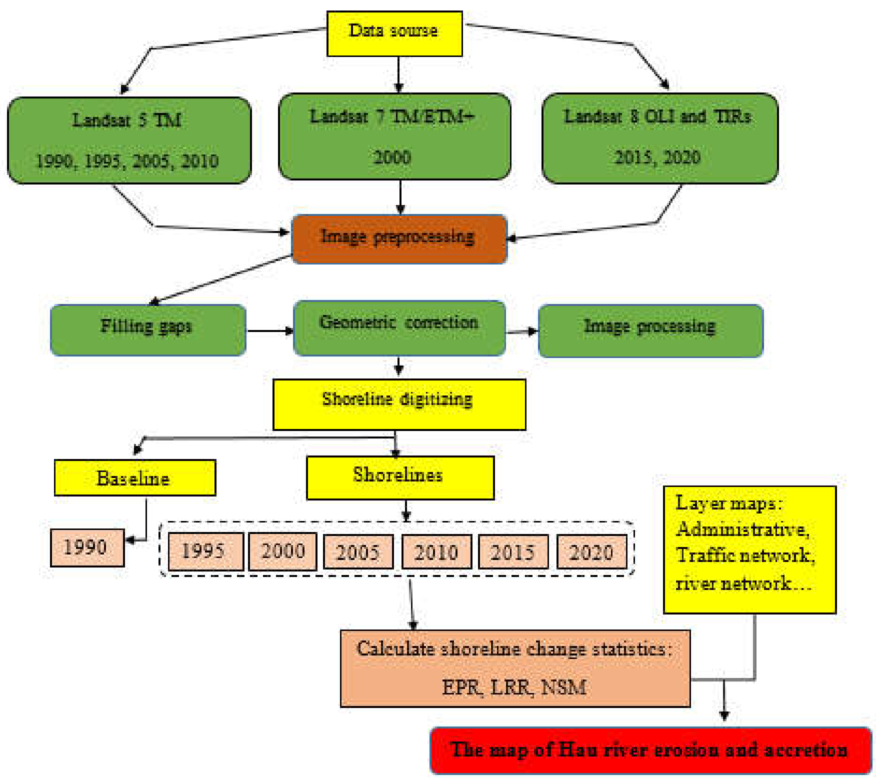


Figure 2: The framework of shoreline changes calculation

Shoreline determination

The study used the image ratio method of Alesheikh (2006) to separate the water-land boundary, then determined and extracted the Shoreline. According to the process shown in Fig. 3 with Landsat 8 image, the method of separating the water-land boundary by Alesheikh algorithm uses band 3 (green), band 5 (near-infrared) and band 6 (medium infrared). Research on the spectral characteristics of water shows that the water has the ability to absorb most of the incoming radiation energy in an infrared wave, so in this range of the reflected energy is almost zero. In the spectral bands of the Landsat image, the middle infrared is most effective in determining the boundary between water and land.

Analytical results using ENVI 4.7 software were converted to *.tiff file format to continue editing work to obtain riverbank lines over the years in ArcGIS. Riverbank lines defined as *.shp have been uploaded on Google Earth to check the accuracy along the waterfronts in the study area for the years: 2015 and 2020. The results of the riverbank extraction for these years are shown in Fig. 4:

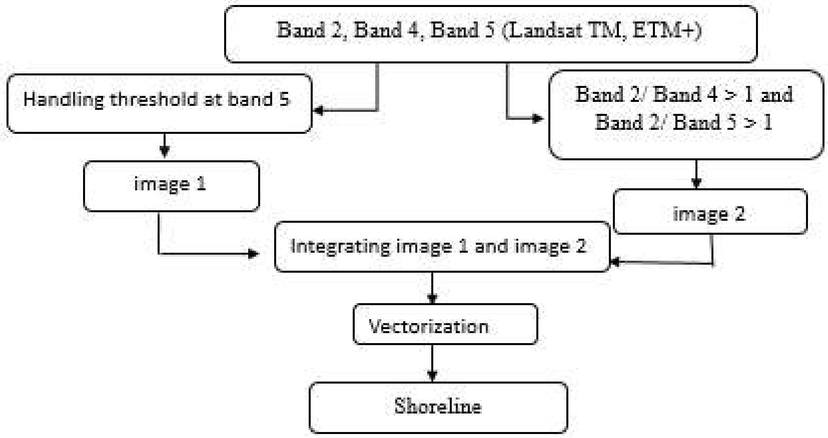


Figure 3: Image ratio method according to Alesheikh (2006)

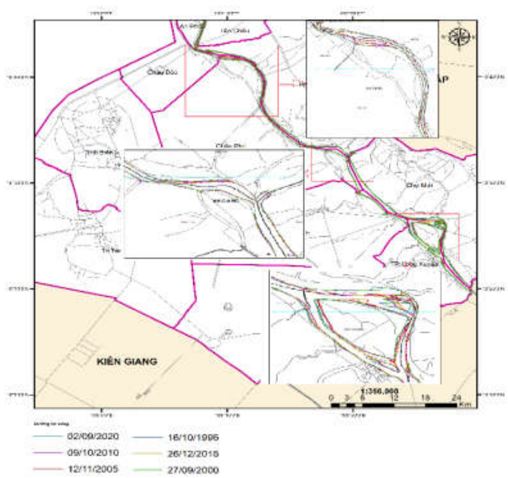


Figure 4: The results the shoreline extracted over the years

Figure 5: The extracted shoreline in 2015 on Google Earth

Shoreline change calculation

Based on the results of the river bank extracted over time, analysis of the shoreline changes was implemented by using the DSAS tool, the process of calculating and analyzing the results of the shoreline changes includes the steps that have shown in Fig. 6:

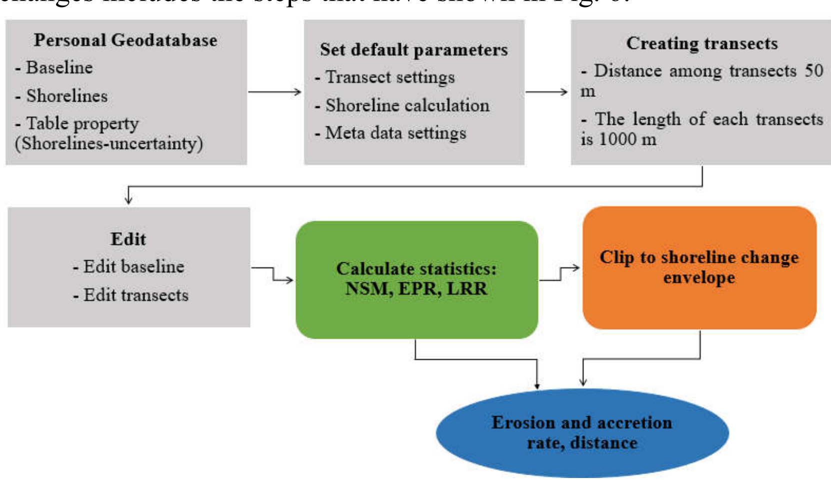
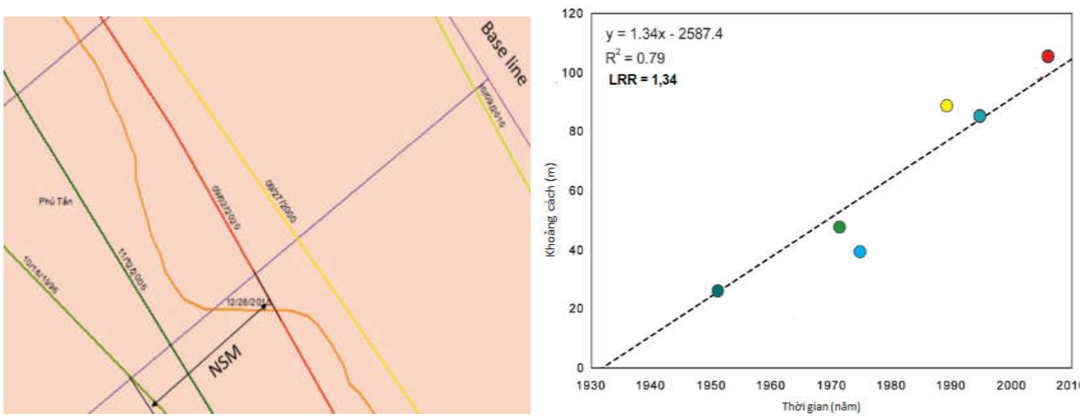


Figure 6: Steps to calculate shoreline changes using DSAS in ArcGIS

Calculation of statistical parameters: The intersection between the cross-section and the shoreline will form the basis for DSAS to calculate statistically the parameters that change over time. In DSAS, there are many methods of calculating shoreline changes such as Net Shoreline Movement (NSM), Endpoint Rate (EPR), Linear Regression Rate (LRR), in which, LRR shows shoreline change (erosion or accretion) values over time and NSM is the shoreline displacement distance, so these two standards are used to analyze the results.

- The NSM is the distance from the shoreline displaced from the oldest position to the newest position at each cross-section perpendicular to the baseline. The ratio of the shoreline displacement to time is the EPR value. The NSM study shows the total distance of shoreline displacement from 1995 to 2020 (Fig. 7a).

- The LRR shows the rate of variation of the shoreline over time, this value is calculated using a statistical method using all the EPR data for which the shoreline cuts each section from which the return curves build linear regression. Thus, at each cross section, the slope of the linear regression line is constructed based on the least squares method of the shoreline variation rate. (Fig. 7b).



a. Real shoreline displacement *b. Regression line and LRR coefficient*

Figure 7: Change result statistics

3. Results

3.1. Statistics of changes in river banks

The Hau river is one of the two main river branches of the Mekong river system, flowing into the sea, located in the lower Mekong River in the territory of Vietnam. The Hau river, which runs through An Giang province, is over 80 km long and flows through 8/11 districts, towns and cities of An Giang province.

The results of riverbank changes in the study area are listed in Table 2. A detailed statistics table at the commune level on the rate of riverbank accretion/erosion rate in the Hau river area, An Giang province in the period from 1995 to 2020.

Table 2. Statistics on the speed of accretion and erosion area along banks of the Hau river, An Giang province from 1995 to 2020

District	Commune	Maximum accretion speed (m/year)	Maximum erosion speed (m/year)	Average accretion/ erosion (m/year)	Erosion area (ha)	Accretion area (ha)
An Phu	Vinh Hau	9.1	-	4.9	-8.5	48.1
	Vinh Loc	9.7	-2.8	3.1	-0.1	35.1
	Phuoc Hung	4.7	-4.3	0.3	-1.5	15.6
	An Phu	8.3	-0.6	4.2	-	14.9
	Vinh Truong	7.1	-10.3	0.4	-11.1	20.2
	Da Phuoc	8.3	-57.3	-0.1	-	36.1
Tan Chau	Chau Phong	3.7	-4.3	-1.3	-21.6	3.1
Phu Tan	Phu Hiep	6.3	-1.3	1.3	-4.9	25.1

District	Commune	Maximum accretion speed (m/year)	Maximum erosion speed (m/year)	Average accretion/ erosion (m/year)	Erosion area (ha)	Accretion area (ha)
	Hoa Lac	0.9	-2.2	-0.7	-13.6	0.8
	Phu Binh	3.7	-2.2	0.8	-5.3	17.0
	Binh Thanh Dong	7.1	-2.1	2.0	-5.1	42.8
	Tan Hoa	6.6	-1.0	0.4	-0.3	3.0
	Tan Trung	3.1	-1.8	0.2	-1.5	1.8
Cho Moi	My Hoi Đong	2.1	-4.4	0.3	-6.8	4.3
	Nhon My	20.3	-4.0	3.9	-23.7	79.8
	Long Giang	39.0	18.1	25.2	-	122.0
	Long Kien	39.0	14.5	27.3	-	46.3
	An Thanh Trung	32.8	-0.7	4.2	-0.5	22.4
	Hoa Binh	8.0	-8.1	-0.6	-37.9	27.5
	Hoa An	2.7	-8.3	-3.6	-218.8	-26.2
Chau Doc	Chau Phu B	0.9	-1.7	-0.4	-3.5	-
	Vinh My	14.7	-0.6	8.6	-0.6	49.4
Chau Phu	Khanh Hoa	9.3	-2.3	1.3	-6.5	27.8
	My Phu	8.3	-1.2	5.1	-0.6	21.2
	Vinh Thanh Trung	0.7	-5.6	-1.1	-13.2	-
	Cai Dau	1.2	-1.5	-0.3	-3.3	0.7
	Binh Long	4.3	-1.0	0.6	-0.8	6.5
	Binh My	28.6	-1.6	0.4	-4.9	2.1
	Binh Thuy	7.0	-4.8	-0.7	-32.5	9.7
Chau Thanh	An Chau	14.7	-57.3	1.5	-37.2	3.5
	Binh Thanh	14.5	-57.3	-2.8	-7.2	20.8
Long Xuyen	Binh Loc	11.7	-2.9	2.2	-0.9	28.6
	Binh Khanh	0.1	-2.6	-1.2	-1.5	0.4
	My Binh	0.1	-2.9	-1.2	-4.7	0.1
	My Long	19.8	-1.4	8.2	-0.4	16.1
	My Phuoc	14.7	0.3	11.9	-	31.4
	My Quy	0.3	-2.1	-1.2	-1.2	0.5
	My Thoi	0.0	-2.6	-1.0	-4.6	-
	My Thanh	-0.2	-5.1	-1.1	-6.8	0.1
	My Hoa Dong	36.5	-50.2	0.1	-162.7	181.6

In the period from 1995 to 2020, shoreline changes occurred in all communes with a total area of 654,1 ha erosion and accretion of 940,1 ha over the entire river section of the study area. In all districts along the river, accretion and erosion occur. The speed of riverbank changes is very different according to space. Some locations in Long Giang, Long Kien and An Thanh Trung communes have an accretion speed of over 30 m/year. My Hoa Dong is the commune with the largest area of shoreline change. Under the influence of the dynamics of the shoreline, this commune tends to erode in the upstream and deposit in the downstream part of the island. Long Xuyen City and Cho Moi district are the two areas with the most intense shoreline changes and the greatest concentration of high-speed shoreline erosion/accretion sections in the study area. Typically, communes of Hoa Binh and Hoa An (Cho Moi district), Chau Phong commune (Tan Chau district), Binh Thanh commune (Chau Thanh district), Binh Thuy commune (Chau Phu district) have sections of erosion with high speed from 3 - 10 m/year. Besides, in all estuaries with the Hau river, there have been changes, notably the erosion, typically Vam Nao river.

3.2. Changes in river banks in An Giang province in the period from 1995 to 2020

The map of changes in river banks from 1995 to 2020 showed that changes in river banks are common in the entire section of Hau river flowing through An Giang province, but there is a difference between the left bank, right bank and middle bank (Fig. 8). According to the map of bank accretion and erosion of Hau river, An Giang province, going from upstream to downstream, riverbank erosion occurred in both river banks and most riverside communes. The speed of riverbank changes between regions is also different.

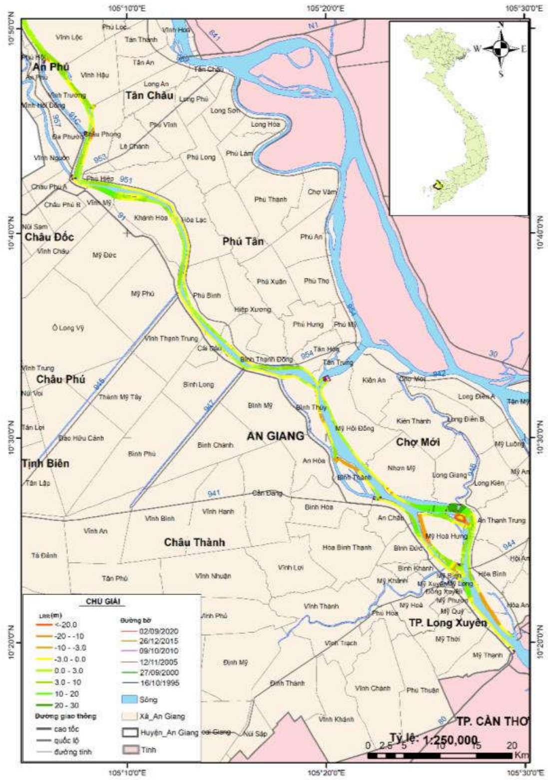


Figure 8: The rate of river erosion and accretion from 1995 to 2020

Going from upstream to downstream, erosion of negative value (-) mainly occurs on the right bank and accretion of positive value (+) mainly occurs on the left bank of the Hau river. Considering the whole river section, the accretion trend is more dominant than erosion. However, the process of river erosion is quite complicated, with many strong erosion points such as Chau Phong commune (Tan Chau), Binh Thuy, Binh Thanh (Chau Thanh), Nhon My, Hoa Binh, Hoa An (Cho New), My Hoa Hung (Long Xuyen city) in the Fig. 9 and 10. Some areas have strong erosion, the annual erosion rate is up to 3 - 10 m, causing the erosion of national highways, houses and property of residents in the riverside area.

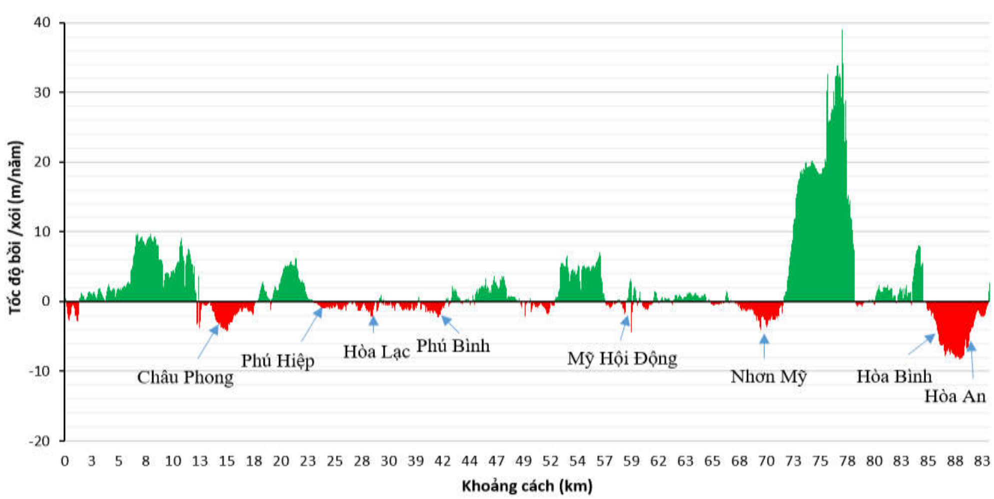


Figure 9: The rate of accretion and erosion on the left bank of the Hau river section in An Giang province from upstream

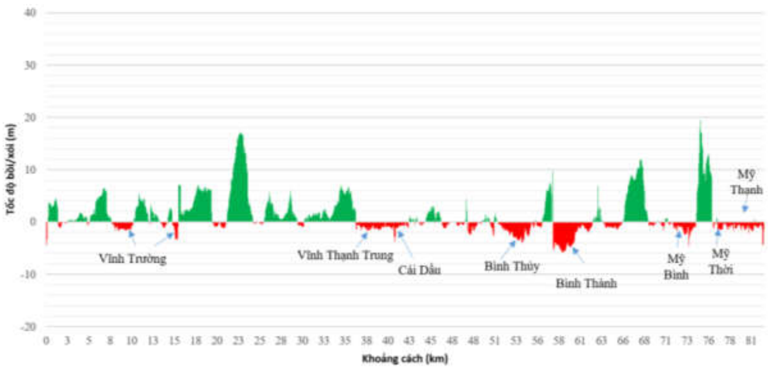


Figure 10: The rate of accretion and erosion on the right bank of the Hau river section in An Giang province from upstream

4. Conclusions and discussions

In the study period from 1995 to 2020, the total erosion area in the study area was calculated to be 654,1 ha, mainly distributed in Cho Moi district (287.7 ha, accounting for 28%) and Long Xuyen city (182, 8 ha, accounting for 44%). Hot spots on the river bank with strong erosion in Hoa Binh commune and Hoa An commune (Cho Moi district), Binh Thanh commune (Chau Thanh district), Binh Thuy commune (Chau Phu district), Chau Phong commune (Tan Chau district). Erosion is often characterized by dunes in the middle of the river, curved sections along rivers where it is strongly affected by currents. Therefore, these areas need measures to protect and minimize shoreline erosion.

Remote sensing images collected for the research periods need to be calculated and considered at the same time as the flood season so as not to be affected by the water level changes between seasons in the river, thereby increasing the accuracy of the solution. The DSAS is an effective tool to calculate shoreline erosion/accretion rates at different times in the area's past. Therefore, erosion/accretion sections on Hau river, An Giang province can be monitored, detected in time and help managers find out the cause and measures to reduce erosion and minimize the level of economic damage and ensure safety for people living along the riverside.

The riverbank change process is influenced by many factors, including natural and artificial ones. The main natural factors are coastal structure, shoreline direction, wind impact, longshore current, flood. Besides, the cause is also due to human impacts, such as sand exploitation, construction of hydroelectric systems in the upstream area. Since the amount of sand on the Hau River decreases, the flow changes, causing riverbank erosion, greatly affecting living and development on both sides of the river.

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