Investigation of Shoreline Change in Phan Thiet Bay, Binh Thuan, Vietnam

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Abstract

Phan Thiet bay in VIetnam has eroded and accreted for many years. That causes serious consequences because main activities of community in Phan Thiet bay are tourism and fishery which depend on shoreline significantly. Not only the economy but also people's life and environment are affected by erosion and accretion. Both natural factors and human factors may cause shoreline change such as waves, currents, structures along the coast or changing of sediment from river. This study aims to investigate the effect of jetties on shoreline in Phan Thiet bay, Binh Thuan, Vietnam by analyzing the Landsat satellite images by using Geographic Information System (GIS), and determining End Point Rate of shoreline change by Digital Shoreline Analysis System (DSAS). The result could be one source for an appropriate plan of coastal management in this area. The study found that after the Jetties were built in 1997 and 2004, the shoreline change rate was lower than that recent years from 2016 to 2020.

Keywords: Phan Thiet bay, Shoreline change, Jetty, Geographic Information System (GIS), Digital Shoreline Analysis System (DSAS)

1. Introduction

Coastal shoreline which is the interaction line along which water meets the land and air. Shoreline can change naturally. Human activities make shoreline change more serious. About 60% of the population in the world live in the coastal zone [1]. Shoreline change can affect to coastal communities, coastal infrastructures and the coastal biodiversity. The shoreline retreats where the erosion occurs is global problem which affects many coastal areas around the world. It results in the loss of land and related things such as community, beaches, water resources system, ecosystem. The accretion causes the siltation in shipping channels, river mouths and lagoon inlets so that the water flow and navigation are obstructed. In Vietnam, many extreme event and hazards happened in coastal areas. That is a challenge for Vietnamese to manage coastal erosion and sedimentation. Specially erosion has become more and more serious [2]. Phan Thiet bay which is located in Binh Thuan province, one of the most eroded area in the south of the central part of Vietnam [3], covers a shoreline of about 50 km long from Mui Ne headland to Ke Ga headland (**Fig. 1**). Tourist industry and fishery is the main parts of Phan Thiet social-economic development. Many coastal projects which affect shoreline have been built to develop the local fisher industry and navigation [4]. The large jetties and tourism infrastructure such as seawall 1, seawall 2, group of groins 1, and group of groins 2 (**Fig. 2**) (Table 1) seem to cause coastal erosion of neighboring areas [5]. It is important for coastal scientist, managers and engineers to assess how the shoreline change in the past to find the appropriate countermeasures or plans for preventing, mitigating and managing coastal disaster.

Hydro-meteorology conditions can have effects on the shoreline position. In Binh Thuan province, there are South-West monsoon and North-East monsoon seasons. In South-West monsoon, from May to October, the rainy season, the mild windspeeds form W/SW are predominant. The waves are calm. In North-East monsoon from November to April, dry season, The gusty wind speeds and high waves from E/NE cause erosions [4]. In one month, the tide is diurnal 18 to 22 days, and semidiurnal 6 to 8 days [6]. Climate change phenomenon such as sea level rise may affect shoreline position. The average global sea level rise rate is 3.2 mm/year in the period 1993 to 2010 [7]. While in Vietnam, the rate of sea level rise is 3 mm/year, lower than the average of the world, in the period of 1993 to 2008 [8].

This study aims to access erosion and accretion in Phan Thiet bay during periods 1988 to 2020. The shoreline positions are tracked from Landsat satellite images by using Geographic Information System (GIS), Shoreline change (erosion and accretion) is accessed by using Digital Shoreline analysis System (DSAS).

The study area is from Ke Ga to Mui Ne in Phan Thiet bay including 3 segments separated by Ca Ty river mouth and Phu Hai river mouth in Fig. 1. Segment 1 is from Ke Ga to Ca Ty river. Following is segment 2 from Ca Ty river mouth to Phu Hai river mouth. The last segment is segment 3 from Phu Hai river mouth to Mui Ne.

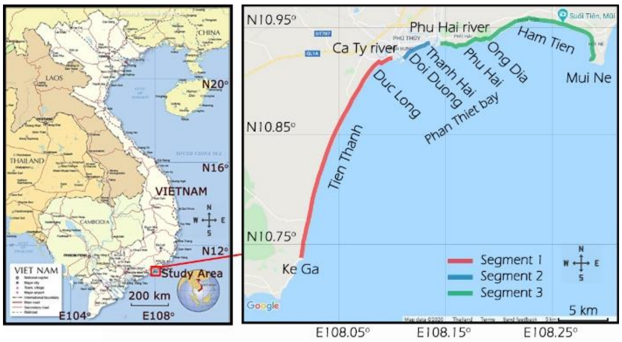

Fig. 1 Study area map with transects used for accessing shoreline change from Ke Ga to Mui Ne

Many coastal structures were constructed to protect the beach in Phan Thiet as shown in the **Fig. 2**, and Table 1 shows details of these structures including location, year that project was built, and size of the structure.

Fig. 2 Location of existing coastal and marine structure in area

Table 1 Information of coastal structure in study areas

	Location	Year of project	Length (m)
Reclamation	Jetty 1 to Duc Long	2006 (not yet finish)	3180
Jetty 1	Ca Ty river mouth	South jetty: 1997	396
		North jetty: 1994	397
seawall 1	Doi Duong	2011	2530
Jetty 2	Phu Hai river mouth	South jetty: 2004	437
		North jetty: 2004	526
Group of groins 1 (Ong Dia)	Romana resort	2009	220
	Cat Trang groin resort	2009	130
	Amaryllis resort	2011	106
	Lotus Mui Ne resort	South groin: 2016 (extended in 2017)	144
		North groin: 2017	60
	Victoria Phan Thiet resort	South groin: 2015	30
		North breakwater: 2015	400
	Poshanu resort resort	2010	135
	Ong Dia groin	2012	134
Group of groins 2 (West of Ham Tien)	Sunsea resort	2019	32
	Blue Ocean resort	2018	52
	Coco beach resort	South groin: 2019	25
		North groin: 2018	26
	Sunny beach resort	Groin 1 (South): 2018	28
		Break water 2: 2017	82
		Groin 3: 2017	27
		Groin 4: 2018	26
		Groin 5 (North): 2018	128
	Rach Dua Tropico resort	Seawall: 2019	77
	Sunrise resort	Groin 1 (South): 2017	19
		Breakwater 2: 2017	14
		Breakwater 3: 2017	23
		Groin 4: 2017	18
		Breakwater 5: 2017	45
		Groin 6 (North): 2017	29
	Tia Nang resort	Breakwater 1 (South): 2018	72
		Groin 1: 2019	16
		Groin 2 (North): 2018	16
	Tien Dat resort	Groin 1 (South): 2018	61
		Groin 2: 2018	24
		Groin 3: 2018	22
		Groin 4: 2018	25
Seawall 2	Ham Tien	2017	1520

2. Methodology

Landsat satellite images in location of path 124, and row 52 with the World Geodetic System 1984 (WGS1984) coordinate are used for digitizing shorelines in 1988, 1995, 2004, 2016 and 2020 by GIS. The details of Landsat satellite images, including WRS path, WRS row of the study area, and time, are showed in **Fig. 3**. The Net Shoreline movement (NSM) and Linear Regression Rate (LRR) are calculated by Digital Shoreline Analysis System (DSAS) based on the distance of shoreline positions to the baseline. The shoreline positions are determined in GIS from the color of the satellite images.

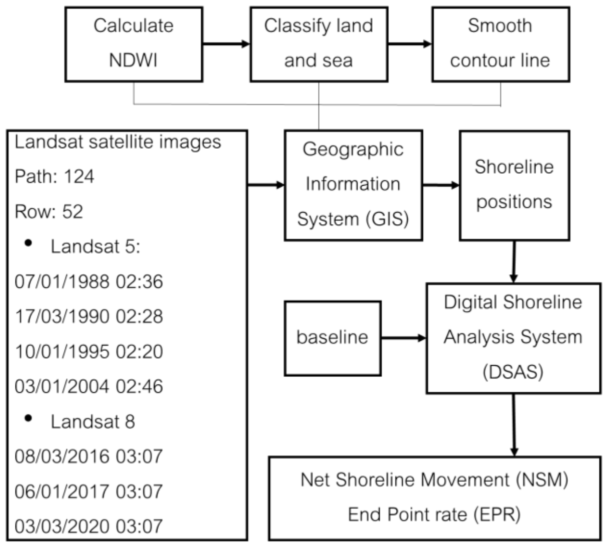

Fig. 3 Framework of Study

2.1 *Extracting shoreline*

The shoreline could be manually or automatically extracted. The limitation of tracing the shoreline automatically is not being effective for complex shoreline where the shoreline is not smooth [9]. The available images of Google are more limited than Landsat images which are used for tracing shoreline automatically in this study. Automatic method is based on the difference between the water and land spectrum which is spectral band ratio methods [9]. Comparing Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI), it is more suitable to extract shoreline based on NDWI [10].

Many Landsat images are available in the website (https://earthexplorer.usgs.gov/) with their spectral bands. Landsat 5 Thematic Mapper images includes 7 spectral bands. While there are 2 more bands in Landsat 8 Operational Land imager images, which consist of 9 spectral bands as shown in Table 2 [11].

Table 2 Spectral bands of Landsat 5 images and Landsat 8 images

Band	Name Landsat 5 (wavelength (μm))	Name Landsat 8 (wavelength (μm))
Band 1	Blue (0.45 – 0.52)	Coastal aerosol (0.43 – 0.45)
Band 2	Green (0.52 – 0.60)	Blue (0.45 – 0.51)
Band 3	Red (0.63 – 0.69)	Green (0.53 – 0.59)
Band 4	Near Infrared (NIR) (0.76 – 0.90)	Red (0.64 – 0.67)
Band 5	Short-wave Infrared (1.55 – 1.75)	Near Infrared (NIR) (0.85 – 0.88)
Band 6	Thermal Infrared (10.4 – 12.5)	SWIR 1 (1.57 – 1.65)
Band 7	Short-wave infrared (2.08 – 2.35)	SWIR 2 (2.11 – 2.29)
Band 8		Panchromatic (0.50 – 0.68)
Band 9		Cirrus (10.6 – 11.19)

ArcMap is the analyzing geospatial processing program from ESRI's ArcGIS. The land and sea areas are defined by NDWI value in equation (1) and equation (2) as shown in **Fig. 4**. NDWI value of each cell is calculated from Green band image and NIR band image by using Raster Calculator tool in ArcMap. The NDWI of land area cell is lower than 0. The NDWI of the sea area cell is higher than 0 [12]. In **Fig. 5**, land and sea are respectively represented by green color and blue color. The shoreline is the contour line based on NDWI value after being smoothed as illustrated in **Fig. 6**.

NDWI (Normalized difference water index) of Landsat 5 is determined from Green band and NIR band. The resolution of those band images is 30 m [13].

$$NDWI = \frac{Green(band\,2) - NIR(band\,4)}{Green(band\,2) + NIR(band\,4)} \quad (1)$$

NDWI (Normalized difference water index) of Landsat 8 images with 30 m resolution [13]:

$$NDWI = \frac{Green(band\,3) - NIR(band\,5)}{Green(band\,3) + NIR(band\,5)} \quad (2)$$

In this research, the shorelines are assessed from 1988, first year Landsat image was taken, to present 2020 dividing to 4 periods of time which are shown in Table 3.

Table 3 Four periods of time: from 1988 to 1995, from 1995 to 2004, from 2004 to 2016, from 2016 to 2020

Time	Details
1988	First year of available Landsat image in this area
1995	After starting to build Jetty 2 in 1994, and before the Jetty 2 was completed in 1997
2004	The Jetty 1 was built
2004 to 2016	From 2006, the reclamation project and groups of groins 2 were built. During this period the shoreline retreat landward and move seaward. The net shoreline movement was low.
2016 to 2020	Since 2016, there have been 23 coastal structures built. In 2017, sea wall 1 was built. Group of groins 1 was built. Some groins in group of groins 2 were built.

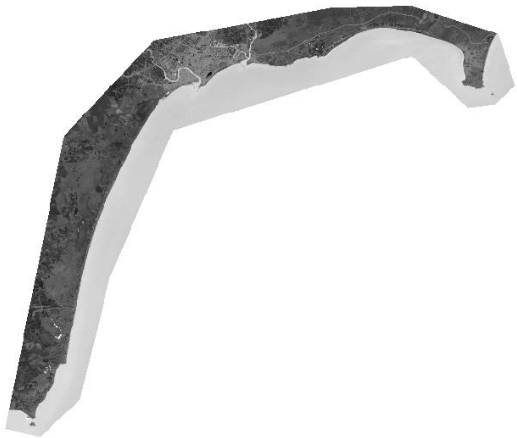

Fig. 4 NDWI value map from Green band and NIR band in 03 March 2020 in GIS

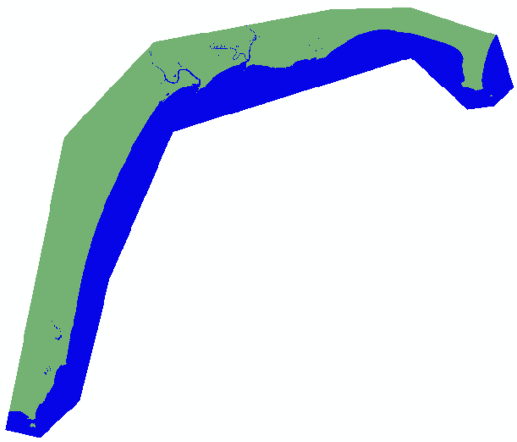

Fig. 5 Classify map based on NDWI value case of 03 March 2020

Fig. 6 Determine shoreline by smoothing NDWI contour line case of 03 March 2020

2.2 Digital Shoreline Analysis System (DSAS)

DSAS, a tool in ArcMap, is used for assessing the shoreline movement by determining rate of change statistics from shoreline positions tracked from satellite images [14]. the landward baseline is created based on the shorelines with the same trend. The transects are generated afterward with the distance between the transects is 50 m in this study as shown in **Fig. 7**, since the shoreline is not complex and not change so much in the range of 50 m. Moreover, the 50 m transect interval were also used by many previous studies [15-17]. Transects are the lines perpendicular to the baseline and cross shoreline at the intersection. The results of DSAS are Shoreline Change Envelope (SCE), Net Shoreline Movement (NSM), End Point Rate (EPR), and Linear Regression Rate (LRR). In this study, NSM and EPR are determined. Net shoreline movement is for assessing the total change in shoreline movement between the first year and the last year of each period. In this study, 4 period time length are different. The Rate of shoreline change, which is EPR, determined by dividing the shoreline movement by the time between the first year and the last year of each period. Annual rate of shoreline change is for comparing between 4 periods.

The Net Shoreline Movement (NSM) and End Point Rate (EPR) of shoreline in 4 periods as shown in **Fig. 8** and **Fig. 9** are calculated after creating baseline and 921 transects in 3 segments separated by 2 rivers.

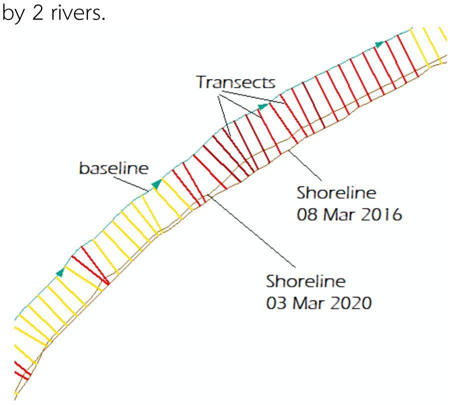

Fig. 7 Shorelines, baseline, and transects

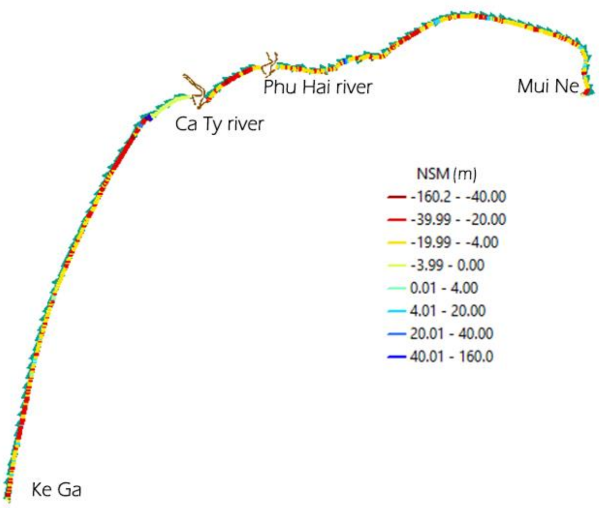

Fig. 8 Transects and Net Shoreline movement (NSM) between 08/03/2016 to 03/03/2020

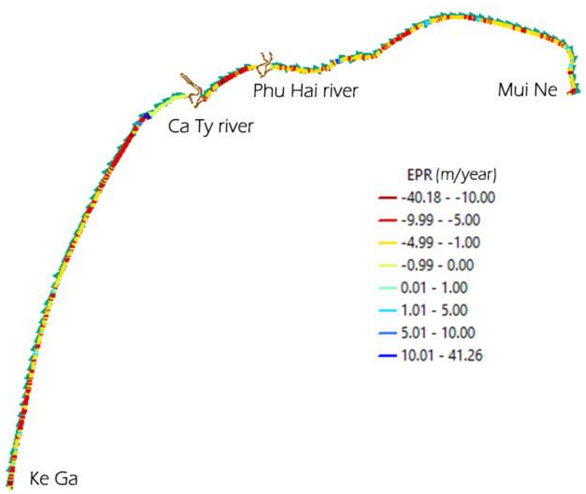

Fig. 9 Transects and End Point Rate (EPR) between 08/03/2016 to 03/03/2020

3. Results

3.1 Validation of the DSAS method

The result of this study is validated by comparing author's EPR result to Linh's EPR result [18]. The EPR of Linh's study and author's study in 3 segments from 17 Mar 1990 to 06 Jan 2017 are in same trend as shown in graph of **Fig. 10**. The average values of shoreline change rate are compared in Duc Long (from transect 394 to 419) and Ham Tien (from transect 700 to 879). The percent difference in Duc Long is -4.19% for NSM, and -5.30 for EPR. In Ham Tien, the percent different is -1.12% for NSM, and -6.84 for EPR as shown in Table 4.

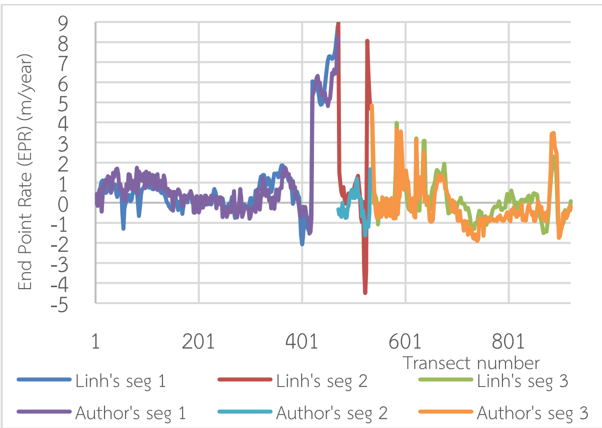

Fig. 10 End Point Rate result (m/year) of [18] and Author.

Table 4 Comparing result of this study and result of Linh [18]

Result		Duc Long 394 - 419	Ham Tien 700 - 879
mean NSM	Linh's (m)	-16.55	-13.60
	Author's (m)	-17.24	-13.75
	diff	0.69	0.15
	% diff	-4.19	-1.12
Mean EPR	Linh's (m/year)	-0.61	-0.48
	Author's (m/year)	-0.64	-0.51
	diff	0.03	0.03
	% diff	-5.30	-6.84

Since the percentage differences of 2 study results are small, this can be implied that the method of this study can be used for further discussion.

3.2 Rate of shoreline change results

The shorelines of 3 segments are assessed in 4 periods as shown the reason in Table 3. After applying ArcMap to extracting the shoreline, the results of shoreline change rate, which is End Point Rate (EPR), are determined as shown in Fig. 11, Fig. 12, Table 5, and Table 6. The seaward accretion is represented by positive value. The negative value represents the landward erosion.

The study area includes 3 segments that are segment 1 (Tien Thanh, Duc Long) connected segment 2 (Doi Duong, Thanh Hai) by Ca Ty river mouth. The north of segment 2 are Phu Hai river mouth, and segment 3 (Phu Hai, Ong Dia, and Ham Tien). The width of rivers has changed by time because of erosion and sedimentation process. The widths of the river mouths change by time and are measured by GIS. From 1988 to 2020, the width of Ca Ty river ranged from 912 m to 982 m. The width of Phu Hai river ranged from 885 m to 1098 m.

The first period, from 1988 to 1995, before the Jetty 1 (**Fig. 2**) was built from 1994 to 1997, The accretion and erosion occurred in some small specific area. Generally, the shoreline slightly changed. The average shoreline change rate in Tien Thanh of segment 1 was -1.38 m/year (mild erosion) **(Fig. 11a)**. In Duc Long near the Ca Ty river mouth in segment 1 was accreted with the rate up to 8.22 m/year. In segment 2, between Ca Ty river mouth and Phu Hai river mouth, the erosion was severe (more than -5 m/year) **(Fig. 12**a). The shoreline in Phu Hai near Phu Hai river mouth was eroded with the highest erosion rate was -9.91 m/year. The average shoreline change rate in Ham Tien was -0.78 m/year (No erosion).

The second period, after the Jetty 1 (**Fig. 2**) was built, from 1995 to 2004, the significant accretion and erosion were found in Thanh Hai of segment 2 near Phu Hai river mouth with the high rate was 7.97 m/year and erosion rate was -10.01 m/year (**Fig. 12**b). The shoreline change rate was less than 5 m/year in Tien Thanh in segment 1 **(Fig. 11**b) and Ham Tien in the segment 3 (**Fig. 12**b).

In 2004, the jetty 2 (**Fig. 2**) was built. Since 2006, the reclamation project has been built in Duc Long of segment 1 until now. The third period, from 2004 to 2016, many groins of group 1 (**Fig. 2**) have been built in segment 3 near Ong Dia. The accretion occurred in that area. In other areas, the end point shoreline change rate was less than 5 m/year as shown in **Fig. 11**c and **Fig. 12**c.

Recently, the fourth period, from 2016 to 2020, the shoreline has changed more. In the South of Duc Long reclamation project, the beach was eroded up to -13.32 m/year (severse erosion) (**Fig. 11**d). In the segment 2, the highest erosion rate was -13.93 m/year. But the shoreline hasn't retreated landward beyond the sea wall 1 in Doi Duong (**Fig. 12**d) which was built in 2011. In segment 3, both erosion and accretion occurred seriously with the range of shoreline change rate is from -10.3 m/year to 10.3 m/year (**Fig. 12**d). Near the seawall 2, in the East of Ham Tien, the erosion seriously threats the tourism places along the coast without protect structure.

The shoreline has complicatedly changed. Predicting how shoreline will change in future is neccessary for coastal management and planning. After this study, the author will assess shoreline positions in future corresponding some different scenarios that are shoreline change with structures and without structures.

Table 5 Shoreline change rate (m/year) of each area in period 1 and period 2.

	Period 1 (1988 - 1995)			Period 2 (1995 - 2004)		
	Min	Max	Average	Min	Max	Average
Tien Thanh	-7.50	3.58	-1.48	-2.14	4.71	0.65
Duc Long	-1.62	8.22	3.42	-0.33	4.52	2.74
Doi Duong	-6.93	1.72	-2.72	-2.67	7.45	-0.04
Thanh Hai	-5.28	3.76	-3.02	-10.01	7.97	0.02
Phu Hai	-9.91	6.79	-3.45	-2.55	1.29	-0.19
Ong Dia	-6.68	1.18	-1.92	-2.68	2.67	0.13
Ham Tien	-4.96	5.41	-0.78	-3.28	2.10	-0.51

Table 6 Shoreline change rate (m/year) of each area in period 3 and period 4.

	Period 3 (2004 - 2016)			Period 4 (2016 - 2020)		
	Min	Max	Average	Min	Max	Average
Tien Thanh	-0.84	3.51	1.16	-10.50	3.32	-4.46
Duc Long	-4.06	13.13	4.88	-13.32	41.26	-1.00
Doi Duong	-3.64	4.44	1.95	-13.93	-1.78	-6.38
Thanh Hai	-3.74	3.82	-0.90	-10.14	-3.24	-6.50
Phu Hai	-1.75	10.81	0.58	-8.87	1.04	-4.33
Ong Dia	-1.92	8.51	1.61	-7.71	10.30	-3.27
Ham Tien	-1.45	7.09	0.84	-10.30	6.46	-3.85

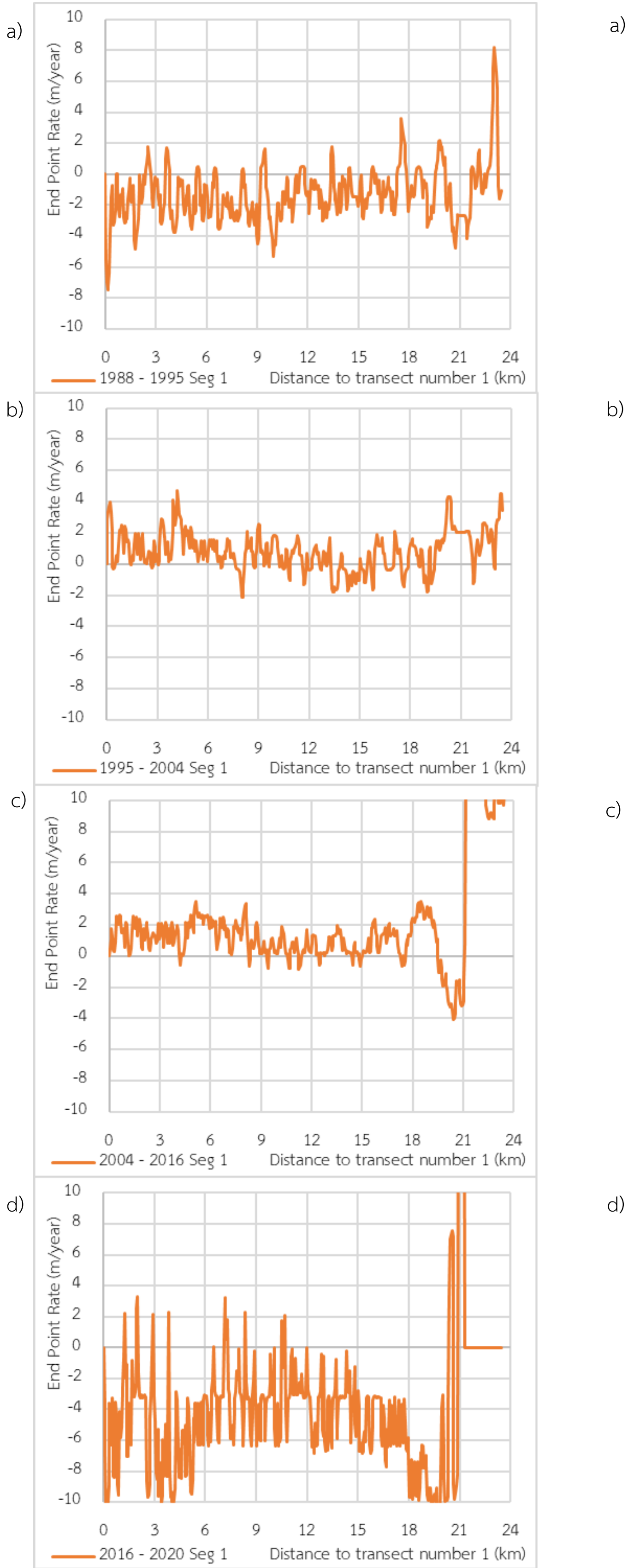

Fig. 11 End Point Rate (EPR) result in Segment 1 a) 1988-1995 b) 1995-2004 c) 2004-2016 and d) 2016-2020

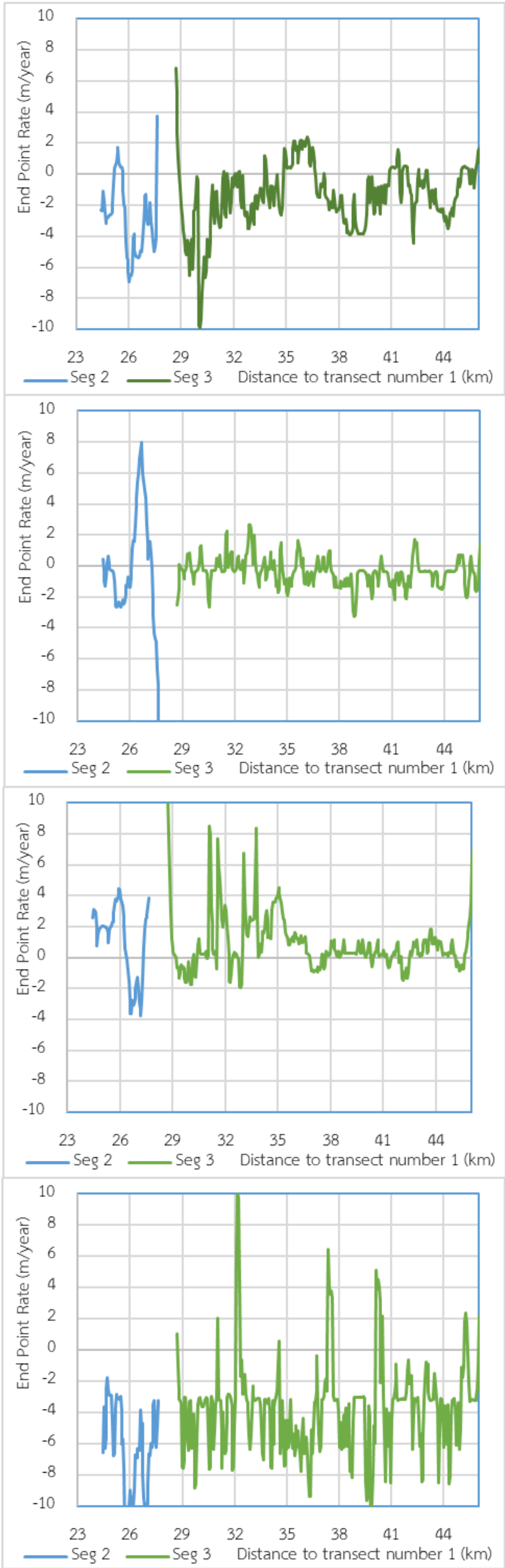

Fig. 12 End Point Rate (EPR) result in Segment 2 and Segment 3 a) 1988-1995 b) 1995-2004 c) 2004-2016 and d) 2016-2020

4. Conclusion and Discussion

The shorelines are analysed by using Geographic Information System (GIS) and Digital Shoreline Analysis System (DSAS). The shoreline has changed for many years. Recently, the problem become more serious in many areas in Phan Thiet bay with severe erosion rate in segment 3 and segment 1.

The life of people in this area was affected significantly by shoreline change. The navigation in the river mouth was obstructed by accretion. Because of the erosion, land and many related things along the coast of Phan Thiet bay were lost. Many people had to move their house. The method in this study is suitable for assessing shoreline in this area. More studies are necessary to be carried on for investigating the causes of shoreline change in this area.

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