Coastline abrasion and sedimentation changes on the Banyuasin coast

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Abstract. This study provides information regarding the potential effects of land use changes that occur in the Banyuasin coastal area, South Sumatra (BCASS) related to increased sedimentation rates and shoreline changes. Variation of shoreline changes in time series is carried out by utilizing spatial data in the form of Landsat satellite imagery data for 42 years, starting from 1978 to 2020 and an additional tool, namely the Digital Shoreline Analysis System (DSAS) method. To see differences in shoreline delineation in different Landsat image years, the researchers used the NSM (Net Shoreline Movement) and EPR (End Point rate) methods to determine the rate of shoreline changes by dividing the distance between the shoreline and the time. The model was formed from the results of a spatial analysis of 5 villages in the Banyuasin II sub-district, affected by this change in shoreline, namely the villages of Tanah Pilih, Muara Sungsang, Rimau Sungsang, Sungsang III and Sungsang IV, over intervals of 10 years, starting from 1978 to 2020. The results obtained from the five identified locations indicate shoreline changes by looking at the pattern of shoreline distribution through abrasion and accretion. The distribution patterns are based on the results of spatial analysis that has succeeded in showing the occurrence of abrasion and accretion of the shoreline in general.
Key Words: Banyuasin coast, Landsat image, Sembilang National Park, special economic zone.

Introduction. The Banyuasin coastal area of South Sumatra (BCASS) has a very unique ecosystem due to the existence of the Sembilang National Park (SNP) conservation area (Febriansyah et al 2019; Sumiyati & Julaikha 2021) and of a special economic zone (SEZ) covering an area of 22030 ha (BAPPENAS 2018). SNP has an area of 202896.31 ha, of which approximately 87000 ha are mangrove forest areas (GWI 2016; Theresia et al 2016). Mangrove ecosystems (ME) are tropical coastal vegetation communities dominated by several species of mangrove trees, which grow and develop in tidal muddy coastal areas (Bengen 2004; Haya et al 2015; Karimah 2017). ME in BCASS is a natural system of protection against abrasion caused by coastal waves. In addition, the ME can bind sediments because of the mangroves' tight and strong roots (Pham et al 2019).

ME in BCASS suffers some pressures, both threats/pressure from the sea and from the mainland. Pressure from the land is caused by human activities, population growth, industrial activities, settlements (Kathiresan 2012), which pose a threat to space and natural resources in coastal areas. Land changes in Banyuasin coastal area may have a major negative impact on the sustainability of resources in the area, such as increasing erosion and sedimentation (Theresia et al 2016; Febriansyah et al 2019; Sutasoit et al 2021; Oh et al 2021). Sedimentation can cause changes in the morphology of coastal areas and water bathymetry (Hamzah & Ndohali 2008; Febriyanti et al 2017; Wang et al 2018; Darmiati et al 2020).

Coastal morphology has a tendency to display changes in both accretion and abrasion over the years. This pattern of change is under the influence of many factors derived from natural and human activities. In addition, the coast undergoes certain changes on a shorter or longer time scale as seen from the addition of a representative amount of sediment supply (Darmiati et al 2020).

The main sources of sediment transportation to the shoreline in BCASS are climate change related to rainfall, land use, and distribution of seabed substrates, which will affect the sediment supply to the beach in the form of both abrasion and sedimentation. Land change can directly affect the sediment supply in BCASS and affect the sediment supply downstream and in coastal areas. For this reason, proper planning and management is needed in BCASS regarding land use utilization, and on the availability of sediment that can affect the BCASS morphology.

The novelty of this research is that the location chosen to be the object of study is a unique area compared to coastal areas in general, because in this location there are the SNP conservation area and a SEZ location. The study examines the processes of shoreline change in 42 years in BCASS.

Material and Method. This study began with extracting and analyzing Landsat image data for 42 years starting from 1978 to 2020 with intervals of ten years, using the DSAS (digital shoreline analysis system) tool, to determine differences in shoreline delineation throughout the years. The process continued by using the NSM (net shoreline movement) and EPR (end point rate) methods to determine the rate of change of the shoreline by dividing the distance between the shorelines by the time. The date/year of the shoreline delineation was divided into a time span of approximately 10 years starting from 1978-1988, 1988-1998, 1998-2008, 2008-2020, obtaining five shoreline delineations. The results were divided according to 5 villages in the Banyuasin II District: Tanah Choose, Muara Sungsang, Rimau Sungsang, Sungsang III, and Sungsang IV. Furthermore, trends or patterns related to shoreline changes that are formed in BCASS were obtained.

Description of the study sites. The research creates a shoreline map reviewed using DSAS tools with ArcGIS software. Then an analysis was carried out regarding the pattern of land use change that occurred in BCASS.

In BCASS, there is a monsoon climate influenced by two seasons, namely the western and eastern monsoons, with transition seasons between them. Climate affects the conditions of BCASS related to the intensity of rainfall. The average rainfall and duration of rain that occurs from April to June is 200 mm as the east monsoon continues. Part of the BCASS is an estuarine area (semi-enclosed waters) strongly influenced by tidal currents. Tidal energy originating from the water tides and currents movement has a dominant influence on the process of circulating seawater masses in the area of interest. According to Simatupang et al (2016), these tides and current circulation patterns which move water masses will affect the distribution of sediment particles. This can be seen from the pattern of sedimentation distribution that occurs in BCASS. Towards the mouth of the river, the sediment will be finer and dominated by clay and sandy silt classes. This is influenced by the presence of large rivers that discharge into BCASS. Based on the processing of tidal data from 1978 to 2022 obtained from the Indonesian Geospatial Agency/BIG/BRIN, the type of tidal tide that occurs at BCASS is singular and dominant. According to Setyawan & Pamungkas (2017), the tides in the western part of Indonesia have a single type (diurnal tide), with influence on seabed topography. In addition, the tides that occur in BCASS are a reaction to the tidal system in the Pacific and Indian oceans (dual type tide). When the propagation of tidal energy occurs, it will pass through shallow waters so that the resonance system in shallow waters will affect the tidal pattern that occurs at this location. Therefore, the dominant type formed is diurnal tide. The tides of sea water can generate ocean currents called tidal currents. Movement of sediment in the water column influenced by the movement of this current. Furthermore, when the energy that occurs becomes smaller, it will cause particle deposition and this will influence changes in the coastline tidal currents (Kurniawan et al 2016).

This event can be seen in BCASS, which is a semi-enclosed water area, with shallow water and river estuaries. The research site map can be seen in Figure 1.

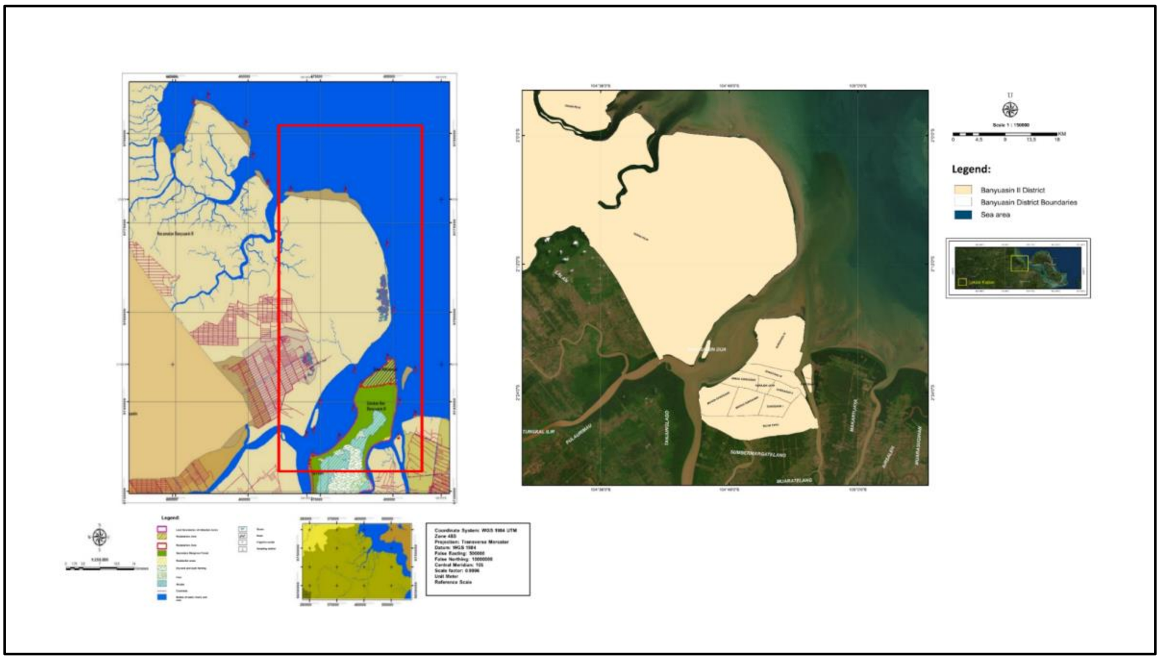

Figure 1. Research site map.

The data in this study were collected from analysis of Landsat imagery for 42 years (1978-2020), which were then combined with field data (Table 1). The image data used in this research utilizes Landsat path/row 14/061 and 124/062 data.

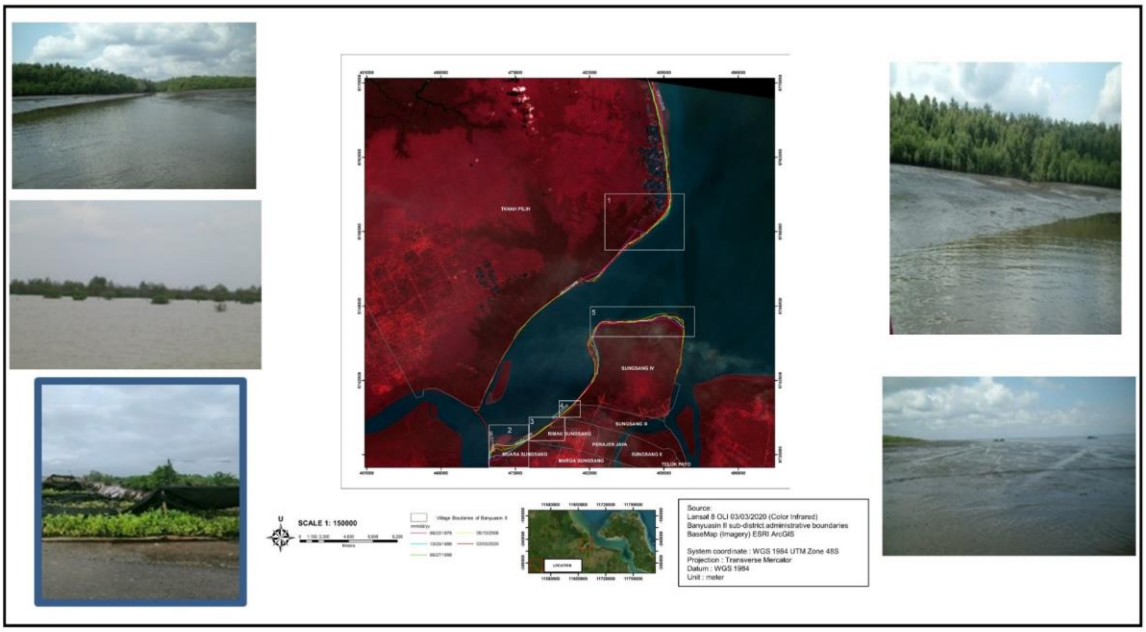

Figure 2. Landsat image for the studies are showing the location of the located samples and the studied sites.

According to Joesidawati (2016) and Di Paola et al (2018), using sensory and geospatial techniques added to DSAS will be useful to monitor changes in the long term, which will provide a comprehensive view of the erosion and accretion patterns of coastal areas with economic value.

The distribution of dates/years of shoreline delineation is divided into a span of approximately 10 years, starting from 1978-1988, 1988-1998, 1998-2008, 2008-2020 and has 5 shorelines using the same satellite imagery on different dates and years.

Table 1

Landsat satellite imagery data for 42 years

Satellite image	*Recording date*	*Path/Row*	*Sensor type*
Landsat 3	22.06.1978	124/062	Multispectral Scanner (MSS)
Landsat 5	20.10.1988	124/062	Thematic Mapper (TM)
Landsat 5	27.06.1998	124/062	Thematic Mapper (TM)
Landsat 7	13.05.2008	124/062	Enhanced Thematic Mapper Plus (ETM+)
Landsat 8	03.03.2020	124/062	Operational Land Imager (OLI)

Processing of Landsat satellite image data was done using ArcGIS software. Atmospheric correction and radiometric normalization increased pixel values and removed unwanted atmospheric influences. A map projection to the UTM (universal transverse mercator) was created, with the spheroid and datum WGS84, applying geometric rectification. Classification and creation of the unsupervised classification algorithm were applied, then applied into 24 iterations with a threshold convergence of 0.95 and a standard deviation of 1. The results were then described and classified into 25 clusters in each image made of land and sea clusters.

Results and Discussion. The results of the shoreline delineation are divided into several villages in the Banyuasin II sub-district, which are affected by changes in the shoreline (Table 2, Figure 3).

Table 2

Results of beach tracking in Banyuasin II District

Village	*Length (m)*	*Initial Coordinate (UTM)*		*Final Coordinate (UTM)*	
		East	*North*	*East*	*North*
Tanah Pilih	39.948	487546	9770079	471697	9739598
Muara Sungsang	4.270	472548	9735098	476131	9736405
Rimau Sungsang	4.062	476146	9736416	479381	9738513
Sungsang III	1.686	479402	9738530	480672	9739701
Sungsang IV	26.767	480493	9739728	489831	9739402

The shoreline during 1978-1988. 723 transects were generated using DSAS for beaches in the BCA Banyuasin II District, which were divided into the 5 villages (Table 3). The results of processing shoreline changes using the DSAS tool are presented in Figures 3 and 4. The results were obtained by observing shoreline changes and combining 2 shorelines in different years using the EPR and NMS (Figure 4).

The EPR calculation method using DSAS indicates that there has been an average of forward/accretion/sedimentation shoreline change of 15.18 m per year, starting from 1978 to 1988. Forward/accretion shoreline changes with a maximum change value of 71.35 m per year occurred in Tanah Pilih Village during 1978-1988. The NSM calculation shows that there is an average change in the forward shoreline of 156.80 m. The longest forward shoreline change is 737.09 m, which occurred in Tanah Pilih Village. As for the EPR backward/abrasion, there was an average shoreline change of -5.61 m per year in 1978-1988 (Table 4), with the greatest shoreline change of backward/abrasion of -39.07 m per year in Tanah Pilih. NSM backward/abrasion occurred on an average shoreline change along -57.94 m, with the greatest shoreline change of backward/abrasion of -403.66 m in Tanah Pilih Village.

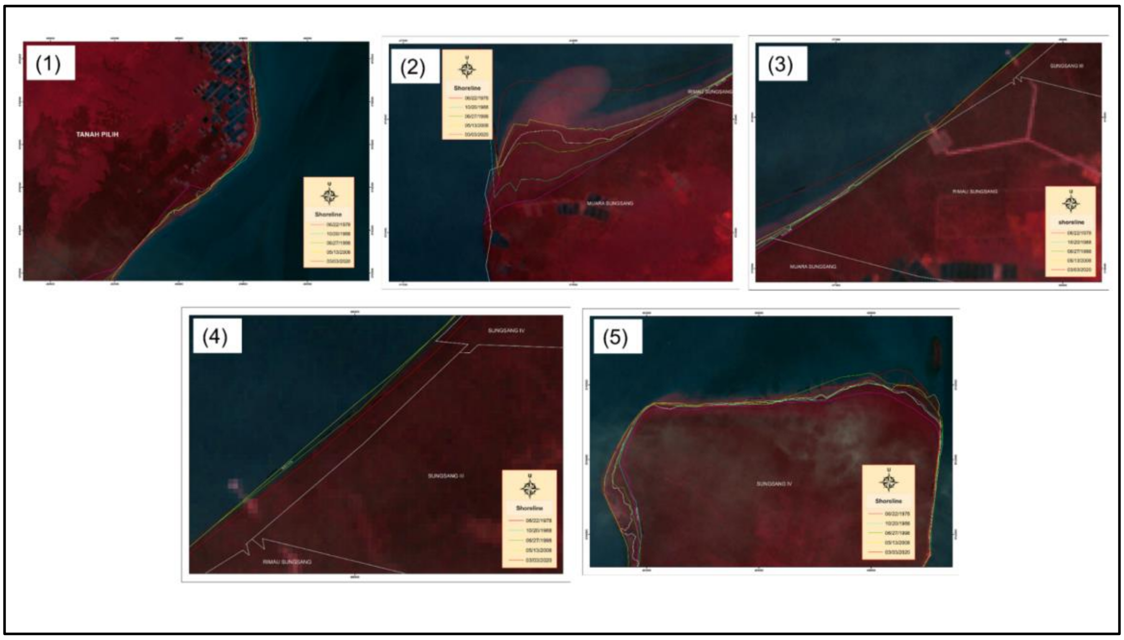

Figure 3. Maps of shoreline changes in five villages; 1 - the shoreline of the Tanah Pilih Village area; 2 - the shoreline of the Muara Sungsang Village area; 3 - the shoreline of the Rimau Sungsang Village area; 4 - the shoreline of the Sungsang III Village area; 5 - the shoreline of the Sungsang IV Village.

Table 3

Transect information at research site for shoreline changes in 1978-1988

Information	*1*	*2*	*3*	*4*	*5*
	Tanah Pilih	*Muara Sungsang*	*Rimau Sungsang*	*Sungsang III*	*Sungsang IV*
Transect	1-367	368-405	406-420	-	421-607
Transect space (m)	100	100	100	100	100
Transect length (m)	1500	1500	1500	1500	1500
Distance from the baseline to the shoreline (m)	2000	2000	2000	2000	2000

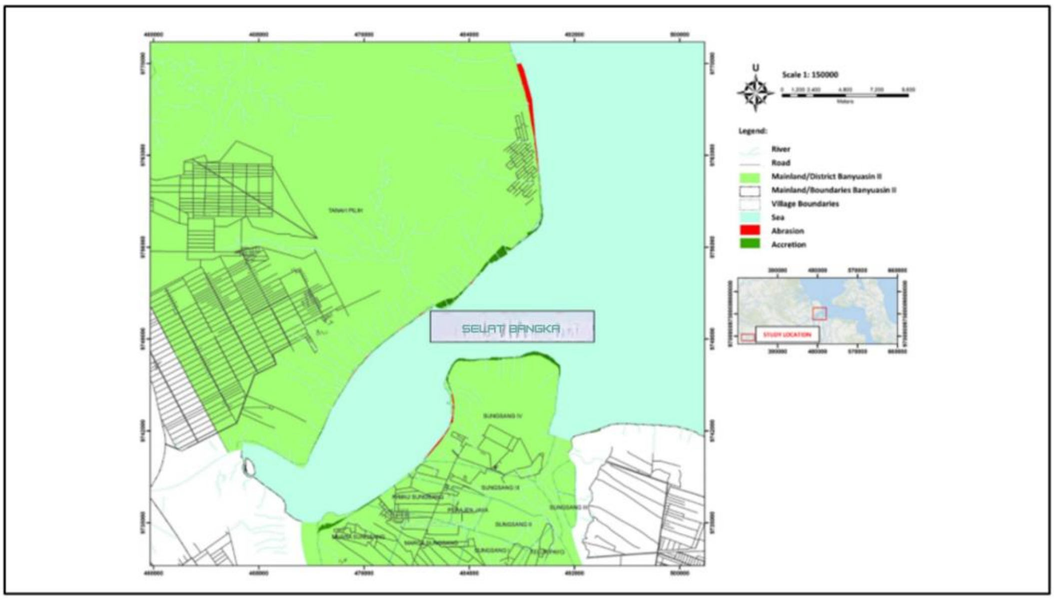

Figure 4. Maps of shoreline changes in 1978-1988 at Banyuasin II Sub-District.

Table 4

The results of shoreline changes using 2 different shorelines (1978-1988)

Villages	*Tanah Pilih*	*Muara Sungsang*	*Rimau Sungsang*	*Sungsang III*	*Sungsang IV*
NSM Accretion (Max)	737.09	442.46	56.51	0	304.1
NSM Accretion (Min)	1.67	11.46	7.61	0	7.12
NSM Accretion (Average)	369.38	226.96	32.06	0	155.61
EPR Accretion (Max)	71.35	42.83	5.47	0	29.43
EPR Accretion (Min)	0.16	1.11	0.74	0	0.69
EPR Accretion (Average)	35.755	21.97	3.105	0	15.06
NSM Abrasion (Max)	-403.66	-1.11	0	0	-164.3
NSM Abrasion (Min)	-3.18	-1.11	0	0	-5.98
NSM Abrasion (Average)	-203.42	-1.11	0	0	-85.16
EPR Abrasion (Max)	-39.07	-0.11	0	0	-15.91
EPR Abrasion (Min)	-0.31	-0.11	0	0	-0.58
EPR Abrasion (Average)	-19.69	-0.11	0	0	-8.25
Total					
Average shoreline change (forward) (m year^{-1}) (EPR)					15.18
Average shoreline change (backward) (m year^{-1}) (EPR)					-5.61
Forward max (m) (EPR)					71.35
Backward max (m) (EPR)					-39.07
Average shoreline change (forward) (NSM)					156.80
Average shoreline change (backward) (NSM)					-57.94
Forward max (m) (NSM)					737.09
Backward max (m) (NSM)					-403.66

Note: NSM - net shoreline movement; EPR - end point rate.

The shoreline during 1988-1998. 524 transects were generated using DSAS in the Banyuasin II District area between 1988-1998 (Table 5 and Figure 5). The results were obtained by observing shoreline changes and combining 2 shorelines in different years using the EPR and NSM calculation methods.

Table 5

Transect information at the research site of shoreline changes in 1988-1998

Information	*1*	*2*	*4*	*5*	*6*
	Tanah Pilih	*Muara Sungsang*	*Rimau Sungsang*	*Sungsang III*	*Sungsang 1V*
Transect	1-293	294-328	329-340	-	341-524
Transect space (m)	100	100	100	100	100
Transect length (m)	1500	1500	1500	1500	1500
Distance from the baseline to the shoreline (m)	2000	2000	2000	2000	2000

Table 6 shows that the EPR calculation method produced an average forward/accretion shoreline change of 15.32 m per year in 1988-1998, and forward/accretion shoreline changes with a maximum value of 71.16 m per year in Muara Sungsang Village. NSM produced an average forward/accretion shoreline change of 148.28 m in 1988-1998, with the longest forward/accretion coastline change of 688.83 m in Muara Sungsang Village.

As for the EPR backward/abrasion, there was an average shoreline change of -3.00 m per year in 1988-1998, with the greatest change in shoreline backward/abrasion at -13.89 m per year in Tanah Pilih Village. The backward/abrasion average shoreline change determined with NSM was -29.01 m in 1988-1998, with the greatest change of -134.49 m in Tanah Pilih Village.

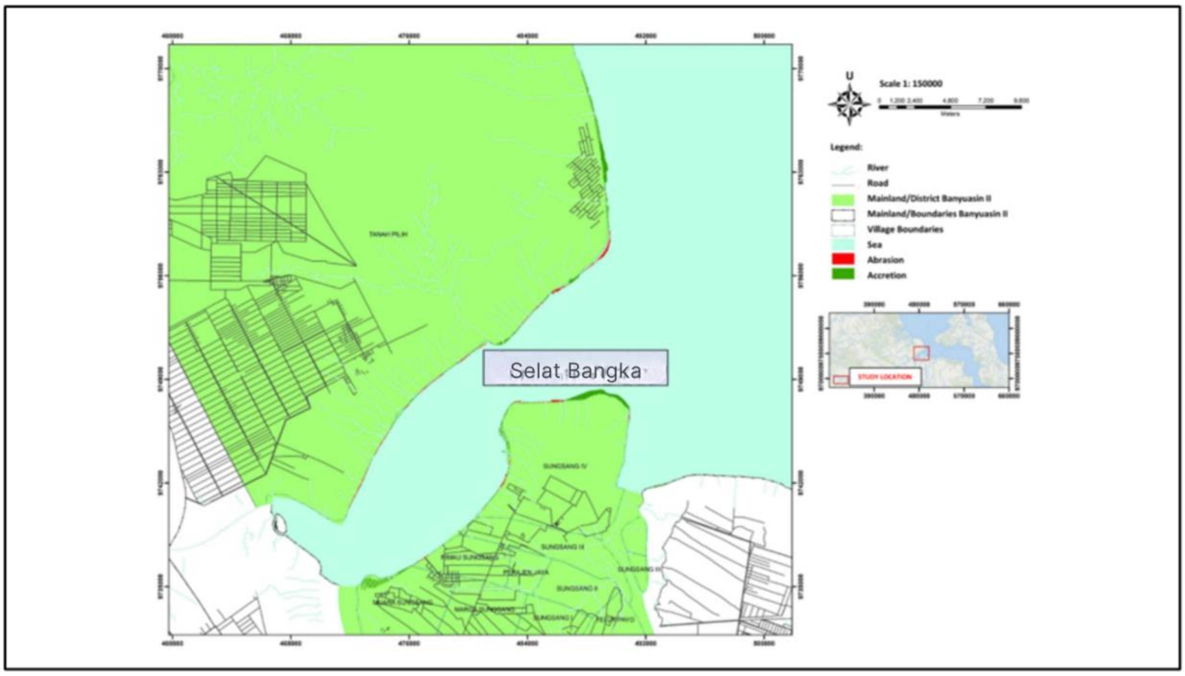

Figure 5. Maps of shoreline changes in 1988-1998 at Banyuasin II Sub-District.

Table 6

The results of shoreline changes using 2 different shorelines (1988-1998)

Villages	*Tanah Pilih*	*Muara Sungsang*	*Rimau Sungsang*	*Sungsang III*	*Sungsang IV*
NSM Accretion (Max)	356.81	688.83	0	0	408.33
NSM Accretion (Min)	1.24	26.52	0	0	1.08
NSM Accretion (Average)	179.03	357.68	0	0	204.71
EPR Accretion (Max)	36.86	71.16	0	0	42.18
EPR Accretion (Min)	0.13	2.74	0	0	0.11
EPR Accretion (Average)	18.50	36.95	0	0	21.15
NSM Abrasion (Max)	-134.49	0	-28.37	0	-123.56
NSM Abrasion (Min)	-2.11	0	-1.25	0	-0.35
NSM Abrasion (Average)	-68.30	0	-14.81	0	-61.96
EPR Abrasion (Max)	-13.89	0	-2.93	0	-12.76
EPR Abrasion (Min)	-0.22	0	-0.13	0	-0.04
EPR Abrasion (Average)	-7.06	0	-1.53	0	-6.40
Total					
Average shoreline change (forward) (m year^{-1}) (EPR)					15.32
Average shoreline change (backward) (m year^{-1}) (EPR)					-3.00
Forward max (m) (EPR)					71.16
Backward max (m) (EPR)					-13.89
Average shoreline change (forward) (NSM)					148.28
Average shoreline change (backward) (NSM)					-29.01
Forward max (m) (NSM)					688.83
Backward max (m) (NSM)					-134.49

Note: NSM - net shoreline movement; EPR - end point rate.

The shoreline during 1998-2008. 618 transects were generated using DSAS in the Banyuasin II District in 1998-2008 (Table 7). The results of processing shoreline changes using the DSAS tool are presented in Figure 6. The results of changes in shoreline distance are presented in Table 8. EPR showed an average forward/accretion shoreline change of 14.63 m per year in 1998-2008, with a maximum of 57.00 m per year in Sungsang IV Village. NSM determined an average forward/accretion shoreline change of 144.51 m in 1998-2008, with the longest forward/accretion coastline change of 563.17 m in Sungsang IV Village.

Table 7

Transect information at the research site of shoreline changes in 1998-2008

Information	*1* *Tanah Pilih*	*2* *Muara Sungsang*	*3* *Rimau Sungsang*	*4* *Sungsang III*	*5* *Sungsang IV*
Transect	1-327	328-361	362-385	386-402	403-618
Transect space (m)	100	100	100	100	100
Transect L length (m)	1500	1500	1500	1500	1500
Distance from the baseline to the shoreline (m)	2000	2000	2000	2000	2000

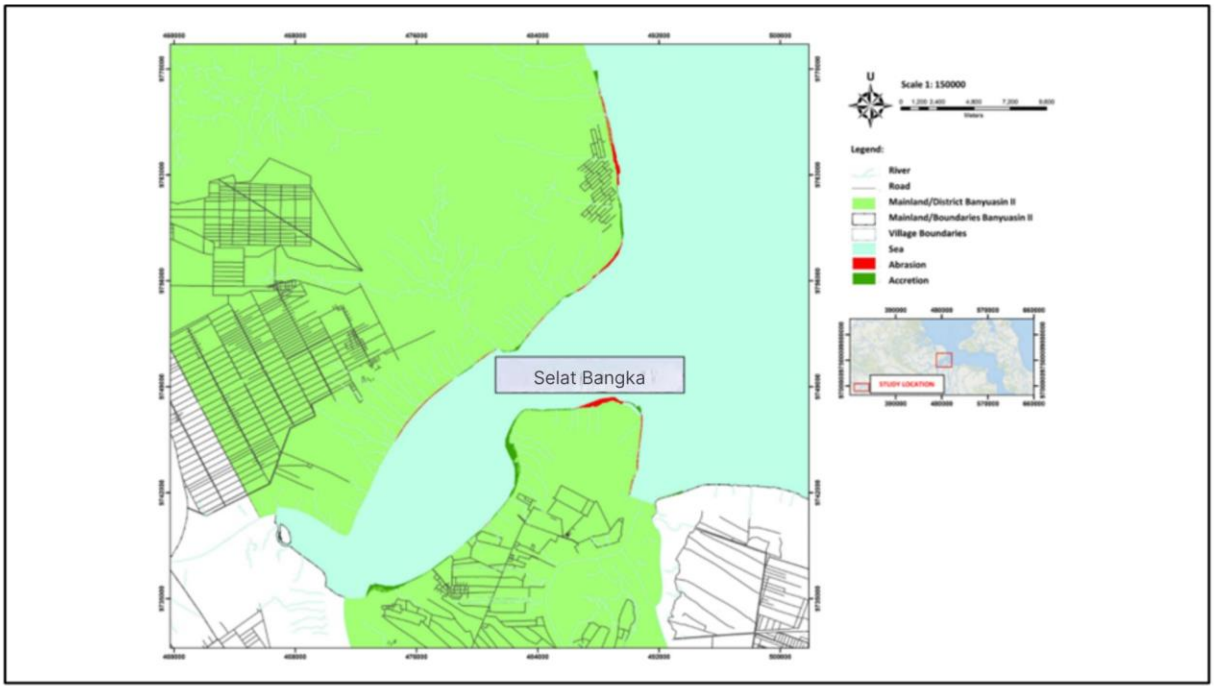

Figure 6. Maps of shoreline changes in 1998-2008 at Banyuasin II Sub-District.

According to EPR, backward/abrasion had an average shoreline change of -6.08 m per year in 1998-2008, with the greatest change in shoreline of -36.57 m per year in Sungsang IV Village (Tables 7 and 8). Backward/abrasion, according to NSM, had an average shoreline change of -60.07 m, with the highest value of -361.26 m in Sungsang IV Village.

Table 8

The results of shoreline changes using 2 different shorelines (1998-2008)

Villages	*Tanah Pilih*	*Muara Sungsang*	*Rimau Sungsang*	*Sungsang III*	*Sungsang IV*
NSM Accretion (Max)	257.01	469.69	57.85	43.66	563.17
NSM Accretion (Min)	4.63	43.44	1.37	2.89	1.38
NSM Accretion (Average)	130.82	256.57	29.61	23.28	282.28
EPR Accretion (Max)	26.01	47.54	5.86	4.42	57.00
EPR Accretion (Min)	0.47	4.4	0.14	0.29	0.14
EPR Accretion (Average)	13.24	25.97	3	2.36	28.57
NSM Abrasion (Max)	-236.38	0	0	0	-361.26
NSM Abrasion (Min)	-2.47	0	0	0	-0.56
NSM Abrasion (Average)	-119.43	0	0	0	-180.91
EPR Abrasion (Max)	-23.93	0	0	0	-36.57
EPR Abrasion (Min)	-0.25	0	0	0	-0.06
EPR Abrasion (Average)	-12.09	0	0	0	-18.32
Total					
Average shoreline change (forward) (m year^{-1}) (EPR)					14.63
Average shoreline change (backward) (m year^{-1}) (EPR)					-6.08
Forward max (m) (EPR)					57.00
Backward max (m) (EPR)					-36.57

Note: NSM - net shoreline movement; EPR - end point rate.

The shoreline during 2008-2020. 723 transects were generated using DSAS in the Banyuasin II District in 2008-2020 (Table 9). The results of processing shoreline changes using the DSAS tool are shown in Table 9 and Figure 7. The results of changes in shoreline distance are shown in Table 10.

Table 9

Transect information at research sites for shoreline changes in 2008-2020

Information	*1*	*2*	*3*	*4*	*5*
	Tanah Pilih	*Muara Sungsang*	*Rimau Sungsang*	*Sungsang III*	*Sungsang IV*
Transect	1-394	394-425	426-464	467-481	482-723
Transect space (m)	100	100	100	100	100
Transect length (m)	1500	1500	1500	1500	1500
Distance from the baseline to the shoreline (m)	2000	2000	2000	2000	2000

Table 10 shows that, with the EPR calculation method, there was an average forward/accretion shoreline change of 23.36 m per year in 2008-2020, with a maximum of 82.16 m per year in Muara Sungsang Village. With the NSM calculation method, there was an average forward/accretion shoreline change of 275.78 m in 2008-2020, with the longest forward/accretion coastline change of 969.89 m in Muara Sungsang Village.

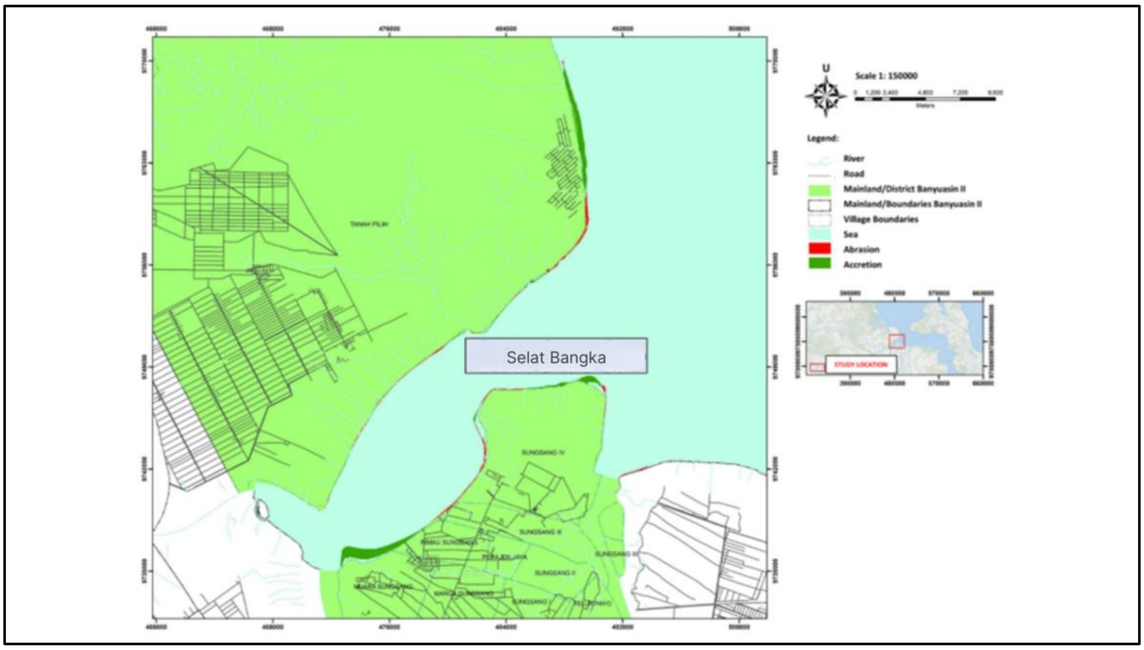

Figure 7. Maps of shoreline changes in 2008-2020 at Banyuasin II Sub-District.

Table 10

The results of shoreline changes using 2 different shorelines (2008–2020)

Villages	*Tanah Pilih*	*Muara Sungsang*	*Rimau Sungsang*	*Sungsang III*	*Sungsang IV*
NSM Accretion (Max)	466.11	969.89	389.90	0	517.23
NSM Accretion (Min)	0.61	403.53	9.67	0	0.82
NSM Accretion (Avg)	233.36	686.71	199.79	0	259.03
EPR Accretion (Max)	39.48	82.16	33.03	0	43.81
EPR Accretion (Min)	0.05	34.18	0.82	0	0.07
EPR Accretion (Avg)	19.765	58.17	16.93	0	21.94
NSM Abrasion (Max)	-17.36	0	-42.59	-78.08	-154.77
NSM Abrasion (Min)	-0.05	0	-5.39	-47.68	-0.25
NSM Abrasion (Average)	-8.71	0	-23.99	-62.88	-77.51
EPR Abrasion (Max)	-204.97	0	-3.61	-6.61	-13.11
EPR Abrasion (Min)	-0.63	0	-0.46	-4.04	-0.02
EPR Abrasion (Avg)	-102.8	0	-2.04	-5.33	-6.57
Total					
Average shoreline change (forward) (m year^{-1}) (EPR)					23.36
Average shoreline change (backward) (m year^{-1}) (EPR)					-23.35
Forward max (m) (EPR)					82.16
Backward max (m) (EPR)					-204.97
Average shoreline change (forward) (NSM)					275.78
Average shoreline change (backward) (NSM)					-34.62
Forward max (m) (NSM)					969.89
Backward max (m) (NSM)					-154.77

Note: NSM - net shoreline movement; EPR - end point rate.

As for the EPR backward/abrasion, there was an average shoreline change of -23.35 m per year in 2008-2020, with the greatest change of -204.97 m per year in Tanah Pilih Village. The backward/abrasion, according to NSM, had an average of -34.62 m, with the highest value of -154.77 m in Sungsang IV Village.

Based on the development of shoreline changes that occurred in BCASS, it can be seen that the pattern of shoreline changes during the period 1978-2020 (42 years) formed an accretion-abrasion-accretion pattern. Location areas that present accretion within a certain period of time will turn into mangrove ecosystem areas, so that the land area will increase over time.

Conclusions. By conducting sampling, collecting data in the field, and analyzing Landsat satellite imagery for 42 years at the BCAAS location, the results have shown changes in the coastline. Coastline changes at the study site indicate that there has been a change in the coastline with a changing pattern of abrasive and accretionary actions located at the Tanah Pilih village, Muara Sungsang village, Rimau Sungsang village, Sungsang II and IV villages.

Conflict of Interest. The authors declare that there is no conflict of interest.

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