Detection of Coastline Changing by Using Remote Sensing Imagery (Case Study in Talawi District, Tanjung Tiram District, Lima Puluh Pesisir District Batu Bara Regency)

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IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

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To cite this article: Rumondang *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1118** 012025

Detection of Coastline Changing by Using Remote Sensing Imagery (Case Study in Talawi District, Tanjung Tiram District, Lima Puluh Pesisir District Batu Bara Regency)

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Abstract. The high pressure in utilizing coastal areas and oceans causes in coastal damage. The coastline is the confluence of land areas and sea areas, where the existence of the line and the position of the coastline can change and undergo changes over time, and the position of the existence of the line is not fixed. The purpose of this study is to find out the changes in the coastline of the Coal District, Talawi District, Tanjung Tiram District and Lima Puluh Pesisir District in 2017-2022. The data analysis technique was used in this study is quantitative descriptive analysis. The data processing includes: Data Acquisition using Satellite Imagery (*Raster)* data. The data is used by satellite imagery was selected based on 2017 until 2022 coverage representative the lowest percentage of cloud cover in the study area. Supporting Spatial Data (vectors). The Digital Shoreline Analysis System (DSAS) is *a plug in* for esri ArcGIS 10.4 - 10.6 desktops to calculate historical coastline change rate statistics. Based on the results of coastline delianiation, it can be seen that the length of coastal gasis in 2017 in The Lima Puluh Pesisir District is 10.48 Km, in 2022 there was a decrease to 10.42 Km while based on RBI data on a scale of 1:50,000 in the 2014 update year was 17.37 Km. The length of the coastline of Tanjung Tiram District in 2017 was 24.31 Km, there was a decrease in 2022 to 23.44 Km and based on RBI data of 16.90 Km. TheTalawi District has the length of the coastline was 3.16 Km in 2017, there is an increase in 2022 to 3.22 Km while the coastline on the RBI map was 3.23 Kilometers in length.

1. Introduction

The coastal area of North Sumatra Province has a coastline of 1300 km, so it has enormous potential in producing inland fishery resources and marine fisheries. The fisheries and marine potential of North Sumatra comes from marine fish farming activities of 100,000 Ha, ponds of 20,000 Ha, freshwater fish farming of 81,372.84 Ha, and public waters of 155,797 Ha (KKP, Batubara 2015) Batu Bara Regency is one of the regencies located in the coastal area of the East Coast of North Sumatra with an area of 904.96 km^2, so it has a high potential for marine fishery resources. This area consists of 5 sub-districts which have 21 villages located in coastal areas with a coastal length of 58 km, including the Talawi district, Tanjung Tiram district, Lima Puluh Pesisir District. The high pressure in utilizing coastal area and oceans has resulted in damage to beaches [1][2][3] and ecosystems [4][5][6][7], one of which is mangrove ecosystems[8][9]. Mangrove damage in the coastal area of Batu Bara Regency has occurred since the 1990s. Based on the results of interviews with the community in the sub-district, it was happened when there was a change in land use, namely the conversion of mangroves into ponds, plantations, agriculture, settlements and tourist areas,this caused loss of natural protection of the beach and then wind, waves, currents easily hit the coast of the regency Batu Bara. At the same time, there was a change in hydro-oceanographic patterns due to reclamation and coastal buildings in the area adjacent to the coast of Talawi District. The coastal erosion disaster in the coastal area of Talawi district, Tanjung Tiram district, Lima Puluh Pesisir district began with the destruction of mangrove ecosystems. The conversion of mangroves into pond land leads to the loss of natural coastal protection [8][10].

The coastline is the physical interface of the land area and water areas physical interface. High dynamics through continuous interactions between the geosphere, hydrosphere, and atmosphere causes the position of the coastline to change frequently over time [11][5] due to several parameters morphodynamics such as the movement of sediments [12]in the littoral zone and the dynamic nature of the water surface in coastal boundaries (e.g. currents, tides, waves) [13]. [14] given the importance of studies of coastline determination and coastline change (a phenomenon that varies in magnitude, speed and duration), it is necessary to assess: sea level changes, coastal zone protection, estimating coastal development, assistance in coastal monitoring, coastal evolution and assessing coastal hazards. In recent decades, earth observation data such as aerial photographs [15], satellite imagery [16], and GPS data [17] have become sources and means integral to evaluating coastline changes. The data is temporally available at the same location in a long, more cost-effective time series.

Currently, calculating the historical rate of change of the coastline and predicting the change of the coastline with a high degree of accuracy can be done easily[15] (United States Geological Survey (USGS) developed a geographic information system plug-in as a platform called *the Digital Shoreline Analysis System* (DSAS) using an observation-based approach. This results in a transect of cement mortar and gravel perpendicular to the reference baseline at user-defined distances along the coastline. The distance between the baseline and each point of intersection of the coastline on the transect helps calculate coastline changes by distance measurements and related statistical calculations and generates all calculations connected to a transect file with an attribute table. DSAS helps determine the morpho-dynamics of the coastline and the shifts associated with its coastal geometry [18]. Monitoring coastline changes is an effective way to study changes in the environment and ecology of coastal zones. Therefore, coastline monitoring has become important for sustainable development and environmental protection changes in the coastline of the Batu Bara regency from 2017 to 2022. The Landsat imagery series has been used to measure the rate at which coastlines change due to human and natural interference. This method is efficient, fast, reliable and economical. In short, it is a useful tool for recording and monitoring coastline changes.

2. The data analysis method

This research was conducted in Batu Bara Regency, Talawi district, Tanjung Tiram district, Lima Puluh Pesisir district from May to July 2022. The data collection technique used is a data collection technique in the form of document studies. The document intended in this study is in the form of satellite imagery contained in the google earth pro application. So, changes to the coastline can be done by *overlaying* (overlapping) imagery from 2017 until 2022. Image analysis was carried out to determine the percentage change in the coastline change of the three sub-districts using the *ArcGIS* application. The initial stage carried out in this study was conducted by *georeferencing.*

The data was obtained by using Sentinel 2 satellite imagery data was selected based on the 2017 and 2022 coverage representatives, which was the lowest percentage of cloud cover in the study area. The data is obtained by downloading on the Supporting Spatial Data (*vector*) site. The supporting spatial data used in this study is RUPA Bumi Indonesia (RBI) data for Batu Bara Regency in *shapefile* (shp) format, which is officially issued by the Geospatial Information Agency (BIG). The software used in data processing is Esri ArcGIS version 10.5 and Digital Shoreline Analysis System (DSAS) v5.0. The Digital Shoreline Analysis System (DSAS) is a *plug-in* for esri ArcGIS 10.4 - 10.6 desktops to calculate historical coastline change rate statistics. The Digital Shoreline Analysis System (DSAS) provides automated methods, establishes measurement locations, performs rate calculations and provides statistical data on coastline changes. To delineate the coastline, it is necessary to separate water bodies from other objects using Esri ArcGIS Software version 10.5. In this study, the algorithm used is *the Normalized Difference Wetness Index* (NDWI). NDWI is an algorithm used for the detection of water bodies. Furthermore, the data from coastline delineation in 2017 and 2022 on the study site area was further processed using the Digital Shoreline Analysis System (DSAS).

3. Results and Discussion

3.1 Coastline Delineation

The results of the sentinel image coastline delineation in 2017 and 2022 showed changes in the coastline area in the Coastal Area of Talawi District, Tanjung Tiram District and Lima Puluh Pesisir District. The changes referred to in terms of land reduction (abrasion) and land addition (accretion) within a period of 5 years (2017-2022), as shown in Gambar 1, 2 and 3, are as follows. Several standard methods of coastline delineation have now been developed to facilitate monitoring coastline changes using remote sensing. The coastline in this study was the waterline at the time of satellite imagery recording [15][19].

Figure 1. Results of delianiation of the Coastline of Talawi District

Figure 2. Results of delianiation of the Coastline of the Lima Puluh Pesisir District

IOP Conf. Series: Earth and Environmental Science 1118 (2022) 012025 doi:10.1088/1755-1315/1118/1/012025

Figure 3. Results of delianiation of the Coastline of Tanjung Tiram District

From the results of the delineation of the coastline, it can be seen that the length of the coastal line in 2017 in the Lima Puluh Pesisir District is 10.48 Km. In 2022 there will be a decrease to 10.42 Km, while based on RBI data on the scale of 1:50,000, the update year 2014 is 17.37 Km. The length of the coastline of Tanjung Tiram District in 2017 was 24.31 Km. There is a decrease in 2022 to 23.44 Km and, based on RBI data, 16.90 Km. Talawi district had a coastline length of 3.16 Km in 2017, experiencing an increase in 2022 to 3.22 Km, while the coastline on the RBI map is 3.23 Km long. In detail, the length of the coastline at the study site based on the results of delineation and RBI data is presented in Table 1.

Table 1. Length of delineated Coastline at The Research Site

District	Coastline Length (Km)		
	RBI	2017	2022
Lima Puluh Pesisirs	17,37	10,48	10,42
Tanjung Tiram	16,90	24,31	23,44
Talawi	3,23	3,16	3,22

Identification of Coastal Abrasion and Accretion Locations: The location of coastal abrasion and accretion is carried out by overlaying the longest coastline with the current coastline. The result of overlapping coastline changes in the last 6 years, namely 2017 to 2022, are presented in Table 2. Most of the coasts of the Batu Bara Regency have undergone changes that indicate the occurrence of abrasion with a degree of abrasion that is evaluated. The largest level of abrasion occurred in the Tanjung Tiram District. There were 142 locations experiencing abrasion and 57 Accretion locations. Coastal abrasion also occurs in The Lima Puluh Pesisir District there are 38 Abrasion locations and 55 locations that experience accretion, and in Talawi District, there are 8 locations that experience abrasion. Abrasion and 19 sites experienced accretion at 100 meters along the coastline. During this period, the coast of Batu Bara Regency also experienced accretion or sedimentation. Based on the results of satellite imagery data processing, it was detected that at the location, there was a change in the coastline in the period 2017 to 2022 at the study site. While in Detail, the number of locations that experienced Abrasion and Accretion at the research site based on the results of satellite imagery data processing is presented in the table following. Another cause of coastline changes is the dynamics of oceanography in the waters of the Batu Bara, in the form of i) regular rise and fall of sea levels which affects the current around the coast and the geomorphology ofthe coast. ii) ocean waves, the height of the waves are related to the danger of inundation of seawater and the transport of sediments along the coast. The impact of high waves hitting the coast will affect changes in the coastline that occur along the coast. The greater the energy of the ocean waves that hit, the greater the sediment particles entering and leaving the coast and vice versa [20].

Table 2. Number of abrasion and accretion locations at the Research Site

District	Number of Locations	
	Abrasion	Accretion
Lima Puluh Pesisirs	38	55
Talawi	8	19
Tanjung Tiram	142	57

The distribution of locations experiencing abrasion and accretion in 3 sub-districts of the study location spatially can be seen in the following figure. The rate of change in the coastline of The Batu Bara Regency for each duration of the observation year is quite dynamic.The dynamic process of coastlin changes in the range of 2017-2022, it looks very dynamic. abrasion has occurred almost along the line of Batu Bara Regency, more than 100 meters in some locations. The main cause of the abrasion process of the Batu Bara Regency beach is large ocean currents and waves which are characterized by the magnitude of the value of each characteristic of the wave and current so thatthe beach is easily abrased. The large wave height produces currents pouring down the coast at a high speed, so that more and more coastal material is eroded or lost to the beach that deeper that coastal currents carry on the waters. This is in accordance with what was stated by [21]that the oceanographic characteristics that play an important role in the processof coastal abrasion are the currents that drain the coast (*longshore current)* and waves. Wave energy is a factor that affects abrasion along the Batu Bara Regency, so the greater the wave energy, the greater the abrasion that occur. [20]states that the strength of abrasion is determined by the magnitude of the waves that blow to the coast. The large wave energy will cause strong waves that blow to the shore, which can form coastal destructive waves that have altitude and speed large propagations. So that the water that turns again has less time to seep into the sand. When the waves come back hitting the shore there will be a large volume of water collecting and transporting coastal material towards the beach direction.

The abrasion that occurs in Batu Bara Regency is strongly influenced by the speed of the current. The speed of the longshore current can transport sediment that has been moved by waves, waves coming towards the coast can cause coastal currents that play a role in to the process of sedimentation or coastal abrasion. According to [21] the wave that causes the occurrence of longshore currents is an abrasion study of Batu Bara Regency of North Sumatra Province, the main cause of sediment movement [22]. So the large current speed will cause coastal abrasion because the sediment transport process is getting faster. Unlike the wave energy and current speed, the relationship between the abrasion speed and the size of the sediment diameter (*mean size*) based on the results of linear regression analysis it is known that the two variables have a negative relationship. This means that the smaller the mean size value, the greater the abrasion speed value. The difference in the diameter of the sediment (mean size) will affect the speed in the sediment transport process. In general, coarse-sized particles will be deposited at a location not far from the source, on the contrary, the finer the particles will be further transported by currents and waves, then the further they are deposited from the source. So the finer or smaller the size of the sediment grains, the larger the abrasive beach[15]. The distribution of locations in each sub-district that experiences abrasion is presented in Figures 4, 5 and 6.

Figure 4. Distribution of locations experiencing Abrasion and Accretion in Talawi District

Figure 5. Distribution of locations experiencing Abrasion and Accretion in The Lima Puluh Pesisir District

Figure 6. Distribution of locations experiencing Abrasion and Accretion in Tanjung Tiram District

Based on the results of the processing of 2017 and 2022 satellite imagery data along the coastline of The Lima Puluh Pesisir District, Talawi and Tanjung Tiram District, it can be seen that the maximum value of abrasion inthe Lima Puluh Pesisir District in 2017-2022 is 67.4 Meters and Accretion is 167.3

Meters. In Talawi District, the maximum value of the Abrasion rate is 34.3 meters, and accretion is 36.9 meters, and inTanjung Tiram District, the maximum Abrasion rate value is 126.6 meters while the accretion is 151.9 meters. In detail, the maximum value of the Abrasion rate and Accretion at the study site based on the results of satellite imagery dataprocessing is presented in Table 3. In the final period, 2017 to 2022, it can be seen that abrasion events are very dominant along th Coal Regency line, and accretion can also be found in several parts coastline in each subdistrict. Observations uring the six years of coastline changes were triggered due to changes in land conversion that were as likely to increase every year, resulting in water masses not being well distributed based on time and space. This is further exacerbated by the large number of coconut and oil palm plantations that make this area easy to dry. This makes the groundwater level lower and the material of the swamps on the surface becomes dry, especially in the dry season. When the rainy season arrives, rainfall will increase the mass of water.

Table 3. Maximum Value of abrasion and accretion rates at the Study Site

	Maximum Value (Meters)	
District	Abrasion	Accretion
Lima Puluh Pesisir	67,4	167,3
Talawi	34,3	36,9
Tanjung Tiram	126,6	151,9

The average value of the Abrasion rate in the Lima Puluh Pesisir District is 16.7 meters, and the accretion is 38.0 meters. The abrasion rate of Talawi District has an average value of 20.9 meters, and the accretion is 15.0 meters, while in the Tanjung Tiram District, the average value of its Abrasion rate is 23.4, and its accretion average is 20.0. In detail, the average value of the Abrasion and Accretion rates at the study site based on the results of satellite imagery data processing is presented in the following table.

Table 4. Average value of abrasion and accretion rates at the Study Site

	Average Value (Meters)	
District	Abrasion	Accretion
Lima Puluh Pesisirs	16,7	38,0
Talawi	20,9	15,0
Tanjung Tiram	23,4	20,0

The average value of the highest Abrasion rate per year is experienced by Tanjung Tiram District at 3.9 meters per year, while the lowest average Abrasion rate is experienced by The Lima Puluh PesisirDistrict at 2.8 meters annually. For the highest average value, the accretion rate per year is experienced by the Lima Puluh Pesisir Districts of 6.3 meters per year, while the average value of the lowest Accretion rate per year is experienced by Talawi Sub-district is 2.5 meters per year. In detail, the average value of the Abrasion and Accretion rate per year at the study site based on the results of satellite imagery data processing is presented in Table 5.

Table 5. Average Value of abrasion and accretion rate per year at The Study Site.

	Average Value Per Year (Meter)	
District	Abrasion	Accretion
Lima Puluh Pesisirs	2,8	6,3
Talawi	3,5	2,5
Tanjung Tiram	3,9	3,3

The largest abrasion area for the 2017-2022 period is in Tanjung Tiram District, which covers an area of 35.29 Ha and the smallest Abrasion area is in Talawi District, which is 1.29 Ha, while the largest Accretion area is there in the Lima Puluh Pesisir District covering an area of 23.39 Ha and the smallest accretion area in the Talawi District which is 3.52 Ha. In detail, the area of Abrasion and Accretion at thestudy site based on the results of satellite imagery data is processed in Table 6.

Table 6. Area of abrasion and accretion at the Research Site

	Spacious (Ha)	
District	Abrasion	Accretion
Lima Puluh Pesisirs	4,63	23,39
Talawi	1,29	3,52
Tanjung Tiram	35,29	13,53

4. Conclusion

Research shows that the GIS-based *Digital Shoreline Analysis System* (DSAS) has succeeded in extracting important information on the pace of coastline dynamics, both addition (accretion) and subtraction (abrasion). The dynamics from 2017-2022 are a very dynamic period of change, both for the addition and reduction of coastlines. The coastal line is important in determining the boundaries of a territory or country because to determine the boundaries of a country or the boundaries of Indonesian sea waters are measured from the coastline. From the data processing results, it can be concluded that most of the coasts of Batu Bara Regency have undergone changes that indicate the occurrence of abrasion with a degree of abrasion that is evaluated. The largest level of abrasion occurred inhe Tanjung Tiram District. There were 142 locations experiencing Abrasion and 57 Accretion locations. Coastal abrasion also occurs in Lima Puluh Pesisir District there are 38 Abrasion locations and 55 locations that experience Accretion, and in Talawi District, there are 8 locations which experienced Abrasion, and 19 locations experienced Accretion at intervals of 100 meters along thecoastline. During this period, the coast of Batu Bara Regency also experienced accretion or sedimentation. Based on the results of processing satellite imagery data, it was detected that at the location, there was a change in the coastlin in the period from 2017 to 2022.

Acknowledgments
The authors wish to thank the LPPM University of Riau and the Ministry of Research, Technology and Higher Education (Ristekdikti) for funding this research following the applied research grant with Contract Number: 1649 /UN.19.5.1.3/PT.01.03/2022.

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