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SHORELINE CHANGE DETECTION USING DSAS IN PARIAMAN CITY, WEST SUMATERA

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Received: August 18th, 2021 / Accepted: April 24th, 2022 / Published: June 30th, 2022
https://DOI-10.24057/2071-9388-2021-097

ABSTRACT. This study was conducted to determine the shoreline change that occurred in the coastal of Pariaman city due to accretion and erosion. The present study of the shoreline changes along Pariaman City was done using DSAS 5.0 vector analysis. Landsat 5 TM 1989, Landsat 7 ETM+1999 and 2011, and Landsat 8 OLI/TIRS 2020 images were interpreted first. The results indicate that during 1989 – 1999 there was abrasion with an average distance of change of 281,60 m. The period from 1999 to 2011 was characterized by accretion with an average distance of change of 15,98 m. The latter period 2011 – 2020 was dominated by accretion with an average distance of change of 53,68 m. The indicated fundamental output of the study is to provide useful scientific information and data for development planning and coastal areas, especially those managing the environment and their ecosystems, as well as for the government and related stakeholders and academics and scientists for the use of resources and space in coastal areas. Stakeholders include the city government office in Padang Pariaman, Ministry of Marine Affairs and Fisheries, Regional Disaster Management Agency and Ministry of Public Works and Public Housing of Republic of Indonesia.

KEY WORDS: Shoreline change, DSAS, abrasion, accretion

CITATION: Prarikeslan W., Arif D.A., Barlian E., Syah N., Nanda Y., Sutriani W. (2022). Shoreline Change Detection Using Dsas in Pariaman City, West Sumatera. Geography, Environment, Sustainability, 2(15), p. 116-123
https://DOI-10.24057/2071-9388-2021-097

ACKNOWLEDGEMENTS: The authors would like to thank Lembaga Penelitian dan Pengabdian Masyarakat Universitas Negeri Padang for funding this research.

Conflict of interests: The authors reported no potential conflict of interest.

INTRODUCTION

The threats that occur in the area are becoming increasingly large and include natural and anthropogenic disturbances in the form of sea-level rise, abrasion, and various activities that overexploit resources. Indeed, over 80% of the world's beaches are experiencing coastal erosion with rates ranging from 1,0 cm/year to 30 m/year, and this presents a serious hazard to many coastal regions (Addo A, Walkden, Mills & T 2008). Shoreline change detection is indispensable for monitoring coastal zoning (Nassar, et al. 2019).

Coastlines are unique features on the Earth's surface. Coastlines are one of 27 features recognized by the International Geographical Data Committee (IGDC). A coastline is generally defined as the meeting line between land and water bodies. A coastline can be interpreted easily, but it is difficult to record because water levels are always changing. To determine and record the line of meetings, a coastline is coordinated with tidal events where the shoreline is drawn based on a certain tide level (Li, Di, & Ma 2001). A coastline becomes the position of the water surface at a certain time, which occurs dynamically and can be an indicator of the occurrence of abrasion and accretion events on a beach (Genz, Fletcher, Dunn, Rooney, & J.J. 2007). The place where the interactions between tides occur is called the coastal zone. Ccoastlines continue to change due to geomorphic processes in the form of abrasion and accretion, periodic storms, flooding, and continuous changes in sea level (Nayak 2002).

The movement of shorelines over time is usually a predictable component of variation that can be regarded as a signal or trend and short-term variation or noise. Long-term phenomena, such as a rise in sea level or a shift in natural sediment supply, occur over periods of decades to centuries and produce torn predictable trends (Dolan, Fenster, & Holme 1991).

The world's population of 45% occupies coastal areas, which results in continued pressure on coastal areas as a result of the development process and exploitation of land resources, and coastal areas only cover 20% of the world's total land area (Mentaschi, Vousdoukas, Voukouvalas, & Feyen 2018). This pressure is caused by the development of the fishing, tourism, and settlement industries, which depend on conditions such as water quality, physical infrastructure, and biodiversity. Coastal residents utilize the diversity of coastal ecosystem resources in various ways, such as agricultural use, developed land, and tourism (Burt & Bartholomew 2019). This can be seen at Pariaman Beach, where dynamic changes in the coastline occur due to geomorphic processes in the form of abrasion, accretion, periodic storms, floods, and continuous changes in sea level. Pariaman Beach is relatively flat, with a slope of less than 20 degrees and depth variations ranging from 0 meters to 125 meters for distances up ot 20 km to sea. At distances of 0 meters (beach) to 5000 meters to sea, the maximum water depth is 20 meters (Ondara et al. 2018). The current velocity of the water of Kota Pariaman ranges from 0 m/s to 0.03 m/s, with the dominant direction being perpendicular to the coast. In the northern part of the waters, as well as the southern part, the dominant current comes from the north, making the area prone to abrasion and accretion.

Periodic analysis of shorelines is needed to monitor coastal areas, and the use of remote sensing is very efficient in obtaining information on shoreline dynamics (Rajasree, Deo, & Nair, 183.221-234). In addition, temporary analysis of coastal areas is also useful in understanding the distribution of shoreline dynamics and assisting in the formulation of coastal area policies (Zhang 2011).

Data time series with a spatial resolution similar to that of imagery are often needed to unify a process over a long period (Kasim & Salam 2015). Data time series with high resolution are very difficult to obtain, especially in Indonesia, which is a developing country. Therefore, to overcome problems related to data time series availability, multiscale analysis data integration can be considered. Various studies in various cases have been carried out using different spatial and temporal resolution integrations (Armenakis & Savopol 2004) (Zimmermann & Bijker 2004).

Geographic Information System (GIS) based methods are used by utilizing DSAS tools, an extension of ArcGIS developed by the USGS to calculate shoreline changes through temporal data (Qiao et al. 2018). The use of the DSAS is very important in analyzing the rate of shoreline change, as indicated by the rate of erosion and sedimentation, which is very useful in developing coastal areas economically as a basis for policy-making (Raj, Gurugnanam, Sudhakar, & Francis 2019).

The purpose of this study is to analyze multitemporal shoreline changes by utilizing satellite imagery from 1989, 1999, 2011, and 2020. Statistical image processing using DSAS 5.0 tools is useful for measuring the rate of accretion and abrasion at the study site.

MATERIALS AND METHODS

The research was conducted on the coast of Pariaman city as a representative of the west coast of the island of Sumatera, Indonesia (Fig. 1). This location is one of the locations where tourism is growing rapidly in West Sumatra. This study was carried out with GIS (ArcGIS) and image processing tools using MultiMate. This research was conducted using ArcGIS and ENVI software. Both types of software are applications for processing spatial data, Landsat satellite imagery data in this case. After geoprocessing the image data on ENVI, the coastline is extracted each year. The coastline is then converted into a shapefile, which will then be processed in ArcGIS. To see changes in the coastline, one of the tools in ArcGIS is used, namely, the DSAS. The DSAS is an add-on product in ArcGIS that builds transects from predefined baselines to estimate shoreline change. The DSAS is one of the change detection applications developed by the USGS.

Coastal analysis can be performed by utilizing various types of imagery (Fawzi & Iswari 2018). High-resolution imagery is very good for shoreline delineation because it produces detailed information but is very expensive if monitoring is performed regularly (Zhao, Guo, Yan, Wang, & Li 2008). Therefore, Landsat imagery is used, which has a fairly good resolution but at an affordable cost. The main data were obtained from Landsat satellite images at different recording times, namely, in 1989, 1999, 2011, and 2020, which covered 31 years. The selected image has a spatial resolution of 30 meters. Image descriptions are presented in Table 1.

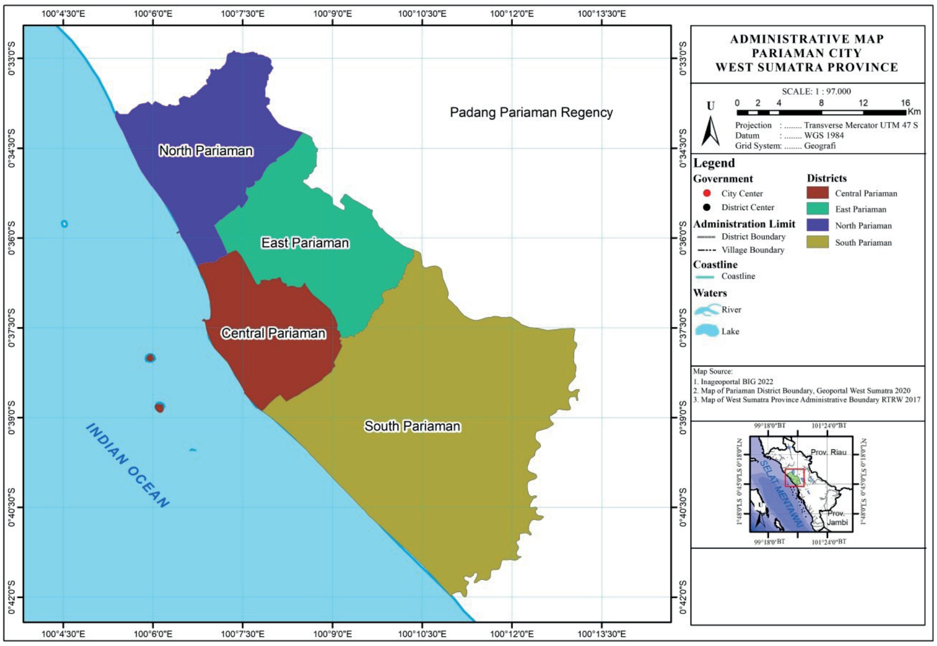


Fig. 1. Landsat image description

Table 1. The assessment of various bandwidth selection methods

Year	Path and Row	Landsat	Spatial Resolution
1989	127 – 60	Landsat 5 TM	30
1999	127 – 60	Landsat 7 ETM+	30
2011	127 – 60	Landsat 7 ETM+	30
2020	127 – 60	Landsat 8 OLI/TIRS	30

Image processing begins with image cutting to focus on the research location. The Image recording quality is different from one another, so radiometric correction is needed to improve the poor quality image caused by image damage and atmospheric noise (Ardiansyah 2015). Image calibration is performed using radiometric calibration and atmospheric correction with Fast Line of Sight Atmospheric Analysis of Spectral Hypercubes (FLSAAH). The final stage in image analysis is overlaid, so geometric correction must be performed to ensure that all images have the same spatial resolution (Darmiati 2020). Coastal extraction is performed by digitizing the on-screen image (Arief 2011). The on-screen digitalization process has the disadvantage of relying on visual ability to identify objects but has a good degree of accuracy (Kasim, Multiple Method Approach in Monitoring Coastline Change using Landsat Remote Sensing Dataset and GIS 2012). To help the shoreline extraction process, spectral analysis was performed. On Landsat 5 and Landsat 7 TM images, ETM+ images were obtained using the -5 band because they can distinguish between soil and rock objects, and shoreline extraction from Landsat 8 OLI/TIRS images was perform by using the combined RGB method (color RGB) (Nugraha 2016). It is the best method for shoreline determination using visual interpretation because it shows a clear boundaries between sea and land (Winarso & Budhiman 2001).

Data Analysis

The shoreline of Pariaman city is 6,52 km long and divided into 4 segments. The shoreline dynamics observed using DSAS 5.0 tools are the net shoreline movement and endpoint rate in 1989–1999, 1999–2011, and 2011–2020. The baseline is based on the shoreline in the topography map obtained by the Geospatial Information Agency (BIG). In the DSAS, net shoreline movement (NSM) analysis is used to determine the magnitude of the distance of temporal shoreline changes. A positive (+) NSM measurement indicates that the beach has accretions, and a negative value (-) indicates that the beach has undergone abrasion. Next, the rate of shoreline change is measured with the end point rate (EPR). The EPR method calculates the rate of shoreline change by comparing the difference between the distances of the oldest shoreline and the most recent shoreline in a predetermined period. Data that are positive (+) indicate that the beach has accretions, and data that have a negative value (-) indicate that the beach has experienced abrasion (Arif, Prarikeslan, & Syaharani 2020).
To understand the movement of the coastline in a certain time interval, it is very important to use shoreline statistics. This movement indicates the direction of change in this region. Abrasion and accretion are two important factors that cause shoreline changes. The previously generated transect lines were used to generate statistics along the coast on each transect to see trends in shoreline changes that occurred (Kallepalli, Kakani, James, & Richardson 2017).

a. Net shoreline movement (NSM). These NSM statistics provide information on the distance between the youngest and oldest shorelines, with negative or positive symbols indicating abrasion or accretion, respectively.

NSM = distance between the oldest and youngest shorelines

b. End point level (EPR). EPR statistics are easy to use to calculate and compare 2 lines.

EPR = NSM distance /time between the oldest and most recent shorelines

RESULTS

In general, the physical components of the beach in the eastern part of the study site include silt, sand, and gravel deposited from the erosion of the Bukit Barisan process. Sandy beaches are highly dynamic places due to the low resistance of materials to dynamics factors (Ward 2010). Physiographically the Pariaman city coast is a coast under wave erosion conditions, and the erosion process of the coastal area has resulted in the decline of the shoreline. The shoreline, as the object of this research, was extracted from three Landsat images. NSM and EPR measurements were performed between 1989 and 1999, 1999 and 2011, and 2011 and 2020.

Shoreline Change from 1989–1999

In 1989–1999, abrasion occurred, with an average abrasion distance of 281,60 m and an average change in the shoreline of 28,16 m/year. The shoreline change map from 1989–1999 is shown in Fig. 2.

Shoreline changes in Pariaman city between 1989 and 1999 indicate the occurrence of abrasion/erosion in the coastal area, which caused the land area to decrease. The land area decreased with an average distance of 281,60 m at a rate of 28,16 m/year. This shows that the changes that occured are very substantial, so coastal management must make decisions so that the land does not continue to experience dangerous abrasion/erosion. The abrasion that occurs is influenced by hydro-oceanographic activities such as wind, which triggers the height of the waves and the strength of the waves that hit the land.

Based on the above matrix for 1989–1999 coastal management decisions must be made so that abrasion does not continue to occur with a very large rate of change. This is in line with structural management decisions, such as decisions to protect coastal buildings, make groins along the coast at a certain length and distance, and plant crops that can protect the coast from the energy of large waves.

Table 2. Shoreline change from 1989-1999

Segment	Net Shoreline Movement (m)		End Point Rate (m/year)		Process
	(+)	(-)	(+)	(-)	
1	-	270,91	-	27,09	Abrasion
2	-	313,51	-	31,35	Abrasion
3	-	272,40	-	27,24	Abrasion
4	-	269,59	-	26,96	Abrasion
Total	-	281,60	-	28,16	Abrasion

Source: Primary data processing

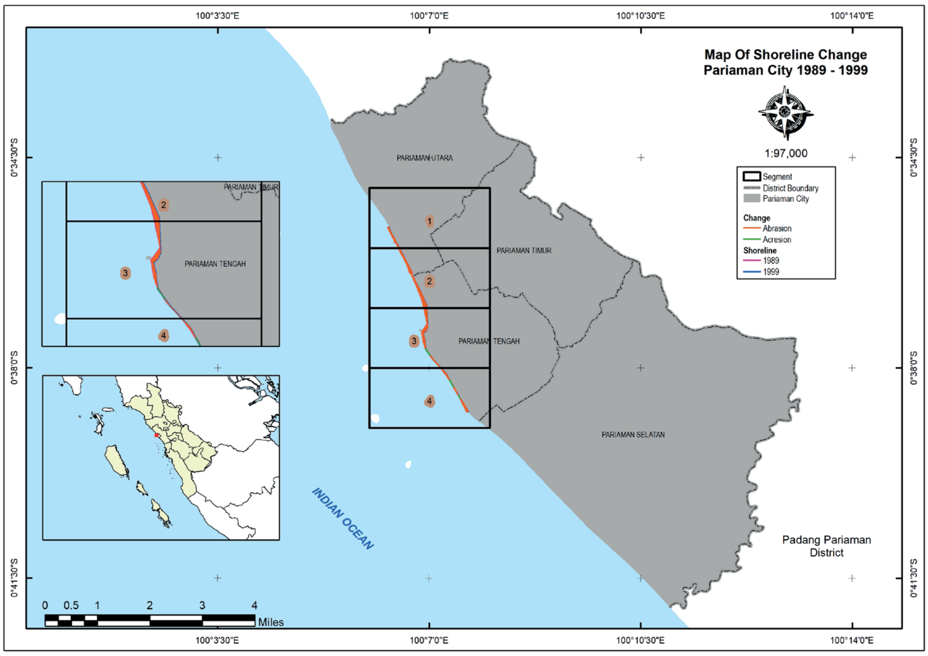


Fig. 2. Shoreline change from 1989-1999

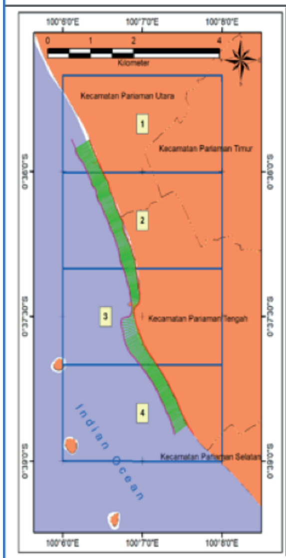
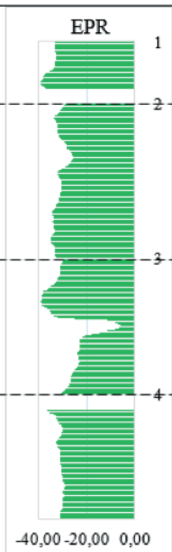
Locations of Zone	Rate of Change, EPR (m/yr)	Segment	ERP (m/yr) [Mean]	Evaluation	Risk Level	Decision
		1	-27,09	Very high erosion		Required
		2	-31,35	Very high erosion		Required
		3	-27,24	Very high erosion		Required
		4	-26,96	Very high erosion		Required

Fig. 3. Decision matrix showing shoreline evolution and risk assessment for the EPR zone between 1989 and 1999

Shoreline change in 1999–2011

From 1999–2011 the average abrasion distance was 15,98 m, with an EPR of 1,33 m/year, while the average accretion distance was 17,68 m, with an EPR reaching 1,47 m/year (Fig. 3). The dominant coastal dynamic process that acts on all segments is accretion. The longest average added distance of 29,82 m occurs in segment 3, with an EPR value of 2,48 m/year. Changes in the 1999–2011 shoreline are presented in Table 3.

Table 3. Shoreline change in 1999-2011

Segment	Net Shoreline Movement (m)		End Point Rate (m/year)		Process
	(+)	(-)	(+)	(-)	
1	10,22	-	0,85	-	Accretion
2	16,12	27,84	1,34	2,32	Abrasion
3	29,82	9,52	2,48	0,79	Accretion
4	14,56	10,58	1,21	0,88	Accretion
Total	17,68	15,98	1,47	1,33	Accretion

Source: Primary data processing

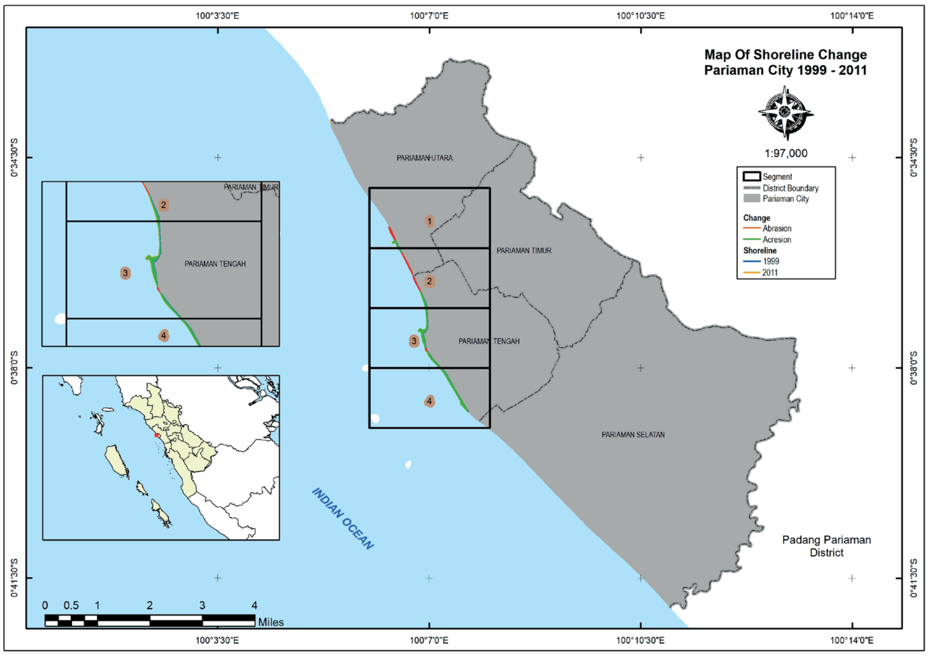


Fig. 4. Shoreline change in 1999–2011

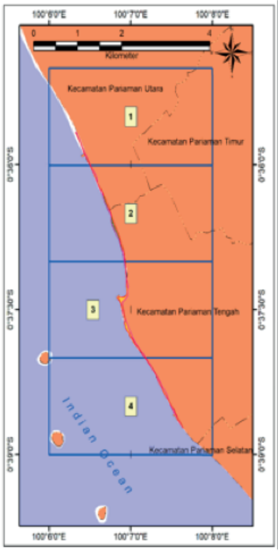
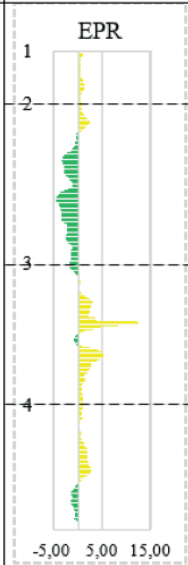
Locations of Zone	Rate of Change, EPR (m/yr)	Segment	ERP (m/yr) [Mean]	Evaluation	Risk Level	Decision
		1	0,85	Moderate Accretion		Not - Required
		2	-2,32	Very high erosion		Required
		3	2,48	Very high accretion		Not - Required
		4	1,21	Very high accretion		Not - Required

Fig. 5. Decision matrix showing shoreline evolution and risk assessment for the EPR zone between 1999 and 2011

Changes in the coastline in Pariaman city between 1999 and 2011 indicate the occurrence of abrasion and accretion in the coastal area, which causes changes in the coastline. Land increases with an average rate of change of 1,47 m/year, but along the coast, abrasion also occurs, with an average rate of change of 1,33 m/year. This shows that the changes that occur are very dynamic, so it is necessary to make coastal management decisions so that the land does not continue to experience adverse abrasion/erosion. Fig. 5 shows the shoreline change matrix or dynamics that occurred. Between 1999 and 2011, there were changes in the form of abrasion and accretion, which must be studied so that abrasion does not occur continuously. Structural management of coastal areas in the form of buildings or making groins along the coast is effective in reducing the rate of abrasion that occurs along coasts. In segment 2, it is necessary to build coastal protection structures and groins to reduce abrasion.

Shoreline Change in 2011–2020

From 2011–2020, the average abrasion distance was 5,94 m, with an EPR of 0,44 m/year, while the average accretion distance was 53,68 m, with an EPR reaching 5,96 m/year (Fig. 4). The dominant coastal dynamic process that acts on all segments is accretion. The longest average added distance of 66,52m occurs in segment 3, with an EPR value of 7,39 m/year. Changes in the 2011–2020 shoreline are presented in Table 4.

Changes in the coastline in Pariaman city between 2011 and 2020 indicate the occurrence of abrasion and accretion in the coastal area, which causes changes in the coastline. Land increases with an average rate of change of 5,96 m/yar, but along the coast, abrasion also occurs,with an average rate of change of 0,44 m/year. This shows that the changes that occur are very dynamic; therefore, it is necessary to make coastal management decision so that the land does not continue to experience harmful abrasion/erosion.

Table 4. Shoreline change in 2011-2020

Segment	Net Shoreline Movement (m)		End Point Rate (m/year)		Process
	(+)	(-)	(+)	(-)	
1	58,94	7,69	6,55	0,88	Accretion
2	31,13	-	3,46	-	Accretion
3	66,52	3,93	7,39	0,44	Accretion
4	58,13	-	6,46	-	Accretion
Total	53,68	5,94	5,96	0,44	Accretion

Primary data processing

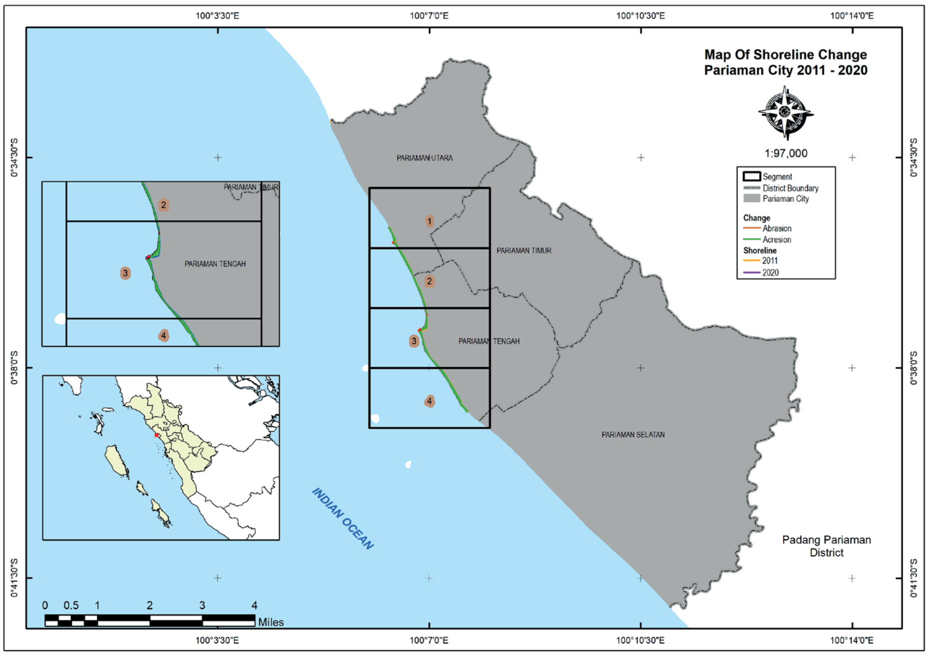


Fig. 6. Shoreline change in 2011–2020

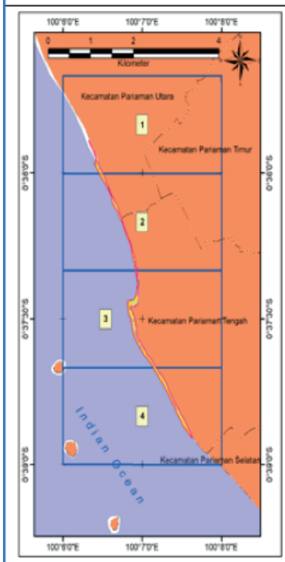
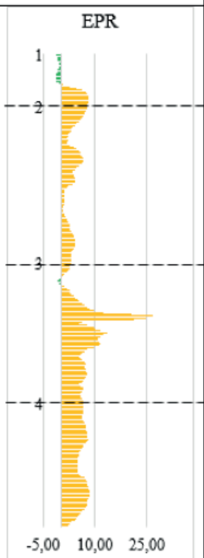
Locations of Zone	Rate of Change, EPR (m/yr)	Segment	ERP (m/yr) [Mean]	Evaluation	Risk Level	Decision
		1	6,55	Very high Accretion		Not - Required
		2	3,46	Very high Accretion		Not - Required
		3	7,39	Very high Accretion		Not - Required
		4	6,48	Very high Accretion		Not - Required

Fig. 7. Decision matrix showing shoreline evolution and risk assessment for the EPR zone between 2011 and 2020

Fig. 7 shows the matrix or the dynamics of shoreline changes that occur. Between 2011 and 2020, there was a change in the form of accretion, which must be studied so that abrasion does not occur continuously. Structural management by making coastal groins along the coast is effective in reducing the rate of abrasion that occurs along the coast. From 2011–2020, the land area continues to increase. This indicates that in the upstream area, there is soil damage or erosion, which causes 30% of the sediment to enter the river and move upstream so that the land area increases or undergoes accretion.

Segment 3 is an area where the accretion process is very dominant. This condition is caused by its position near the river mouth. Sediment input resulting from the erosion process of upper lands gathers in this region. Structural management is also one of the factors in the accretion process. At this location groins were built to protect tourist sites. Based on NSM and EPR measurements, during each observation period, a very dominant accretion process occurred due to hydro-oceanographic factors. This process increases the risk of abrasion due to waves on the beach. Underwater morphological conditions also influence the refraction process and eventually form a longshore current (Bird, 2008). Furthermore, sediments resulting form the erosion of upper lands are carried by longshore currents. The trend of shoreline dynamics also increased, with the erosion rate reaching 281,60 m in 1989-1999, 15,98 m in 1999-2011 and 5,94 m in 2011–2020.

With the characteristics and dynamics of coastal and marine areas, development potentials and problems, and government policies for the marine sector, optimal and sustainable coastal and marine development can only be achieved through integrated coastal and marine management.

DISCUSSION

Coastline changes have an impact on coastal ecosystems. Ecosystem life is disrupted by coastline changes. The erosion of sandy beaches represents a real threat to coastal economies. This is especially the case for those territories that derive their family income from tourist services, being a major factor for the socio-economic development of tourist communities (de paula 2021). This can occur due to the influence of human activities as well as hydro-oceanographic factors. Based on wave data obtained from wind data calculations show that the dominant wave from the direction of west, while based on the beach geomorphology, sand shoal (Sandy Spit) generally trending north-south. This shows that the wave forms an angle when touch the shoreline and the direction of the current parallel to the coast (longshore current) dominant from the north, causing the abrasion process continues to progress towards north along with the construction of groynes in along the coastline of Pariaman (Solihuddin, Tb.2011).Therefore, changes in coastlines must be handled. As a direct result of this finding, there will hopefully be efforts to overcome abrasion naturally (back to nature), such as planting coconut trees and fir trees around coasts to reduce the impact of greater abrasion as well as building breakwater and coastal protection buildings and moving seawards. Government management has also considered the condition of the river mouth, which is the meeting point between upstream activities and marine activities (waves and tides). Optimal management must be continued to reduce the risk of coastal abrasion. By comparison with other coastal areas of the world, the analysis of erosion data shows that in European coastal zones, 1500 km are artificial coasts (Balearic Islands, Gulf of the Lion, Sardinia, Adriatic, Ionian and Aegean coasts) occupied by harbors (1250 km) (Corine 1998). According to the data collected by Corine, approximately 25% of the Italian Adriatic coast and 7.4% of the Aegean coast show an evolutionary tendency toward erosion, whereas approximately 50% of the Euro-Mediterranean coastal zone is considered stable. Coastal states commit themselves to the integrated management and sustainable development of coastal areas and the marine environment under their national jurisdiction. The regional significance of this research is knowing areas with very high erosion and accretion extents so that it is easier to find solutions to solve these problems (Benasa G. 2006).

CONCLUSIONS

The calculated shoreline change statistics are NSM and the EPR. NSM refers to the amount of change over time, and the EPR refers to the rates of change. Therefore, further analysis (trend investigation and hazard line construction) was carried out using the EPR.

Shoreline change is a threat to cities that have coastal areas. Changes in coastlines are an indicator of coastal dynamics due to the iterative reactions between hydro-oceanography and human activities. From 1989–1999 the process of abrasion or a reduction in a land area of 281,60 m dominated the dynamics that occurred in Pariaman city. Then, between 1999 and 2011 and 2011 and 2020, accretion or an increase in land area dominated.

The changes (abrasion and accretion) occurring in this region were investigated using change detection of shorelines extracted from satellite imagery spanning 31 years. The overall change is estimated from 1989–2020. The impact of local phenomena is indicated by short-term trends, while long-term trends are used to calculate the overall change.

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