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ANALYSIS OF SHORELINE DYNAMICS FOR COASTAL MANAGEMENT PRACTICE IN PARIAMAN, WEST SUMATERA

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ABSTRACT: Coastal dynamics have a significant effect on the use of coastal resources where more than 60 percent of cities in the world develop in this region and use it for urban infrastructure, settlements, and economic development. shoreline change is one of many indicators of coastal dynamics which is the result of interaction between biotic, abiotic and human activities which further influences policy and management practices for coastal areas. This paper presents the results of study on shoreline dynamics in Pariaman, West Sumatra using vector analysis in DSAS 4.3 between 1988-2003 and 2003-2018. The shoreline is interpreted from three Landsat images, namely Landsat 5 TM 1988, Landsat 7 ETM + 2003 and Landsat 8 OLI / TIRS 2018 that have been corrected (radiometric and geometric). The shorelines derived from Landsat combined with shoreline from topographic map by Badan Informasi Geospasial (BIG) as baseline for net shoreline movement (NSM) and end point rate (EPR) analysis. Then, The data of shoreline changes is used as a basis for qualitative analysis of local government policies on coastal management. The results show that shoreline changes occur dynamically wherein 1988-2003 abrasion occurred with an average rate of 2.88 m/yr and accretion of 1.64 m/yr while in the 2003-2018 an abrasion rate of 2.76 m/yr occurred and accretion rate 1.12 m/yr. This condition occurs along with the increase of longshore current speed. Some of the locations also have faster abrasion and accretion rates due to structural built.

Keywords: Shoreline change, DSAS, Abrasion and accretion, Coastal management

1. INTRODUCTION

Coastal areas globally are under pressure from the development process as part of the exploitation of land resources which only covers 20% of total world land but is occupied by more than 45% of the world's population [1][2]. This pressure is caused by the availability of abundant resources in coastal areas that contribute to the development of the fishing, tourism and settlement industries which basically depend on conditions such as water quality, physical infrastructure, and biodiversity diversity [3]. Coastal residents utilize the diversity of coastal ecosystem resources in various ways such as agricultural use, developed land and tourism [4]. These developments directly affect the balance of coastal ecosystems.

Coastal conditions throughout the world have unique morphological characteristics and resource availability which further facilitates the development of coastal areas especially in economic development [5][6]. Pariaman is one of the developing coastal areas in West Sumatra. Based on report [7], the number of industries increased significantly to 372 percent in the period 2013-2019 The development of these assets indicates the growth of the level of land use in coastal areas and increases the risk of land quality degradation that can result in beach erosion, reduced fish production, decreased groundwater quality, and seawater intrusion [8].

Coastal area development increases the risk of disasters due to coastal dynamics [9]. The dynamics of the coastal environment are caused by agents such as wind, waves, tides, currents and also human intervention that changes the dynamic balance of coastal morphology [10]. Based on research in developing coastal areas [11], population activity contributes to changing shorelines. Human intervention in terms of increasing population, assets, and land subsidence also intensifies damage in coastal areas [12]. However, changes in shoreline are not only caused by population activities but also the dynamics of the sea and its coast [13]. Periodic analysis of shorelines is needed for monitoring coastal areas and the use of remote sensing is very efficient in obtaining information on shoreline dynamics [14]. In addition, temporal analysis of coastal areas is also useful in understanding the distribution of shoreline dynamics and helping in the formulation of coastal area policies [15].

Analysis of shoreline dynamics can be done in various ways, including terrestrial surveys and remote sensing-based GIS. Terrestrial surveys generally produce accurate information but require a lot of resources (time, labor, and costs) [16]. Therefore, GIS-based methods are used by utilizing DSAS tools, an extension program from Arcgis developed by USGS to calculate shoreline changes through temporal data [17]. The use of 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 the coastal area economically as a basis for policymaking [18].

The purpose of this study is the analysis of multitemporal shoreline changes utilizing satellite imagery. Statistical image processing using DSAS tools is useful for measuring the rate of sedimentation and abrasion at the study site. In addition, observations were also conducted to investigate coastal area management based on coastal dynamics.

2. MATERIAL AND METHODS

The study was conducted on the Pariaman coast, part of the west coast of the island of Sumatra, Indonesia. Administratively it is located in eight sub-districts which are enclosed in two regencies namely Padang Pariaman Regency and Pariaman City. This location is one of the developing locations in West Sumatra.

2.1 Image Processing

Coastal analysis can be done by utilizing various types of imagery. High-resolution imagery is very good for shoreline delineation so that it produces detailed information, but is very expensive if monitoring is done regularly [19]. Therefore, Landsat imagery is used which has a fairly good resolution but at an affordable cost. The main data was obtained from Landsat satellite images in different recording times, namely in 1988, 2003, and 2018 which covered 30 years. The selected image has a spatial resolution of 30 meters. Image descriptions are presented in table 1.

Table 1 Landsat Image Description

Year	Path and Row	Landsat	Spatial Resolution
1988	127-60	Landsat 5 TM	30 m
2003	127-60	Landsat 7 ETM+	30 m
2018	127-60	Landsat 8 OLI/TIRS	30 m

Image processing begins with image cutting to focus on the research location. Image recording quality is different from one another so radiometric correction is needed to improve the bad quality image caused by image damage and atmospheric noise. The image calibration process is carried out using Radiometric Calibration to sharpen the image appearance and atmospheric correction using FLAASH (Fast Line of Sight Atmospheric Analysis of Spectral Hypercubes) to eliminate atmospheric interference. The final stage in image analysis is overlay so that it needs to be done geometric correction to ensure all images have the same spatial resolution. Coastal extraction is done by digitizing on-screen. The onscreen digitization process has the disadvantage of relying on visual ability to distinguish objects but has a good degree of accuracy. To help the shoreline extraction process, spectral analysis was performed. On Landsat 5 TM images and Landsat 7 ETM + images performed using the -5 utilizing band because they can distinguish soil and rock objects and shoreline extraction in Landsat 8 OLI / TIRS images were processed by using the combined RGB method (color RGB) because it's the best method for shoreline determination using visual interpretation because it will show a clear boundary between sea and land [20].

2.2 Data Analysis

The Padang Pariaman and Pariaman City shoreline are 58 km long and divided into 17 segments of 3 km each to facilitate the analysis process. The observed shoreline dynamics are the net shoreline movement and end point rate in 1988-2003 and 2003-2018 using DSAS tools. The baseline is based on the shoreline in topography map by the Geospatial Information Agency (BIG). In DSAS, the Net Shoreline Movement (NSM) analysis is used to find out the magnitude of the distance of shoreline changes temporally. A positive (+) value on the NSM measurement results indicates the beach has accretion, and a negative value (-) indicates the beach has abrasion. Next, measurements are taken of the rate of shoreline change with the End Point Rate (EPR). The EPR method calculates the rate of shoreline change by comparing the difference in distance of the oldest shoreline to the most recent shoreline in a predetermined time period. Data that is positive (+) indicates that the beach has accretion and data that has a negative value (-) means that the beach is experiencing abrasion.

3. RESULT AND DISCUSSION

In general, the physical condition of the beach is composed of silt, sand, and gravel deposited material resulting from the erosion of the Bukit Barisan process in the eastern part of the study site. Sandy beach is a highly dynamics place due to the low resistance materials to beach dynamics factors [21]. (Ward, 2010). Physiographically, the Pariaman coast is a wave erosion coast, which is characterized by the erosional process of the coastal area marked by the decline of the shoreline. The shoreline as the object of research was extracted from the three Landsat images. Measurements made were NSM and EPR between 1988-2003 and 2003-2018.

3.1 Coastal Changes In 1988-2003

Changes in the shoreline measurement results show that in 1988-2003 was abrasion with average abrasion rate reaching -2.49 m/yr and a change in the average distance of a changing shoreline of -37.99 m, while the average accretion rate that occurred of 1.42 m/yr with an average shoreline distance of 21.70 m. Shoreline changes map in 1988-2003 is shown in Fig. 2.

The process that occurred in the 1988-2003 period was abrasion dominant, this condition is seen from the comparison of the dynamics of erosion and accretion in the observed period of the year, the erosion process is very dominating. Even in segment 12 and segment 17, there is no accretion process. The highest average abrasion rate occurred in segment 17 of -5.06 m/yr with an average shoreline change distance of -77.23 m. The highest accretion rate occurs in segment 8 which is 3.58 m/yr with a mean shoreline change distance of 35.41 m. Changes in the shoreline of 1988-2018 are presented in Table 2.

Table 2 Shoreline change in 1988-2003

Segment	Net Shoreline Movement (m/yr)		End Point Rate (m)		Process
	+	−	+	−	
1	1,32	-1,97	20,19	-29,99	Abrasion
2	0,76	-1,78	11,65	-27,12	Abrasion
3	1,88	-2,19	28,66	-33,39	Abrasion
4	0,25	-3,53	3,75	-53,83	Abrasion
5	1,10	-1,83	16,74	-27,90	Abrasion
6	0,73	-3,29	11,08	-50,16	Abrasion
7	1,25	-4,62	19,13	-70,44	Abrasion
8	3,58	-2,41	54,66	-36,81	Accretion
9	2,52	-0,63	38,48	-9,58	Accretion
10	1,17	-1,43	17,85	-21,80	Abrasion
11	1,37	-3,43	20,94	-52,32	Abrasion
12	-	-3,79	-	-57,86	Abrasion
13	1,18	-2,04	17,99	-31,15	Abrasion
14	0,66	-2,25	10,07	-34,34	Abrasion
15	1,90	-0,75	28,91	-11,45	Accretion
16	1,67	-1,34	25,47	-20,45	Accretion
17	-	-5,06	-	-77,23	Abrasion
Total	1,42	-2,49	21,70	-37,99	Abrasion

Based on measurements of coastal dynamics in the same period (Fig. 1), the average recorded wind speed was 4.74 knots from the southwest. This condition directly affects the formation of waves in the same period reaching up to 0.8 m height. this condition directly affects the littoral process of abrasion and accretion in the coast.

wind generally affects the process of sediment movement where fine sediments will be easily transported from the coast. this condition will have an impact on the occurrence of abrasion and erosion depending on the condition of the wave energy. morphological conditions can be responsible for the increase in wave energy. deep nearshore morphology tends to cause an increase in wave energy which in turn increases the erosion process.

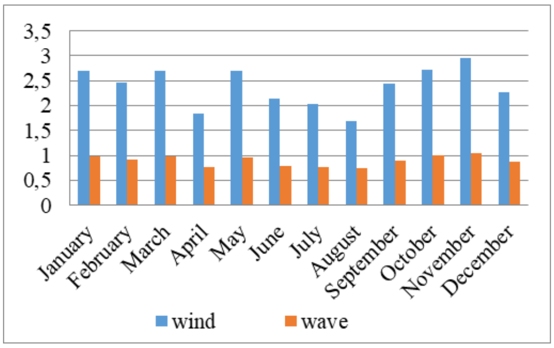

Fig. 1 Wind Speed and Wave generated

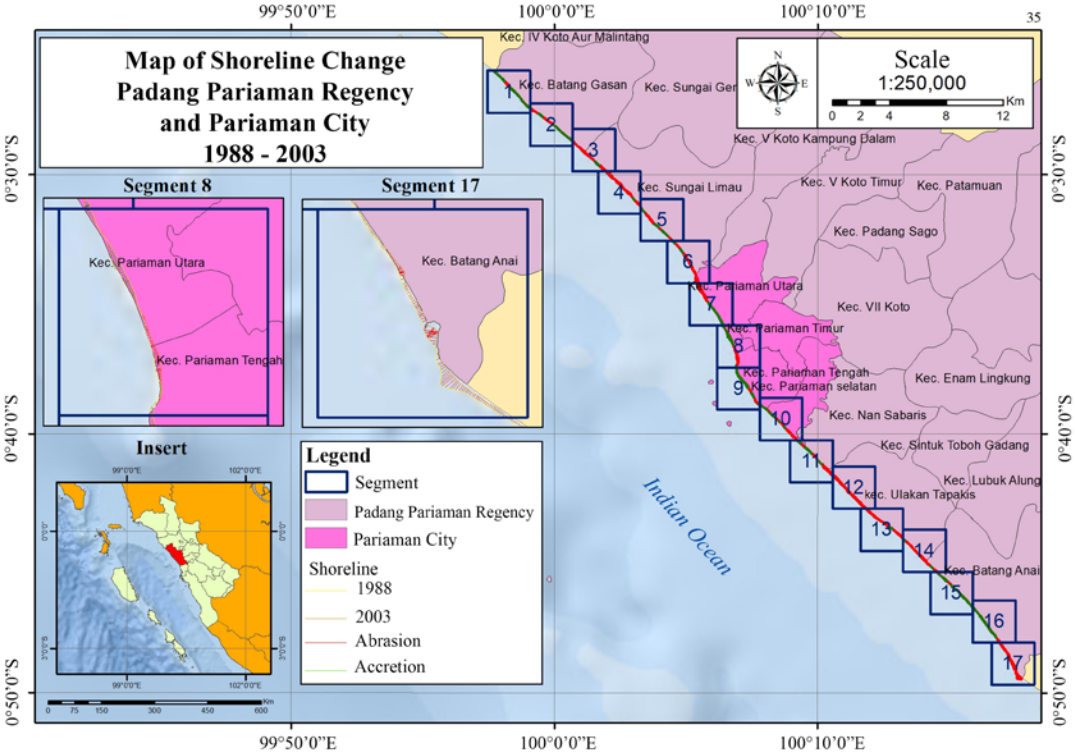

Fig. 2 Shoreline Change in 1988-2003

3.2 Coastal Changes In 2003-2018

In 2003-2018 the average abrasion rate was -2.73 m/yr with EPR -41.86 m while the average accretion rate was 1.03 m/yr with EPR reaching 15.80 m (Fig. 4). The dominant beach dynamics process that works on all segments is abrasion. even a small segment (2, 12, 13, 15, and 16) did not experience accretion in the observed time period. The highest abrasion rates occurred in segments 17 and 15, each of -3.89 m/yr and -3.61 m/yr with EPR values of -59.65 m and -55.28 m, respectively. The highest average accretion rate of 1.58 m/yr occurred in segment 6 with an EPR value of 24.25 m. Changes in the 2003-2018 shoreline are presented in table 3.

Table 3 Shoreline change in 2003-2018

Segment	NSM (m/yr)		EPR (m)		Process
	+	−	+	−	
1	0,78	-3,04	11,92	-46,59	Abrasion
2	-	-2,81	-	-43,06	Abrasion
3	1,32	-3,03	20,25	-46,51	Abrasion
4	1,33	-2,16	20,39	-33,04	Abrasion
5	0,12	-2,24	1,88	-34,34	Abrasion
6	1,58	-2,31	24,25	-35,38	Abrasion
7	0,71	-3,54	10,85	-54,22	Abrasion
8	1,08	-2,56	16,48	-39,24	Abrasion
9	1,26	-3,47	19,30	-53,13	Abrasion
10	0,82	-2,24	12,60	-34,40	Abrasion
11	1,27	-1,81	19,46	-27,81	Abrasion
12	-	-2,80	-	-42,95	Abrasion
13	-	-1,73	-	-26,45	Abrasion
14	1,12	-1,99	17,20	-30,50	Abrasion
15	-	-3,61	-	-55,28	Abrasion
16	-	-3,21	-	-49,17	Abrasion
17	0,98	-3,89	14,98	-59,65	Abrasion
Total	1,03	-2,73	15,80	-41,86	Abrasion

Coastal dynamics in 2003-2018 (Fig. 3) showed a wind speed of 4.54 knots from the southwest. Such conditions have an impact on the process of wave formation which reaches 1 meter. This certainly has a direct impact on the process of abrasion and accretion in coastal areas. Waves and wind as the driving agent of coastal dynamics taking place in spatial and temporal scales so that it affects sediment transport and ultimately has an impact on the accretion and abrasion process. Wind also affect current density and subsequently affect wave circulation patterns.

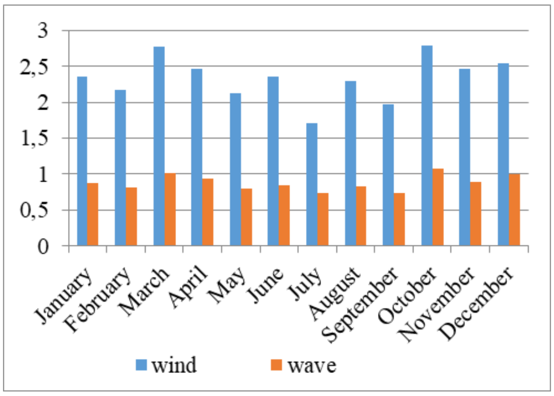

Fig. 3 Wind Speed and Wave generated 2003-2018

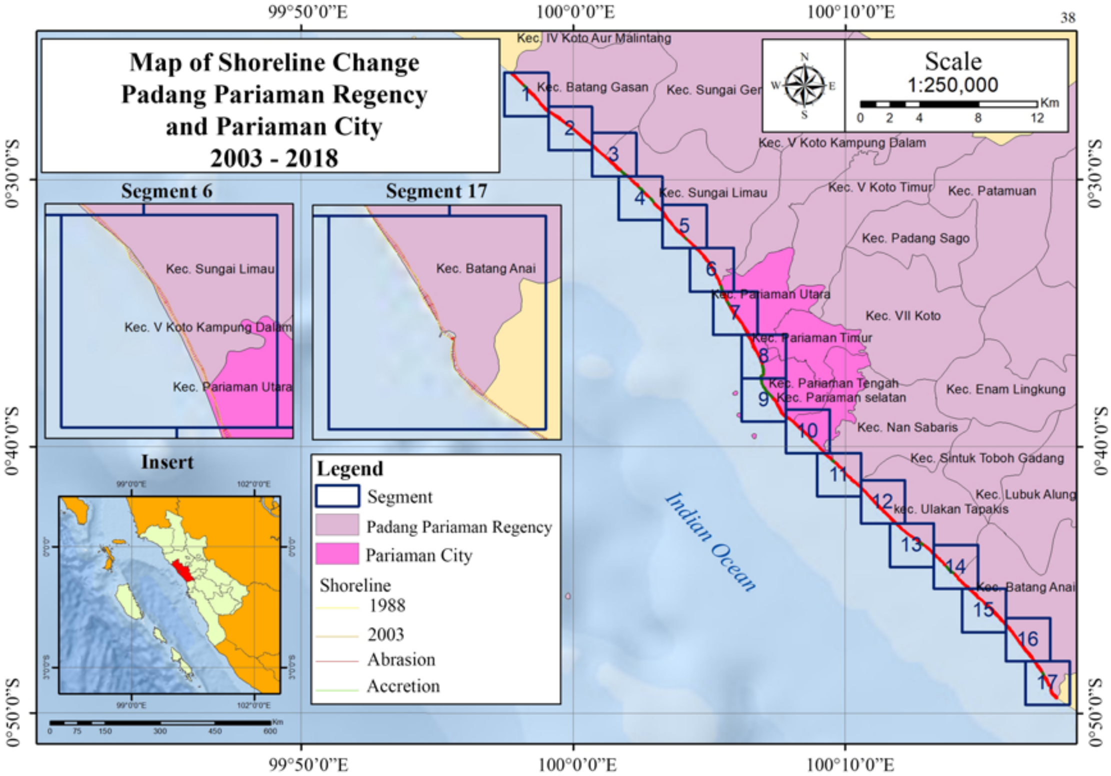

Fig. 4 Shoreline Change in 2003-2018

In 1988-2003 the abrasion process occurred 140.84 ha while the accretion was 54.35 ha. Dominant abrasion occurred in segment 17, namely 20.44 ha. The dominant accretion process occurs in segment 9 of 10.47 ha and the area of abrasion that occurs is only 0.28 ha. The 2003-2018 abrasion period occurred at 211.35 ha while the accretion occurred only at 9.83 ha. the highest abrasion process occurred in segment 15 of 18.78 ha while the highest accretion occurred in segment 9 covering an area of 2.74.

Segment 9 is an area where the accretion process is very dominant. This condition is caused by its position near the river mouth. Sediment input resulted from the erosion process of upper lands gathering in this region. Structural management is also one of the factors in the accretion process, in which this location was built groin to protect tourist sites.

Based on NSM and EPR measurements, at each observation period, a very dominant abrasion process occurred due to hydro-oceanographic factors. The wind factor directly impacts the wave height. In the September-March period, an increase in wind speed was followed by a significant increase in wave height. 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 [22]. Furthermore, sediments which are the result of erosion of upper lands will be carried by longshore currents. The trend of shoreline dynamics has also increased, where the period of 1988-2003 erosion rate only reached 2.49 m/yr while the 2003-2018 period reached 2.73 m/yr. climate change may be one of the causes of the increasing dynamics of shorelines (Dada, Agbajea, Adesinaa, & Asiwaju-Bello, 2019).

4. CONCLUSION

Coastal dynamics are a threat to developing coastal cities. Coastal change is one indicator of coastal dynamics that is the result of the interaction of factors such as waves, currents, wind, sediment input, and human activities. Abrasion is one of the dominant processes that occurs where a beach retreat can reach 41 meters with an abrasion rate of up to 2.73 meters/year. The trend of shoreline dynamics has also increased in each observation period which is a threat to human activity. The structural method is one of the shoreline management methods that has been carried out by constructing groins for sediment traps to increase beach accretion.

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