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SHORELINE CHANGES ANALYSIS OF WEST PASAMAN REGENCY, WEST SUMATERA

Ruzana Dhiauddin[1)] & Semeidi Husrin[2)]

[1)]Institute for Coastal Resources and Vulnerability Agency for Marine and Fisheries Research and Development, MMAF
[2)]Research and Development Center for Marine and Coastal Resources,
Agency for Marine and Fisheries Research and Development, MMAF

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ABSTRACT

[Shoreline Changes Analysis of West Pasaman Regency, West Sumatera] According to the Hazard Vulnerability Index from BNPB, Indonesia's National Disaster Management Authority, West Pasaman Regency is one of the area with high vulnerability index located in West Sumatra Province, where all of its coastal areas are adjacent with The Indian Ocean. Coastal erosion and extreme waves have been reported to be the most prominent hazards, beside anthropogenic factors, along West Pasaman coastal area. This research was conducted to estimate the loss of shoreline in the area, and how far it has been shifted over the years. Thus, to achieve the objective, the dynamic of shorelines from different time scales was analyzed using quantitative data (satellite images, Netherland Map of Indonesia, and Indonesia topography map), and the statistical output of DSAS (Digital Shoreline Analysis System). The results were validated by a field survey in 2011 and interviewed local people in 2015. We found the highest erosion, about 8.44 m/y, has been occurring in Sasak Ranah Pasisie District, which separate 14 Km from where the highest accretion, about 23.7 m/y, in Kinali District took place.

Keywords: shoreline changes, West Pasaman, coastal area, erosion, accretion, DSAS

INTRODUCTION

West Pasaman, one of the regencies in the West Sumatra Province, which is passed by the equator is located between $0^{o}03'$ N to $0^{o}11'$ S and $99^{o}10'$ E to $100^{o}04'$ E. It has an area of 3,887.77 Km^2 or about 9.29 % of West Sumatera. Morphology of the regency was formed by the structural area, volcanic, fluvial and marine dynamics, which makes the variety of the slopes. Most of its terrain are flatland and undulated, while the rest of them are hilly and mountainous. With this geomorphological condition, the topography of West Pasaman tends to be varied that leads the elevation ranges between 0 to 2,912 m ASL.

West Pasaman Regency has about 800.47 Km^2 of coastal area with 152 Km of shoreline, which adjacent to the Indian Ocean as shown by Figure 1. Besides frequent storm from the Indian Ocean, the economic activities and population density around coastal area might cause the water zones between the coastal and mainland area are vulnerable to the disasters (Gersanadi, 2013). According to Pujotomo (2009), a coastal zone was defined as the interface of land and sea, very dynamic and constantly changing in short term, medium and long terms.

In 2008, the wave in west coast of Sumatera Island reported reached 4 meters in height raised the possibility of erosion along the coastal area. The prone areas in West Sumatera Province related to this hazard are Pesisir Selatan Regency, Padang City, Padang Pariaman Regency, Pariaman City, Agam Regency, and West Pasaman Regency. BNPB (Badan Nasional Penanggulangan Bencana) as Indonesia's National Disaster Management Authority recorded some high wave/erosion events in West Pasaman Regency. Those events described in Table 1.

Based on the problems mentioned above, the objective of this research is to measure shoreline changes (erosion or accretion) along the coastal area. By measuring the shorelines over different time series, we successfully determined how much its changing, the locations, interfering factors and possible mitigation measures in the future.

Corresponding author:
Jl. Pasir Putih I Ancol Timur, Jakarta Utara 14430. Email: ruzanadhiauddin88@yahoo.com

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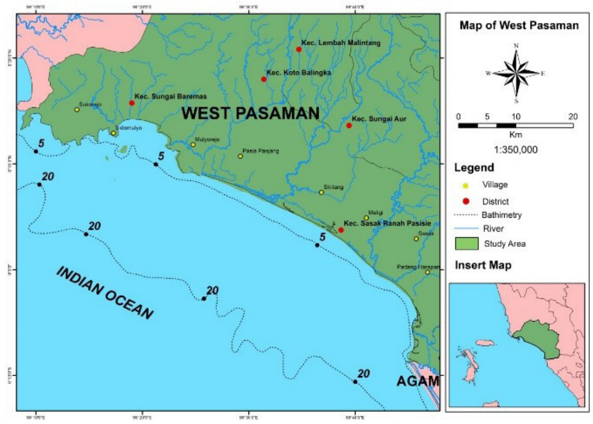

Figure 1. West Pasaman Regency as the study area.

Table 1. Coastal erosion events in West Pasaman Regency (source: BNPB, http://dibi.bnpb.go.id)

No.	Date (dd/mm/yy)	Damage	Annotation
1	17/05/2007	46 houses severely damaged 136 houses slightly damaged	Sasak Ranah Pasiesie Sub District
2	08/03/2012	58 houses severely damaged	-

METHODOLOGY

Shoreline Delineation

In this research, basically we applied the quantitative method. Secondary data that necessary for measuring shoreline changes, presented in Table 2, were collected and processed to generate the shoreline for each time series.

The coastal area of West Pasaman Regency was selected as the study area where the shoreline change measurement took place. The spatial analysis was carried out by overlaying the delineated satellite imageries and Netherland Map of Indonesia (West Pasaman Regency). All the delineating and overlaying were processed by using ArcGIS 10.0 with 1: 24,000 scales. This step only produces shorelines for each year. Although without any exact numbers, the changes still can be figured out visually. The details of how the images were processed is presented by the following diagram (Figure 2).

Shoreline Analysis

All the delineated shorelines, as one of the required data, that were generated manually from previous step must be processed further to obtain the shoreline changes rate in meter/year. To complete this step, first we need a tool to analyze the shoreline changes automatically, called DSAS (Digital Shoreline Analysis System). It is a freely available software application that works within the Environmental Systems Research Institute (ESRI) Geographic Information System (ArcGIS) software. For this research, we employed DSAS 4.3 under ArcGIS 10.0. The DSAS has been applied in some researches by Oyedatun (2014) at Crantock Beach (southwest England), Kabuth, *et al.* (2014) in Denmark, Romine, *et al.* (2012) and Genz, *et al.* (2007) in Hawaii.

After DSAS is completely installed, we need another required data called the baseline. Baseline also has to be delineated manually, as well as the shorelines. It might be created offshore, onshore or the combination of both. In this research we combined the offshore and the onshore methods that refer the 1954's shoreline flow as the oldest available shoreline. Baseline is necessary for DSAS to generate the transect lines, the line that cast perpendicularly from the baseline to the shorelines, in order to measure the distance between one shoreline to another. The following figure illustrates the necessary steps in DSAS work flow (Figure 3).

The distances between shorelines for each transect and shoreline changing rate were calculated by the selected statistical method. In this study, we applied End Point Rate (EPR) method, which measures the distances between the oldest shoreline and the recent one (or the selected shoreline) over time elapse between shorelines,

Table 2. Geospatial Data

No.	Data (Scale/ Resolution)	Year/ Date (dd/mm/yyyy)	Source	Extracted Information
1	Landsat imagery (30 m)	29/04/2003	http://earthexplorer.usgs.gov/	Shoreline
2	Netherland Map of Indonesia (1:25,000)	1954	-	
3	Indonesia Topography Map (1:10,000)	2004	BAKOSURTANAL	Administrative boundary

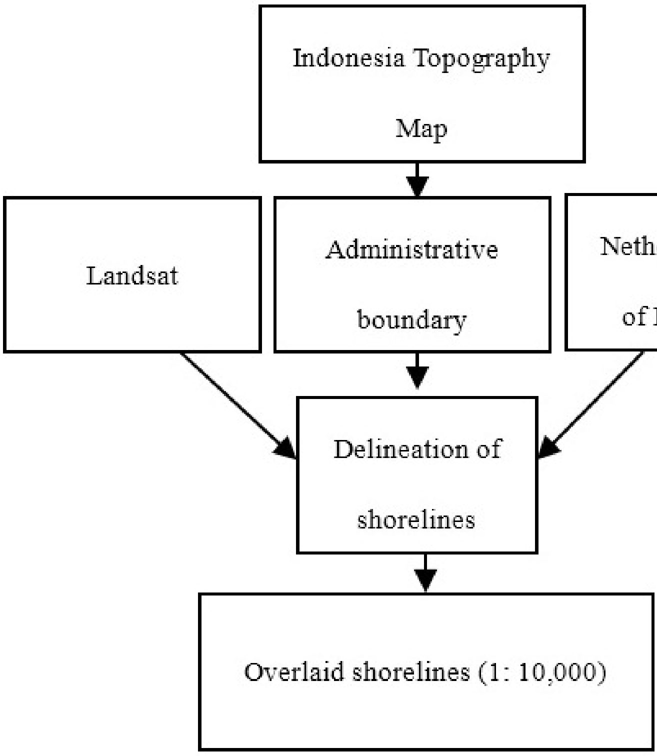

Figure 2. Shoreline Processing Flowchart.

$$\mathrm{EPR} = \frac{distance\ in\ meters}{time\ between\ oldest\ and\ most\ recent\ shoreline}$$

The results were the rate of shorelines changes in West Pasaman Regency, either in positive or negative signs, which is the final output of the study.

RESULTS AND DISCUSSION

Overlaid Shorlines

The first result is a map of the overlaid shorelines of year 1954, 2003, and 2015 (Figure 4). It shows the changing of shoreline's position of West Pasaman Regency over the years. The zoomed part inside the black box indicates that shorelines were receded year by year. In another part, both coastal erosion and accretion were occurred. The exact numbers of the changes and its location will be explained in the following sections.

Shoreline Changing Rate

The calculation of shoreline position was executed by employing numbers of shorelines along transect line. The establishment of transect line is always perpendicular to the baseline with a user-defined length and spacing between the transects. This transect lines cannot be generated without the baseline, because it was treated as the starting point of the transect lines. The measurements could only be performed when the transect line intersect with at least two shorelines.

About 74 baselines were developed along West Pasaman Regency's coastal area. It was placed in both offshore (seaward) and onshore (landward) positions, as described in Figure 5, with respect to the 1954's shoreline. Transects were defined 500 meters

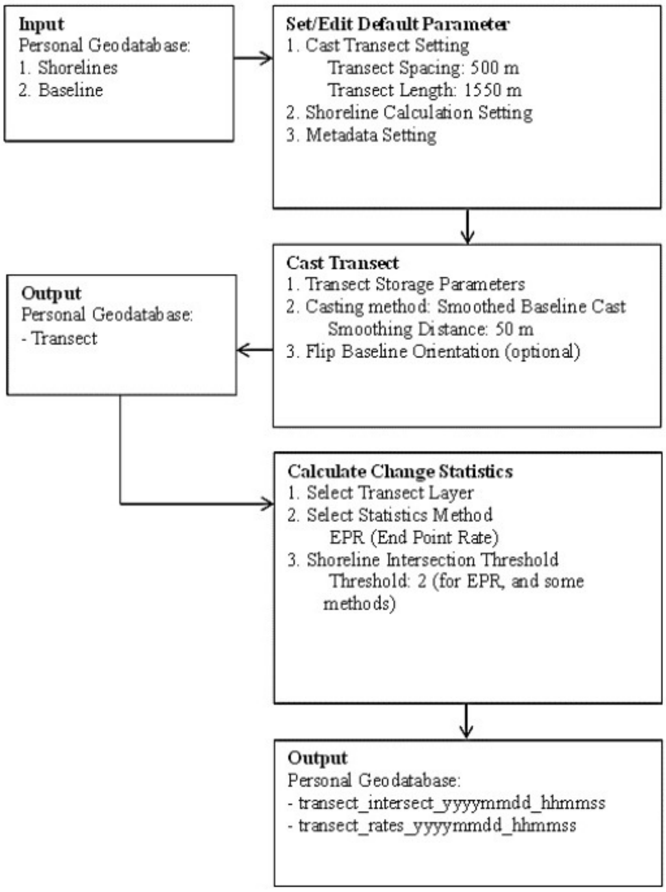

Figure 3. Workflow shoreline changes rate calculation (after Thieler, *et.al.,* 2009).

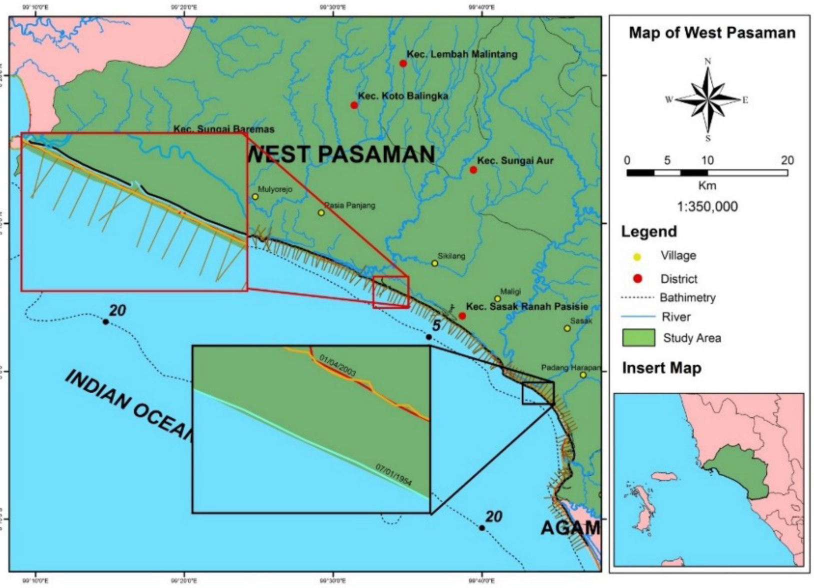

Figure 4. The overlaid shorelines map of year 1954 (blue), 2003 (red), and 2015 (orange).

spacing and 1,550 m length for each transect. Hence, 270 transect lines were generated, ordered from the west to the east.

In general, the changing rates were obtained by averaging the shorelines distance and time gap between. Moreover, EPR method, that was implemented for each transects line, measures shoreline movement of the oldest and the most recent one and then divided by year lapse in between. Consequently, not all available shorelines were utilized, only shorelines of year 1954 and 2015, which denoted the changes, happened in 61 years all over West Pasaman. It has to be noted that in applying EPR, user may not set the shoreline intersection threshold exceeding the number of available shorelines. In addition, numbers of changing rates follow the number of transect lines. Therefore, we decided to take the changing rate average of all transects in order to derive the approximate rate of shoreline movement along West Pasaman coastal area between year 1954 to 2015. Table 3 summarizes shoreline changing rate together with the number of transect lines for related rate and its category. Only rate for 242 transect lines are presented below due to another 28 lines were not intersected with both shorelines of 1954 and 2015, which gave no calculated distance value.

The table indicates that shorelines were changed in negative and positive sign. Based on the category adapted from a research conducted by Aboudha and Woodroffe around Australian coastal area in 2006, we came up with 5 categories of the shoreline changes. We found there were stable changes occurred in Sungai Baremas, Koto Balingka, Sasak Ranah Pasisie and mostly found in Sungai Aur District. Meanwhile, coastal erosion appeared almost along West Pasaman coastal line, which passes through Sungai Baremas, Koto Balingka, and Sasak Ranah Pasisie District, where all coastal erosion levels occurred in these three districts. We identified that the highest coastal erosion rose in Sasak Village, administratively part of Sasak Ranah Pasisie District, which reached 8.44 m/y. This result is agreed with 2011 survey of West Sumatera's north coastal area (Fig. 6 and 7). It found that Sasak Ranah Pasisie District was severely affected by coastal erosion since 1980's that made the village along its coastal area shifted around 1 Km, (Ramdhan *et al,* 2011). Triatmodjo (2014) in his book of Perencanaan Bangunan Pantai (Coastal Building Planning) also classified Sasak as one of village with coastal area degradation.

Moreover, accretion developed in 5 districts; Sungai Beremas, Koto Balingka, Sungai Aur, Sasak Ranah Pasisie and Kinali District. The biggest accretion, about 23.7 m/y, was found in Kinali District that also where the sediment commonly transported. Finally, we took the average rate of shoreline changes to identify which event commonly occurred in our study area, and then 0.667 m/y came up as result that indicates West Pasaman Regency experiencing moderate coastal erosion. All the locations of where the shoreline changes happened are presented in Figure 6 below.

In general, this regency's coastal area experienced both coastal erosion and accretion at the same time. The biggest value of coastal erosion

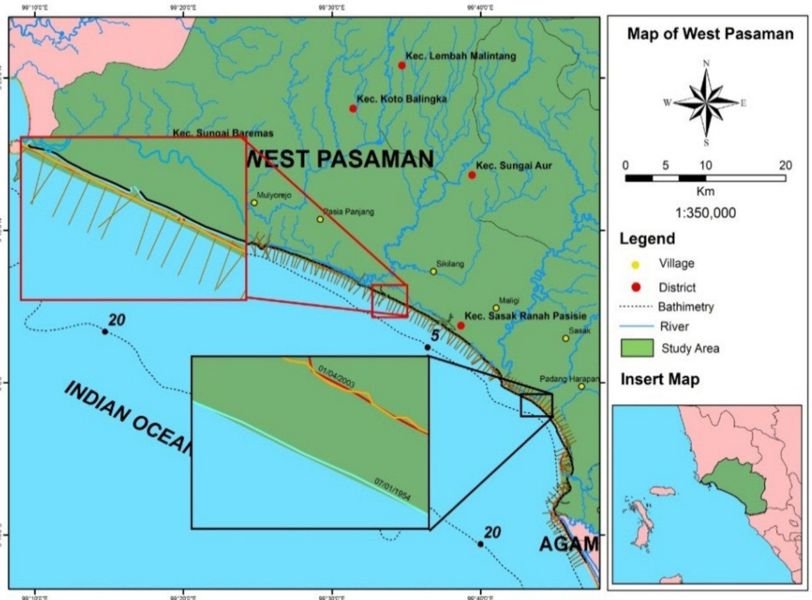

Figure 5. Detail view of baselines (black) and transects (brown) line development nearby Sikilang Village.

Table 3. Changing rate of several transect lines

No.	End Point Rate (EPR) (m/y)	Number of transect line(s)	Category
1.	2.01 --23.7	55	Accretion
2.	1.01 --1.98	48	Stable
3.	-0.99 -- 1	82	Erosion (Moderate)
4.	-1.96 -- -1.11	12	Erosion (High)
5.	-8.44 -- -2.02	45	Erosion (Very high)

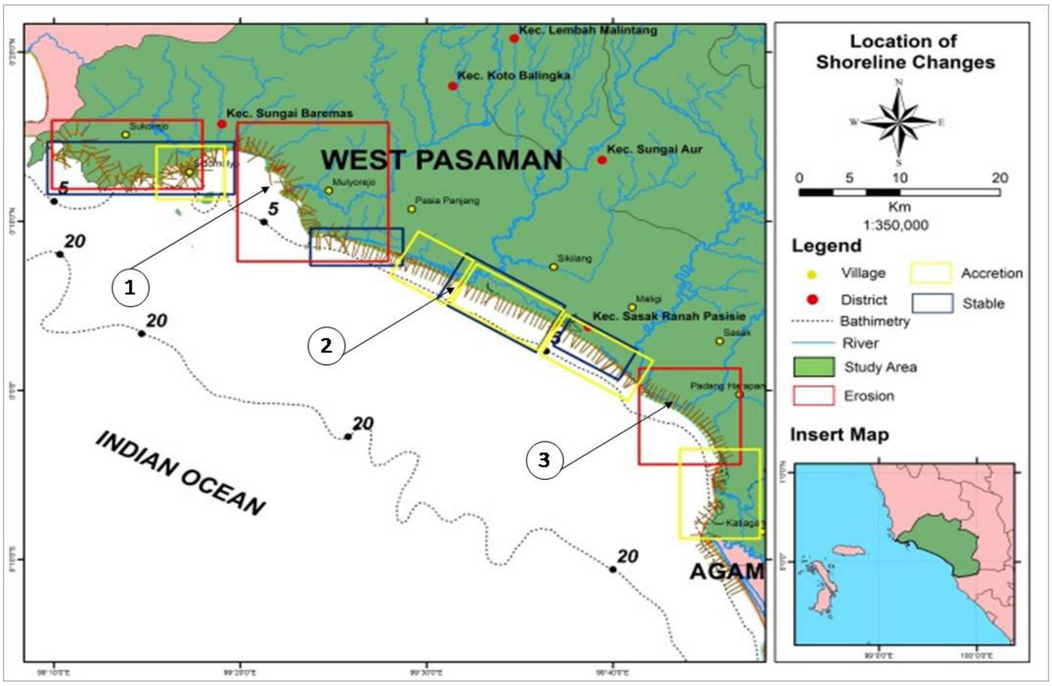

Figure 6. The shoreline changes location, which distributed all around West Pasaman Regency.

Figure 7. Shoreline conditions in West Pasaman Regency, 1: Erosion in Air Bangis, 2. Acretion in Sikabau dan 3. Erosion in Sasak (see Fig. 6) (Ramdhan *et al.,* 2011).

and accretion were found in Sasak Ranah Pasisie and Kinali District, respectively, which 14 km apart. This brings us to the assumption that the sediments of eroded coastal area transported to the nearby area (accretion). Based on the interview of local people conducted in 2015, we found that the shoreline has been decreasing year by year along Sasak Ranah Pasisie District, especially after the storm occurrence. A published map classified West Pasaman Regency into low to high coastal erosion area in 1:7,500,000 scale map confirm our result (P3SDLP, 2013). However, we provide more detailed map with 1: 350,000 scale and give detail information of erosion/ accretion rates.

As described in Geological Map of Padang, Painan and Lubuk Sikamping Sumatera, most of West Pasaman's structure formed by alluvium sediment (Qal) that consisted of silt, sand, and gravel, which made West Pasaman more vulnerable toward coastal erosion hazards. Beside geological structure, Kabuth, *et al.* (2014) stated that shoreline dynamics also related with hydro-oceanography processes such as wave and litoral currents, tidal and extreme events. The tidal type in West Sumatera is a mixed dominant semidiurnal, which means there are two high and one low water occur each day. We discover from the previous study (Ramdhan *et al.,* 2011) that mean tidal in West Sumatera ranges between 0.9138 m to 1.0957 m, which classified into very low (≤ 0.99) and low (1.0 – 1.9) microtidal. Furthermore, the same study also found that dominant waves, generated from 10 years wind datas, came from the west generating longshore currents along the coastline towards Southeast direction. Strong longshore currents are combined with drastic changes of landuse upstream and the existance of coastal structures at certain areas have made severe coastal erosion inevitable as observed in Sasak (Figure 7).

CONCLUSION

The assessment of shoreline change around West Pasaman Regency was successfully done by employing time series shoreline derived from Landsat imageries and DSAS supporting software. The average result, 0.667 m/y, indicates that generally the regency is experiencing coastal erosion event, where the highest occurred in Sasak Village in Sasak Ranah Pasiesie District about 8.44 m/y. In addition, we believe that the changing of the shoreline that lead to erosion, accretion and even coastal hazards is closely related to the geological structure, climate and hydro-oceanography of the specific area. While the assessment of its vulnerability would be sufficient if land cover, population density around coastal area and other important parameters also analyzed.

Finally, we hope this research can provide baseline information for managing coastal area along West Sumatera Province, especially in West Pasaman Regency. Moreover, authorities need to pay attention of giving proper education about coastal area buffer zone and coastal hazards quick response and management to the people around the coastal area. Futhermore, the establishment of proper planned sea walls or other types of shoreline protection (e.g. green belts) may help to stabilze the coastline.

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