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Analysis of Shoreline Changes Period 1991 – 2001 Pasumpahan Island, Padang, West Sumatera

Analisis Perubahan Garis Pantai Periode 1991 – 2001 Pulau Pasumpahan, Padang, Sumatera Barat

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Abstract

Pasumpahan Island is an area that is affected by currents, waves and sedimentation processes because it is directly adjacent to the Indian Ocean and the mouth of the Pisang River, this causes changes in the coastline in the form of abrasion and accretion on the island. This study aims to determine the effect of currents, waves, and sedimentation processes on the rate of change of the shoreline for 10 years (1991-2001) on Pasumpahan Island. This research was conducted in March 2022 on Pasumpahan Island, Padang City, West Sumatra Province. The method used is a survey method to obtain primary data including current speed, heightwaves and sediments. The study method used is a quantitative method with a multi-temporal satellite imagery approachusing the Digital Shoreline Analysis System (DSAS) software with the End Point Rate (EPR) approach. The results of the analysis of current velocity values ranged from 0.21-0.28 m/s, wave heights ranged from 0.24-0.55 m, the average diameter of the sediment ranged from 0.83-1 Φ. The results of image data processing show that there has been a change in the shoreline in the form of low category abrasion (0.4 m/year), stable (1.42 m/year), and accretion (3.07 m/year) on Pasumpahan Island.

Keywords: Currents, Waves, Sedimentation, Shoreline Changes, Pasumpahan

Abstrak

Pulau Pasumpahan merupakan daerah yang dipengaruhi oleh arus, gelombang dan proses sedimentasi karena berbatasan langsung dengan Samudera Hindia dan muara Sungai Pisang, hal ini menyebabkan perubahan garis pantai berupa abrasi dan akresi pada pulau tersebut. Penelitian ini bertujuan untuk mengetahui pengaruh arus, gelombang, dan proses sedimentasi terhadap laju perubahan garis pantai selama 10 tahun (1991-2001) di Pulau Pasumpahan. Penelitian ini dilakukan pada bulan Maret 2022 di Pulau Pasumpahan, Kota Padang, Provinsi Sumatera Barat. Metode yang digunakan adalah metode survey untuk mendapatkan data primer meliputi kecepatan arus, tinggi gelombang dan sedimen. Metode kajian yang digunakan adalah metode kuantitatif dengan pendekatan citra satelit multi temporal menggunakan *software Digital Shoreline Analysis System* (DSAS) dengan pendekatan *End Point Rate* (EPR). Hasil analisis nilai kecepatan arus berkisar antara 0,21-0,28 m/s, tinggi gelombang berkisar antara 0,24-0,55 m, diameter rata-rata sedimen berkisar antara 0,83-1 Φ. Hasil pengolahan data citra menunjukkan telah terjadi perubahan garis pantai berupa abrasi kategori rendah (0,4 m/tahun), stabil (1,42 m/tahun), dan akresi (3,07 m/tahun) di Pulau Pasumpahan.

Kata Kunci: Arus, Gelombang, Sedimentasi, Perubahan Garis Pantai, Pasumpahan

1. Introduction

The shoreline is an imaginary line that divides the sea from the land. According to (Undang-Undang Informasi Geospasial No. 4 Tahun 2011 pasal 13), the coastline is the meeting line between the land and the sea which is affected by sea tides. In its definition, the coastline is divided into 3 types, namely the lowest low tide coastline (LAT), the average high sea level coastline (MSL), and the highest high tide coastline (HAT). On the Indonesian Coastal Environment Map and the National Marine Environment Map, the coastline is determined based on the position of the lowest ebb sea level.

West Sumatra has vast waters, which are about 138,750 km^2, with a coastline length of 375 km, with as many as 186 islands lined up from north to south of West Sumatra (DKP Provinsi Sumatera Barat, 2008). Pasumpahan Island is one of the small islands in the city of Padang. The morphology of Pasumpahan Island is a flat island and partly hilly with white sandy beaches. Based on (Decree of the Mayor of Padang with Decree No. 224/2011) Pasumpahan Island has been made one of the regional marine conservation areas (KKLD) in Padang City.

Pasumpahan Island is one of the coastal areas that is prone to sea level rise, tidal flooding, abrasion and accretion because it is in a low topographical area. Beach abrasion or accretion is caused by sediment transport along the coast, causing sediment to move from one place to another (Triatmodjo, 2012). Abrasion is a process of erosion or reduction of land caused by the activity of sea waves. The process of abrasion can continue dynamically so that special countermeasures are needed so that erosion on the coastal plains does not take place continuously (Satyanta *in* Putra *et al.*, 2016).

Shoreline changes can be monitored using sensing satelite technologyremote control multi temporally. Remote sensing is a technique that allows people to collect data without going directly to the field. Shoreline data obtained from landsat image processing using the Digital Shoreline Analysis System (DSAS) software with the End Point Rate (EPR) approach (Anggraini, 2018). This study aims to determine the rate of change of the coastline and determine the effect of currents, waves, and sedimentation processes on shoreline changes in the Pasumpahan Island area

2. Material and Method

2.1. Research Location

This research was carried out on Pasumpahan Island in March 2022. Data analysis was carried out at the Physical Oceanography and Chemical Oceanography Laboratory, Department of Marine Science, Faculty of Fisheries and Marine, Universitas Riau.

2.2. Method

The research was conducted using a survey method in which direct observations were made in the field (in situ) to obtain primary data. The primary data taken is current velocity, wave, and sediment data. For secondary data, Landsat image data for 1991 and 2001 were downloaded from the USGS (United States Geographical Survey) website. Analysis of landsat image data was carried out on DSAS using the End Point Rate (EPR) approach, this method is used to calculate the rate of change of the coastline by dividing the distance between the oldest coastline and the current coastline by time. Where a distance that is positive (+) means the coastline is advancing and data that is negative (-) means the coastline is retreating (Setiani, 2017)

2.3. Procedur

2.3.1. Station Determination

The location of the research station is located on Pasumpahan Island, Teluk Kabung District, Padang City, West Sumatra Province. Measurements of currents, waves and sampling of sediments were carried out at 6 stations within ±50 m of the coastal area around Pasumpahan Island (Figure 1). The position and number of research stations were determined based on the circumference of Pasumpahan Island, which is about 1,916 m long and 6 station points are considered to represent changes in the coastline that have occurred on Pasumpahan Island. Station positions are determined using a GPS (Global Positioning System).

2.3.2. Current Velocity Measurement

Current speed is measured using a current drogue, which has a rope length of 2 m. The current drogue is released into the waters at the same time as the stopwatch is activated. Then wait until the rope is fully stretched and record the time. A compass is used to determine the direction of the current. Current speed is measured at 6 station points around Pasumpahan Island. Stations 1, 2, and 3 are located on the east side of the island, these locations are part of the waters adjacent to the mouth of the Pisang River. Meanwhile, stations 4 and 5 are located on the north and west sides of the island, which is part of the waters directly adjacent to Sikuai Island, and station 6 is located on the south side of the Pasumpahan island.

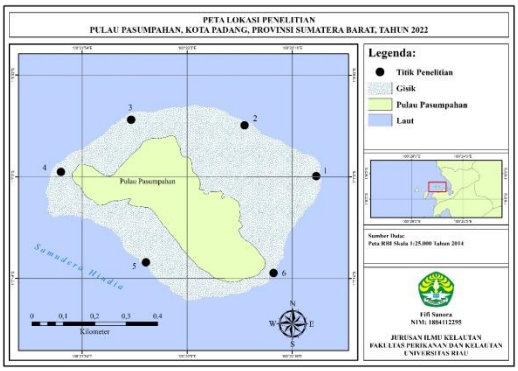

Figure 1. Map of Research Locations

2.3.3. Survival Rate of Vannamei Shrimps

Measurement of wave height is carried out using a scale pole that is plugged into the waters. Data collection was carried out by recording the peak and trough values of the waves using a camera for 3 minutes. Wave height is measured at six station points around Pasumpahan Island. Stations 1, 2 and 3 are located on the east side of the island; these locations are part of the waters adjacent to the mouth of the Pisang River. Meanwhile, stations 4 and 5 are located on the north and west sides of the island, which are part of the waters directly adjacent to Sikuai Island, and station 6 is located on the south side of the Pasumpahan Island.

2.3.4. Sediment Data Collection

Beach sediment collection was carried out once at 6 stations as much as 500 g. Furthermore, the samples were taken to the laboratory for analysis of sediment samples. The procedure for determining the type of sediment was carried out based on references to Rifardi (2008). In the grain analysis of coastal sediments, the wet sieving method was used. The results obtained are the average diameter or mean size (Ø) obtained from the graphical method according to, Folk and Ward (1957) in Rifardi (2001).

3. Result and Discussion

3.1. General Condition of Research Area

Geographically, Pasumpahan Island is located in the administrative area of Teluk Kabung Selatan Village (Sungai Pisang), Bungus Teluk Kabung District, Padang City. The coordinates are located at 01'07'04" LS and 100'22'03" ES. The morphology of Pasumpahan Island is a flat island and partly hilly with white sandy beaches. Directly adjacent to the Indian Ocean and the mouth of the Pisang River. The research location consists of 6 stations located around Pasumpahan Island. For more details can be seen in Table 1 and Figure 2.

Table 1. Research Locations on Pasumpahan Island

Station	Location	Coordinate
I	East Side of the Island	100˚ 22' 02.73" E 01˚ 06' 56.57" S
II	East Side of the Island	100˚ 21' 56.80" E 01˚ 06' 57.83" S
III	North Side of the Island	100˚ 21' 50.86" E 01˚ 07' 02.07" S
IV	West Side of the Island	100˚ 21' 52.92" E 01 ˚07' 07.55" S
V	West Side of the Island	100˚ 22' 03.85" E 01˚ 07' 15.39" S
VI	South Side of the Island	100˚ 22' 12.80" E 01˚ 07' 12.82" S

a b

Figure 2. Research Locations

3.2. Flow Speed

The results of the analysis of current velocity values in the coastal waters of Pasumpahan Island can be seen in Table 2.

Table 2. Current Speed and Direction Data

Station	X (Longitude)	Y (Latitudes)	Current Speed (m/s)	Flow Direction
1	100.367425	1.115714	0.25	31^o to BD
2	100.3657778	1.116064	0.24	226^o to BD
3	100.3641278	1.117242	0.21	308^o to BL
4	100.3647	1.118764	0.21	211^o to BD
5	100.3677361	1.120942	0.28	221^o to BD
6	100.3702222	1.120228	0.26	248^o to BD

Based on the observations that have been made, the current velocity in the waters of Pasumpahan Island consists of slow and medium categories. The current speed of the slow category ranges from 0–0.25 m/s at stations 1-4. Medium-speed currents, namely 0.25–0.5 m/s are found at stations five and six. Longshore currents can transport sediment that has been moved by waves, waves coming towards the coast can cause coastal currents that play a role against the process of sedimentation or beach abrasion. Therefore, a large current velocity will cause beach abrasion and accretion due to the faster sediment transport process.

There are several areas that experience accretion due to slow currents and are close to the mouth of the Pisang River, where sediment deposition occurs and land is added (Muryani, 2010). Currents in the slow category indicate an area experiencing accretion protected from high currents and waves. While moderate category currents indicate an area experiencing abrasion, currents in this category are destructive to coastal areas (Halim *et al.*, 2016). The sedimentation process that occurs along the coast can cause harm to coastal communities because, in addition to affecting shoreline instability, the sedimentation process can cause siltation of river mouths and can disrupt existing fishing boat traffic.

3.3. Wave Data

The results of the analysis of wave values in the coastal waters of Pasumpahan Island can be seen in Table 3.

Table 3. Wave data for Pasumpahan Island

Station	X (Longitude)	Y (Latitudes)	Wave Height (m)	Wave Energy (Nm/m^2)
1	100.367425	1.115714	0.53	344,1
2	100.3657778	1.116064	0.55	370.56
3	100.3641278	1.117242	0.52	331,24
4	100.3647	1.118764	0.51	318,62
5	100.3677361	1.120942	0.24	70,56
6	100.3702222	1.120228	0.25	76,56

Based on the observations that have been made, the wave heights in Pasumpahan Island waters consist of low and very low categories. The low category wave height ranges from 0.5 – 1 m at stations 1-4 and the very low category is <0.5 m at stations 5 and 6. The highest wave energy is at station 2 with a value of 370.56 nm/ m^2 and the lowest value is found at station 5 with a value of 70.56 nm/m^2.

Sea waves are one of the parameters that affect shoreline changes. Waves will undergo a transformation from the deep sea to the shallow sea. Based on the analysis conducted, the wave height at the study site ranged from 0.24-0.55 meters. The height of the waves that are formed is caused by the wind blowing on the surface of the seawater. The wind is one of the energies that can generate waves on a surface. Based on BMKG data (Meteorology, Climatology, and Geophysics Agency), the average wind speed in the waters of Pasumpahan Island is 1.5-5.9 m/s. The wind speed obtained shows that the friction from the wind pressure affects the wave height that is formed at the study site. The longer the wind blows, the higher the waves are formed. Wave height also affects wave energy, the higher the wave, the higher the energy formed. Large wave energy can cause beach abrasion and accretion.

The waves at the research location include constructive and destructive waves. In areas that experience constructive accretion (beach forming), it tends to precipitate beach material. In areas that experience abrasion, there are waves that are destructive (beach destroyers) that can erode the beach. There are other parameters that trigger abrasion and accretion in several areas, such as the absence of coastal protection structures and the lack of coastal protection vegetation.

3.4. Sediment Characteristics

The results of the analysis of the average diameter (Mz) of sediments in Pasumpahan Island waters range from 0.83 to 1 Φ (Table 4).

Table 4. Average Diameter Value (Mean size)

Station	Mean Size (Φ)	Classification
1	0.83	*Coarse Sand*
2	0.8	*Coarse Sand*
3	1	*Medium Sand*
4	0.9	*Coarse Sand*
5	1	*Medium Sand*
6	1	*Medium Sand*

Based on the observations that have been made, it is found that the diameter of the sediment on Pasumpahan Island is included in the category of coarse sand and medium sand with a value of 0.83 – 1 Φ, included in the category of unstable sediment with a relatively fast movement. This is due to the location of the island that is directly influenced by the flow of the Pisang River estuary. Sediment particles from the Pisang River are carried by the current so that they experience precipitation that causes the accretion process to occur. In addition, Pasumpahan Island is also directly facing the open sea, namely the Indian Ocean, so sediment sources originating from the high seas undergo a transportation process until they are finally deposited into the sediment.

3.5. Shoreline Changes 1991-2001

Shoreline changes at each research station from 1991-2001 can be seen in Table 5.

Table 5. Shoreline Changes at Each Research Station 1991-2001

Station	Value (m/yr)	Category
1	- 0.71	Low Abrasion
2	- 0.95	Low Abrasion
3	1.26	Stable
4	2,29	Accretion
5	- 0.86	Low Abrasion
6	2.05	Accretion

Based on the table above, there is a change in the coastline in the low abrasion, stable, and accretion categories. Low abrasion occurs at station 1 (-0.71 m/yr), station 2 (-0.95 m/yr), and station 5 (-0.86 m/yr). Changes in the shoreline categorized as stable occur at station 3 with a value of 1.26 m/year. Accretion occurs at stations 4 and 6 with values of 2.29 m/year and 2.05 m/year. However, changes to the shoreline in the low abrasion, stable, and accretion categories also occur at several other points on Pasumpahan Island that can be seen in Figure 3.

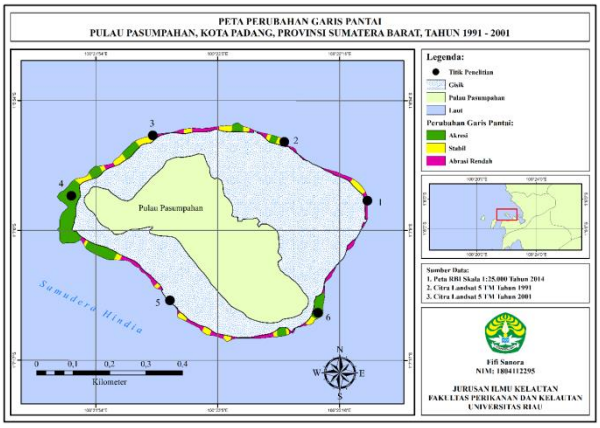

Figure 3. Shoreline Change Map 1991-2001

Here's the value changes in the coastline on Pasumpahan Island in 1991-2001 as a whole: a) Accretion: The land area of Pasumpahan Island increases by ±2.11 to 5.76 m/yr, with an average speed of 3.07 m/yr. Dominated on the west side of the island. b) Low Abrasion: The land area of Pasumpahan Island is decreasing ±0.34 m to -1.1 m/yr, with an average speed of 0.4 m/yr. Dominated on the east, north, and south of the island. Stable: The land area did not experience significant changes, namely ±1.02 m to 1.97 m/year, with an average speed of 1.42 m/year. Dominated on the north, west, and south of the island. The results of the percentage change in coastline status in 1991-2001 on Pasumpahan Island can be seen in Table 6.

Shoreline changes in 1991-2001 had 283 transect lines with 10 distances between lines, observed based on the occurrence of accretion, low abrasion, and stable phenomena on Pasumpahan Island. The results showed that the shoreline changes that occurred on Pasumpahan Island from 1991-2001 were dominated by low category abrasion (51.23%; 145 transects), accretion (22.61%; 64 transects), and stable (26. 14 %; 3 transect lines).

Table 6. Percentage of Shoreline Change Status in 1991-2001

Status	Number of Transects	Percentage (%)
Low Abrasion	145	51.23
Accretion	64	22.61
Stable	74	26.14
Total	283	100

Abrasion is caused by currents and waves that block the beach, causing the beach material to erode and land subsidence occurs. The accretion that occurs is caused by the flow of sediment particles carried by currents and waves from the mouth of the Pisang River. This is in accordance with Istiqamah *et al.* (2016), accretion occurs in coastal waters adjacent to river mouths and areas with small wave energy and the percentage of storms. Large volumes of freshwater runoff due to prolonged rains can cause the sedimentation process and sediment transport processes from river bodies to the sea, as well as human activities (anthropogenic) in managing land. Coastal accretion can cause silting evenly towards the sea that will gradually form a plain in the form of a delta or raised land.

4. Conclusion

Based on image processing using DSAS, it is known that the rate of change of coastline in 1991-2001 for the abrasion process is 150 m, with an average rate of 0.4 m/year. Other changes are the accretion of 72 m with an average speed of 3.07 m/year, and there are areas that do not experience significant changes or are in a stable condition of 60 m with an average speed of 1.42 m/year. Waves, current velocity, and average diameter of coastal sediments are parameters or natural factors that can determine the size of the abrasion and accretion that occurs.

5. Suggestion

A more detailed study of currents and waves is needed to describe the sediment transport processes that occur in areas experiencing abrasion and accretion. In addition, it is very necessary to do a ground check over a longer period to get measurement results in the field that is close to the results of image interpretation. With this research, it is hoped that continuous preventive action and rehabilitation of the coastal environment on Pasumpahan Island can be taken.

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