A dynamics condition of coastal environment in Padang City-Indonesia

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Abstract. Padang City is located on the West coast of Sumatra Island that borders directly with the Indian Ocean. The coastal region of the city stretches from Pasia Jambak beach, Muara Anai in the North to Sungai Pisang in the South. The coast of South section is different from the coast of North section, because the Southern coastline is heterogeneous because there are many small bay, small islands and narrow beaches directly adjacent to the volcanic hills. This research aims to determine the dynamics condition of a coastal environment based on the characteristic (length, velocity, energy, and height), sediment transport value, accretion/abrasion factor value, and coastal equilibrium in Padang City. The method used in this study is the calculation of wavelength (L₀), wave velocity (C), wave energy (E), run-up height (Hₛ), and sediment transport (Q) to determine accretion/abrasion factor and equilibrium (G₀). Furthermore, it is done by Geographic Information System (GIS) approach to spatial information of research location. Research result shows that coastal region (beach) in Padang City tends to experience accretion along the beach of Pasia Sabalah, Panjalinan North, Panjalinan South, Parkit, Purus South, Purus North, Muaro Padang, Air Manis North and Pasia Putih. While the abrasion conditions occur in Pasia Jambak, Parupuk Tabing, Bung Hatta University beach, Air Manis South and Sungai Beremas.

1. Introduction

The coastal region is very dynamic since the energy from ocean and land meet. The changes around coastal region occur slowly or fast, the depends on the equilibrium between topographic, rock structure and its behavior towards the wave, tidal, wind, and biological factor [1]. The process of equilibrium between the sediment source and the force acting on the shore will tend to cause the shoreline to change in the form of abrasion and accretion. [2] explain that the abrasion will cause the coastline to retreat to the land, while the advance coastline towards the sea is known as accretion. Abrasion disasters are often heard because they are more detrimental than accretion that only interfere with the management of ports and shipping lanes. The development of abrasion disasters is an illustration of the negligence of coastal utilization that is only for the benefit of the economy without understanding the natural processes of the coast. This problem is almost encountered in all the beaches in the world [3,4].

[5] explain if the shoreline experience abrasion and accretion that occur in a place, and it is difficult to overcome because the process usually works with high frequency for a long time, where the
development of coastal areas should consider the suitability of land between planned with their characteristics. The equilibrium dynamics are the common problems faced along Padang City coastal region, in the form of accretion and abrasion of coastal, caused by the wave and current movement. These events induced properties damages and loss of economic activities. [6,7] add the coastal hazards become the social and economic problems that are difficult to completely overcome by the local government. Material detriment in the future become bigger along with climate changes, which affect ocean wave behavior. Moreover, the wave behavior influences the dynamics of the coastal region [8]. To reduce the negative effect, well planning and management of coastal region must be applied. This research aims to determine the dynamics of a coastal environment based on the characteristic (length, velocity, energy, and height), sediment transport value, accretion/abrasion factor value, and coastal equilibrium in Padang City.

2. Research Methods

The research was conducted along Padang City coastal region, started from the beach of Pasia Jambak, Muara Anai in North part to Sungai Pisang in the South part. Padang City has about ± 65 km of shoreline. It located in Sumatera west section coastal region between 0°44′00″-1°08′35″S and 100°05′05″-100°34′09″E (Figure 1).

The value derived from series of measurements, wave height ($H_0$), wave period ($T$), seashore slope ($Tg \alpha$) and median of sediment size/percentile ($D_{50}$), was substituted into data analysis formula in order to find wave parameter that meets the research purpose. Data analysis employed in this research show by following formulas:

**Wavelength**

$$L_0 = 1.56 \ T^2$$  \hspace{1cm} (1)

where:
\( L_0 = \) Wavelength (m)  
\( T = \) Wave period (sec) [9].

**Wave Velocity**
\[
C = \frac{L}{T} \tag{2}
\]

where:
\( C = \) Wave velocity (m/sec)  
\( L_0 = \) Wave length (m)  
\( T = \) Wave period (sec) [9].

**Wave Energy**
\[
E = \frac{1}{8} \rho g H_0^2 \tag{3}
\]

where:
\( E = \) Wave energy (Kg/sec²)  
\( \rho = \) Sea water specific gravity (1.025 kg/m³)  
\( g = \) Earth gravity (9.81 m/sec²)  
\( H_0 = \) Wave height (m) [9].

**Run-up Height**
\[
H_b = 0.39 x g^{1/5} (T x H_0^2)^{2/5} \tag{4}
\]

where:
\( H_b = \) Run-up height (m)  
\( T = \) Wave period (sec)  
\( g = \) Gravity constants (9.8 met/sec²)  
\( H_0 = \) Wave height (m) (Triatmodjo, 1999).

**Sediment Transport**
\[
Q = 1.646 x 10^6 H_b^2 \tag{5}
\]

where:
\( H_b = \) Run-up height (m)  
\( Q = \) Sediment volume (m³/day) [10].

**Factor of Accretion and Abrasion**
\[
G_0 = (H_0/L_0)(Tg Q)^{0.27}(D_{50}/L_0)^{-0.67} \tag{6}
\]

where:
\( H_0 = \) Wave height (m)  
\( L_0 = \) Wave length (m)  
\( D_{50} = \) Median of sediment size value (mm)  
\( Tg \alpha = \) Seashore slope (°) [10].

Coastal region can be categorized as abrasion, accretion or equilibrium after we found the \( G_0 \) value, which then matches the following criteria:
\(< 0.0556 = \) abrasion  
\( > 0.111 = \) accretion  
\( 0.556 - 0.111 = \) equilibrium [10].

3. Results and Discussion
The results of field measurement show found the value of wave height \( (H) \), seashore slope \( (\alpha) \), the median of sediment size value\( (D_{50}) \), and wave direction \( (\lambda) \) at the research location as listed in Table 1 below.

| Location          | \( H (m) \) | \( T (sec) \) | \( \% \) | \( \alpha (\degree) \) | \( D_{50} \) | \( \lambda (\degree U) \) |
|-------------------|-------------|---------------|---------|----------------|-------------|---------------------|
| Pasia Jambak      | 1.63        | 17            | 10      | 2.8 = 2\(^{\circ}\)51'0" | 0.221       | 216                 |
| Pasia Sabalah     | 1.29        | 14            | 22      | 8.2 = 8\(^{\circ}\)7'0" | 1.632       | 221                 |
| Panjalinan North  | 1.18        | 13            | 23      | 11.15 = 11\(^{\circ}\)13'0" | 1.132       | 213                 |
| Panjalinan South  | 1.71        | 23            | 35      | 17.1 = 17\(^{\circ}\)2'0" | 1.053       | 237                 |
| Parupuak Tabing   | 1.09        | 13            | 17      | 8.3 = 8\(^{\circ}\)9'0" | 0.341       | 239                 |
| Parkit            | 1.79        | 17            | 22      | 11.1 = 11\(^{\circ}\)13'0" | 1.567       | 242                 |
| Bung Hatta beach  | 1.15        | 14            | 20      | 8.2 = 8\(^{\circ}\)7'0" | 0.342       | 222                 |
| Purus North       | 1.50        | 14            | 23      | 8.2 = 11\(^{\circ}\)13'0" | 1.652       | 267                 |
| Purus South       | 1.38        | 14            | 24      | 8.2 = 10\(^{\circ}\)19'0" | 1.032       | 266                 |
| Muaro Padang      | 1.37        | 15            | 26      | 10.2 = 10\(^{\circ}\)17'0" | 1.609       | 249                 |
| Air Manis North   | 1.19        | 12            | 19      | 9.0 = 9\(^{\circ}\)2'0" | 1.591       | 243                 |
| Air Manis South   | 1.47        | 16            | 16      | 4.6 = 4\(^{\circ}\)33'0" | 0.386       | 208                 |
| Sungai Baremas    | 1.02        | 15            | 27      | 11.1 = 11\(^{\circ}\)11'0" | 0.912       | 195                 |
| Pasia Putih       | 1.10        | 14            | 22      | 9.47 = 9\(^{\circ}\)29'0" | 1.691       | 197                 |

Source: Data Analysis, 2017

3.1 Wavelength
The results of wavelength values were can be seen in Table 2 below.

| Location            | \( (L_s = 1.557^{\circ}) \) |
|---------------------|------------------------------|
| Pasia Jambak        | 450.84                       |
| Pasia Sabalah       | 305.76                       |
| Panjalinan North    | 263.64                       |
| Panjalinan South    | 825.24                       |
| Parupuak Tabing     | 263.64                       |
| Parkit              | 450.84                       |
| Bung Hatta beach    | 305.76                       |
| Purus North         | 305.76                       |
| Purus South         | 305.76                       |
| Muaro Padang        | 351.00                       |
| Air Manis North     | 224.64                       |
| Air Manis South     | 399.36                       |
| Sungai Baremas      | 351.00                       |
| Pasia Putih         | 305.76                       |

Source: Data Analysis, 2017.

The based on formula mentioned before, that wave velocity proportionally related to wavelength. the rising of wavelength will be followed by the rising of wave velocity value. The highest wave velocity (35.88 m/sec) took place at PanjalinanSouth beach, while the slowest (18.72 m/sec) took place at Air Manis North. Wave velocity average along Padang City around 23.51 m/sec.

3.2 Wave Velocity
The results of wave velocity values were can be seen in Table 3 below.

### Table 3. Wave velocity value

| Location              | \( C = L/T \) |
|-----------------------|----------------|
| Pasia Jambak          | 26.52          |
| Pasia Sabalah         | 21.84          |
| PanjalinanNorth       | 20.28          |
| PanjalinanSouth       | 35.88          |
| Parupuak Tabing       | 20.28          |
| Parkit                | 26.52          |
| Bung Hatta beach      | 21.84          |
| Purus North           | 21.84          |
| Purus South           | 21.84          |
| Muaro Padang          | 23.04          |
| Air Manis North       | 18.72          |
| Air Manis South       | 24.96          |
| Sungai Baremas        | 23.04          |
| Pasia Putih           | 21.84          |

Source: Data Analysis, 2017.

The based on formula mentioned before, that wave velocity proportionally related to wavelength. the rising of wavelength will be followed by the rising of wave velocity value. The highest wave velocity (35.88 m/sec) took place at PanjalinanSouth beach, while the slowest (18.72 m/sec) took place at Air Manis North. Wave velocity average along Padang City around 23.51 m/sec.

### 3.3 Wave Energy

The results of wave energy values were can be seen in Table 4 below.

### Table 4. Wave energy value

| Location          | \( E = \frac{1}{8} \rho g H_0^2 \) |
|-------------------|---------------------------------|
| Pasia Jambak      | 3.34                            |
| Pasia Sabalah     | 2.09                            |
| PanjalinanNorth   | 1.75                            |
| PanjalinanSouth   | 3.68                            |
| Parupuak Tabing   | 1.49                            |
| Parkit            | 4.03                            |
| Bung Hatta beach  | 1.66                            |
| Purus North       | 2.83                            |
| Purus South       | 2.39                            |
| Muaro Padang      | 2.36                            |
| Air Manis North   | 1.78                            |
| Air Manis South   | 2.72                            |
| Sungai Baremas    | 1.31                            |
| Pasia Putih       | 1.52                            |

Source: Data Analysis, 2017.

Amount of wave energy is determined by wave height \( \rho \) and \( g \) value are the constants of sea water specific gravity ( \( \rho = 1.025 \text{ kg/m}^3 \), \( g = 9.81 \text{ m/sec}^2 \)). The higher the wave, the bigger the energy of the wave produces. Parkit beach had the biggest value of wave energy (4.03 Kg/s²) and the smallest value in Sungai Beremas beach (1.31 Kg/s²). The wave energy average of all the coastal region in Padang City around 2.35 Kg/s².
3.4 Run-up Height

The results of run-up height values were can be seen in Table 5 below.

| Location               | $H_b=0.39xg^{1/3}(T \times H_b^2)$ |
|------------------------|-----------------------------------|
| Pasia Jambak           | 2,343.99                          |
| Pasia Sabalah          | 599.30                            |
| Panjalinan North       | 356.39                            |
| South Panjalinan       | 4,029.74                          |
| Parupuak Tabing        | 239.69                            |
| Parkit                 | 3,743.54                          |
| Bung Hatta beach       | 337.43                            |
| Purus North            | 1,273.95                          |
| Purus South            | 839.64                            |
| Muaro Padang North     | 867.49                            |
| Air Manis North        | 343.15                            |
| Air Manis South        | 1,316.06                          |
| Sungai Baremas         | 198.45                            |
| Pasia Putih            | 270.18                            |

Source: Data Analysis, 2017.

The run-up height is determined by the period value and the wave height. If the period and the higher the wave, the run-up height also greater. After observing close we conclude that wave period value not much affected in determining run-up height value. The based on field survey result, the biggest run-up height value took place at Panjalinan North beach about 4,029.74 m and the smallest at Sungai Beremas beach about 198.45 m. The run-up height average of all the coastal region in Padang City around 1,197.07 m.

3.5 Sediment Transport

The results of sediment transport values were can be seen in Table 6 below.

| Location               | $Q = 1.646 \times 10^6 H_b^2$ |
|------------------------|--------------------------------|
| Pasia Jambak           | 958,619                        |
| Pasia Sabalah          | 763.3                          |
| Panjalinan North       | 22,160                         |
| Panjalinan South       | 2,356                          |
| Parupuak Tabing        | 10,024                         |
| Parkit                 | 2,830                          |
| Bung Hatta beach       | 19,866                         |
| Purus North            | 1,395                          |
| Purus South            | 123,004                        |
| Muaro Padang North     | 971                            |
| Air Manis North        | 20,545                         |
| Air Manis South        | 1,287                          |
| Sungai Baremas         | 6,872                          |
| Pasia Putih            | 404                            |

Source: Data Analysis, 2017.
Sediment transport is the parameter that related to run-up height, where the high run-up height values will result in high sediment transport value. [11] explain run-up the high also related with wave height and energy, high wave brings the high amount of wave energy which produces the high value of run-up height and then triggers high amount of sediment transport. The highest sediment transport appeared at Pasia Jambak beach about 958,619 m$^3$/day, and the smallest amount at Pasia Putih beach about 404 m$^3$/day with the average of sediment transport value around 8,2,935m$^3$/day.

3.6 The factor of Accretion and Abrasion

The results of accretion and abrasion factors ($G_0$) values for all calculate parameter results were can be seen in Table 7.

| Location          | $G_0 = (H_0/L_0).Tg.\alpha.\phi_0/D_{50}/L_0$ | Dynamic |
|-------------------|---------------------------------------------|---------|
| Pasia Jambak      | 0.001                                       | abrasion|
| Pasia Sabalah     | 14.413                                      | accretion|
| PanjalinanNorth   | 10.855                                      | accretion|
| PanjalinanSouth   | 6.728                                       | accretion|
| Parupuak Tabing   | 0.003                                       | abrasion|
| Parkit            | 17.601                                      | accretion|
| Bung Hatta beach  | 0.002                                       | abrasion|
| Purus North       | 18.769                                      | accretion|
| Purus South       | 10.201                                      | accretion|
| Muaro Padang      | 14.518                                      | accretion|
| Air Manis North   | 17.139                                      | accretion|
| Air ManisSouth    | 0.003                                       | abrasion|
| Sungai Baremas    | 0.005                                       | abrasion|
| Pasia Putih       | 11.899                                      | accretion|

Source: Data Analysis, 2017

$G_0$ is describing the dynamic condition that occurs in the coastal region. Based on the data calculation analysis shows $G_0$ value less than 0.00556, it means coastal region tend to recede (abrasion), $G_0$ value between 0.0556 and 0.111 means the coastal region is in the equilibrium condition, and if $G_0$ value above 0.111 expresses the accretion (augmented). $G_0$ is the calculation results of $H_0$ (wave height), $L_0$ (wavelength), $Tg.\alpha$ (seashore slope), and $D_{50}$ (median of sediment size value/percentile).

The based on $G_0$ value in Table 7, there are 9 locations in the coastal region of Padang City that the accretion, ie in Pasia Sabalah beach, Panjalinan North beach, Panjalinan South beach, Parkit beach, Purus North beach, Purus South beach, Muaro Padang beach, Air Manis South beach and Pasia Putih beach. Meanwhile, the 5 locations are in abrasion condition, ie in Pasia Jambak beach, Parupuak Tabing beach, Bung Hatta University beach, Air Manis South beach and Sungai Beremas beach. The dynamic form of coastal environment can be observed by wave parametric measurement and calculation that define as $G_0$ value. Although wave period, velocity, energy, run-up height, and sediment transport values were high they were not always bringing negative effects to the coastal region. [12] add positive or negative effects depend on $G_0$ value at the end of the calculation. The high value of wave period, velocity, energy, run-up height, and sediment transport at Pasia Sabalah beach, Panjalinan South beach, Parkit beach and Purus South beach cannot be straightly assumed as abrasion area. In fact, based on field survey, those beaches lead to accretion.

The existence of beach building also contributes in forming dynamic of the coastal environment. Pasia Jambak beach, Panjalinan South beach, Parkit, Purus North beach and Air Manis South beach had the high value of wave parameters (except $G_0$ value). The existence of beach protection building has provided resilience/protection to the disaster that hit in the coastal region of Padang City.
[13] explain the collaboration of wave energy, sediment supply from the estuary and the existence of the beach building, took part in forming dynamic of the coastal environment. This makes the link between $G_0$ parameters, $H_0$ as wave high, $L_0$ as wavelength, $Tg$ as seashore slope, and $D_{50}$ as median sediment size are difficult to correlate. Whereas $G_0$ is the value that determines the formation of dynamics of the coastal environment. It seemed there was “$X$” variable that cannot be ignored, which influenced $G_0$ and it was the collaboration of coastal-estuary adjacency and the existence of beach building. The coastal condition also one of the determinants of dynamic of the coastal environment. [14] add beaches protected by bay safer than those that adjacent to the open ocean. We assume that bays might be the natural protection of the coastal region from abrasion, which initiates by wave dynamics energy.

By identifying the relation between $G_0$ value, another parameter, existence of the beach building, and coastal physical condition (estuary and bay) along in the coastal region of Padang City, can be concluded that during a dry season/during research activities (July 2017), condition of the coastal region in a state of abrasion and accretion.

3.7 The condition of Coastal Environment

Jambak beach, Pasia Sabalah beach, and North Panjalinan beach stretch from Panjalinan estuary to Batang Anai estuary in the Northern part of Padang City. In the estuary (North and South) of Panjalinan estuary, the government has built a Jetty type beach building. Jetty is a beach building that is made perpendicular to the beach that is placed on both sides of the estuary of the river that serves to withstand sediment/sand that travels along the coast and settles in the mouth of the river [15]. With this Jetty building in the research location causing sediment transport from the South coast to the North, coast tends to become obstructed. Due to the energy value and run-up height relatively small and also due to the existence of Jetty, resulting in sediment stuck and sediment combing towards the North coast. This indicates a wave of energy-depleting sediment transporting through the Jetty.

South Panjalinan beach, Parupuak Tabing beach, and Parkit beach stretch from the Kuranji estuary in the South to the mouth of the Panjalinan river in the North. Based on the condition of the field, the condition of Parkit beach until Patenggangan beach has been built groin and revetment. [16] explain groin is a coastal protective building that is usually made perpendicular to the coastline and serves to capture and retain sediment transport along the coast so that the presence of groin will be able to reduce/stop coastal erosion. While the revetment is a coastal building built with a parallel shoreline that serves as a protective coastal wall against erosion and ground wave overtopping. [7] add the revetment causes the shore to be protected from the erosion process and the presence of groin leads to the sediment being caught which in turn causes the sediment to enter larger than the exit volume so that the beach is accretion.

Groin and revetment conditions built at the site of research have begun to accumulate sand. Indicates there has been a high sediment buildup. When associated with coastal conditions, the sedimentation originating from the Kuranji watershed has been carried by wave power from the Kuranji estuary to the area along the North of Parkit beach. Large sediment supply and large wave energy have caused sediment to transport to the North of this coast. This is what causes the high accumulation of sediment in the area along the North coast of Parkit beach to Patenggangan beach. The beach on the campus of Bung Hatta University and North Purus beach stretch from the mouth of the Banjir Kanal estuary in the South to the Kuranji estuary in the North. Muara Banjir Kanal almost the same with the Panjalinan estuary. Where both sides of the river estuary have been built Jetty. With the construction of groin and revetment around the campus beach of Bung Hatta University, means the existence of coral reef ecosystems and coastal buildings has caused sediments from the South of deposited. With the existence of beach buildings on the South side of the coast, conjecture strong even in the storm season, Bung Hatta Beach tends to be vulnerable to abrasion.

South Purus beach and Muaro Padang beach stretch from Batang Arau estuary in the South to the mouth of the Banjir Kanal estuary in the North. Beach Muaro Padang is precisely in the park area has experienced accretion. With the low sediment supply from the South, causing the coast to lack of
sediment. But with the existence of **groin** and **revered** in the North, the beach will not undergo much change. Low sediment supply and wave energy will also not be able to erode the beach due to the presence of beach buildings. Means in this area tend to be safe from the danger of abrasion in both dry and storm season.

North Air Manis beach and South Air Manis beach stretch from Batang Arau estuary in the North up to the legend Stone Malin Kundang in the South. The beach in this area experienced abrasion in the South and accretion in the North. conjecture strong with not yet unbuilt beach buildings, waves during hurricane seasons has caused abrasion on the South side of the coast.

Sungai Beremas beach and Pasia Putih beach are directly adjacent to the volcanic hills and are located on the edge of the bay. This coastal area has several bays such as Bayur bay and Bungus bay which is the largest and most important bay on the western coast of Sumatra island [17]. Pasia Putih beach located on Bungus bay. If associated with a coastal location within the bay, then the existence of the bay causes the sediment to not get out and move away from the shore. [18,19,20] explain the existence of bays that surround the coast, causing relatively small values of wave parameters to be measured, and resulting in relatively protected coast from coastal abrasion hazards. But in these storm seasons, the beach is abrasion.

![Figure 2. Map of results research.](image-url)
4. Conclusion

The wave energy value, run-up Height and the sediment transport value are strongly influenced by the wave height value in the form of a proportional relationship (the higher the wave value, the wave energy value, the high wave value and the sediment transport value are also high, and vice versa). The existence of beach building and the natural physical state of the beaches in Padang City (river estuary and bay), contributes to the coastal dynamics that occur. The average run-up height during the dry season (end of July 2017) was 2.35 kg/s² and the average sediment transport along the coast of Padang City during the dry season (end of July 2017) was 82,935.6 m³/day. Most of the beaches in Padang City during the dry season (late July 2017) tend to experience accretion ie in Pasia Sabalah beach, Panjalinan North beach, Panjalinan South beach, Parkit beach, Purus North beach, Purus South beach, Muaro Padang beach, Air Manis South beach and Pasia Putih beach. Meanwhile in abrasion condition ie in Pasia Jambak beach, Parupuk Tabing beach, Bung Hatta University beach, Air Manis South beach and Sungai Beremas beach. Along the Beach of Padang City during the dry season (end of July 2017) there is no equilibrium of beaches found.

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