Spatial analysis of accretion, abrasion and shoreline change in banda aceh coastal area

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Abstract. The coast of Banda Aceh City has a gentle sloping beach morphology, making it prone to changes in coastlines due to hydro-oceanographic dynamics. Areas that are particularly vulnerable are the mangrove areas and around the Krueng Aceh estuary and coastal area of Lampulo. Therefore, to determine the extent of shoreline changes, a spatial analysis of coastal vulnerability was carried out with the aim of knowing how much change had occurred at Lampulo beach in Banda Aceh City of Aceh Province. The research was conducted using Google Earth data technology and the use of Geographic Information System (GIS) software. The analysis was carried out over a period of 14 years starting from 2004 to 2017. Field data verification and georeferencing were also carried out to check the accuracy of mapping and calculations. The results showed that in 2004-2005 there was a large erosion that changed the shape of the coastal profile where the mangrove coastline turned into water without mangroves as a result of the tsunami on December 26, 2004. In 2008-2009, after the construction of the breakwater and the Port of Lampulo there was a large accretion occurred having the impact on the morphology of the coast. The results also concluded that the annual average accretion value was 20.48 ha and the annual abrasion was 19.28 ha. The value of shoreline reduction due to abrasion is around 217.25 ha and accretion of 166.56 ha over a period of 14 years.

1. Introduction

Beach is a geographical form consisting of sand found in the coastal area of the sea. The coastal area is the boundary between land and sea waters. The formation of the beach is due to the material being carried by the waves to the shore continuously [1]. Research on changes to the coastline in Aceh caused by coastal dynamics due to natural factors has been carried out by various parties, both domestic and foreign [2].

Apart from natural factors, there are also several activities that are thought to have resulted in changes to the coastline [3], such as taking sand for reclamation, development around the coast, such as the construction of the Lampulo Ocean Fishery Port (PPS). The Lampulo Ocean Fishery Port (PPS) Banda Aceh is located at coordinates 5°35'11.11" N and 95°19'8.44" E, where the position of the Lampulo Ocean Fishing Port (PPS) is in the northern part of Banda Aceh city bordering by Krueng Aceh estuary.
The development of this port has positive impacts such as economic development that affects activities around the port and has negative implications in the form of changes in ocean flow patterns, waves and changes in coastlines [4-6], especially due to the presence of port pools and breakwater construction. One of the negative implications of this development is coastline changes [7]. How much is the beach changes around the pier [8] is a question we want to answer. Therefore, this research is important to do to find out how much changes in the coastline in Banda Aceh City, especially around the Ocean Fishery Port (PPS) Lampulo. The study area is focused on areas that are suspected of experiencing sedimentation and abrasion.

2. Material and Method

2.1. Study area

This research was conducted at Lampulo beach, Banda Aceh city, Aceh Province from February 2018 to March 2018 with the coordinate point 5°34’56.45” N 95°19’23.96” E (Figure 1). The area was chosen because of beach structure (fishery port) near by the mouth of the river. This coastal structure is believed to have implications for silting around the mouth of the Krueng Aceh river.

![Figure 1. Map of the research location](image)

2.2. Data Collection

2.2.1. Satellite imagery data

The research data was taken from medium to high resolution of satellite imagery data. The data was processed from 2004 to 2017. At every year in September, the shoreline image were saved as a yearly data being processed and compared to the data in 2017 as a control data. The satellite images obtained are sourced from Google Earth Pro software in the form of JPEG (Joint Photographic Expert Group) file format.

The method used in this study is based on the analysis of Google Earth data from 2004 to 2017 with several stages being carried out, namely the preparation stage and the data processing stage which are also accompanied by the field survey stage. The preparation stage is the stage of collecting input data in the form of aerial photography data from Lampulo beaches from 2004 to 2017 from Google Earth. Image data processing is carried out using GIS software and several stages of data processing are carried out to produce information on changes to the coastline at the study location.
2.2.2. Field survey
In the field, geometric correction was done by looking for a number of ground control points (GCP) that are recognized from both image and filed reference points. Rectification is carried out, at least 4 points are required to be used as Ground Control Points (GCP).

The field survey stage (Ground Check) was carried out and focused on finding data. Supporting data obtained in the field and related agencies such as sub-district administrative maps, Banda Aceh district maps and other information that supports research data. This is done to support the accuracy of the results of data interpretation. Google Earth. Determination of location using the method of consideration (Purposive Sampling Method). Field surveys are carried out on each identified object (abrasion or accretion) after data processing is carried out [9].

2.3. Data Analysis
Digitization was carried out which aims to change the raster data format to vector data format. The object to be digitized is the coastline. After the digitization stage is complete, the four shoreline overlaps are carried out. The result of the overlay is a change in the coastline which will then be analyzed for changes [10].

The result of the overlay is a change in the shoreline which will then be analyzed how much the change is. After carrying out the overlay stage, it can be seen how extensive changes in the shoreline have occurred, such as changes in the extent of coastal erosion (abrasion) and the extent of additional beaches caused by sediment movement (accretion). Layouting is carried out after the shoreline change analysis process is complete. The next stage is the layout (map view). Layout is the final result that will be displayed in the form of a map showing the results of the coastline change, map legend, scale text, scale bar, cardinal directions, and map source [11, 12].

2.4. Google Earth Data Analysis
Analysis of shoreline changes is carried out by processing Google Earth Pro aerial photography analysis data by way of overlapping (Overlay) to produce shoreline changes from 2004 before the Tsunami to 2017 after the Tsunami. The results of the polyine digitization of the shoreline on Google Earth aerial photos from 2004 to 2017 with a scale of 1: 1000 to produce high accuracy between sea and land boundaries. The results of the overlapping process (Overlay) were carried out from 2004 to 2017 looking at the abrasion and accretion values (Figure 2).

Figure 2. Ground checking for verification data
The accuracy of the interpretation of Google Earth data is obtained from a field survey by taking 4 points in the area that can represent areas of abrasion and accretion. At point 1 is open land, there are coconut trees that are ± 6 meters from the coastline and there is a breakwater. At point 2, the coast progresses very far at low tide and is also limited by a breakwater which is about ± 10 meters from the coastline. At point 3, a breakwater can be seen on the edge of the coastline, at this point there is a buildup of sedimentation which is caused by the presence of a port, which changes the current pattern on the coast. At point 4, there is a buildup of sedimentation at low tide because at point 4 it is very close to the estuary. At this point the beach has been bounded by a breakwater which is ± 10 meters from the coastline (Figure 2).

3. Result and Discussion

3.1. Changes in Coastlines and Coastal Areas
Changes in coastlines and coastal areas can change from year to year, changes occur because they are caused by natural factors such as waves, sedimentation, waves, currents and can also be caused by human activities such as taking sand for reclamation, development around beaches such as ports and breakwater. Table 1. shows changes in the area of the coast each year. In 2004, the coastal area was 20.9 ha, then in 2005 it became 20.55 ha due to abrasion from the tsunami. In 2006 there was another abrasion so that the coastline area was 20.34 ha. 2007 and 2008 saw further abrasion which led to a reduction in the coastline, where the original coastline area was 19.98 ha to 19.79 ha. In 2009 there was a very large reduction in the coastline so that the area of the coast in 2009 was 5.21 ha. In 2009, a breakwater and an Ocean Fishery Port (PPS) were built. In 2010 there was an addition of the coastline so that the coastal area was 5.37ha. In 2011, the coastline experienced a slightly larger addition so that the total area of the coast in 2011 was 6.43 ha. In 2012, there was a reduction in the coast by 0.17 ha, so that the coastal area in 2012 became 6.26 ha. In 2013, the coastal area was also reduced so that the coastal area was 6.03 ha. In 2014, there was also a reduction of the coastline to 5.51 ha, and in 2015 and 2016 there was an addition of coastline, where the area of the coast from 5.79 ha became 6.24 ha. In 2017 there was a reduction in the coast which was only a little so that the coastal area in 2017 is 6.01 ha.

| Year | Coast Line (Km) | The Area (ha) |
|------|----------------|--------------|
| 2004 | 4,967          | 20.9         |
| 2005 | 14,857         | 20.55        |
| 2006 | 14,857         | 20.34        |
| 2007 | 14,857         | 19.98        |
| 2008 | 13,738         | 19.79        |
| 2009 | 3,386          | 5.21         |
| 2010 | 3,519          | 5.37         |
| 2011 | 3,496          | 6.43         |
| 2012 | 3,497          | 6.26         |
| 2013 | 3,505          | 6.03         |
| 2014 | 3,64           | 5.51         |
| 2015 | 3,632          | 5.79         |
| 2016 | 3,692          | 6.24         |
| 2017 | 3,678          | 6.01         |

The length of the coastline has also changed every year, in 2005 there was a very large shoreline change with a coastline length of 14,857 Km which was caused by the Tsunami in 2004 where the length of the coastline in 2004 was 4,967 Km. The length of the coastline from 2005 to 2007 has a fixed
coastline length of 14,857 km. In 2008, the length of the coastline decreased to 13,738 km. 2009 saw a very large decrease in the length of the coastline so that the length of the coastline in 2009 was 3.386 Km. The degradation of the coastline was due to the construction of a breakwater and the Lampulo Ocean Fishing Port (PPS). From 2010 to 2017, the length of the coastline remained consistent, the longest coastline in 2010 to 2017 was 3,692 km in 2016 and the shortest was 3,496 km in 2011.

3.2. Abrasion and Accretion

Based on a simple shoreline change analysis using the overlapping technique (Overlay) between coastal land polygons in data obtained from Google Earth from 2004 to 2017. Overlay is carried out to see the rate of change in abrasion and accretion in the estimated coastal area in units. ha / year. The abrasion and accretion values can be found from the Symmetrical Difference Tool in the Overlay Arctoolbox.

Table 2 shows that from 2004 to 2017 the coast underwent changes, either abrasion or accretion. In 2004-2005, there was an abrasion of 217.25 ha and no accretion occurred in 2004-2005 which resulted in a reduction of the beach area by 217.25 ha. This reduction in coastal area was caused by the 2004 tsunami disaster on the beach of Lampung. In 2005-2006 there was no change in abrasion and accretion until 2006-2007. In 2007-2008, the abrasion that occurred was 0.08 ha and there was no accretion. In 2008-2009 the abrasion and accretion that occurred was greater than that of 2008-2009, the abrasion that occurred in this period was 30.45 ha and 197.01 ha accretion which caused an additional beach area of 166.56 ha. This addition had an impact on the construction of breakwaters and ports. on the beach of Lampulo. In 2009-2010, the abrasion was 0.37 ha and accretion was 37.44 ha. In 2010-2011 the abrasion and accretion occurred smaller than 2009-2010, namely the amount of abrasion was 0.17 ha and the accretion was 10.69 ha. In 2011-2012 the abrasion value was getting smaller so that the abrasion value was 0.12 ha and there was no accretion at all, 2012-2013 the abrasion was greater than the previous year which was 0.3 ha and 8.18 ha accretion. In 2013 - 2014 there was no addition or reduction in abrasion and accretion. In 2014-2015, the abrasion was greater than the previous 5 periods, namely 1.25 ha and there was no accretion at all. In 2015-2016 there was very little abrasion of 0.04 ha and accretion of 1.57 ha. In 2016-2017 the abrasion started to increase slightly by 0.61 ha and the accretion also increased to 11.32 ha. The average value of abrasion per year is 19.28 ha and accretion is 20.48 ha. This shows that within 12 years the beach accretion was greater than the coastal abrasion.

| Year     | Accretion (ha) | Abrasion (ha) |
|----------|----------------|---------------|
| 2004 - 2005 | 0              | 217.25        |
| 2005 - 2006 | 0              | 0             |
| 2006 - 2007 | 0              | 0             |
| 2007 - 2008 | 0              | 0.08          |
| 2008 - 2009 | 197.01         | 30.45         |
| 2009 - 2010 | 37.44          | 0.37          |
| 2010 - 2011 | 10.69          | 0.17          |
| 2011 - 2012 | 0              | 0.12          |
| 2012 - 2013 | 8.18          | 0.3           |
| 2013 - 2014 | 0              | 0             |
| 2014 - 2015 | 0              | 1.25          |
| 2015 - 2016 | 1.57          | 0.04          |
| 2016 - 2017 | 11.32         | 0.61          |
| **Average/year (ha)** | **20.48** | **19.28** |

The results of the annual layout map can show that in 2004-2005 there was a large erosion that changed the shape of the coastal profile. This erosion was caused by large waves during the 2004 tsunami. In 2008-2009 there was a large accretion after the construction of the breakwater and port so that it made the position. The coastline has not changed but has its own impact on the morphology of
the coast, such as the accumulation of sedimentation in the right and left corner of the port where the breakwater has been built. This statement is in accordance with the opinion of [6] which states that the causes of changes in the coastline are due to human activities (anthropogenic) is the taking or changing of the function of coastal protection land and development in an area that is not in accordance with the prevailing rules. This is what causes the imbalance of sediment transport on the port side.

![Coastline Change Map](image)

**Figure 3.** Map of coast line changes for year of (a) 2004-2005, (b) 2008-2009, (c) 2016-2017.

**Table 3.** Addition and reduction of the Lampulo coastline area

| Year   | shoreline (ha) | Dominant change |
|--------|----------------|-----------------|
| 2004-2005 | -217.25        | Erosion         |
| 2005-2006 | 0              | -               |
| 2006-2007 | 0              | -               |
| 2007-2008 | -0.081         | Erosion         |
| 2008-2009 | +166.56        | Sedimentation   |
| 2009-2010 | +37.068        | Sedimentation   |
| 2010-2011 | +10.52         | Sedimentation   |
| 2011-2012 | -0.12          | Erosion         |
| 2012-2013 | +7.87          | Sedimentation   |
| 2013-2014 | 0              | -               |
| 2014-2015 | -1.25          | Erosion         |
| 2015-2016 | +1.52          | Sedimentation   |
| 2016-2017 | +10.71         | Sedimentation   |

In general, shoreline changes that occurred in Lampulo during the period 2004-2017 were more dominated by accretion than abrasion processes. This is evidenced by the shoreline shift distance that occurs longer accretion than the abrasion process (Table 3). Changes in abrasion and accretion coastlines
generally change from time to time in line with natural changes such as the activity of waves, winds, tides, and currents as well as river delta sedimentation. Changes in abrasion and accretion coastlines can also occur due to human activities such as port construction, breakwater and beach reclamation. The largest abrasion shoreline change occurred in 2004 - 2005 which was caused by high waves during the tsunami disaster in 2004 and the largest change in the accretion coastline occurred in 2008-2009 which was caused by the construction of a breakwater and port.

Table 3. shows the addition and subtraction of the Lampulo coastline with the minus (−) and Plus (+) symbols. In 2004-2005 erosion occurred (−) 217.25 ha. In 2005-2006 to 2006-2007 there was no erosion or sedimentation. 2007-2008 erosion occurred (−) 0.081 ha. In 2008-2009 there was sedimentation of (+) 166.56 ha. In 2009-2010 there was a reduction of (+) 37.068 ha. In 2010-2011 there was sedimentation of (+) 10.52 ha. In 2011-2012 there was a small amount of erosion (−) 0.12 ha. In 2012-2013 there was another sedimentation of (+) 7.87 ha, 2013-2014 there was no erosion or sedimentation. In 2014-2015 there was an erosion of (−) 1.25 ha. In 2015-2016 there was sedimentation of (+) 1.52 ha. In 2016-2017 there was sedimentation of (+) 10.71 ha.

The shoreline changes that occurred on the Lampulo beach were very large due to the 2004 tsunami waves so that in 2005 the lampulo coast experienced large abrasions. The result of this tsunami wave changed the physical shape of the coast to the left of the port. This statement is in accordance with [7], who stated that the influence of the 2004 tsunami waves caused the land to experience abrasion so that it changed its morphological shape, but this was temporary because of the influence of normal waves and the process of coastal sediment deposition after the tsunami which helped adjust the shape of the coastal profile back to its like beginning.

This does not apply to Lampulo beach, where this condition lasted until 2008. In 2009 a port and breakwater had been built so that the position of the coastline returned to its original position, but there was a buildup of sediment on the right and left sides of the port, especially sediment accumulation in the estuary delta. river. The dominance of shoreline changes in Lampulo from 2004 to 2017 occurred more sedimentation than erosion.

4. Conclusions

Based on the research that has been carried out, the conclusions that the area of Lampulo coast has changed every year, starting from 2004 to 2017. In 2004 a large amount of coastal erosion occurred due to the large tsunami waves, erosion that occurred was 217.25 ha. The average value of abrasion per year is 19.28 ha and accretion of 20.48 ha. This shows that within 12 years the beach accretion was greater than the coastal abrasion. Changes in the coastline at Lampulo occurred as a result of the 2004 tsunami waves and as a result of breakwater and port development activities. The dominance of shoreline changes in Lampulo from 2004 to 2017 occurred more erosion than sedimentation.

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