Analysis of Coastal Abrasion Rate of Laha Village Ambon City Using Satellite Data

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Abstract

The coastline is the boundary between the sea and land. Line changes are caused by abrasion and accretion. Abrasion and accretion occur throughout the coast of Laha so the coastline undergoes quite drastic changes. This study aims to determine how much the average rate of abrasion and coastal accretion per year and how much the average area of abrasion and accretion for 10 years of recording data on the Laha coast. This study uses the remote sensing method as a rapid study to detect the rate of abrasion and accretion on Laha Beach using Landsat 8 images in 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022 as primary data Calculation of shoreline changes using DSAS (digital shoreline analysis system) using the NSM (net shoreline movement) statistical method. The results of the 10-year coastal abrasion rate study occurred thoroughly on the coast of Laha Beach. The highest abrasion occurred in 2018-2019 with an average value of NSM -15 cm/year while the highest accretion occurred in 2019-2020 with an average value of NSM +19.97 cm/year. Abrasion area for 10 years with an average value of NSM of -89.29 m2 / year while accretion for 10 years with an average value of NSM of +70.70 m2/ year. With the rate of abrasion that occurs, it is necessary to build coastal buildings evenly so that abrasion can be minimized.

Keywords: *Abrasion-accretion, ARCGIS, Landsat 8, Laha Beach, Shoreline*

1. Introduction

Laha Village is one of the areas located in Ambon City, Maluku Province. Laha village area is a lowland area. Laha village has a very important role because it is a tertiary center III that helps service the special area of the airport which will continue to be developed as an aviation safety security area and tertiary distribution airport services. Efforts to analyze the rate of abrasion and accretion on Laha Beach because the Laha Beach area is categorized as the beach experiencing abrasion. Judging from the condition and characteristics of the beach currently, Laha Beach's damage is mostly influenced by natural factors.

Figure 1. Trees Falling on the Beach

The damage at Laha Beach can be seen in Figures 1, which are the collapse of trees on the beach due to abrasion and also the foundations of former buildings on the beach as shown in Figure 2. Initially, the former building was on land and far away from the shoreline but over time, due to abrasion that occurs, the shoreline has shifted past the former building and the collapsed tree.

Figure 2. Trees Falling on the Beach

Coastal abrasion is one of the processes of erosion of rock or hard material such as walls or rock cliffs also followed by landslides and material collapse caused by wave power. (Istiqomah et al., 2015) Coastal erosion is the retreat of the shoreline from its original position. Accretion is a change in the coastline due to the process of sedimentation from the land carried by seawater (Driptufany, 2020)

The factors that cause coastal damage are divided into 2 (two), namely hydro-oceanographic factors and anthropogenic factors. Hydro-oceanography is a natural factor that causes the process of coastal damage, including tides, wind, waves, currents, sedimentation, and depth that take place continuously (Wattimena & Ayal, 2019). Anthropogenic factors are human activities in coastal areas that do not heed the rules of nature.

Landsat satellites are the oldest satellites on earth launched by the United States. The existence of Landsat satellite imagery began in 1972. Landsat satellites can be used to monitor land cover mapping, coastline mapping, geological mapping, sea surface temperature mapping, and analysis and monitoring of coastline changes, Landsat satellite images also have different resolutions and have their respective uses.

Monitoring and analyzing changes in the area and position of the coastline is very useful in providing information about which areas are experiencing abrasion and accretion in the coastal area being analyzed. (Sutikno, 2014). Digital Shoreline Analysis System (DSAS) is an add-on software that works on ArcGIS software developed by ESRI and USGS. Digital Shoreline Analysis System is used to calculate changes in shoreline position based on time statistically and geospatially based. (Esa et. al, 2017). Calculations on DSAS can be done with several methods including Shoreline Change Envelope (SCE), Net Shoreline Movement (NSM), and End Point Rate (EPR).

The rate of change is obtained from the change in distance between one point and another point divided by the length of time the point change process occurs mathematically this is formulated as follows.

$$R_{se} = \frac{X_0}{t} \qquad (1)$$

Where Rse is the rate of line change (cm/year), X0 is the distance between points on one line and points on the next shoreline, t is the length of time observed.

By using the rate of change, further shoreline changes can be determined. Technically, the estimation is determined by multiplying the value and the length of time of observation. Mathematically it can be formulated as follows:

$$\bar{Y} = R_{se} \text{ x } (y_t - y_1) \qquad (2)$$

Where $\bar{Y}$ is the new point while y1 is the observation limit. Validation is done using the RMSE formula as a comparison of numerical results and experimental results using Root mean square error (RMSE) shows appropriate and measurable results (Sihombing, 2018).

$$\text{RMSE} = [n^{-1} \sum_{i=1}^{n} (-X_{MOD} X_{ORG})^2 \ (-Y_{MOD} Y_{ORG})^2]^{1/2} \quad (3)$$

Where XMOD and YMOD are the coordinates of the forecasted coastline while XORG and YORG are the coordinates of the reference coastline.

The method calculates the rate of shoreline change by dividing the distance between the oldest shoreline and the current shoreline by the time, as shown in Figure 3.

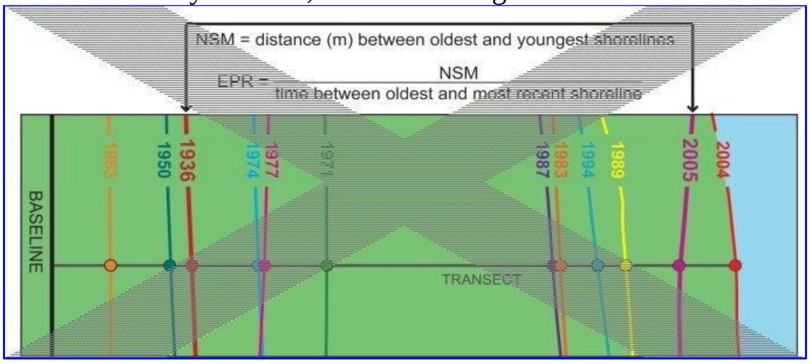

Figure 3. Trees Falling on the Beach

2. Method

2.1. Location and Time of Research

This research was conducted along the coast of Laha Village, Ambon City, Maluku Province. The research time is planned within 2 months. The location map and pictures of the current beach conditions are shown in Figure 4 and Figure 5.

2.2. Type of Research

This research is quantitative descriptive research with a spatial analysis approach or spatial analysis based on remote sensing imagery, namely Landsat 8 OLI TIRS imagery. This research uses a spatial analysis approach to help solve the problem by exploring the data and evaluating various trends so that it is expected to be able to make high-quality forecasts.

Figure 4. Research location map

Figure 5. Beach Abrasion Condition (November 23, 2022)

2.3. Type of Research

The data collection technique is in two parts. First, primary data collection was conducted by conducting a field survey. Second, secondary data collection is obtained by downloading the official USGS (United States Geographical Survey) website http://eartexlorer.usgs.gov/. LData collection from 2013 until 2022 using Landsat 8 as a satellite with OLI TIRS band 8 as sensor type with 15 m and 30 m resolution.

2.4. Type of Research

The process carried out in this study consists of 2 (two) stages of analysis (Hakim et al., 2014) namely: Analysis and interpretation of satellite love data (landsat) for mapping coastline changes and Calculation with DSAS (Digital Shoreline Analysis System). Analysis and interpretation of satellite love data (landsat) for mapping coastline changes, among others: 1) Image cropping: Image cropping is done to capture the focus of the study area, 2) Image restoration: Image restoration is done to improve the quality of satellite imagery that is poor due to damage from the satellite or atmospheric disturbances, 3) Image enhancement, is the merging of bands that are needed to emphasize the land and water boundaries to simplify the process, 4) Shoreline digitization is a process of combining bands. The Landsat 8 OLI TIRS bands that are merged are band 2, band 4, and band 5. The merging of these bands is done with composite bands in the order of band 542, 5) Overlaying, between the coastlines of the selected data year, the areas of abrasion and accretion can be identified. To determine the level of shoreline, change or the level of coastal abrasion is done by using.

Calculation of shoreline changes using the Digital Shoreline Analysis System (DSAS) application. The statistical method in DSAS used is NSM. The reference line or baseline is used as the starting point for making transects. The 2013-2022 shoreline becomes the shoreline that will be calculated for distance and rate of change. After the calculation process is complete, the average shoreline change is calculated, and the selection of transects that experience maximum changes in each segment. DSAS parameters required in DSAS processing include Baseline parameters, Shoreline parameters, and Transect Parameters. The baseline is the line used as the starting point for making transects. The baseline used in this study has requirements: a) The baseline is connected to the geodatabase. The geodatabase is a repository for statistical results and a link between DSAS parameters. To connect with the geodatabase, the baseline has an attribute in the form of an ID as a link between other DSAS parameters, b) The baseline has a similar coordinate system. The coordinate system of the baseline is customized and similar to that of the other parameters, to prevent the parameters from overlapping, c) The baseline is adjusted to the condition of the coastline, the baseline is perpendicular (facing) following the coastline. In this study, the baseline does not cut or touch the coastline, if the baseline cuts or touches the coastline when running statistical calculations do not run and there will be a coastline that is skipped by the calculation, d) The baseline was placed onshore. Placement of the baseline onshore aims to determine how much shoreline change occurs on land.

The shoreline is the delineation of the coastline resulting from the processing of the BILKO method. The shoreline used in this study has requirements: 1) Shoreline is linked to the geodatabase and has attributes such as ID, among others, 2) Shoreline has geometric values and has a coordinate system similar to other DSAS parameters.

Transect Parameters; a transect is a perpendicular line from the baseline to intersect 2 shorelines. Transects used in this study have requirements: 1) Transects are linked to the geodatabase and have an attribute of ID, 2) Transects have similar geometric values and coordinate systems, 3) Transect space is the distance between transects (using 50 meters), 4) Transect Length is the length of the transect. A transect length of 15,000 meters was used. Transect length is adjusted to the shape of the coastline and the furthest distance between the baseline and the coastline.

3. Results and Discussion

3.1. Abrasion Rate Analysis 2013-2022

Analysis of the coastal abrasion rate of Laha Village using landsat satellite data with the addition of the DSAS (Digital Shoreline Analysis System) tool on the ArcGIS 10.3 software. This study uses Landsat 8 OLI TIRS satellite data downloaded through the official USGS (United States Geographical Survey) website http://eartexplorer.usgs.gov/ with different year variations and divided into four points, based on the results of monitoring on the Landsat satellite and the use of the NSM (net shoreline movement) method in DSAS we can find out which points are experiencing abrasion and accretion in the Laha Village coastal area with a coastal length of 3,579 meters analyzed. Figure 6 shows an overview of abrasion that occurred on the coast of Laha Village in 2013-2022.

In Figure 6 there is a graph that shows the level of change and the rate of abrasion on Laha Village Beach for the period 2013-2022. The figure shows the rate of abrasion and accretion that occurs at each point, where the red location is abrasion, and the light blue color is accretion. Abrasion and accretion that occurred on the coast of Laha village for 10 years of recording data increased every year with varying levels and conditions at each point.

Figure 7, Figure 8, and Figure 9 below are graphs of changes in the coastline of Laha Village using three methods contained in DSAS including NSM, SCE, and EPR. This graph illustrates the level of change and the rate of abrasion on the Laha Village Beach for the period 2013-2022.

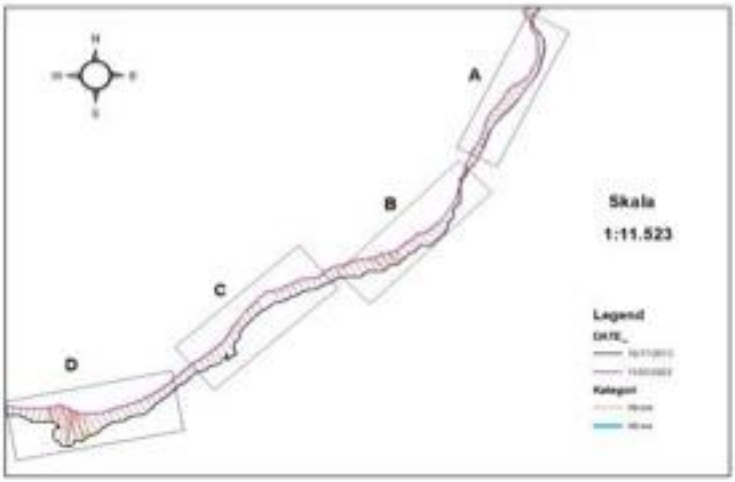

Figure 6. Map of Laha Village Beach Abrasion Rate Analysis 2013-2022 Source: ArcGIS 10.3

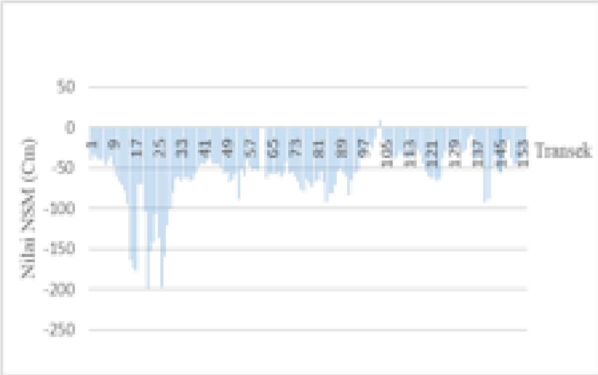

Figure 7. Graph of changes in Laha Village Beach 2013-2022 with the NSM method

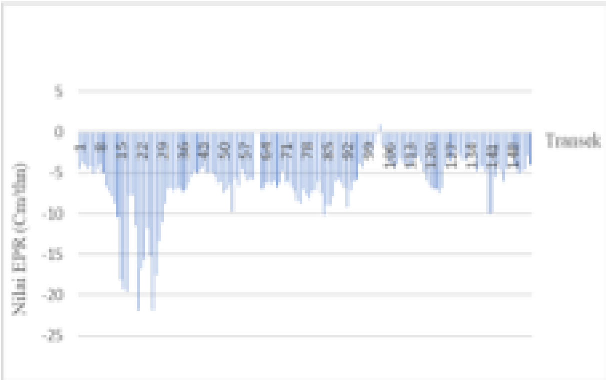

Figure 8. Graph of beach change in Laha Village 2013-2022 using EPR method

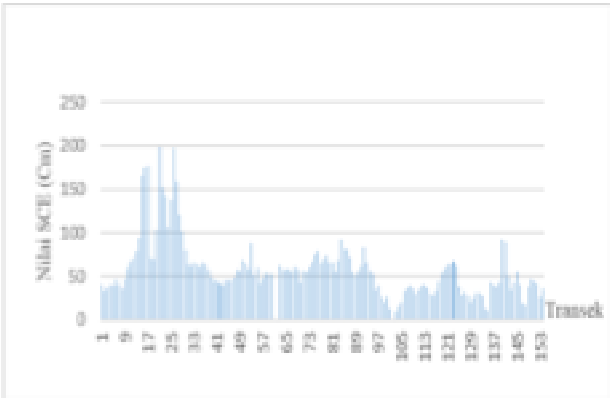

Figure 9. Graph of beach change in Laha Village 2013-2022 using SCE method

3.2. Abrasion Rate Analysis 2013-2022

Figure 10 shows the area of abrasion that occurred on the coast of Laha Village in 10 years of recording data.

Table 1 shows the results of the average area of abrasion and accretion that occurred on Laha Beach. Based on Figure 8, it is known that abrasion and accretion occur at each point where the red location is abrasion, and the light blue color is accretion. Changes in the coastline of Laha village in 10 years of recording data from the above area data show that there have been changes in the coastline with a maximum abrasion area of 113.534 m 2minimum abrasion 0.01 m2 with an average value of abrasion area that occurs 89.29 m2 while the maximum area of accretion is 90.21 m2 minimum accretion 0.01 m2 with an average value of accretion that occurs 70.70 m2 as shown in table 1.

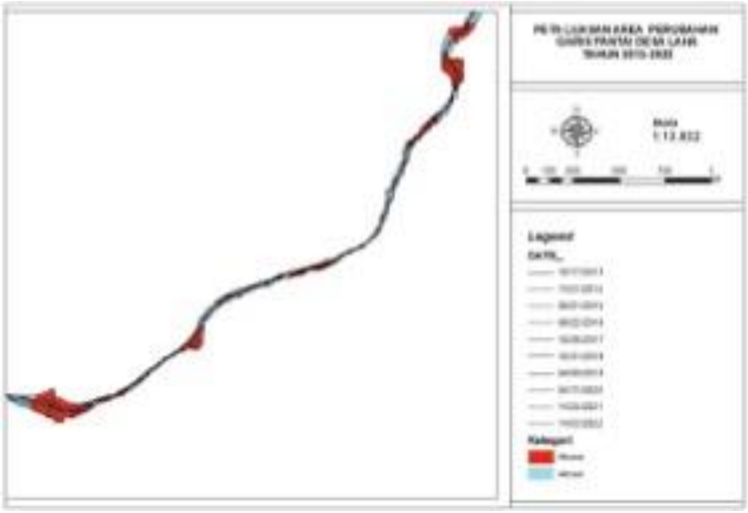

Figure 10. Laha Village Beach Abrasion Rate Analysis Map for 10 years

Source: ArcGIS

Table 1. Average Abrasion and Accretion Area

Category 1	**Category 2**	**Area Abrasion accretion m^2**	**Total area changes per year m^2**
	Minimum	-0.01	-113.534
Abrasion	Maximum	-1135.34	
	Average	-89.26	
	Minimum	0.01	90.21
Accretion	Maximum	902.1	
	Average	70.70	

Source: Data Processing Results of Landsat 8 Satellite Imagery, 10 Years of Recording Data Note. Distance in m^2 abrasion (-) accretion (+)

Table 2. Results of Average Shoreline Change per Year

Year	**Abrasion**			**Accretion**		
	Max	**Min**	**Average**	**Max**	**Min**	**Average**
2013-2014	-77.37	-0.01	12.54	+57.63	+0.12	+9.73
2014-2015	-123.72	-0.06	-18.83	+33.55	+0.06	+7.26
2015-2016	-62.64	-0.08	-9.36	+53.05	+0.05	+14.60
2016-2017	-77.93	-0.31	-19.60	+29	+0.03	+8.42
2017-2018	-32.53	-0.01	-9.47	+31.3	+0.04	+3.77
2018-2019	-154.22	-0.2	-15	+99.32	+0.47	+13.54
2019-2020	-32.08	-0.04	-5.35	+140.37	+0.02	+19.97
2020-2021	-50.36	-0.01	-9.13	+21.31	+0.05	+7.41
2021-2022	-48.34	-0.18	-12.10	+0.67	+0.05	+14.53
Area	-113.534	-0.01	-89.29	+90.21	+0.01	+70.70

Source: Data Processing Results of Landsat 8 Satellite Imagery, 10 Years of Recording Data Note: distance in cm abrasion (-) accretion (+).

Table 3. Results of Average Shoreline Change Rate per Year

Year	Rate of change (cm/yr)		Area of change (m^2 /yr)	
	Abrasion	Accretion	Abrasion	Accretion
2013-2014	-12.54	+9.73	-77.37	+52.63
2014-2015	-18.83	+7.26	-123.72	+25.42
2015-2016	-9.36	+14.60	-62.64	+45.27
2016-2017	-19.60	+8.42	-72.93	+20.98
2017-2018	-9.47	+3.77	-32.53	+16.46
2018-2019	-15	+13.54	-154.22	+99.32
2019-2020	-5.35	+19.97	-32.08	+140.37
2020-2021	-9.13	+7.41	-50.36	+21.31
2021-2022	-12.10	+14.53	-48.34	+37.82
Average annual rate of change	-11.138	+9.91		

Source: Data Processing Results of Landsat 8 Satellite Imagery, Per Year Note: distance in cm abrasion (-) accretion (+).

3.3. Identification of Average Beach Change Rate

From the results of the analysis carried out, the results of the rate and changes in the coastline of Laha can be obtained as follows. Table 3 shows that the highest abrasion area occurred in 2018-2019, namely -154.22 m, with an average abrasion of -15 m in each transect. Table 3 presents the average rate of change of the largest beach each year and the results of the average rate of change per year of Laha Beach using the NSM method. The highest accretion occurred in 2019-2020, namely +140.37 with an average accretion of +19.97 m at each transect.

4. Conclusion

The results of the analysis of the coastal abrasion rate of Laha Village, Ambon City for 10 years along the coast of Laha Village both abrasion and accretion processes. The average rate of shoreline change due to abrasion is 11.13 cm/year, while the average rate of shoreline change due to accretion is 9.91 cm/year. The highest shoreline changes due to abrasion occurred in 2018-2019 with an average value of 15 cm/year with an abrasion area of 154.22 m^2/year. While the highest change in coastline due to accretion occurred in 2019-2020 with an average value of 19.97 cm/year with an abrasion area of 140.37 m/year^2.

Accuracy and patience are required both when digitizing the coastline and when analyzing using DSAS. This research does not consider tidal variables so for future research it is better to consider tidal data.

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