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Study of Coastline Shifts on the West Coast of Lampung Using Remote Sensing Data

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Abstract

This study specifically aims to identify coastal abrasion as seen from the coastline shift, from 1989 to 2020 in Pesisir Utara Sub-district and Lemong Sub-district, Pesisir Barat Regency, Lampung Province, by interpreting remote sensing data. The data used are Landsat satellite imagery for 1989, 2000, 2006, and 2020. Landsat satellite imagery are corrected by radiometric and geometric correction. The geometric correction is registered to Landsat imagery in 1989. The corrected satellite imagery is digitized for the coastline. The results of the digitized coastline were then overlaid, then the coastline shift was calculated from 1989 to 2020. The coastline shift calculation was carried out at 16 locations in Pesisir Utara Sub-district and Lemong Sub-district. The results of calculations at 16 sample locations show that there has been a shift in the coastline due to coastal abrasion from 1989 to 2020 of 2.0 m/yr. For areas where the coastal conditions are rocky and there are shallow rocks in front of it, the coastline shift is only small, such as in the cape area before Walur Village. This coastline shift was also evidenced by direct checking of the area and asking local residents, the results showed that the overall shift of the coastline was caused by coastal abrasion.

Keywords: abrasion; coastal; geometric correction; landsat.

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Introduction

The coastline is the meeting line between sea water and land whose position changes according to the position during tides, the influence of waves and ocean currents (Setiyarso et al., 2016; Yasir et al., 2021). Coastline changes are sometimes caused by social and natural factors, such as human activities in the coastal zone, long-term and short-term sea level changes, storm events, subsequent recovery, and so on (Alimuddin & Aryanti, 2020; Suniada, 2015; Wang et al., 2017; Xu, 2018). Changes in the coastal environment can occur slowly to quickly, depending on the power balance between topography, rocks and their properties with waves, tides and wind (Harianja et al., 2019). Accretion and abrasion of Coastal occur due to the input of sediment from the mainland to the coastal area and the influence of hydro-oceanographic factors in the form of waves and currents that carry sediment (Astuti et al., 2021; Fuad et al., 2019; Wang et al., 2017). The process of accretion and abrasion results in unbalanced coastal conditions and impacts on coastal areas.

The following are some studies related to coastline changes. The coastline change that occurred in Gianyar Regency based on SPOT satellite imagery in 2009 and 2015 was 22,441 m. The average rate of coastal erosion that occurred in Gianyar Regency based on SPOT satellite images in 2009 and 2015 was 3,202 m/yr (Aryastana et al., 2016). Most of the changes in the coastline in Kendal Regency occurred in the bay area and along the headland, during the period

1972 to 1991 there were abrasion and accretion covering 765.14 acres and 356 acres (Arief et al., 2011). The coastline in Bentenan Village, Pusomaen District, Minahasa Tenggara experienced an average change of 165 m towards the mainland in the period 1985-2008 (Opa, 2011).

The coastal area in Pesisir Utara Sub-district and Lemong Sub-district, Pesisir Barat Regency is a coastal area located on the West Coast of Lampung Province. The geographical condition of the coast of Pesisir Barat Regency which is directly facing the Indian Ocean and the absence of small islands as natural breakwaters, has caused many coastal areas in the Pesisir Barat Regency to experiencing abrasion which has resulted in changes in the coastline. From direct observation in the field, many coastal areas in the Pesisir Barat District experienced abrasion (Fig. 1 to 3) which causes coastline shift. The protection of the coastal areas of the Pesisir Barat Regency requires careful planning. In planning for the development of coastal protection, supporting data will be needed, one of which is the coastline shift. In addition to direct monitoring in the field, another method that can be used to monitor coastline shift due to abrasion is the interpretation of remote sensing data, field monitoring is only to check the results of the interpretation. The development of remote sensing technology is currently leading to an increase in spatial and temporal resolution for information acquisition and monitoring purposes (Lubis D et al., 2017). At present the use of remote sensing image datasets such as Landsat and geographic information systems (GIS) plays a very important role as a cheap and easy method of providing coverage data on coastal areas and the dynamics therein (Avtar et al., 2020; Kasim, 2012).

The aim of this study is to identify coastal abrasion as seen from the coastline shift from 1989 to 2020 in Pesisir Utara Sub-district and Lemong Sub-district, Pesisir Barat Regency, Lampung Province, by interpreting remote sensing data.

Figure 1. The condition of the west cross road in Lemong Sub-district has been affected by abrasion.

Figure 2. The condition of the coast behind SMAN 1 Lemong.

Figure 3. The condition of the coast behind Balam Village.

Materials and Methods

The location of the study will be specifically on coastal sections, which have experienced abrasion, starting from the Lemong Sub-district to the Pesisir Utara Sub-district in Balam Village, Pesisir Barat Regency, Lampung Province (Fig.4).

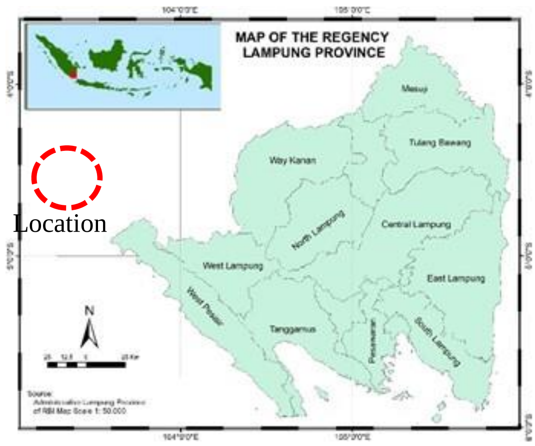

Figure 4. Map of the research sites in the West Pesisir Regency (Balai Pelaksanaan Jalan Nasional Lampung, in Sulistyorini, 2021).

The expected result of this research is the rate of coastline change due to coastal abrasion. The satellite imagery used in this study are Landsat TM Satellite Imagery recorded in 1989, Landsat ETM+ Satellite Imagery recorded in 2000, Landsat 7 ETM+ Satellite Imagery recorded in 2006, and Landsat 8 Satellite Imagery recorded in 2020, as well as visual data obtained with direct observation of the field. The method of implementing this research consists of several stages: Collection of Landsat imagery; Landsat satellite imagery correction process; Digitizing the coastline on each Landsat satellite imagery; Analysis of coastline changes.

The flowchart of the research implementation can be seen in Fig. 5. The results of this study were maps of the coastlines for 1989, 2000, 2006, and 2020, along with their shift values from every year. The satellite imagery data used are Landsat satellite imagery for 1989, 2000, 2006 and 2020. These Landsat imagery can be downloaded for free on the web page: https://earthexplorer.usgs.gov/ (Achoh et al., 2021).

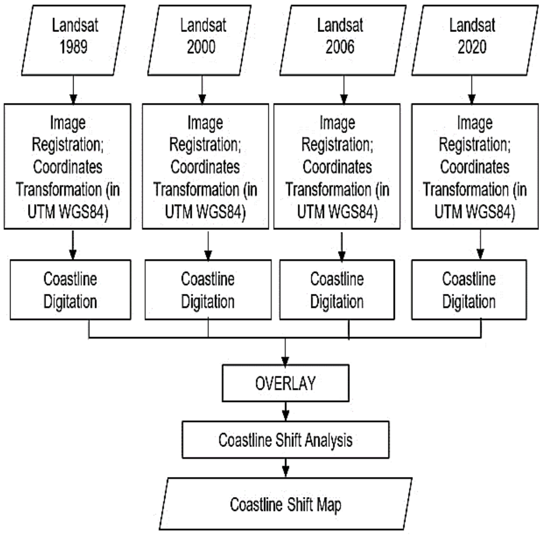

Figure 5. Flowchart of research implementation

Image Enhancement

Image enhancement is carried out in several stages:

1. Create RGB displays on Landsat imagery for each year (1989, 2000, 2006, and 2020) with the aim of adjusting the brightness of the color pixels in the image. Fig. 6 shows each satellite image after sharpening.
2. Improving image quality by adjusting the RGB histogram to achieve the image quality we want.

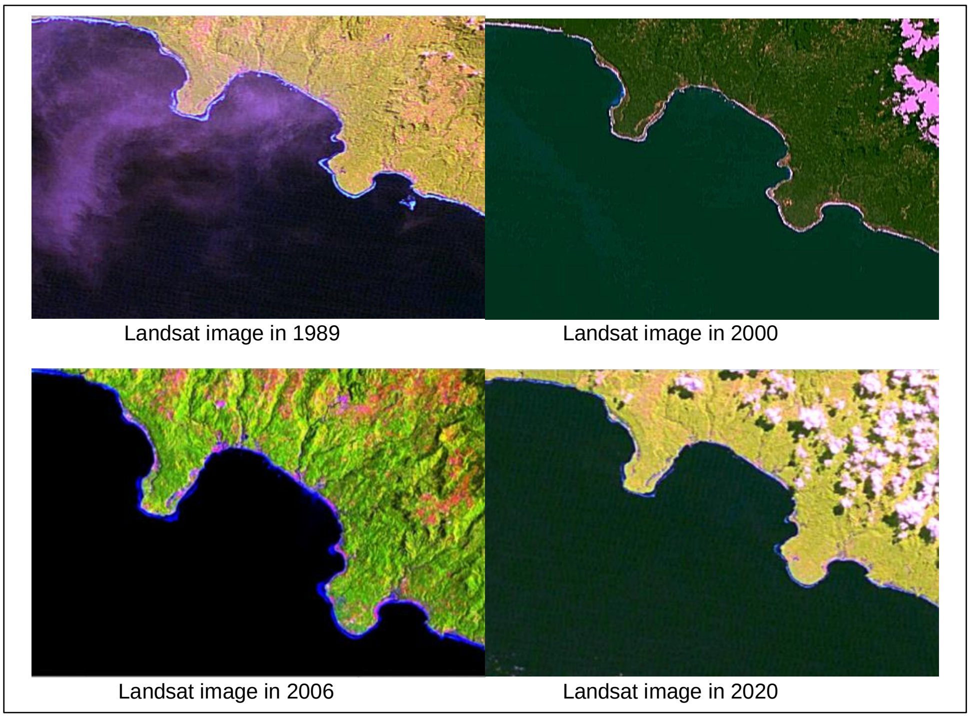

Figure 6. Satellite imagery after enhancement (in 1989, 2000, 2006 and, 2020).

Geometric Correction

The geometric correction is carried out by registering the 2000, 2006, and 2020 satellites to the 1989 image. The image registration steps are carried out by: Identification of allied points (GCP) and check points. GCPs coordinates are in the form of field observation coordinates with GPS; Digital image processing using the rectification method (Shawal et al., 2014), in this process coordinate transformation is carried out using: the UTM (Universal Transverse Mercator) projection system which refers to the World Geodetic System 1984 reference ellipsoid (ICAO, 2002). The chosen transformation method is polynomial. The geometric correction is carried out using ground control points (image to map rectification).

The results of geometric correction need to be seen for their accuracy. Accuracy is the degree of closeness or accuracy of an information that is on a map or in a digital database with the actual value (Thurston et al., 2003). The magnitude of the error is indicated by the RMSe (root mean square error) value (Chai & Draxler, 2014). RMSe is the value of the difference between the actual value and the measured value (Chai & Draxler, 2014). The greater the RMSe value, the greater the error value of the measurement results against the actual conditions (Simbolon et al., 2017). Here is the formula for calculating RMSe.

$$RMSe = \sqrt{(RMSx)^2 + (RMSy)^2} \quad (1)$$

$$RMSx = \sqrt{\sum Dx^2/n} \quad (2)$$

$$RMSx = \sqrt{\sum Dy^2/n} \quad (3)$$

$$\sum Dx^2 = \ {dx_1}^2 + {dx_2}^2 + \cdots {dx_n}^2 \quad (4)$$

$$\sum Dy^2 = \ {dy_1}^2 + {dy_2}^2 + \cdots {dx_n}^2 \quad (5)$$

Satellite imagery contain various geometric distortions that must be corrected. This distortion is generated by factors such as variations in the height of the satellite, the verticality of the satellite and its speed. Random distortions and complex systematic distributions are corrected using field tie point analysis. GCP is an appearance whose location is known and its position can be precisely determined on satellite imagery. A good appearance as a tie point, among others, the intersection of highways, rivers and so on. In the correction process, a large number of tie points are placed according to the image coordinates and field coordinates, the coordinate values are then used for the least quadrant analysis (Lillesand & Kieffer, 1997).

Coastline Digitization

The sharpened and geometric corrected imagery are then exported to the Quantum GIS application program. The corrected Landsat satellite imagery for 1989, 2000, 2006 and 2020 were then digitized for the coastline. Digitization is done by on screening. The result of this digitization is then the calculation of the coastline shift with the initial reference to the 1989 image. The digitized coastline of each Landsat image can be seen in Fig. 7. There are 16 (sixteen) locations where the coastline shift is calculated, which are 3 locations in Balam Village, 4 locations in Kerbang Dalam, 2 locations in Kuripan Village, 3 locations in Walur Village, and 4 locations in Penengahan Village. These locations were chosen because the soil structure is sandy beaches which are prone to abrasion due to natural phenomena.

Coastline Shift Analysis

Coastline shift were calculated from 1989-2020, 1989-2006, 1989-2000, and 2006-2020, using the Euclidean Distance Method as follows (Mustofa & Suasana, 2020; Pamungkas, 2019)

$$D = \sqrt{(X_{th\,n+1} - X_{th\,n})^2 + (Y_{th\,n+1} - Y_{th\,n})^2} \quad (6)$$

where the value of D is the shift, X/Y $_{(th\ n+1)}$ is value of x/y years to n+1, X/Y $_{(th\ n)}$ is value of x/y years to n.

Figure 7. Digitized coastline results from Landsat satellite imagery.

Results and Discussion

The results of geometric correction using the registration method have an accuracy of range (RMSE) below 2 meters, with a pixel resolution of 30m Landsat satellite imagery, so the accuracy is still below 1 pixel, which is 30 m.

Coastline Shift Calculation

The sixteen locations whose coastline shift values were calculated can be presented in Fig. 8 to 13, while the results of the coastline shift calculation from 1989 to 2020 can be seen in Table 1.

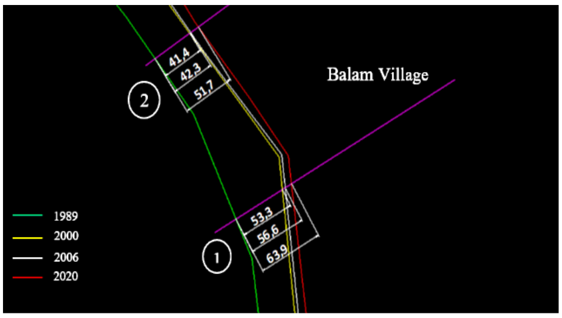

Figure 8. Coastline shift on location 1 and 2.

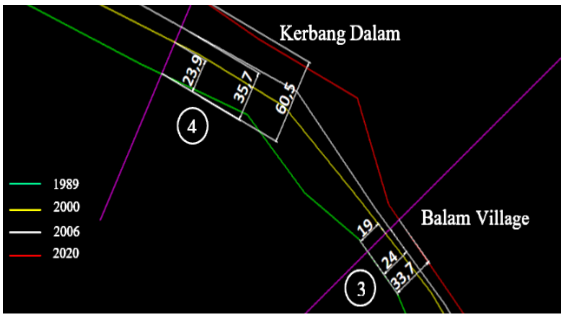

Figure 9. Coastline shift on location 3 and 4.

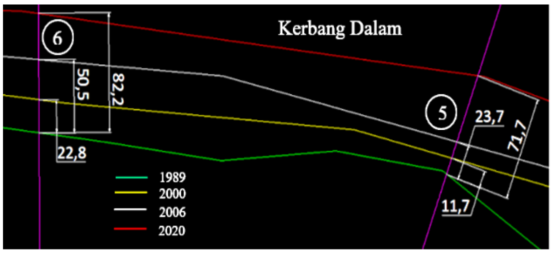

Figure 10. Coastline shift on location 5 and 6.

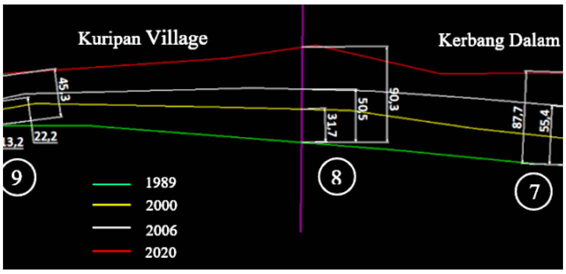

Figure 11. Coastline shift on location 7 – 9.

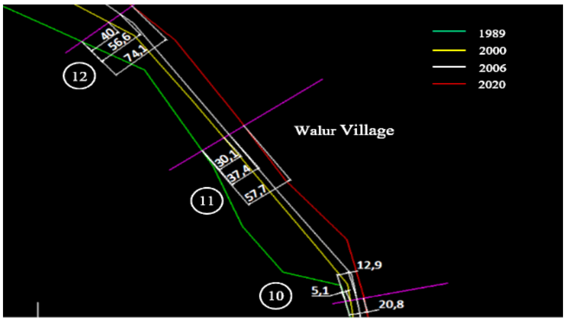

Figure 12. Coastline shift on location 10 – 12.

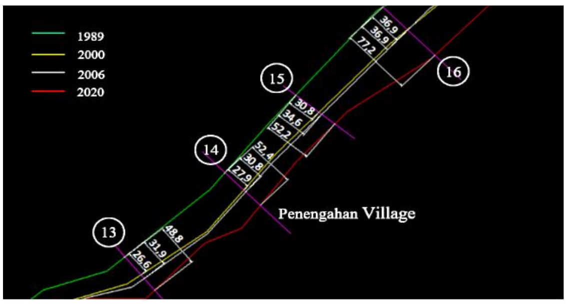

Figure 13. Coastline shift on location 13 – 16.

Table 1. The results of calculating coastline shift.

No	1989-2020		1989-2006		1989-2000		2000-2006		2006-2020		Avrg.	Location
	Dist. (m)	Shift m/yr	Dist. (m)	Shift m/yr	Dist. (m)	Shift m/yr	Dist. (m)	Shift m/yr	Dist. (m)	Shift m/yr	Shift m/yr	
1	63.9	2.1	56.6	3.3	53.2	4.8	3.4	0.6	7.3	0.5	2.1	Balam
2	51.7	1.7	42.3	2.5	41.5	3.8	0.8	0.1	9.4	0.7	1.7	Balam
3	33.7	1.1	24	1.4	19	1.7	5.0	0.8	9.7	0.7	1.1	Balam
4	60.5	2.0	35.7	2.1	23.9	2.2	11.8	2.0	24.8	1.8	2.0	Krb.Dalam
5	71.7	2.3	23.6	1.4	11.6	1.1	12.0	2.0	48.1	3.4	2.3	Krb.Dalam
6	82.2	2.7	50.5	3.0	22.8	2.1	27.7	4.6	31.7	2.3	2.7	Krb.Dalam
7	87.7	2.8	55.4	3.3	25.1	2.3	30.3	5.1	32.3	2.3	2.8	Krb.Dalam
8	90.3	2.9	50.5	3.0	31.7	2.9	18.8	3.1	39.8	2.8	2.9	Kuripan
9	45.3	1.5	22.2	1.3	13.2	1.2	9.0	1.5	23.1	1.7	1.5	Kuripan
10	20.8	0.7	12.9	0.8	5.1	0.5	7.8	1.3	7.9	0.6	0.7	Walur
11	57.9	1.9	37.4	2.2	30	2.7	7.4	1.2	20.5	1.5	1.9	Walur
12	74.1	2.4	56.7	3.3	39.9	3.6	16.8	2.8	17.4	1.2	2.4	Walur
13	48.8	1.6	31.9	1.9	26.6	2.4	5.3	0.9	16.9	1.2	1.6	Penengahan
14	52.4	1.7	30.8	1.8	27.9	2.5	2.9	0.5	21.6	1.5	1.7	Penengahan
15	52.2	1.7	34.6	2.0	30.8	2.8	3.8	0.6	17.6	1.3	1.7	Penengahan
16	77.2	2.5	36.9	2.2	36.9	3.4	0.0	0.0	40.3	2.9	2.5	Penengahan
Average					**27.5**	**2.5**	**10.2**	**1.7**	**23.0**	**1.6**	**2.0**	

From Table 1 there are several things that can be discussed, related to the coastline shifts that occur:

1. The greatest shift occurred between 1989 and 2000 with an average shift for 16 locations of 2.5 m/yr, then in the period 2000 to 2006, there was a decrease in coastline shift, which is an average for 16 locations of 1.7 m/yr. Furthermore, in the range of 2006 to 2020 there was an increase in the shift of the coastline again, which is with an average shift for 16 locations of 1.6 m/yr.
2. Overall, the magnitude of the average coastline shift from 1989 to 2020 for 16 locations was 2.0 m/yr, with the largest shift occurring in the Kuripan area of 2.9 m/year, while the smallest shift occurred at the Walur Village location that is equal to 0.7 m/yr.
3. The results of this analysis were also proven by asking directly to the elders in the Balam Village area that before 2000 the village road (Fig. 14) was on the talud that was built, whereas currently it is being moved in front towards the land about 50 meters from the talud (Fig. 15).

The local residents also said that from the talud that was visible (Fig. 14) previously there were about 5 rows of coconut trees towards the beach which have now been lost due to abrasion. From the results of the coastline shift analysis, there was a shift from 1989 to 2020 of 42.3 m, if the distance between coconut trees is ± 8 m, then for 5 rows of coconut trees there is a distance of ± 40 m, so the results of analysis using remote sensing data are not significantly different.

Figure 14. Condition of the coast in 2020 at Balam Village, at first it was a village road.

Figure 15. The condition of the village road was moved about 50 m from the beach.

At the end of the village of Balam Village it can also be seen (Fig. 16) that the condition of the ditch installed has been destroyed by coastal abrasion, so it is necessary to find a suitable construction solution to tackle coastal abrasion.

Figure 16. The Beach conditions at the end of Balam village.

In the Kuripan village area (Fig. 17), it was once a village, but now it no longer exists and has been moved about 2 km from the beach. The results of the analysis used Landsat imagery from 1989 to 2020, there was a shift of 45.3 to 90.3 m.

Figure 17. The condition of the village was lost due to coastal abrasion in the Kuripan village.

The results of direct observations in the field show that the condition of the coast is sloping with a stretch of coast in the form of sand and no coast resistance, only in the form of shrubs, this situation allows large abrasion to occur. There needs to be special handling for this kind of area, so that coastal erosion can be controlled.

Conclusion

Based on the results and discussion there are several conclusions that can be drawn; The first, the geographical conditions of the Pesisir Barat District facing the Indian Ocean with no islands as break water, especially Pesisir Utara and Lemong Sub-districts experienced coastline shift from 1989 to 2020 an average of 2.0 m/yr. The biggest shift occurred in Kuripan Village, which was 2.9 m from 1989 to 2020. Second, for the cape area before the Walur Village the coastline shift is only small, this is because the cape area has a rocky hillside, and in front of the cape there is a natural break water in the form of shallow coral, so the incoming waves are broken up first by the shallow reef. Third, from the results of this study it can also be concluded that remote sensing data is very supportive for making maps of coastline shifts, rapidly and low cost, and if using satellite imagery with better resolution such as GeoEye imagery (0.5 m resolution) it will a more accurate map of coastline shifts can be made.

The last, the average coastline shift of 2.0 m/year can be input for the local government to prevent even greater coastline shifts. Almost along the coast of Pesisir Barat Regency, Lampung Province, has great tourism potential, If it is managed properly, this tourism potential can bring large income to local government.

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Author Contribution

Romi Fadly: Concept and designed the analysis, collected the data, contributed data or analysis tools, performed the analysis, wrote the paper; **Citra Dewi**: Concept and designed the analysis, collected the data, contributed data or analysis tools, performed the analysis, wrote the paper; **Fajriyanto**: Collected the data, contributed data or analysis tools, wrote the paper.

Conflict of Interest

The authors declare there is no conflict of interest with anyone.

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