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Research Article

Long-Term Monitoring of Shoreline Changes in Cilacap Regency, Central Java, Based on Landsat 8 Imagery (2016–2025)

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Abstract: This study evaluates 10-year shoreline changes (2016–2025) in Cilacap Regency using Landsat-8 satellite imagery. Remote sensing analysis identified both erosion and accretion processes along the coast. The shoreline was divided into transects perpendicular to the coast, and changes were measured using the Haversine and Euclidean Distance methods. The Haversine method recorded the smallest change at transect 11 (0.3 meters) and the largest at transect 9 (122.24 meters), while the Euclidean Distance method produced similar results, with a minimum of 0.3 meters at transect 11 and a maximum of 121.59 meters at transect 9. Paired T-test results indicated no significant difference between the two methods, confirming their reliability for analyzing 10-year shoreline changes. ANOVA further showed no significant differences among years within each transect or across transects during the study period. These findings demonstrate that remote sensing combined with quantitative measurement techniques provides an effective and reliable approach for long-term coastal monitoring in Cilacap Regency.

Keywords: Cilacap Regency; Coastal Mentoring; Landsat 8; Remote Sensing; Shoreline Change

1. Introduction

Indonesia, an archipelagic country with about 70% of its territory consisting of marine waters, has approximately 81,000 km of coastline—one of the longest in the world. This vast coastal area supports abundant natural resources and high biodiversity that play an important role in national development and local livelihoods. (Ardhi C F et al., 2018). However, shoreline positions are not static; they constantly shift due to natural processes such as abrasion and sedimentation, as well as human activities including sand mining and reclamation (Arifin dkk, 2020).

Cilacap Regency, located on the southern coast of Java Island, stretches along roughly 105 km of shoreline facing the Indian Ocean. This geographical position makes it highly vulnerable to coastal hazards such as erosion, sediment accumulation, and mangrove degradation. Therefore, monitoring shoreline change in Cilacap is essential for understanding coastal dynamics and supporting sustainable coastal management (Muhammad Hanisa et al., 2024) & (Aryastana et al., 2016).

Remote sensing and Geographic Information Systems (GIS) offer efficient tools for long-term shoreline observation, providing wide spatial coverage and reduced field survey costs. This study applies Landsat 8 satellite imagery from 2016 to 2025 to analyze shoreline changes in Cilacap Regency. The results are expected to serve as a scientific basis for coastal protection, infrastructure planning, and environmental management in the region.

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2. Reaserch Methodelogy

Data Collection

This study uses secondary data obtained indirectly through remote sensing techniques. The main dataset consists of Landsat-8 satellite imagery covering the coastal area of Cilacap Regency from 2016 to 2025. The images were downloaded from the official USGS Earth Explorer platform (https://earthexplorer.usgs.gov). A total of ten image sets were selected, representing annual observations from 2016 to 2025 for shoreline change analysis.

No.	Tanggal	Nama File
1	15/05/2016	LC08_L2SP_120065_20160515_20200907_02_T1
2	25/05/2017	LC08_L2SP_121065_20170525_20200903_02_T1
	18/05/2017	LC08_L2SP_120065_20170518_20200904_02_T1
3	12/05/2018	LC08_L2SP_121065_20180512_20200901_02_T1
	05/05/2018	LC08_L2SP_120065_20180505_20200901_02_T1
4	15/05/2019	LC08_L2SP_121065_20190515_20200828_02_T1
	08/05/2019	LC08_L2SP_120065_20190508_20200829_02_T1
5	10/05/2020	LC08_L2SP_120065_20200510_20200820_02_T1
6	13/05/2021	LC08_L2SP_120066_20210513_20210524_02_T1
7	24/05/2022	LC09_L2SP_120066_20220524_20230415_02_T1
8	19/05/2023	LC08_L2SP_120066_20230519_20230524_02_T1
9	05/05/2024	LC08_L2SP_120066_20240505_20240513_02_T1
10	30/04/2025	LC09_L2SP_120066_20250430_20250502_02_T1

Mapping

Shoreline change was calculated to identify accretion and erosion processes. The analysis used Microsoft Excel with the Haversine and Euclidean Distance formulas Haversine based on decimal degree coordinates and Euclidean using UTM coordinates. Both methods provided quantitative information on shoreline displacement.

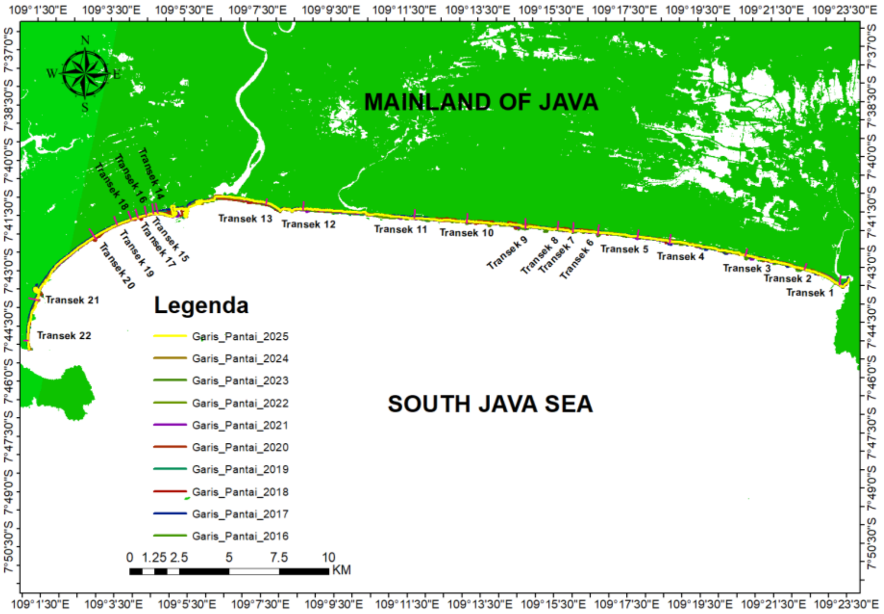

Figure 1. Mapping Transect Location.

Reaserch Flowchart

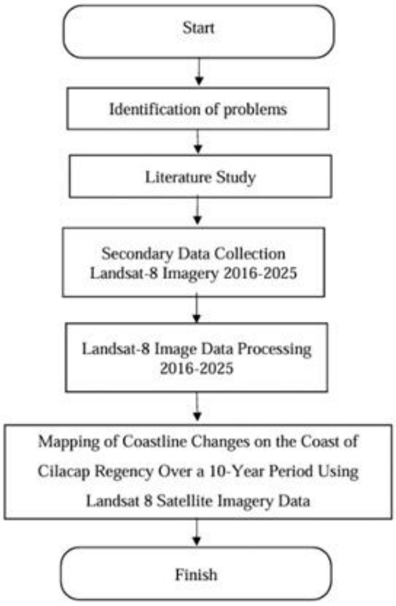

Figure 2. Reaserch Flowchart.

Data Processing Flowchart

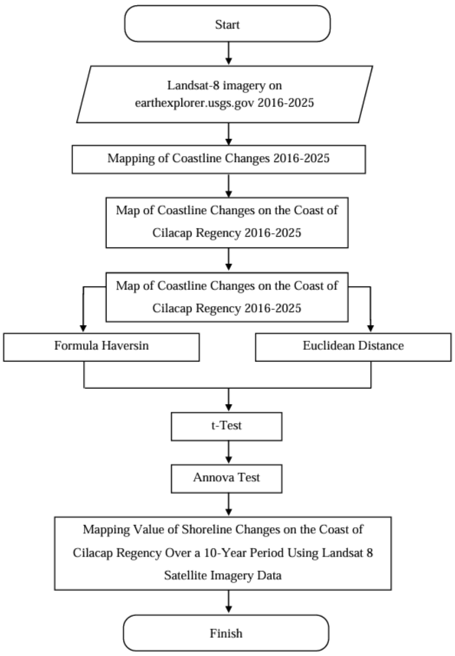

Figure 3. Procesing Flowchart.

3. Results and Discussion

Analyzing Coastal Changes with the Haversine Technique

Using the Euclidean Distance method, shoreline variations for each transect over a decade were computed. The corresponding changes in Pati Regency are presented in the following figure:

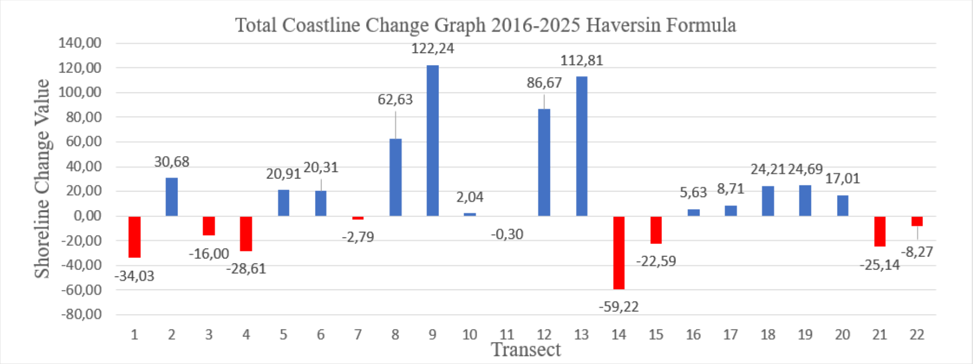

Figure 4. Graph Formula Haversine.

The smallest shoreline change was recorded at transect 11, measuring 0.3 meters, while the largest change occurred at transect 9, with a value of 122.24 meters.

Analyzing Coastal Changes Using the Euclidean Distance Method

Shoreline changes for each transect were measured using the Haversine method. The resulting coastline change values for Pati Regency, obtained through the Haversine formula, are presented in the following figure:

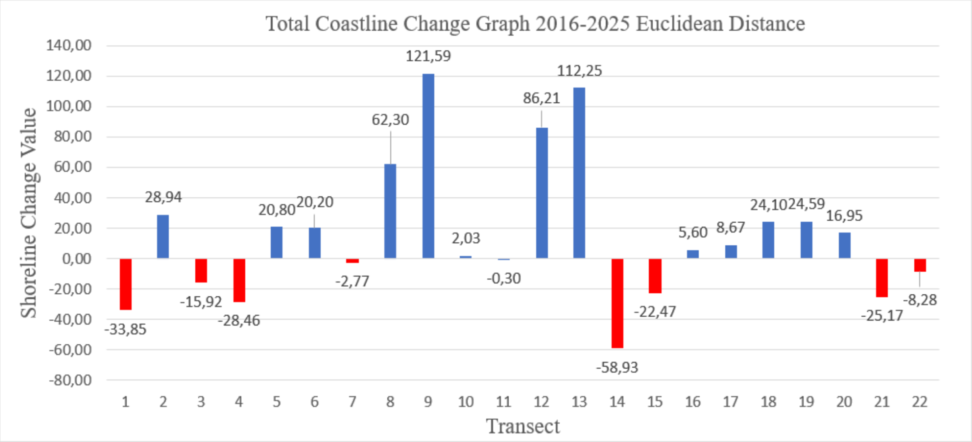

Figure 5. Graph Euclidean Distance.

Based on the Euclidean Distance calculation, the smallest shoreline variation occurred at transect 11 (0.3 meters), while the largest was at transect 9 (121.59 meters).

Accretion in transects 8–13 is influenced by the gentle seabed topography in the central zone, which causes waves to break farther from the shoreline, thereby reducing wave energy and allowing sediment to settle more easily. In contrast, erosion in transects 1, 4, 14, and 21 occurs in the sediment deficit zones, affected by wave reflection from nearby islands and human activities that disrupt sediment supply.

t-Test

The T-test was conducted to determine whether there is a significant difference between two variables. After calculating using the Haversine and Euclidean Distance formulas, a T-test was performed to examine the differences in results and the methods used. The comparison of both methods based on the T-test is presented in the following table:

	Formula Haversine	Euclidean Distance
Mean	17,88652603	17,7106724
Variance	2078,645227	2056,124676
Observations	21	21
Pooled Variance	2067,384951	
Hypothesized Mean Difference	0	
df	40	

	Formula Haversine	Euclidean Distance
t Stat	0,012532431	
P(T<=t) one-tail	0,495031564	
t Critical one-tail	1,683851013	
P(T<=t) two-tail	0,990063128	
t Critical two-tail	2,02107539	

Based on the analysis, the t-value (P(T≤t) one-tail) is smaller than the t-table value (t Critical one-tail). This condition indicates that the null hypothesis (H_0) is accepted, while the alternative hypothesis (H_1) is rejected. This means that the Haversine and Euclidean Distance methods do not show a significant difference in determining shoreline changes. The T-test shows no significant difference between the Haversine and Euclidean Distance methods, as the null hypothesis is accepted. Both methods yielded comparable results for shoreline changes in Cilacap Regency over the past 10 years.

Annova Test

ANOVA (Analysis of Variance) was used to examine differences among two or more variables. The previous T-test results indicated no significant difference between the Haversine and Euclidean Distance methods in calculating shoreline changes in Cilacap Regency over a 10-year period. The results of the comparison between both methods using ANOVA are shown in the table below:

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	6749,41036	20	337,4705178	0,12566441	0,999998618	1,646027152
Columns	36102,0585	7	5157,436925	1,920482637	0,07059408	2,075588793
Error	375968,601	140	2685,490004			
Total	418820,069	167				

The ANOVA results show that for rows, F_calculated = 0.1257 is less than F_table = 1.6460, indicating H0 is accepted and H1 rejected, with no significant differences among years for each transect. For columns, F_calculated = 1.9205 is less than F_table = 2.0756, meaning H0 is accepted and H1 rejected, showing no significant differences across transects each year. Overall, there are no significant differences among transects during the study period.

4. Conclusion

Coastline mapping in Cilacap Regency using Landsat-8 satellite imagery demonstrates that remote sensing effectively monitors shoreline dynamics, revealing spatial variations of erosion and accretion. Statistical tests confirm the reliability of both Haversine and Euclidean Distance methods, witht t-Test is t_calculate < t_table and Annova Test is F_calculated < F_table, indicating no significant difference between the two or among transects across the study period. The highest accretion occurred at transect 9, reaching 122.24 meters (Haversine) and 121.59 meters (Euclidean), while the smallest change was recorded at transect 11 with 0.3 meters for both methods. Accretion in transects 8–13 is influenced by gentle seabed topography that weakens wave energy, longshore currents transporting sediment from river mouths, and the presence of port structures that retain sediment deposition. Conversely, erosion in transects 1, 4, 14, and 21 occurs within sediment-deficit zones, influenced by wave reflection from nearby islands and human activities disrupting sediment supply. Overall, coastal change in Cilacap is governed by the combined effects of Indian Ocean wave dynamics, seabed morphology, longshore currents, and anthropogenic interventions such as port construction and reclamation.

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