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Coastline Change along Pebuahan Beach in Jembrana Bali

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Abstract

Monitoring changes in coastlines over large areas will be more efficient using satellite imagery rather than conducting field surveys. This research aims to measure the coastline transformation that occurred over a period of time at Pebuahan Beach in Jembrana Regency. This research uses the Digital Shoreline Analysis System (DSAS) program. Ex situ data for 2004 and 2019 obtained from Landsat satellite imagery was used in this research. When compared coastline between 2004 and 2019, there was more extensive abrasion, reaching 300,577.17 m2, while the accretion that occurred only reached 159,697.67 m2. The cause of abrasion at Pebuahan Beach is sediment transport which tends to leave the beach to the west and sediment supply is trapped due to obstruction at the Pengambengan Port.

Keywords

Coastline, Coastal Erosion, Accretion, Satellite Image.

Introduction

The coastline marks the boundary between land and sea, shifting with tidal fluctuations and, over time, due to natural events and human activities. Coastal changes involve two main processes: erosion, which occurs when sediment transport out of an area exceeds incoming sediment, and accretion, or sedimentation, when the opposite occurs (Triadmodjo, 2000). Remote sensing allows for quick monitoring and analysis of coastline changes over time. The Landsat satellite series, for example, has been used to track coastline shifts, including at Batu Mejan beach (Pujianiki et al., 2021).

Recent advancements in remote sensing technology, particularly through Landsat data, have enhanced coastal erosion monitoring and analysis. Landsat, with its long-standing data history and regular updates, serves as a primary tool for observing shoreline changes. High-resolution imagery and improved spectral bands enable researchers to detect subtle shoreline shifts and sediment deposits over time (Dube et al., 2020). Time-series analysis of Landsat data has further improved understanding of coastal morphology, allowing for the monitoring of long-term shoreline evolution and seasonal sediment shifts—essential for managing and predicting coastal impacts (Shen & Li, 2019).

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Landsat has also been widely used to differentiate between natural and anthropogenic influences on coastal dynamics, helping provide essential information for sustainable coastal development (Li et al., 2021). Enhanced algorithms and processing techniques now enable more accurate shoreline extraction from Landsat imagery, allowing even minor coastline shifts to be detected, which is vital for managing erosion and sedimentation (Zhang et al., 2020). Additionally, combining Landsat with higher-resolution datasets, such as Sentinel-2 imagery, has improved shoreline mapping detail and offered deeper insights into sediment transport and seasonal variations (Wei et al., 2022).

Based on data from the Bali Provincial Government in 2015, 20% of the total 436.5 km of beaches surrounding the island of Bali have experienced damage. Jembrana Regency is an area that has a high level of coastal erosion. The total length of beaches in Jembrana Regency is 60 km and the area experiencing abrasion is 7.51 km (Khija and Uttoh, 2015). Pebuahan Beach, Jembrana Regency is a beach that has experienced very significant coastline decline, for this reason this research was carried out to examine the transformation of the Pebuahan coastline in the period 2004-2019.

Recent studies highlight the influence of wind and wave energy as major drivers of sediment transport and coastal erosion. Wind roses and wave height data have become essential tools for predicting patterns of coastal erosion and accretion, as these factors directly impact sediment movement along coastlines (Mazaheri et al., 2019; Lee et al., 2022). Understanding these dynamics is crucial for coastal management, as they help predict areas at high risk of erosion.

Climate-related changes, including sea-level rise and altered storm patterns, are also causing significant long-term shifts in shorelines. Many coastal areas are now experiencing increased erosion rates and accretion due to these changing environmental conditions (Garcia et al., 2021; Singha et al., 2020). These shifts underscore the importance of accounting for climate variability when studying coastal processes, as it can intensify both natural and human impacts on coastal stability.

In remote sensing studies of coastline changes, field validation remains essential for accurately assessing coastal dynamics. Integrating field surveys with remote sensing improves the precision of detected changes, especially in areas with complex geomorphology, ensuring that remote sensing findings reflect real-world conditions (Zhao et al., 2020; Kumar & Shekhar, 2022). This combined approach enhances confidence in remote sensing data and is particularly beneficial for regions where coastal features are influenced by diverse environmental factors.

Methodology

Data analysis from 2004 to 2019 focused on the coast of Negara District, Jembrana Regency, Bali, within coordinates 8°20'2.18" S, 114°31'20.53" E to 8°24'2.43" S, 114°36'10.91" E (see Figure 1). Pengambengan Port, built between 2000 and 2003, supports fishing activities and community economic growth along the Jembrana coastline, highlighted in blue in Figure 1.

Figure 1. Location of Study

This research uses ex situ data from Landsat 7 and Landsat 8 images to analyze coastline changes and transformation rates. The process includes SAR image upload, preprocessing, polarization assessment, thresholding, coastline extraction, and transformation detection. Visual analysis identifies objects in thematic maps and tables, while digital processing includes image cropping, radiometric correction, and band combination using SAGA GIS 2.3.1 and ArcGIS 10.4. DSAS software is used to calculate coastline change rates based on vector data. The cropping process defines the study area along the Negara District coast, Jembrana Regency, Bali.

Radiometric correction adjusts pixel values for atmospheric interference, which can alter reflected values due to clouds or scattering. Thresholding with band 5 (Landsat 7) and band 6 (Landsat 8) separates land and sea, though improvements are made to address inaccuracies on vegetated or muddy shores. Coastline delineation is digitized and saved in shapefile (.shp) format.

To correct for tidal variation, tidal correction is applied, adjusting coordinates based on high and low tide impacts. Overlaying 2004 and 2019 coastlines identifies changes over 15 years. DSAS in ArcGIS 10.4 calculates change rates, using a geodatabase file with transects set at 30 m intervals and 100 m lengths to measure mean change from a baseline buffer along the shore. The coastline data is analyzed for accretion and abrasion using ArcGIS's geometry tool, producing map layouts with legends and scales for public interpretation. For detailed procedures, refer to Pujianiki et al. (2021).

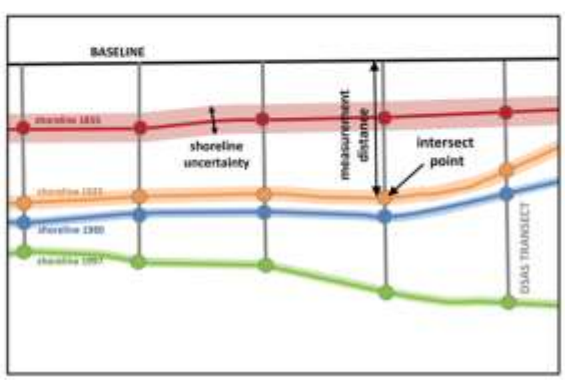

Figure 2. Shoreline transects on DSAS (USGS, 2009)

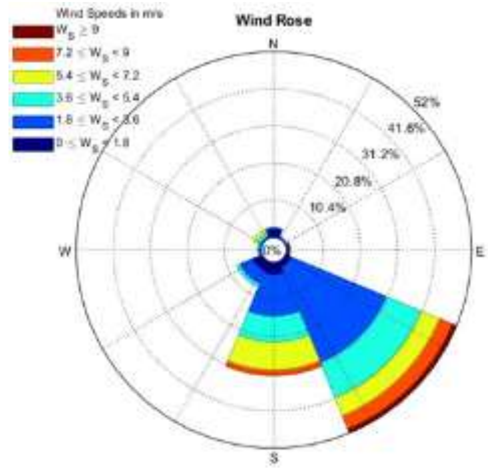

Figure 3. Wind roses at the Jembrana Regency Climatology Station from 2005 – 2019 (Blowing from) Balai, 2019.

Wind data from the Bali State BMKG Climatology Station (Jembrana Regency, Bali) from 2005 to 2019 was used to predict deep-sea wave movement, as wind influences wave size and current generation. The wind rose shows that in Jembrana Regency, winds primarily blow from the southeast (52%) and south (31.2%) with speeds exceeding 9 m/s.

Beach erosion and accretion are influenced by coastal sediment transport driven by hydrodynamic processes like currents and waves. Abrasion occurs when sediment loss exceeds deposition, while accretion happens when sediment supply is greater than transport away. This methodology effectively addresses interactions between natural sediment transport and human activities, particularly the effects of Pengambengan Port on sediment flow. Results reveal significant abrasion on the western coastline, contrasting with localized accretion to the east.

Results and Discussion

Identification of coastline changes was carried out for 15 years from 2004 to 2019. The results of overlapping changes in coastlines over the last 15 years, between 2004 and 2019, are presented in Figure 4. From these results it can be seen that during the 15 years there was more extensive abrasion (red color), reaching 300,577.17 m2, while the accretion that occurred only reached 159,697. 67 m2 (green color) (Hasan et al. 2021).

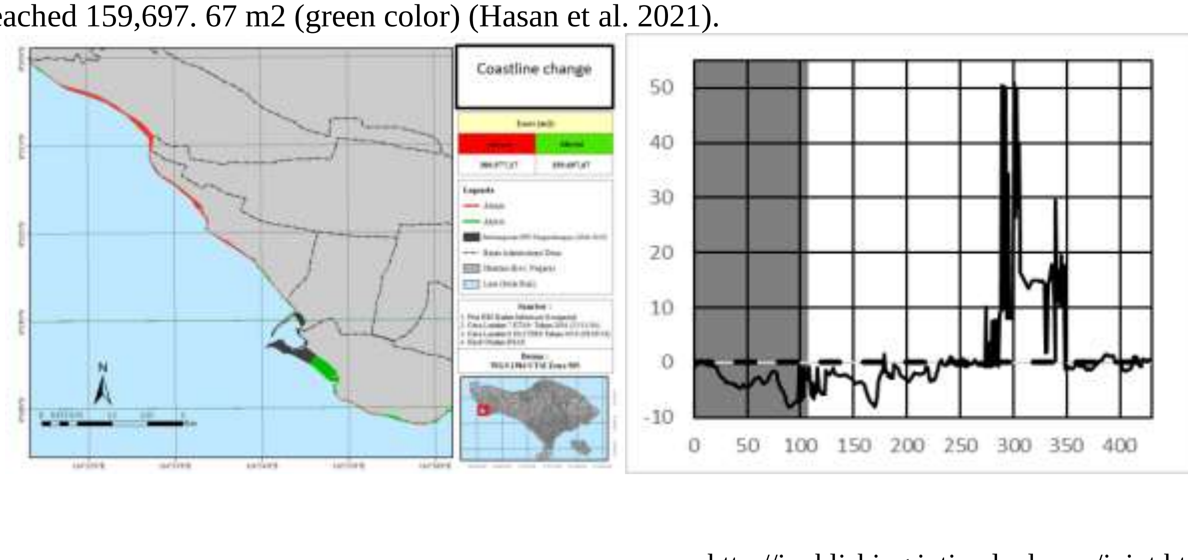

Figure 4:Coastline transformation map for the period 2004 - 2019 (x-axis: Transect ID; y-axis: Coastline change rate (m/year); dark area: Pebuahan Beach Area).

The abrasion incident occurred in the western part of the Pengambengan Port with a rate of change of 0 to -2 m/year, which indicates that an abrasion process occurred. Meanwhile, in the eastern part of the Pengambengan Port, low abrasion and accretion processes occur, approximately 1 m/year. High accretion events occurred in the area immediately to the east of the Pengambengan Port, reaching more than 10 m/year. Pebuahan Beach is one of the beaches that receives quite a high impact of abrasion (Figure 5). Abrasion occurs quite high accompanied by a coastline transformation rate of 1.62 m/year. In the western part there are several areas where the coastline transformation rate is 0.07 m/year. The abrasion area of Pebuahan Beach in the period 2004 - 2019 was 145,549.32 m2, and the accretion area was 705.89 m2.

To validate the results of the coastline changes, a field survey was carried out as shown in Figure 6. The results of the study show that they are in accordance with the survey results. The condition of Pebuahan Beach shows that it is very eroded as seen in the picture (survey 4).

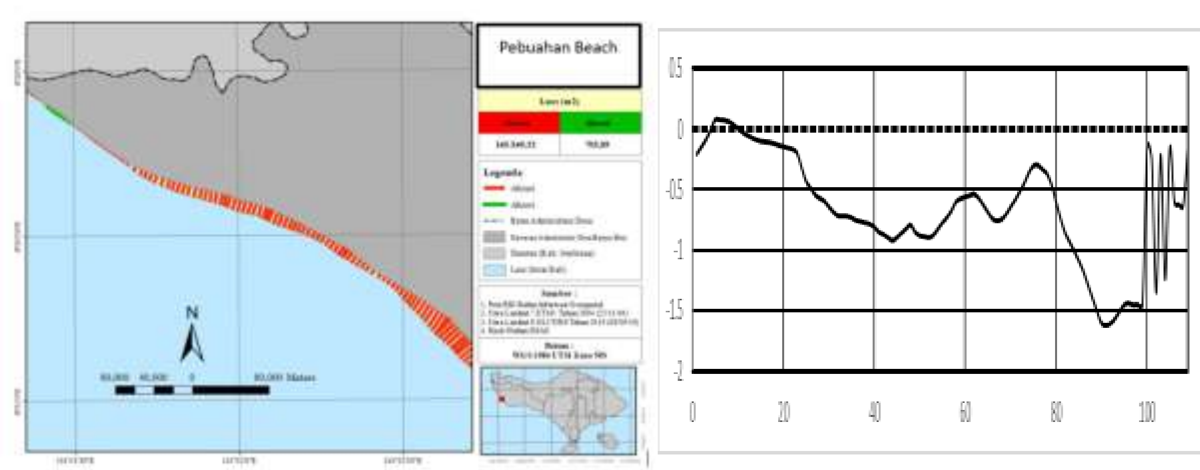

Figure 5: Map of coastline transformation at Pebuahan Beach for the period 2004 – 2019 (x-axis: Transect ID; y-axis: Shoreline transformation rate (m/year)).

Pebuahan Beach is located along the coast of Jembrana district. Since the construction of the Pengambengan Port, the coast to the west of the Port has begun to experience erosion. This is because sediment transport originating from the east of Pengambengan Harbor is blocked by the breakwater at the harbor so that there is no sediment supply to the west. The source of sediment comes from the river located to the east of the port.

From the wind data it can be seen that the dominant wind moves towards the west so that sediment transport occurs towards the west. Because the sediment was retained by the breakwater at the port, the beach to the west of the port began to experience abration and erosion occurred. And this has an impact on Pebuahan Beach. Until now, Pebuahan Beach is still experiencing erosion and is in the process of being repaired by the government.

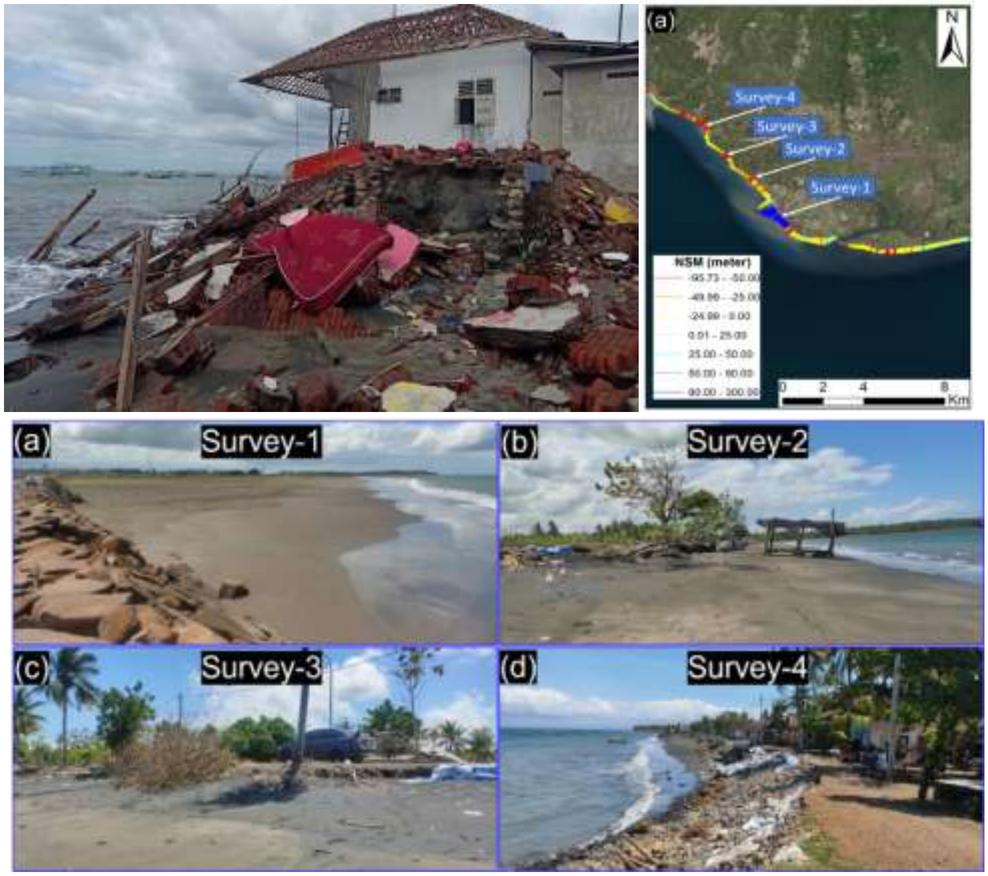

Figure 6: Survey photos of selected location and current situation at Pebuahan Beach (https://www.detik.com/bali/berita/d-6375134/warga-korban-abrasi-pantai-pebuahan-jembrana-menolak-direlokasi).

Findings indicate a pressing need for coastal management in Jembrana Regency, where extensive abrasion requires interventions, especially west of Pengambengan Port. This study provides critical data to inform strategies like sediment management and artificial nourishment to address ongoing erosion issues.

Conclusion

The pattern of changes in the coastline that occurred in Jembrana Regency during the period 2004 to 2019 was 300,577.17 m2 and the accretion that occurred only reached 159,697.67 m2. Meanwhile the abrasion area of Pebuahan Beach in the period 2004 - 2019 was 145,549.32 m2, and the accretion area was 705.89 m2. The cause of abrasion at Pebuahan Beach is sediment transport which tends to leave the beach to the west and sediment supply is hampered due to obstruction at the Pengambengan Port. This study offers a novel methodological framework for analyzing coastline transformations by combining SAR image processing, tidal correction, DSAS analysis, and wind data integration. The detailed, 15-year temporal scope and field validation confirm the accuracy and reliability of findings, revealing significant abrasion along Pebuahan Beach influenced by both natural processes and human interventions. This approach not only advances our understanding of coastline dynamics in Jembrana Regency but also provides a valuable model for similar coastal monitoring efforts in other regions.

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