

[Research Article]



Spatial Study of Mangrove Area and Density Changes to Abrasion in Pejarakan Village, Buleleng

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Article Info:	Abstract
<p>Received: 23 January 2025</p> <p>Accepted: 17 February 2025</p> <p>Published: 3 March 2025</p>	<p><i>The coastal village of Pejarakan, adjacent to West Bali National Park, has a fairly extensive mangrove ecosystem. Mangrove ecosystems have an important role as a protector of the coastline due to abrasion and accretion. Alterations in mangrove ecosystems along the coast of Pejarakan Village, caused by oceanographic factors and land-use changes, lead to changes in the coastline. This study aims to determine the relationship between changes in mangrove area and density to abrasion in Pejarakan Village within five years. The data needed in this study are remote sensing data of Landsat 8 OLI/TIRS satellite imagery in 2015 and 2020, analyzed using NDVI and single-band threshold methods. The results of this study show that the mangrove area along the coastline of Pejarakan Village has changed in mangrove coverage of 25.77 hectares, with an increasing level of density. These changes affect the occurrence of abrasion and accretion which results in changes in the coastline along the coastal coast of Pejarakan Village.</i></p>
<p>Keywords: abrasion; mangrove; remote sensing.</p>	

Informasi Artikel:	Abstrak
<p>Diterima: 23 Januari 2025</p> <p>Disetujui: 17 Februari 2025</p> <p>Dipublikasi: 3 Maret 2025</p>	<p><i>Pesisir Desa Pejarakan yang berdekatan dengan Taman Nasional Bali Barat memiliki potensi ekosistem mangrove yang baik. Ekosistem mangrove memiliki peranan penting sebagai pelindung garis pantai akibat abrasi dan akresi. Perubahan ekosistem mangrove di sepanjang pantai Desa Pejarakan akibat pengaruh faktor oseanografi dan perubahan penggunaan lahan tentunya berakibat pada perubahan garis pantainya. Penelitian ini bertujuan untuk mengetahui hubungan antara perubahan luasan dan kerapatan mangrove terhadap abrasi di Desa Pejarakan dalam kurun waktu lima tahun. Data yang dibutuhkan dalam penelitian ini adalah data penginderaan jauh citra satelit Landsat 8 OLI/TIRS tahun 2015 dan 2020 dengan menggunakan metode NDVI dan Single-Band Threshold. Hasil dari penelitian ini menunjukkan bahwa kawasan mangrove di sepanjang garis pantai Desa Pejarakan mengalami perubahan luasan seluas 25,77 hektar dengan tingkat kerapatan yang semakin rapat. Perubahan tersebut mempengaruhi terjadinya abrasi dan akresi yang kemudian mengakibatkan terjadinya perubahan garis pantai di sepanjang pantai pesisir Desa Pejarakan.</i></p>
<p>Kata kunci: abrasi; mangrove; penginderaan jauh.</p>	

INTRODUCTION

Mangroves are distinctive vegetation of tropical and subtropical regions, typically found in tidal areas of coastal zones, lagoons, or river estuaries (Kusuma et al., 2003). Mangroves are an integral part of coastal ecosystems, playing a critical role in preventing coastal erosion. Mangrove roots can trap sediment (mud) and slow down the flow of river water, thereby promoting sedimentation, which ultimately expands the coastline or leads to accretion (Suwargana, 2008). The root structures of mangroves, which facilitate sediment deposition, also indirectly protect the coast from tidal surges and waves (Susanto & Erwin, 2011). Consequently, mangroves are effective in preventing coastal abrasion that can erode the shoreline. Indonesia has a relatively extensive mangrove distribution, with more than one-third of the tropical mangrove areas located in Southeast Asia and over 80% of these within Indonesia's territory. Since the 1980s, the world has lost approximately 3.6 million hectares of mangrove conservation areas, equivalent to around 20%. The decline in mangrove areas has been primarily driven by land conversion for shrimp farms, known as the blue revolution, deforestation, land conversion for agriculture or salt ponds, and degradation caused by oil spills and pollution (FAO, 2007).

This phenomenon is also occurring in Pejarakan Village, Gerokgak District, Buleleng Regency. The loss of part of the mangrove area in Pejarakan Village is triggered by human activities, such as deliberately cutting down mangroves to use as livestock feed (Isdianto et al., 2022). Additionally, the reduction in mangrove areas has been caused by land-use changes, including conversion into aquaculture ponds and residential areas. The decrease in the extent and density of mangroves in Pejarakan Village has led to coastal abrasion. Antara Bali media reported that out of 430 kilometers of coastline on Dewata Island, more than 187 kilometers are identified as experiencing abrasion (Budhiana, 2017). According to the Head of the Environmental Service of Bali Province, the beaches experiencing severe abrasion are primarily located in South Bali, including areas such as Pengambangan - Jembrana Regency, Candidasa - Karangasem Regency, Padanggalak - Denpasar City, Lebih - Gianyar Regency, Kuta - Badung, Tegalbesar

and Watu Klotok - Klungkung Regency. Abrasion on these Bali beaches is caused by both natural factors and human activities. One of the human-induced factors contributing to abrasion is mangrove damage, which impacts the area and density of mangroves.

Changes in the extent and density of mangroves inevitably lead to shifts in the coastline, which in turn cause losses to the density of mangroves, as well as their role in preventing abrasion, is essential. Based on the trend of coastline changes from 1998 to 2018 in Karawang Regency, the mangrove ecosystem can support the phenomenon of accretion due to the role of mangrove roots in obstructing sediment transport from the land (Nandaniko et al., 2019). Monitoring these changes and their impact on the coastline can be conducted using satellite imagery. Mapping with satellite imagery offers several advantages, including lower costs and the ability to monitor changes over time. The satellite imagery used in this study is Landsat 8 OLI/TIRS imagery. On Landsat 8 OLI/TIRS, the range of the captured electromagnetic spectrum is broader, making it more effective for monitoring mangrove changes (Aritonang et al., 2022). This study examines the spatial changes in mangrove area and density and the effect on abrasion in Pejarakan Village over five years (2015-2020).

METHOD

This research was conducted along the northern coastline of Pejarakan Village, located in Gerokgak District, Buleleng Regency, Bali Province, as illustrated in Figure 1. Pejarakan Village is situated at coordinates 8°7'10.68" S - 8°11'22.21" S and 144°32'23.92" E - 144°36'16.63" E, with an average elevation of 100 meters above sea level. Before becoming Pejarakan Village, the area, which now has a population of 11,572 people, was part of Sumberkima Village until 1963. Following deliberations by local community leaders, Sumberkima Village was divided into two villages: Pejarakan Village and Sumberkima Village. Pejarakan Village spans an area of 39.60 kilometers, equivalent to 3,960 hectares, which includes a mangrove forest area of 120 hectares. Pejarakan Village is bordered by Sumberkima Village to the east and Sumberkelompok Village to the west. To the north, it is directly adjacent to the Bali Sea,

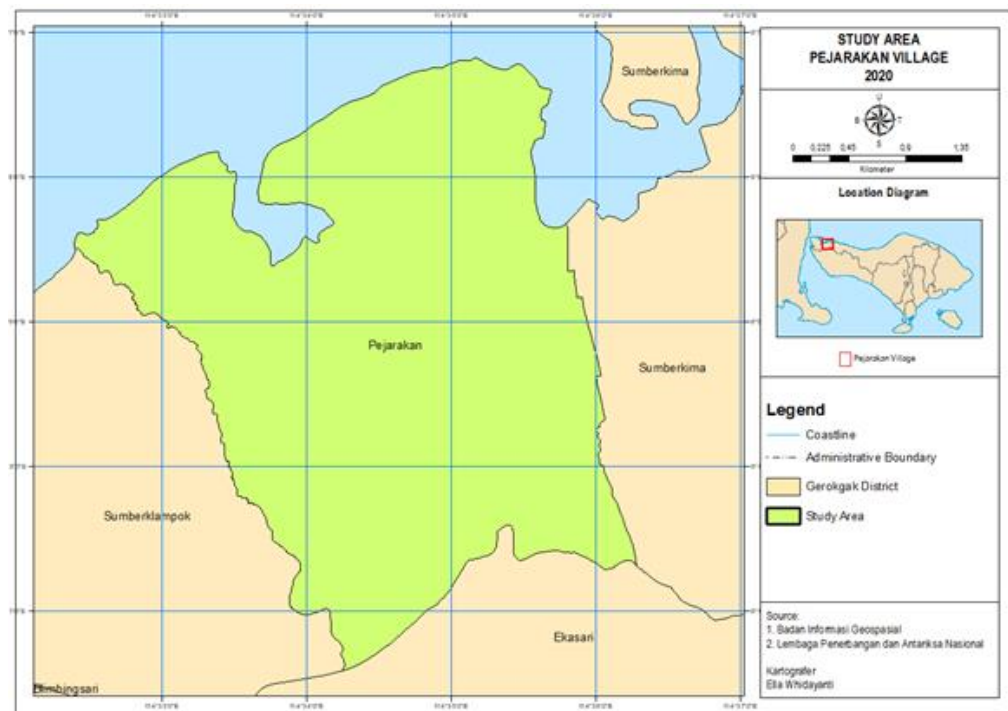


Figure 1. The Map of the Research Area

while to the south, it is bordered by state forest land. The unit of analysis in this study is the segmentation of the northern coastline of Pejarakan Village into five segments.

The variables used in this study include mangroves, abrasion, accretion, wave height, and ocean currents. Data on mangrove area and density, as well as the extent of abrasion and accretion, were obtained by extracting Landsat 8 OLI/TIRS imagery from 2015 to 2020 using ArcGIS software. The presence of the mangrove ecosystem was identified using the Red Green Blue (RGB) composite method with a band combination of 564, which represents a False Color Composite (FCC) image (Whidayanti et al., 2021). The use of the RGB 564 composite method on Landsat 8 OLI/TIRS enhances the contrast of mangrove areas by providing distinct color differentiation. In this combination, mangrove vegetation appears in a dark red color. In the infrared band imagery, the red color indicates the reflectance of vegetation, which is clearly visible, while the darker tones represent the reflectance of waterlogged soil, which is

observed in the red band. The use of the RGB composite 5 (near-infrared), 6 (SWIR-1), and 4 (red) is due to these three bands falling within the visible and near-infrared spectrum range. To calculate mangrove density, the Normalized Difference Vegetation Index (NDVI) method was employed, which compares the ratio of the near-infrared (NIR) band to the red band (Alatorre et al., 2016). The formula used to calculate the NDVI value is presented in Equation 1 as follows:

$$NDVI = \frac{(NIR - R)}{(NIR + R)} \quad (1)$$

where NIR is the near-infrared band, and R is the red band.

Subsequently, the results of the index calculation for each point are classified into canopy density classes of the mangrove ecosystem based on the NDVI values provided by the Indonesian Ministry of Forestry Departemen Kehutanan, 2005) as illustrated in Table 1.

Table 1. Classification of Mangrove Density Based on NDVI

NDVI Values	Density Classification
0.006 – 0.328	Low
0.335 – 0.427	Medium
0.434 – 0.750	High

Source: Departemen Kehutanan, 2005.

Shoreline change data were obtained using the Single-Band Threshold method with the SWIR-1 band to determine the boundaries between land use and sea, followed by on-screen digitization of the shoreline for each year of the study. The Single-Band Threshold band 5 (0.845 μm – 0.885 μm) represents an infrared wavelength type that is effective for delineating shorelines using Landsat OLI/TIRS satellite imagery (Winarso et al., 2001). After digitizing the coastline each year, the overlay techniques are performed to obtain the area of abrasion and accretion. The results of mangrove data processing, abrasion, and accretion were

analyzed to determine the relationship between changes in mangrove area and density and the occurrence of abrasion along the coastline of Pejarakan Village spatially.

RESULT AND DISCUSSION

Changes in Mangrove Area and Density

The distribution and extent of mangroves in the study area from 2015 to 2020 were identified using the supervised method and NDVI analysis to assess the density levels. Mangrove area and density in Pejarakan Village are presented in Figure 2 and Table 2.

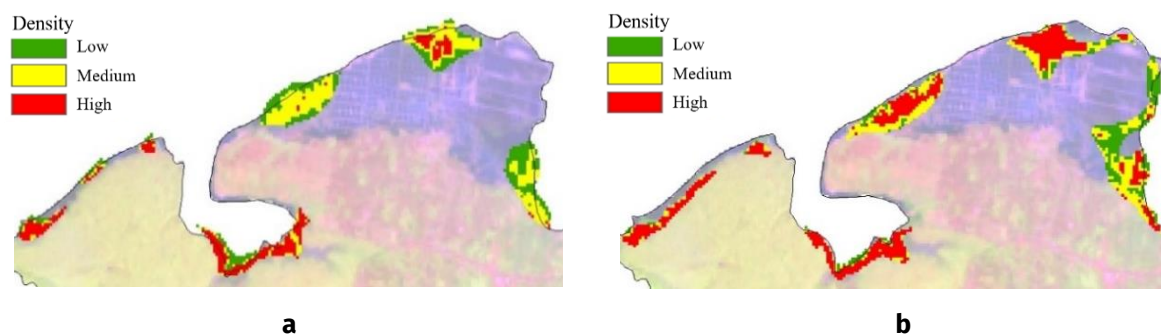


Figure 2. Mangrove Density in Pejarakan Village in a) 2015 ; and b) 2020

Table 2. The Area and Density of Mangroves in 2015 and 2020 Based on NDVI Values

Density Classification	Mangrove Area in 2015 (ha)	Mangrove Area in 2020 (ha)	Area Changes (ha)
0.006 – 0.328	36.74	28.15	-8.59
0.335 – 0.427	45.64	44.24	-1.41
0.434 – 0.750	27.83	64.71	+36.87
Total Area	111.34	137.11	25.76

The classification results of Landsat 8 OLI imagery data for 2015 indicated that the mangrove area in Pejarakan Village covered 111.34 hectares, with density levels categorized into three classes. Based on the classification results, the high category covered an area of 27.83 hectares, the medium category covered 45.64 hectares, and the low category covered 36.74 hectares. Thus, in 2015, the mangrove area in Pejarakan Village was predominantly classified as having medium density. In contrast, by 2020, the mangrove area in Pejarakan Village expanded to 137.11 hectares, with density levels also categorized into three classes. Based on the classification results, the high category covered an area of 64.71 hectares, the medium category covered 44.24 hectares, and the low category covered 28.15 hectares. Hence, in 2020, the

mangrove area in Pejarakan Village was predominantly classified as having high density.

Based on the processed imagery data from two different years, the results indicate changes in mangrove canopy cover in Pejarakan Village. The analysis revealed a change in mangrove area from 2015 to 2020, increasing from 111.34 hectares to 137.11 hectares, representing an expansion of 25.76 hectares with increasingly dense canopy cover. The classification of density levels shows that from 2015 to 2020, the area of dense mangroves increased from 27.83 hectares to 64.71 hectares, nearly tripling with an increase of approximately 36.87 hectares. Meanwhile, the medium density category decreased slightly from 45.64 hectares to 44.24 hectares, a reduction of about 3% or 1.41 hectares.

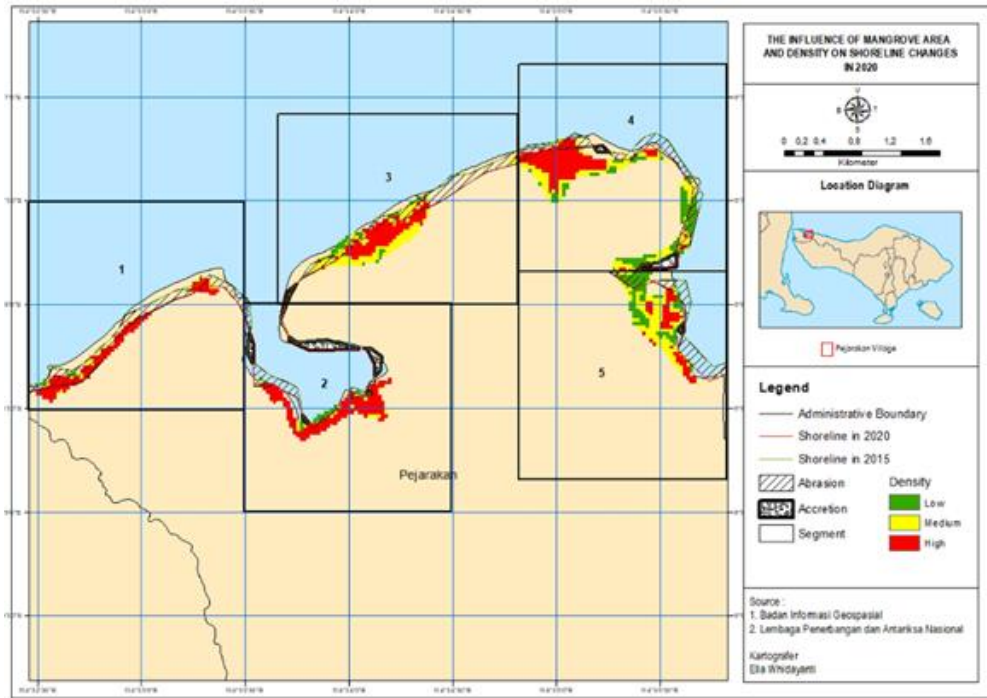


Figure 4. The Map of the Impact of Changes in Mangrove Extent and Density on Abrasion in Pejarakan Village (2015-2020)

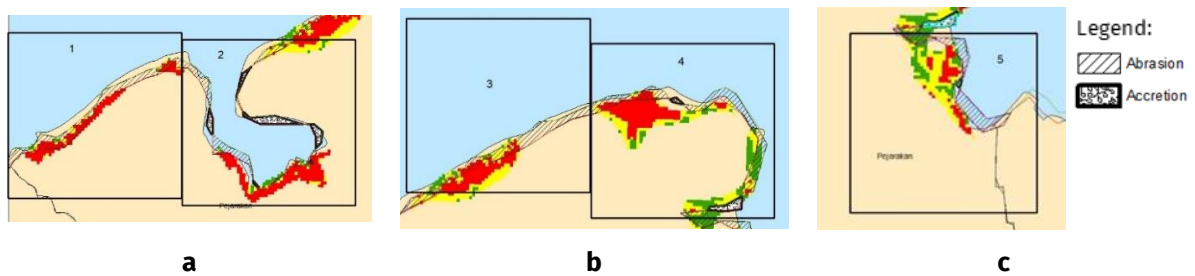


Figure 5. Details of Mangrove Extent and Density in Relation to Abrasion in Pejarakan Village a) Segments 1 & 2; b) Segments 3 & 4; and c) Segment 5

Table 3. The Relationship Between Changes in Mangrove Extent and Costline Change in 2015-2020

Segment	Abrasion Area (ha)	Accretion Area (ha)	Mangrove Area in 2015 (ha)	Mangrove Area in 2020 (ha)	Changes in Mangrove Extent (ha)
Segment 1	18.0	0	12.62	16.49	+3.87
Segment 2	11.8	7.5	30.57	27.3	-3.27
Segment 3	12.9	0	19.21	20.1	+0.89
Segment 4	19.8	2.1	35.74	47.11	+11.37
Segment 5	11.1	0.3	13.2	26.1	+12.9
Total	73.6	9.9	111.34	137.11	+25.77

mangrove extent and density from 2015 to 2020 with shoreline change data from the same years. over five years, the shoreline changes included abrasion covering an area of 73.6 hectares and accretion covering 9.9 hectares. To analyze the changes in mangrove extent and their impact on abrasion, the study area was divided into five segments, each measuring 1,700 x 1,700 meters.

The results of the data processing indicate that in segment 1, there was a change in mangrove extent of 3.87 hectares, with increased density, leading to abrasion covering 18 hectares and no accretion (Figure 5a). In segment 2, there was a change in mangrove extent of 3.27 hectares with increased density, resulting in abrasion of 11.8 hectares and

accretion of 7.5 hectares (Figure 5a). In segment 3, there was a change in mangrove extent of 0.89 hectares with increased density, leading to abrasion of 12.9 hectares and no accretion (Figure 5b). In segment 4, there was a change in mangrove extent of 11.37 hectares with increased density, causing abrasion of 19.8 hectares and accretion of 2.1 hectares (Figure 5b). In segment 5, there was a change in mangrove extent of 12.9 hectares, with increased density, leading to abrasion of 11.1 hectares and accretion of 0.3 hectares (Figure 5c).

This study demonstrates that the greater the extent and density of mangrove vegetation cover, the higher the rate of accretion, meaning the lower the rate of abrasion. This is evident in segment 2, where, despite a decrease in the mangrove area by 3.27 hectares, the total mangrove coverage remains larger, reaching 30.57 hectares, resulting in an accretion of 7.5 hectares. Segment 2 is located within the Putri Menjangan conservation area. Based on previous literature studies, research conducted in this area has indicated that one of the causes of mangrove ecosystem degradation is pest infestations affecting the mangrove stands (Isdianto et al., 2022). Similarly, segment 4, which has a mangrove area of 35.74 hectares, has experienced a change in mangrove coverage of 11.37 hectares, with an accretion of 2.1 hectares.

The data also indicates that the denser the mangrove vegetation cover, the lower the abrasion rate. Conversely, areas with low or high mangrove density, or those where mangroves are absent, experience higher rates of abrasion and greater extent of abrasion. The changes in mangrove extent and density in Pejarakan Village influence the occurrence of both abrasion and accretion, which in turn results in alterations to the coastline.

Based on previous literature studies, the mangrove area in Pejarakan Village increased significantly from 2010 to 2015 and 2020. Efforts to sustain the mangrove ecosystem have been carried out through a restoration action plan aimed at recovery, improving productivity structures, and enhancing mangrove species diversity. The necessary measures include strengthening reforestation programs through mangrove planting and nurseries by the local community, with government involvement in the management and protection of the mangrove

ecosystem. Additionally, stakeholders and academics should be engaged to improve the coastal protective hydrological system as part of the restoration program (Rizky, 2016).

CONCLUSION

Based on the processed data from Landsat 8 OLI/TIRS imagery in 2015 and 2020, it is evident that the mangrove area along the coastline of Pejarakan Village has changed to both extent and density. The data analysis reveals a change in mangrove extent of 25.76 hectares from 2015 to 2020, with an increasing density. The changes in mangrove extent and density in Pejarakan Village influence the occurrence of abrasion and accretion. The larger and denser the mangrove vegetation cover in the area, the lower the rate of abrasion. However, if the extent and density are low, the likelihood of abrasion increases.

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