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Investigating Influencing Factors of Shoreline Changes in Bantul's Tourist Coastal Areas Using GIS and Satellite Data

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ABSTRACT

The littoral zone is the most vulnerable area to the impacts of climate change and human activities. Current weather anomalies and the development of human activities in coastal areas are on the rise. Remote sensing and geographic information system approaches have been widely used to monitor shoreline changes using easily accessible satellite imagery. This study aims to identify the dominant factors driving littoral change at Bantul Beach and assess the relationship between tourism activity and coastal abrasion. This study uses the Geographic Information System (GIS) analysis method using Landsat-8 satellite imagery from 2013 to 2023. In monitoring shoreline changes, NDWI and DSAS analyses were conducted to identify factors influencing coastal changes. A study was also conducted to examine the parameters of the coastal profile, wind, waves, tides, and human activities. Based on 10 years of image data, the study location has generally experienced high abrasion, with an average EPR value of -1.51 m/year, an average SCE value of 47 meters, and a dominant negative NSM value. The most influential factors are the slope of the shoreline and waves, especially during high waves or storms. The increase in the number of tourists in Bantul Yogyakarta tourism spots is not linearly correlated to the occurrence of abrasion. There needs to be coastal protection and mitigation that prioritizes the dominant factors causing abrasion, utilizing a soft engineering approach and local wisdom.

Keywords: Shoreline changes, Tourist Coastal Areas, DSAS, Landsat-8, Bantul Yogyakarta

ABSTRAK

Garis pantai merupakan wilayah yang paling rentan terhadap perubahan iklim dan aktivitas manusia, anomali cuaca yang terjadi saat ini serta perkembangan aktivitas manusia di wilayah pantai semakin meningkat. Pendekatan penginderaan jauh dan sistem informasi geografis telah banyak digunakan untuk monitoring perubahan garis pantai dengan menggunakan citra satelit yang dapat diakses dengan mudah, Tujuan dari penelitian ini adalah menganalisis faktor faktor yang mempengaruhi perubahan garis pantai di tempat wisata pantai bantul dan melakukan perhitungan hubungan aktivitas pariwisata dengan perubahan garis pantai. Penelitian ini menggunakan metode analisis Sistem Informasi Geografis (GIS) dengan menggunakan citra satelit Landsat-8 tahun 2013 - 2023, dalam melakukan monitoring perubahan garis pantai dilakukan analisis NDWI dan DSAS, untuk pendekatan faktor yang mempengaruhi terjadinya perubahan pantai yang terjadi dilakukan analisis terkait dengan parameter profil pantai, angin, gelombang, pasang surut dan aktivitas manusia, Dari hasil data citra 10 tahun secara umum lokasi studi telah terjadi abrasi tinggi dengan nilai EPR rata rata -1.51 m/tahun, rata rata nilai SCE 47 m serta nilai NSM dominan negatif. Faktor yang paling berpengaruh adalah faktor kemiringan garis pantai dan gelombang, khususnya saat gelombang tinggi atau badai, peningkatan jumlah wisatawan di spot spot pariwisata Bantul Yogyakarta tidak berkorelasi secara linier terhadap terjadinya abrasi. Perlu adanya mitigasi perlindungan pantai yang sesuai dengan faktor dominan penyebab abrasi yang mengedepankan pendekatan soft engineering dan kearifan lokal.

Kata kunci: Perubahan garis pantai, Wisata Pantai, DSAS, Landsat-8, Bantul Yogyakarta

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1. Introduction

Indonesia is highly vulnerable to disasters (Zikra et al., 2015), including natural disasters influenced by climate change, such as landslides, forest fires, droughts, storms, floods, and land loss due to rising sea levels (Angra & Sapountzaki, 2022; Chaudhary & Piracha, 2021; B. Al Hakim et al., 2015) as well as due to erosion (Hendriyono et al., 2015). Besides posing a threat to the ecology, these disasters can devastate both onshore and offshore infrastructure, destroying forest and coastal ecosystems and leading to material (economic) and non-material losses (B. A. Hakim et al., 2022). According to the Climate Change Performance Index (CCPI) performance data, Indonesia's ranking has consistently declined each year, with the country currently ranked 36th (Burck et al., 2023). This ranking is lower than Indonesia's CCPI ranking in 2020, which was 20th.

As a crucial region supporting the global economy, coastal areas are particularly vulnerable to disasters, including those related to natural and hydrometeorological events (Shroder et al., 2023; Tillekaratne et al., 2023). Coastal regions, which directly border the sea, have varied topographical conditions, making them highly susceptible to hydrometeorological disasters (WFP, 2022). Hydrometeorological disasters, including floods, droughts, cyclones, heatwaves, and storms, are natural events that have a significant impact on communities and ecosystems. These phenomena are generally triggered by extreme weather conditions and exacerbated by climate change, leading to increased frequency, intensity and scope of affected areas (Kahraman & Polat, 2023; Shroder et al., 2023). The factors contributing to these disasters are also highly complex and interconnected, making it challenging to distinguish the causative factors of one disaster from those of another.

Coastal abrasion is a form of shoreline erosion influenced by natural and anthropogenic factors. Natural drivers of abrasion include tidal floods (Gumara & Meilianda, 2024), Storms and High Water Levels (Elallati et al., 2024; Gopinath et al., 2023; Paul et al., 2024), sea level rise (Hadi, 2018; Kim et al., 2021), as well as wind and sediment transport (Elallati et al., 2024), Anthropogenic factors include coastal development (Biondo et al., 2020; Elallati et al., 2024), mangrove deforestation and land-use changes (Hadi, 2018) and the overexploitation of coastal resources (Elallati et al., 2024).

The coastal areas in Bantul Regency, directly bordering the Indian Ocean, face a high threat of danger (W. Adi et al., 2023). Between 2013 and 2023, BNPB recorded six extraordinary incidents related to Tidal Waves/Abrasion that resulted in coastal abrasion in the Bantul Coastal Region (BNPB, 2023). It was reported that the tidal wave incident on July 25, 2018, led to abrasion on several beaches, causing damage to homes, buildings, and public facilities. Changes in land use along the coastal areas can also contribute to coastal abrasion, disrupting coastal ecosystems and natural barriers, ultimately leading to abrasion.

On the southern coast of Yogyakarta, Indonesia, New tourist locations are developed along the coastal areas, which is also evident in the Bantul Coastal Region. Many new tourist destinations have emerged along the coast, expanding beyond the well-known Parangtritis Beach. New famous beaches include Pandansimo Beach, Baru Beach, Kuwaru Beach, Gua Cemara Beach, Samas Beach, Depok Beach, and Parangkusumo Beach. The Bantul coast is experiencing abrasion (BNPB, 2023; Pratama et al., 2021). Investigating the changed characteristics of the sea and the conditions on land is essential to determine how these factors contribute to the ongoing abrasion.

Technological developments that integrate remote sensing (RS) and geographic information systems (GIS) have been widely recognized as a practical approach to monitoring shoreline change and coastal erosion. Multitemporal analysis using Landsat and other imagery has been widely employed to assess the processes of erosion, accretion, and physical changes resulting from human activities in coastal areas (Chettiyam Thodi et al., 2023; Gopinath et al., 2023; Paul et al., 2024). Using high-resolution satellite imagery, such as Landsat-8 or Sentinel-2, provides improved spatial and temporal Accuracy that is useful for data-poor coastal areas (Saleem & Awange, 2019). To perform a good quantification of shoreline change values, the Digital Shoreline Analysis System (DSAS) method allows for accurate calculation of shoreline change through parameters such as Net Shoreline Movement (NSM) and End Point Rate (EPR), which supports long-term evaluation of coastal areas (Chettiyam Thodi et al., 2023; Gopinath et al., 2023).

While studies of shoreline change have been conducted globally and on many Indonesian coasts, very few studies specifically address the tourist coastal area of Bantul. This research presents an opportunity to apply existing methodologies to a new geographical context characterized by unique and distinct environmental characteristics and anthropogenic factors that influence shoreline change. Most studies still focus on physical shoreline change without adequately considering socioeconomic impacts. By integrating local community perspectives and economic data using a human activity approach, a more comprehensive understanding of the relationship between human activity and shoreline change in the tourism area sector can be obtained (Bushra et al., 2021). Although some studies have provided correlations between shoreline change and climatic variables such as sea surface temperature and sea level rise, more focused research is needed on how climate change explicitly affects the shoreline in the Bantul region of Yogyakarta.

Developing indicators of sensitivity to shoreline change, incorporating both physical and socioeconomic variables, will enhance the understanding of vulnerability in coastal tourist destinations, paving the way for more targeted coastal management strategies (Portz et al., 2023). In addition, a comparative study between Bantul Yogyakarta and similar coastal areas could reveal trends and drivers unique to shoreline change, thus expanding our understanding of coastal dynamics in Indonesia (Sui et al., 2020). Although the merging of RS and GIS technology has enhanced the monitoring of shoreline change, additional work is needed regarding the issues and possibilities specific to the coastal tourist area of Bantul. Local studies that integrate socioeconomic factors and high-precision satellite images can help deepen understanding of the region and make sustainable coastal management easier and more effective.

This research uses satellite data to investigate the factors influencing abrasion, particularly in the tourism areas of Bantul Regency. This study aims to identify the dominant factors driving littoral change at Bantul Beach and assess the relationship between tourism activity and coastal abrasion, providing recommendations for sustainable coastal management.

2. Materials and methods

2.1. Study Area

The research location is in the coastal area, encompassed within the administrative boundaries of Bantul Regency, Special Region of Yogyakarta, Indonesia, as illustrated in **Figure 1**. It borders Gunung Kidul Regency to the east, Yogyakarta City and Sleman Regency to the north, Kulon Progo Regency to the west, and the Indian Ocean to the south. Generally, the topography of Bantul varies, being relatively flat with slopes ranging from 0 to 15%, particularly in the coastal areas, and becoming more undulating towards the north. Additionally, there are steep hills, especially in the border regions with Gunungkidul Regency, with slopes ranging from 25 to 45%. In 2022, the population was 1,013,170, with a population growth rate of 1.45% (BPS, 2023).

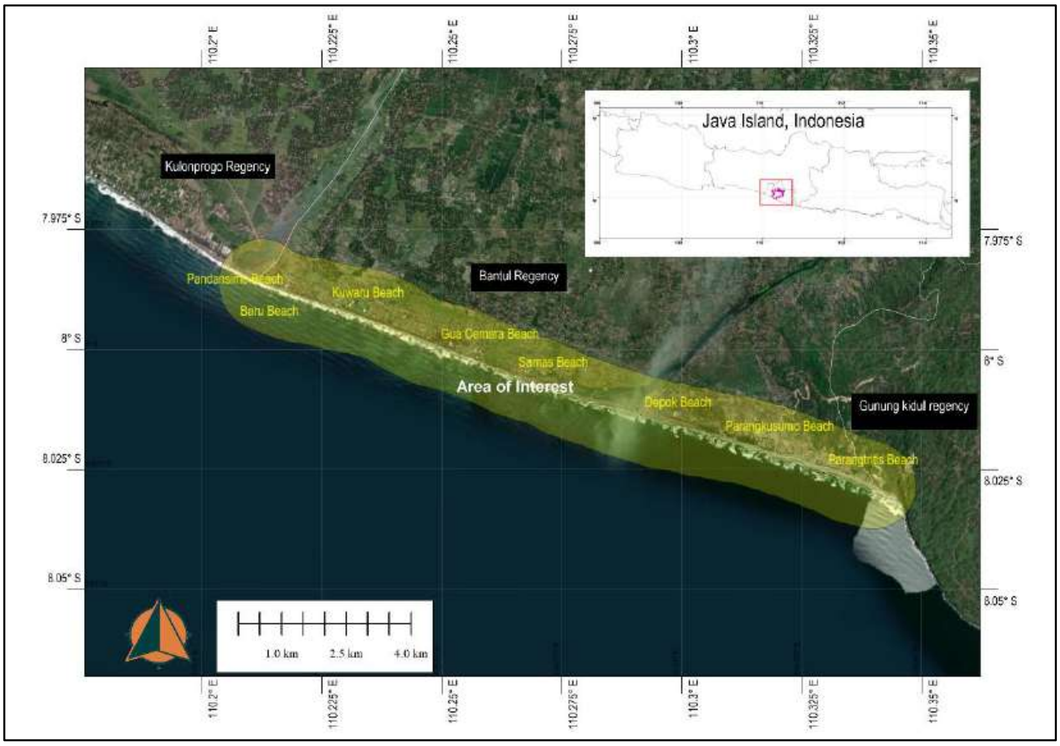

Figure 1. Area of Research – Coastal Area of Bantul Regency, Yogyakarta

2.2. Data

The data utilized in this research consists of satellite image data and climate-related information. In addition to direct analysis, several datasets related to climate parameters are used as inputs for numerical calculation models. Briefly, the data used in this study are summarised in **Table 1**. The DSAS calculation process for determining the value of monitoring changes in the shoreline utilizes Landsat-8 satellite images from 2013 to 2023. Landsat satellite images analyzed further meet the qualifications: having cloud cover in the study area of <20% and having similar air level conditions when recording between one image and another image of less than 20 cm. Adding tidal criteria to the selection of images ensures that one image is relatively at the same tidal level (sea level) as another, thereby reducing the bias in further analysis. The Landsat-8 imagery used was recorded on 28-08-2013, 29-07-2014, 25-07-2015, 07-05-2017, 24-07-2018, 07-11-2019, 29-07-2020, 18-12-2022 and 06-04-2023 (six satellite images of Landsat-8).

Table 1. Data for analysis of shoreline changes in the study area

No	Data	Years	Sources
1	Landsat-8	2013 - 2023	– https://earthexplorer.usgs.gov/
2	Wind	2012- 2023 2017	– https://cds.climate.copernicus.eu/ – BMKG DIY
3	Hydro Oceanography Data: Bathymetry, Tide and Current Wave	2022 2012-2023	– https://cds.climate.copernicus.eu/ – https://srgi.big.go.id – https://tanahair.indonesia.go.id/ – Numerical Modeling
4	Bantul Regency Tourism and Regional Income Data	2017-2022	– BPS, 2023
5	Data on Tidal Wave and Abrasion Disasters in the DIY Region	2012-2023	– BNPB

2.3. Methods

Several methods can be employed to determine changes in the shoreline. Among these methods is direct measurement, which involves placing monitoring instruments or conducting time-series surveys related to changes in coastal conditions (Risandi et al., 2020). Additionally, changes in the shoreline can be assessed through satellite image analysis (Chettiyam Thodi et al., 2023; Patel et al., 2024; Sui et al., 2020). Satellite images, characterized by their spatial and temporal properties, can be analyzed to track changes in the shoreline.

For the analysis of shoreline changes, this study utilizes Landsat-8 images. Landsat-8 is adequate for mapping abrasion changes (Darwish & Smith, 2023; Natih et al., 2020; Nazeer et al., 2020) and offers several advantages. Before further analysis, satellite images undergo filtering, which addresses cloud conditions, performs geometric and radiometric analysis, and extracts data and bands. Utilizing the Normalized Difference Water Index (NDWI) method (Latuamury et al., 2021; Liuzzo et al., 2020), spatial analysis of the satellite image is performed to determine the shoreline at the time of image acquisition. NDWI is a method used to measure water content on the Earth's surface by utilizing specific differences in light reflectance. For Landsat-8, NDWI is calculated using the following formula:

$$NDWI = \frac{float\ (band3 - band8)}{float\ (band\ 3 + band\ 8)} \ .... \qquad (1)$$

This formula utilises floating-point equations for more detailed calculations, where band 3 represents Near-Infrared (NIR) and band 8 represents Short-Wave Infrared (SWIR).

In the NDWI value analysis, the threshold function uses values of 1 and 0. This value is used to define land and water areas, where a value of 1 or positive is used to describe land areas, while a value of 0 is used to describe water or sea bodies. Landsat-8 imagery has an image resolution of 30 m x 30 m. The results of NDWI data analysis can sometimes form sharp angles at several points or areas. Therefore, smoothing and automatic reclassification analysis are performed on the shoreline derived from the NDWI analysis, as illustrated in the sample of satellite imagery with processing in **Figure 2.**

Analysis related to the value changes along the shoreline utilizes the DSAS Version 5.0 from the USGS (Himmelstoss et al., 2021). The DSAS method has been widely employed for shoreline analysis with favourable outcomes (Alwi et al., 2023; Benkhattab et al., 2020; Nazeer et al., 2020). Parameters that can be analyzed using DSAS include the calculation of the distance of changes in each shoreline, as analyzed using the Net Shoreline Movement (NSM), End Point Rate (EPR), and Linear Regression Rate (LRR) methods. In the DSAS analysis, the input used to calculate the NSM, EPR, and LRR values comes from the NDWI analysis of the image. However, the corrections mentioned were made before the calculation, and the Accuracy of the value also could not reach 100% of the real conditions; this can happen because of the large image resolution and georeferencing Accuracy, which can differ between taking one image and another image that has been compared, and the shoreline extraction process.

NSM calculates the distance of shoreline changes, representing the distance between the digitized shoreline in the first and final years for each transect in meters. The distance between one transect and another is 50 meters, with the length of the shoreline analyzed being approximately 17 km. EPR is calculated by dividing the distance between the initial and final shorelines by the time elapsed. Meanwhile, the linear regression rate (LRR) is used to analyse shoreline changes using linear regression statistically.

To understand the factors causing abrasion, an analysis is conducted regarding tides, wind waves, and anthropogenic factors associated with human activities in coastal areas. The study area is outlined in **Figure 3**, which generally delimits the study area.

(a) (b) (c)

Figure 2. Sample of satellite imagery (a) actual colour, (b) analysis NDWI, (c) analysis NDVI (https://dataspace.copernicus.eu)

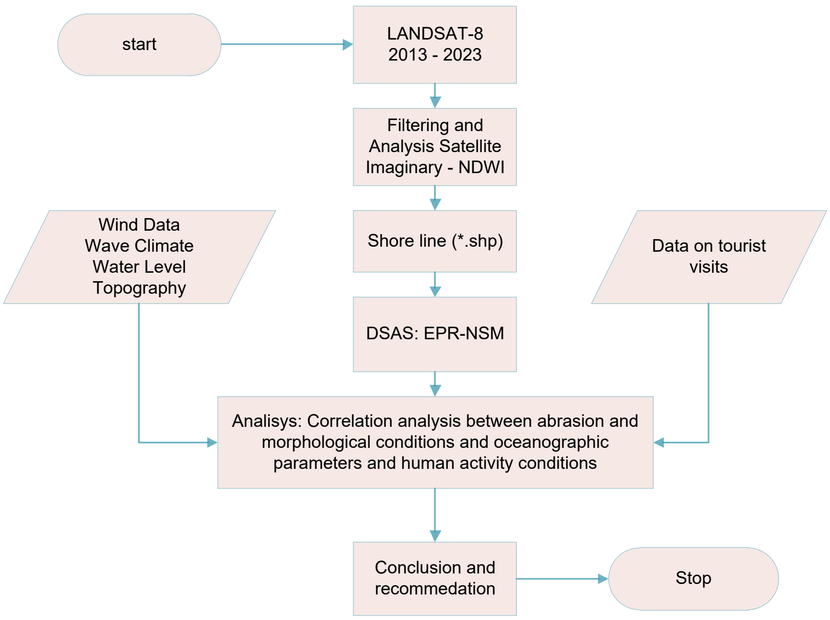

Figure 3. Flowchart of research methods

3. Results and Discussion

The coastal region of Bantul Regency has significant potential to be developed into a world-class tourist destination. At least 14 potential beach tourism sites can be developed in this coastal area. The government has only developed five beaches: Parangtritis Beach, Samas Beach, Goa Cemara, Pandansimo Beach, and Kuwaru Beach. Parangtritis Beach remains a tourist favourite, accounting for 85% of the total beach tourism destinations in Bantul in terms of visitors and revenue (Kabupaten Bantul, 2023).

Based on the Landsat-8 image processing from 2013 to 2023 and shoreline change analysis using DSAS, the study area has experienced varying shoreline changes from 2013 to 2023. These changes vary between locations, as illustrated in **Figures 4, 5, 6,** and **7**. The annual values of abrasion and accretion can be described through EPR analysis in **Figure 4** and **Figure 6**. The maximum accretion rate is 8.02 m/year around the Parangtritis beach area, while the maximum abrasion rate is -10.69 m/year at the Pandan Simo, Bantul estuary, described in **Figure 8**. Overall, the EPR value across all studied segments over the ten years is -1.51 meters per year.

The SCE Value analysis results show significant changes in the shoreline. The average SCE value of the study area is 47 meters, the NSM value varies, as illustrated in **Figure 5** and **Figure 7**, and positive values indicate that sediment deposits or accretion have occurred while negative values indicate abrasion; from **Figure 7**, on average, abrasion has happened where the NSM value is predominantly negative.

Analyzing five locations designated by the Bantul Regency government as beach tourism sites, we aimed to identify the factors influencing shoreline changes. An analysis was conducted at five locations designated by the Bantul Regency government as beach tourism sites: Parangtritis Beach, Samas Beach, Goa Cemara, Pandansimo Beach, and Kuwaru Beach. This location was selected based on data on tourist attractions managed by the Bantul district government. Additionally, this is the only location that provides data on tourist visits, which will serve as a reference for the influence of human activities at the study location. A comparison of abrasion and accretion values that occurred in the study area concerning the shoreline slope is presented in Table 2. From the analysis of shoreline slopes using SRTM-Batnas 2023 data presented in Table 2, it was found that coastal areas with slopes <2% experience abrasion, while beach tourism locations with slopes tend to be >2% undergo abrasion.

The influence of wind on shoreline changes was examined using ECMWF data, validated with measurements from BMKG Yogyakarta International Airport (Fatkhuroyan & Wijayanto, 2020). Wind conditions as measured by (Fatkhuroyan & Wijayanto, 2020) and ECMWF data exhibit similarities in wind speed and direction. Therefore, for the analysis of the 2013-2023 period, the ECMWF data were used. From the data of 2012-2023, the average wind blows from the southeast by 33% with an average speed of 3.72 m/s, as shown in **Figure 9**. Additionally, wind conditions between different locations in the Bantul beach tourism areas also share similar characteristics, as they face the sea directly and have short distances between locations. If measurement data are available at each research location station, then the effect of wind on abrasion at each location can be further analysed. However, because the available data is uniform across all locations, the impact of wind on abrasion values at each location cannot be directly compared. The effect of wind on shoreline changes in each location is relatively consistent. From the results of data analysis as depicted in **Figure 9**, the wind conditions in the study area are predominantly from the southeast, causing changes in coastal morphology including abrasion or accretion to increase at the peak of the east season.

As a region directly adjacent to the ocean, abrasion can also be caused by high waves. Wave height and direction are analyzed using ECMWF data for the Yogyakarta region. The analysis reveals that the wave direction in the study area is from south to north, with an average height of 1.9 meters. Between November 27 and December 3, 2017, Cyclone Dahlia and Cempaka occurred in the Indian Ocean, prompting an analysis of wind and wave data in the waters of Yogyakarta during this period. This analysis was to determine whether the cyclone affected the dynamics of oceanography in the waters of Yogyakarta. The influence of storms on wave height is analyzed and illustrated in **Figure 10**, which describes how storms affect wave height.

Wave heights higher than the average can lead to abrasion in coastal areas with gentle slopes. The gentle slope of the shoreline facilitates the infiltration of waves and their potential to damage coastal sections. No research has discussed the magnitude of abrasion due to storms on the abrasion that occurred in the study area during the high waves caused by cyclones Cempaka and Dahlia at the end of 2017. The data collected were news reports in the mass media about abrasion caused by high waves in several locations along the coast of Yogyakarta.

Conducting numerical modelling, we aimed to determine the characteristics of currents and tides in the study area. The model results were validated against tide observations at the Sadeng Station, Yogyakarta. Hydrodynamic modelling results, including tide and current conditions, are presented in **Figure 11**. Mean Sea Level (MSL) = 0, with Mean High-Water Springs (MHWS) = -1.127 m, Mean Low Water Springs (MLWS) = -1.127 m, and Tidal Range of 2.364 m. Generally, the tide type in the waters of Bantul is a mixed tide prevailing semidiurnal, and the current speed in shallow waters tends to be influenced by tides, with a predominant bidirectional flow in the north-south direction.

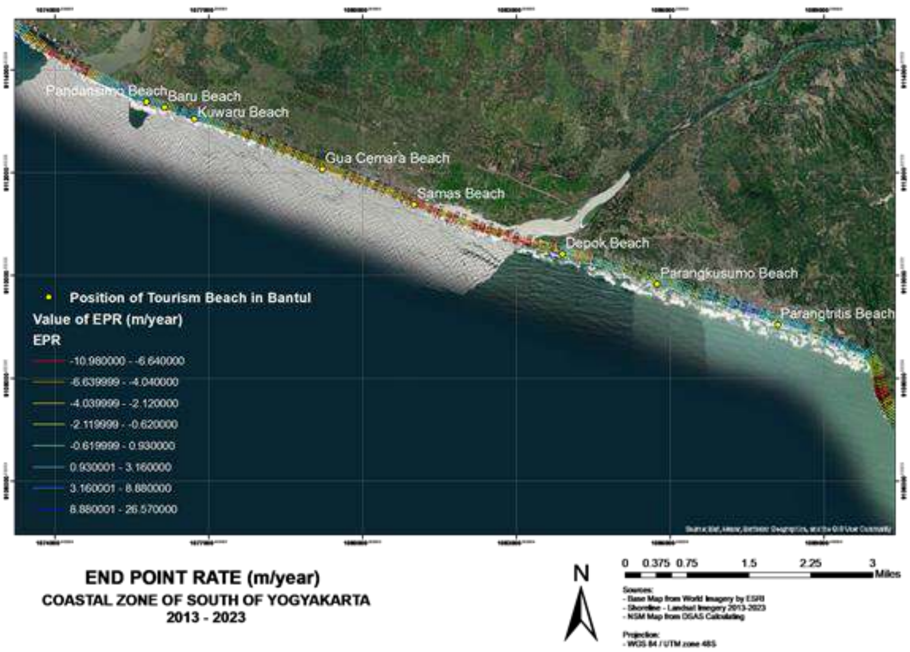

Figure 4. The results of the DSAS analysis for EPR values from 2012-2023

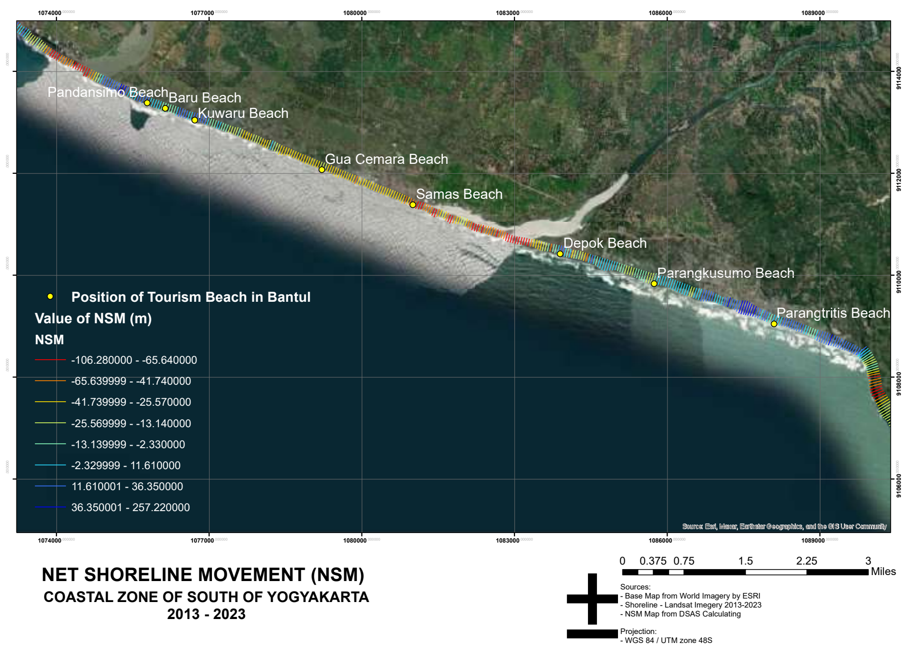

Figure 5. The results of the DSAS analysis for NSM values from 2012-2023

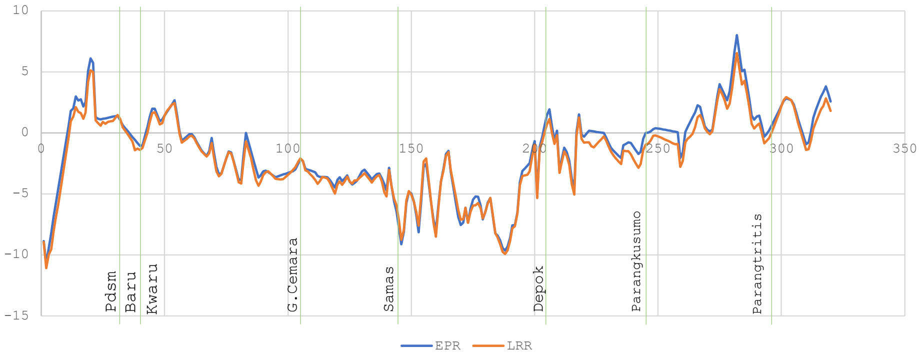

Figure 6. Values of EPR and LRR, SCE in the Study Area from 2012-2023

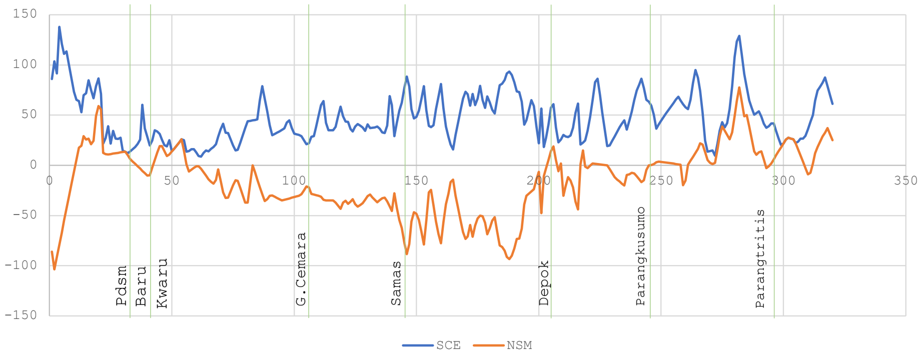

Figure 7. Values of SCE and NSM in the Study Area from 2012-2023

Figure 8. Morphological Conditions of the Coast around the Progo River Estuary (a) 2013, (b) 2017, and (c) 2022 (Sources: Google Imagery, 2023)

Table 2. Coastal Slope (%) in Location of Study

Location (Beach)	Pandansimo	Kuwaru	Gua Cemara	Samas	Parangtritis
The result of abrasion or accretion (m/year)	1.162	1.06	-2.6	-6.7	1.52
Slope Value (%)	3.0	4.6	1.2	1.2	2.0

Surface elevation experiences clear tidal variations, indicating the influence of gravity cycles that affect tidal wave conditions. The current direction also varies, with some periods when the current is heading directly towards the beach. Fluctuations in surface height, high current speeds, and current directions, as described in **Figure 11**, that head toward the beach have the potential to cause increased erosion of the coastline. High current speeds and directions that flow toward the beach contribute to the process of coastal abrasion. Fast currents carry kinetic energy that can erode beach material, such as sand and sediment, and increase the potential for erosion. Fluctuations in sea surface height, which follow tidal patterns, can exacerbate the process of abrasion, especially when seawater is at its maximum height, causing waves to sweep away beach material. In addition, current directions that head directly towards the beach exacerbate the impact of erosion, as they can erode the beach directly or carry away beach material. The combination of these three factors increases the potential for long-term abrasion that can damage the coastline and coastal ecosystem. In addition to natural factors, this study also examines human activities. The impact of human activities in this study is assessed by collecting data on the number of tourists recorded at the study locations. Data collection was carried out through the Tourism Office of Bantul Regency, and the number of tourist visits is presented in the following graph **Figure 12**.

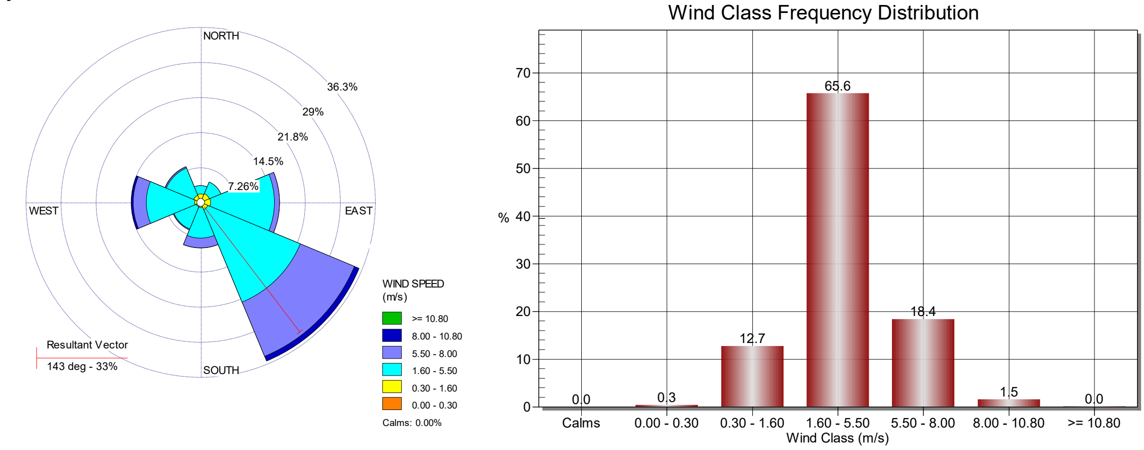

Figure 9. Analysis of wind data in the waters of Yogyakarta from 2012-2023

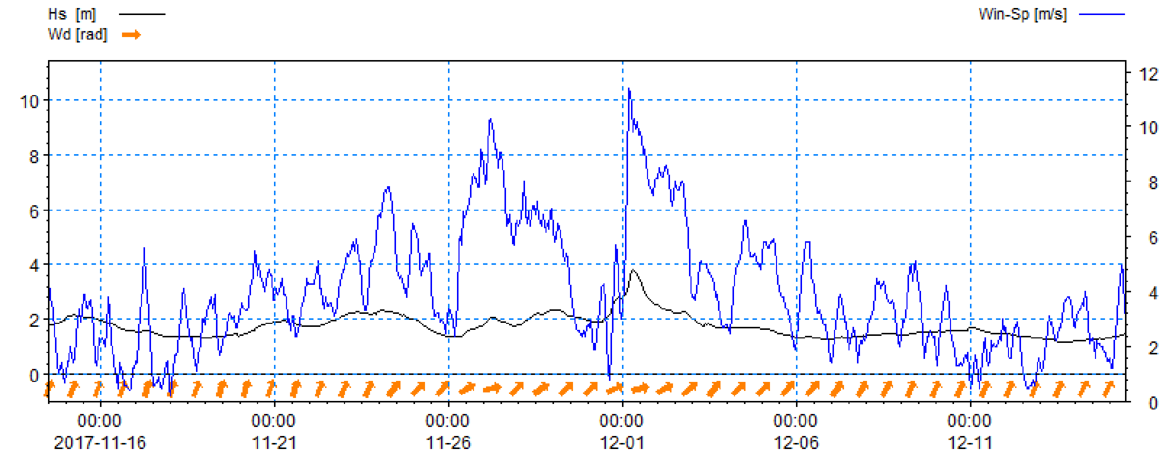

Figure 10. Hs (Significant Wave Height), Wd (Wave Direction), and Win-Sp (Wind Speed) in the Study Area from November 15, 2017, to December 15, 2017

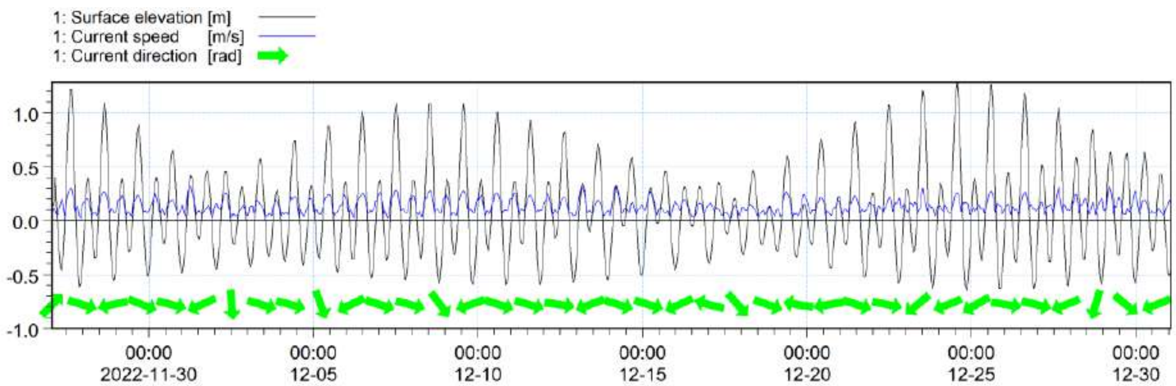

Figure 11. Tidal and Ocean Current Conditions in the Study Area

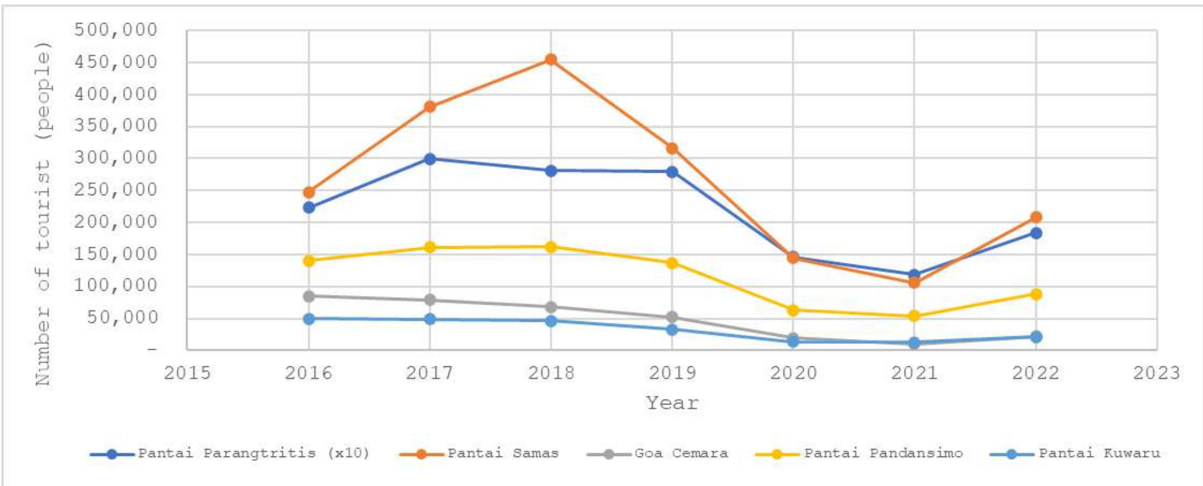

Figure 12. Number of tourists visiting the spot Bantul's tourist from 2016-2022 (Kabupaten Bantul, 2023)

Parangtritis Beach remains a popular destination for tourists visiting the beaches in Bantul. According to the data for the year 2022, Parangtritis Beach received 1,838,200 visitors, making it the most visited beach. The second most visited is Samas Beach, with 208,111 visitors. Other beaches have relatively low visitation, each receiving less than 100,000 visitors annually. Parangtritis Beach experiences a higher volume of tourism activity than other locations. Despite the increased human activities, Parangtritis has not experienced abrasion. This condition may be because human activities in these study locations do not significantly impact abrasion, and the activities remain within the environmental capacity limits in these areas.

From the physical data, which includes wind, waves, tides, and slope, the factor significantly influencing abrasion is the slope of the beach. Under normal conditions, a gently sloping beach with a gradient of less than 2% is highly vulnerable, as observed at Samas Beach and Gua Cemara Beach. Severe abrasion events occur due to storm-induced tidal waves, impacting the wave conditions (Mörner & Finkl, 2019; Oo et al., 2023).

The results of wind and wave data processing that occurred in the Southern Waters of Yogyakarta, as depicted in **Figure 10**, when the Cempaka and Dahlian cyclones occurred in 2017, shows that the Cempaka and Dahlian cyclones had a significant impact on the dynamics of oceanography in the waters of Yogyakarta, a considerable increase occurred on 27-30 November 2017 when the cyclone track approached the waters of Yogyakarta, at that time the wave height reached 4 meters, This condition aligns with previous research (Malawani et al., 2019) with an average wind speed of 10 $m.s^{-1}$. The increase in wind speed will increase the wave energy that hits the coast, potentially causing abrasion in coastal areas. Cyclones have a significant impact on coastal erosion in Indonesia by increasing the height of the axis, causing storm surges, and creating obstacles to sediment transport. These impacts are exacerbated by damage to protected coastal ecosystems, making it critical to manage and mitigate the effects of cyclones on coastal sustainability.

In general conditions, beaches with steeper slopes will be more abraded than beaches with gentler abrasion (Dionísio António et al., 2023; Rijnsdorp et al., 2022); this is because the distribution of wave energy and current flow is greater when compared to gentle beaches, in addition, gentle beaches will reduce wave energy. After all, waves will be distributed faster.

From the comparative analysis of abrasion against the slope of the coastline at the study observation station, it turns out that beaches with gentle slopes are more susceptible to abrasion than steeper beaches, several factors that can cause such conditions include, wave height in Yogyakarta waters tends to be high so that it can sweep a wider area, with high wave intensity will continue to erode coastal sediments on a large scale, in addition, seen from the tidal data presented in **Figure 11**, the tidal rise at the study location reaches 2,364 m, this will make the range of wave propagation further during high tide conditions, another factor is the type of sediment, finer sediment will be more susceptible to abrasion (Dionísio António et al., 2023) with constant current and wave conditions, in addition, extreme weather factors such as high waves will increase the erosion of sediment accumulation which is usually deposited over a specific period of time, an increase in extreme high waves during storms is depicted in **Figure 10**, so that when extreme waves occur abrasion will occur more quickly during high wave periods.

Analysis related to wave and tidal data was conducted to provide an overview of oceanographic conditions in the study area. Due to the limited global data and a small study area, there was no comparison between the influence of oceanographic parameters at one observation station and another, as the impact of the oceanographic parameters obtained was consistent across all stations. Oceanographic analysis in this study was used to provide an overview of the general influence on all study areas and to identify specific events, such as tropical storms that occurred in the Indian Ocean, which received a response in coastal regions; this is illustrated in **Figure 10**. In further studies, short-term monitoring can be carried out during tropical storms by analyzing images taken before and after the storm, allowing for the specific quantification of the storm's influence on the amount of abrasion that occurred in the Bantul tourism area.

It is possible to conduct a more intricate numerical calculation utilizing fewer time steps to acquire precise values of alterations in the shoreline. Annual satellite imagery might fail to capture the accurate influence of storm-induced tidal surges on the abrasion rate during a given period. Therefore, it is necessary to conduct firsthand field measurements to gain a comprehensive understanding of the details. Additional research may be warranted to delve into the complexities of land use modifications and coastal development in shoreline changes influenced by human activities. Developing coastal infrastructure can alter sediment movement patterns, resulting in accretion and abrasion in the surrounding areas.

4. Conclusion

The Landsat-8 satellite imagery is compelling for mapping shoreline changes along the coastal areas of Bantul Regency, Yogyakarta. The annual values of abrasion and accretion can be illustrated through EPR analysis. The maximum accretion rate is 8.02 m/year, while the maximum abrasion rate is -10.69 m/year. Overall, the EPR value across all studied segments over the ten years is -1.51 meters per year. The analysis indicates that the most influential factors contributing to abrasion in this region are the slope of the shoreline and, more specifically, tidal waves induced by storms.

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