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MONITORING COASTAL LINE CHANGES USING THE DIGITAL SHORELINE ANALYSIS SYSTEM (DSAS) METHOD IN THE COASTAL AREA OF MEKKATTA VILLAGE, MEJENE REGENCY

Haryanto Asri[1*], Femiliani Novita Sari[1]

[1]Faculty of Fisheries and Marine Sciences, Muhammadiyah University of Mamuju

*Corresponding author: haryantoasri22@gmail.com

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ABSTRACT

Analysis of coastline changes in Mekkata Village from 2013 to 2023 was conducted using the baseline of the nearest coastline to the mainland. This baseline was used as a reference point for transects measuring changes. The shoreline encompasses the coastline during the research period. Net Shoreline Movement (NSM) was employed to differentiate between erosion and accretion in the study area, showing an average shoreline change value of -9.72 meters towards the mainland, indicating predominant erosion. According to DSAS, it is observed that the coastline of Mekkata Village experienced erosion along 41 transects, while 31 transects exhibited accretion, highlighting significant changes. The most notable erosion area was identified along transects 60, 61, and 62, indicating consistent land reduction. Meanwhile, the most accretion-prone transects were 11, 12, and 13, signifying substantial land addition. The predominant erosion process is suspected to be influenced by the gentle slope of the coastal area and the composition of sand material. Human activities such as deforestation and river mouths also contribute to erosion. The absence of coastal protection structures allows direct waves and currents to impact the shore, potentially causing erosion. Meanwhile, accretion areas around river mouths indicate the formation of emergent land or deltas.

Keywords: Coastline, Coastal Geomorphological Changes, DSAS, Erosion and Accretion, NSM.

INTRODUCTION

Indonesia is known as one of the world's largest maritime countries and is often referred to as an archipelagic nation. The Indonesian territory is surrounded by vast waters, spanning 3.25 million square kilometers (Directorate General of Sea Spatial Management, 2020). Coastal areas are geographically situated between land and sea. These regions possess unique ecological dynamics, combining interactions between the marine and terrestrial environments and serving as habitats for a large portion of the global human population. The coastline, as the boundary between land and sea, is a focal point in geographical and environmental studies. The dynamics of the coastline consistently undergo changes due to various factors such as erosion, accretion, and human activities. A profound understanding of these changes is crucial for maintaining coastal environmental sustainability and anticipating potential impacts on surrounding communities.

Mapping changes in the coastline is a vital approach in understanding the evolution of coastal regions. One method utilized in this mapping is the Digital Shoreline Analysis System (DSAS). DSAS harnesses satellite image technology to accurately track changes in the coastline and provides crucial spatial data for comprehending coastal area dynamics.

Google Earth Pro satellite imagery serves as a critical data source in coastline change analysis. The advantages of resolution and periodic data availability from Google Earth Pro images enable detailed mapping of coastline changes over specific periods. The combination of DSAS methodology with data from Google Earth Pro has opened new opportunities to comprehend the dynamics of coastline changes in various coastal regions.

In the context of the coastal area of Mekkatta Village, Majene Regency, mapping changes in the coastline and conducting related analyses of coastal area dynamics are immensely important. In recent times, changes in the coastline of this area have drawn serious attention. Studies related to this matter are crucial for understanding the factors influencing coastline changes and their impacts on the livelihoods of the surrounding communities.

The objective of this research is to map the changes in the coastal coastline of Mekkatta Village from 2013 to 2023 using the DSAS method and data from Google Earth Pro satellite imagery. Through in-depth analysis of coastline changes, this research aims to provide better insights into the coastal area dynamics of Mekkatta Village, Majene Regency, and contribute to sustainable management efforts of the coastal environment.

MATERIAL AND METHOD

Time and Location

The location of this research is along the coastal area of Mekkatta Village, Majene Regency, conducted over a duration of Two month from September 3rd to November 2nd, 2023. Mekkatta Village is one of the 12 villages/urban districts within the Malunda Subdistrict of Majene Regency. Geographically, the coordinates of Mekkatta Village are approximately 3°11'34" S - 3°12'34" S and 118°57'12" E - 118°58'12" E. Mekkatta Village shares administrative boundaries; it borders Malaya Village and Mamuju Regency to the north, Bambangan Village to the east, Mekkatta Selatan Village to the south, and the Makassar Strait to the west.

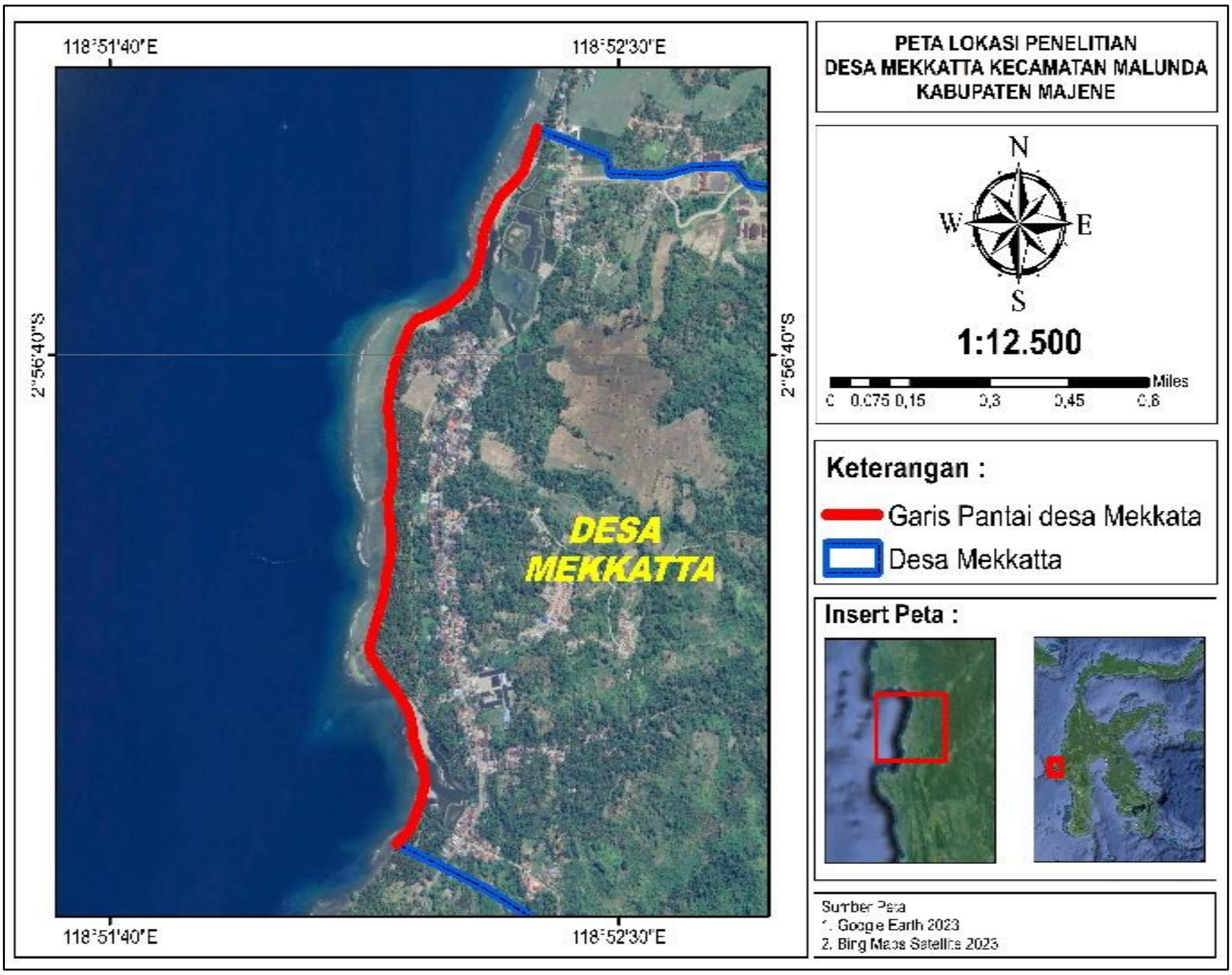

Figure 1. Research Location

Data and Equipment

The data and equipment used in this research are as follow (Table 1 and 2) :

Table 1. Research Data

No	Type Data	Date	Source
1	The coastline of Mekkatta Village	25/05/2013	Google Earth Pro
2	The coastline of Mekkatta Village	11/09/2018	Google Earth Pro
3	The coastline of Mekkatta Village	02/10/2013	Google Earth Pro
4	The administrative boundaries of Mekkatta Village		

Table 2. Research Equipment

No	Equipment	Type	Function
1	Personal Computer (PC)	Hardware	Used for inputting and processing data
2	Camera	Hardware	Used for taking photographs
3	Arcgis 10.7	Software	Used for the process of separating land and sea boundaries, digitization, DSAS analysis, and map layouting
4	Google Earth Pro	Software	Used for downloading images
5	M.S Excel	Software	Used for calculating the rate of coastline change and for creating coastline change graphs.
6	Tool DSAS	Software	Used for calculating coastline changes.

Data collection

The data collection process in this research involves both primary and secondary data. The primary data consists of spatial data of the coastline from 2013 to 2023 downloaded from the Google Earth Pro software. Meanwhile, the secondary data comprises administrative map data of Mekkatta village, Malunda district, Mamuju regency.

Data processing

Geometric Correction

The process required is due to the geometric distortion between the imagery produced by remote sensing and the represented objects. These distortions involve imperfections in the geometry of images recorded during the imaging process, resulting in changes in the size, position, and shape of the image that do not correspond accurately to the actual conditions. This correction process is crucial before using the images to ensure good quality of the satellite imagery used (Lukiawan et al., 2019). For example, in the geometric correction of Mekkatta Village, the WGS 1984 UTM 50 South datum is used to ensure precision and accuracy in representing the image within the appropriate coordinate system. This helps to rectify distortions and enhance the accuracy of information contained within the image.

Coastline Digitization

The Google Earth Pro imagery from 2013, 2018, and 2023 underwent a process called digitization. Digitizing Google Earth satellite imagery is a crucial step in analyzing coastline changes. Through digitization, researchers map the coastline using specialized software to mark the boundary between land and water. This process involves visual interpretation and selecting points that represent the coastline in the image. Digitization allows for recording the land-water boundary necessary for identifying changes in the coastline over time. With precise digitization, changes in the coastline can be accurately observed, providing profound insights into coastal environmental dynamics.Top of Form

Coastline processing using DSAS.

DSAS is an additional software developed to operate within the ArcGIS software framework initiated by ESRI in collaboration with USGS. The DSAS application includes calculations for Net Shoreline Movement (NSM), Shoreline Change Envelope (SCE), End Point Rate (EPR), Linear Regression Rate (LRR), and Weighted Linear Regression Rate (WLR) (Oyedotun, 2014). Its primary advantage lies in being open-source. DSAS focuses primarily on analyzing coastline changes but also has the capability to handle various boundary changes within specific timeframes. Before calculating coastline changes, researchers establish transect lines based on predetermined time intervals (Himmelstoss, 2009).

This software offers several methods, one of which is NSM (Net Shoreline Movement). NSM is used to measure the distance of shoreline changes between the oldest and newest coastlines. Data analysis using DSAS is performed within the ArcGIS software with the aim of generating visualizations of shoreline changes, which will be further analyzed in subsequent research stages. This is in line with the research conducted by Istiqomah et al. (2016) that examined shoreline changes along the coast of Demak Regency using the DSAS application with NSM calculations

In the operationalization of DSAS, a personal geodatabase is created in ArcGIS to categorize the various coastlines. This geodatabase creation involves the generation of new features with line types or Line Features. The data needed in the geodatabase creation process includes coastline data for the years 2013, 2018, and 2023. During the geodatabase creation process, two types of data will be generated: baseline and shoreline. Each of these records coastline information within the context of observed changes (Syafitri, 2023). The baseline data utilizes the buffered coastline data from 2013, while the shoreline data utilizes overlayed coastline data from 2013, 2018, and 2023.

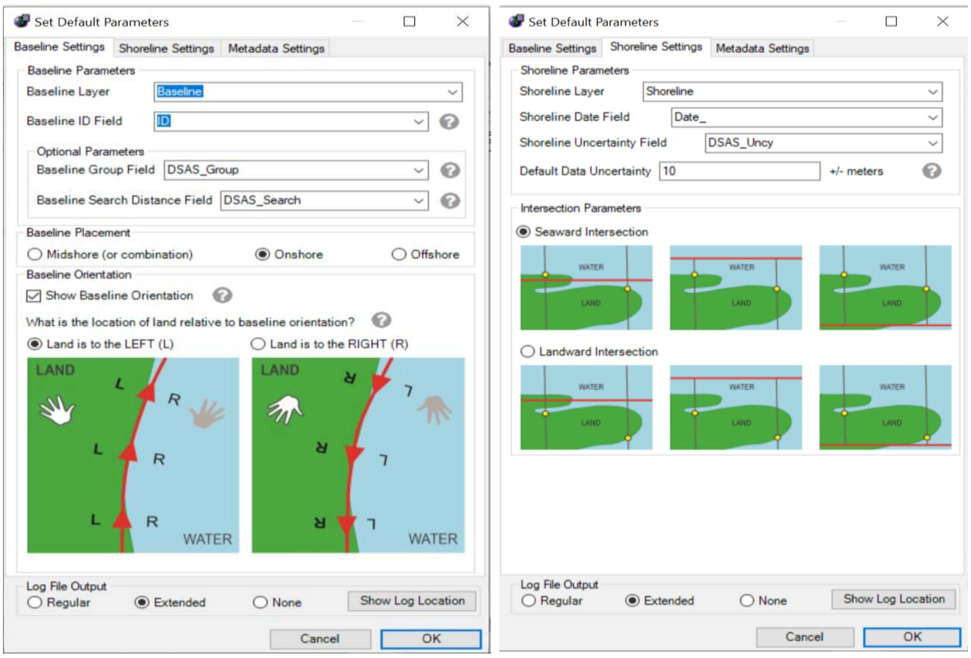

Figure 2. Baseline and Shoreline Input Process on DSAS

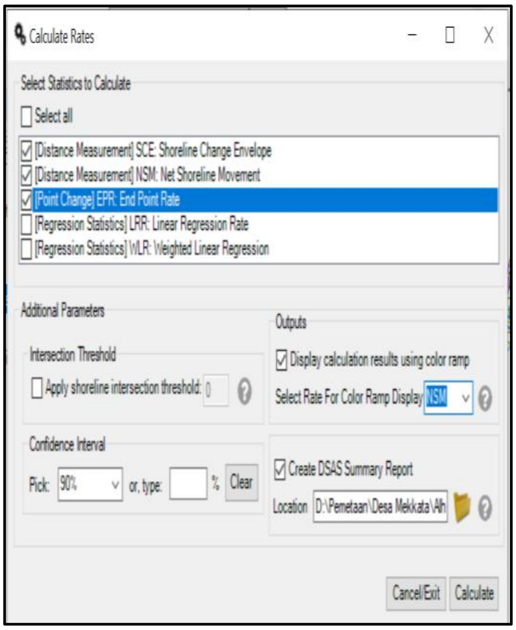

Figure 3. NSM calculation process

Analysing coastline changes using DSAS holds significant value in geospatial research. Its capacity to process data and present visualizations of coastline changes provides profound insights, enabling researchers to comprehend environmental changes occurring along the coastline within specific timeframes.

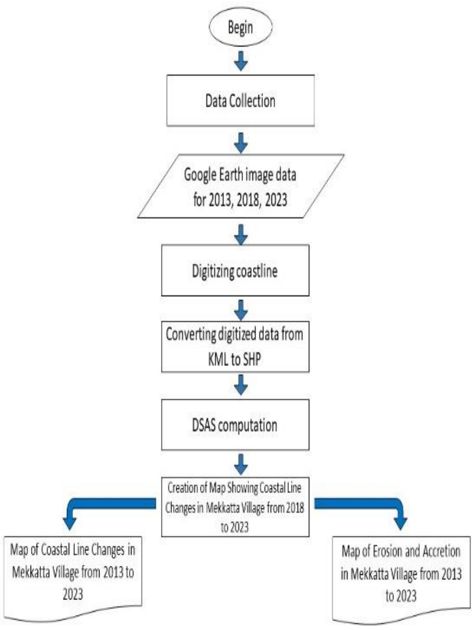

Figure 4. Research Flowchart

RESULTS AND DISCUSSION

Results and Analysis of Coastline Changes

The coastline changes between 2013 and 2023 were analyzed using a baseline derived from the combination of the nearest shoreline to the land. This baseline served as the starting point for transects to measure changes. The baseline's value was set at 0, representing the starting point before the processing began. The shoreline encompassed the coastline during the study period. This research considered the total coastline changes and differentiated between erosion (abrasi) and accretion (akresi) in the study area using the NSM method. A 30-meter transect interval was selected to ensure image pixel accuracy, while the baseline facilitated coastline identification at 100-meter intervals. NSM generated 71 transect lines along the study area's coastline, with an average shoreline change of -9.72 meters towards inland, indicating erosion. The varying number of transects in the study area was influenced by the area's shape and size. NSM exhibited positive values for accretion and negative values for erosion, aligning with observed coastline change conditions. The results of the coastline change calculations using the NSM method are presented in the following table:

Table 3. NSM Processing Results

Number of Transects	Mean	Maksimum Value (NSM)	Minimum Value (NSM)
71	5,21	19,88	-69,09

In table 3 above, it can be observed that the average shoreline change is 5.21 meters towards the sea. Therefore, it can be stated that from 2013 to 2023, Mekkatta Village experienced accretion by 5.21 meters towards the sea. Additionally, the maximum value obtained is 19.88 meters, indicating accretion, and the value of -69.09 meters indicates erosion.

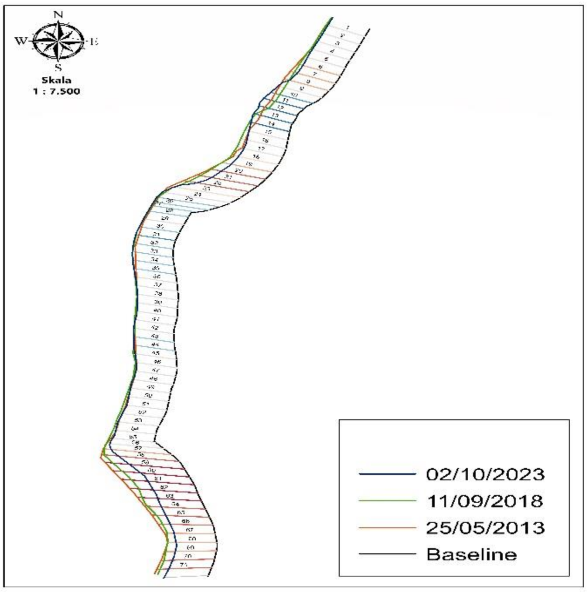

Figure 5. Transect of changes in the coastline of Mekkatta Village

In the above figure 5, it is noted that there are 71 transects created for the analysis of shoreline changes in Mekkatta Village. In this analysis, the baseline data utilized is the coastline of Mekkatta Village from the year 2023 that has been buffered using ArcGIS 10.7 software. Meanwhile, the Shoreline data used consists of the coastlines of Mekkatta Village from the years 2013, 2018, and 2023.

Results of Mekkatta Village Coastline Validation Analysis

The coastline of Mekkata Village in 2013, 2018, and 2021 was mapped together and used as a reference baseline alongside the latest shoreline in 2023, with the creation of a 100-meter buffer zone towards inland (onshore). In this study, the utilization of a baseline created based on the buffer of the current shoreline is intended to observe coastline changes over time. When establishing transects, the distance between each transect was set at 30 meters. This distance selection took into account the significant length of Mekkata Village's coastline, deemed capable of providing adequate detail and covering the entire study area.

To calculate the shoreline changes in 2013, 2018, and 2023, the Digital Shoreline Analysis System (DSAS) method was employed. DSAS analysis utilized transect lines as references to assess coastline changes. In this study, these transects were positioned towards the sea with the baseline on land (onshore). The interval between these transects was set at 30 meters, resulting in a total of 71 transects. DSAS was automatically used to measure the distance and rate of coastline changes in Mekkata Village over a 10-year period, from 2013 to 2023 (Figure 6).

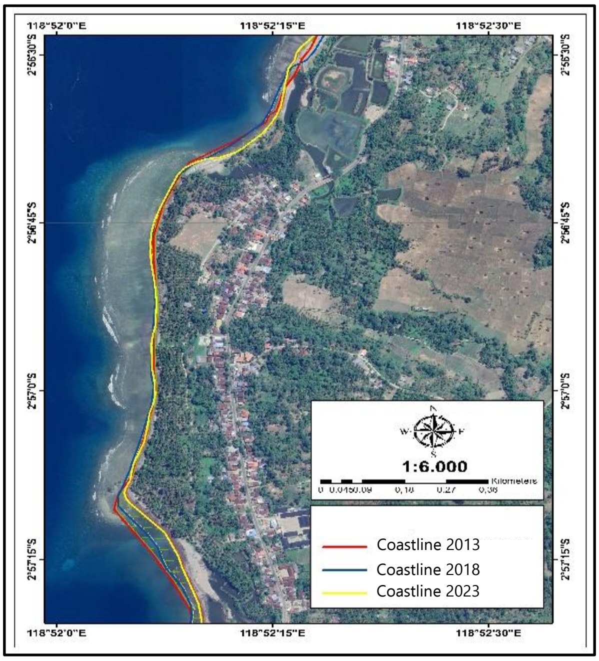

Figure 6. Changes in Mekkatta Village Coastline (2013-2023)

The applied analysis method was Net Shoreline Movement (NSM). The NSM calculations resulted in positive values (+) for accretion (land addition) and negative values (–) for erosion (land reduction). Based on the DSAS calculations, it is observed that over the 10-year period, Mekkata Village's coastline experienced a dominance of erosion or land reduction, noted by a total of 41 erosion transects. Nevertheless, there are still several locations showing accretion, totaling 31 accretion transects, albeit in smaller numbers compared to erosion. From the coastline change analysis in Mekkatta Village, the value of erosion area obtained was 2.43 hectares from 2013 to 2023, and the accretion area value was 0.24 hectares from 2013 to 2023.

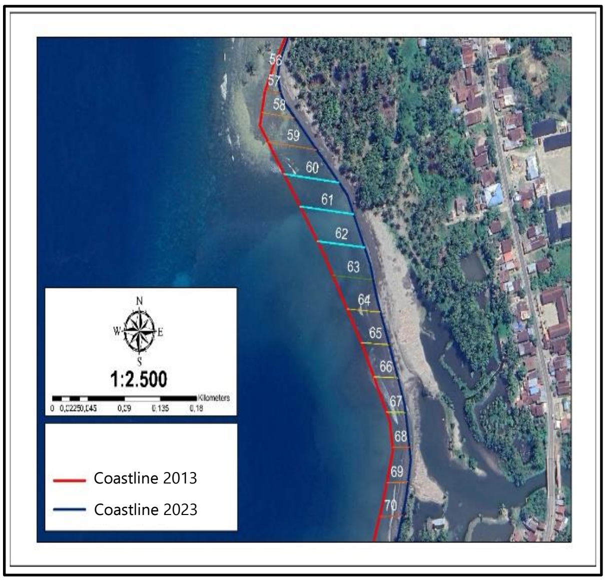

Figure 7. Widest Abrasion Transect

The most prominent transect line indicates the most significant erosion. The widest erosion transect area (Figure 7) is situated along transects 60, 61, and 62 (highlighted transect lines). In this section, the marked transect lines indicate the most substantial land reduction or erosion compared to other locations. This highlights areas along the coastline where consistent erosion processes consistently cause land or terrain reduction.

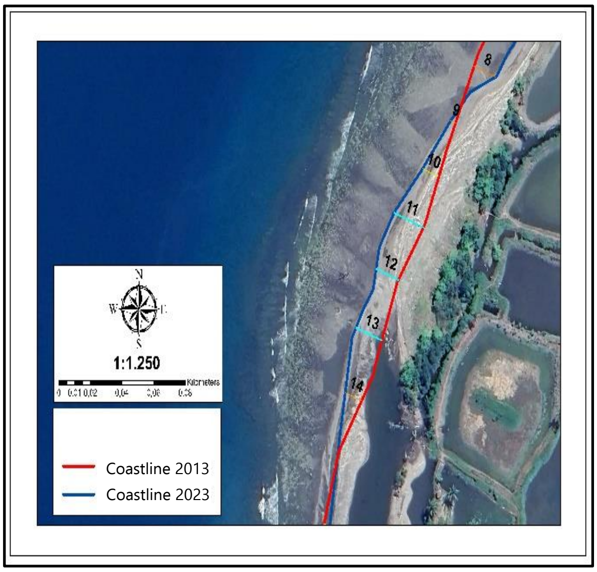

Figure 8. Widest Accretion Transect

The transect lines displaying the most significant accretion highlight substantial land addition or accretion. The widest accretion transect area (Figure 8) is positioned along transects 11, 12, and 13 (highlighted transect lines). This section portrays locations along the coastline where the accretion process results in substantial land addition compared to other areas. The results of coastline changes from 2013 to 2023 in Mekkata Village over a 10-year period are presented in the following graph (Figure 9).

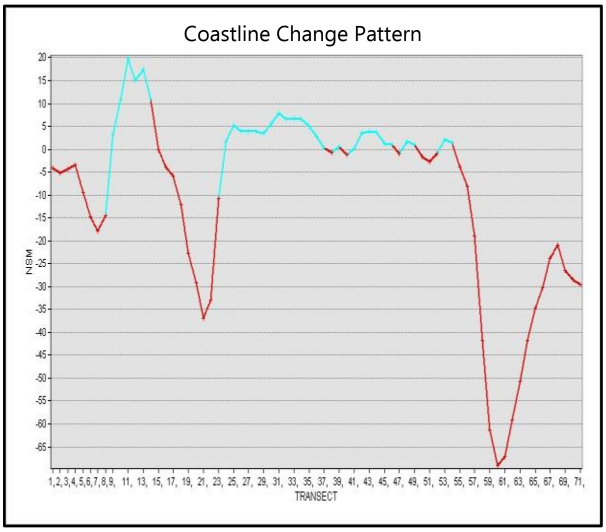

Figure 9. Coastline Change Pattern (NSM)

The above Figure 9 represents the pattern of coastline changes in Mekkatta Village from 2013 to 2023. There are 71 transects where the blue-colored lines indicate accretion that occurred from 2013 to 2023, whereas the red-colored lines indicate erosion that occurred from 2013 to 2023.

The use of satellite imagery and DSAS method to calculate coastline changes provides time efficiency compared to direct field measurements. Satellite imagery, capable of displaying extensive Earth surface conditions, allows detailed observation of coastlines. Moreover, the high spatial resolution of the satellite imagery used in this study enables clearer identification of surface objects. The DSAS method also automatically calculates shoreline change values in terms of distance and rate, aiding in an efficient analysis of coastline changes. The advantages of this technology drive efficiency in coastline change analysis.

Calculating coastline changes using data from Mekkata Village in 2013, 2018, and 2021 as the primary reference for measuring distance and change rate. Therefore, accuracy in data processing, especially in extracting shorelines from satellite imagery, significantly influences the results of coastline change calculations using the DSAS method. Analysis results using Google Earth Pro satellite imagery and DSAS indicate that Mekkata Village experienced coastline changes over a 10-year period (2013-2023), including erosion or accretion along its coastline.

DSAS analysis results indicate a dominance of erosion events compared to accretion in Mekkata Village. Factors supporting erosion along most of Mekkata Village's coastline are likely due to gentle beach slope and the presence of sandy beach materials. This aligns with findings by Hidayah et al. (2018), stating that beaches with gentle slopes and sandy substrates are susceptible to sediment particle movement, either through deposition or erosion, potentially altering the coastline. In the study area, coastal areas of Mekkata Village with sandy substrates tend to experience higher erosion. Additionally, high erosion rates occur in areas affected by human activities such as deforestation and regions around river mouths, significantly influencing coastline dynamics.

Figure 10. Sandy coastal substrate of Mekkatta Village Beach

According to Wulandari et al. (2022), erosion has the potential to reduce land area and trigger tidal floods. Furthermore, erosion poses a serious threat to the coastline, agricultural land, settlements, ponds, and structures along the shoreline. Besides coastal geomorphological factors, natural phenomena are also suspected to influence the coastline changes at the research location. This condition arises due to the absence of significant development, such as reclamation, which can lead to a drastic increase in the coastline or stronger accretion. Sustained natural phenomena become the primary factor causing continuous changes in the coastline of Mekkata Village. This emphasizes the importance of understanding the role of natural phenomena in altering coastal dynamics and promotes monitoring of coastline changes caused by natural factors. Wati et al. (2020) explained that high sea waves generate high-speed coastal currents, resulting in the erosion of beach materials. Along Mekkata Village Beach, the waters are open without islands in front, which means they do not affect wave height or current patterns. In open waters, strong waves and repetitive currents can significantly impact the coastline by eroding parts of the beach, altering the coastline's shape. However, open waters can also result in accretion, where sea sediment brings additional materials to the coastal area, expanding the coastline with material accumulation in the coastal zone.

On the coastal area of Mekkatta Village, there are no building structures serving as coastal protections such as breakwaters, revetments, and groins. The function of a breakwater is to shield the coast from erosion by dissipating wave energy before it reaches the shore. Revetments serve to protect a coastline or slope surface from wave and current influences, while groins function to trap sediments carried along the coast, preventing them from moving elsewhere (Triatmodjo, 2011). This situation allows waves, currents, and tides to directly impact the coastline, which over time can cause erosion. Meanwhile, areas experiencing accretion in Mekkatta Village are located around river mouths, evident in the formation of emergent land or deltas. These findings align with Hazazi et al. (2019), stating that accretion can cause water shallowing and the formation of emergent land towards the sea over time. This condition indicates that the interaction between coastal dynamics and factors like river flow and sea currents can influence erosion and accretion patterns in a coastal area.

CONCLUSION

The analysis of coastal changes in Mekkata Village from 2013 to 2023 demonstrates the dominance of erosion as the primary event, with 41 transects indicating significant land reduction. However, there are 30 transects that show accretion, albeit in a smaller proportion. The most notable erosion area is found in transects 60, 61, and 62, while the largest accretion area is identified in transects 11, 12, and 13. The main contributing factors to erosion include gentle coastal slope inclination and the predominance of sandy beach material. Human activities such as tree cutting and areas surrounding river mouths also influence the erosion rate. Meanwhile, the areas around river mouths show signs of accretion with the formation of emergent land or deltas.

Recommendations for coastal management in Mekkata Village include the construction of coastal protection structures to mitigate the impact of erosion caused by waves and currents. Managing human activities to minimize contributions to coastal erosion is also crucial. Further research on the interaction between human activities and nature is recommended. Involving the local community in coastal and environmental management is necessary to sustain the ecosystem of Mekkata Village's coastline.

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