Shoreline changes analysis of Kendal Coastal Area

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Abstract. Shoreline changes occur due to abrasion and accretion processes that are triggered due to intensive human activities in coastal areas. The shoreline in the Kendal region is dynamic, and shows mixed results from tidal and dominated by riverine activity. The shoreline changes have different impacts, all of which may not be visible. Coastal dynamics in the Kendal region cause spatial-temporal shoreline changes. To observe these we need a long and continuous set of data. The purpose of this study is to determine changes in the shoreline in parts of the Kendal coastal district and to calculate the value of the changes. The data used were derived from TM data 1990, to OLI data 2017. To derive the shoreline from the satellite data, a band ratio of Red band to IR band was employed. The shorelines were digitized and saved along with the appropriate MM/DD/YYYY added to the attribute table. The Digital Shoreline Analysis System (DSAS) was used to compute rate-of-change statistics. The Digital Shoreline Analysis System (DSAS) is an extension of ArcGIS, developed by USGS. Using the extension, transects were laid every 100 m. Then, using NET SHORELINE MOVEMENT (NSM), LINEAR REGRESSION RATE (LRR) and END POINT RATE (EPR), the changes every 100 meters were analyzed and stored in a table. Subsequently, using the table, erosion, and accretion, were analyzed, and understood. The farthest accretion process was 1763.29 m and 792.14 m for the abrasion processes.

1. Introduction

Indonesia is the largest archipelagic country in the world with 13,000 islands and the second longest shoreline in the world. As an archipelago, most parts of Indonesia are directly adjacent to the sea. The sea border with the land is a coastal area which is a region that is vulnerable to changes due to the formation and development of coastal landscapes [1]. Changes in coastal landscapes can be caused by nature or humans [2].

Shoreline changes are processes that occur dynamically (continuously) through various processes, including both erosion and accretion of the beach [3]. In addition, coastal environments have high dynamics; for example, physical processes, sea level rises, land subsidence, and erosion-sedimentation [3]. Changes in the shoreline can be positive because of the sedimentation process, which result in the coastal area having additional land, so activities there increase. The progress of the shoreline can be said to be profitable because of the emergence of new land, but it can cause urban drainage problems in the coastal area [4].

Changes in the shoreline are not always profitable, as they can be assessed as causing land loss due to abrasion [5]. Which is a natural processes changes in the shoreline are one of the most important problems on the North Coast of Java [5]. The assessment of physical aspects in coastal areas is vital because they play an important role in development [5]. Urgency of coastal areas in development

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because coastal areas have an important position in development [3]. Changes in the shoreline on the north coast are currently quite serious, resulting in various kinds of loss and danger for the society.

Kendal Regency is one of the areas in Central Java that experiences abrasion. About 19 km of the total shoreline of 41 km, or 46.3% has experienced abrasion [6]. Around 404 ha of land on the coast of the region has been eroded due to such conditions. Kendal Fisheries and Tourism Service data show that abrasion has occurred in seven sub-districts of the northern coast, namely Rowosari, Kangkung, Cepiring, Kendal, Patebon, Brangsong, and Kaliwungu, with the most severe conditions being seen in Patebon Sub-District [6]. Moreover, according to data from the Kendal Regency Environmental Agency (BLH), abrasion on the north coast of Kendal Regency has now expanded to affect 1,150 ha [7]. Therefore, there is a need for spatial analysis of the changes in the Kendal Regency shoreline, so that the current shoreline conditions can be identified and used as a reference frame for the authorities to implement coastal management and planning in accordance with the natural conditions, and oriented towards the sustainability of community economic activities and environmental sustainability.

Kendal Coastal Area is a very dynamic region, with a variety of complex geomorphic processes that occur, as well as demographic processes, such as economic activities utilizing the space available in coastal areas. Industrial areas in the north coastal region of Central Java, such as Kendal City and Semarang, are regional assets that need to be preserved [8]. This problem is a trigger for the need to immediately map the dynamics of shoreline changes to establish various processes and problems that can arise in the coastal area of Kendal Regency. Based on the above problems, the purpose of this study is to determine the changes in the shoreline of some of the coastal areas of Kendal and to calculate the value of the changes.

2. Study Area
The research was conducted with an eastern boundary located on the Blorong River with coordinates 6053'28.78 "LS and 110014'25.78" BT. The western boundary of the study location was located on the Sibeo River with coordinates 6052'55.11 "LS and 110007'27.51" BT (Figure 1). The choice of location was made because the problems found on the north coast of Java had generally reached a critical point, with changes in the coastline causing various kinds of loss and danger for the interests of the Kendal Regency Coastal Community.

The selection of research location was also based on the following considerations (1) Kendal Regency, including the coastal area of the north Java coast, is experiencing a massive shoreline change process; (2) the dynamics of the shoreline changes lead to various kinds of loss and danger the Kendal Coastal community; (3) according to the Department of Fisheries and Marine Kendal (2006), the Coastal Area of Kendal Regency has lost around 404 ha due to wave erosion; and (4) Bodri River has high sedimentation rates [9].
3. Method
Quantitative and statistical research methods were employed. The quantitative method, which was mathematical and systematical used remote sensing technology, based on the processing of the image data obtained, while the statistical method was conducted by processing the data on coastal abrasion and accretion rates.

The materials used were Landsat 5 TM and 8 OLI / TIRS Imagery Year 1990-2017 multispectral, with 30 meter corrected spatial resolution. A series of images was obtained from the data provided by the National Aeronautics and Space Administration (NASA). The images are summarized, (in Table 1).

| Satellite Imagery | Resolution (m) | Censor | Radiometric | Path/Row | Date          |
|-------------------|----------------|--------|-------------|----------|---------------|
| Landsat 5 TM      | 30             | TM     | 8 bit       | 120/65   | 28/10/1990   |
| Landsat 5 TM      | 30             | TM     | 8 bit       | 120/65   | 22/09/1999   |
| Landsat 5 TM      | 30             | TM     | 8 bit       | 120/65   | 19/09/2017   |
| Landsat 8 OLI     | 30             | OLI    | 12 bit      | 120/65   | 09/10/2017   |
Relative changes in shoreline position were determined using an approach similar to that employed in the Digital Shoreline Analysis System (DSAS) [10], but implemented in computer code to enable further exploration of the transect time series. Proper baseline constructed by the user and serves as the starting point for all transect cast by the DSAS application. Transects intersect each shoreline to create a measurement point, and these measurement points are used to calculated shoreline change rates. [10]

Calculation of the value of erosion and coastal sedimentation was made using an additional extension to the software from ArcGIS, namely the Digital Shoreline Analysis System (DSAS) [10]. The shoreline changes that had occurred were measured using the Net Shoreline Movement (NSM) statistical method. The rate of shoreline change in the form of erosion and temporal sedimentation was calculated by determining the line in each shoreline temporally. The calculations were made using the EPR and LRR methods, which are statistical analyses performed automatically on a computer.

4. Result and Discussion
The results of the shoreline extraction were analyzed based on four observation periods, 1990-1999, 1999-2009, 2009-2017 and 1990-2017. The results of the mapping show various dynamic conditions in each year of the analysis.

The shoreline conditions found at a number of points indicate the shoreline advancing towards the sea, while others show it retreating towards the land. The observations also show that the coastal area of Patebon Subdistrict, specifically Bodri estuary and the east area, experiences intensive dynamics compared to the area to the west. which covers part of the coastal area of Patebon District, the coastal region of Cepiring District, and part of the coastal area of Kangkung District.

The shoreline shift was measured using the Net Shoreline Movement (NSM) statistical calculation, which is a computational analysis of statistical calculations from DSAS. The NSM method resulted in a change in the length of the shoreline, not the rate of change, so the result of this calculation shows how far the shoreline has changed. The use NSM method was chosen because it has the right principle for expressing shoreline changes by measuring the total distance between the shoreline and the earliest time with the most recent shoreline at the time of measurement.

The results obtained from the NSM calculations (Figure 2) also show the process of shoreline dynamics, that is, whether the shoreline has eroded or accreted. Shoreline erosion refers to retreat towards the land or the or if the resulting NSM value is negative. On the other hand, shorelines that experience accretion, or an increase in their advance towards the sea, can be seen from positive NSM values. The oldest shoreline in the study is that of 1990 and the most recent that of 2017.
4.1. Shoreline Change from 1990-1999

The results obtained from the shoreline observations from 1990-1999 (Figure 3) show significant changes, especially in the Bodri estuary. These can be seen from the change in the direction of the estuary, which in 1990 northeast, whereas the results of the 1999 shoreline mapping showed that the direction of the Bodri River estuary had changed to the northwest. Changes in the shoreline of the coastal areas of Kendal Regency experienced varied growth and tended to move towards the east in 1992 [11]. The direction of the Bodri River estuary changed the west due to the abrasion on its east side, which was quite extensive. The eastern part of the estuary showed severe abrasion, so the extent of the delta area decreased by an average of 16 ha / year [12]. This phenomenon shows that an intensive oceanographic morphodynamic process is occurring in the Bodri River Estuary.

The changes that have occurred indicate that oceanographic control is more dominant than land area control. The process of coastal morphodynamics that occurred in this period shows that there was a shift in the forces forming the Kendal coastal area, with the initial marine forces and being replaced by more dominant fluvial forces. The impact of the wave patterns, sea surface flow, tides and changes in river discharge can cause changes in the location of river mouths [13].
4.2. Shoreline Change from 1999-2009
Observation of the shoreline changes between 1999 dan 2009 showed a significant shift at several points, especially around the Bodri estuary. The total change calculation using the NSM shows that the greatest change in the shoreline occurred in the western part of estuary in 2009, where it advanced 371 meters from its position in 1999. The progress of this shoreline position indicates that accretion had occurred in that location. A map of the shoreline changes in 1999-2009 is presented in Figure 4.

![Figure 4. Shoreline Change from 1999-2009.](image)

4.3. Shoreline Change from 2009-2017
Changes in the shoreline revealed by the results of the mapping for 2009-2017 show the dynamics that are still dominant at the mouth of the Bodri River. The mapping results show that in 2017 the shoreline shifted further towards the north compared to 2009. The NSM calculation shows that it had shifted to a farthest point of 1690.88 meters from its initial position in 2009. The shoreline change map for this period is shown in figure 5.
4.4. Shoreline Change from 1990-2017

The results obtained from observation of the shoreline changes from 1990-2017 show that the distribution of shoreline changes had varying patterns and were spread throughout the study area. Areas with advanced shorelines (accretion) were generally located downstream of river estuaries. This shows that areas with advanced shorelines are those close to the source of sediment, in this case, the river is a sediment carrying medium which later, due to the marine and land forces, created a process of sedimentation in the coastal areas. Accretion the east, is located at the mouth of the Blorong River, in the middle of the mouth of the Bodri River, and in the west is located at the estuary of the Sibeo River. On the other hand, shoreline retreat (abrasion) is dominant in the coastal area of Patebon Subdistrict located between the mouth of the Bodri River and the Blorong River Estuary. However, the coastal area between the Bodri and Sibeo rivers experienced small dynamics of change.

The results obtained from the shoreline mapping from 1990-2017 show the dominance of the various abrasion and accretion processes as presented in Figure 6. Based on the figure, it can be seen that in this period the process of coastal change can be divided into three zones, based on changes in shoreline the dominant one. Namely accretion zones, accretion zones to abrasion, and stable zoning.

The accretion zone, which is the zone of the coastal region with a dominant accretion pattern, its in three locations, namely in the vicinity of the estuary of the Blorong River, the mouth of the Bodri River, and the estuary of the Sibeo River. Administratively, the zones around the Blorong River estuary are in Kota Kendal District, while the locations around the Bodri River estuary are in Patebon District. Sibeo River estuary is administratively located in Kangkung District. Physically, the morphological form of this zone is formed from the sedimentation process that created a delta at the mouth of the river.

Accretion to abrasion zones, namely coastal areas that experience processes with accretion patterns to abrasion, are administratively in Patebon Subdistrict, which is between the mouth of the Blorong River and the Bodri River estuary. The physical condition of this zone has irregular coastal morphology due to the abrasion process, and the material is sandy mud. The area is vulnerable to abrasion due to its morphology, jutting towards the sea, meaning the potential of wave energy becomes high.
Stable zones, are coastal areas which are administratively located in Cepiring District and part of Kangkung District. The physical condition of the coast in the zones is a smooth morphology. The coastal material found on the beach is sandy mud, and the dominant geomorphic process is balanced sediment transport [12].

![Figure 6. Shoreline Change from 1990-2017.](image)

4.5. Shoreline Changes Rate
In general, the coastal area of the study had experienced a shoreline change rate of 3.33 meters / year based on calculations using the LRR method, and 3.76 meters / year based on those using the EPR method. The value of the shoreline change rate of more than 2 meters / year includes a very high accretion process [14]. This process is in accordance with Sanjoto, et al., 2012 which found that overall the Bodri Delta coast of Kendal Regency tends to experience growth [12]. Coastal growth in the research area was caused by the sedimentation process, which also causes accretion of the shoreline. The sedimentation process that had occurred in the coastal study area is presented in Table 2.

| Location                        | Method   | West (Cepiring Subdistrict) | Bodri Estuary | East (Patebon Subdistrict) | Kendal Coastal Area |
|---------------------------------|----------|----------------------------|---------------|----------------------------|---------------------|
|                                 | LRR (m/yr) Mean | 3.96 | 4.91 | 1.39 | 3.33 |
|                                 | Highest   | 17.73 | 48.65 | 27.26 | 48.65 |
|                                 | Lowest    | -0.30 | -0.48 | 0.32 | -0.30 |
EPR (m/yr) | Mean  | 4.06 | 4.30 | 1.70 | 3.76 |
|-------------|-------|------|------|------|------|
| Highest     | 17.01 | 65.43| 29.61| 65.43|      |
| Lowest      | 0.16  | 0.20 | -0.24| 0.16 |      |

5. Conclusion
The shoreline changes through the temporal imagery of observations from 1990 to 2017 showed that it had undergone very dynamic changes, including abrasion and accretion in a number of locations. The accretion process had occurred in estuaries, such as the Blorong River estuary in the east, the Bodri River estuary in the centre, and the Sibeo River estuary in the west. The greatest change that had taken place was accretion in Patebon Subdistrict, with a value of 1763.29 meters in the Bodri River estuary. The greatest change in shoreline in the form of shoreline to land (abrasion) occurred in Patebon District with a value of -792.14 meters.

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