Spatiotemporal Shoreline Change Analysis in the Downstream Area of Cisadane Watershed Since 1972

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Abstract. Identifying shoreline changes in coastal areas is significant in order to achieve success in coastal management and planning. Understanding the shoreline changes and the driving factors can be an essential reference in developing appropriate preventive measures. This study analyzed changes in shoreline on the downstream area of Cisadane Watershed by utilizing multispectral Landsat Satellite Imagery from 1972 until 2019. The results of this study indicate that in the downstream region of the Cisadane River, there has been significant accretion. That can be caused by the Cisadane River carrying a lot of material, which then settles and forms new land. In other places, however, along the coast of the Cisadane watershed, abrasion generally occurs in residents' ponds areas, such as Kramat Village and Lemo Village, causing community losses. Abrasion in this area occurred due to ocean waves, sea-level rise, and the lack of mangrove areas.

1. Introduction

The coastline is an area that limits land and sea in a particular time condition [1]. The coastline is an important indicator of the dynamics of changes in the earth's surface. Coastal changes that continue to occur will be an indicator of whether erosion or accretion has occurred in an area. Both geological forces that occur in the long term or extreme phenomena in the short term can change the shape and location of the coastline [2]. In general, hydrometeorology, geological and vegetation are the main factors in shoreline changes [3]. However, often, human activities along the coast can also have a direct impact on changes [4].

Shoreline changes can be very complex and unstable and vary from place to place. Thus the measurement of shoreline changes becomes an important aspect in environmental monitoring and coastal area management activities [1]. For the protection and management of resources, the development of coastal areas must be planned. Changes in coastlines must be investigated, and maps of changes in coastlines must be updated [4][5][6]. Analysis of coastline changes can help to identify dangerous coastal areas and detect the dynamics of uncontrolled coastline changes in the short, medium or the long term [7].

The pattern of shoreline changes can be estimated by monitoring Spatio-temporal changes in coastal areas. Data sources used include historical and aerial photographs, coastal maps, ground and GPS surveying, and satellite images [7][8][9][10]. Each method has its advantages and disadvantages. Land surveying provides more detailed information but requires a lot of effort and cost in data collection. Coastal map, historical and aerial photographs usually can give good data but have limited and area and time. The use of satellite imagery will be efficient because it requires less time, less expensive and it covers more areas than other methods [5]. In fact, there is already a lot of literature describing satellite imagery extraction in a semi / automatic way, both using Landsat or Sentinel which can already be accessed online for free [4][11][7].

This study using geographic information systems (GIS) also remote sensing techniques, to analyzed shoreline changes in the downstream area of Cisadane Watershed. The length of the coastal area approximately is 32 km. Most of the research in this area is about the water quality of the stream or spatial planning. However there very limited studies about the shorelines changes in this area [12], the closes one is shoreline change in Jakarta [13] or the Muara Gembong, Bekasi Regency [14]. This study was analyzed temporal changes that happen in the shorelines of the downstream area in Cisadane Watershed during 1972-2019. Furthermore, to be able to determine the effect of shoreline changes in
the research area, shoreline changes will be analyzed using the Net Shoreline Movement (NSM), End Point Rate (EPR) and Shoreline Change Envelope (SCE) [15].

2. Methods

2.1. Study Area
The Cisadane watershed is one of the strategic areas in Indonesia where urbanization, industrialization and agricultural activities are the main activities. There are nine villages located alongside the coastline, which are Kramat, Kohod, Tanjung Burung, Tanjung Pasir, Muara, Lemo, Salembaranjaya, Kosambi, and Dadap. In the downstream area, agricultural was dominant along the coast. But over time some industrial areas began to grow in this region. As in figure 1, this area is located west of Jakarta bay. The total coastline in this area is around 32.83 km.

![Figure 1. Research Area](image)

2.2. Material and methods
The use of Landsat temporally to map changes in coastlines has been carried out in various places, such as Turkey [3], China [16][17] and Indonesia [18]. Landsat was used in many aspects related to earth surface mapping. In this research, we try to cover the longest period possible. The oldest satellite imagery of this area was taken is in 1972, the Landsat 1 MSS (Multispectral Scanner). The newest satellite imagery of this area was taken is in 2019, the Landsat 8 OLI (Operational Land Imager). The data are analyzed from a variety of data sources, as seen in table 1. There are about fourteen satellite images that we use to see the shorelines dynamic in 47 years. The shortest interval data that we use is two years and the longest is seven years, this is happening because of the limitation of the data available to be processed. Landsat is used because it has a wide recording area coverage in each scene, has many bands that contain several values in the electromagnetic spectrum range that can be used to assess changes in coastline, have records that can be analyzed over a period of several decades, and the data is easy, fast, and free through the internet [19]. Because the lowest tide and highest tide on the coastal area of Java is generally not very varied in one year, the selection of data can be made without being affected by the recording month.
Table 1. Data source and their specification.

| Acquisition year | Data Type     | Path/Row | Resolution |
|------------------|---------------|----------|------------|
| Oct 1, 1972      | Landsat 1 MSS | 131 / 064| 60         |
| Jun 21, 1976     | Landsat 2 MSS | 131 / 064| 60         |
| Aug 28, 1982     | Landsat 3 MSS | 131 / 064| 60         |
| May 3, 1989      | Landsat 3 MSS | 131 / 064| 60         |
| May 27, 1992     | Landsat 5 TM  | 122 / 064| 30         |
| Aug 08, 1995     | Landsat 5 TM  | 122 / 064| 30         |
| Sept 14, 2000    | Landsat 5 TM  | 122 / 064| 30         |
| Sept 4, 2005     | Landsat 5 TM  | 122 / 064| 30         |
| June 22, 2007    | Landsat 5 TM  | 122 / 064| 30         |
| Aug 1, 2010      | Landsat 5 TM  | 122 / 064| 30         |
| Oct 12, 2013     | Landsat 8 OLI | 122 / 064| 30         |
| Oct 18, 2015     | Landsat 8 OLI | 122 / 064| 30         |
| Sept 9, 2017     | Landsat 8 OLI | 122 / 064| 30         |
| May 22, 2019     | Landsat 8 OLI | 122 / 064| 30         |

Shorelines can be identified by using the bands in the infrared also visible wavelengths. This is can happen because the water show low reflectance, whereas vegetation and soils exhibit high reflectance in the infrared wavelength [17]. Think about at temporal and economic factors, remote sensing is considered as the most economical and fastest method of identifying coastlines [6]. In addition, the possibility of monitoring one area on a different time makes remote sensing far superior to other methods in studies that determine shoreline changes. Considering the lack of data on the field, especially in developing countries like Indonesia, the use of satellite imagery is considered the most economically and appropriate method because it provides access to current and archived data. [20]. The method used to extract the coastline from satellite images is divided into two groups: first, digitization on the screen as a manual method using visual interpretation and second, semi-automatic/automatic coastline extraction using some parameter [21][22].

The next stage, as shown in Figure 2, is image preprocessing, which is the stage that ensures that the image to be processed is ready for use. The stages carried out include rectification, radiometric calibration, and radiometric correction. Normalized Difference Water Index (NDWI) was used for water-featured extraction, the evaluation of the index results through visual interpretation of satellite images and comparing with the maps revealed that the NDWI index produced the best result in the study area. Extraction of shorelines from the raster into vector data then analyzed by the Digital Shoreline Analysis System (DSAS). Analysis of shoreline changes conducted among others Net Shoreline Movement (NSM), End Point Rate (EPR) and Shoreline Change Envelope (SCE). The NSM is a method calculation of the distance between the most recent and the earlier shorelines in every transect zone. The SCE is a method calculation of the distinction between the closest and farthest shorelines. ERP is a method that calculates the yearly rate of shoreline change, the ERP value is acquired by dividing the distance shoreline changes and time elapsed between the first and the latest data measurements. After statistical data and shorelines map that comes from DSAS analysis, we are doing the result interpretation or the act of explaining, reframing, or otherwise showing the understanding of shorelines dynamics in the research location.

![Figure 2. Workflow Scheme of the Research](image-url)
3. Results and Discussion

3.1. Shoreline Extraction

The Shoreline extraction can be used with the high water-line of the ocean was considered to be an indication of the coastline. The high water line uses typically the shoreline indicator because it is can be seen in most of the satellite images[23]. NDWI was used to extract the series coastline data from the satellite images. The assessment of the index outcome through the visual interpretation of Landsat images and then comparing the result with the maps disclosed that the NDWI index makes the best outcome in this research area. The coastlines that were transformed to vector form from the raster form were edited by visible interpretation of assorted band combinations. The vector form also transferred into the geodatabase after making the obligatory rectifications. In a simple word, the raster data were transformed into vector form and then the vector data were generalized.

Temporal coastline changes continue in the downstream area of Cisadane Watershed. The coastline is identified by extracting the boundary between land and sea. Histogram threshold approach using various wave combinations can display land-sea by calcifying pixels into two classes that are land and sea. As seen in Figure 3, the dark color indicates water conditions, while the light indicates dry areas or land. In plain view of the two satellite images, the most striking change is sedimentation in the upper Cisadane river or around Tanjung Burung. As for the eastern and western regions, coast abrasion has been seen.

![Figure 3](image_url)

**Figure 3.** Differentiation of Land and Water Interface on Landsat imagery, (1972) Landsat 1 RGB: NI2 NI1 R; (2019) Landsat 8 RGB: SW2 SW1 NI

3.2. Shoreline Identification from 1972 to 2019

Identification of abrasion and accretion is done by overlaying shoreline extraction from 1972 until 2019. The length of the coastline in 1972 was 27.81 km while in 2019 it increased to 32.83 km. As seen in figure 4, the greatest dynamic changes in the coastline occur in the upper Cisadane river, the Tanjung Burung area. Whereas the east and west areas are much less dynamic in shoreline changes. In the middle region, accretion occurs while in the erosion of the eastern and western regions generally occurs. Only the Dadap and Kosambi regions in the eastern area of das Cisadane experienced accretion. Overall the total accretion that occurs in this area is 608.31 Ha, while the abrasion that occurs is about half smaller, 366.17 Ha.
3.3. Analysis of spatiotemporal shoreline changes from 1972 to 2019

In total, there are 421 transects with a distance of 50 meters to analyze spatial changes temporally in the research area. Intervals every 50 m are good enough for this study because transect intervals below 30 m will not provide further estimates for the detection of shoreline changes due to data resolution. Changes that occur during the measurement period will be detected and analyzed using the NSM, EPR and SCE methods utilizing Geographic Information System. Polygon overlay analysis will also be used to determine changes in the coastline and determine areas that have changed.

The Net Shoreline Movement (NSM) method is a calculation of the distance between the oldest and most recent coastlines in each transect area [24]. The maximum value of NSM was 2.607 m (accretion) located in Tanjung Burung Village, the minimum was -1.430 m (Abrasion) located in Salembaran Jaya, and the average value of NSM is 245 m. In the SCE method is the calculation of the difference between the closest and farthest coastlines. In this calculation method, very different from NSM, the most significant changes will be calculated independently from time to time [25] [24]. The maximum value of Shoreline Change Envelope (SCE) was 2.965 m also located in Tanjung Burung Village, the minimum was 44 m in Tanjung Pasir Village, and the average value of SCE is 686 m. Both NSM and SCE report a distance (Figure 5) [26].

![Figure 4. Left – The Accretion and Abrasion Area Since 1972; Right – Shorelines Dynamics by Year](image)

![Figure 5. The SCE and NSM Graphic](image)
The EPR method is very different from the NSM and SCE, the ERP method calculates the annual rate of change. The EPR value is obtained by dividing the total distance of the coast change based on the time difference from each data. Tanjung Burung was the highest EPR which is 15-55 m in a year (Figure 6). The most stable area in Tanjung Pasir which is only less than 1 meter per year. Kramat and Lemo areas are areas with erosion levels reaching -15 – -30 meters per year. Kohot, Salembaran Jaya, and Kosambi are areas with the abrasion levels about 1 – 15 meters per year. Based on the ground check validation on the field, the accretion happens in this area because of the sedimentation process that happens in the Downstream of the Cisadane River.

![Figure 6. End Point Rate (EPR) of the Shorelines Changes](image)

4. Conclusions
The temporal use of Landsat satellite imagery data can help analyze spatial changes in the coastline. The overlay result from 1972-2019 coastline extraction can show that the coastline in the upstream coast of the Cisadane river experiences accretion due to high river sedimentation but in areas where there is no sedimentation accretion occurs. This sedimentation gives some positive impacts, for example, are the new land that can be used to be a habitat for an ecosystem and also some additional area for ponds. On the other side, the worst abrasion occurs in the villages of Lemo and Kramat that can reach 30 m per year. The abrasion generally occurs in some residents’ ponds areas, for example, Kramat Village and also the Lemo Village that causing community losses. The cause of the abrasion not yet calculated but from some identification, it could be happening because of the sea level rise, ocean waves, longshore current and also land-use change from mangrove areas into ponds.

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