Trend of Coastline Change for Twenty Years (1994-2014) in Cirebon, Indonesia

Syawaludin A. Harahap*, Noir P. Purba, Mega L. Syamsuddin
Marine Science Department, Faculty of Fisheries and Marine Science Universitas Padjadjaran, Jalan Raya Bandung-Sumedang KM. 21, Jatinangor 45363, Indonesia
*E-mail address: syawaludin.alisyahbana@unpad.ac.id

ABSTRACT

There are many factors lead to coastline change, and coastal erosion by the sea-water can lead to the reduction of land areas. Meanwhile, with sedimentation, there will be an increase in landmass. Cirebon, which is part of the northern coastal area of West Java Province, is located on lowland with a dense population and rapid urban development. Several studies have been conducted during the past decade in the coastal areas of Cirebon with research results indicating that most of the coastal areas in Cirebon are subject to landslides at various scales ranging from vulnerable to bad conditions. Based on this, it is necessary to do a study aimed to know the time series trend of coastline change in Cirebon, Indonesia. This study is expected to provide valuable information on the latest conditions of coastal areas in Cirebon, and can be used as a basis for land use and coastal management planning, as areas of potential loss to erosion can be identified and future mitigation of the coastal areas can be undertaken. The configuration of changes in coastline was determined using remotely sensed data of Landsat 7 TM/ETM+ satellite. Imagery data was processed using MNDWI. Accordingly, Cirebon has for twenty years (1994-2014), experienced a significant shift in the coastline. The average value of the coastline advancing toward the sea is 643 meters and coastline setback is 343 meters, or there has been an average shift of the coastline of approximately 986 meters. Meanwhile, over the past twenty years, the length of the coastline has increased by around 2.2 kilometers. The value of coastline onward that is greater than the setback indicates that changes in the coastline in Cirebon tend to experience accretion. Conclusively, Cirebon’s coastline changes show an increasing trend in length and domination by the accretion (sedimentation) process.

Keywords: Cirebon, coastline change, erosion, Landsat imagery, MNDWI, sedimentation, West Java
1. INTRODUCTION

The coastline is the line that forms the boundary between the coast (mainland) and a major body of water (sea, lake, etc.) [1]. Many people already know that this relatively narrow area located in a coastal region has a very complex, dynamic and delicate environment. Such a condition comes about because this area is a transition - a mixture between land and marine process [2]. The dynamic process of the coast is very much influenced by natural physical and anthropogenic factors [3, 4]. These factors can create a change of coastal land configuration, bringing about a change in the coastline. Generally, from time to time, the coastline changes in line with natural physical changes such as wave activity, tides, currents, and wind, as well as sedimentation occurring in the river delta area [5-7]. However, anthropogenic effects also play a major role in shoreline changes, for example, by landed assets alongshore. These are not only encouraging erosion, but also causing the depreciation of landed assets [8].

Change of coastline also comes about due to the disruption of the coastal area and its ecosystems. These are coming under increased pressure from land reclamation, anthropogenic impact, climate change and sea-level rise [10-13]. Examples of items affected include buildings and embankment and canals that are located around the beach. Furthermore, the Mangrove Forest as a beach buffer may have its function changed to serve as an aquaculture area. Moreover, its destruction for settlement, industrial and reclamation purposes can result in a change of coastline. The problem in planning the coastal environment is, therefore, to determine the pattern of changes in the coastline that have occurred or will occur in a certain period. By knowing the patterns that occur, the coastal environment development planning can succeed optimally [9].

In the last three decades, coastal erosion and abrasion have led to the deterioration of coastline in various coastal areas in Indonesia. These changes threaten the life and livelihoods of coastland communities [14]. Cirebon, which is part of the northern coastal area of West Java Province (Figure 1), is located on a lowland and has a dense population and faces rapid urban development. As with other areas on the northern coast of Java Island, Cirebon is a populated area with high levels of activity, ranging from agricultural activities, fisheries and upwards to large industries. According to [15], the consequence of the continued growth of development activities, population growth, urbanization, and a movement towards the coast, especially if these activities are not well ordered, will reduce the carrying capacity and also increase vulnerability in the coastal areas [16].

There are several studies have been conducted during the past decade in the coastal areas of Cirebon, with research results indicating that most of the coastal areas in Cirebon have been subject to landslides at various scales ranging from vulnerable to bad conditions. Furthermore, seawater intrusion has penetrated up to several kilometers of the land, so that degradation is changing the coastline in the region [17]. In addition, there may be other problems such as increasing pollution, whether waste pollutes from households or industrial waste. The impact of global warming which results in sea level rise can also trigger the rate of erosion so that accelerating coastline changes. It is feared that it will cause most of the coastal plains on the northern coast of Java including Cirebon to be lost due to inundation processes [18, 19].

Information on coastline change by time-series trend constitutes an essential and vital input in any coastal management plan so that areas of potential loss to erosion can be identified and appropriate land use planning adopted [20, 21]. Unfortunately, in Cirebon, such information is lacking and, where present, is often of doubtful reliability.
Figure 1. Indonesia map with inset box (at the bottom) representing the study area in the Cirebon, West Java
Based on the reasons that have been explained, it is necessary to do a study aimed to know the time series trend of coastline change in Cirebon, Indonesia. The result of this study is expected to provide valuable information on the latest conditions of coastal areas in Cirebon. It can be used as a basis for land use management and future mitigation of the coastal areas [22].

2. MATERIALS AND METHODS

Natural physical changes in coastal areas that can be visually observable are coastline changes. The coastline may change at any time because it is very dynamic. Hence, changes occur relatively quickly [3]. Besides, this area is very wide and parts are remote. So studying coastal change requires an effective, efficient approach and acceptable accuracy. Researchers and experts have tried a variety of approaches to study the dynamics of change that occur in coastal areas, both by modeling and direct observation. However, with these approaches, it is still felt that the actuality to conduct monitoring quickly and in real-time while still maintaining a high level of accuracy, is lacking.

Coastline change is a phenomenon that occurs through natural processes in coastal areas that can be recognized from remote sensing data image processing analysis. One of the remote sensing data that can be used to see this phenomenon is data from satellites. With this data, mapping, inventory, monitoring and evaluation of environmental damage can be carried out quickly to assist in damage prevention, as well as management and future planning of the coastal area [23]. In connection with this study, the implementation of the study consisted of three stages, namely data collection, data processing, and analysis. Briefly, this stage can be seen in Figure 2:

![Figure 2. Flow diagram of the study.](image-url)
2. 1. Scope of study area

The study area covers the coast of Cirebon along the coastline that extends outward from north to southeast. Administratively, Cirebon is part of West Java Province. The coastal area of this region covers the Cirebon Regency (which consists of eight sub-districts) and the city of Cirebon. Consequently, eight sub-districts and city are coastal, namely Kapetak, Suranenggala, Gunungjati, Cirebon City, Mundu, Astanajapura, Pangenan, Gebang and Losari (can be seen again in Figure 1. Geographically, Cirebon is in the coordinates of 108°40’ - 108°48’E and 6°30’ - 7°00’S, with administrative boundaries as follows: (1) Northern, bordering with Indramayu Regency; (2) southern, bordering Kuningan Regency; (3) Western, bordering Majalengka Regency; and (4) Eastern side, bordering Brebes Regency, Central Java Province.

2. 2. Dataset and method

In this study, the configuration of changes in coastline was determined using the imagery data of Landsat 7 TM/ETM+ satellite, by downloading from the USGS Data Center (http://earthexplorer.usgs.gov/). There are 12 imagery data sets collected for the path - 121/row 65 has 30 meters spatial resolution that is cloud-free in the Cirebon study area during the period from 1994 to 2014. Figure 3 is a cross-section of Landsat imagery that has been downloaded to represent 2014 image data that is free of clouds in the study area. Inside the red rectangle in the figure is the area of research study that is Cirebon coastal in the coordinate boundary 108°31’ - 108° 49’E and 6°35’ - 6°45’S.

![Figure 3. Display of Landsat 7 ETM+ imagery year 2014 path 121/row 65 in pseudo color with inset red box as the scope of study area (left side) while the right side displays a subset/cropping of study area (false color) (Source: www.earthexplorer.usgs)](image_url)

The data was analyzed using the observation method with comparative descriptive analysis. The observation was done with a remote sensing approach. There are many studies which detect coastline changes using satellite imagery that have been conducted previously,
e.g. [24-31]. This study follows similar stages in the process of image data processing using modification of normalized difference water index (MNDWI) [32-36]. By using MNDWI, we can delineate water bodies and can find the area of individual water bodies, and finally convert the reclassified image into a vector format.

3. RESULTS AND DISCUSSION

The coastline of an area is always changing due to the movement of seawater that is heading towards the coast or leaving the coast. The form of change is in the form of forward and backward coastlines. Changes in the beach must, however, be seen at certain periods, not only in the conditions of the moment. Forward or backward coastlines are temporary if there is no human intervention in them, for example, in the western season the material along the coastline that is affected will move eastward by the longitudinal coastal current system, and vice versa if the east season, coastal material is transferred will be returned to the starting position. The results show that the coastline dynamics of Cirebon are strongly influenced by hydro-oceanography aspects, coastal morphology and human activities [37]. In Figure 4, the results of the Landsat imaging process and analysis show that the Cirebon coastline has for twenty years (1994-2014), experienced a significant shift in the coastline.

The coastline that experiences forward or backward movement in Cirebon can be indicated as being the result of the process of accretion and erosion of the coast (abrasion) so that the coastline moves forward or backward from the old coastline. From this description it can be inferred that the differences in the characteristics of coastline change on the Cirebon coast, generally are divided into two, namely a coastline that is improved by sedimentation and a coastline that declines due to erosion. Still, in Figure 4, we can see that inside the black rectangular the coastline of 1994 (indicated by the arrow line A) was forward, this indicates that the location experienced abrasion in 2014. Meanwhile, inside the area of the red polygon, the 1994 coastline was behind (indicated by arrow line B) which indicates accretion has taken place in 2014. Based on spatial calculations, the average value of the coastline advancing toward the sea (accretion) is 643 meters and coastline setback (abrasion) is 343 meters. From this value, it can be ascertained that during the past twenty years there has been an average shift of the coastline of approximately 986 meters. The value of coastline onward that is greater than the setback indicates that changes in the coastline in Cirebon tend to experience accretion.

This result is in line with research conducted by [38] at Pangenan beach, Cirebon, where this location is also dominated by accretion (sedimentation). In the study, it was also discovered that sediment is dominated by coarse mud that is very well sorted, skewed very well and platykurtic. This accretion phenomenon also occurs along the north coast of Java, as is also the case in Central Java [39]. Cirebon coast oscillates naturally and has a high sensitivity to these physical factors and is coupled with unstable beach types. Refer to [40], the types of beaches along the coast of Cirebon consist of three types, namely, muddy beaches, mangrove forest beaches, and sandy beaches. Hutabarat and Evans [41] state that currents are one of the factors that play a role in the transport of sediment in coastal areas. The sediment will be trapped somewhere if the current and other oceanographic conditions are not dominant compared to the force of gravity. One of the phenomena caused by sediment deposition is rising land formation. Rising land formation comes about due to sediment deposition of material carried and dropped by currents which subsequently experience changes in surface height [42].
Along with changes in coastline position, further in Figure 5, the trend of changes in coastline length in Cirebon for twenty years can be noticed. In general, the changes in coastline length shows an increasing trend. Over the past twenty years, the length of the coastline has increased by approximately 2.2 kilometers. This is most evident especially when viewed in the period between 2013-2014, where the increase in coastline length surged compared to the previous annual period, and reached 100 meters. This was made possible by the abrasion and accretion processes which were also high in that period along the coast of Cirebon.
Currently, abrasion and sedimentation that has come about on the coast tend to increase the coast line in various regions [43]. Changes in the coastline have engendered various kinds of loss and danger to the interests of the community. Abrasion and sedimentation are indicators of changes in coastline and have become one of the important problems in Indonesia’s coastal areas. One of its results is that it begins to decrease the area of coastal ecosystems such as seagrass [44], coral reefs [45, 46], mangrove forests [47] and habitat for marine life such as sea turtles [48], etc. This condition can further trigger coastline changes due to the abrasion and sedimentation of the coastal areas. The process of abrasion occurs due to ocean currents and ocean waves that continuously hit the shoreline and a relatively flat beach. In contrast, accretion is caused by the accumulation of sediments originating from land deposited on the coast mainly through river mouths. To reduce the impact of coastline changes, the community should take care to prevent coastal abrasion. The method can be done by greening the coastal area, by planting mangroves on the beach and reducing the upstream land use to reduce land openings.

Coastal erosion and sedimentation are of major concern in coastal management. Changes in morphology have caused significant impact on land use and socio-economic development in coastal areas [49]. The assessment of land use and the effective management of shoreline erosion are necessary because of the complicated developmental issues and detecting what is happen negatively to the coast [50]. Many property owners and government agency programs engage in coastal engineering activities designed to protect property and beaches, such as beach nourishment or seawall or breakwater construction [51]. Land erosion is highlighting the need for effective coastal protection measures. However, in some areas, the so far accumulated coastline (mainly sandbars) is shrinking due to the use of coastal protection measures. This is because coastal protection measures used in one place may reduce the transfer of sand from land to longshore drift and thus its accumulation in another [52].

The issue of global warming is no less important than the aforementioned caused changes in the coastline. Global warming has added water to the oceans by melting ice in the polar regions, creating a sea-level rise. Rising sea levels will be among the most significant impacts of climate change. Sea level will increase as a result of thermal expansion of the oceans and an increase in ocean volume as land ice melts and fresh water runs off [53]. The rate of sea-level
rise has increased over the past 200 years as averages temperatures have increased. Sea-level rise, a dominant driving force of change for coastal regions, is becoming increasingly important as a hazard to humans and urban areas in the coastal zone worldwide as global climate change takes effect [54]. Due to the impact of sea-level rise, the coastal area, in general, will be impacted by the natural factors that cause erosion and accretion processes to happened with more complicated processes.

Environmental conditions resulting from industrialization and urbanization have also adversely affected coastal ecosystems and socio-economic life in several communities living on the coast [55]. Moreover, increases in population migration that are increasingly focused on coastal areas have an impact on economic development itself. This has implications for development that is focused on coastal areas and will certainly have an impact on the stability of coastal areas, as continued development will affect coastline stability [56]. Therefore, efforts to prevent environmental degradation in coastal areas should be an important and fundamental agenda in the framework of policy planning and implementation of integrated coastal zone management (ICZM), namely by expanding the scale of interests, space and time [57-65].

4. CONCLUSIONS

This study was conducted using an observation method with a remote sensing approach based on the MNDWI technique applied to Landsat 7 TM / ETM + imagery to determine the trend of coastline change for twenty years (1994-2014) in the Cirebon region. The data analyzed show that a significant shift in coastline has come about as the coastline experiences forward or backward movement. This has been indicated to being the result of the process of coastal accretion and erosion (abrasion). During the last twenty years, there has been an average shift of the coastline of approximately 986 meters. In addition, changes in the coastline show that in Cirebon region it tends to experience accretion (sedimentation). Over the past twenty years, the length of the coastline has increased approximately 2.2 kilometers. The result of this study is expected to provide valuable information on the implementation of ICZM of coastal areas in Cirebon.

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References


