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Coastline changes in Indramayu Regency between 1989–2019

Kusnanto[a], Yudi Setiawan[bc], I Wayan Nurjaya[d]

[a] Postgraduate School, IPB University, Natural Resource Management and Environment, IPB University, IPB Baranangsiang Campus, Bogor, 16144, Indonesia [+62 81808914190]
[b] Department of Forest Conservation and Ecotourism, Faculty of Forestry and Environment, IPB University, IPB Darmaga Campus, Bogor, 16680, Indonesia
[c] Environmental Research Center, IPB University, IPB Darmaga Campus, 16680, Indonesia
[d] Department of Marine Science and Technology, Faculty of Fisheries and Marine Affairs, IPB University, IPB Darmaga Campus, Bogor, 16680, Indonesia

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Corresponding Author:
Kusnanto
Natural Resources and Environment Management, IPB University;
Tel. +6281808914190
Email:
kusnanto.psl@gmail.com

Abstract. *Coastline changes include accretion (raised soil) and abrasion. This study aims to analyze coastline changes in the Indramayu Regency between 1989 and 2019, as well as the causing factors. The secondary data were obtained from Landsat 5 Satellite Imagery in 1989, 1999, 2009, and Landsat 8 in 2019. This analysis used BILKO method, which is a Landsat image analysis to separate land and sea areas. Then overlay method was used to delineate boundary. Spatial analysis showed coastline changes in the Indramayu regency of both accretion and abrasion. In the 1989–1999 period, there was an accretion of 319 ha, while there was an abrasion 1.291 ha. Furthermore, in the 1999–2009 period, there was an accretion of 349 ha, and an abrasion of 1.125 ha. Also, in the 2009–2019 period, there was an accretion of 698 ha, and abrasion of 358 ha. Meanwhile, the factors that cause coastline changes are natural such as wind, waves, and currents, as well as human factors, such as the conversion of mangrove land to ponds and also planting activities. Therefore, efforts made by the government are making wave containment tools and planting mangrove vegetation.*

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INTRODUCTION

Coastline change is a soil accretion or abrasion phenomenon (soil erosion in coastal areas) due to natural factors such as waves, ocean currents, wind speed, bathymetry, and others (Besset *et al.* 2017; Saputro *et al.* 2017; Arif *et al.* 2020), as well as human factors such as sediment dredging, breakwater (Zed *et al.* 2017), mangrove (Soraya *et al.* 2012; Nguyen *et al.* 2018; Xioa *et al.* 2020), and others. Indramayu Regency is located on the north coast of Java Island, and it consists of 11 sub-districts and 36 villages directly adjacent to the sea with a long coastline of 147 km. The coastal sub-districts in this Regency are also research locations including Sukra, Patrol, Kandanghaur, Losarang, Cantigi, Pasekan, Indramayu, Balongan, Juntinyuat, Karangampel, and Kerangkeng.

The coastline in Indramayu is very dynamic, and in 2006, the length was 114 km (BPS Indramyu 2006). Meanwhile, in 2018, the Statistics Agency issued data that the line length was 147 km (BPS Indramyu 2018). This information shows that there has been an increase in the coastline length by 33 km within 12 years. Furthermore, in 2006, the Department of Maritime Affairs and Fisheries measured the abrasion that occurred on the Indramayu coast along 45,6 km. The coastline in this regency, between the 1990s and 2019, experienced changes in both abrasion and accretion (sedimentation), which could harm people living on the coast. Also, sedimentation causes river estuaries silting and land conflicts such as the struggle for land ownership. Furthermore, abrasion is very detrimental to the community because it damages ponds and buildings.

Therefore, remote sensing technology and geographic information system are very suitable for identifying and monitoring coastline changes (Kiruparajah 2018; Wicaksono and Wicaksono 2019; Elkafrawy *et al.* 2021). Spatial data utilization for coastlines research using images with various resolutions showed that it is possible to integrate satellite images to increase the details and accuracy of change analysis, visually and digitally automatic computations. Meanwhile, accuracy in selecting methods, image types, resolution (spatial and temporal), image acquisition time, and the suitability of research objectives are needed to avoid misinterpretation or analysis. Therefore, it is necessary to study the coastline changes using remote sensing technology. This study aims to analyze the coastline changes that occurred in Indramayu Regency from 1989–2019, both abrasion and accretion, as well as the causing factors. This will help determine which sub-district experiences abrasion and accretion based on time periods. Furthermore, this paper can provide information regarding areas to be immediately addressed.

DATA AND METHODS

Time and Location

This study was conducted from February to August 2019, and the locations were 11 Coastal Sub-districts in Indramayu Regency, including Sukra, Patrol, Kandanghaur, Losarang, Cantigi, Pasekan, Indramayu, Balongan, Juntinyuat, Karangampel, and Kerangkeng. Figure 1 showed research location in Indramayu Regency.

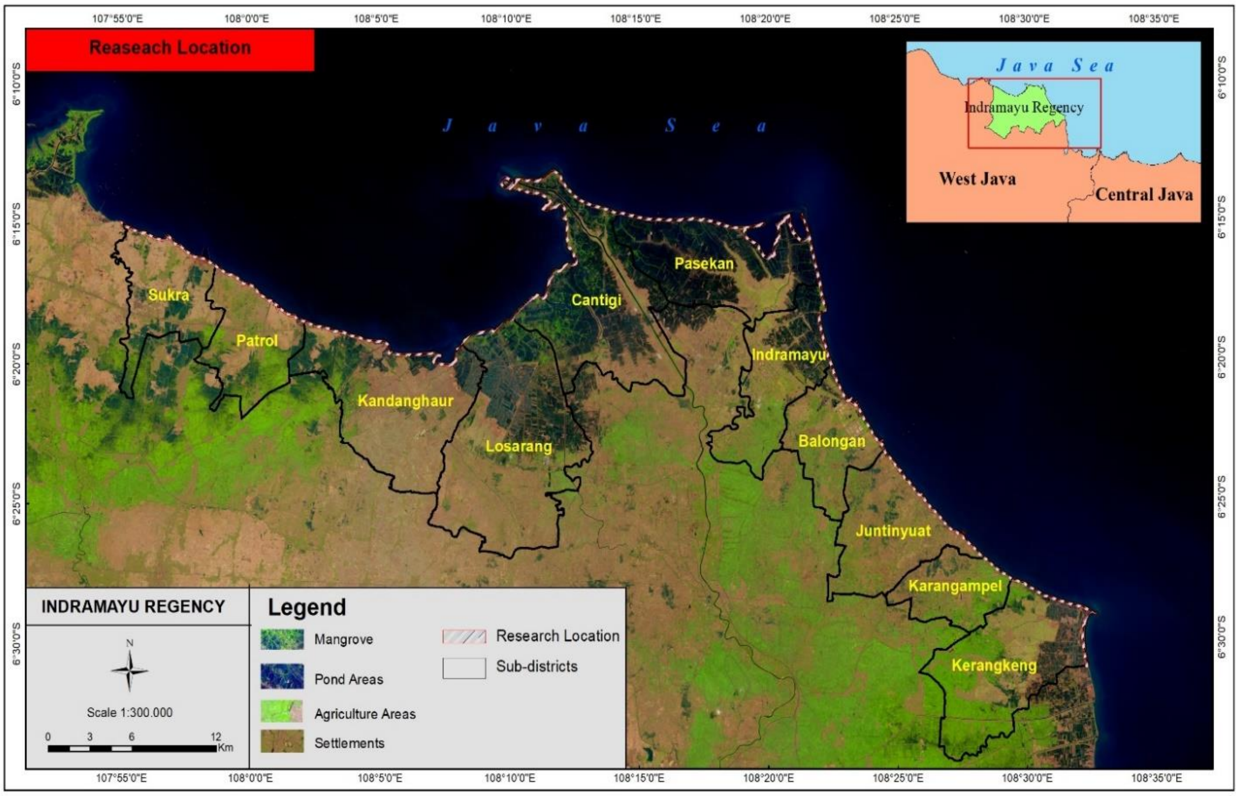


Figure 1 Research location

Tools and Materials

The tools used in field sampling were GPS, stationery, rope, and cellphone. Furthermore, the tools used to process data analysis were laptops, Microsoft Office software, ArcGis 10.4, and ENVI. Also, the materials were Landsat TM 5 and OLI 8 imagery which were downloaded from *usgs.gov* website. The Landsat 5 imagery used was 1989, 1999, and 2009, as well as the 2019 Landsat 8 imagery.

Types, Sources, and Data Collection

This study used primary and secondary data. Primary data were obtained directly from field observation, measurements, and interviews. Meanwhile, the secondary data were obtained from literature studies, downloads from websites, maps from related agencies, and various relevant sources. The Landsat imagery was downloaded from *usgs.gov* website. Table 1 showed Landsat satellite sensor type and acquisition date.

Table 1 Description of Landsat Satellite image data

Year	Satellite Sensor Type	Acquisition Date
1989	Landsat 5 Multispectral Scanner (MMS)Path 121/ Row 64 Path 121/ Row 64	April 10, 1989
1999	Landsat 5 Thematic Mapper (TM) Path 121 / Row 64	August 28, 1999
2009	Landsat 5 Thematic Mapper (TM) Path 121/ Row 64	September 24, 2009
2019	Landsat 8 Operational Land Imager (OLI) Path 121/ Row 64	September 4, 2019

Coastline Change Analysis

In analyzing change, two methods were used, namely, BILKO and overlay. The BILKO method was used to analyze Landsat imagery which separates land and ocean boundaries. Therefore, they can be easily delineated. After the Landsat Image delineation for each time period, an overlay analysis was conducted to see the area experiencing accretion and abrasion.

BILKO Algorithm Method

The BILKO algorithm method was first introduced through The UNESCO Bilko Project in 1987 in collaboration with the Marine Science Training and Education Program (TREDMAR), which aims to build scientific capabilities in the field of coastal and marine remote sensing based on computerized modules. The algorithm determines the boundary between land and sea by utilizing Brightness Value (BV). Meanwhile, the channels used in this formula are NIR (Near Infrared) and SWIR (Short Wave Infrared), which are infrared waves that have low reflectance in water and high reflectance on land. This BILKO formula uses the nearest integer technique with an 8-bit format. Based on module 7 BILKO Lesson 4 (Hanifa *et al.* 2004), the algorithm is described as follows:

$$((INPUT1/((N*2)+1)*(1))+1)$$

Description:

N : The minimum BV value for Landsat imagery

INPUT1 : NIR or SWIR band

Overlay Method

The overlay method is an analysis of geographic information systems that combines two or more spatial data into one. In this study, the data used were shoreline data from delineation for every 10 years, namely 1989, 1999, 2009, and 2019. The data produced were on changes in Indramayu Regency coastline, and the amount of accretion and abrasion were further analyzed. The results of overlay analysis can be seen in which areas have occurred abrasion and accretion. Areas identified as experiencing abrasion and accretion will be calculated spatially using calculated geometrics in the ArcGis 10.4 application. The results of the overlay analysis are shown in Figure 4.

Ground Check Point (GCP)

Ground checkpoints or field observations were carried out to validate the Landsat Image analysis results. Furthermore, the results were compared with the field observations in the coastal area of Indramayu. The addition of landmarks the accretion event while abrasion is eroded due to wave energy.

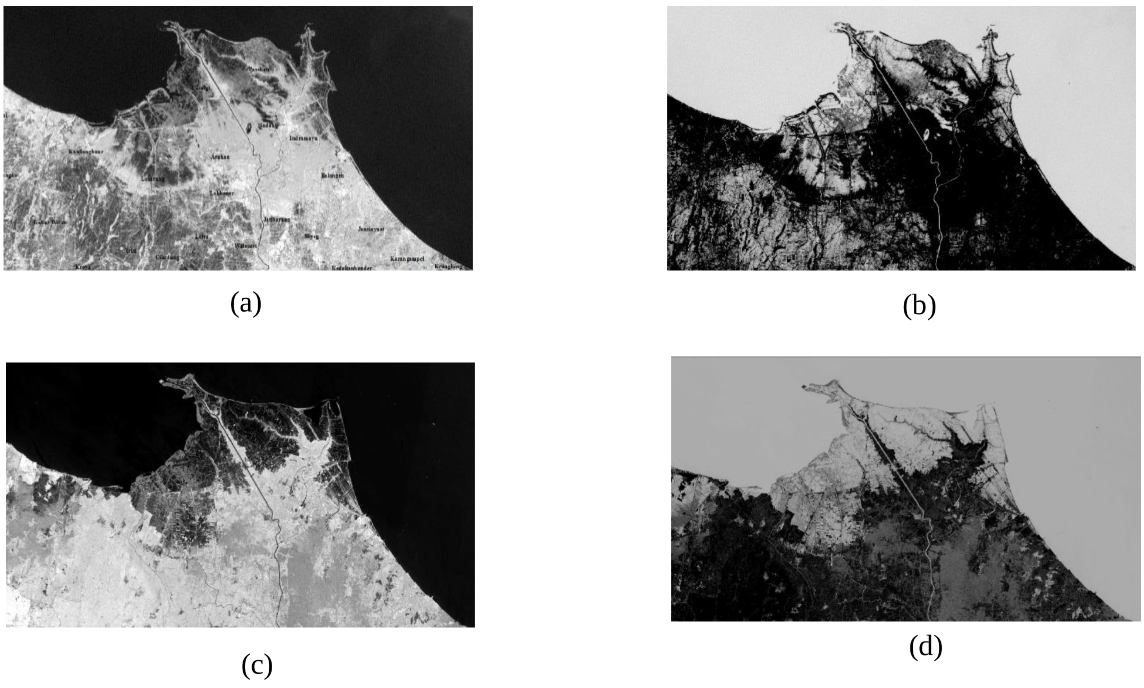
Description Analysis

Description analysis is used to explain the factors that cause coastline changes in Indramayu Regency by using literature studies from journals and previous research.

RESULT AND DISCUSSION

The BILKO Algorithm Results

The channels used in BILKO are those with high reflectance to land and low to water. Meanwhile, infrared waves have a low reflectance on water and high on land. In Landsat satellite imagery, the channels that meet the criteria are NIR and SWIR (Hanifa *et al.* 2004). In this study, the channel used was SWIR (Short Wave Infrared) for both Landsat 5 and 8. Before analyzing the SWIR Channel on Landsat, geometric corrections were first made. This correction is intended. Therefore, the location is correct on the earths on Landsat 5 and Landsat 8 SWIR band 6.

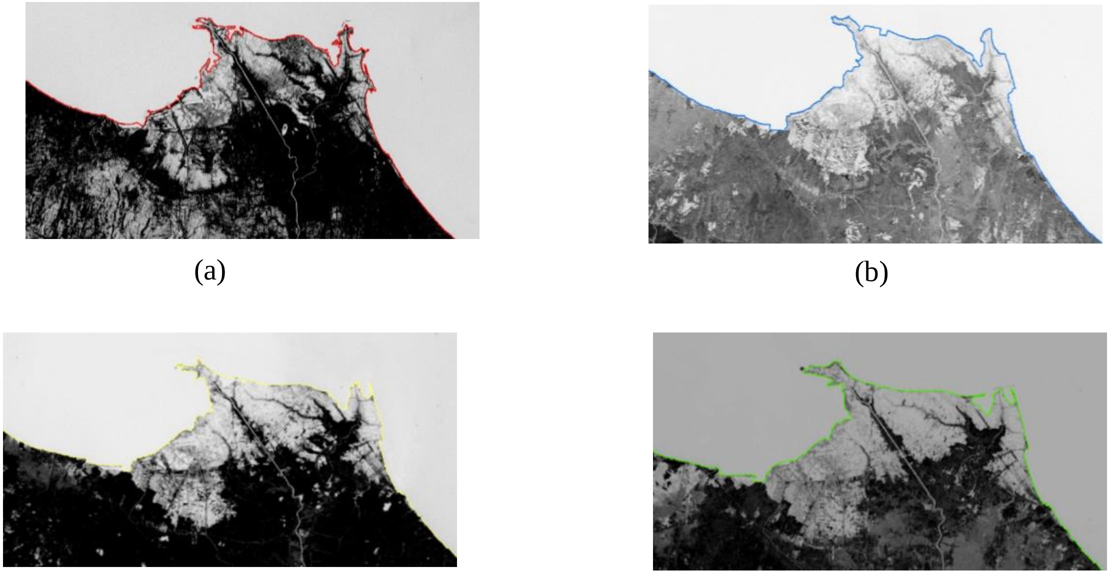


(a) (b) (c) (d)

Figure 2 (a) Landsat 5 of 1989 before Bilko analysis, (b) Landsat 5 of 1989 after Bilko analysis, (c) Landsat 8 of 2019 before Bilko analysis, (d) Landsat 8 of 2019 after Bilko analysis

Bilko's analysis showed the difference between land and sea. Visually, ocean areas appear lighter gray than the land, where it appears dark black. Meanwhile, prior to Bilko's analysis, the land and sea areas were faint. The difference in hue between land and sea makes it easier to delineate on screen. Figure 2 shows the

Landsat image prior to the bilko algorithm, while Figure 3 shows the Landsat image that has been subjected to the bilko algorithm. Figure 3 makes it easier to distinguish between land and sea.



(a) (b)

(c) (d)

Figure 3 Landsat imagery delineation results, (a) 1989, (b) 1999, (c) 2009, (d) 2019

The Analysis Results of Indramayu Coastline Change Overlay

The Figure 4 Showed delineation results of Landsat images for each time period that was further overlaid. Therefore, the areas experiencing accretion and abrasion in a certain period were known. From the results of this overlay analysis, it was found that the area that experienced accretion and abrasion in each sub-district in a certain time period was obtained.

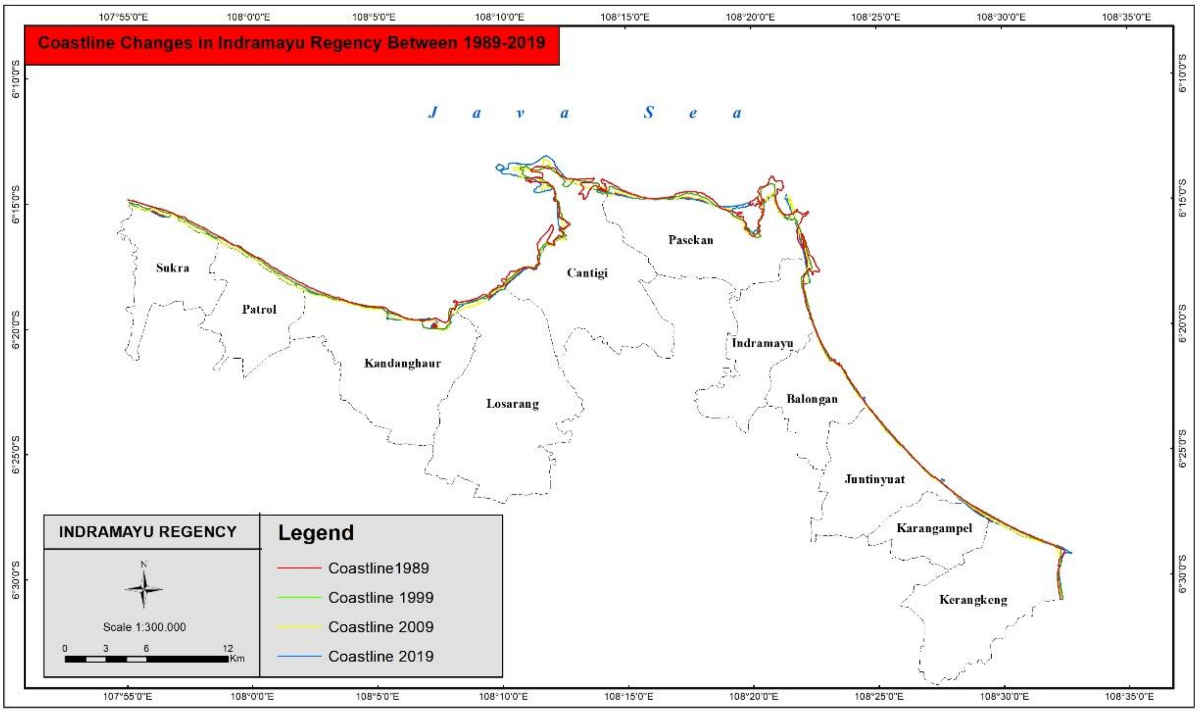
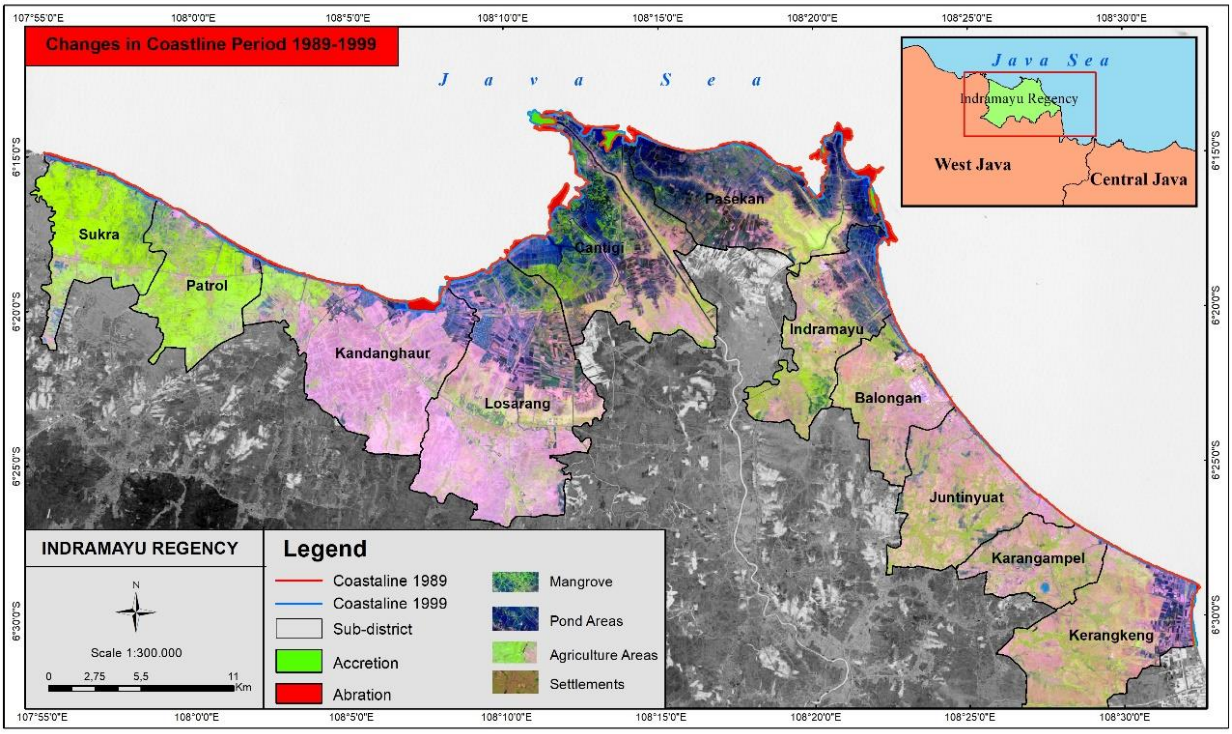


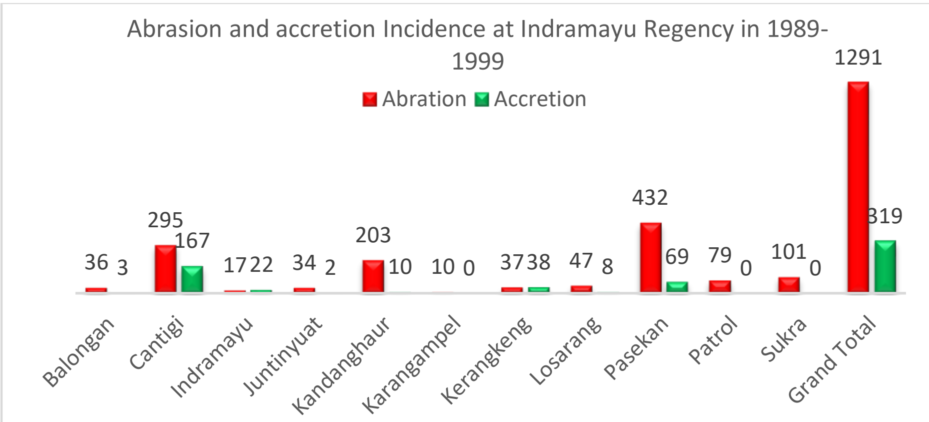
Figure 4 Overlay analysis result of Landsat

Changes in Coastline Period 1989-1999

Based on the overlay results in the 1989–1999 period, the accretion distribution occurred in Juntinyuat, Losarang, Kandanghaur, Indramayu, Kerangkeng, Pasekan, and Cantigi sub-districts. Meanwhile, the sub-districts that did not experience accretion were Karangampel, Patrol, and Sukra. The three districts that did not experience accretion experienced high abrasion levels, such as in the Sukra sub-district, where there was abrasion covering an area of 101 ha, Patrol 79 ha, and Karangampel 10 ha. Furthermore, Cantigi experienced high accretion of 167 ha. Kerangkeng districts experienced an accretion 38 ha. Pasekan sub-district experienced high abrasion, reaching 432 ha, while the accretion was 69 ha. During this period, many mangroves land clearing was carried out into ponds without being balanced with rehabilitation programs or other coastal vegetation. Figure 5 presents data on changes to the coastline, both accretion and abrasion in Indramayu Regency in the 1989–1999 period.



(a)

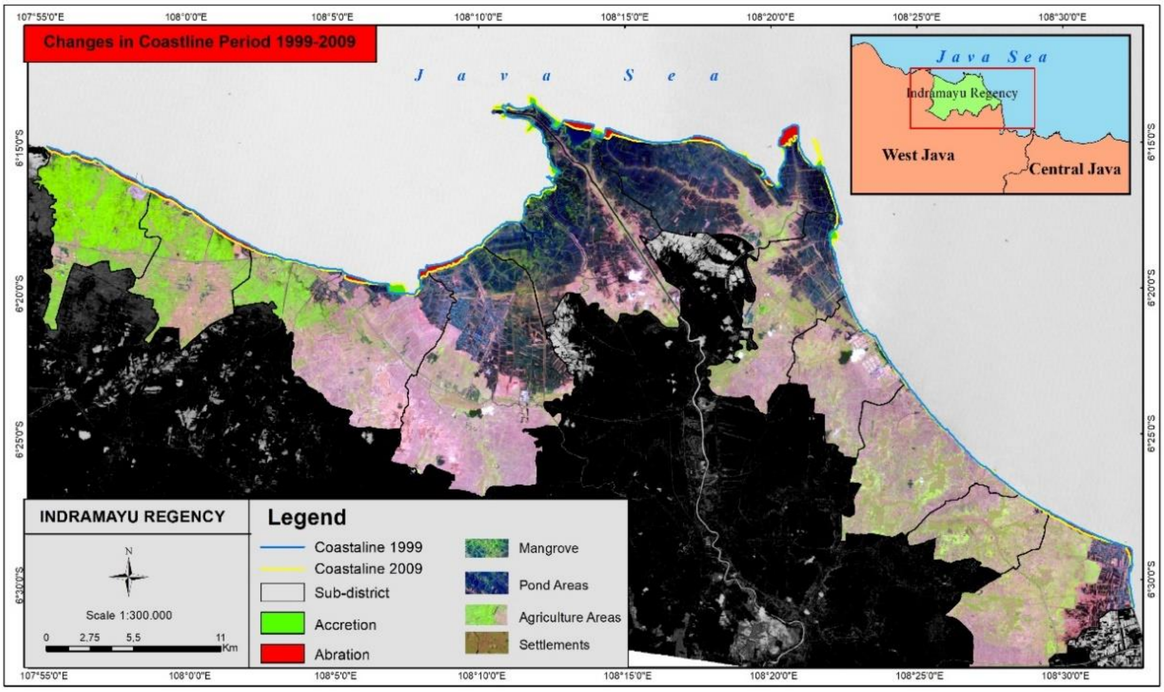


(b)

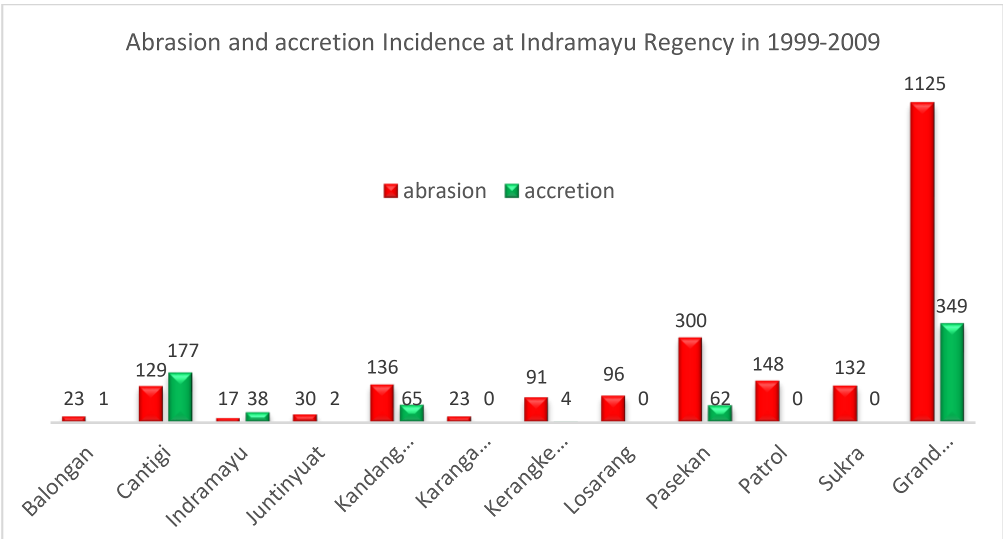
Figure 5 (a) Changes in coastline in 1989–1999, (b) diagram of abrasion and accretion incidence at Indramayu Regency in 1989–1999

Changes in Coastline for the Period 1999-2009

Between 1999–2009 the overall abrasion incidence decreased but not significantly. In this period, the abrasion level in the previous period was 1.291 ha, down to 1.125 ha. Meanwhile, the sub-districts that are still experiencing an increase in abrasion are Karangampel, Losarang, Patrol, and Sukra. Also, the sub-district that experienced a high increase in abrasion was Patrol, where, in the previous period 79 ha had increased to 148 ha, and there was no accretion. Meanwhile, the accretion rate began to increase from 319 ha in the 1989–1999 period to 349 ha in 1999–2009. The sub-district that experienced high accretion was Cantigi, with an area of 177 ha, but the abrasion was also high at 129 ha. Pasekan there was highly abrasion of 300 ha in 1999–2009. Figure 6 describes the data on abrasion and accretion incidence in Indramayu Regency from 1999–2009.



(a)

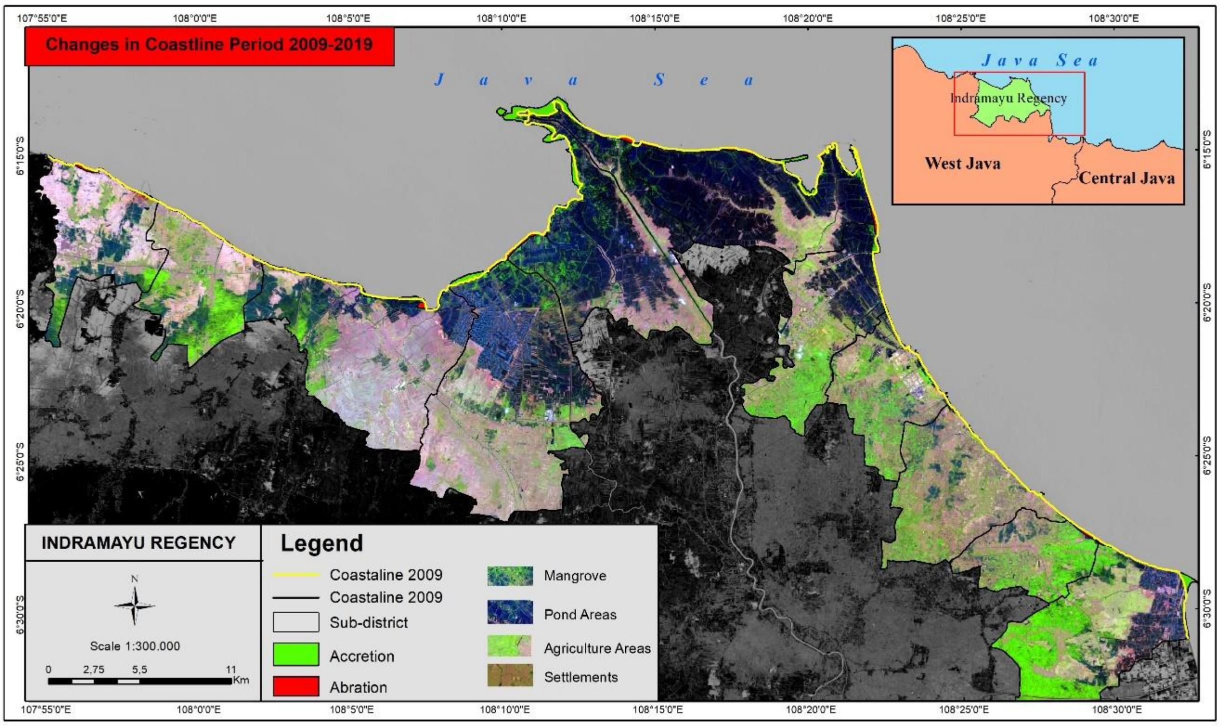


(b)

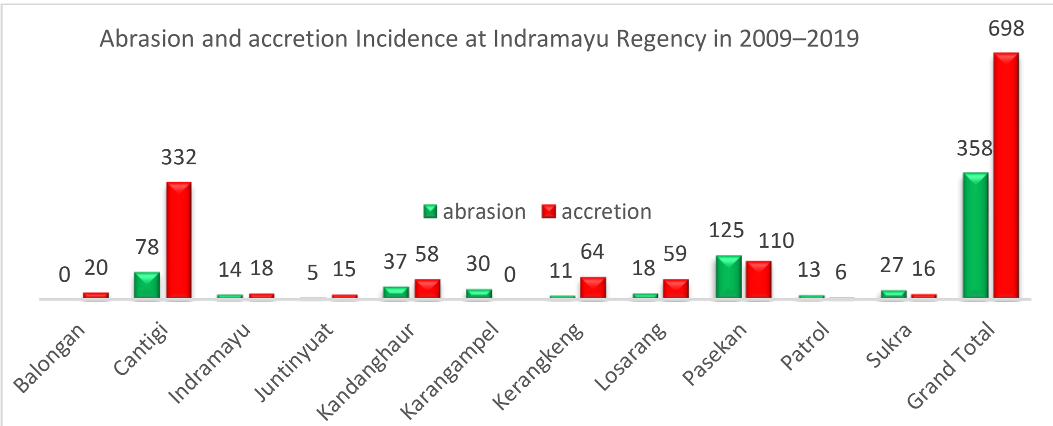
Figure 6 (a) Changes in coastline in 1999–2009, (b) diagram of abrasion and accretion incidence at Indramayu Regency in 1999–2009

Coastlines Changes in the 2009–2019 Period

In the 2009–2019 period, there was a decrease in abrasion and a significant increase in accretion. In the previous period, there was an abrasion of 1.125 ha down to 358 ha. Meanwhile, accretion, which was 349 ha in the previous period, increased to 698 ha. Almost every subdistrict in this Regency has decreased abrasion and increased accretion. However, there are still areas that experienced an increase in abrasion, namely Karangampel sub-district, which experienced an abrasion of 30 ha, although there was an increase compared to the previous period. Meanwhile, the sub-districts with high accretion were Cantigi, with an area of 306 ha, and Pasekan, with an area of 110 ha. During this period, efforts were made to eradicate abrasion by both the government and the community. The government made wave breakers with both large river stones and concrete. Meanwhile, the community began to carry out greening activities along the coast and planting mangroves and other coastal vegetation. Figure 7 (a) explained that changes in coastline in 2009–2019, and (b) diagram of abrasion and accretion incidence at Indramayu Regency in 2009–2019.



(a)



(b)

Figure 7 (a) Changes in coastline in 2009–2019, (b) diagram of abrasion and accretion incidence at Indramayu Regency in 2009–2019

Coastline Changes Causes at Indramayu Regency in 1989–2019

The dynamics of coastal areas in the Indramayu Regency greatly influence the coastline changes, both abrasion, and accretion. Meanwhile, sediment transport that occurs along the coast is the main cause of coastline changes (Triatmodjo 1999). Those trapped along the coast gradually become good land called emergent land or accretion. Sediment derived from land that enters the river flow and is carried to the sea through the estuary will also cause changes in coastline shape (Nybakken 1993). Nontji (2002) stated that currents moving parallel to the coastline (longshore current) tend to result in sedimentary material movement, where the material is carried away by currents leading to abrasion. Also, waves have an important role in the process of changing coastlines. In fact, waves with large energy will have more impact on coastline changes (Angkotasan *et al.* 2012). Coastal waves and currents play an important role in coastline change, sometimes carrying sediment to shore, or causing erosion and land loss (Suripin *et al.* 2017). Changes in the coastline are not only from natural factors but also from humans, such as excavation, activities that cause coastal and sea sedimentation, reclamation, coastal protection, deforestation and planting of coastal forests, regulation of river flow patterns, and also agricultural land development (Bird and Ongkosongo, 1980). Damage to mangrove ecosystems also affects coastline changes. According to Soraya *et al.* (2012), a decrease in the area of the mangrove forest ecosystem affects the coastline changes that occurred in Blanakan sub-district, Subang Regency by 41% and 59%. Meanwhile, Astjario and Astawa (2007) stated that mangroves play a role in sedimentation development which subsequently becomes deltas.

Wind and Wave Energy

Indramayu beach area is open and directly adjacent to the Java Sea causes seasonal winds (monsoons) throughout the year, which affect changes in the coastline. In the wet or rainy season, the wave height causes a large amount of energy. Therefore, it can quickly erode the land along the coast. According to Kalay (2008), the wave height in the Indramayu bay area (Kandanghaur and its surroundings) ranges from 0,418–1,79 m and is formed during the wet season with the dominant wind direction from the north. Meanwhile, according to Ilahude and Usman (2009), the wave height in Indramayu waters ranges from 1–1,5 m and has an average wind speed of 6 m/sec. When the wind speed in certain seasons reaches over 10 knots, then the wave height can be up to 2,75 m. For the north coast, the wind direction that most influences the dynamic process of the coast is north, northwest, and northeast winds, while for the southeast coast is north, northeast, and east.

Longshore Current

Longshore currents generated by wave energy have an important role in supplying sediment around the coast. This current movement carries sediment from the abrasive areas to other parts. Therefore, over a long time, this area will experience additional land or accretion. On muddy beaches, the sedimentation process occurs due to currents generated by tides and waves (Darmiati *et al.* 2020). The existence of a longshore current causes sedimentation to the northwest of Indramayu (Indramayu, Pasekan, and Cantigi sub-Districts). Also, currents along the coast arise after the wave energy has refraction due to changes in coast depth (Ilahude and Usman 2009). The current movement in Indramayu Bay generally moves from east to west, with the movement pattern in the inner part of the bay (Kandanghaur and its surroundings) changing according to the season. Based on this current movement, it can be seen that sedimentation from the eastern and southeastern regions (Juntinyuat, Karangampel, Kerangkeng sub-Districts) is carried to the northwest (Indramayu, Pasekan, Cantigi Districts). Meanwhile, when there is an abrasion in the western region (Losarang, Kandanghaur, Patrol, Sukra), sedimentation will be carried to the coastal area of Subang Regency. Conversely, the sedimentation occurring in the Kerangkeng area comes from the coastal area of Cirebon Regency.

Mangrove Vegetation

The existence of mangrove vegetation around the coast influences coastline changes. Also, mangrove has a function in maintaining stability and protecting the coast from abrasion (Nontji 2002). Soraya *et al.* (2012) stated that the decline in the mangrove forest ecosystem area affected changes in the coastline that occurred in Blanakan sub-district, Subang Regency, by 41% and 59%. Meanwhile, Astjario and Astawa (2007) stated that mangroves play a role in sedimentation development which further becomes deltas. Mangrove areas would reduce incoming waves and ocean currents, so that the surrounding land is protected from abrasion (Nguyen *et al.* 2018; Xioa *et al.* 2020).

Figure 8 Cuting mangroves for ponds

However, in Indramayu Regency, the mangrove area has continued to decline. In 1989, the area reached 3.397 ha, decreased by 45,48% to 1852 ha in 2002, and further decreased by 43,20% to 1.052 ha in 2015 (Sodikin *et al.* 2017). This reduction was largely due to being converted into ponds, and some of the wood was taken for building materials and firewood. Figure 8 showed cuting mangrove for ponds in Indranayu Regency.

Efforts to Handle Abrasion and Accretion Utilization

The coastline changes in the Indramayu region, and both accretion and abrasion influence people's lives. Abrasion would be very detrimental to coastal communities (Kiruparajah 2018). Abrasion has detrimental impacts on the community, such as the loss of ponds and houses. Meanwhile, accretion has a positive impact, but there is also a negative impact. The positive impact is the emergence of emergent lands that are used for agriculture, aquaculture, and tourism. In addition, the negative impact is silting in river estuaries which can hamper the speed of transportation and also prone to causing land conflicts.

Table 2 The Abrasion at Indramayu Regency in 1989–2019

Period	Abrasion Area (ha)
1989-1999	1291
1999-2009	1125
2009-2019	358

The high level of abrasion in this Regency, especially between the 1989–2009 period, destroyed and damaged agricultural lands, pond areas, and buildings. Therefore, the government and society are making efforts to minimize abrasion. In fact, the government is building a wave barrier, both large river stones and concrete. This is considered quite effective, because between the 2009–2019 period, the level of abrasion decreased. These efforts not only reduce and minimize abrasion but also cause accretion.

The accretion that appears in the coastal area is utilized by the community in various fields, including aquaculture land such as shrimp and milkfish ponds, as well as tourism. Meanwhile, accretions that appear in areas where accessibility is difficult are used for fishponds, while areas with easy access are used as tourist attractions.

CONCLUSION

There was a coastline change both accretion and abrasion between 1989–2019 in 11 sub-Districts in Indramayu Regency. Accretion in the 1989–1999 period was 319 ha, 1999–2009 was 349 ha, 2009–2019 was 698 ha, and 1989–2019 period was 746 ha. Meanwhile, Abrasion in the 1989–1999 period was 1.291 ha, 1999–2009 was 1.125 ha, 2009–2019 was 358 ha, and 1989–2019 period was 2.127 ha. Coastlines changes in this regency are caused by natural and human factors. The natural factors include monsoons, waves, longshore currents. Meanwhile, the human factor is the making of wave breaks and planting mangrove vegetation. In addition, the accreted land is used for shrimp and milkfish cultivation, as well as for tourism.

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