

ANALYSIS OF SHORELINE CHANGES IN INDRAMAYU DISTRICT USING NORMALIZED DIFFERENCE WATER INDEX (NDWI)

Analisis Perubahan Garis Pantai di Kabupaten Indramayu Menggunakan Normalized Difference Water Index (NDWI)

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ABSTRACT

Indramayu Regency is one of the areas on the north coast of Java Island with a coastline length of ± 140 km. Over the past 15 years, abrasion and accretion phenomena have occurred in Indramayu Regency, causing significant changes to the coastline. Therefore, remote sensing technology is one of the solutions to identify beaches that experience shoreline changes. The purpose of the study was to analyze changes in coastline and determine the extent of accretion and abrasion in each sub-district in Indramayu Regency over time. The method used is Normalized Difference Water Index (NDWI) which identifies shoreline changes based on differences in water and land and detects changes in coastal accretion and abrasion. The data used is secondary data consisting of Landsat 8 OLI (Operational Land Imager) images in 2015, 2019, and 2023 and Indramayu Regency coastline data in 2015 sourced from Bappeda Indramayu Regency. The results of the analysis of the length of the coastline in Indramayu Regency have experienced significant changes where the coastline is getting longer. The difference in the length of the coastline is around ± 3.29 km in the 2015-2019 period and around ± 7.29 km in the 2015-2023 period. The results of the analysis show that there are significant changes in the incidence of accretion and abrasion in Indramayu Regency. In 2015 to 2023 the incidence of abrasion decreased by ± 49.51 Ha by about 20% and the incidence of accretion in 2015 to 2023 decreased by ± 93.88 Ha by about 25%.

Keywords: Abrasion, Accretion, Landsat 8, NDWI, Shoreline Change

ABSTRAK

Kabupaten Indramayu merupakan salah satu daerah di pesisir utara Pulau Jawa dengan panjang garis pantai ± 140 km. Selama 15 tahun terakhir telah terjadi fenomena abrasi dan akresi di Kabupaten Indramayu yang menyebabkan perubahan signifikan pada garis pantai. Oleh karena itu, teknologi penginderaan jauh menjadi salah satu solusi untuk mengidentifikasi pantai yang mengalami perubahan garis pantai. Tujuan penelitian untuk menganalisis perubahan garis pantai dan mengetahui luasan akresi dan abrasi setiap kecamatan di Kabupaten Indramayu dari

waktu ke waktu. Metode yang digunakan adalah Normalized Difference Water Index (NDWI) yang mengidentifikasi perubahan garis pantai berdasarkan perbedaan perairan dan daratan serta mendeteksi perubahan akresi dan abrasi pantai. Data yang digunakan adalah data sekunder yang terdiri dari citra Landsat 8 OLI (Operasional Land Imager) tahun 2015, 2019, dan 2023 serta data garis pantai Kabupaten Indramayu tahun 2015 yang bersumber dari Bappeda Kabupaten Indramayu. Hasil analisis panjang garis pantai di Kabupaten Indramayu mengalami perubahan yang signifikan dimana garis pantai semakin memanjang. Selisih panjang garis pantai sekitar $\pm 3,29$ km pada periode 2015–2019 dan sekitar $\pm 7,29$ km pada periode 2015–2023. Dari hasil analisis menunjukkan bahwa terdapat perubahan signifikan pada kejadian akresi dan abrasi di Kabupaten Indramayu. Pada tahun 2015 hingga tahun 2023 kejadian abrasi menurun ± 49.51 Ha sekitar 20% dan kejadian akresi pada tahun 2015 hingga tahun 2023 menurun sebesar ± 93.88 Ha sekitar 25%.

Kata Kunci: Abrasi, Akresi, Landsat 8, NDWI, Perubahan Garis Pantai

INTRODUCTION

Coastal areas are the connecting route between land and sea. Land areas are limited and influenced by the physical properties of the sea and marine socio-economics, while the sea is limited by natural processes and the impact of human activities on the environment on land (Salim, 2011). As explained in Law No. 1 of 2014, it is explained that coastal areas are transition zones between land and sea ecosystems that are influenced by changes both on land and at sea (Indonesia, 2014). According to Kay and Alder (1991), coastal areas are natural landscapes where land and sea meet (Kay & Alder, 1999). Coastal areas are areas that are very vulnerable to environmental pressures, both from the sea and from land. Coastal areas have a strategic role and are vulnerable to environmental changes and human activities, so the utilization of coastal areas needs to find an optimal balance between utilization, management and conservation in the utilization of coastal areas (Sagala *et al.*, 2021).

Indramayu Regency is a regency in West Java which is geographically located at 107°51" to 108°36" East Longitude and 6°15" to 6°40" South Latitude. The Central Statistics Agency of Indramayu Regency explained that Indramayu Regency is located in the northern part of West Java province which directly borders the Java Sea (Central Statistics Agency, 2023). Indramayu Regency is approximately 52 km northwest of Cirebon City, 144 km from Bandung City via Sumedang and 205 km from Jakarta to the east. According to Hafiidh (2018) the topography of Indramayu Regency is mostly lowlands or sloping areas with an average land slope of 0 – 2% (Hafiidh *et al.*, 2018). Indramayu Regency consists of 31 sub-districts with 317 villages/sub-districts and has an area of 2,099.42 km² (Central Statistics Agency, 2023). The coastline in Indramayu Regency is ± 140 km long and there are 3 small islands, namely Biawak Island, Gosong Island and Cendikian Island. Non-biological resources, such as mining and minerals and the very high diversity of biological resources such as mangroves, coral reefs, seagrass beds and sandy beaches in the coastal areas of Indramayu Regency are very potential (Maryanto *et al.*, 2017).

The intensity of human activities such as tourism, fisheries and others has caused an increase in the need for land so that coastal areas experience intensive damage and change. Not only due to human activities, environmental damage due to significant natural changes can affect the condition of coastal areas. Kusnida (2008), explained that in the last fifteen years, along the northern coast of West Java, especially in Indramayu Regency, there has been a process of abrasion and accretion and changes in the coastal environment due to the interaction of natural and human activities along the coast of Indramayu Regency (Kusnida & Astjario, 2008).

Abrasion is a process of erosion or reduction of coastal land caused by the activity of sea waves that cause the loss of coastal land substrate so that its area is reduced (Hadyanti & Pamungkas, 2013). Abrasion in coastal areas is caused by various factors, namely natural factors and human factors. Natural factors that affect abrasion are sea waves, tides, ocean current patterns, overwash, deflation and so on, while human factors that affect abrasion include dredging of sand material. In addition to abrasion, accretion often occurs in coastal areas. Accretion is the addition of land or the emergence of new land in coastal areas and usually the process of coastal accretion occurs in coastal waters where there are many river estuaries and also small wave energy and areas where the percentage of possible storms is small (Munandar & Kusumawati, 2017). With the conditions of accretion and abrasion that occur in coastal areas due to the interaction of very complex human and natural activities, this can affect the condition of the coastline in coastal areas, especially in Indramayu Regency (Kusnida & Astjario, 2008). Based on the problem of utilizing technology, one of them is using remote sensing technology to determine changes in the coastline due to accretion and abrasion in coastal areas.

Current remote sensing technology can produce data about the earth's surface that is fast, efficient, effective, and complete. And the advantages of remote sensing data are reducing human error and the data obtained is up to date depending on the increasingly short temporal resolution of the image (Zaidan *et al.*, 2022). Therefore, remote sensing technology can be applied to study the phenomenon of coastal area changes in large areas. Monitoring changes in the coastline in the coastal area of Indramayu Regency is important to detect the possibility of abrasion and accretion so that information is obtained for further planning, handling and monitoring of the affected coastal areas. Based on the problems above, until now there has been no in-depth study of coastline changes using time-based remote sensing technology in Indramayu Regency. The purpose of this study is to analyze changes in the coastline and determine the extent of accretion and abrasion in each sub-district in Indramayu Regency from time to time.

RESEARCH METHODS

This research was conducted in the coastal area of Indramayu Regency. The research material includes changes in the coastline as well as abrasion and accretion that occurred in Indramayu Regency from 2015 to 2023. The study area covers eleven sub-districts located on the coast of Indramayu Regency, namely Sukra, Patrol, Kadanghaur, Losarang, Cantigi, Pasekan, Indramayu, Balongan, Juntinyuat, Karangampel and Krangkeng Districts. The research was conducted from October 2023 to February 2024. The data used in the study of coastline changes and abrasion and accretion events were in the form of Landsat 8 satellite imagery data from 2015 October, 2019 November and 2023 August obtained through the official website, namely <https://earthexplorer.usgs.gov/>.

The research flow carried out includes the process of taking image data, processing image data, taking and processing supporting data in the form of a Topographic Map of Indonesia. The satellite imagery taken must take into account tidal conditions so that the coastline to be processed is in the same tidal conditions. The next satellite image processing is image pre-processing correction. The corrections made are in the form of atmospheric, geometric and radiometric corrections (Mather, 1987). Ramdhani (2021) explains that radiometric correction is to reduce atmospheric interference obtained when recording image data. The reflectance value received by the sensor will experience deviations due to atmospheric interference (Ramadhani *et al.*, 2021). To eliminate radiation errors from the image due to atmospheric scattering (radiance path) using atmospheric correction (Rujord & Tier, 2012). To correct the

pixel position of the image using geometric correction to transform, you can see the image of objects on the earth's surface recorded by the sensor (Lukiawan *et al.*, 2019).

After the initial processing of the image data, the analysis is carried out. The Normalized Difference Water Index (NDWI) method is a calculation process that aims to separate land and sea areas. In calculating NDWI, an algorithm is used that aims to define water bodies by utilizing maximum water reflection from the green band and minimum water reflection in the near infrared (NIR) band in satellite imagery. The NDWI formula is as follows (Gao, 1996):

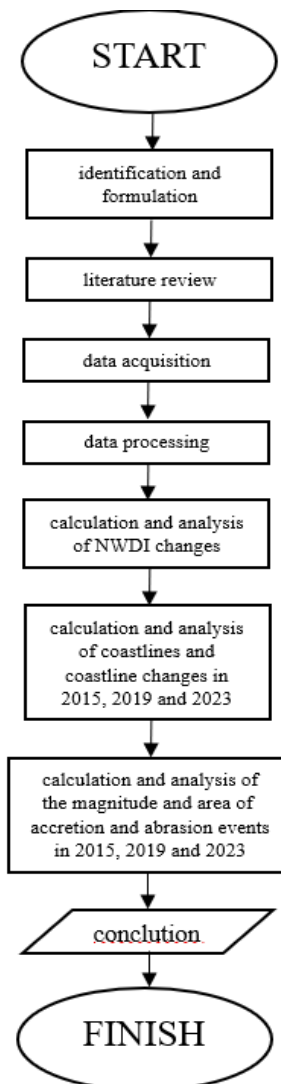
$$NDWI = \frac{GREEN - NIR}{GREEN + NIR} \dots\dots\dots (2. 1)$$

Information:

GREEN = Green channel reflectance value (Band 3)

NIR = Infrared channel reflectance value (Band 5)

Furthermore, after carrying out the NDWI classification process, the determination of land and sea boundaries is carried out through an on-screen digitization process using ArcGIS software. The digitized coastline is then overlapped with the coastline per year to calculate changes in the coastline based on the length of the line and its difference. Then the changes in the area of accretion and abrasion on the coast are analyzed. The research flow diagram can be seen in Figure 1.



Picture1. Research Flowchart

RESULTS

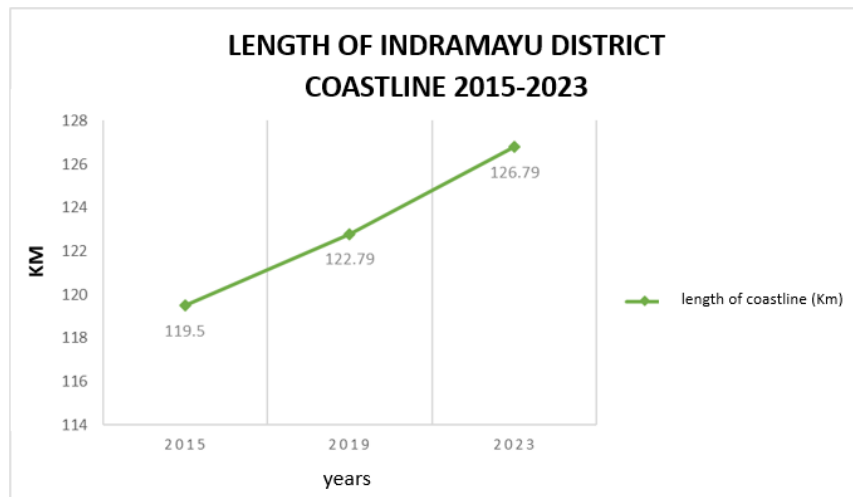
Indramayu Regency is one of the regencies in West Java whose coastal area borders the Java Sea and has a coastline of ± 140 km and Indramayu is a regency whose economy relies on the utilization of coastal areas. (UNDP Indonesia 2007). Referring to the report source of the Indramayu Regency Environmental Agency in 2015, it explains that from the length of the coastline in Indramayu Regency, there are 70 km of coastal areas affected by abrasion. Coastal areas affected by abrasion include Juntinyuat, Krangkeng, Indramayu, Pasekan, Losarang, Kandanghaur, Sukra and Patrol Districts. Abrasion that occurs on the coast of Indramayu Regency is caused by the influence of natural factors and human factors. Natural factors that influence abrasion are the characteristics of the coast in Indramayu which are alluvial so that the soil layer is loose so that the coast will be eroded if hit by high waves. Another factor causing abrasion is the destruction of mangrove forests which function as abrasion barriers. Not only that, development that juts out towards the sea and marine pollution are also factors causing abrasion. For marine pollution, it will initially cause mangrove plants to die. When the mangrove plants die, there will be no more coastal abrasion barriers. So efforts are needed to overcome abrasion by re-identifying changes in the coastline and also efforts to increase vegetation and create breakwaters or wave retaining walls. (Handayani & Wulandari, 2015).

Identification of shoreline changes in the coastal area of Indramayu Regency using satellite imagery. Shoreline analysis was only carried out in eleven sub-districts in the coastal area, namely Sukra Sub-district, Patrol Sub-district, Kandanghaur Sub-district, Losarang Sub-district, Cantigi Sub-district, Pasekan Sub-district, Indramayu Sub-district, Balongan Sub-district, Juntinyuat Sub-district, Karangampel Sub-district and Krangkeng Sub-district. The period of years studied was from 2015 to 2023. The results of the digitization of the shoreline of Landsat 8 imagery from 2015 to 2023 obtained from the on-screen digitization of the NDWI calculation results which were then overlaid into one layer clearly show the changes that occurred. During the 8-year period, shoreline changes were dominated by the progress of the shoreline so that the shoreline became longer due to accretion and abrasion events. The tabulation of shoreline changes can be seen in Table 1.

Table1. Length of the Indramayu Regency Coastline 2015-2023

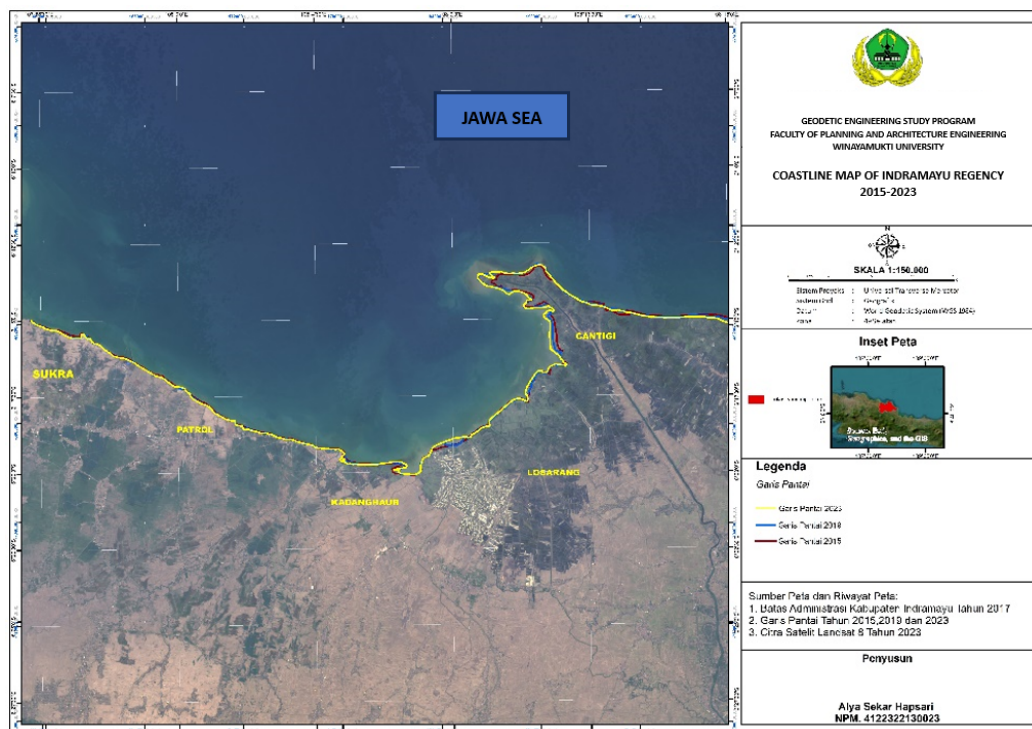
Year	Coastline Length (Km)
2015	119.5
2019	122.79
2023	129.79

Based on Table 1. It is explained that in 2015 the coastline of Indramayu Regency had a length of ± 119.5 km, in 2019 it increased by 3.29 km so that the coastline became ± 122.79 km and in 2023 it increased by 7 km so that the coastline in 2023 became ± 129.79 km. The results of the analysis show that the coastline in Indramayu Regency experiences a difference in the length of the line every year. Significant changes in the coastline cause the coastline to become longer every year.

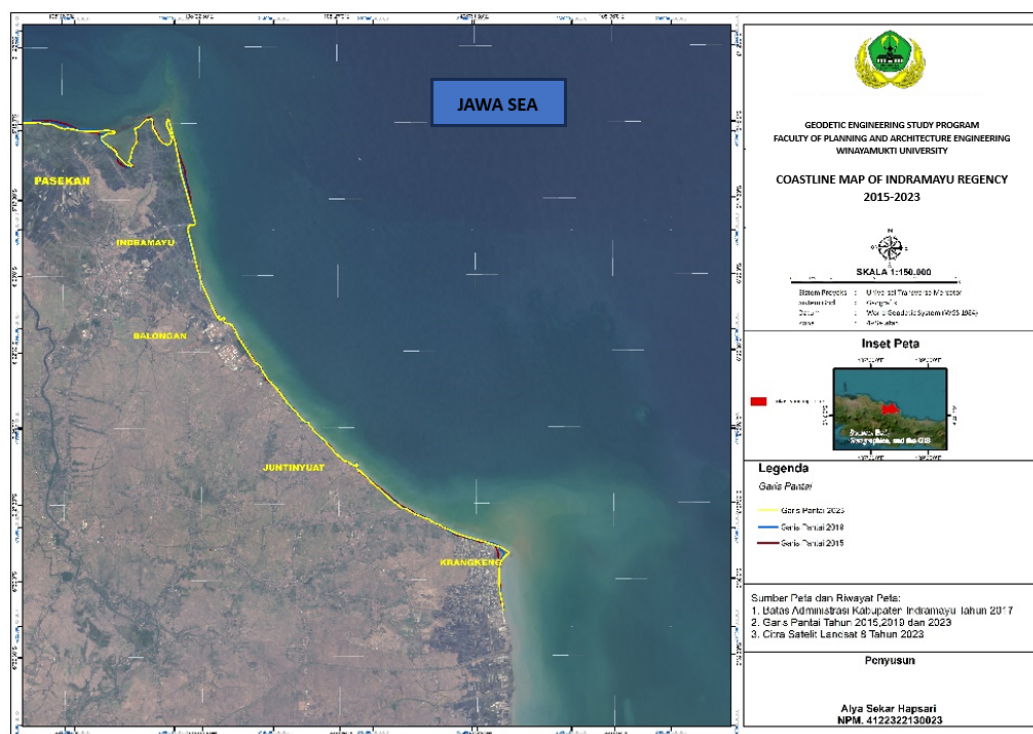


Picture 2. Changes in the Coastline of Indramayu Regency 2015-2023

To facilitate the delivery of information on the results of the coastline delineation from 2015-2023, it is divided into 2 parts, where part (A) consists of 5 sub-districts, namely Sukra, Patrol, Kadanghaur, Losarang and Cantigi sub-districts, while part (B) consists of 6 sub-districts, namely Pasekan, Indramayu, Balongan, Juntinyuat, Karangampel and Krangkeng sub-districts. The delineation results are made in the form of maps that can be seen in Figure 2 and Figure 3.



Picture3. MapIndramayu Regency Coastline Overlay 2015-2023 Part A



Picture4. Indramayu Regency Coastline Overlay Map 2015-2023 Part B

The factors that influence changes in the coastline of Indramayu Regency due to natural factors are wind, waves, ocean currents, sea tides, river diversity, direction and speed of coastal typology. On the other hand, the main anthropogenic factor is the conversion of mangrove areas. (Fahmi, Syahidan, Casmudi, & Dirwanto, 2024; Pasaribu, Pranoto, Waluyo, & Devi, 2022)

DISCUSSION

The results of coastline delineation and NDWI calculations with different year periods provide a visualization of abrasion and accretion events in sub-districts located on the coast of Indramayu Regency. The condition of the coastline that changes its position to retreat (away from the sea and closer to the land) from the previous year is said to have experienced an abrasion event, while the coastline that moves forward (away from the land and closer to the sea) from the previous year is said to be an accretion event (sedimentation/landslide).

Accretion that occurs on the coast generally occurs due to the supply of river sediment to the sea with the movement of sediment contained in the sea water mass. (Bird, 2008; Munandar & Kusumawati, 2017). The accretion process that occurs in Indramayu Regency comes from a natural process originating from freshwater flow and soil sedimentation processes and due to human activities such as changes in coastal function into ponds. While abrasion is the process of coastal erosion due to the power of ocean currents and destructive ocean waves. Abrasion on the coast of Indramayu Regency is generally characterized by shallow water areas and steep shoreline profiles. The coastal abrasion process that causes the retreat of the coastline is caused by two natural processes, namely strong marine erosion and the low speed of river sediment supply to the sea. (Hadyanti & Pamungkas, 2013)

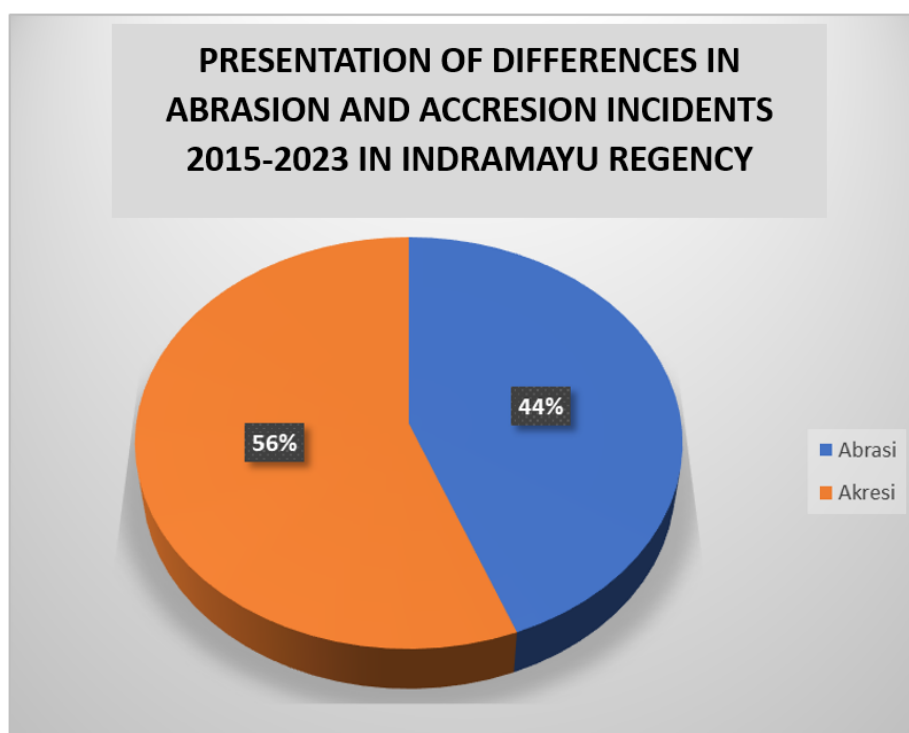
To determine the condition of abrasion or accretion in an area, on-screen digitization is carried out by integrating two results of coastline digitization from satellite images with different years. Determination of changes in the coastline due to accretion and abrasion refers to the 2015 coastline which is delineated/overlaid on the 2019 and 2023 coastlines. The total

area of abrasion and accretion conditions in Indramayu Regency in 2015 - 2023 is shown in Table 2.

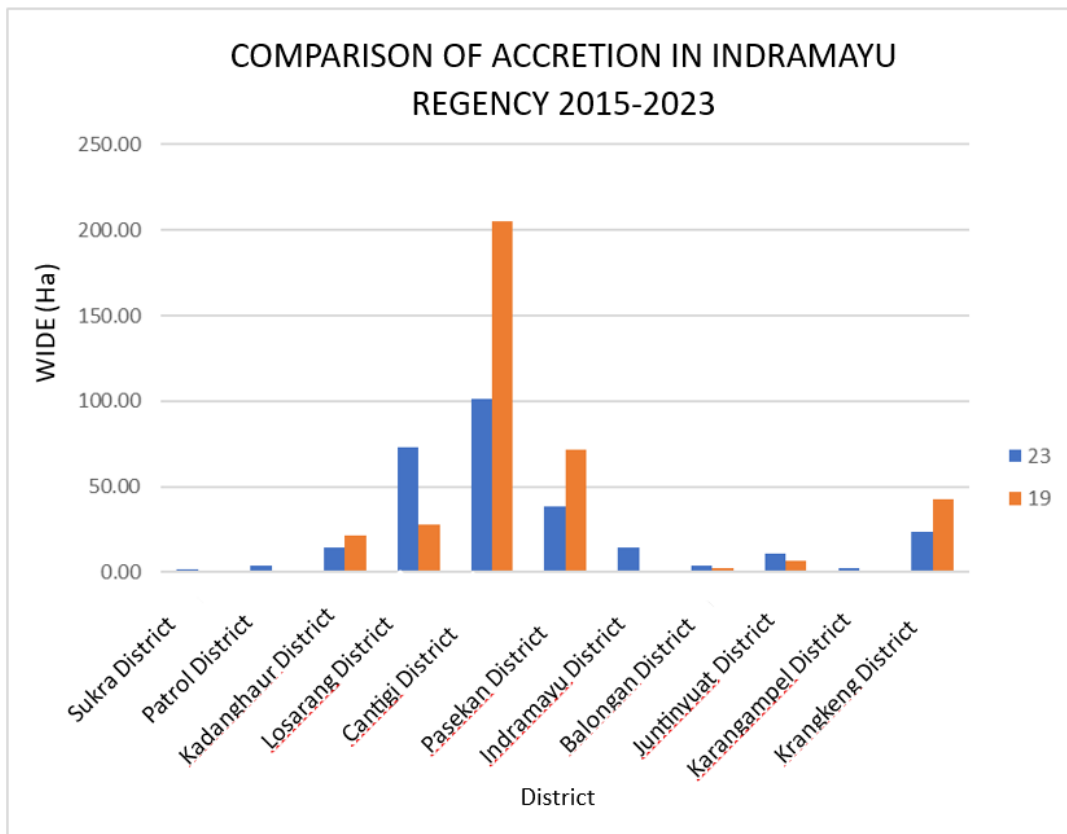
Table2. Area of Abrasion and Accretion of Indramayu Regency 2015-2023

Year	Area (Ha)	
	Abrasion	Accretion
2015-2019	254.40	380.86
2019-2023	204.89	286.99

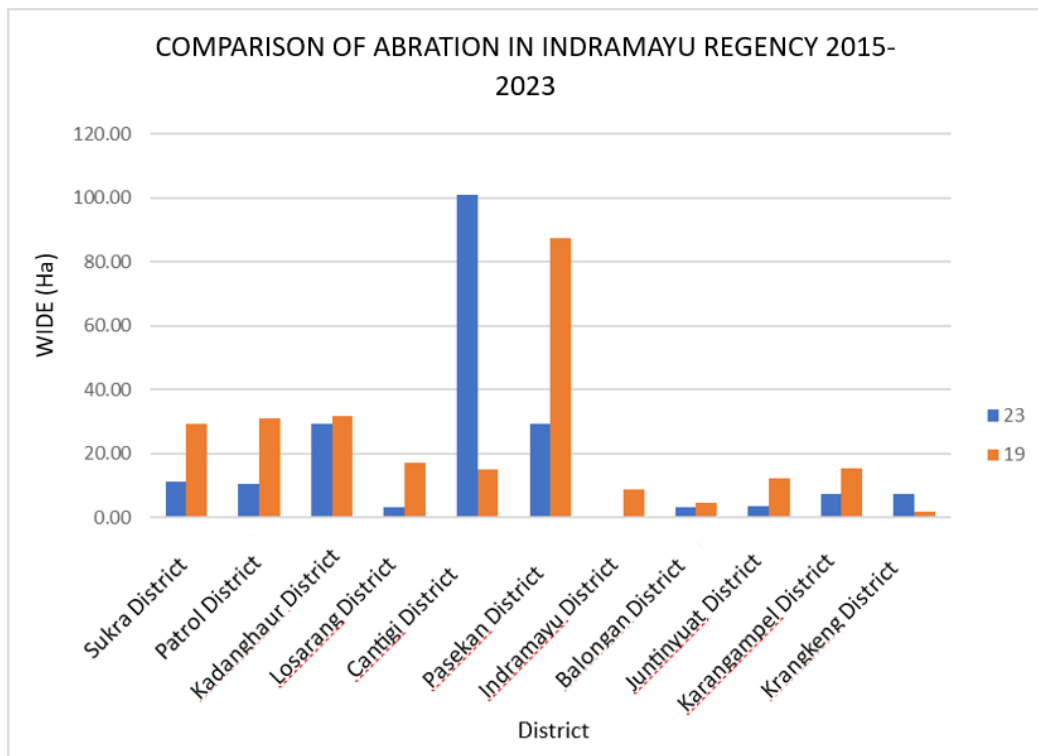
Based on Table 2. In 2015 to 2023 there were significant changes. The abrasion incident decreased by ± 49.51 Ha or around 20% from 2015 to 2023. While for the accretion incident, the same thing happened with the abrasion incident, it decreased by ± 93.88 Ha or around 25% from 2015 to 2023. The abrasion incident in Indramayu Regency according to the Bappeda of Indramayu Regency is often caused by several factors, namely rising sea levels, tides that cause coastal areas to erode. In the coastal areas of Indramayu Regency which border the Java Sea, such as Cantigi District and Patrol District, there are no breakwaters or mangrove trees. Breakwaters and planting mangroves are one of the efforts to protect the coast from the impact of sea waves and abrasion and to increase the role and function of damaged coastal ecosystems. (Epilia & Sukada, 2021). Meanwhile, the accretion incident in Indramayu Regency was caused by the many river estuaries located on the coast, causing sedimentation that forms deltas or other river deposits, creating land that emerges around the river estuary area. With the addition of land due to this accretion, it can cause new problems, namely changes in the position of the coastline and the status of land or land ownership, so a more in-depth study is needed regarding the addition of land.



Picture5. Percentage of Changes in Abrasion and Accretion Incidents in 2015-2023 in Indramayu Regency



(a)



(b)

Picture 6. Changes in Coastal Area Based on (a) Accretion and (b) Abrasion Events in 2015-2023 per Sub-district in Indramayu Regency

One form of balance of interaction between oceanographic and geological factors in coastal areas is the occurrence of coastal abrasion and accretion. Oceanographic factors include the ebb and flow of sea water, waves and ocean currents. While geological factors that affect coastal balance include the morphology of rocks that form the coast. Abrasion will occur if oceanographic factors are stronger than geological factors. (Fahmi, Syahidan, Casmudi, & Dirwanto, 2024; Hasanudin & Kusmanto, 2018).

Based on Figure 6 part (a), the accretion conditions that occurred between 2015 and 2023 occurred the most in the Cantigi District area. The accretion incident that occurred in 2015 - 2019 was 205.3 Ha and increased by 101.34 Ha in 2019 - 2023. So the percentage of the influence of the accretion incident in Cantigi District on the coastal area of Indramayu Regency is 46%. The accretion that occurs in Cantigi District is because the Cantigi District area is a large river estuary of the Cimanuk River, so the possibility of deposits or sediment at the river estuary that occurs is quite a lot, the deposits that occur are caused by large amounts of suspended mud from the movement of sea waves and high tides that block in front of the river estuary and sea currents coming from the left and right of the river mouth (Jaya *et al.*, 2021; Chodriyah & Pralampita, 2017).

Meanwhile, the abrasion incidents explained in Figure 6 part (b) in 2015-2019 occurred mostly in Pasekan District with an affected area of 87.49 Ha, while in 2019-2023 the most occurred in Cantigi District with an affected area of 100.90 Ha, an increase of 85 Ha from 2015-2019. These two districts are located right next to the south of the Java Sea, so the possibility of abrasion incidents due to oceanographic factors such as rising sea tides, waves and increasing ocean currents can affect coastal conditions.

Based on the research results, the increase in the number of areas affected by accretion in Indramayu Regency requires an appropriate solution in solving the problem of sedimentation or sedimentation in river estuaries. One solution that can be used is to build a coastal protection structure in the form of a jetty. The jetty was chosen because the jetty is a coastal protection structure that is made specifically for river estuary areas. With the jetty, sediment or sediment carried by the ocean current will not enter the river estuary, then the sediment that is caught can become new land but is not in the river estuary (Ikhwan *et al.*, 2018). Meanwhile, to overcome the increasing number of areas affected by abrasion in Indramayu Regency, it is recommended to carry out rehabilitation and planting of mangroves along the coast experiencing abrasion, design breakwater structures to reduce the impact of the intensity of oceanographic factors along coastal areas prone to abrasion, stop the conversion of land functions from mangrove areas to other uses, and prohibit sand mining in coastal areas. (Fahmi *et al.*, 2024; Ramadhan, 2022).

CONCLUSION

The results of the analysis of the length of the coastline based on the NDWI index value in Indramayu Regency from 2015 to 2023 experienced significant changes, namely the coastline became longer. Where the coastline in 2015 was ± 119.5 km long, increased by ± 7.29 km so that in 2019 the coastline became ± 122.79 km and in 2023 it increased by ± 4 km so that the length of the coastline became ± 129.79 km. Changes in the coastline in Indramayu Regency are influenced by various factors. The condition of the position of the coastline in Indramayu Regency can retreat (away from the sea and closer to the land) from the previous year due to abrasion, while the coastline whose position has advanced (away from the land approaching the sea) from the previous year is due to accretion (sedimentation/landslide).

Accretion and abrasion events from 2015 to 2023 experienced many changes. Abrasion events from 2015 to 2019 were 254.40 Ha and decreased by ± 49.51 Ha or around 20% from 2015 to 2023. Meanwhile, accretion events from 2015 to 2019 were 380.86 Ha and similarly,

abrasion events decreased by ± 93.88 Ha or around 25% from 2015 to 2023. Oceanographic and geological factors in coastal areas can affect coastal abrasion and accretion events. Therefore, solutions are needed such as the construction of jetties, breakwaters and rehabilitation of coastal areas for mangrove planting to overcome and reduce the increase in area due to accretion and abrasion.

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