The Dynamics of Changes in the Coastline of the Sayung Coastal Community in Demak Regency Using Remote Sensing Imagery

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Abstract. Shoreline changes indicate dynamic events in coastal areas. Communities around the coast will feel the impact of changes in the coastline. The purposes of this study are (1) to analyze the level of shoreline change from 2015 to 2021 and (2) to analyze the effect of tidal flooding on shoreline changes in Sayung District, Demak Regency. This study used descriptive qualitative analysis and the Normalized Different Water Index (NDWI) method and conducted accuracy and validity tests. Analysis of tidal flooding is a factor that influences shoreline changes by using an analysis of the distribution of affected areas so that areas that often experience tidal flooding can be identified. (1) The results of this study are significant abrasion and accretion from 2015 to 2021 in a coastal village with a beach length of 20.9 km which has experienced 122.14 Ha of coastal abrasion and 17.53 Ha of accretion with an abrasion percentage (86%) and accretion (14%). Overall rate of abrasion (17.44 Ha/year) and accretion (2.50 Ha/year). (2) Tidal flood areas that occur in coastal areas result in areas that are eroded or sea level rise causes changes. The immigration process for coastal residents will be carried out to maintain their economy and life because living in coastal areas that are prone to changes in the coastline will harm them, especially for their daily needs. Local governments need to routinely and provide material assistance to underprivileged citizens for immigration in appropriate places.

Keywords: Shoreline Changes · Normalized Different Water Index · Tidal Flood

1 Introduction

Indonesia is a maritime country consisting of several large islands and thousands of small islands spread from Sabang to Merauke. This makes Indonesia the country with the fourth longest coastline in the world after Canada, the United States and Russia, which reaches 99.093 km (BIG, 2013). The area of Indonesian waters reaches around 62% of its territorial area, and has enormous potential and diversity of biological resources, causing many human activities related to marine and coastal waters (Supriharyono, 2000).The issue of global warming has become a great concern at this time, because it directly impacts global climate change which creates an unstable atmosphere in the lower layers, especially those close to the earth's surface (Susandi et al., 2008). We can

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see climate change temporally, as a result of natural changes or caused by various human activities (IPCC, 2007). Rising sea levels and extreme weather that causes extreme waves to form tidal floods cause shoreline changes in coastal areas. The Sayung District area, especially in the coastal area, with several villages inundated by tidal floods, including 10 submerged villages including public facilities such as: schools, places of worship, houses and graves with an average submerged water level of 10–110 cm (BPBD Central Java, 2020).

Sayung District is one of the sub-districts in Demak Regency. This sub-district is located 14 km from the center of Demak City on the west. This sub-district is close to Semarang Regency, Sayung District is located in the north of Central Java Island which often experiences tidal floods and more than 300 ha over the past 5 years have been inundated due to tidal floods with a tidal flood height of 10–100 cm (BAPPEDA Demak, 2020). In the coastal areas, there are 4 villages experiencing abrasion hazard dynamics, namely Bedono Village, Surodadi Village, Sriwulan Village, and Timbulsloko Village. The village that is currently experiencing the most severe damage is Bedono Village, in fact, two hamlets in the village have now has been submerged due to the rob, namely Senik Hamlet and Tambaksari Hamlet, following the Pandansari Hamlet which is in danger of drowning. If it is not handled immediately, it is feared that in the next few years the tidal water will reach the northern coast of Semarang - Demak (BAPPEDA Demak, 2000 in Damaywanti, 2013). As a result of this rising sea level, the pond area has sunk and it has reached people's homes. This tidal flood causes changes in land use to become narrower and even disappear due to rising sea levels. An obvious case is that of pond farmers who have lost their livelihood and have changed professions to factory workers. The purpose of this study is to estimate mass movement by utilizing Sentinel-2 remote sensing data and using the NDWI (Normalized Difference Water Index) technique to identify water and landslide disasters.

2 Method

2.1 Overview of Study Area

The research area is located in Sayung District, Demak Regency, Central Java Province. Astronomically, Sayung District is located at 6°56'31.4" to 6°57'08.2" South Latitude and 110°29'26.4" to 110°31'33.2" East Longitude. Sayung District is one of the sub-districts in Demak Regency. To the north of this region is bordered by the Java Sea. To the east it is bordered by Karang Tesih District, to the south by Mranggen District, and to the west by Semarang City. The geological structure of Demak Regency consists of alluvium, Miocene sedimentary facies, Pliocene sedimentary facies, Pleistocene volcanic facies and Pliocene limestone facies. In the process of forming volcanic land (Muria Volcanic Activity), fluvial (Sedimentation carried by rivers) and marine (tidal activity along the coast). Coupled with the process of sedimentation from the Randublatung Valley which was lifted from the Juwana River and Wulan River, as well as sedimentation resulting from the process of sea tides.

The landforms in Sayung District, Demak Regency are volcanic land (Mount Muria activity), fluvial (sedimentation carried by rivers) and marine (tidal activity along the coast). Mount Muria, which was once separated from Java Island, is now united and forms

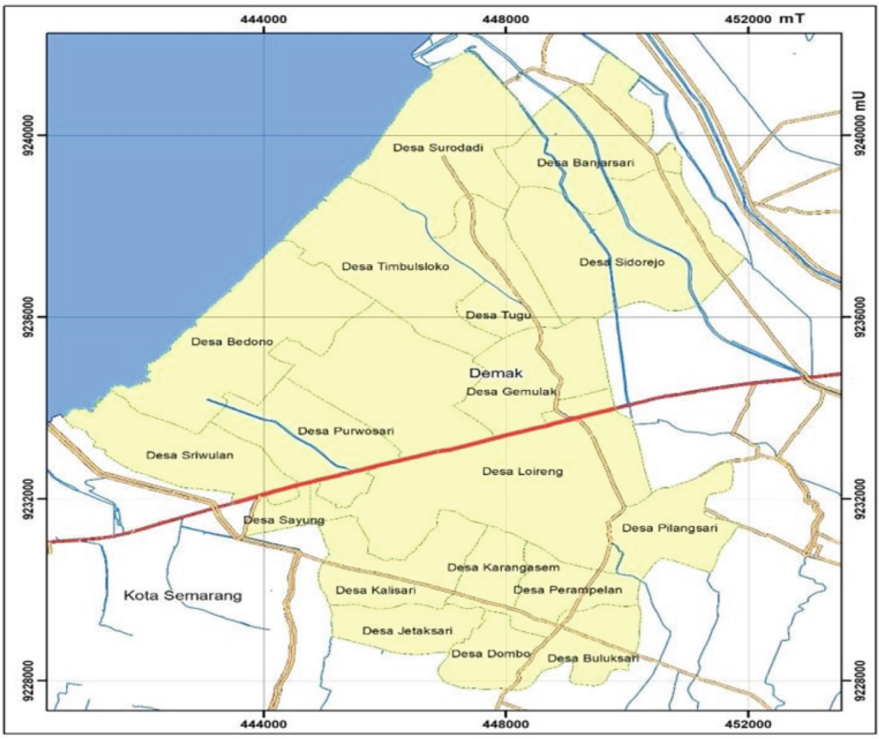

Fig. 1. Study Area

a vast alluvial plain. This is caused by a strong sedimentation process originating from the activity of Mount Muria, coupled with a sedimentation process from the Randublatung Valley lifted from the Juwana River and Wulan River, as well as a sedimentation process by sea tides. This process lasts a very long time and is continuous. The coastal area of Sayung District includes lowlands with relatively flat topography, less than 2% and has an elevation of 0 to 5 m above sea level (Subardjo, 2004). Sayung District has a land surface structure that is mostly derived from silt (swampy soil), so it is very susceptible to soil movement. This research takes the area, namely four villages located in the coastal area, which in the category of coastal areas in this region are areas with tidal floods that have occurred for a long time. The decrease in the groundwater level and the loading due to buildings and landfills has accelerated the rate of consolidation and land subsidence, so that this has resulted in an increasingly widespread tidal flood in Sayung District. Based on the background above, it can be seen directly the research location in the map in Fig. 1.

2.2 Scope of Analysis

The coastal area of Sayung District is an area where sea and land transition occurs due to the influence of the sea and is limited in terms of administrative area. In the coastal

area of Sayung District, there are four villages in the coastal area, namely Sriwulan Village, Bedono Village, Timbulsloko Village and Surodadi Village. The research area is in the coastal area of Sayung District which has experienced abrasion and accretion or changes in the coastline. The analysis of this study utilizes 2 Sentinel-2 images recorded on February 24, 2015, February 19, 2018 and September 22, 2021. The highest rainfall in 8 years (2015–2021) occurred in 2019. Remote sensing data will be divided into 2, namely master and slave. The master is the image data that is recorded earlier than the slave image. To obtain the estimated average value of mass movement in each village in Sayung District, the images were processed and will be processed in ENVI 5.1.

2.3 Method for Obtaining Data

The shoreline changes were obtained through satellite imagery and field observations. Photo images acquired by the Sentinel-2 satellite are downloaded from the USGS Earth Explorer page. The flow of research carried out includes processing satellite imagery, field data collection and processing of supporting data. Field observations were carried out to ensure the authenticity of the processed data with field conditions. Image restoration is carried out to improve the quality of satellite images that are not good as a result of damage to the satellite or because of it atmospheric disturbance. In interpreting coastal area images with Sentinel 2 imagery is the right choice where the level of accuracy is quite high, namely 10 m from the surface of the earth, so observing coastal areas, especially in the District area, is easier by knowing the areas of erosion and abrasion and separating land and water areas in the coastal area. This also does not deny validation of the research location to clarify the accuracy of Sentinel-2 image data. Geographic Information System (GIS) digitization is a process by which certain objects such as roads, houses, rice fields, rivers and others that were previously only raster formats are converted into vector objects (polygons, lines, points). The digitization process on Sentinel-2 imagery is to determine the area under study and to observe the area in the form of coastlines and tidal flood inundation areas in Sayung District, Demak Regency.

The overlay technique in this study was used to determine the level of shoreline change and the effect of tidal flooding on shoreline changes as information for researchers to compare multitemporal changes. Overlay method between the 2015 shoreline change map and the 2021 shoreline change map. The output of the overlay results is a shoreline change map which can be analyzed using a descriptive method. Spatial analysis was carried out to analyze the degree of shoreline change using a method that is commonly used, namely the calculation of the End-Point Rate (EPR). The latest data or in the following year. From these results it can be seen the level of shoreline change and the impact of shoreline changes for communities around the coast of Sayung District, Demak Regency. And also descriptive analysis of the data analysis method used to identify shoreline changes is descriptive analysis (Sujaweni, 2014). To get the results of this study through the stages in Fig. 2.

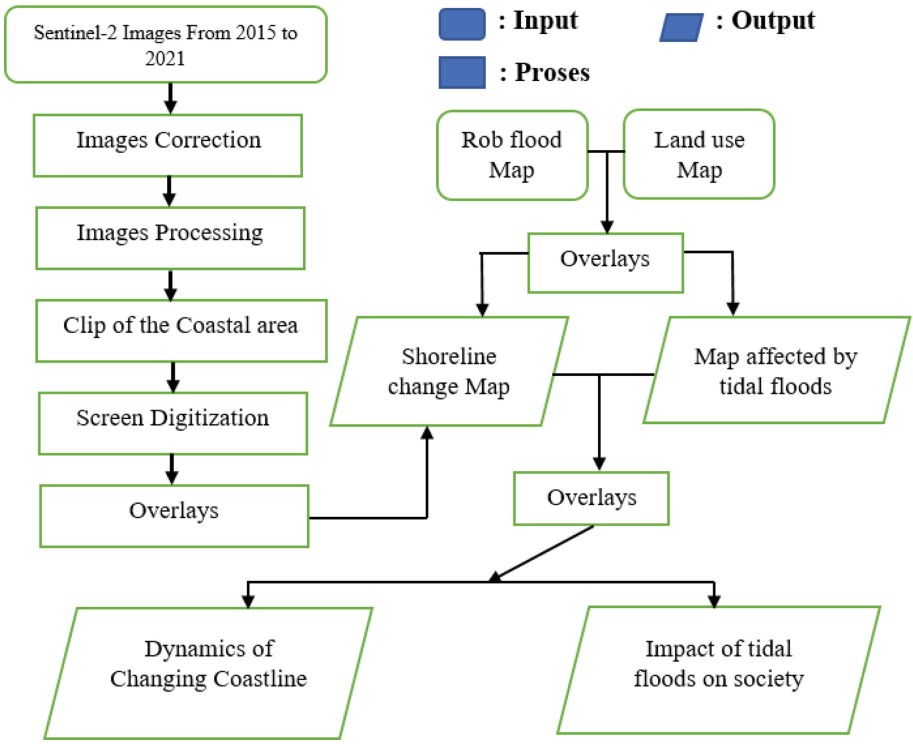

Fig. 2. Research flow chart

3 Results and Discussion

The coastal area is an area that has a dynamic nature and occurs continuously due to natural phenomena and certain factors. Coastal areas including beaches are areas that are vulnerable to various natural phenomena, one of which is a change in the coastline (Suharyo & Hidayah, 2019). The coastline is also known as the meeting line between the sea water and the land whose position changes according to the position during the tides. The coastline can change due to natural factors that affect coastal conditions, including the emergence of waves and currents that cause sedimentation and abrasion. Environmental conditions and coastal land use greatly affect changes in coastline, so that changes in coastline require significant monitoring. The coast of Sayung District has a surface structure dominated by silt (swampy soil), so it is prone to ground movement. Sayung District has a coastline length of 20.9 km (BPBD Demak, 2020). The fairly long coastline of Sayung District spans four coastal villages, namely Sriwulan Village, Bedono Village, Timbulsloko Village and Surodadi Village.

It is undeniable that the villages adjacent to the four villages have experienced abrasion and accretion because the Sayung District is an area that is very vulnerable to changes in the coastline until now. The change in the coastline in Sayung District can be seen through the satellite imagery that is processed and overlaid or overlaid on the satellite imagery. This research takes a temporally vulnerable 3 years in order to get

Table 1. Level Abrasion and Accretion areas in the range of 2015 – 2018

No.	Village Name	The Dynamics of Changing Coastlines		Information
		Accretion	Abrasion	
1.	Sriwulan	0	-6.97	Abrasion
2.	Bedono	3.78	-14.09	Abrasion
3.	Timbulsloko	2.44	-3.50	Abrasion
4.	Surodadi	0	-5.80	Abrasion
5.	Loireng	1.57	-1.91	Abrasion
Total (Ha)		7.79	-32.27	Abrasion

more real results that the coastal areas are experiencing changes and estimate the average results per year. This research takes images in 2015, 2018 and 2021, each of which is overlayed to find out areas of abrasion and accretion.

3.1 Shoreline Changes from 2015 to 2018

In this first period of research, within a period of 3 years, namely 2015 to 2018, with enough time to observe the results of shoreline changes, there have been quite a lot of abrasion and accretion dynamics. This first period dominates the existence of an abrasion area that is quite extensive so that the coastline pattern retreats to Loireng Village, this concludes that changes in the coastline are triggered by abrasion activity. To produce an analysis of shoreline changes, this first period calculation is shown can be seen in Table 1 and Fig. 3.

The movement of the coastline during this year's period shows that from 2015 to 2018 there was a change in the coastline of Sayung District with medium abrasion level dynamics. This explains that in that year the coastline did not experience significant changes and only certain areas dominated the land reduction area, namely abrasion (reduction of land area). Approximately 31.77 Ha of abrasion events and 7.79 Ha of accretion events, from this figure the area of abrasion is greater than accretion for a period of 3 years and a significant area of abrasion is Bedono Village, this is because the village area has direct contact with the sea area. The main factor causing the reduction in land area is the tidal flood disaster because the intensity of sea level rise in the 2015 to 2018 period is quite high and causes inundation of coastal areas. The eroded area in this period per year reaches 2.15 Ha/year, from this figure it can be concluded that the eroded area is large enough so that periodic handling is needed to reduce areas that are increasingly sinking.

3.2 Shoreline Changes from 2018 to 2021

Starting from the second period of research, namely from 2018 to 2021 with a period of 3 years, Sayung District experienced many dynamics of shoreline changes, especially

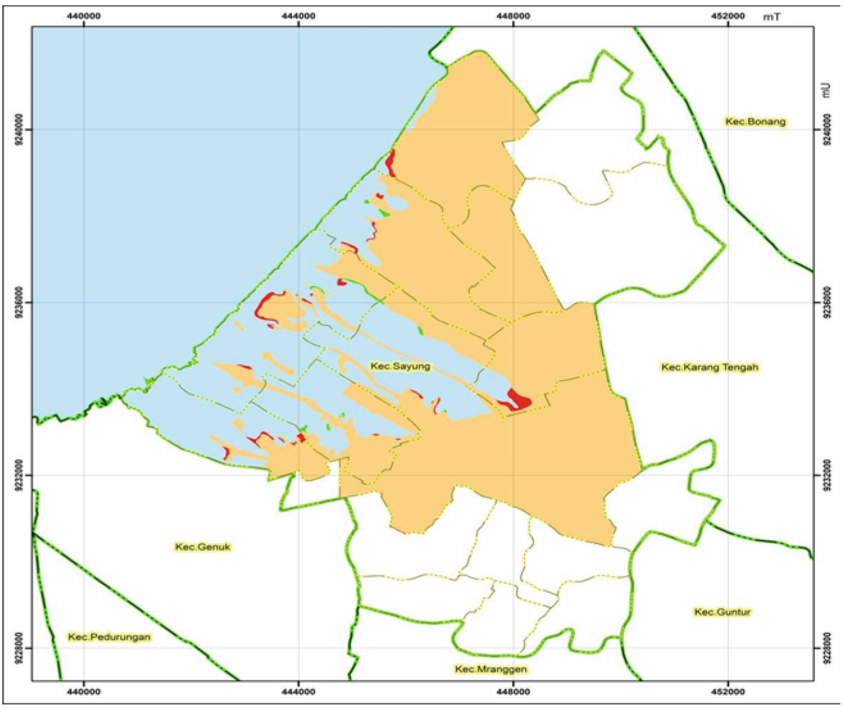

Fig. 3. Maps of Changes Shoreline of 2015–2018

abrasion events and can be seen in Fig. 4, besides that, the dynamics of accretion events are also present in several villages around the coast. According to previous researchers, the retreat of the coastline occurred very drastically in 2019 where the map shows abrasion areas dominating Loireng Village. To see the results of the analysis, there are calculation values for the area of abrasion and accretion, which can be seen in Table 2 and Fig. 4.

Table 2. Level Abrasion and Accretion Areas in the Range of 2018–2021

No.	Village Name	The Dynamics of Changing Coastlines		Information
		Accretion	Abrasion	
1.	Sriwulan	2.82	-12.50	Abrasion
2.	Bedono	1.01	-40.51	Abrasion
3.	Timbulsloko	1.53	-2.51	Abrasion
4.	Surodadi	0	-13.99	Abrasion
5.	Loireng	4.38	-20.36	Abrasion
Total (Ha)		9.74	-89.87	Abrasion

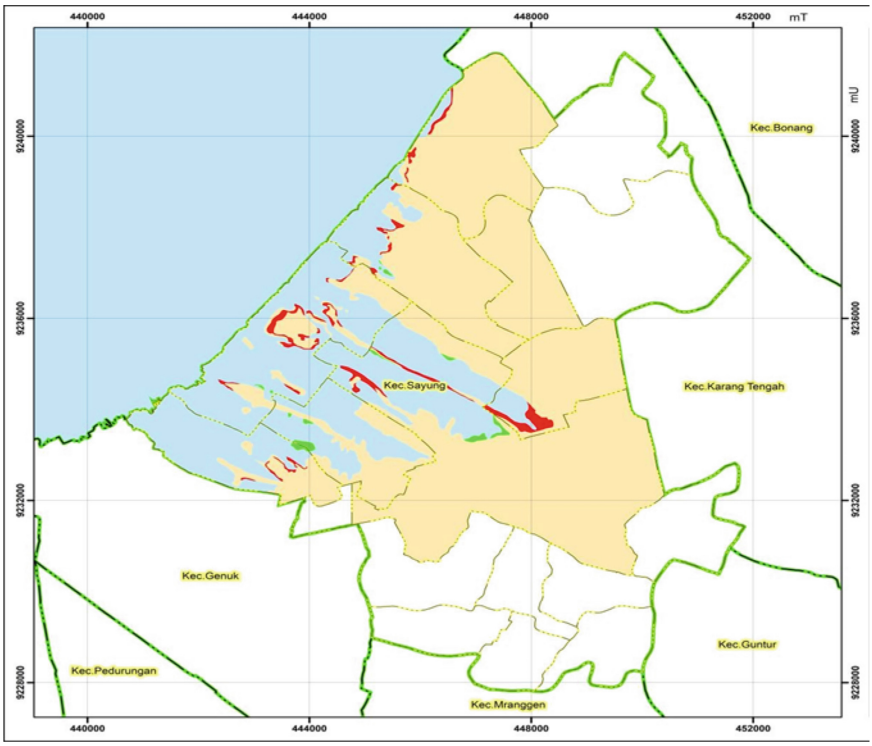

Fig. 4. Maps of Change Shoreline of 2018–2021

The most prominent factors influencing changes in the coastline for the second period of this year from 2018 to 2021 are also the reduction in land area. This was influenced by the extreme weather that hit Sayung District, causing areas prone to flooding, especially tidal floods where these floods inundated areas with a fairly flat slope, causing great concern to the local community. The area that dominates the duration of the tidal inundation is the soil subsidence factor where this factor causes the infiltration area to be slow or fast in tidal flood inundation. Where the group of residents whose area has experienced a reduction in land area of 13.99 Ha with an average of 5.99 Ha/ year. Apart from that, the area with the most extensive land reduction is Bedono Village with an area of 40.51 Ha in the period 2018 to 2021. The abrasion events in this period were triggered by an exit in 2019 which resulted in the coastline retreating to Loireng Village and experiencing abrasion covering an area of 18.45 Ha with an average of 6.15 Ha/year, this is caused by high enough rainfall that triggers a pattern of sea level rise where this increase in pattern causes areas to be inundated and progressively disappears from sinking. Accretion events in the period 2018 to 2021 were intensive in Loireng Village with an area of 4.38 Ha.

Table 3. Level Abrasion and Accretion Areas in the changes of 2015–2021

No.	Village	The Dynamics of Changing Coastlines		Information
		Accresion	Abrasion	
1.	Sriwulan	2.82	-19.47	Abrasion
2.	Bedono	4.79	-54.60	Abrasion
3.	Timbulsloko	3.97	-6.01	Abrasion
4.	Surodadi	0	-19.79	Abrasion
5.	Loireng	5.95	-22.27	Abrasion
Total (Ha)		17.53	-122.24	Abrasion

3.3 Shoreline Changes from 2015 to 2021

Changes in the coastline from 2015 to 2021 are experiencing levels of abrasion and accretion that are quite severe, causing factors to change the coastline starting from reducing the land area of the coastal area and adding areas. From a visual view, it can be concluded that the transect line dominates the pink color, this indicates a retreating coastline or it is called abrasion. In addition, there is also the addition of land that triggers the advancement of the coastline. The following is the calculation of the rate of change of the coastline for the period 2015 to 2021 in Table 3 and Fig. 5.

This 7-year study obtained a total abrasion area of 122.14 Ha with the most affected village, namely Bedono Village due to the location factor of the village being close to the shoreline so that the village continues to experience the effects of sea level rise or tidal flooding (rob). The highest accretion rate is found in Loireng Village with an area of 5.95 Ha from 2015 to 2021 where this village repeats to maintain the area and the impact of sediment deposition from sea to land. The total area of accretion for 7 years is 17.53 Ha. This tidal flood disaster will continuously result in the forward and backward pattern of the coastline, this is an absolute law that coastal areas are dynamic. The village that has experienced a significant reduction in land area, namely Bedono Village, where this village is geographically located at the forefront of other villages which is very prone to flood disasters, besides that many areas in this area have not yet installed sea wave forts, this is very influential because if there is support sea waves automatically land areas that have been maintained by wave support so that land sediments will not dissolve towards the sea. In addition, the area of additional land area is in the form of vegetation, namely mangrove plants. The personnel in overcoming the changes in the coastline that occurred in the Demak Regency government for the protection of the land in Bedono Village by building hard and soft structural technologies.

3.4 The Effect of Rob Floods on Shoreline Changes

Natural disasters that cause changes in the coastline are tidal floods, this affects changes in the coastline in coastal areas so that puddles of water spread to residential areas.

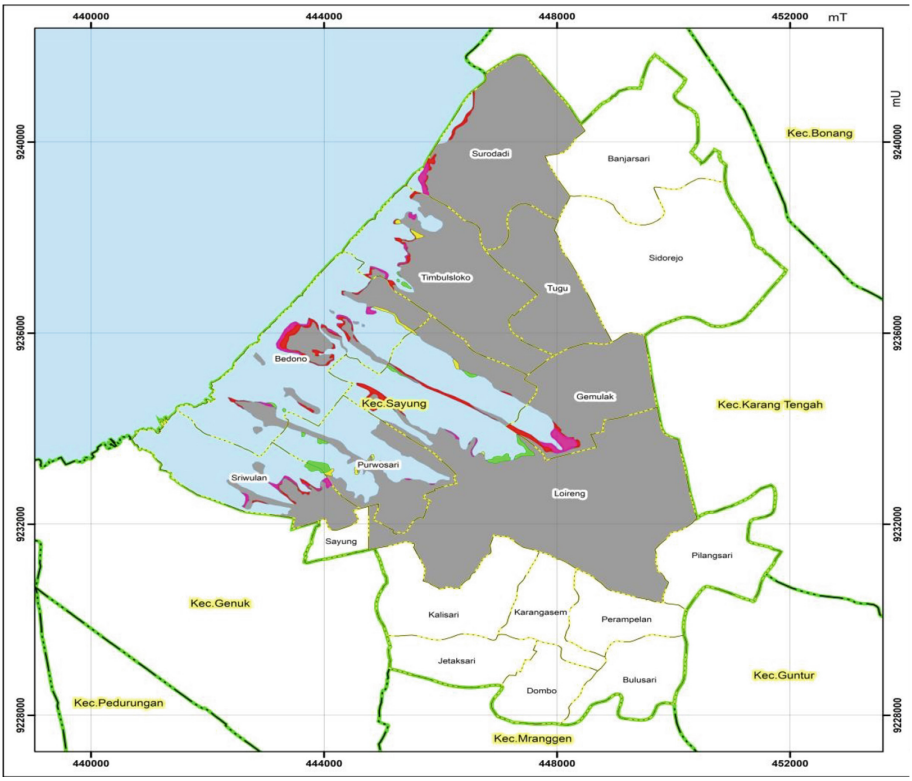

Fig. 5. Maps of Change Shoreline of 2015–2021

Starting from the 7-year research period, this is enough time to find out what impact the tidal flood natural disaster has had, with the time of shrinking and the start of tidal floods in coastal areas also carrying sediments from the sea towards the land and sediments from the mainland towards sea. In addition, there are settlement locations in Bedono Village, to be precise in Dukuh Rejosari and Dukuh Tambaksari, where tidal floods or tidal floods with high intensity inundate every day and gradually cause the loss of these settlements which eventually turn into the sea. This can result in a flood inundation effect resulting in a change in the shoreline. It can be seen that the coastal area is a dynamic area (changing) where this area is very prone to experiencing erratic changes. Map of inundated areas and inundated areas due to tidal floods in the coastal area of Sayung District, Demak Regency.

Figure 6 and Fig. 7 show a map of tidal flood inundation that occurred in the Kecamayan Sayung coastal area with coastline overlays for 2015, 2018 and 2021. The tidal flood inundation area map above states that tidal flood inundation in coastal areas results in changes in the coastline. This flood event is one of the dominant factors in the retreat of the coastline in Sayung District. Timbulsloko Village is the village with the least inundation area, which is 143.42 Ha with an inundated residential area of 1.43 Ha, this is because the topology of the Timbulsloko Village area is quite high in parts of the area

Fig. 6. Map of Flood Inundation in the Coastal Area of Sayung District

far from the coast. For Surodadi Village, the inundation area was quite severe, namely 621.34 Ha due to the tidal flood factor in the previous year. Looking at the map of the tidal flood inundation in other villages in the coastal area, it will expand in 7 years, explaining that the pattern of sea level rise is caused by tidal flooding. The following is a picture of the tidal flood that occurred in the coastal area.

The pattern of sea level rise in Sayung District is influenced by the tides which are of the daily inclined mixed type single. Rising sea levels cause changes in sedimentation patterns and siltation in river mouths which can interfere with access to and from boats used by fishermen to go to sea (Diposaptono et al., 2009). Explaining that sloping beaches are more susceptible to the movement of sediment particles as the main component forming the beach profile compared to steeper beaches. Related to the tidal flood inundation area when sea water experiences the highest tide it will increase and expand inland according to the land surface or morphology will adjust it. The morphological elements of the coastal plains that affect the distribution of tidal flood inundation include the slope of the slope, the length of the coastal slope and the shape of the slope as well as its location or distance from the coastline and the channels of surface water runoff. The decrease in land use as a result of being inundated by sea water during high tide has a direct impact on the community and changes in the coastline, such as a decrease in the level of health, a decline in the local economy due to transportation and productivity disturbances.

This tidal flood is one of the factors that causes changes in the coastline, where water that overflows from the sea to the land and extends to the area around the coast allows when it recedes to carry sediment from the mainland to the sea area. So that the coastal area experienced shrinkage of land to sea area. Not only has there been a reduction in land but there has also been additional land from the impact of this tidal flood.

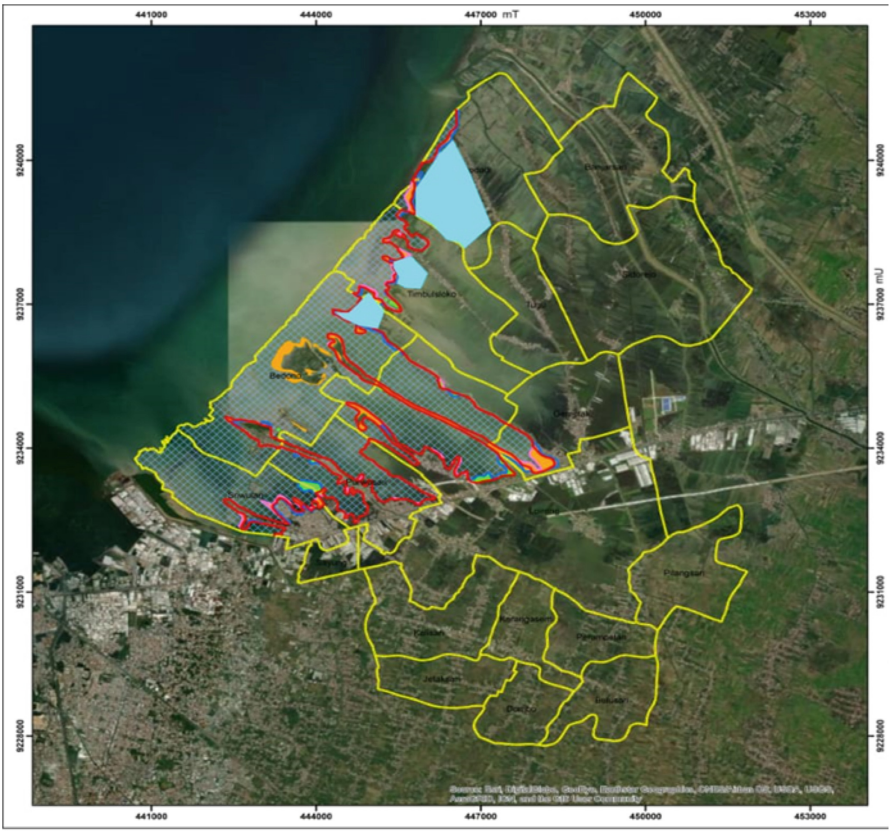

Fig. 7. Coastal location affected by tidal floods causing shoreline changes

4 Conclusions

Monitoring changes to the coastline that occurred in the Sayung District area from the analysis of Sentinel-2 imagery from 2015 to 2021 are in the form of abrasion and accretion. The main factor causing abrasion is the occasional tidal flood and inundation and high sea waves resulting in a pattern of sea level rise, while the accretion factor is additional sediment from runoff from the watershed system and addition of land area in the coastal area by the local community. For access to the pond area. Overall, the coastline of Sayung District experienced accretion along 21.80 km with a total area of 17.53 Ha and abrasion along 79.20 km with a total area of 122.14 Ha for a span of 7 years of study. 2. Tidal floods that occur at any time, especially in coastal areas where the slope level is almost the same as the mainland. The case that occurred in Sayung District was a tidal flood disaster that occurred almost every month and had many impacts on coastal areas and affected changes in coastlines. From the results of the analysis of this study, the areas affected by the inundation of the tidal floods are mainly slums located around coastal areas with submerged heights of 10–100 m of water discharge.

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