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Analysis of shoreline changes in Yogyakarta coastal areas using remote sensing method

Analysis of shoreline changes in Yogyakarta coastal areas using remote sensing method

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Abstract. Yogyakarta coastal areas in Indonesia are marine resources that affect the socioeconomics such as local trade, international trade, marine catches, and tourist attractions. The existence of activities in the marine sector creates the potential for shoreline change. The detection of coastline change, such as abrasion and/or sedimentation, using remote sensing is considered as a very effective method because the shoreline is found as highly dynamic nature. This study analyses shoreline changes in Yogyakarta coastal areas from 2010 to 2019 using satellite imageries obtained from Google Earth Pro platform and the processing data using AutoCAD software. The average coastline changes occur 2.90 m of abrasion per year at Parangtritis Beach and 1.98 m of sedimentation per year at Krokoh Beach. The effort to prevent shoreline changes at Parangtritis shore areas is by constructing coastal protection structures. Further research is needed to determine soft and/or hard coastal protection structures.

1. Introduction

The outbreak of the COVID-19 pandemic has dramatically affected global socioeconomic activities since early 2020. According to *Badan Pusat Statistik* Daerah Istimewa Yogyakarta Province, in 2021, COVID-19 cases were found in 100 villages: 34 villages in Bantul Regency, 34 villages in Sleman Regency, 5 cases in Kulon Progo Regency, 17 cases in Gunung Kidul Regency, and 10 cases in Yogyakarta [1]. Some researchers found that there is a correlation between climatic parameters and COVID-19 [2]. The results of the data collection during the year of 2018-2020 showed that the average air temperature in Daerah Istimewa Yogyakarta Province was in the range of 25.94^{o}C to 28.00^{o}C. In 2020, the humidity was in average rate of 78% which is considered high. This is quite reasonable considering Daerah Istimewa Yogyakarta Province is in the tropical climate. The rainfall in 2020 was 3,057.80 millimeter; higher than in 2019. In addition, the number of rainfalls in 2020 has been the highest in the last three years [3].

The Mlati Climatology Station in Yogyakarta informed that there was an early warning of high sea waves in the southern area of Daerah Istimewa Yogyakarta Province from 29 to 30 November 2020. The height of sea waves ranged from 2.5 m to 4 m. The Maritime Meteorological Center stated that the cause of the high sea waves in the southern Yogyakarta coastal area was due to the significant difference in air pressure between the center of high pressure in the Indian Ocean, west Australia, and low air pressure in the west of the ocean. These results increase the wind speed between 39-62 km/hour. The increase in wind speed has an impact on high waves in southern Yogyakarta coastal area [4].

Natural disasters due to tidal waves in Yogyakarta coastal area during 2020 occurred in 12 villages, i.e., 6 villages in Kulon Progo Regency, 1 village in Bantul Regency, 5 villages in Gunung Kidul Regency [4]. The natural disasters in Yogyakarta coastal area affect the shoreline. The coastline change in the shore area of Yogyakarta is very important to observe. Dynamic shoreline changes can result in erosion and/or sedimentation. Remote sensing method has been used for 10 years to detect the change of coastline in Yogyakarta shore area and was obtained from Google Earth Pro platform. In addition, the data of coastline from Google Earth Pro platform was easily imported in the form of images to AutoCAD software. The results of this study are very important for the management of coastal areas. If the coastline change is very significant, it will affect socioeconomic activities. It is necessary to provide information to the surrounding community concerning the importance of coastal management and efforts to handle the disasters in seashore. Furthermore, it is anticipated to consider the construction of coastal protection structure.

2. Materials and Methods

2.1. Coastline change

Seashore is an exclusive environment in which atmosphere, hydrosphere and lithosphere connect to each other. Coastline is one of the most significant linear geographies on the earth's surface which shows the dynamic nature [5-6]. Coastal zone and its environmental management include the information about coastlines and their changes [7-9]. Visual interpretation of airborne remote sensing data is still widely and popularly used for coastal delineation [10-11]. A variety of remote sensing data and techniques are available to detect, extract and monitor the coastline [12-13]. The coastline is delineated on the multi temporal satellite images in the Google Earth platform by visual interpretation [14]. The shoreline change was detected using Digital Shoreline Analysis Sistem in ArcGIS [15]. Estimation of shoreline change using satellite images is considered as a very effective method because the coastline is found highly dynamic. This study focuses to develop a methodology to collect shoreline data using satellite imageries obtained from Google Earth Pro platform. The coastline change was determined using AutoCAD [16].

2.2. The study area

Daerah Istimewa Yogyakarta Province in Indonesia is located near the southern coast of Java Island, surrounded by Central Java Province on the three sides, and with the Indian Ocean on the south. Figure 1 shows Daerah Istimewa Yogyakarta Province which was taken from Google Earth platform. The research site was a coastal area of Daerah Istimewa Yogyakarta Province. The study area included the shore along Kulon Progo Regency, Bantul Regency, and Gunung Kidul Regency.

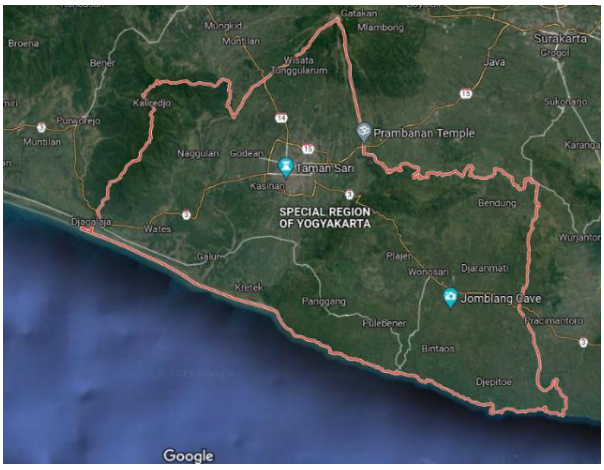

Figure 1. Daerah Istimewa Yogyakarta Province from Google Earth engine

At Kulon Progo Regency, there is New Yogyakarta International Airport (NYIA) which is located on the coast of Glagah Beach in the district of Temon [17]. This airport opened in 2019 and is projected to be one of the largest airports in Indonesia (Figure 2). This airport is equipped with tsunami mitigation facilities.

Figure 2. New Yogyakarta International Airport on the coast of Glagah Beach

Parangtritis Beach is a tourist seashore on the southern coast of Java Island in Bantul Regency within Daerah Istimewa Yogyakarta Province. Parangtritis Beach has become a tourism icon in Yogyakarta because it is one of favorite tourist destinations in Daerah Istimewa Yogyakarta province (Figure 3). Parangtritis Beach is an enchanting sloping beach combined with rocky hills, dunes, and a white sandy beach [18].

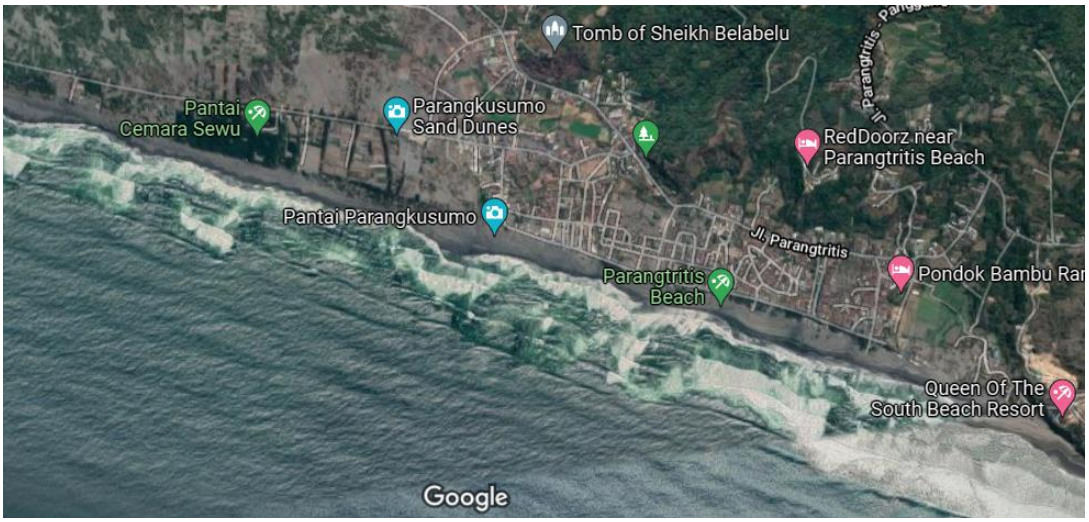

Figure 3. Parangtritis Beach

Gunung Kidul Regency is a regency in the southeast area of Daerah Istimewa Yogyakarta Province. The southern coast of Gunung Kidul Regency is rough and wild but exotic, with several beautiful beaches: Baron, Kukup, Krakal, Drini, Sepanjang, Sundak, Siung Beach, Wediombo and Sadeng (Figure 4). Some of these beaches provide fresh fish and other sea product supplied by local fishermen. The most notable one is Baron beach. There is a park next to the beach which is surrounded by seafood

restaurants and hostels. There is a fresh fish market on the east side of the beach. On the west side, a river flows out from an almost sea-level cave on the side of the western ridge. The beach itself is khaki-colored and sprawled with traditional fishermen's boats. Beside the main beach, there is a kilometer of practically untouched white sand beach lying beyond the eastern ridge [19].

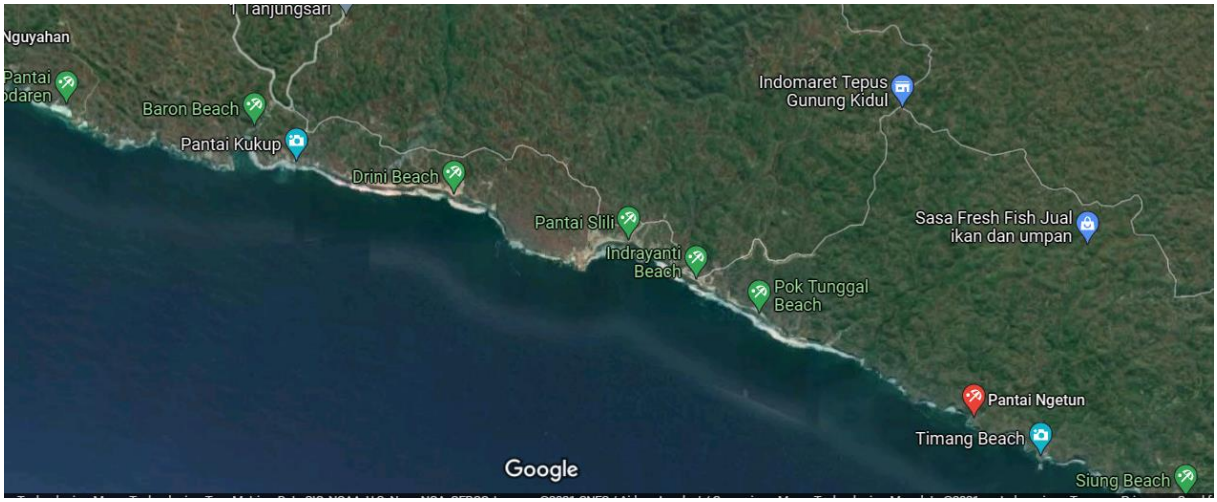

Figure 4. Southern Coast of Gunung Kidul Regency

2.3. Shoreline data along Yogyakarta coast area

Coastline data at the Yogyakarta shore area were obtained using satellite imagery from Google Earth Pro platform. They had been collected from 2010 to 2019 and in the same month, i.e., November, when the average of wind speed and wave are very high. Google Earth Pro platform has coastline settings to make it easier for users to draw shoreline using path. Shoreline data at Yogyakarta coast area in 2010 can be seen in Figure 5. The Yogyakarta's coastline length is about 113-kilometers.

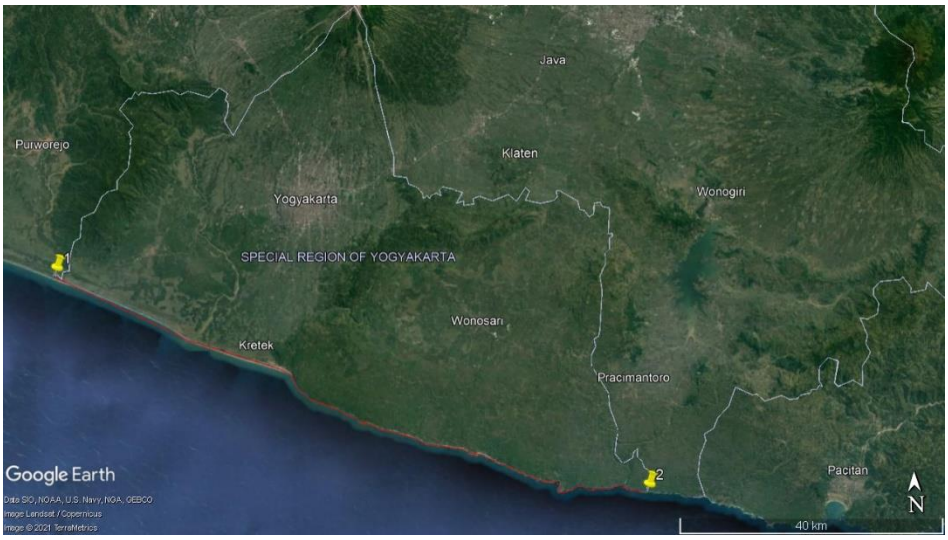

Figure 5. Coastline of Yogyakarta in 2010

The multi-temporal satellite imagery is the acquisition of remotely sensed data from more than one period. The multi-temporal imaging in 2010-2019 were used as primary information in obtaining necessary shoreline data. The multi-temporal imageries detected the shoreline positions and manually delineated using the path line to map shoreline positions. The multi-temporal of Yogyakarta coastline

from 2010 to 2019 were simply imported from Google Earth Pro engine to AutoCAD application. The advantages of AutoCAD are that it allows user to show complex group drawing for clear understanding, has an auto dimensioning that helps in designing easy and accurate drawings, and helps in a digital tracing such as coastline. The length of the coastline in Yogyakarta is divided into 19 points, where the distance between points is about 7 kilometers (Figure 6). Changes in the coastline each year can be evaluated using the AutoCAD application.

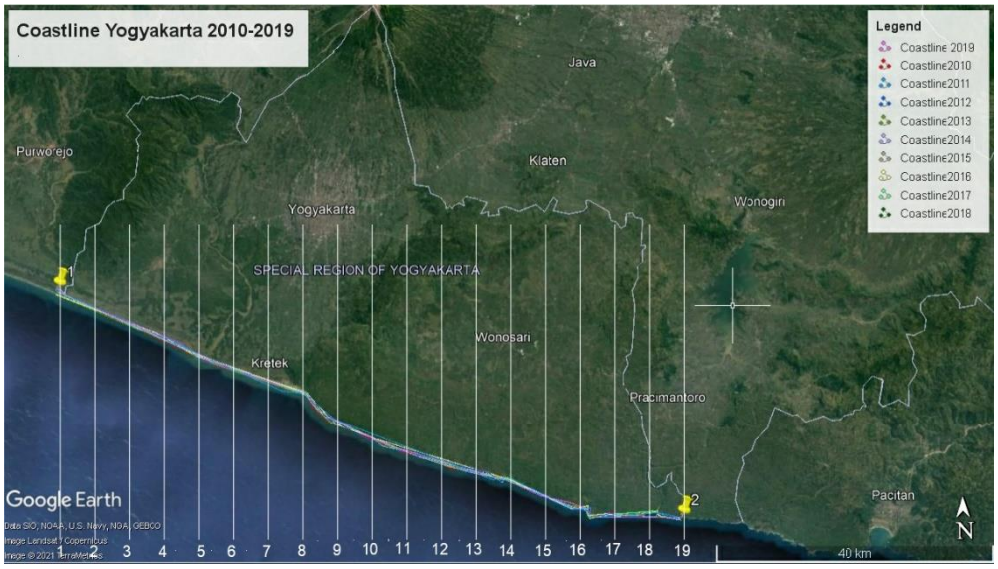

Figure 6. Divided spaced intervals along the shoreline

3. Result and Discussion

Shoreline change was investigated using the simple tracing technique in AutoCAD application. Coastline data in 2010 was used as the baseline in analysing the coastline change. Figure 7 and Table 1 show the results of coastline changes at point 1 each year from 2010 to 2019. The positive values indicate the accretion and negative values indicate erosion. The coastline changes at point 1 from 2010 to2019 show that erosion occurs. The maximum of erosion at point 1 raised in the year of 2012, however the average shoreline changes at point 1 is -0.01m/year.

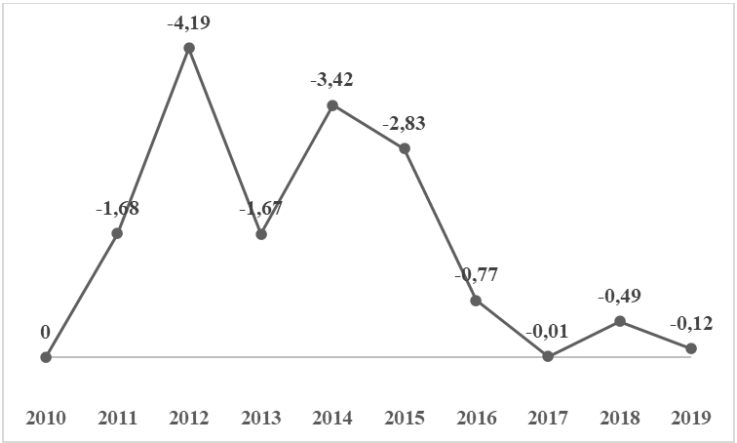

Figure 7. Position of coastline at point 1 in every year from 2010 to 2019

Table 1. Coastline change at point 1

Range of year	Coastline change (m)	Position of coastline (m)
2010-2011	-1.68	-1.68
2011-2012	-2.51	-4.19
2012-2013	2.52	-1.67
2013-2014	-1.75	-3.42
2014-2015	0.59	-2.83
2015-2016	2.06	-0.77
2016-2017	0.76	-0.01
2017-2018	-0.48	-0.49
2018-2019	0.37	-0.12

The results of shoreline changes at Kulon Progo Regency can be seen in Table 2. The maximum average of shoreline changes happens at point 4 which indicates the erosion. Point 4 is located at Glagah Beach near the New Yogyakarta International Airport. To reduce the impacts of waves that cause the erosion at Glagah Beach, installing five-meter artificial dunes and dense vegetation 300 meters from the coast were conducted.

Table 2. Coastline change at Kulon Progo Regency

Range of year	Point 1	Point 2	Point 3	Point 4	Point 5
2010-2011	-1.68	-8.06	-7.40	-8.91	-6.14
2011-2012	-2.51	2.77	-0.98	-2.85	1.13
2012-2013	2.52	-2.69	-0.40	0.55	-0.79
2013-2014	-1.75	6.30	-0.01	2.87	0.26
2014-2015	0.59	1.43	1.44	1.02	0.62
2015-2016	2.06	0.65	0.57	-0.25	-0.85
2016-2017	0.76	0.45	-1.15	-2.96	-0.32
2017-2018	-0.48	-0.59	0.58	1.67	-0.17
2018-2019	0.37	0.64	-0.82	-2.59	0.29
Average	-0.01	0.10	-0.91	-1.27	-0.66

Table 3 shows the coastline changes at Bantul Regency. The maximum average of erosion is 2.90 m and occurs at point 7 where Parangtritis Beach is located. Changes that lead to land areas were due to the geographical position of Parangtritis Beach which is facing the Indian Ocean. It is considered vulnerable to abrasion with sloping areas and sand mining. Furthermore, Parangtritis Beach does not have breakwaters (Figure 8). The large abrasion is probably caused by the reduced supply of sand from

Table 3. Coastline change at Bantul Regency

Range of year	Point 6	Point 7	Point 8
2010-2011	-1.80	-11.50	-2.37
2011-2012	-2.23	-13.80	0.49
2012-2013	-1.40	13.80	0.50
2013-2014	2.46	-4.83	0.97
2014-2015	2.43	-2.41	-0.49
2015-2016	-0.56	6.86	0.79
2016-2017	2.26	-13.42	0.12
2017-2018	-1.23	6.60	0.56
2018-2019	0.60	-7.36	-0.34
Average	0.06	-2.90	0.02

the rivers that flow to the South Coast from Mount Merapi because sand mining occurs at the river mouth. On the other hand, the sand dunes at Parangtritis Beach attract many tourists to visit. To protect the Parangtritis Beach from erosion, the sand dunes need to be designed and formed consequently.

Figure 8. Parangtritis Beach as tourist attractions

The average of coastline changes from 2010 to 2019 at Gunung Kidul Regency is shown in Table 4. The maximum average of shoreline change at Gunung Kidul Regency is 1.98 m accretion of sediments. The maximum average of shoreline changes occurs at point 19 where Krokoh Beach is positioned. Krokoh Beach is located in Songbanyu, Girisubo, Gunung Kidul Regency, which is the eastern border area of Daerah Istimewa Yogyakarta with Central Java. The change in coastline leading to the ocean area is proven by the presence of the largest sediment deposits that occurred from 2010 to 2019 with environmental conditions (Figure 9). The environmental condition of Krokoh Beach which is flanked by two cliffs is likely to make the waves break so that it does not cause severe beach erosion for Krokoh Beach.

Table 4. Average of coastline changes at Gunung Kidul Regency

Point	Average of coastline change (m)	Point	Average of coastline change (m)
9	-0.27	15	-0.35
10	-0.60	16	-0.76
11	-0.37	17	0.14
12	-1.31	18	0.34
13	0.50	19	1.98
14	-0.53		

Figure 9. Accretion of sediments at Krokoh Beach

4. Conclusion

The largest average change in coastline is 2.90 m abrasion per year at Parangtritis Beach, Bantul Regency. The environmental load at Parangtritis Beach with the presence of sand mining at the mouth of the river causes sediment transport to be hampered so that it erodes the land. This incident has an impact on the socioeconomic activities of the people on the coast as well as on tourist attractions at Parangtritis Beach. It is necessary to build a protective beach at the location of Parangtritis Beach.

At Krokoh Beach, the largest accretion of sediments occurred. The largest average change of sedimentation is 1.98 m per year. Krokoh Beach is flanked by two cliffs, ensuing in split waves and a high surface elevation, resulting in large sedimentation.

The significant of shoreline change distresses socioeconomics activities. The management of the coastal zone must be held accountable for both the effect of human activities as well as the impacts resulting from corresponding changes in the coastal zone. The information relating to the significant of coastal management and effort to grasp the disasters in seashore is essentially given to the public. Additionally, it is projected to consider the construction of coastal protection structure.

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