IDENTIFYING THE IMPACT OF SHORELINE CHANGE ON LAND USE IN BEDONO VILLAGE WITH GOOGLE EARTH

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Abstract

Sloping coastal areas pose a threat to environmental degradation. Previous data and research show that the north coast of Java Island is a sensitive area to abrasion that was exacerbated by sea level rise and land subsidence, one of which occurs in Bedono Village, Demak Regency. Bedono Village is the village that has lost the most land. Based on the latest administrative boundary data, Bedono Village has been divided into three pockets surrounded by sea areas. This study aims to determine the spatial-temporal impacts of shoreline changes on land use in Bedono Village using Google Earth data. In the last two decades, there has been a significant change in the coastline and its impact on land use change. Residential areas continue to decrease in size, reaching 16.38 ha. Ponds, as the most dominating area in 2003, also continued to decrease in area by 127.27 ha or 100% of the initial area. The loss of this land use was replaced by the inundation of sea water that continued encroaching into the land area. A total of 197 residential building units were lost, or an average of 788 people were affected. This study concluded the severe facts and impacts of shoreline change that must be addressed to reduce potential losses.

Keywords: *shoreline change, spatial-temporal, land use change, Google Earth data*

Introduction

The north coast of Java is the busiest economic and trade route in Java (Wayan et al., 2017). The north Java coast land route, called Pantura, connects urban areas starting from Cilegon, Jakarta, Cirebon, Semarang, to Surabaya. The development of the north coast of Java cannot be separated from the flat morphological conditions so that the land is easy to cultivate or utilize (Noor Anna et al., 2010). In the primary economic sector, land on the north coast of Java is widely used as rice fields and ponds, including in Bedono Village (Ari Setyati et al., 2018). Bedono Village is located on the north coast of Java, precisely in Sayung Subdistrict, Demak Regency (Ramadhani, 2021). Since the 1990s, the Bedono Village area has been widely used as a pond area for tiger shrimp farming, which was popular then (Damayanti, 2019).

On the other hand, the sloping north coast of Java poses a severe environmental threat, namely shoreline change (Sardiyantmo, 2013). Erosion and rising sea levels are factors that cause changes in the coastline of Bedono Village (Ervita & Marfai, 2017). The main factor of shoreline change is erosion that occurs in Sayung Sub-district (Ervita & Marfai, 2017). Bedono village has the most erosion, reaching 96.96 ha in 2011 (Rejeki, 2011). Sea level rise exacerbates shoreline changes in Bedono Village (Ervita &

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Marfai, 2017). The results of altimetry satellite observations in 2006-2016 showed a sea level rise in Sayung District of +5.52 mm/year (Prasetyo et al., 2019a). The results of the Digital Analysis Shoreline System (DSAS) calculation of Sayung Sub-district are the areas with the largest abrasion in Demak District, reaching -691 m during 2006-2016 (Prasetyo et al., 2019b). This abrasion has caused Bedono Village almost to sink (Sulistyowati et al., 2023).

Based on this phenomenon, effective and efficient monitoring efforts are needed to determine changes in conditions in coastal areas (Das Neves et al., 2023). Analysis through remote sensing data can provide geospatial information quickly to see changes in coastal areas (Sutrisno et al., 2019). Through remote sensing, the study of coastal areas has changed from a data-poor science to a data-rich one (Vitousek et al., 2023). This study aims to determine the impact of shoreline change on land use in the Bedono Village area, Sayung Subdistrict, Demak Regency, through remote sensing data. The effect of land use change is identified quantitatively based on the location. Not only that, this study also determines the number of changes in residential buildings due to changes in the coastline so that the number of people who experience these losses can be estimated.

Research Methodology

To determine land use change, a spatial-temporal examination with satellite imagery data and a period is necessary to collect satellite imagery over time. This study focuses on land use change due to shoreline shifts over 20 years. Satellite imagery from 2003, 2013, and 2023 will be utilized. In addition to identifying land use modifications, this study also conducted a spatial-temporal analysis of settlement structures.

Many satellites are available, and many will be launched to monitor the Earth's surface (Ustin & Middleton, 2021). Satellite imagery specifications continue to evolve with better capabilities in recording data as technology develops. The latest satellites cannot only provide data with good spatial resolution but also provide data with a tight recording interval so that there are many data archives. The abundant availability of satellite imagery data allows for spatial-temporal analysis at specific intervals. There are now many satellite image data providers, both paid and free. This research will use satellite image data from the Google Earth application. Google Earth provides a database of satellite imagery up to a high resolution capable of identifying buildings and a reasonably complete data archive that allows for spatial-temporal analysis.

Spatial-temporal analysis was conducted on the dynamics of land use and the number of residential buildings resulting from geospatial information extraction from Google Earth data. Geospatial information on land use and buildings was extracted manually by interpreting satellite image data. A comparative land use analysis was conducted to determine the change trend. Meanwhile, the identification of affected buildings was also undertaken to see the change trend from year to year. In estimating the number of affected residents, we used Presidential Regulation No. 73/2011 on the Construction of State Buildings, which regulates the minimum area standard for state houses of 36 m^2. Then, referring to SNI 03-1733-2004 concerning Procedures for Planning Residential Environments in Urban Areas, the building area of 36 m^2 is intended for houses with 4 (four) residents. So, in this study, the estimated number of occupants is based on the assumption of 4 people living in each 1 (one) house.

This research takes Bedono Village as a case study of shoreline change that has occurred significantly in the last two decades. This condition causes the land area of Bedono Village to be divided into three zones separated by sea water. The current geographical condition of Bedono Village can be seen in Figure 1. The map of the administrative area of Bedono Village is shown by the yellow line sourced from the Center for Boundary Mapping, Geospatial Information Agency, with satellite imagery in 2023 as a background.

Figure 1. Administrative Area of Bedono Village

Results and Discussion

Data from Google Earth

To obtain satellite image data, Google Earth, because the process is easy and complete enough, data archive was used in this research. Delineation of the official administrative boundaries of Bedono Village was converted from shapefile (.shp) to KMZ (.kmz) format following the file extension standard in Google Earth so that it can be read. The search for satellite image data focused on the administrative area of Bedono Village to see the condition of the land cover. Historical imagery provided by Google Earth allows us to know the condition of Bedono Village at different times. Figure 2 shows the administrative boundary of Bedono Village in yellow, with satellite imagery from 2003, 2013, and 2023 from Google Earth in the background.

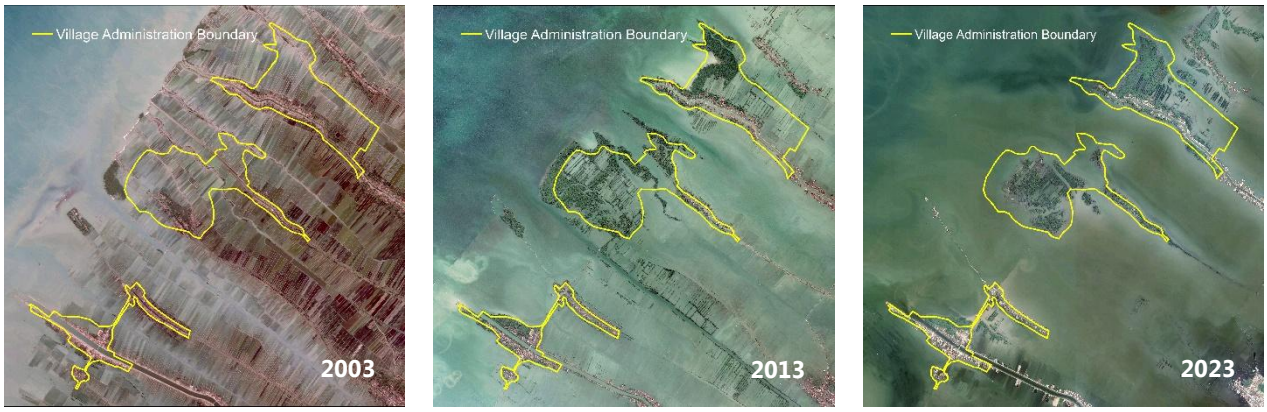


Figure 2. Google Earth Time-Series Data of Bedono Village Area in 2003, 2013, and 2023

The results of a time-series data search on Google Earth show a significant change in the coastline of Bedono Village. The condition in 2003 showed that the entire area of Bedono Village was still land. The enclave area of Bedono Village in the center and north is still quite far from the

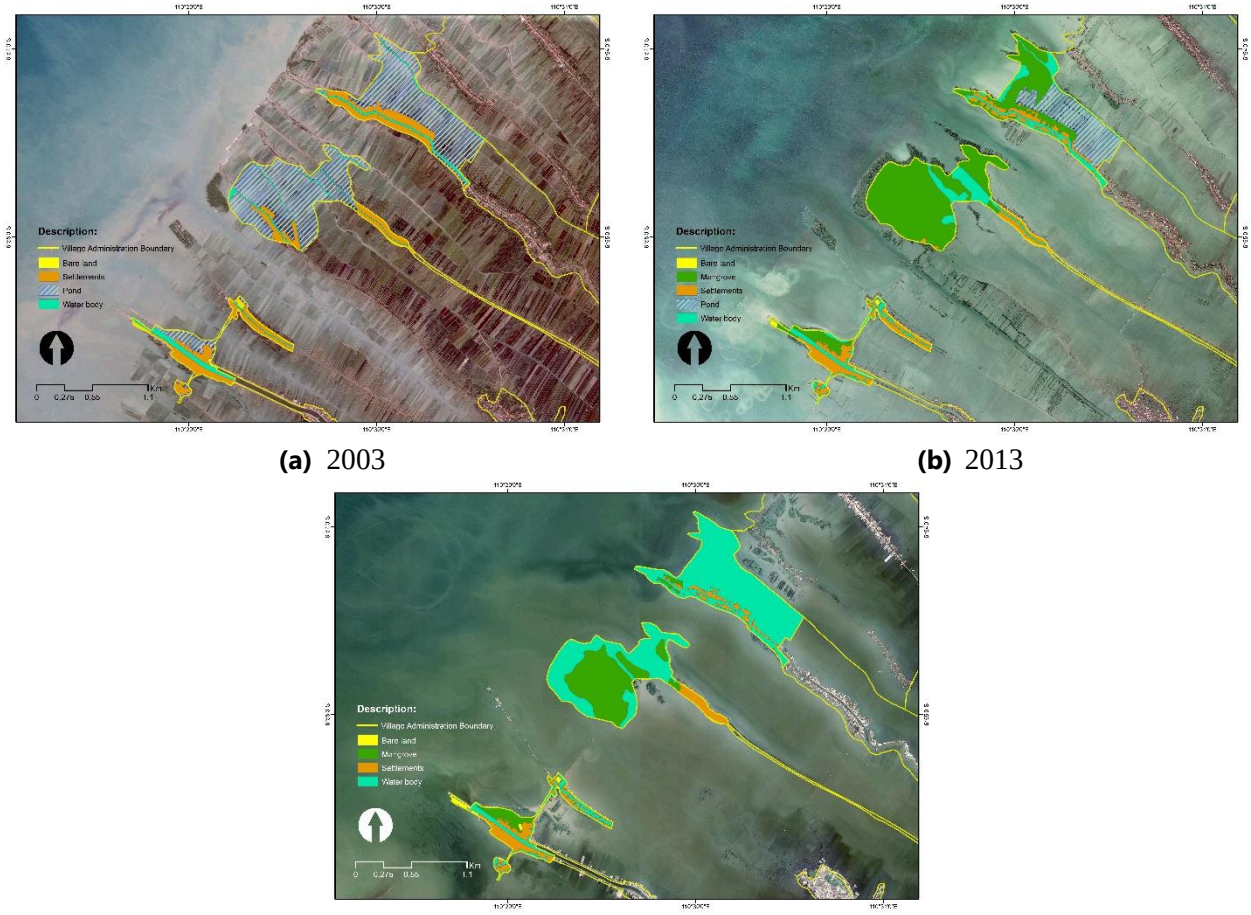
shoreline, with a distance of about 170-875 m. In the south, the enclave is already visible. Meanwhile, sea water intrusion has been seen in the southern part of the enclave, marked by the sinking of pond areas. The southern enclave is also directly adjacent to the shoreline. This enclave suggests that sea water intrusion began before 2003.

In just ten years, there has been massive sea-water intrusion that has significantly altered the coastline. The coastline has entered the land area behind the administrative boundary, separating Bedono village into three parts. The road network connecting the three regions has been submerged and cannot be used. Low-lying areas in the form of ponds within the village administrative delineation are beginning to be submerged.

Sea water continues to enter the land area in the next decade. The current condition shows more and more puddles within Bedono Village. The ponds are increasingly swallowed by sea water and are no longer visible. Mangrove areas that were visible in 2013 are diminishing, leaving only puddles. Even the central part of the enclave is no longer connected to the road network to the mainland of Java. The central part appears to be the most affected due to the small amount of land left.

Land Use Change Analysis

The three land use time-series data from Google Earth will be compared to analyze land use change. The larger scale display will clearly show the land use changes due to sea water intrusion over the past 20 years. Google Earth data from 2003, 2013, and 2023 were manually digitized with mapping software. The results of each year's land use delineation were calculated to determine its composition. For more details, land use changes in 2003, 2013, and 2023 can be seen in Figure 3.



(a) 2003 **(b)** 2013

(c) 2023

Figure 3. Comparison of Land Use in Bedono Village in 2003, 2013, and 2023

The results of land use calculations in 2003 showed that Bedono village land use was still dominated by pond areas covering 127.27 ha or 69.74% of the village area. The second largest land use is a settlement area of 38.01 ha or 20.83%. Next, land use is a water body in the form of a river flow of 15.76 ha or 8.64%. Meanwhile, no mangrove forest area exists because the entire village area is still land. Significant changes occurred in 2013, as evidenced quantitatively from previously no mangroves to the most dominating area of 93.11 ha or 51.02%. Water bodies became the second largest area at 33.46 ha or 18.34%. Water bodies within the village administration appear to be rivers and marine areas. The third and fourth are ponds and settlements with an area of 29.72 ha or 16.29% and 25.55 ha or 14%, respectively. The composition of land use changes continues to occur, and in 2023, it is dominated by water bodies covering 116.81 ha or 64.01%. Most of Bedono Village has been inundated by sea water, followed by a mangrove area of 42.71 ha or 23.40%. Then, the remaining settlement area is 21.62 ha or 11.85%. By 2023, there will be no pond area within the administrative area of Bedono Village. A more complete time-series land use composition of Bedono Village can be seen in Table 2.

Table 2. Land Use Composition of Bedono Village 2003-2023

Land Use	Area (ha)			Changes
	2003	2013	2023	
Open land	1.45	0.64	1.35	-0.10
Mangrove	0.00	93.11	42.71	42.71
Settlement	38.01	25.55	21.62	-16.38
Ponds	127.27	29.72	0.00	-127.27
Water body	15.76	33.46	116.81	101.05
Total	182.49	182.49	182.49	

* Data Analysis on November 2023

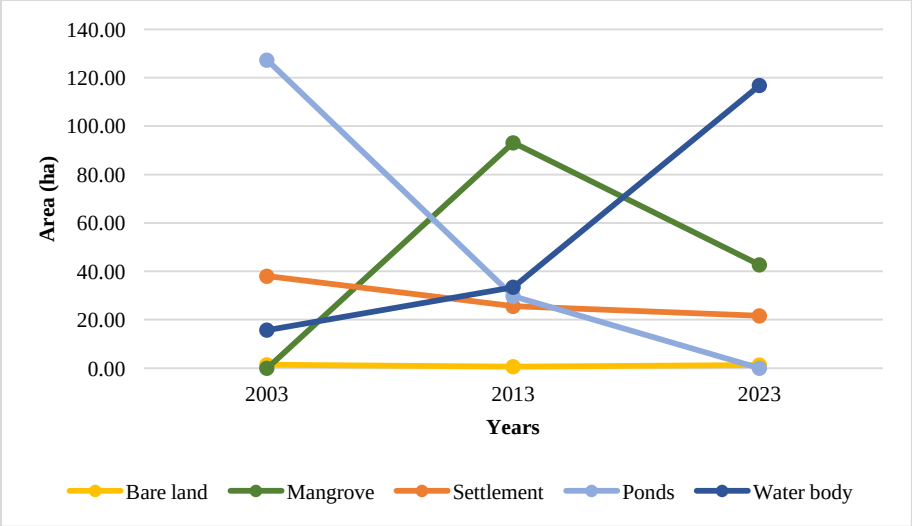


Figure 4. Graph of Land Use Change Rate of Bedono Village 2003-2023

From the time-series land use composition data, the rate of change of each type of land use can be analyzed (Figure 4). The graph of the rate of land use change in Bedono Village from 2003 to 2023 shows several patterns of change. Open land offers no significant change, with an area always less than 1%. The mangrove area experienced a sharp increase in 2013, then a sharp decrease in 2023. In 2003, there was no mangrove area at all, then a sharp rise in 2013 due to more waterlogged areas, and a decrease in 2023. Water bodies will always increase, becoming the most dominant area in 2023. Ponds and settlements show an ever-decreasing trend as the water body area increases due to ongoing sea water intrusion.

Settlement Building Change Analysis

A time-series comparison of the number of residential buildings was also conducted in this study to illustrate how many people are affected by shoreline change in Bedono Village. Following the trend of decreasing settlement areas, the number of dwellings continues to decline. An example of a significant reduction in residential areas can be seen in Figure 5. Housing buildings in 2003 can still be seen clearly, indicating residential areas connected by footpath networks. The condition in 2013 changed drastically, leaving only a few houses no longer connected to road networks around the yellow administrative village boundaries. In a decade, the area looked almost unpopulated. Then, in 2023, the condition got even worse; the residential area was gone, and only mangrove areas remained within the administrative boundaries of Bedono Village. Even visually, no land was left, only tidal areas overgrown with mangroves. New houses were found yearly in some locations, but more often, houses were submerged by sea water.

To estimate the number of people affected using identified residential buildings only. Public facilities such as places of worship and schools were not included as they do not reflect the population. In 2003, a total of 1.031 residential buildings could be identified. In 2013, there was a decrease in the number of residential buildings by 66 units to 965 buildings. In 2023, there was almost a 2-fold decrease from the previous 10-year period, amounting to 131 units and leaving 834 residential buildings. The total reduction of residential buildings is 197 units, resulting in a population affected of 778 people. Changes in the number of buildings and residents affected in more detail can be seen in Table 3.

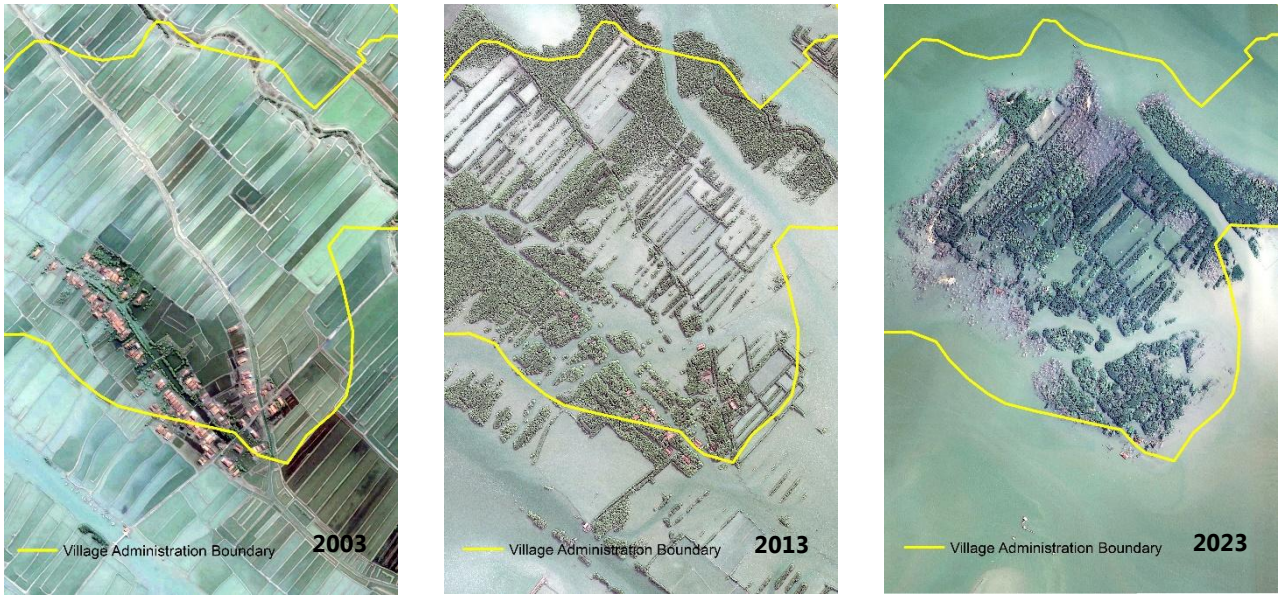


Figure 5. Lost Settlement in Bedono Village

Table 3. Number of Buildings and Estimated Number of Affected People

Years	Number of Residential Buildings (unit)	Estimated population (people)
2003	1.031	4.124
2013	965	3.860
2023	834	3.336
Total	-197	-778

* Data Analysis on November 2023

* Assumption of 1 house inhabited by 1 (one) family consisting of 4 people, based on SNI 03-1733-2004

Conclusions

The conclusion from the series of research stages that have been carried out is that the shoreline changes significantly and greatly affect the land use in Bedono Village. The area of settlements and ponds continuously decreases,

and there is no longer any pond area in Bedono Village. The number of buildings reduced in the last 20 years has almost reached 200 housing units, with an estimated population of 778 people affected. More than half of the village area is now a body of water, indicating that Bedono Village is close to sinking. If this changing trend continues without effort from various parties, Bedono Village may stay on the administrative map of Sayung Subdistrict, Demak Regency.

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