COASTLINE CHANGE DETECTION USING REMOTE SENSING APPROACH IN BULELENG REGENCY, BALI PROVINCE

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ABSTRACT: Coastline change induced by abrasion and accretion is complex processes triggered by natural and non-natural factors. The monitoring of these changes is very important to predict future changes, especially for the low-lying landscape that should be considered vulnerable to sea-level rise. Recently, the utilization of optical imaging satellites especially Sentinel-2 imagery for coastal areas has been used widely and effectively, considering the capability which has good resolution with a wide swath and high revisit time. The aim of this study is to detect and analyze the coastline changes of Buleleng Regency within the past 4 years from 2015 to 2019. This study was conducted along the coastline of 20 villages in Buleleng Regency, Bali Province, Indonesia using Sentinel-2 image with the acquisition date 19 March 2019, to describe the current condition and 23 November 23 2015, as an initial condition. The coastline detection is divided into two steps. First is image classification by supervised classification where each pixel has been labelled with one or three classes. And the second by applying the Modified Normalized Difference Water Index (MNDWI) to make border segmentation between sand and water. By using the overlay method between two satellite images, the areas experiencing abrasion and accretion can be determined. The result showed that the coastline changes of Buleleng Regency are dominated by abrasion processes where the total change in the entire study area is equal to 216,170 m^2. The highest abrasion was experienced by Temukus Village with 32,578 m^2 of loss. This study provides valuable information and can be used to prepare and develop adaptation policies for future mitigation of coastal areas.

1. INTRODUCTION

Coastal is an area that is always changing which has a dynamic nature (Winarso, *et al.,* 2001). Changes in the coastal area can occur slow to fast, depending on the factors that influence it. Coastline changes are indicated by the change of position, not only determined by a single factor but by several factors and their interactions which is a combined result of the process by nature and humans. Natural processes come from influence by oceanographic processes on the ocean like a wave, changes in current patterns, tide variations, and climate change. The coastal damage is caused by human activities (anthropogenic) such as land conversion which affect sediment transport along the coast.

Several beaches in Indonesia have experienced a lot of coastline changes due to occurrence abrasion and accretion such as in Buleleng Regency, Bali Province. The coastal area in Buleleng Regency is used in various land-use activities to support local community income. Buleleng Regency has a length of coastline 127 km and 29 km of coastline still experiencing the abrasion. Based on the Provincial Government of Bali (2015), almost 15 km of coastline has been handled. Human activity is the main cause of a disturbing balance system of dynamic processes in coastal areas.

Remote sensing is the advanced technology which is frequently used to monitor the coastline change through satellite image recording due to their large coverage and low cost. Remote sensing can observe an object on the earth surface to obtain the appropriate information desired without directly contacting the object and providing historical acquisition image archives. This technique has proved its effectiveness in providing accurate information for monitoring coastline changes. For example, Toure *et al*. (2019) conducted a study of the art review of coastline detection using optical remote sensing with different key concepts. In 2019, Valderrama-Landeros and Flores-de-Santiago revealed a highly distinct result of assessing coastal erosion and accretion trends along two contrasting subtropical rivers based on remote sensing data on spatial and temporal scales at the southern part of the Santiago River mouth. Dewi and Bijker (2020) utilized remote sensing and GIS techniques to observe the dynamics of shoreline in Sayung, Indonesia using a combination of fuzzy classification and post-classification comparison. Sui *et al*. (2020) studied the characteristics of Indonesia's coastline changes in the past 28 years, concluded that the area of Indonesia's landward erosion was 388.09 km^2, and the area of seaward expansion was 770.14 km^2.

This study aims to detect and analyze the coastline changes of Buleleng Regency within the past 4 years from 2015 to 2019 and expected to provide valuable information that can be used as a reference to the government, local community and related stakeholders in order for regional development and adaptation policies for future mitigation of coastal areas.

2. THE METHODS

2.1 Study Area

The study was conducted in Buleleng Regency, the northern coast of Bali Province, Indonesia. Consist of 20 villages in 3 districts, which is approximately 28 km of coastline and characterized by a low-lying landscape with an elevation of less than 10 m above mean sea level. The coastal typology of this study area consisted of marine deposition with beach material from iron-sand. The area has a mixed semidiurnal tide with values ranging from 2.0 to 2.2 m of tidal range.

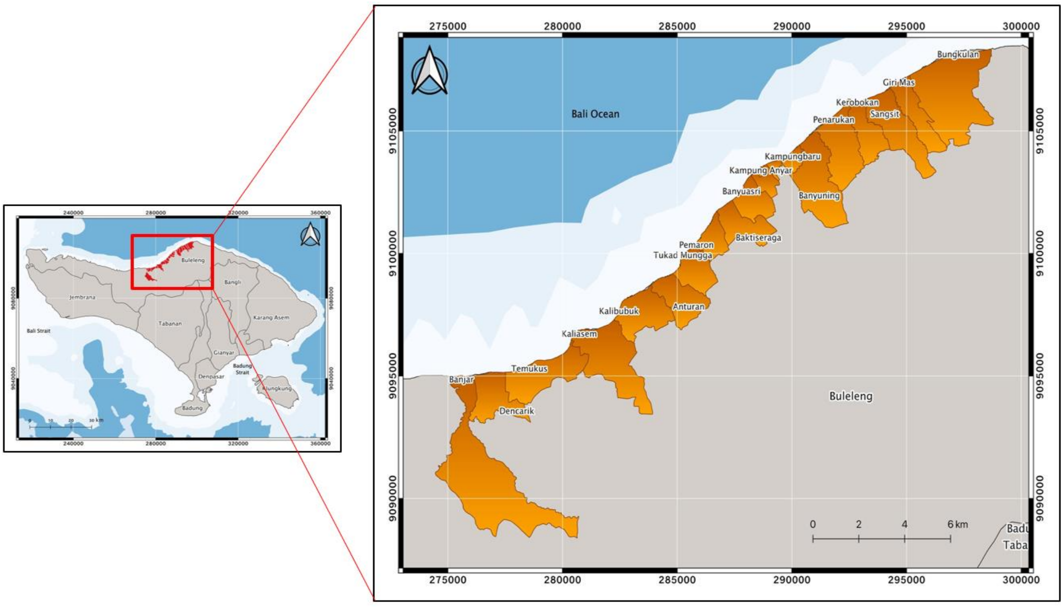

Figure 1. Study area

2.2 Datasets

Multitemporal image data is needed to identify the coastline changes. Multitemporal image meaning that some image has time different, with a significant interval. Image data need to be processed to see the changes by image compositing. The composite image shows a difference in a complete physical picture between land and water with welding characteristics based on pixel value. Analysis of differences in image processed results can be determined whether there is or not changes.

The coastline change analysis is carried out by comparing Sentinel-2 image with the acquisition date 19 March 2019, to describe the current condition and 23 November 2015, as an initial condition. All images were projected in UTM Zone 50S.

Table 1. Astronomical Tide Level Information

Acquisition Date	Astronomical Tide Level (m)
23 November 2015	0.154
19 March 2019	0.156

Sentinel-2 is a multispectral image with fine resolution provided by European Space Agency (ESA) which has a mission to observe the land, vegetation, water, and coastal areas. This satellite launched on June 23th, 2015, and free of charge. Sentinel-2 has 13 spectral bands: near infrared and four bands at 10 m, six bands at 20 m, and three bands at 60 m spatial resolution (European Space Agency, 2018). Each of these bands has each function. For coastline detection applications, the relevant spectral bands are the visible bands (Blue, Green, Red), the near-infrared band (NIR), and the short-wave infrared band (SWIR).

2.3 Pre-processing

Prior to extracting the coastline, the Top of Atmosphere (TOA) images are pre-processed as follows:

Cloud masking: The cloud mask is used to discriminate the reflectance of cloudy and cloud-free pixels. The percentage of cloud cover is calculated based on the number of cloudy pixels inside the area of interest and a user-defined cloud cover threshold is used to discard all the images that exceed a certain percentage of cloud cover.

Down-sampling: Spatial resolution of the satellite image needs to be enhanced to achieve optimal coastline detection. The 20 m SWIR1 band of Sentinel-2 images is down-sampled to 10 m by bilinear interpolation so that all the bands are at 10 m resolution.

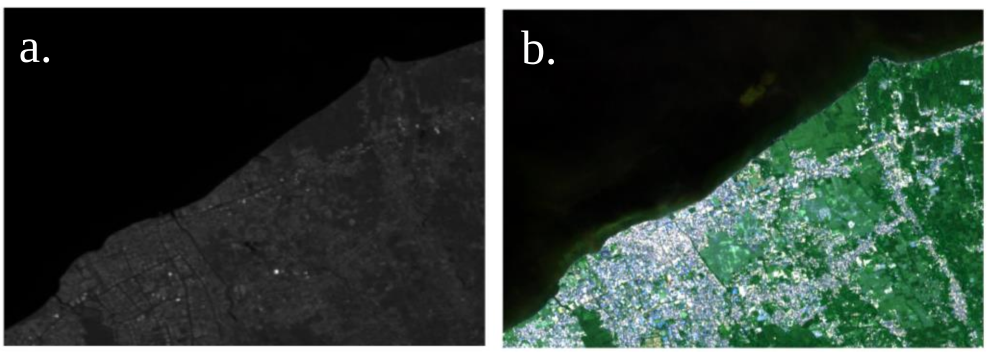

Figure 2. a) The 20 m band image; b) The 10 m band image

Figure 3. The down-sampled to 10 m image

2.4 Coastline Change Detection

There are two steps in this algorithm: (i) image classification (ii) sub-pixel resolution border segmentation by applying The Modified Normalized Difference Water Index (MNDWI).

The objective of image classification is to extract information from a set of homogeneous and natural regions into classes. This step is to find the pixels within every image that correspond to sand and water by supervised classification.

Modified Normalized Difference Water Index (MNDWI) is one of the best methods to discriminate water from land features with an accuracy rate of 99.85% (Xu, 2006). This method also widely applied to mapping the water bodies (Du *et* al., 2016; Hasan *et al.*, 2019). MNDWI calculated as follows:

$$MNDWI = \frac{SWIR1-Green}{SWIR1+Green} \quad (1)$$

Figure 4. a) RGB image of certain study area; b) Output of image classification where each pixel has been labelled with one of three classes; c) Grayscale image of the MNDWI pixel values

Where SWIR1 and Green are the pixel intensity in the short-wave infrared band (1.55-1.65 µm) and green band (0.52-0.6 µm). The MNDWI value is computed for each pixel, resulting in a grayscale image with values ranging from -1 to 1.

Coastline changes that occur at Buleleng Regency obtained by comparing coastline in 2015 and 2019 using the overlay method. This method is commonly used to detect longer-term coastline changes. The displaced coastline is then measured and the rate of change calculated.

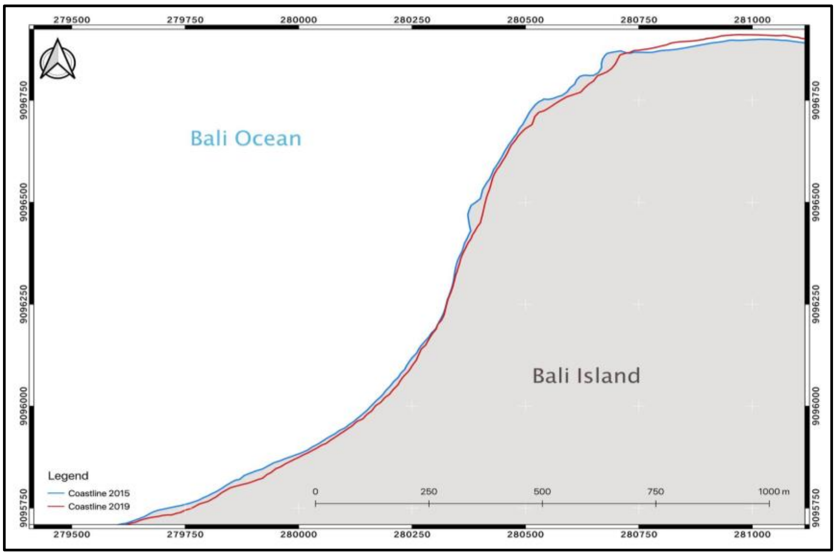

Figure 5. The overlaying image from different years

3. RESULT AND DISCUSSION

The coastal morphology of Buleleng Regency generally grouped into "mountainous cost", that is coastal made by volcanic eruption and classified as sandy beach. Based on satellite image overlay can note that the whole study area experienced the coastline change mostly is abrasion (Figure 6, Figure 7, and Figure 8). In general, all along the coastline at the study area shows that for 4 years there has been a change in its coastline. Figure 6 showed that the most abrasion was observed along the Temukus Village with 32,578 m^2 and the accretion was confined to Kaliasem Village with 8,756 m^2. The details of area changes in Banjar District can be seen in Table 2. As with abrasion, accretion will occur. The reason for this accretion could be caused by the longshore current processes that allow the water to transport sediment.

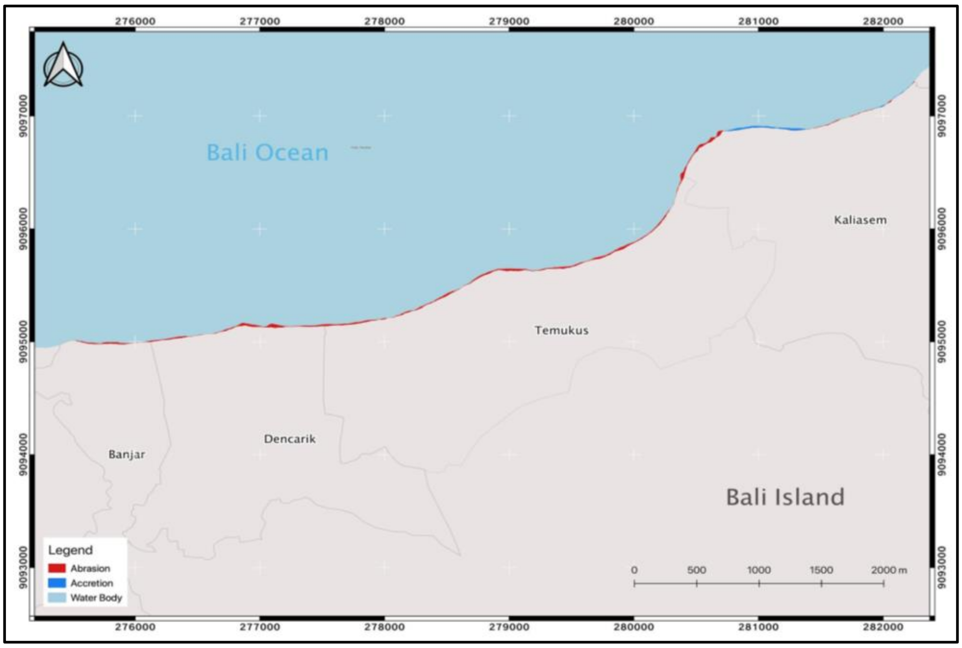

Figure 6. Coastline change at Banjar District

Buleleng District consists of 12 villages. The coastal area in this District is currently experiencing damage due to abrasion (Table 2) and not much vegetation, because the narrow and rocky beach as seen at Penarukan beach, is quite difficult to develop mangrove plantation. However, it was also found the possibility to develop mangrove plantation, even though the area was not large. Hence, the most abrasion was observed along Panarukan village with 26,499 m^2. Meanwhile, at Kampung Bugis is already covered by artificial buildings, such as concrete slabs to restrain the rate of abrasion. From Figure 7, it is obvious that during this period the study area at Buleleng District experienced the abrasion with total sediment loss 117,845 m^2, with the largest contribution of the changes at Panarukan village. The second-largest abrasion is also obvious at Banyuasri village with 20,805 m^2.

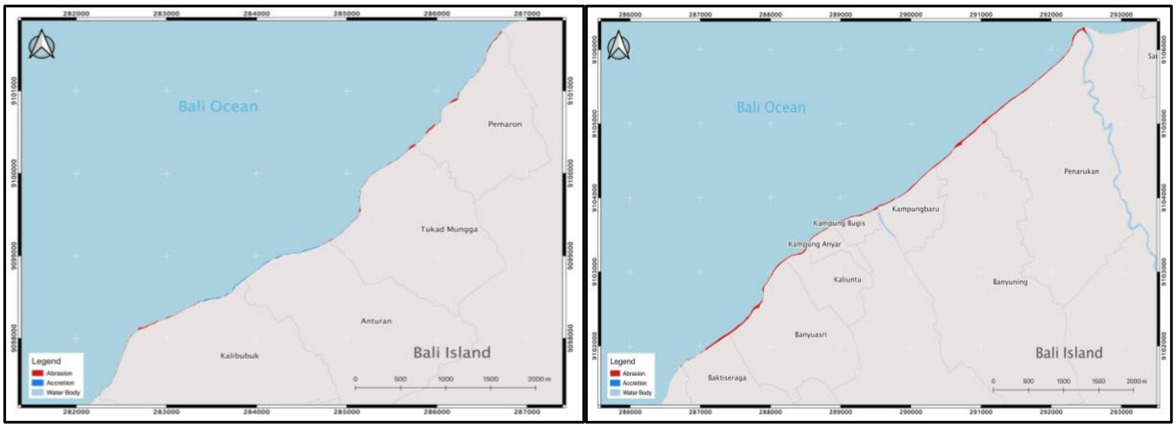

Figure 7. Coastline change at Buleleng District

The coastline of 2019 at Sawan District was retreat as compared to 2015. Total sediment loss at this district is 36,980 m^2 with the most abrasion located at Bungkulan village with 18,573 m^2 changes. At Sawan District, there are three rivers which cut away the coastline and enter the sea (Figure 8). The accretion was occurring in the river between Sangsit and Giri Mas village. This happens due to the sediment deposition that occurs caused by reduction of current velocity when reaching a point where the coastline disappears, either because of a river and unable to carry the sediment back to the ocean. On the other hand, the river mouth is also a great vulnerable area to coastline changes. This area is very dynamic considering the changes occur as a result of sedimentation processes and may take seasonally.

Figure 8. Coastline change at Sawan District

Table 2. Information of coastal area changes (m^2) at Buleleng Regency in the past 4 years

District	Village	Sediment Loss (m^2) Abrasion	Sediment Increment (m^2) Accretion
Banjar	Banjar	4,577	-
	Dencarik	14,059	-
	Temukus	32,578	-
	Kaliasem	10,131	8,756
	Total	61,345	8,756
Buleleng	Kalibubuk	5,975	4,953
	Anturan	498	5,205
	Tukad Mungga	4,533	1,892
	Pemaron	8,275	1,364
	Baktiseraga	10,227	39.48
	Banyuasri	20,805	82.95
	Kaliuntu	4,479	-
	Kampung Anyar	4,082	-
	Kampung Bugis	6,984	-
	Kampung Baru	10,711	-
	Banyuning	14,777	-
	Penarukan	26,499	-
	Total	117,845	13,536.43
Sawan	Kerobokan	11,413	-
	Sangsit	5,499	597
	Giri Mas	1,495	1,558
	Bungkulan	18,573	721.7
	Total	36,980	2,876.7

Waves and ocean currents are natural phenomena that greatly affect the study area. The waves that occur are influenced by wind and fetch distance. Dominant waves at Buleleng Regency coming from the west and east according to the monsoons (Triadi *et al.,* 2016). Wind speeds of continuously reaching the coastal area can erode the land area, which in turn brings backflow the longshore current that results in sediment transport to other places.

The coastline changes in the study area are caused by several natural factors, including wind and waves, currents, tides, as well as sediment transport. Based on Balai Wilayah Sungai Bali-Penida in Balipost (2018) the main factor which triggered the abrasion is the sediment loss. The volume of sand can actually be maintained if the watershed from the upstream area flows sedimentation to the beach in large volumes. But the sediment supply from the watershed has been reduced so that the ocean waves will easily erode the land.

Technically, the occurrence of abrasion is because of sediment loss in the coastal zone. This sediment loss is influenced by the wave or other factors. Due to the importance of the processes that occur along the coastline, rapid and reliable techniques are required to monitor the changes. The abrasion also triggered by the bare land with no vegetation covers along the study area (Wesnawa, 2015).

Coastal areas in Buleleng Regency are also threatened by the sea-level rise which the rate per year is 5.1 cm/year (Putra, 2013). This sea-level rise could affect abrasion, transport, and deposition of sediment which are responsible in maintaining the coastline (Cartier, *et al.*, 2013).

Figure 9. The revetment at Buleleng beach to protecting the coastline from abrasion (Source: Balipost)

Many prevention attempts have been conducted by the local government and local community as the effort to protect the coastal area has been made by building the revetment, seawall, groin, artificial headland and detached breakwater. But the existing coastal protection structures are not optimal in efforts to protect the coast.

4. CONCLUSION

The coastline of 2019 at Buleleng Regency was retreat as compared to 2015. Analysis of Sentinel-2 image to obtain coastline change data shows that the whole study area experienced the coastline change mostly is abrasion. The rate of abrasion for these periods is more than 54,042 m^2/year causing the coastline retreat for almost 216,170 m^2 for four years. This coastal abrasion is a major problem at Buleleng Regency and has not been resolved optimally. The newly-launched Sentinel-2 can provide fine spatial resolution multispectral imagery at a fine temporal resolution. This study suggests that multi-temporal satellite data with GIS can be effectively used for detection of coastline change; however, there is a need to improve the spatial, as well as temporal resolution, for a more accurate assessment. Sediment reduction from the watershed may be one reason for the abrasion along the study area. The Temukus village is more vulnerable to abrasion due to the high abrasion rate.

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