Detection of Arosbaya Coastline Changes Using Sentinel-2A (Study Year of 2015-2018)

M Taufik\textsuperscript{1, 3}, L D Nugraini\textsuperscript{2}, D G Pratomo\textsuperscript{1}, A Kurniawan\textsuperscript{4} and W Utama\textsuperscript{5}

\textsuperscript{1, 3, 4} Geomatics Engineering Lecturer, Institut Teknologi Sepuluh Nopember
\textsuperscript{2} Geomatics Master Student, Institut Teknologi Sepuluh Nopember
\textsuperscript{5} Geophysics Engineering Lecturer, Institut Teknologi Sepuluh Nopember

*Email: taufik_m@geodesy.its.ac.id, lysadoraayu@gmail.com

Abstract. Coastal changes are influenced by several natural conditions like beach balance and estuary. The most obvious fact from this condition which can be seen by 10 meter resolution of Sentinel-2A imagery is the erosion and accretion at the coastal area. This study found that the average of Arosbaya coastline changes from 2015 until 2018 suffer from erosion up to -1.099 meters. The coastline changes in Lajing village is uniform from south to the north. Almost all coastline shave eroded, with the average of -16.365 meter erosion and -83.105 meter maximum erosion value. However, Tengket village which is located in the north of Lajing shows different result. A high number of accretions is identified in this village with accretion rate up to 15 meters and the maximum accretion rate up to 275.0432 meters. The condition of Tengket village shows that the new land is unstable. It is not only because of natural ocean parameters from south still influenced by the Madura strait exit but also the sediment build-up from Tambangan estuary in the north of Tengket village. The effect of this condition takes form of area changes both of coastal villages from 2015 until 2018 period. There was 701.565 ha of area loss in Lajing Village; however, 902.6912 ha of new area was constructed in Tengket village making Arosbaya became 167.034 ha larger in 2018 than in 2015.

Keywords: Arosbaya, Coastline Changes, Sentinel-2A

1. Introduction

1.1. Background

Triatmojo (1999) in Sulma\textsuperscript{1} said that coastline is unfixed border between land and waters which move following sea water tides and beach erosion. Meanwhile, the coastline change rate is interpreted as a coastline profile in the stability process (back and forth) every year\textsuperscript{1}. The coastline set in the Indonesian Earth Map is determined by the average of sea level\textsuperscript{2}. The coastline changing speed in the coastal area is influenced by dynamic balance of the beach. The most obvious facts that can be seen from satellite images are erosion and abrasion at coastal areas. A stable beach is formed if beach balance value is zero. On the other hand, erosion will be discovered if beach balance is in positive value otherwise abrasion will be identified when beach balance value is negative\textsuperscript{3}.

The dynamic process of beach balance is influenced by sediment movement near the beach area\textsuperscript{4} like littoral drift from oceanographic parameters, such as: current, tide and wind. The continuous interaction between them and waters bottom causes the morphology of coastal region become very dynamic. Beach with parallel current, called long-shore current, has current which flows in the shallow water parallel with coastline and generally downwind. Long-shore sediment transport caused
by current along the beach is often sufficient enough to erode the bottom of waters [5]. The function of current is as sediment transport media which is influenced by wave blow act as corrosion agent [6].

Arosbaya is one of the sub-districts located on the west coast of Bangkalan district. As westernmost coast, Arosbaya sub-district has been influenced by current coming from the Madura straits exit in the south to the north direction. However, there is incidentally a large river on the north side of Arosbaya as border to Klampis sub-district whereas downstream of the river ends in Tengket, one of Arosbaya coastal villages. Hence, there is an existing meeting point between long-shore sediments carried by the current from the south with the river mouth in the village of Tengket collected in Tambangan estuary.

Sentinel-2A imagery is a 10 meter resolution of satellite image which not only belongs to free-high resolution imagery but also popular to land and waters study interpretation. Sentinel-2A has various bands with various wavelengths. However, the multi-temporal resolution for coastal changes monitoring has its own limitation because of its launching in the middle of 2015.

1.2. Research Questions and Purpose
This research will discuss about the formulation of the problem as follows:

a. Does Arosbaya coastal area change from 2015 to 2018?
b. How much is coastline change rate in Arosbaya sub-district?
c. How good does Sentinel-2A monitor coastal changes?

This study aims to examine the existence of any coastal changes in Arosbaya sub-district between 2015-2018, to measure the coastal changes rates and to analyze Sentinel-2A’s ability to monitor coastal changes.

2. Methods

2.1. Characteristic of Arosbaya Sub-District Location
Arosbaya sub-district is a coastal area located in the westernmost of Bangkalan district. From the following Figure1, it is illustrated that Arosbaya has two coastal villages. They are Lajing village in the south and Tengket village in the north. Both of them directly adjacent with waters where the Madura Straits and the Java sea meet. The border on the north side of Tengket village is Tambangan river. Arosbaya sub-district location can be seen in the following figure:

![Figure 1. Study Location](image)

2.1.1. Coastline Morphology. Arosbaya has a declivous coast which is indicated by the beach topography having 0.18% average of slope gradient. Bathymetry National known as BATNAS informs that depth at a distance of 1.1 km from the Arosbaya coastal line edge is worth -1 m against MSL. The following Figure2 (b) describes the Arosbaya coastal profile taken from BATNAS-v.1.1. This profile is line 1 cross-section taken from Figure2 (a).
2.2. Data and Tools
This research employs new remote sensing satellite which is launched by ESA in 2015. This Sentinel-2A satellite image has 10 meter resolution being able to capture object with minimum area of 100 square meters per pixel. Sentinel-2A has various spectral bands also. In this study, we try to combine band NIR, red, and green as false infrared color to detect the edge of land. Afterwards, the researchers separate it utilizing visual interpretation.

To examine coastline changes, the researchers utilize two images of Sentinel-2A data, 24th October 2015 and 27th December 2018 images. Those data were collected in rainy season with cloudless sky condition. Moreover, National Bathymetry (BATNAS) version 1.1 having 6-arcsecond resolution is utilized in this research. BATNAS is useful to indicate water depth in Arosbaya coastal area and to derive the side view of coastline change position. From this side view, the researchers hope that high difference of coastlines value between 2015 and 2018 can be calculated.

Arcgis 10.3 is the most used software in this research, not only for on-screen digitizing but also image processing. However, additional software like SNAP software to read .jp2 format and convert it to .tiff format is necessary to employ.

2.3. Research Flowchart
The following subsection depicts the research flow step by step.

![Research Flowchart Diagram](image)

Figure 3. Research Flowchart

From the previous Figure3, we can explain step by step on this research. Firstly, Sentinel-2A image opened in SNAP software to convert .jp2 format to .tiff format. Afterwards, NIR, red, and green band will be processed in Arcgis 10.3 software. These processes include subset and color combination, develop a border between waters and land utilizing on-screen digitizing, and define it as coastal line. The following process is checking the overlay of 2015 to 2018’s coastal line and conducting transect
analysis to get the coastline change rates. The final process will be executed by adding cross-section visualization to get a high difference of coastline changes value.

3. Results and Discussions

3.1. False Color Infrared Band Combination

Natural color combinations in satellite image consist of red-green-blue in visible wavelength sequence. However, sometimes the response of water and vegetation object in this wavelength shows similarity[8] while they are almost always separable in the infrared wavelength. This study employs the characteristics of NIR wavelength interactions to distinguish water color from other objects. The researchers aim to darken the color of water but still maintain the color of other objects. It is useful for detecting land edge and separating land from water. Hence, the researchers can define the border between land and waters from Sentinel image visual interpretation.

By using Near Infrared’s wavelength (NIR), as seen in Figure 4, the color of water will be darker than others. It is because water absorbs energy as much as 90 % of the total energy received. Figure 4 presents that water objects reflect at most 10% of the electromagnetic energy. Water reflects electromagnetic energy in the visible range and casts back a little in NIR range. All energies higher than 1,200 nm will be absorbed[9]. this situation will darken water object when high wavelength value is applied. On the contrary, vegetations will reflect EM energy in maximum value when NIR wavelength is applied, absorbing wavelength in blue and red range because of photosynthesis needs.

Sentinel-2A’s Near Infrared band (B08) which has 842 nm central wavelength is chosen to replace the red in the RGB (Red, Green, Blue) sequence. Green is replaced by Sentinel-2A’s red band (B04) which has 665 nm central wavelength while blue is replaced by Sentinel-2A’s green bands (B03) 560 nm central wavelength. This combination bands (8-4-3 band combinations) suggests false color infrared which is usually utilized for vegetation applications [10].

3.2. RX Detector

This study utilizes Reed-Xiaoli Detector (RXD) to check the 2D position of coastline extracted from Sentinel 2 using 843 band combinations. This method becomes an option when validation in the field is not possible. RXD is an algorithm to detect the spectral or color differences between a region to be tested and its neighboring pixels or the entire dataset[11]. The anomaly defined by this method is spectrally distinct from the image background. The formulation of this method is as follows[11]:

$$\delta_{\text{exp}}(r) = (r - \mu)^T K_{\text{LxL}}^{-1} (r - \mu)$$  \hspace{1cm} (1)

With:
- \(r\) = sample vector
- \(\mu\) = sample mean
- \(K_{\text{LxL}}\) = sample covariance matrix

Linear enhancement is also conducted after RXD application. It is useful when the RXD result needs color manipulation, but it does not eliminate the boundary information obtained from RXD anomaly filters.
Figure 5 illustrates the effect of the NIR Band on the coastline extraction with Sentinel 2 imagery. 843 band combination can distinguish water and land objects because the NIR makes water darker than the natural color combination, sharpening the vegetation objects and defining coastline. RXD shown by Figure 5 makes the 843 combination even more convincing in this study area because no difference is examined between the coastline level extracted from 843 compared to RXD, with a match level of 65.236%.

3.3. Transect Analysis

The transect analysis method used in this research is Net Shoreline Analysis (NSM). The principle of this method utilizes coastline morphological changes through the difference in distance that appears between the old coastline and the new one on each transect [12].

There are two coastal villages in Arosbaya which were examined in this study from 2015 until 2018. Lajing village in the southwest and Tengket village in the northeast. From the NSM method, it is identified that uniform abrasion occurs in Lajing village. This study employs two samples, as shown in the following Figure 6, taking place in the Lajing coastline to identify the behavior of this coastline changes. The result shows that the shoreline average values retreated 17.674 m towards land (see Table 1).

Table 1. Lajing village condition in 2018

| Lajing Village Condition | Value (m) |       |       |
|-------------------------|-----------|-------|-------|
| Abrasion                | max       | min   | Average |
|                         | -1.366    | -83.105 | -17.674 |
| Accretion               | 35.843    | 15.279 | 15.279 |
| Total Value             | 35.843    | -83.105 |         |
| Total transect line     | 453       |       |         |
| Conclusion              | Abrasion  |       | -16.365 |

The red line in Figure 6 indicates abrasion condition; meanwhile, the blue line indicates accretion. Accretion in Lajing village is minority. It is happened only in south with the maximum value of increasing land is 35.843 m in 2018 as noted in Table 1. However, an abrasion on this coast is identified in north region approaching Tengket village. Sample box-a shows the abrasion value being closely resemble the average value. It is found along 4 km from south to north. Getting closer to the north area, the abrasion increases significantly. Sample box-b shows that the abrasion value in this place is higher than that of the previous value. The maximum abrasion value as shown by Table 1 is in -83.105 m; contributing a large value to the total average abrasion value in Lajing Village.

Tengket village present dissimilar findings. High value of accretion was identified in Tengket northernmost area. There is a maximum of 275.043 meters. As presented in Table 2, new land was...
added near Tambangan mouth river for 3 years. This accretion position, strangely, is not fixed. Abrasion occurred on the west side of the new island, as presented by box d of Figure 7, but there was an accretion on the east side as shown in box c of Figure 7. Each box in Figure 7 presents dynamic condition of Tengket village.

**Table 2. Tengket village condition in 2018**

| Tengket Village Condition | Value (m) |
|---------------------------|-----------|
|                           | max       | min     | average |
| Abrasion                  | -4.459    | -79.365 | -35.153 |
| Accretion                 | 275.043   | 2.686   | 66.856  |
| Total Value               | 275.0432  | -79.365 |         |
| Total transect line        | 429       |         |         |
| Conclusion                | Accretion | 15.019  |         |

The changing rate in coastline morphology in Tengket village is relatively fast. From the enlarged box-c, it is identified that within 3 years the transect distance that depicts the difference in position between the 2015 coastline and the 2018 coastline has a relatively large value. The high value of this coastal changes cannot be predicted to remain unchanged in the next 3 years. The abnormal accretion speed is not only influenced by natural factor, but also the unstable condition of this new island.

### 3.4. Cross-section Profiles

To discover the Arosbaya coastline changing condition from another side view, this study attempts to make one cross section sample of each coastal village. This profile aims to exhibit the coastline position extracted from Sentinel and its position from the topography. Figure 8 presents the considerable difference of Lajing village coastline from BATNAS data.

**Figure 7. Transect in Tengket Village**

**Figure 8. Lajing Village Cross Section 1 Profile**

Figure 8 (a) is top view of cross section 1 located in Lajing village. This crossing line is an extension of the transect line plotted over Sentinel images that have been equipped with topographic data. Figure 8 (b) is the coastline position from the Figure (a) side view. From this Figure, the position of 2018 coastline moving 17 cm higher from 2015 coastline and 15 m retreating towards land can be identified. Even this 2018 coastline has shifted as far as 15 meters with a difference in height of only 4 cm from 2006 coastline taken from BIG sub-district boundary data. From this condition, it can be concluded that the slope of the coast also has an effect on the speed of accretion in Lajing village.
The previous Figure 9 illustrates how dynamic Tengket village coastline is in cross-section 2. From left to the right in Figure 9 (b), abrasion in 2015-2018 was recorded as high as ±52 cm and as far as ±55 m eroded this new island which was not exist in 2006. At the same period, the right side of this new island run into significant accretion. 80 m and 52 m of new land have been added with a high difference which is almost non-existent. This dynamic condition also happened in 2006-2015 period with the formation of 102 m new land in cross section 2.

3.5. Coastline Change Rates

Arosbaya coastline change rates are measured by calculating the average of entire transect length, and it is divided by time. Table 3 informs the result of Arosbaya coastline change rates.

| Location               | Total Transect Value | Transect Total Number | Average      | Annotation       | Period | Coastal Changes Rates |
|------------------------|----------------------|-----------------------|--------------|------------------|--------|-----------------------|
| Lajing Village         | -7413.286 m          | 453 unit              | -16.365 m    | Abrasion         | 3 yr   | -5.455 m/yr           |
| Tengket Village        | 6443.360 m           | 429 unit              | 15.019 m     | Accretion        | 3 yr   | 5.006 m/yr            |
| Arosbaya sub-district  | -969.926 m           | 882 unit              | -1.099 m     | Abrasion         | 3 yr   | -0.367 m/yr           |

From 2015 to 2018, Arosbaya coastline has abrasion average value at a rate value of 1.099 m and 0.367 m/year (see Table 3). It is because abrasion which occurred along the coastline of Lajing village, having a coastline length up to 13 km, contributed the value of Arosbaya coastline change significantly. Whereas Table 4 informs Arosbaya coastal area change rates in 2015-2018 period.

| Location               | Area              | Difference         | Annotation |
|------------------------|-------------------|-------------------|------------|
| Lajing Village         | 753297.041 m²     | -701.565 ha       | Lose       |
| Tengket Village        | 5191189.551 m²    | 902.691 ha        | Increase   |
| Arosbaya sub-district  | 44329123.49 m²    | 167.034 ha        | Increase   |

Coastline changes have an impact to region area changes. From Table 4, Arosbaya becomes 167.034 ha larger even though Lajing loses its coastal area due to abrasion. This additional area was caused by the relatively large accretion in Tengket villages in the 2015-2018 period. It is can be seen from Table 4 that 902.691 ha area was added to a new island near to Tambangan river mouth, although
the average change in coastline in this village only increased by 15 m towards the sea as presented by Table 3 and Figure 7.

4. Conclusion
From the result above, it can be concluded that there are coastline changes in Arosbaya from 2015 until 2018 with abrasion at a rate value of -1.099 m and -0.367 m/year. Arosbaya becomes 167.034 ha larger even though Lajing village loses its coastal area due to abrasion. It was caused by the relatively large accretion in Tengket villages with 902,691 ha.

Sentinel-2A is a good image satellite which can be used for coastline detection. When checked by RXD filter, the extracted coastline from Sentinel almost has no difference with a match level of 65.236%. Its high spatial resolution and its number of band help observers to distinguish between land and water objects. This important step determines the accuracy in the on-screen digitizing process, so that it can minimize as many errors as possible. By using 843 band combinations, coastline in Arosbaya can be detected, and the changes can be calculated.

The use of BATNAS data has good prospects in completing the coastline study in the future. However, because of its resolution limitation, BATNAS is not the best choice. Its 6-arcsecond resolution cannot compensate coastline accuracy resolution extracted from the Sentinel data. The profile shown is relatively flat, so the researchers cannot identify the coastline change position from the topography visualization. Even though it is considered as important to know the position of extracted coastline change from satellite imagery as real or temporary driven by tidal behavior. Field bathymetric measurement is suggested for more accurate sea bed topography.

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