SHORELINE CHANGES AFTER THE SUNDA STRAIT TSUNAMI ON THE COAST OF PANDEGLANG REGENCY, BANTEN

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Abstract. The Sunda Strait tsunami occurred on the coast of west Banten and South Lampung at 22nd December 2018, resulting in 437 deaths, with 10 victims missing. The disaster had various impacts on the environment and ecosystem, with this area suffering the greatest effects from the disaster. The utilisation of remote sensing technology enables the monitoring of coastal areas in an effective and low-cost manner. Shoreline extraction using the Google Earth Engine, which is an open-source platform that facilitates the processing of a large number of data quickly. This study used Landsat-8 Surface Reflectance Tier 1 data that was geometrically and radiometrically corrected, with processing using the Modification of Normalized Difference Water Index (MNDWI) algorithm. The results show that 30.1% of the coastline in Pandeglang Regency occurred suffered abrasion, 20.2% suffered accretion, while 40.7% saw no change. The maximum abrasion of 130.2 meters occurred in the village of Tanjung Jaya. Moreover, the maximum shoreline accretion was 43.3 meters in the village of Panimbang Jaya. The average shoreline change in Pandeglang Regency was 3.9 meters.

Keywords: *Landsat-8, Google Earth Engine, Abrasion, Tanjung Jaya, MNDWI*

1 INTRODUCTION

The tsunami disaster occurred on the coast of the Sunda Strait, including the coasts of Pandeglang, Serang and South Lampung Regency. The tsunami occurred on December 22th, 2018 at 21:27 local time (UTC + 7), the result of an underwater landslide after the eruption of Mount Anak Krakatau. At the same time, there was a high tide due to the influence of the full moon. According to BNPB (2019), the impact of the tsunami resulted in the deaths of 437 people, with 10 missing and 31,943 injured

Pandeglang Regency is located on the west coast of Banten in subduction zone. The zone originates from the meeting of the Indo-Australian plate and the Eurasian Plate. Besides earthquakes, there are active volcanoes that can cause damage, either man-made or natural. Mount Anak Krakatau is an active vulcano in the Sunda Strait, located directly opposite Pandeglang Regency. Therefore, there is a need for efforts to minimise the impact on and inventory changes to coastal areas in the management and protection of coastal ecosystems for sustainable development. Remote sensing techniques are currently being developed in various fields, enabling efficient and low-cost monitoring, including that of coastal zones. These are one of the most dynamic environments on the earth's surface because of natural and anthropogenic effects (Goncalves, Duro, Sousa & Figueiredo, 2015). The increasing volcanic activity of Anak Krakatau in 2018 raised concerns about a major disaster in the area around the Sunda Strait, with the potential to spread in all directions. Therefore, the shoreline faced a potential major impact from the volcanic activity in the area.

The increase and decrease in the coastal area each year can be calculated

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and monitored. In most coastal areas, natural changes occur more rapidly than in other environments, apart from areas subject to earthquakes, floods and volcanoes. There are two kinds of shoreline change : forward changes (accretion) and backward changes (abrasion). The former is characterized by indications of deposition and/or merger. However, the coastline is said to be retreating if there is a process of abrasion and/or submergence (Sudarsono, 2011).

A shoreline is defined as a line of contact between land and a body of water. Although is easy to define, it is difficult to capture because of the natural variability of water levels (Bartlett, 2004). A shoreline which can be detected by remote sensing is tide-coordinated shoreline, which is an extraction from a specific tide water level. Water indices are mathematical models which enhance water signals for a given pixel in images obtained from visible/middle infrared scanning sensors (El-Asmar et al., 2010). Shoreline change can be determined by comparing two or more shorelines at different times. A significant change can result in changes to landscapes, which could have environmental and social impacts.

Google Earth Engine (GEE) is a cloud computing platform designed to store and process huge data sets (at petabyte-scale) for analysis and ultimate decision making (Mutanga, 2019). The platform allows users to create and run special algorithms and fast computations and is equipped with many open-source datasets that are linked to cloud computing engines, one of which is Landsat-8 medium resolution satellite imagery.

The mission of Landsat-8 has the primary objective of record an area of the earth's surface globally every 16 days. It was launched in 2013. The satellite is equipped with an OLI sensor with eight different bands with a spectral resolution of 30 meters, one band with a spectral resolution of 15 meters, and a TIRS sensor with two bands of 100 meter resolution.

2 MATERIALS AND METHODOLOGY

2.1 Location and Data

This research on shoreline changes was conducted in Cigeulis and Panimbang districts, Pandeglang Regency, Banten Province, which were the areas affected by the Sunda Strait tsunami. The research area is directly adjacent to the Sunda strait and within ± 52 kilometers of the centre of the tsunami source, Mount Anak Krakatau.

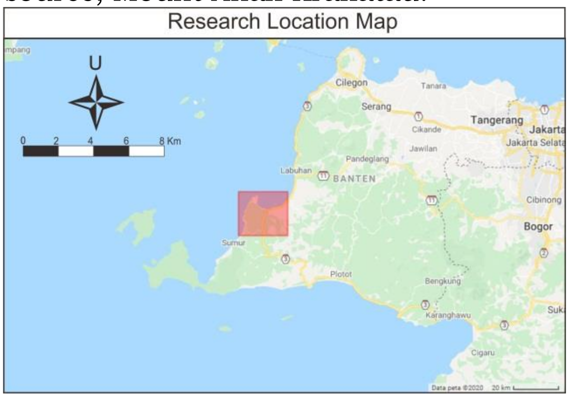

Figure 2-1: Research location map

The data used in the study were administrative boundary data of Pandeglang Regency, obtained from https://tanahair.indonesia.go.id/.

Landsat 8 Surface Reflectance Tier 1 satellite image data from the database of the Google Earth Engine were used so that geometric and radiometric corrections were no longer needed. The satellite imagery used were from 16 July 2019 and 13 July 2018. The required data were tide prediction data, bathymetric data, and Digital Elevation Model (DEM) data, obtained from http://tides.big.go.id/.

2.2 Method

The method used in the research consisted of the preparation stage, the data processing stage, and the analysis stage.

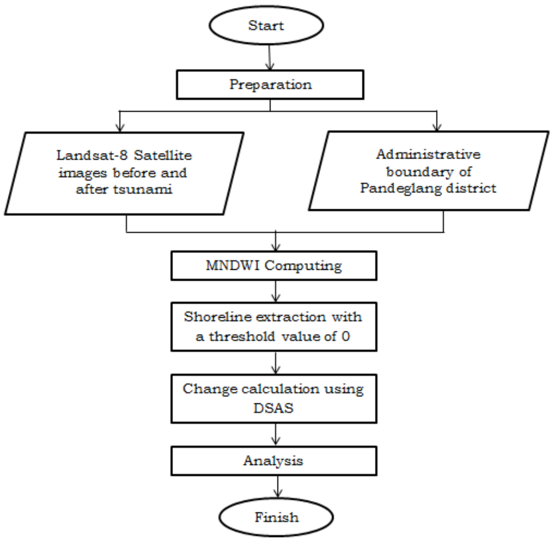

Figure 2-2: Research flow diagram

The first stage of the research was preparation, consisting of a literature review and data collection. The satellite image data used was Landsat-8 Surface Reflectance Tier 1 satellite imagery. These satellite image data are available from April 2013. The characteristic spectrals of Landsat-8 imagery are given in Table 2-1.

Table 2-1: Characteristic spectrals of Landsat-8 images

Spectral Characteristics		
	Landsat 8	**Length(μm)**
OIL	Band 1 Coastral/ Aerosol	0.435 – 0.451
	Band 2 Blue	0.452 – 0.512
	Band 3 Green	0.533 – 0.590
	Band 4 Red	0.636 – 0.673
	Band 5 NIR	0.851 – 0.879
	Band 6 SWIR-1	1.566 – 1.651
	Band 7 SWIR-2	2.107 – 2.294
	Band 8 Panchromatic	0.503 – 0.676
	Band 9 Cirrus	1.363 – 1.384
TIRS	Band 10 TIRS-1	10.60 –11.19
	Band 11 TIRS-2	11.50 –12.51

The data processing stage was performed using the Google Earth Engine, and included the importing of data on the boundaries of the research area and the Landsat-8 Surface Reflectance Tier 1 satellite image. The image was geometrically and radiometrically corrected (surface reflectance) and was cropped according to the research area of interest (AOI) for further analysis.

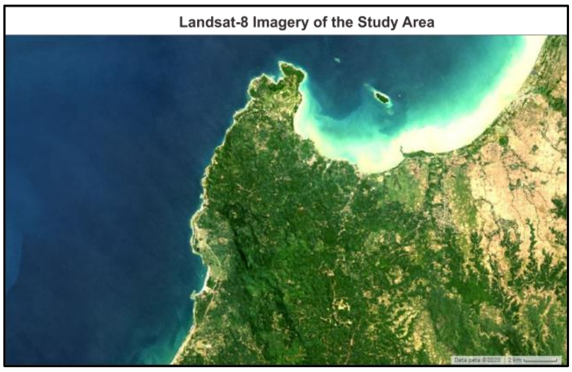

Figure 2-3: Landsat-8 imagery of the study area

Determination of the shoreline was made using the Modification of Normalized Difference Water Index (MNDVI) algorithm, which is more sensitive to water features mixed with vegetation than Normalized Difference Water Index (NDWI) algoritm due to its positive values (Singh et al., 2014). The algorithm uses Landsat TM and ETM^{+} images, as shown in equation (1) (Xu, 2006).

$$MNDWI = \frac{Green - MIR}{Green + MIR} \qquad (2\text{-}1)$$

where: Green: Green band

MIR: Medium infrared band

However, because the satellite imagery used was Landsat-8 Surface Reflectance satellite images which were processed from the Landsat-8 OLI/TIRS sensors, equation (2) was used (Ko et al., 2015):

$$MNDWI = \frac{Green - SWIR}{Green + SWIR} \qquad (2\text{-}2)$$

where: Green: Green band

SWIR1: Shortwave infrared 1 band

The bands used in this algorithm were band 3 (green), which has a wavelength of 0.533-0.590 µm, and band 6 (SWIR1), which has a wavelength of 1.566-1.651 µm. Both of bands have a spatial resolution of 30 meters. Using the MDWI algorithm, accurate classification of land and water can be made. MNDWI is a modification of NDWI using the Green band and the middle infrared (MIR) band. The MNDWI algorithm provides accurate extraction of open water features, as the built-up land, soil and vegetation are all negative values and thus are notably suppressed or even removed. Water classification using the MNDWI algorithm shown a high brightness value with a range between 0 and 1, with the value of non-water very low, within a range of between -1 and 0. Therefore, the algorithm could recognise the water bodies, the rocky coast and the shoreline.

Calculation of shoreline change can be made using the DSAS (Digital Shoreline Analysis System). This is a freely available software application that works within the ArcGIS software and computes rate-of-change statistics for a time series of shoreline vectors (Thieler et al., 2009), which is particularly useful for the evaluation of coastal retreat or accretion rates. A series of transects were cast at right angles from a defined baseline, and the points intersecting all the target lines were used for the calculation of distances and rates of shoreline changes (Gómez et al., 2014).

The results of the shoreline extraction obtained from the Google Earth Engine were exported and processed using DSAS. In this processing, a transect line that was perpendicular to the coastline was used at intervals of 50 meters. In DSAS, the method of calculating the distance change analysis for each coastline uses the Net Shoreline Movement (NSM) method, which measures the distance of the change in the shoreline between the oldest and the newest shoreline (Thieler et al., 2009). The NSMs were calculated as the distance of the shoreline divided by the time elapsed between the baseline and the most recent shoreline. The results of this processing obtained the amount of change in the shoreline of each transect line.

The analysis stage was conducted by comparing the differences in the pattern and position of the coastline before and after the tsunami and based on processing data, predictive tide data, digital elevation model (DEM) data, and bathymetric data. The processed data was corrected for mean sea level (MSL). Correction was made from the difference between the water level and the MSL, divided by the tangent of the coastal slope angle. The coastal slope was obtained from the DEM and bathymetric data. The following was the correction formula for MSL (Prastyo, 2019).

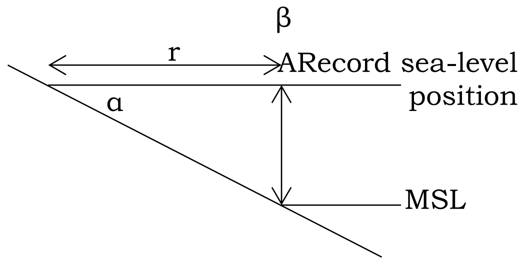

Figure 2-4: Tide correction

$$r = \frac{\beta}{\tan \alpha} \quad (2\text{-}3)$$

where: r: tide correction

β: difference in the record sea level position and MSL

α: angle of the beach slope

3 RESULTS AND DISCUSSION

The research on shoreline changes resulting from the Sunda Strait tsunami using the Google Earth Engine was conducted in the coastal areas of Cigeulis and Panimbang districts, Pandeglang Regency, Banten Province. This area experienced the highest tsunami, a runup type of up to 14 meters.

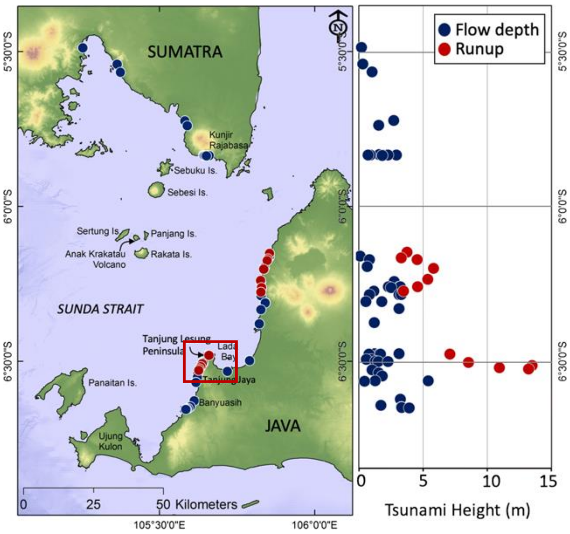

Figure 3-1: Distribution of the measured tsunami flow depth (blue) and runup (red) (Muhari et al., 2019)

In the study, shoreline extraction was conducted in 2018 and 2019 and compared so that the horizontal position differences from the coastline were ascertained. The coastline was identified from the Landsat-8 satellite imagery, analysed using the Google Earth Engine with the MNDWI algorithm, resulting in the different appearance of the extraction results, as shown in Figure 3-2.

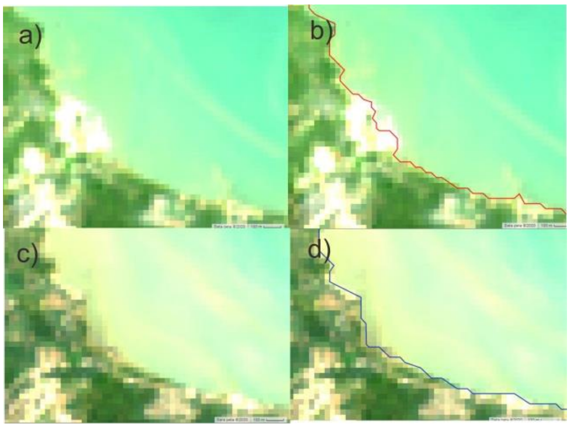

Figure 3-2: a) Satellite imagery from 2018; b) coastline extraction results from 2018; c) satellite imagery from 2019; d) shoreline extraction results from 2019.

In the shoreline extraction, there were differences between the extraction results of the 2018 and 2019 images. These were quite varied in each region. The following were figure. 3-3 shows the results of the 2018 and 2019 coastline overlay from the calculations using the MNDWI algorithm in Tanjung Jaya village.

Figure 3-3: Shoreline extraction overlay, 2018 and 2019

Shoreline changes were observed from the coastline overlay from 2018 and 2019. The changes that occurred at the research location due to the Sunda Strait tsunami varied not only in abrasion but also accretion. Tsunami waves hitting land can damage the coast and cause deformation to it, so abrasion can occur. However, tsunamis can also carry and drag land material, causing sedimentation in coastal areas and accretion. Shoreline changes occur more easily on a gentle slope, where the water level tends to move horizontally. In the study area, the slope of coastal tended to gently, with a slope of below 30°.

The water level at the time the image was taken was 0.095 m in the 2018 image and 0.077 m for the 2019 image. The result of tide correction made showed that did not have a significant impact compared to the spatial resolution of the image, which was 30 meters. This caused the tide corrections to be excluded from the study. The difference in shoreline position before and after the tidal correction could be ignored because visually the difference was only 0.018 m, which is not significant.Changes to the shoreline identifiedby DSAS found that the study area had experienced abrasion, accretion and constant on the shoreline. DSAS processing used the NSM method with 909 transect lines. The shoreline changes are illustrated in Figure 3-5.

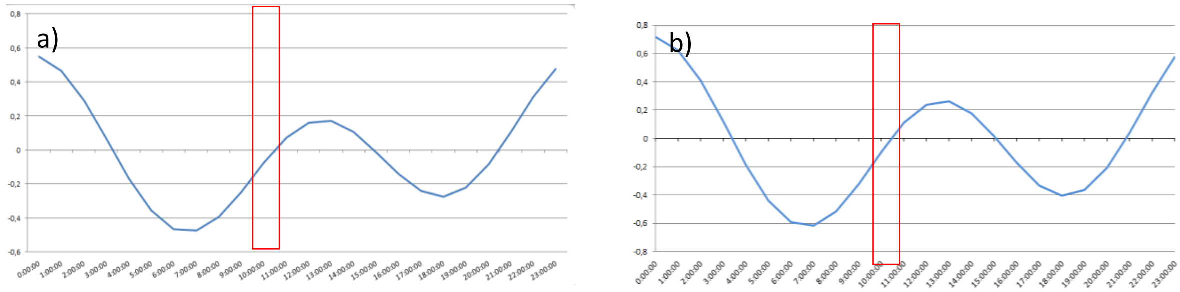

Figure 3-4: a) graph of tide prediction in the study area on 13 July, 2018; b) graph of tide prediction in the study area on 16 July 2019

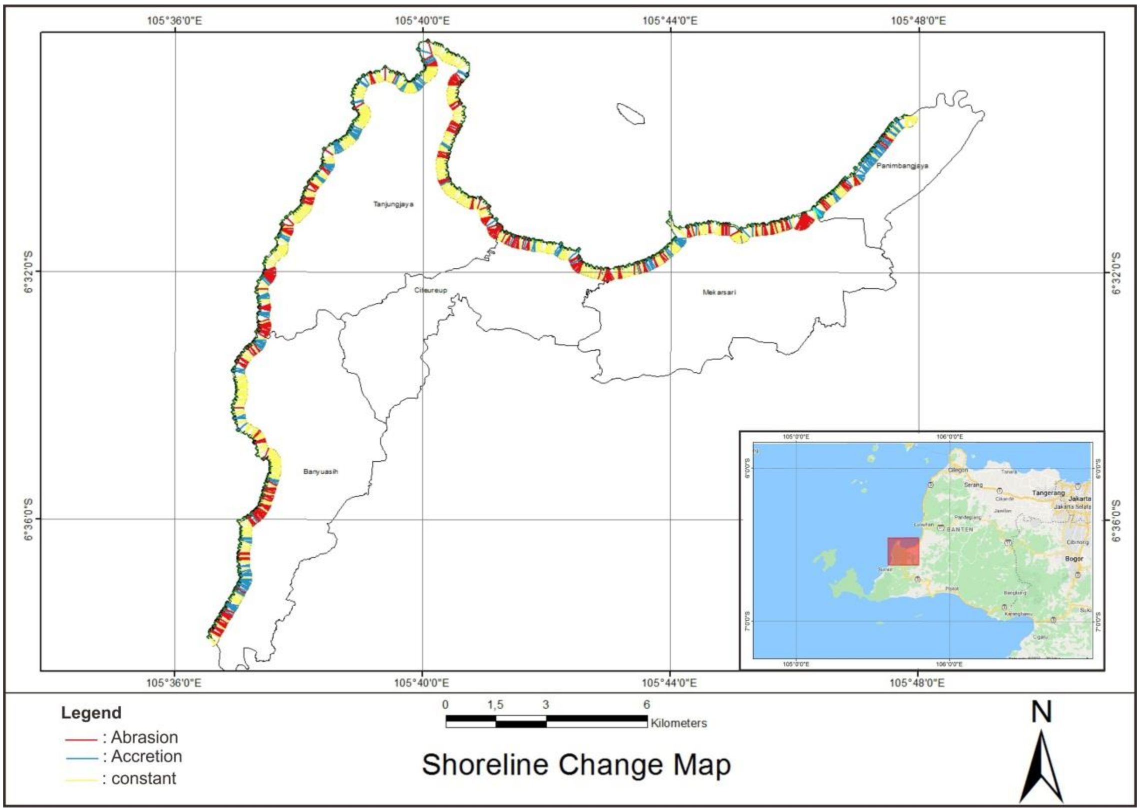

Figure 3-5: Shoreline change map

Changes to the shoreline identified by DSAS found that the study area had experienced abrasion, accretion and constant on the shoreline. DSAS processing used the NSM method with 909 transect lines. The shoreline changes are illustrated in Figure 3-5.

In Pandeglang Regency, there was a change in the coastline of 30.1% from abrasion and 20.2% from accretion, while the remaining area did not have any change. A maximum abrasion of 130.2 meters occurred in the village of Tanjung Jaya, while a maximum accretion of 43.3 meters was experienced in the village of Panimbang Jaya.

In Banyuasih village, the average change in the shoreline was -1.2 meters, while Tanjung Jaya village experienced an average change of -5.3 meters, Citeureup village of -8.0 meters, Mekarsari village of -9.4 meters, and Panimbang Jaya of 8.0 meters.

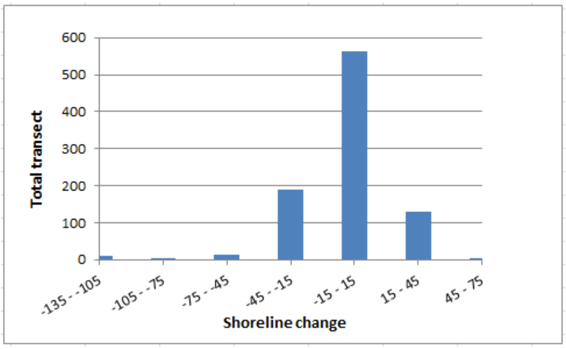

Figure 3-6: Chart of the total transect with the distance of change in the shoreline.

The shoreline changes were dominated by less significant changes, with 564 transect lines on values ranging from-15 to 15 meters. This was followed by classes -45 to-15 with 190 transect lines and classes 15 to 45 meters with 130 transect lines. In Pandeglang Regency, the change in the coastline due to the Sunda Strait tsunami was an average of 3.9 meters of abrasion

From these results, it is clear that there is the need for effective land cover management to take steps to minimise damage to coastal areas. In areas that occurred abrasion, it is necessary to plant mangrove trees as a measure for coastal conservation. It is also important to monitor changes to coastal areas as a basis for taking action in those that require attention. These efforts are important to maintain the resource wealth of coastal areas.

4 CONCLUSION

The analysis found that 30.1% of the coastline on the coast of Pandeglang Regency suffered abrasion and 20.2% suffered accretion, while 40.7% did not change. A maximum abrasion of 130.2 meters occurred in the village of Tanjung Jaya, while maximum accretion of 43.3 meters was experienced in the village of Panimbang Jaya. The average change in the shoreline in Pandeglang Regency was 3.9 meters. Therefore, a good land cover arrangement, such as planting mangrove trees in areas of abrasion, and monitoring to maintain resources in coastal areas are necessary.

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AUTHOR CONTRIBUTIONS

Main Contributor: Fandi Dwi Julianto. Contributing Members: Cahya Riski Fathurohman, Salsabila Diyah Rahmawati, Taufiq Ihsanudin.

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