A spatial study of mangrove ecosystems for abrasion prevention using remote sensing technology in the coastal area of Pandeglang Regency

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Abstract. The coastal area of Pandeglang regency, which faces the Sunda Strait, is prone to natural disasters. Wave height and tides, including tsunami, are disasters that frequently hit the area. The mangrove ecosystem plays an important role in reducing the abrasion that mostly caused by waves. In addition to preventing abrasion, the mangrove root system can hold sediment. So that it will expand the coastline or accretion. This study aims to determine the effect of the existence of mangrove ecosystems on changes in coastline, especially the occurrence of abrasion during 2010 to 2020. The research method uses remote sensing. Data collection uses Landsat 7 ETM+ in 2010, Landsat 8 OLI/TRS in 2015 and 2020. As a result, the mangrove ecosystem area along the coast of Pandeglang Regency had expanded from 1,632 ha in 2010 to 1,728.06 ha in 2015 and decreased to 1,443.19 ha in 2020 due to the 2018 tsunami. Of course, it also affects the occurrence of abrasion, from 2010 to 2015 the abrasion occurrence affected 371.94 ha of coastline and decreased to 273.52 ha until 2020. Spatially, the largest post-tsunami abrasion occurred in the mangrove area of Cimanggu Sub-district, with about 28% of the mangrove area being reduced.

1. Introduction

Indonesia is one of the world’s largest archipelagic countries with a total of 16,651 islands named of which nearly three-quarters are sea [1]. Indonesia has many islands, making Indonesia the second-longest maritime country with the longest coastline, which is approximately 99,093 km [2]. It causes most Indonesia areas that belong to coastal areas to be vulnerable and threatened by changes in hydro-oceanographic activity and human activity. The mangrove ecosystem is one of Indonesia’s potential marine resources that can minimize marine natural disasters. Mangroves are part of coastal ecosystems that have an essential function towards abrasion prevention. Mangrove roots can withstand sediment (mud) and slow water flow from the river, resulting in sedimentation that will eventually expand the shoreline or accretion [3]. Mangrove root structure that can precipitate sediment indirectly also protects the beach from tides and waves, so that mangroves will be useful to prevent coastal abrasion that can erode coastal land [4].

The coast of Pandeglang Regency is one of the areas in Indonesia that has considerable mangrove ecosystem potential. In 2015, the total mangrove ecosystem along the coast of Pandeglang Regency measured 1,764 ha. However, this area will then decrease by about 18% in 2020. The loss or diminishment of mangrove ecosystems along the coast of Pandeglang Regency is triggered by human activity that deliberately cut down mangroves to be used as animal feed and a shift in the functioning of land into ponds and settlement. Another critical factor is the tsunami disaster on the west coast of Banten or around the Sunda Strait area in 2018 caused by Anak Krakatau’s eruption. Antara news Banten recorded along 302 km of coastal coastline Pandeglang Regency along 30 – 40 meters from the indicated
coastline experienced an abrasion. Based on tempo.co, the most severe abrasion occurs along Panimbang Beach to the Tanjung Lesung tourist area.

This existence of mangrove ecosystems shows the role or potential of mangroves for coastal areas in preventing abrasion. It is related to changes in mangrove ecosystem areas that will undoubtedly result in changes in the coastline and cause harm to the surrounding communities. It is necessary to monitor mangrove ecosystem changes that include mangrove area and density and related to abrasion. Monitoring changes in the mangrove ecosystem and coastline (abrasion and accretion) can be mapped using remote sensing imagery. Mapping using satellite imagery has several advantages: it does not cost a lot and can map spatially and temporally. This study’s satellite imagery is Landsat 7 ETM+ in 2010, Landsat 8 OLI /TIRS in 2015 and 2020. This research examines changes in the mangrove ecosystem and related to abrasion disasters that occurred on the coast of Pandeglang Regency within ten years (2010 – 2020) spatially.

2. Methods
This study was conducted along the coast of Pandeglang Regency, Banten Province. Pandeglang Regency is bordered by Serang Regency in the north, Lebak Regency in the east, the Indian Ocean in the south, and the Sunda Strait in the west. Its position, which faces the Sunda Strait, makes it prone to natural disasters. Pandeglang Regency has 2,746.89 km² or 28.43% of Banten Province, with a mangroves ecosystem area of 1,443.19 ha.

The variables used in this research are the area of mangroves, abrasion, and accretion. Data of mangroves, abrasion, and accretion were obtained from Landsat 7 ETM+ in 2010 and Landsat 8 OLI / TIRS in 2015 and 2020. Identification of mangrove objects from Landsat 7 ETM+ in 2010 can be made by using red green blue (RGB) composite with a combination of band 4 (near-infrared / NIR), band 5 (mid-infrared), and band 3 (red) [5]. Meanwhile, Landsat 8 OLI / TIRS in 2015 and 2020 can be done by using RGB composite with a combination of band 5 (near-infrared / NIR), 6 (short-wave infrared / SWIR-1), and band 7 (short-wave infrared / SWIR-2). Furthermore, calculating the density value of mangrove objects used the Normalized Difference Vegetation Index (NDVI) method by calculating the ratio of near-infrared (NIR) and red or short-wave infrared (SWIR) [6]. The following is the formula used to calculate NDVI:

\[
NDVI = \frac{(NIR - SWIR)}{(NIR + SWIR)}
\]  

(1)

\[
NDVI = \frac{(NIR - Red)}{(NIR + Red)}
\]  

(2)

Furthermore, the classification is carried out into classes of mangrove forest canopy density based on the NDVI value issued by the Indonesian Ministry of Forestry in 2005 [7].

| Value of NDVI     | Density Classification |
|------------------|------------------------|
| 0.006 – 0.328    | Rare                   |
| 0.335 – 0.427    | Medium                 |
| 0.434 – 0.750    | Dense                  |

Source: Department of forestry, 2005

Meanwhile, data on abrasion and accretion using the Single Band Threshold band SWIR-1 method to determine land and sea boundaries, manual coastline digitization is then carried out for each year, namely 2010, 2015, and 2020. Single Band Threshold band 5 (1.55 mm – 1.75 mm) is an ideal type of mid-infrared wave for delineating coastlines with Landsat TM and ETM images [8]. After getting the coastline each year, an overlay is performed to see where the area of abrasion and accretion occurs. The
result of mangrove data processing and abrasion was analyzed to determine the relationship between mangrove ecosystem and abrasion along Pandeglang Regency’s coast spatially.

3. Result and discussion

3.1 Mangrove

Figure 1 shows the result of changes in the area and the density of mangroves for ten years from 2010 to 2020. The analysis was obtained using the NDVI algorithm and density slice classification process. In 2010, mangrove density was dominated by the density of rare classes, while in 2015 and 2020, it was dominated by dense classes.

**Figure 1.** Map of mangroves area and density in the coastal area of Pandeglang regency (2010-2020).

**Figure 2.** Graphic of mangrove area and density in the coastal area of Pandeglang Regency (2010-2020).

Figure 2 shows the changes in mangrove area and density from 2010 to 2020. Classification of image data in 2010 shows that the mangrove area in the coastal of Pandeglang Regency is 1,532 ha with density levels grouped into three classes. Figures 1 and 2 shows that in 2010, the dense class category was 719.07 ha (44.05%), medium class of 380.35 ha (23.03%), and rare class of 532.72 ha (32.63%). The in 2015, the dense class category was 1,528.06 ha (86.58%), medium class of 195.07 ha (11.05%), and rare class of 41.67 ha (2.36%). However, in 2020, mangrove's area and density will again decrease, which is 1,443.19 ha or 11.57% from 2010. On fig. 2 shows that the dense class category was 1,003.85
ha (69.55%), medium class of 372.24 ha (25.79%), and rare class of 67.09 ha (4.64%). Based on data processing, from 2010 until 2020, mangrove ecosystems in the research area are dominated by dense class density. So the density index of mangrove vegetation in the research area is considered high.

3.2 Abrasion
Sunda Strait directly borders the coastal area of Pandeglang Regency and Indian Ocean has a long coastline along 302 kilometers. Along the coast, the region underwent ten years of coastline change from 2010 to 2020. Changes in coastline caused abrasion and accretion in the research area.

Figure 3. Map of abrasion and accretion along coastal of Pandeglang regency in 2010-2020

Figure 4. Graphic of abrasion area per segment along coastal of Pandeglang Regency (2010-2020)
Figures 3 and 4 show that the coast of Pandeglang regency has undergone a change in coastline over the past ten years, causing abrasion. From 2010 to 2020, the area has experienced an abrasion of 273.52 ha and an accretion of 644.96 ha. The study area is divided into thirteen segments. Based on the result of analysis per segment, it can be noted that the largest abrasion occurred on segment 13, covering Cibaliung and Cikeusik areas with an area of 65.95 ha or 24.11% of the total abrasion that occurred. Like segment 13, segments 10 and 9 located on Panaitan Island, Cimanggu Sub-District also experienced an extensive abrasion, an area of 55.64 ha (20.34%) and 36.65 ha (13.40%). Simultaneously, the segment that experienced the least abrasion was segment 7, located in the Cimanggu Sub-District, which is an area of 0.46 ha (0.16%). Like segment 7, the other segments that experienced the smallest abrasion are segments 2 and 1, covering the Labuan Sub-District, which is with an area of 1.02 ha (0.37%) and 1.55 ha (0.56%).

3.3 The relation of mangrove ecosystem and abrasion
The coastal area of Pandeglang Regency underwent changes in mangrove area and density from 2010 to 2020. This change in the mangrove ecosystem then affects the changes in its coastline and causes abrasion. Figure 5 shows the association between the change in area and density of mangroves to the abrasion area. An analysis was carried out per segment based on the presence of mangroves in each segment. Of the thirteen segments, some segments have mangroves area segments 4, 6, 7, 9, and 10.

Based on processed data, segment 4, located in Panimbangan, underwent a change in mangrove area from 2010 to 2020, covering 20.24 ha with an area in 2020 of 69.13 ha. Segment 4 also experienced an abrasion of 2.65 ha (0.96%). Then on segments 6 and 7 located in Cimanggu sub-District, there was a change in the mangrove area of 180.57 ha with its current 926.32 ha. Segments 6 and 7 experienced abrasion of 15.68 ha (5.73%) and 0.46 ha (0.16%). While segments 9 and 10 covering Panaitan Island located on Cimanggu sub-District underwent a change in the mangrove area of 28.62 ha with the current area of 447.74 ha. These segments experienced abrasion of 36.65 ha (13.40%) and 55.64 ha (20.34%). Although in these segments (9 and 10), the abrasion rate is relatively high, compared to some other segments that do not have mangroves, the abrasion levels in segments 4, 6, and 7 are relatively low. It indicates a linkage between mangrove ecosystems and abrasion occurs, which in this case is reducing the onion of abrasion.
4. Conclusions
Based on the result data processing of Landsat 7 ETM+ in 2010 and Landsat 8 OLI / TIRS in 2015 and 2020, mangrove areas along the coastal area of Pandeglang Regency have changed, both in terms of area and density. Over ten years, the area underwent a change in the mangrove area of 188.95 ha with a tighter density level. Changes in the area and density of mangroves in the coastal area of Pandeglang regency influenced the change of coastline. The wider and tighter the mangrove vegetation cover in the area, the smaller the abrasion level. However, if the area and density level are low, then the chances of abrasion will be greater.

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