Preliminary study of land cover/land use and geomorphic change of the near shoreline of Aceh Jaya Regency: a multi-temporal and multi-image approach

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Abstract. Land cover/land-use change in Aceh Jaya Regency is greatly affected by the community and local government's increasing activities on land. The continuing development may create a problem due to progressing land use and geomorphic changes along the coastal area since the 2004 tsunami. To examine the land cover/land use and the extent of the geomorphic change to the coastline of Aceh Jaya Regency, a detailed study on the historical shoreline positions and land cover/land-use change was carried out. This preliminary study tried to analyze land use/land cover and geomorphic change from 2004 until 2019 along the coastal area of Aceh Jaya in Aceh, Indonesia, by utilizing multi-temporal and multi-image data. Results show that land use/land cover has considerably changed, primarily to vegetation, open land, and a water body that varied in total area during the year of observation. Coastline changed markedly since 2004 with abrasion reaching up to 436.38 meters from the original coastline, and the loss of land area up to 457.90 hectares, and 5.78 hectares of accretion was added. The longest distance of land that has disappeared from the original shoreline was recorded 436.38 meters from the mainland.

1. Introduction
The development process in Aceh Jaya Regency is carried out in various fields, including land use for agriculture and settlement, 15 years after being hit by a tsunami in 2004. The enormous development impacts land use/land cover change, especially along the coastal area. To avoid external influences on the intensity of land cover/land-use change, local governments and communities should refer to the regional spatial plan's guidelines as a standard reference for land use in the area [1].

Land cover/land-use change in the area is greatly affected by the community and local government's increasing activities. There are many different types of land use, such as rebuilding the infrastructure of government offices, new settlements, and extension of agriculture and estate plantations. This includes land embankment in coastal areas to protect the area from erosion and geomorphic change along the coastal area to protect from a similar catastrophic event to the 2004 tsunami. Land in this area is vital to the survival of ecological processes and is a livelihood source for the Aceh Jaya Regency [2]. Thus, land-use change has progressed in recent years and needs to be studied to make a better local government plan to deal with space allocation for many purposes.
The continuing development may create a problem due to progressing land use and geomorphic changes along the coastal area since the 2004 tsunami. Most of the Aceh Jaya Regency inhabitants prefer to live close to the beach areas, as most of them are fishers and farmers. Many reports have described coastal erosion and geomorphic change since the 2004 Indian Ocean tsunami, e.g., in Lhoknga, Aceh Indonesia [3], and Sendai, Japan [4] Banda Aceh coastal area [5]. Among these, research reports that coastal geomorphic changes have been caused by the tsunami. Many lands have been destroyed along the coastal region due to the tsunami and other agents.

Recent development has also shown that the change of land use/land cover due to the development program is a concern for those whose livelihood relies on the coastal area [6]. To examine the land cover/land use and the extent of the Aceh Jaya regency's geomorphology change at the shoreline, study of land cover/land use and geomorphic change of the near shoreline of Aceh Jaya regency is needed. To better understand the morphological behavior of the near shore environment of Aceh Jaya Regency a detailed study on the historical shoreline positions and land cover/land use change is necessary for the west coast of Aceh Province. Remote sensing data is useful information for assessing historical and present condition of the coastal area of Aceh Jaya Regency. The present study tried to achieve this with a multi-temporal and multi-image analysis of part of Aceh's west coast. This paper presents land use/land cover and geomorphic change from 2004 to 2019 along the coastal area of Aceh Jaya, a part of the west coast of Aceh, Indonesia.

2. Research method

2.1. Selection of the study area

This study is based primarily on secondary data collected for the Aceh regency's selected main coastal area. We limited the point of interest to the coastal region being studied. This study is part of a study of the west coast of Aceh. The selection is based on the site worst hit by the tsunami in 2004 and the number of people who live in this area. The data collected was intended to be used to better understand the processes contributing to the land cover/land use change using a multi-temporal and multi-image approach. This may also beneficial for a better understanding to explain land cover/land-use change in Aceh Jaya Regency. Aceh Jaya Regency is one of the regencies in Aceh Province, Indonesia. Geographically the regency is located between 4°22' - 5°16' LU North Latitude and 95°02' - 96°03’ East Longitude. A flow chart of the study is shown in Figure 1.

2.2. Image classification and processing

This research uses a qualitative descriptive method based on multi-temporal satellite imagery interpretation for 2004, 2008, 2017, and 2009 satellite image data. We used the Landsat image for 2004 as a position point of coastline baseline data before the tsunami, then 2008, 2017, and 2019 images of the study area. To avoid a spatial resolution issue ground check and geometric correction for the images was applied. Image registration, sharpening, cutting, classification, and overlaying process over the area were carried out.

The image was sharpened, then enlarged to distinguish between the sea and the coastline, and digitized through the polyline method to determine the shoreline. The overlaid images were from 2004 (before the tsunami), and from 2008 and 2017 (after the tsunami). Supervised classification with maximum likelihood analysis was carried out to discriminate land cover/land use of the study area.
2.3. Coastline change interpretation
Coastline change of the study area was determined by interpreting the overlay of multi-temporal satellite image data. Three sources of uncertainty were considered when calculating the positional shoreline: rectification, pixel, and digitizing errors [7]. The digitizing error was calculated as the standard deviation of shoreline position from different images before and after tsunami repeated digitization of the same section. Shoreline boundary digitation was carried out through the polyline method on the scale of 1:50,000 for Landsat and SPOT images. Overlaid maps were underdone to restrict shoreline changes for 2004, 2008, 2017, and 2019 images. We did not consider the tectonic setting that primarily controls the formation of the Aceh Jaya Regency since this area is part of Sumatera Island, and it is too complicated to analyze the island's geomorphology separately.
3. Results and discussion

3.1. Land cover/land use

The land use/land cover near the coastal area of Aceh Jaya Regency in 2004, 2008, and 2019 shifted across the land cover/land use types, as shown in Table 1. Land cover change of the coastal area from 2004 to 2007 is dominated by land use for vegetation, open land, and water body. Results also show that land cover types changed, primarily to vegetation, available land, and a water body, which varies in total area for different years of image, analyzed. Vegetation has changed considerably from 2004 to 2008, accounting for a 113.5(2.9%) hectare increase, and between 2008 and 2014 vegetation reduced by -893.1 (19%). Bare land/open land increased 42% from 2004 to 2008 and up to 760% from 2014 to 2017. The smallest change occurred for the paddy rice field, which increased 21% from 2004 to 2008, and decreased by 49% from 2008 to 2017. However, between 2017 and 2019, minimal change occurred along the coastline area. We noticed that small parts on the coastline in 2019 are different from the image in 2017. We assume this was due to the continuing barrier for protecting the coastal region from abrasion and protecting settlement along the coastal line in the study area.

Table 1. Land cover/Land use of surrounding coastal areas in 2004, 2008, and 2019.

| No. | Land Cover Types | Land Cover Area (Ha) | Land Cover Change |
|-----|------------------|----------------------|-------------------|
|     | 2004            | 2008              | 2019             | 2004-2008 | 2008-2017 | 2004-2019 |
| 1   | Vegetation      | 4681.4             | 4794.9           | 3788.24   | 113.5     | -1006.6   | -893.1    |
| 2   | Bare/Open Land | 167.7              | 237.4            | 1453.69   | 69.7      | 1216.3    | 1285.9    |
| 3   | Water           | 832.4              | 734.8            | 519.21    | -97.6     | -215.6    | -313.2    |
| 4   | Mangrove        | 6.92               | 58.99            | 21.5      | 52.1      | -37.5     | 14.5      |
| 5   | Rice Field      | 290.1              | 228.18           | 148.9     | -61.9     | -79.3     | -141.3    |
| 6   | Settlement      | 94.9               | 75.68            | 84.9      | -19.2     | 9.2       | -10.0     |
| 7   | Fish Pond       | 115.1              | 58.63            | 172.2     | -56.4     | 113.5     | 57.1      |

Total area (Ha) 6188.5 6188.5 6188.5

Note: A negative number indicates a decrease in the land cover, while a positive number shows an increase in the land cover.
3.2. The coastline in 2004 (before the tsunami)

The shoreline of Aceh Jaya for the selected locations investigated in 2004 (before the tsunami) is natural without alteration, as shown in Figure 3. It indicates that Aceh Jaya's coastline in 2004 is normally built and gradual change follows the geological time. The red line on the map shows the shoreline of Aceh Jaya naturally without abrupt change.

![Figure 3. Land use and shoreline of Aceh Jaya regency in 2004.](image)

Compared to the Aceh Jaya Regency coastline between 2004-2017, there were changes and severed alterations in which some coastlines that existed in 2014 were not there in 2008 and 2017. This finding also supports a different area in Aceh [8] and [9]. Even though the land-use change for vegetation is small compared to the shift in bare land/open land, vegetation change is the most sweeping change in the area. Bare land/open space in the most incredible change, up 760% in 2017 compared to 2004. This indicates that many settlements and bare land are used for plantation in the image analyzed as the government continues to increase palm oil plantation area [10] and the local community asks for a land concession for palm oil [11].

3.3. The coastline in 2008 and 2017 (after the tsunami)

The coastline of Aceh Jaya Regency in 2008 and 2017 (after the tsunami) varies in terms of distance and extends the area damaged along the coastal region, as shown in Figures 4 and 5. It shows the variation in length from a few meters to more than 436 meters.
From 2008 to 2017, the coastline along the Aceh Jaya Regency did not change much. This finding confirms that from 2008 to 2007, the coastline's geomorphic change is impacted only a small amount by coastal erosion and waves. Collectively, the outcome of shoreline changes over the coast of Aceh Jaya for the periods considered in this study was a stabilization of the area after the tsunami, resulting in a small increases or decreases after the tsunami (2008-2017). Similar findings were found by Meilianda [9] and, Forda and Kenchb [12]. As shown in Figure 5, there were several shoreline...
changes in Aceh Jaya District with different widths of coast and both abrasion and accretion, as clearly noted along the coastline in this area.

3.4. Geomorphic Change

Geomorphologic change is shown by the shoreline change along the coastal area of the Aceh Jaya Regency, as shown in Figure 6. Figure 6 shows three different years: 2004, 2008, 2017 and Figure 7 between 2017 and 2019. Abrasion on the site of research reached 457.90 hectares, and accretion of 5.78 hectares was added along the shoreline of the study site. This result shows the abrasion and accumulation of some shorelines in the study area. Observation in the study area suggests that normal wave conditions play an important role in forming the mild shoreline depressions that occurred after the tsunami. The shoreline change comprises sand and small coral gravel with low density in the area.

It is generally known that coastal landforms such as beach ridges and coastal dunes form sea-level changes and changes of sediment supply that are affected by climatic change; seismic events also are an essential cause of change in the coastal geomorphology of tectonically active areas [13], [14].

Figure 6. The extent of coastline for 2004, 2008, 2017 in the study area.
Figure 7. The extent of coastline for 2017 and 2019 the study area.

There was not much change of coastline between 2008 to 2017 in the Aceh Jaya regency, nor was there much change between 2017 and 2019 (Figure 7). This finding confirms that from 2008 to 2019, the evolution of shoreline and its geomorphology was only impacted a little by coastal erosion and waves. Collectively, the outcome of shoreline changes over the coast of Aceh Jaya for the periods considered in this study was a stabilization of the area after the tsunami, resulting in a small increases or decreases after the tsunami (2008-2019). There were similar findings by Forda and Kenchb [12], Aucan et al., [15] and Liew et al., [16]. Figure 5 shows several changes of shoreline in Aceh Jaya Regency with different widths of coastline and both abrasion and accretion, as clearly noted along the coastline in this area. However, between 2017 and 2019 there were not many differences from the previous year analyzed.

Examining the changes of the shoreline of Aceh Jaya Regency without considering the tsunami effect in 2004, the 2008, 2017an 2019 image analysis might seem to indicate that the changes were not caused by the tsunami, but rather the dynamic geomorphic process in the area. The shoreline changes of the Aceh Jaya Regency shoreline between 2008 and 2017 may have been caused by abrasion along the shoreline area investigated. Clearly, Figure 6 shows the evolution of the coastline. The changes that occurred between 2008-2017 were dominated by abrasion, which was caused by the tsunami and sediment carried by rivers flowing into the coastal area in this region.

4. Conclusions

The tsunami and continuing development have affected the land use and geomorphic changes along the coastal area since the 2004 tsunami in the Aceh Jaya regency. It is concluded that land use/land cover and the coastal area changed over the course of the years 2004, 2008, 2017 and 2019. The changes were primarily to vegetation, open land, and a water body with total varying areas following the observation year. The maximum increase between 2008 and 2017 for vegetation and bare ground was 2.9% in 2008. It reduced to 19% in 2017. However, the land cover and shoreline remain stable of the selected point between 2017 and 2019. The widest coastline change occupied an area of 436.38
hectares among this coastline, and was altered due to abrasion and accretion, which reached an area of 457.90 hectares and 5.78 hectares, respectively.

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