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The Impact of Tsunami on Mangrove Spatial Change in Eastern Coastal of Biak Island, Indonesia

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ABSTRACT
This study was conducted to find out how large was the impact of the tsunami incident of 1996 on the mangrove spatial change and also to understand the distribution and level of mangrove density before and after tsunami in Biak Island (Oridek District and East Biak District), Biak Numfor Regency, Indonesia. In order to determine the condition of mangrove before tsunami, landsat 5 TM satellite image acquisition of July 6, 1994 and landsat 7 ETM+ satellite image acquisition of August 31, 2000 were used. The information about the distribution and extent of mangroves was obtained by analyzing the spectral values based on color composite image (RGB 453) and NDVI analysis. Overlay map of the result satellite image interpretation was used to learn the change of mangrove spatial extent area due to tsunami. The result showed that the mangrove area before the tsunami was 286.83 Ha (high density 36.63 Ha, medium density 140.60 Ha and small density 109.60 Ha), meanwhile the mangrove extent area after the tsunami was 102.51 Ha (high density 24.39 Ha, medium density 22,86 Ha and small density 55.26 Ha). The mangrove conditions before tsunami were crucial to the impact of mangrove area degradation directly. The change of mangrove spatial extent into two districts after tsunami occurred in 1996 amounts to 184.32 Ha, which it approximately 202.50 Ha mangrove being lost and the addition of mangrove in the new area are 18.18 Ha. The tsunami that occurred in 1996 affected the coastal ecosystems, especially the mangrove ecosystems in Oridek District.

Keywords: tsunami of 1996, mangrove spatial change, landsat satellite image, Biak Island

INTRODUCTION

Mangrove is the main ecosystem to support life activity in the coastal area and it is an important role to maintain the balance of biological cycle to the environment. It is also important for coastal societies because it protects the coast from hurricanes and tsunami, to filter the land pollutants. In addition, mangroves are a source of food, medicines, fuel and building materials. Beside the role and function of the mangroves, they experience the decrease in the quality and quantity around the world. The data showed that globally over more than two decades (1980–2005) mangrove lost more than 25% of the total area in the world (FAO, 2007; Giri et al., 2011).

One of the factors causing damage and loss of the coastal ecosystem are natural disasters. Indonesia is an area that is vulnerable to earthquakes and tsunami (Strunz et al., 2011). The Biak Island is an area that is classified as vulnerable to earthquakes and tsunami disasters. On February 17, 1996, an earthquake with the magnitude of Mw 8.2 occurred 60 km northeast of Biak Island, which le to a tsunami with run up height 7.7 meter water (Prawiradisastra and Santoso, 1997; Løvholt et al., 2012; Yudhicara, 2012). Tsunami damaged various coastal ecosystems and infrastructure in Biak Island (Prawiradisastra and Santoso, 1997). Other studies pertaining to the impact of the tsunami on coastal ecosystems concluded that tsunami incidents led to the vulnerability and damage of natural resources in coastal areas, such as mangrove ecosystems (Römer et al., 2012; Mutmainah et al., 2016), coral reef ecosystems (Fernando et al., 2005; Kaiser et al., 2013) and seagrass ecosystems (Kaiser et al., 2013).

Remote sensing technology is one of the technologies that can be used to identify the distribution, density and even spatial extent of mangrove change due to the tsunami that occurred in 1996. This is based on the location of mangroves which is found in the land of sea transition area and provides an unique recording effect if it compared to the another object land vegetation. In addition, the spectral values in satellite image can be extracted into mangrove object information in the range of near-visible and infrared spectra (Suwargana, 2010). Landsat satellite image is the most used solution for mapping mangroves (Kuenzer et al., 2011). Although the Landsat image is categorized as medium-resolution remote sensing data (Roy et al., 2014), many research results show the overall accuracy of mangrove mapping using Landsat satellite image is good (Kirui et al., 2013; Jhonnerie et al., 2014; Hamuna et al., 2018).

Nowdays, the information on the impact of the tsunami of 1996 on coastal ecosystems, especially mangroves on eastern coastal of Biak Island, especially in the District of Oridek and the District of East Biak is limited. Therefore, the purpose of this study is to understand extent of spatial mangrove change after the incident of 1996 by using multitemporal Landsat satellite image. Another purpose of this research is to learn the mangrove distribution and density in the Oridek District and East Biak District, Biak Numfor Regency, Papua Province before and after the Tsunami in 1996. The result of this research is expected to provide the information on the mangrove condition for coastal ecosystem management in Oridek District and East Biak District.

MATERIALS AND METHODS

The study area in this research is located in the eastern coastal area of Biak Island include the Oridek District and the East Biak District, Biak Numfor Regency, Papua Province. This study used primary data and secondary data. The primary data include the satellite Landsat image and field data. Landsat 5 TM satellite image acquisition of July 6, 1994 and Landsat 7 ETM+ satellite image acquisition of August 31, 2000, path 104 and row 61 were used for identification and classification of mangrove distribution and density. The field data will give information about mangrove species and retrieval of 50 mangrove coordinate points using GPS (Global Positioning System) which is used for the validation or testing process of the classification accuracy. The secondary data will achieve from government agencies such as information related to mangrove ecosystems in the research location.

The first thing to do before satellite image processing is to conduct radiometric correction and geometric correction. The purpose of radiometric correction is to reduce the atmospheric disturbance factor as the main source of error by using adjusment histogram method. The next step is performing geometry correction with reinforcing the image, so that the geometry is planimetric. The image of reactivation uses a ground control point with direct coordinate measurements in the field. Landsat 5 TM and Landsat 7 ETM+ satellite image data refer to the exploration of RGB 453 composite image to identify the mangrove vegetation. The first step to classify the image is making training area in order to classify the same color of pixels with a supervised method. The supervised classification was conducted using Maximum Likelihood Classification (MLC) method.

The value of vegetation index in this study is the result of image processing with using transformation Normalized Difference Vegetation Index (NDVI). The value of this vegetation index is calculated as the ratio between the measured reflections of the red band (R) and the infra-red band (approached by the NIR band). In order to calculate the value of mangrove vegetation density the ratio method between near infrared band (NIR) and red band can be used (Green et al., 2000; Uttaruk and Laosuwan, 2017; Laosuwan et al., 2017) with the following equation:

$$NDVI = (\rho 2 - \rho 1)/ (\rho 2 + \rho 1) \quad (1)$$

where: $\rho 2$ is Near Infrared Band (NIR),
$\rho 1$ is Red Band (R) and NDVI is Normalized Difference Vegetation Index

Determination of mangrove density scores was carried out using the results from NDVI calculations divided into three classes, such as rare density, medium density and dense density. All the process stages of Landsat satellite image processing data using ER Mapper 7.0 software. In order to learn how significant the change of mangrove area is a mangrove map of 1994 and 2000 using ArcMap 10.5 software were utilized.

RESULTS AND DISCUSSION

Mangrove distribution and density

The comparison of mangrove density and extent in Oridek District and East Biak District in 1994 and 2000 was presented in Table 1. On the basis of the results of satellite image processing, the mangroves in the study area from 1994 to 2000 degraded from the mangrove area and mangrove density aspect. In 1994, mangroves were dominated by medium densities of approximately 49.02% of the total mangrove area of 286.83 ha, meanwhile the low and high densities were 38.21% and 12.77%, respectively. The condition of mangrove in 2000 was dominated by a low density of 53% of the total mangrove area of 102.51 Ha, meanwhile medium and high densities were 22.30% and 23.79%, respectively.

The density level of mangrove vegetation can be used to determine the extent of mangrove forest degradation. The standard criteria for mangrove degradation include the size of the physical and biological changes of mangrove that can be used determine the condition or status of mangroves. On the basis of the Environment Ministry of the Republic of Indonesia (2004) about standard criteria of mangrove degradation, the mangrove conditions in the eastern coastal area of Biak Island (Oridek District and East Biak District) in 1994 were still in good condition with 61.79% (177.23 ha) and degradation conditions amount to about 38.21% (109.60 ha), meanwhile the mangrove degradation conditions in 2000 reached about 53.91% (55.21 ha) and good condition – 46.09% (47.25 ha). The degradation of mangrove conditions was characterized by sparse mangrove density occurring in Oridek District.

The distributions of mangrove density between Oridek District and East Biak District are different, including the extent and distribution of mangrove density levels in 1994 and 2000 (Figure 1). The extent of mangrove area in Oridek District in 1994 was higher, dominated by medium density mangroves compared with high density in East Biak District. In contrast with the extent of mangroves in 2000, it was higher in the East Biak District which was still dominated by high density compared to Oridek district dominated by low densities. The reduction of the spatial mangrove extent in Oridek District resulted from the impact of 1996 tsunami. The distribution of mangrove vertically to the mainland can be explained by being narrow. It related to the condition of the area; there is no estuary of the river and types of mangrove are thin or narrow. The mangrove distribution in East Biak and Padaido Islands before the 1996 tsunami ranged from 30–250 m, with an average width of 150 m (Wouthuyzen et al., 1995).

Table 1. The comparison of the extent and level of mangrove density in 1994 and 2000

Mangrove density	1994	2000
Rare mangrove	109.60	55.26
Medium mangrove	140.60	22.86
Dense mangrove	36.63	24.39

Mangrove condition after the tsunami in 1996

The changes in the area of mangrove cover pertain to the increase or decrease of mangrove area in a given period. This change in mangrove cover occurs if there is an increase in the mangrove area due to the growth of mangrove forest, while the reduction of mangrove area occurs if the area mangrove is dead or lost and replaced by another land cover. The extent of mangroves change in Oridek District and East Biak District after tsunami disaster in 1996 were presented in Figure 2. The mangrove density conditions before tsunami determine how vast was the extent of lost mangroves because of the tsunami. The decrease of mangrove area happened almost entirely in Oridek District, in which the mangroves affected by the tsunami are dominated by low and medium density mangroves; meanwhile the high mangrove densities in East Biak District are impacted to a small extent. In the period of 1994–2000, there was also an extension of mangrove area by about 18.18 ha which in 2000 was still dominated by low mangrove density. The tsunami of 1996 also affected the change of mangrove densities from the medium density to low densities caused by the tsunami waves.

The tsunami of 1996 contributed to the decrease of mangrove area by 202.50 ha (about 70.59% of total mangrove area in 1994). The condition is related to the run-up height that occurred during the 1996 tsunami, which reached 7.7 m. These highly reduced areas of mangroves led to an increase in the pressure on the human

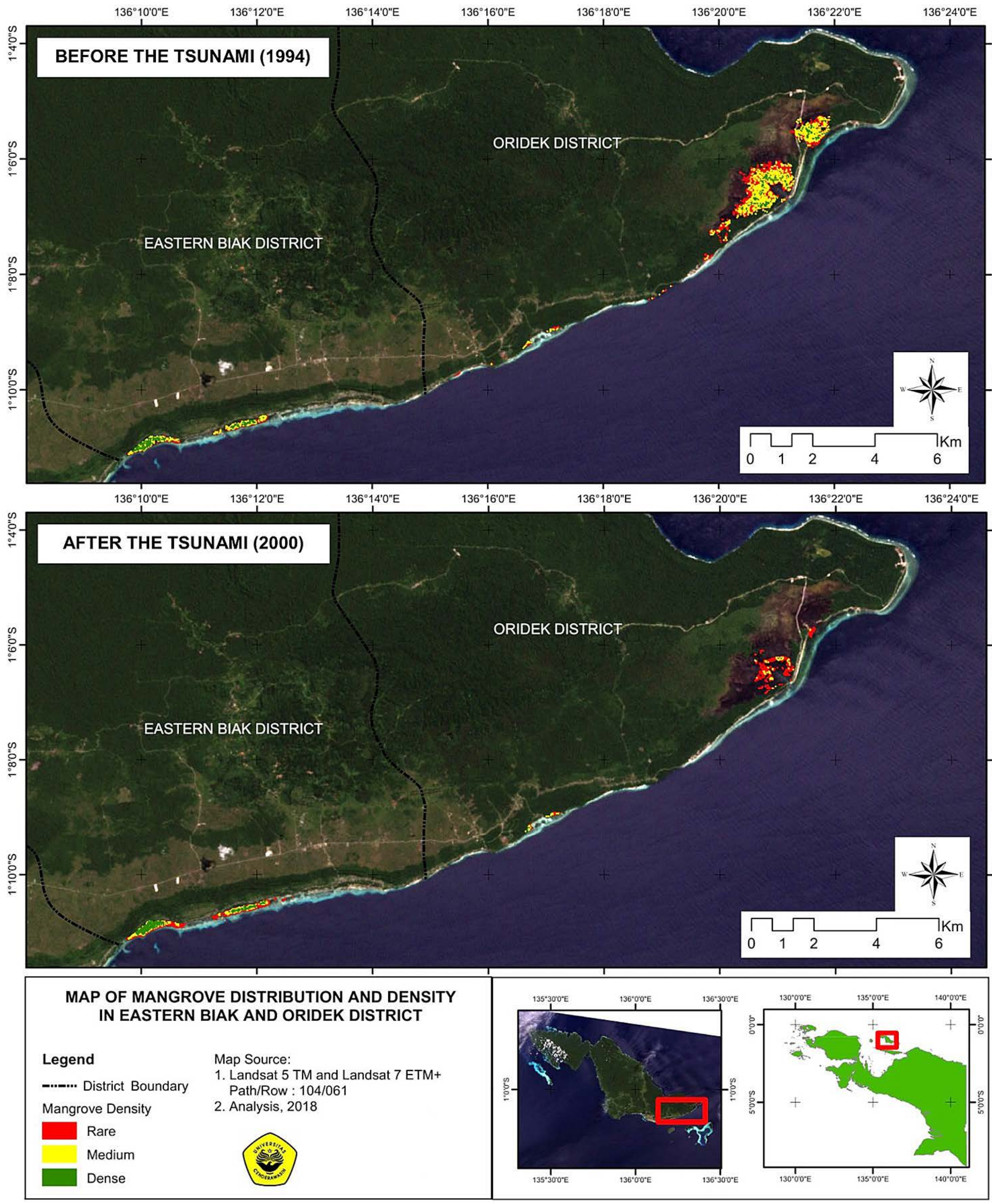

Figure 1. Map of mangrove distribution and density of Oridek District and East Biak District in 1994 (above) and 2000 (below)

security and coastal development to protect against the dangers of coastal disasters such as erosion, flood, high waves and storms (Gilman et al., 2008). The direct impact of tsunami on other coastal ecosystems, such as coral reefs and seagrasses, only occurred in small areas, when compared with the impact on coastal forests such as mangroves with extensive damage and greater negative impact (Römer, 2011).

The tsunami of 1996 occurred without expectation, leading to the changes in the structure of mangrove community. On the basis of the results of several studies, it was shown that the mangrove conditions in the coastal areas of East Biak before tsunami in 1996 were dominated by mangroves *B. gymnorrhiza* and *S. alba* (Wouthuyzen et al., 1995). The structure of the mangrove community after tsunami is still dominated by the *B.*

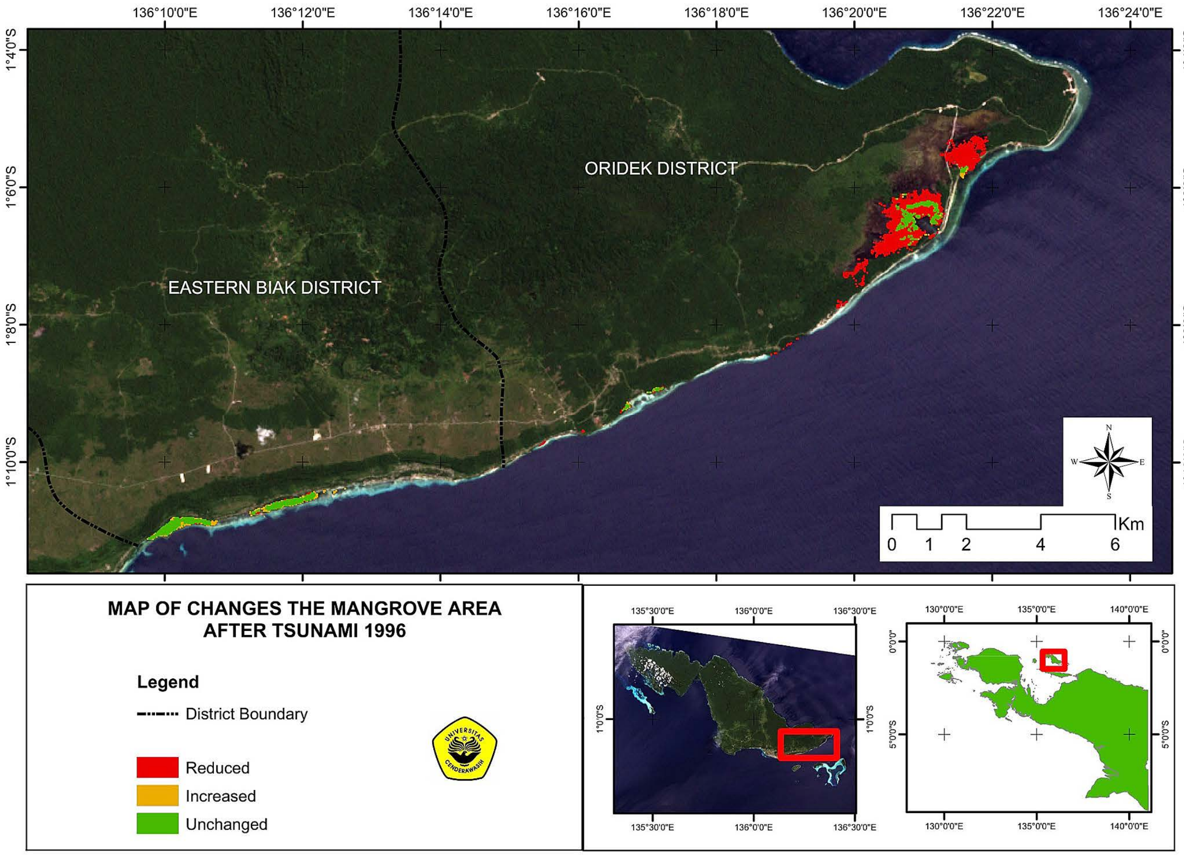

Figure 2. Map of mangrove spatial changes in Oridek District and East Biak District after the tsunami 1996

gymnorrhiza and *S. alba* in the seedling and tree categories due to the suitable substrate conditions, namely sandy sludge substrate; otherwise in the density category, it is dominated by *R. apiculate* and *S. alba* (Katiandagho, 2015). It corresponds with the results of research by (Prasetyo et al., 2016) in which *S. alba* is found more commonly.

CONCLUSIONS

The tsunami in 1996 affected the extent spatial of mangroves in the Oridek District and East Biak District. The total mangrove area was reduced by 202.50 Ha which is dominated by mangrove of low and medium density, meanwhile the addition of mangrove area in a new area which occurred after tsunami (year 2000) is 18.18 Ha. The mangrove area before the tsunami area was 286.83 Ha, meanwhile the mangrove area after the tsunami is 102.51 Ha. The impact also led to the composition change of mangrove densities. As a result, the mangrove densities were becoming sparser after tsunami. The tsunami of 1996 had a great impact on the mangrove ecosystem in Oridek District.

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