Eco. Env. & Cons. 27 (1) : 2021; pp. (439-446)
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ISSN 0971–765X

Spatio-Temporal Dynamics of Mangrove Forests in Surabaya from 1996 through 2016

Sumarmi*[a], Purwanto and Tuti Mutia****

[1]Geography Education Department, Faculty of Social Science, State University of Malang, Malang, Indonesia
[2]Geography Education Department, Faculty of Social Science and Economic, University Hamzanwadi, Indonesia

(Received 26 June, 2020; accepted 1 September, 2020)

ABSTRACT

Surabaya is one of the fastest growing cities in Indonesia. There is rapid development in eastern Surabaya from year to year. This research aimed to identify the expansion of mangrove forests in the last 20 years (1996-2016) based on the data of remote sensing and Geographic Information System, to determine the zoning of mangrove in Surabaya to decrease the effects of global warming, identify the government role and community participation in mangrove conservation in Surabaya. This research was survey research which was designed by using remote sensing and Geographic Information System (GIS) approach. The remote sensing data in the form of Landsat and Quickbird satellite imagery were utilized to identify temporary changes in mangrove forests in the last 20 year period. The results of the study showed that in 1996, the mangrove forests were changed into 1,231 km^2, expanded to 3,3039 Km^2 in 2001, 2,872 in 2006, 4,484 Km^2 in 2011, and 9,459 Km^2 in 2016. Second, there was both negative (declining) and positive changes in mangrove forests. The narrowing mangrove area was caused by the expansion of Juanda airport, residential area, industrial area, and so on. The mangrove forests expanded to the direction of the Brantas estuary which expanded along with the sediment distribution to the Northern part of the east coast. Third, the mangrove conservation was done through business communities. Tourists were invited to plant mangrove directly. Besides, there was also an involvement of local government through the establishment of the local governmental regulation year 2008 regarding protected areas of 338 meters from the seaside.

Key words : *Spatio-temporal dynamics, Mangrove Forest*

Introduction

The mangrove area in Indonesia is approximately 4.5 million hectare (25 percent) of the total area of mangrove in the world. The total mangrove area in Indonesia is bigger than in Brazil (1.3 million ha), Nigeria (1.1 million ha) and Australia (0.97 ha) (Sembiring *et al.,* 2013). However, there is a happening issue of deforestation which results in coastal ecosystem change, and physical, biological, and economic deteriorations. Mangrove forests have many benefits and functions. They maintain the seawater far below the land surface, prevent erosion from storm and wind, decrease the CO_2 content in the air, act as a fixative for water contamination, as a home to marine biota, and as a source of food and medicine (Silver *et al.,* 2010; Mander *et al.,* 2015).

Sedimentation affects the condition of the mangrove forests above it, which influence the mangrove forests' ability to prevent storm and tsunami. The findings of research (Spencer *et al.,* 2016) stated that the geomorphological condition in the coastal

area has to be considered in the implementations of mangrove reforestation and restoration for them to be effective (Barnuevo *et al.,* n.d.2017). The sediment salinity, distance to the nearest coastline, mangrove vegetation communities and vegetation communities under the mangrove will increase the heavy metal concentration (Liu *et al.,* n.d. 2017) and (Habert, 2014).

A spatial planning becomes critical for coastal areas to anticipate the impacts of sea level rise due to global warming on a wide scale and the long dimension of time. The spatial planning policy should include coastal area (including disaster prone area of tsunami and flood) protection. The protection should be centered on the mangrove area (Carson *et al.,* 2016; Wiens, 2016).

The signs of global warming have appeared in the last twenty years. There have been three droughts which caused significant loss (Lloyd *et al.,* 2016); (Osland *et al.,* 2016). Therefore, it is important to anticipate the impacts and solve the problems of large and lengthy sea level rise due to global warming. The problem can be solved by paying attention to protection and cultivation areas. It is necessary to improve the durability of mangrove in anticipating sea level rise. Anthropogenic intervention on the sustainability of mangrove is essential to maintain the coastal ecosystem stability, especially along the changing coastal areas because of urbanization (Willemsen *et al.,* 2016).

In general, investors are invited to participate in urban development by putting investment throughout the city, including coastal cities. There were changes in the eastern area of Surabaya from year to year, which related to Tanjung Perak Harbor, Suramadu Bridge, Juanda Airport expansion, residential area, industrial area, and tourism area. It results in the vulnerability of mangrove forest conservation in such areas.

The coastal area in Surabaya extends from the north to the east. The Surabaya coastal area is influenced by the river mouth of several rivers, such as Bengawan Solo River in Gresik, Porong River in Sidoarjo, and Mas River in Surabaya. The sedimentation of such rivers also affects the mangrove area development.

The researchers used GIS application and remote sensing in the form of Landsat and Quickbird satellite imagery to measure the mangrove area in Surabaya affected by the rapid development, and the expanded sediment (Wahana Komputer, 2014; Bolstad, 2016).

This research aimed to identify the expansion of mangrove forests in the last 20 years (1996-2016) by using remote sensing data and Geographic Information System, the zoning of mangrove in Surabaya to decrease the effects of global warming, the government role and community participation in mangrove conservation in Surabaya.

Materials and Method

This research was a survey research designed with remote sensing and Geographic Information System (GIS). The remote sensing data in the form of Landsat and Quickbird satellite imagery was utilized to identify the temporal changes of mangrove forests for the last 20-year period (from 1996-2016). Such data of changes were then integrated with the data from the field measurement and were subsequently analyzed via GIS to identify the mangrove area expansion. The remote sensing data gathered from Quickbird were used to study the current land utilization related to the activities of the communities around the mangrove area and the governmental policy over the existence of mangrove forests.

The equipment used in this research included a computer, ENVI/Er Mapper Software to analyze the Satellite imagery, GIS Software with ArcGIS 10.2 to analyze the spatial data, Global Positioning System (GPS), and camera. Additionally, the required materials were a topographical map of Indonesia: 1:25,000, topographical map of Indonesia: 1:10,000, Bathymetric Chart/coastal map of Indonesia: 1:50,000, Landsat MSS, TM, ETM+ and Landsat satellite imagery, DEM Aster satellite imagery, and Quickbird satellite imagery.

The object of this study was global warming, centered on the changing mangrove area in East Surabaya. The data collected were in the form of primary and secondary data. The primary data included the data of the existing land use, while the secondary data consisted of satellite imagery, map, and documentation related to spatial planning policy in Surabaya. The techniques utilized in data collection were a survey, interview, and documentation. The survey was used to identify the land utilization in the field directly. The interview was used to collect the relevant data from the authorities, namely the Regional Development Planning Agency of Surabaya and Spatial Planning Agency. The documentation was used to collect the data of

spatial planning policies.

The analysis of the changing mangrove area was performed via NDVI (Normalized Different Vegetation Index) method which is a standard method used to compare the vegetation greenness levels in satellite data. The formula of NDVI is as follow:

NDVI= (NIR – RED) / (NIR + RED).

Results

Changes in Mangrove Area

From the results of satellite imagery analysis, the changes in mangrove area in Surabaya form 1996-2016 are presented in Table 1 below:

Based on Table 4.2 above, the changing trend of Mangrove area can be identified. In 1996, the mangrove forests were changed into 1,231 Km^2, expanded to 3,3039 Km^2 in 2001, 2,872 in 2006, 4,484 Km^2 in 2011, and 9,459 Km^2 in 2016. The trend of the mangrove area changes is presented in the following graph:

Table 1. Trend of Changes in Surabaya Mangrove Area from 1996-2016

No.	Change in Surabaya Mangrove area per year (km^2)				
	1996	2001	2006	2011	2016
	1,231	3,3039	2,872	4,484	9,459

Source: Results of Satellite Imagery Analysis, 2016

Fig 1. Graph of Mangrove Area Changes from 1996-2016

Based on the Figure 1 above, the trend of mangrove area changes kept increasing from 1996. The highest increase occurred in 2016, namely of 9,4590 Km2. The currently developed and existing mangrove forests locate in rivers and coastal areas. In the hinterland, mangrove grows along the river or dyke, while in river mouths or coastal zone, mangrove commonly grows on the river sides. The spatial dynamics of changes in mangrove forests in Wonorejo and the survey results are shown in Table 2 as follow.

Table 2 shows the adverse trend of changes in mangrove areas, namely the transformation of mangrove area into built environment or other land conversions. The mangrove forests distribution due to the land use for built environment is depicted in fig.

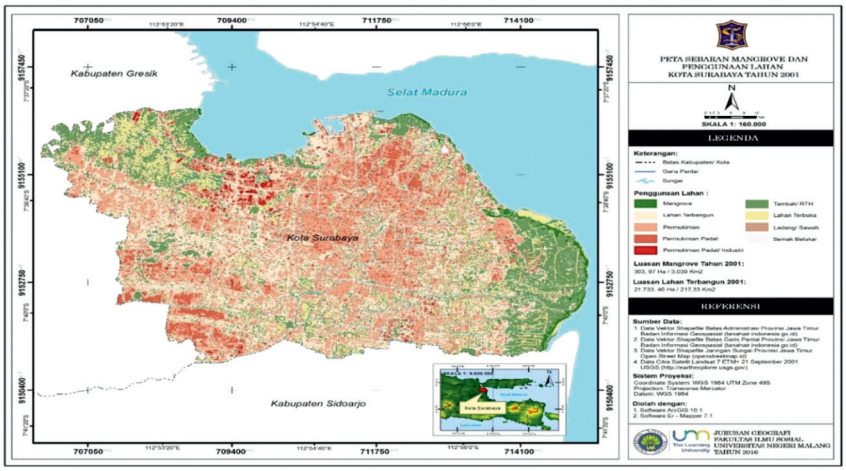

Fig. 2. Distribution Map of Mangrove in 2001

Table 2.

No.	Location	Coordinate		Changes in Vegetation Density (NDVI = 0,1 - 1)				
		X	y	1996	2001	2006	2011	2016
1.	The Main Parking Area of Ecotourism of Wonorejo Mangrove Area	701500	9191892	0,516	0,509	0,594	0,368	0,481
2.	Scrubland (Scrub vegetation) in the ecotourism area	701924	9191725	0,482	0,433	0,677	0,571	0,632
3.	Pond in the ecotourism area	702494	919578	0,359	0,312	0,397	0,217	0,314
4.	River mouth in the ecotourism area	703585	9192102	0,161	0,195	0,125	0,162	0,111
5.	Mangrove forests Measurement Point	703614	9192005	0,187	0,424	0,478	0,793	0,879

2, 3, and 4 in 2001, 2004, and 2011 below:

Zoning of mangrove area spatial planning in Surabaya to decrease the impacts of global warming.

Besides the negative change, mangrove forests also have a positive change, i.e. the expansion of mangrove forests. It is due to mangrove forest growth in coastal areas. Such positive change was detected from the mapping via Landsat satellite from 1996-2016 as presented in the following map.

The Mangrove in Wonorejo is superior to other areas since it locates in the river mouth which takes organic sediment preserving an appropriate ecosystem for mangrove. The natural resource potential is

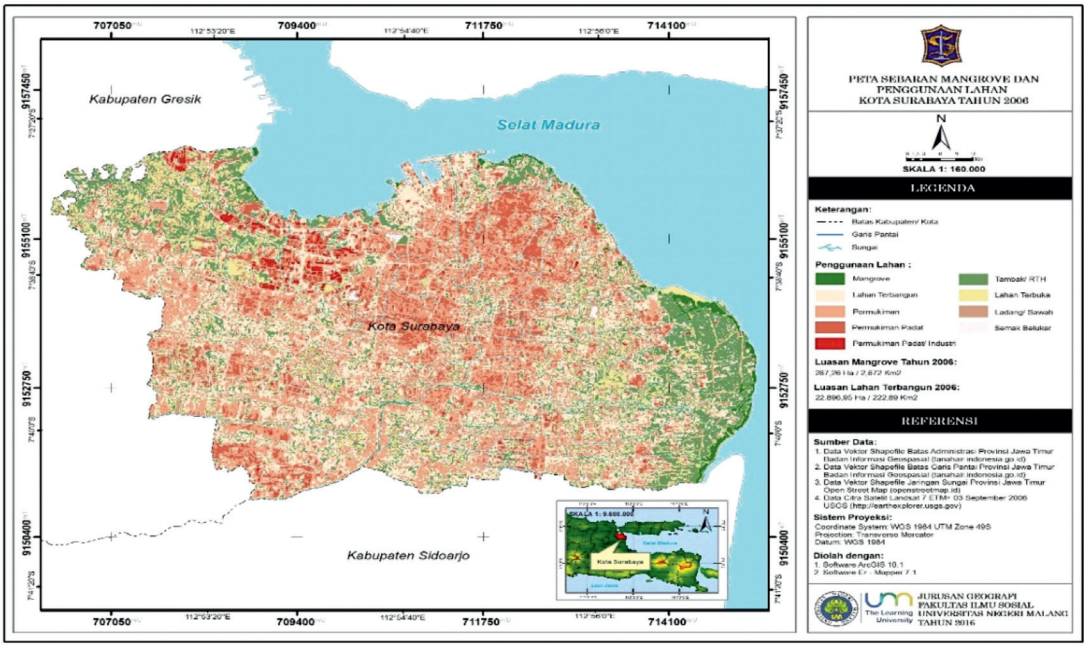

Fig. 3. Distribution Map of Mangrove in 2006

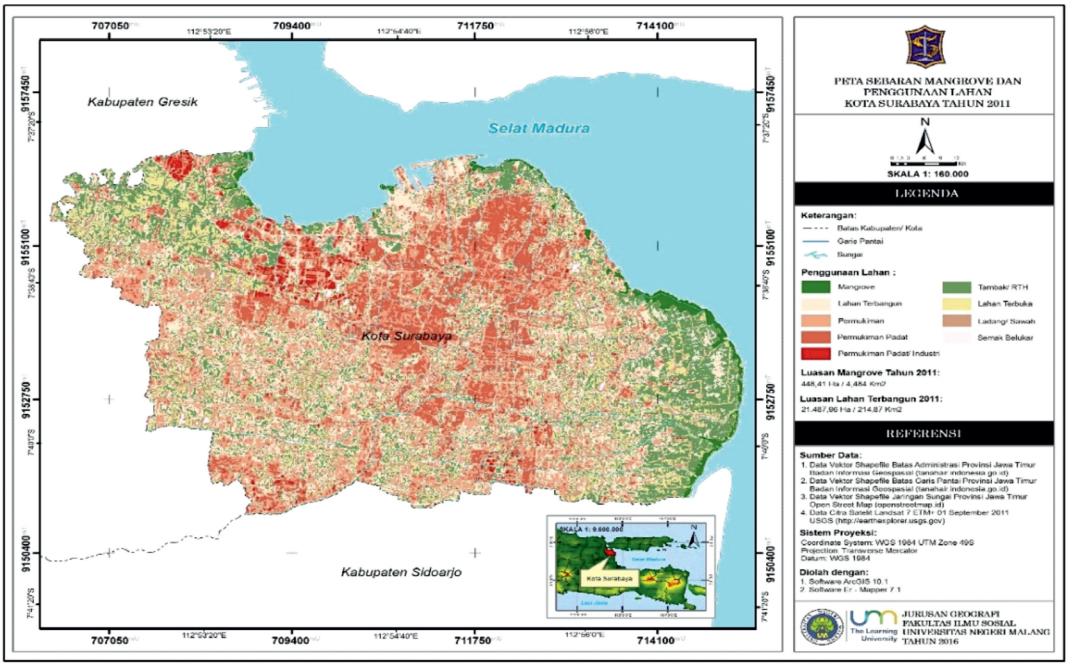

Fig. 4. Distribution Map of Mangrove in 2011

supported by the government and community participation in ecotourism activities (Umam *et al.*, 2015). It can be seen from Fig. 4 and 5 above that the developed mangrove is located in coastal areas. Such development is in line with the sediment distribution from the Brantas river mouth to the Northern east coast.

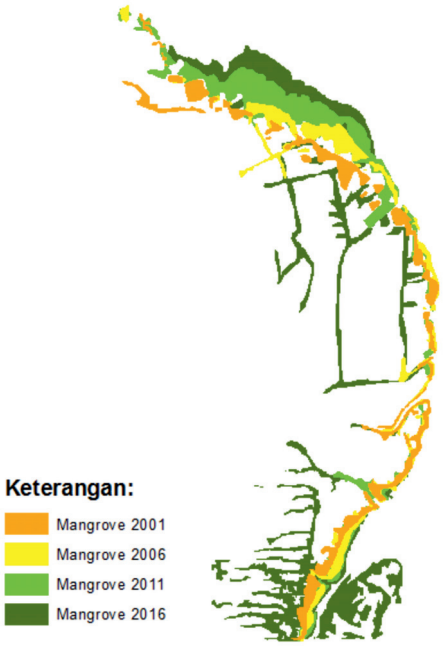

Fig. 5. Trend of Eastern Surabaya Mangrove Area Change from 2001-2016

The Surabaya coastal area is affected by the several river mouths of Bengawan Solo River in Gresik, Porong River in Sidoarjo and Mas River in Surabaya. The river mouths Identifying the government role and community participation in mangrove forests conservation in Surabaya.

The mangrove area in Surabaya extends from the northern to the eastern coastal zone. Surabaya's mangrove area is located in Kenjeran to Wonorejo areas. The mangrove area in Kenjeran is almost gone due to the massive development and beach reclamation to build the tourism area. In contrast, the mangrove area in Wonorejo which used to be damaged has expanded. The expansion of mangrove area in Wonorejo was due to the sedimentation of alluvial material in Mas River which expanded to the sea. Besides, it was also influenced by the community improved awareness to conserve mangrove. The community started to care about and participate in mangrove conservation. The community managed the mangrove ecotourism in Wonorejo with the assistance of the government officials and other institutions. There were also fishermen who were involved in the Mangrove activities in Wonorejo.

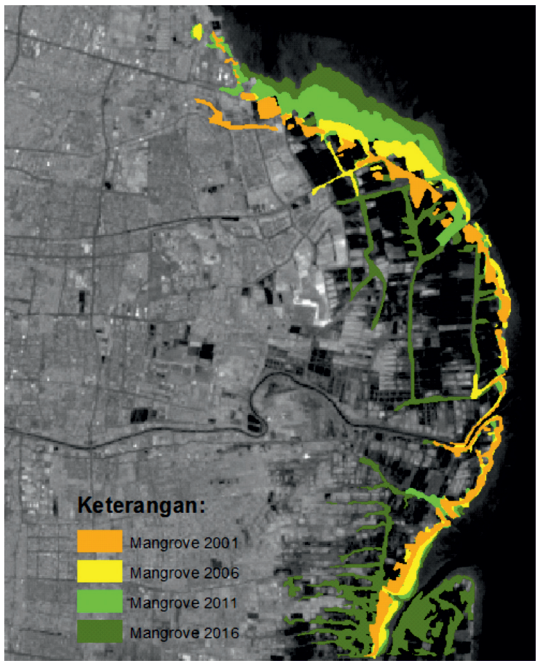

Fig. 6. Correlation between Sediment Distribution and Mangrove Forests Development in Surabaya

There are some data regarding mangrove conservation in Wonorejo taken through a field observation from 9-10 November 2016. The preservation of mangrove ecotourism is implemented in the form of business community. The tourists could purchase mangrove seeds for Rp 5000 and then plant them in the mangrove tourism area in Wonorejo. The tourists could plant the mangrove directly and independently in the holes prepared beforehand by the ecotourism officers. Such activity attracts many aspects of society, including the communities and students from around Surabaya who use the Wonorejo's mangrove area as a real-world supplement of thematic learning about the environment. in the coastal area are also affected by the urban development (Aminah, 2015).

Discussion

The mangrove forests hold a fundamental role for Surabaya as the green lungs of the city. It means that the mangrove forests have vital functions. Besides

as conservation areas preventing seawater erosion and abrasion, they also can prevent global warming. The mangrove forests which are continuously threatened locate in the Eastern area and are affected by the surrounding community activities. The main contributing factor to the changing mangrove area in the western Surabaya is residential area expansion. It results from the limited area for horizontal residential development in the Western, Southern, Northern, and Central areas of the City. The only area which is potential to be developed is the Eastern area of Surabaya which houses the mangrove forests of Gunung Anyar, Wonorejo, and the surrounding areas.

There are also some supporting factors in mangrove conservation and expansion in Wonorejo. The water pump located around the mangrove area contributes to the significant reduction of waste in the river flow. The surrounding community became aware of mangrove conservation by planting seeds and participating in mangrove ecotourism. The essential factor in mangrove conservation is no other than the activities of the surrounding community.

The mangrove condition in Gunung Anyar is quite similar to the mangrove condition in Wonorejo. Mr. Gramang initiated the mangrove ecotourism in Gunung Anyar. He is originated from Central Java. He said that the community used to be fish farmers. However, when the mangrove ecotourism was started to be developed, there was professional diversification of being ship guides. The ecotourism activities in Gunung Anyar were developed independently through the constructions of docks and gazebos. The further development was assisted by some institutions, such as Sampoerna, Pertamina, and governmental institutions which participated in the mangrove conservation in Gunung Anyar. Such companies purchased the mangrove seeds from the farmers and then planted them in the shore of Mas River mouth. However, as said by Mr. Kateman who was a ship guide in Wonorejo Mangrove Ecotourism, many seeds did not perfectly grow due to high tide in Mas River mouth. It is in agreement with the research (Rostika *et al.,* 2016) on the effects of abrasion and human activities on the narrowing mangrove area. Besides abrasion, the intensity of constant sea level rise also needs to be given attention (Carson *et al.,* 2016).

From the observation held on 9-10 November 2016, it can be identified that there was sediment in Mas river mouth utilized to grow mangrove by the community, companies, and institution. The research findings (Ellison, 1999; Verheyden *et al.,* 2004) showed that the variable of sediment also has a significant impact on mangrove development. The eastern coastal area of Surabaya turns out to be a meeting point of 2 rivers flowing from Surabaya and Sidoarjo. There is not any buoyant waste along the Rungkut River flowing from Surabaya. However, on the contrary, the river flowing from Sidoarjo contains a lot of waste and water hyacinth. Hence, if it is not managed immediately, it shall narrow the mangrove area in the river mouth.

The condition of Mangrove in Wonorejo has been changed. There were overlapping rules between the local authority and the government. The community did not have sufficient attitude and knowledge regarding the Wonorejo mangrove forests in 2008 so that there were many logging activities. However, nowadays, the community starts to understand about environmental conservation and participate in the ecotourism activities through community business and others. The research performed by Ariyanti, Erinda *et al.* (2012) stated that the Wonorejo community who used to treat their environment badly started to change and be aware of the environmental potential, and utilized the ecotourism to improve their quality of lives.

Such community awareness influenced the expansion of mangrove area in Wonorejo since there is an active participation of the community in conserving and growing mangrove. Additionally, research findings (Salampessy *et al.,* 2015) pointed out that the government may accommodate the cultural capital in the coastal development and conservation policy. The governmental policy could improve mangrove ecosystem (Rönnbäck *et al.,* 2007). Thus, it is important to develop the continuous green land cover to reduce global warming (Hwang *et al.,* 2017; Sumarmi, 2007; Sumarmi, 2012; Yumino *et al.,* 2015).

Mangrove ecosystem functions significantly not only for the coastal community but also the non-coastal community. There are many beneficial effects of mangrove forests, such as inexpensive housing for marine biota and protection from the storm for the coastal and non-coastal communities. Besides, there are many other side benefits of mangrove, such as the mangrove fruits as food, medicine, and syrup. Since mangrove is a multifunction plant, its conservation is necessary (Siburian and Haba, 2016).

Conclusion

In 1996, the mangrove forests were changed into 1,231 Km^2 expanded to 3,039 Km^2 in 2001, 2,872 in 2006, 4,484 Km^2 in 2011, and 9,459 Km^2 in 2016. There have been changes in mangrove distribution within a decade (1996-2016). Mangrove area expansion to coastal areas, mangrove area conversion into ponds, and into the built environment, causes such changes.

There are negative changes (narrowing mangrove area) and positive changes. The narrowing mangrove area results from Juanda airport expansion, residential development, industrial development, and so on. The mangrove area expanded to Brantas river mouth, which is in line with the sediment distribution to the Northern part of the east coast.

A business community implemented the Mangrove conservation in Surabaya; the tourists are invited to plant mangrove plants. Additionally, there is also an involvement of local government through the establishment of a Local Government regulation in 2008 regarding protected areas of 338 meters from the seaside.

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