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SHORELINE AND MANGROVE ANALYSIS ALONG SEMARANG-DEMAK, INDONESIA FOR SUSTAINABLE ENVIRONMENTAL MANAGEMENT

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ABSTRACT

This study analyses changes in shoreline and mangroves status at the gulf coast of Sayung-Demak, Indonesia. Data on shoreline changes were from high-resolution imagery in 2005, 2010 and 2017 by ArcGIS 10.3, while mangrove diversity data were observed from field studies using the transect method at three locations at the Semarang-Demak beach frontier. Based on the analysis and calculations, it was found that the coastline was decline by 0.49 km from 2005 to 2010, and incline by 3.30 km from 2010 to 2017. Abrasion occurred was 285.07 ha and accretion of 2.40 ha. The composition of mangroves on the border of Semarang-Demak consists of A. alba, A. marina, R. mucronata, R. stylosa, S. casseolaris. For this reason, it is necessary to monitor changes in shoreline and the status of mangroves on the Semarang-Demak border. In addition, it is essential to do integrated environmental management in coping with abrasion.

Keywords: shoreline changes, sustainable environmental management, Semarang-Demak border

INTRODUCTION

Coastal area is sensitive area as its position is under intense pressure of natural processes, such as erosion, natural disasters and anthropogenic processes like urban growth, resources development and pollution. Those threats put the coastal zone a priority for coastal management programs and continuous monitoring of shoreline changes (Ghosh et al., 2015). The shoreline itself is a meeting area between land and sea (Suniada, 2015).

Changes in shoreline as a result of erosion occur in three provinces in Thailand. It is because of natural factors and human activities causing loss of the marine life cycle. Thus, it is economically and environmentally harmful (Tochamnanvit & Muttitanon, 2014). Shoreline changes also occur in Mangalore, India, resulting in higher erosion area compared to extended areas (Shetty et al., 2015). Coastline changes also occur in the Pearl River Estuary, China, which straiten river channels causing more floods in the upper course (Li & Damen, 2010).

In Indonesia, shoreline change occurred between Subang district, West Java with change

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of 350.18 m (Soraya et al., 2012) and Bali caused by abrasion resulting coastline deterioration (Hidayah et al., 2012; Suniada, 2015). Shoreline changes highly affect the coastal border area.

The shoreline here is specifically defined as the line along the coast for protection with a proportional wide to the shape and physical environmental condition with a minimum limit of 100 m from the highest tide to the land (Republic of Indonesia, 2016). The regulation in Indonesia also settles the significance of coastal border conservation. However, the shoreline is prone to environmental damage due to abrasion or environmental changes done by humans such as hotels, settlements, industries, and so on (Suedy et al., 2015).

The high rate of abrasion along Semarang-Demak beach finally changes the coastline. Some researches prove that the shoreline in Sayung, Demak declines away over the years (Marfai, 2012; Ervita & Marfai, 2017). The wave is also responsible for the change and coast destruction. Another problem appears is flooding. This fact causes 221 houses in Bedono (a village at shoreline of Sayung, Demak). They should be evacuated to other areas (Asiyah et al., 2015). Some efforts have been done to handle abrasion, including constructing protective dikes or environmentally friendly residential concepts that integrates physical, social, economy, and spiritual environments (Ristianti, 2016). However, the efforts made have not yet given maximum results as the erosion process has continued to occur intensively since 1994. It causes changes in the coastline in Sayung Demak sub-district (Ervita & Marfai, 2017).

Changes in shoreline due to erosion and tsunami can be prevented by the presence of natural coastal protectors in the border, such as mangroves (Alongi, 2014, 2015; Blankespoor et al., 2016). Mangrove is an ecosystem in the intertidal area connecting sea, brackish water, rivers and land. Mangroves exist in the tropics and subtropics with coordinate location of 250°N and 250°S. Mangroves are also associated with organisms and supporting environmental factors of its ecosystem (Sengupta, 2010) as it is in the Semarang-Demak beach border. However, the status of the mangrove ecosystem at the boundary is currently in problems.

Mangrove problems occurring in Semarang-Demak frontier, Indonesia were caused by abrasion (Marfai, 2012) and land-use changes. These activities alleviate mangrove area and mangrove diversity so that it exacerbates its ecological role. The mangrove ecosystems have crucial ecological functions as it has high productivity and becoming an important place to take refuge (shelter), spawn, lay eggs, grow the fauna associated with it (Sandilyan, 2014), ability to absorb heavy metals (Kariada & Irsadi, 2014) and ability to absorb carbon compounds (Martuti et al., 2017). These ecological roles could optimally work if it is kept away from damages by humans such as over-exploitation and land conversion.

Mangroves planting efforts on the Semarang-Demak border have been done to expand mangrove areas (Chafid et al., 2012). However, mangroves of Demak in 2010-2015 still decreased by an area of 68.17 ha (Faturrahmah & Marjuki, 2017). On the other hand, the border area of Semarang beach also deals with land-use change to meet human needs such as the demands for resident, industry, and so on (Donato et al., 2012; Irsadi et al., 2017). The land-use changes threaten the sustainability of mangrove ecosystem.

This paper clarifies shoreline changes, abrasion, and proves its successful management based on change analysis of mangrove area at the border of Semarang-Demak. The shoreline changes at the border of Semarang-Demak should always be monitored as relevant information and solution for its sustainable environmental management. Due to the fact that is explained before, this study will analyse the change on the shoreline of Semarang-Demak. Identification and analysis of some environmental management has been also employed based on the changes of mangrove area.

METHODS

Time and Research Location

This is a descriptive-explorative research, done in June–December 2018. Observed variables included shoreline changes, mangrove areas, mangrove ecosystems vegetation, and conservation efforts at the coastal border. The locations for the observation of shoreline change, the extent of abrasion and accretion, and mangrove area are administratively involved in Sriwulan, Surodadi, Timbulsloko, Bedono, Demak and Trimulyo Villages, Semarang. Mangrove vegetation was from Trimulyo Village, Semarang City, Bedono Village and Timbulsloko Village, Demak Regency. The research location is the specific area with mangrove and affected by abrasion (Figure 1).

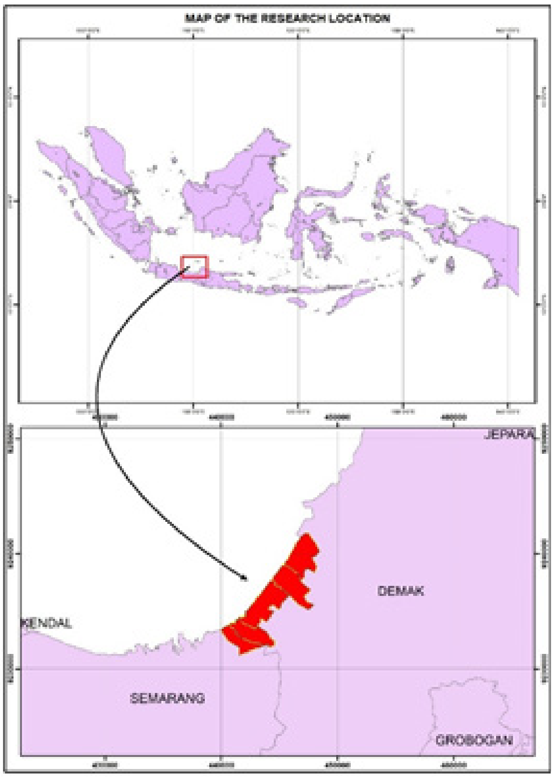

Figure 1. Research Location

Mangrove diversity research site. Sample areas of mangrove diversity were classified into three location based on the density (high, medium, rare). The first location was in Timbulsloko, Demak consisted of three research areas with 15 plots. The second location was in Bedono, Demak consisted of two research locations with 10 plots. The third location was in Trimulyo, Semarang included two research location with 10 plots (Figure 2).

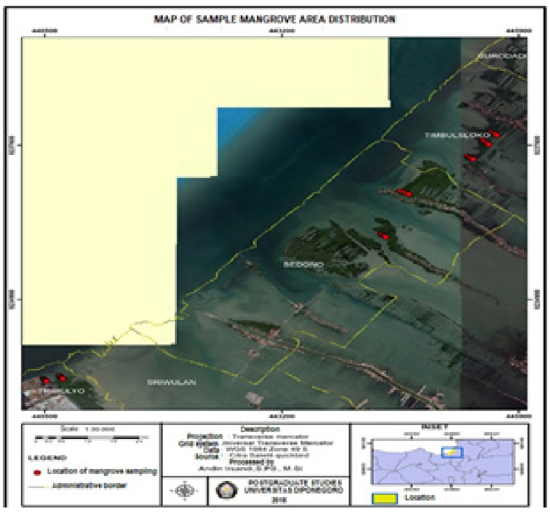

Figure 2. Map of Sample Mangrove Area Distribution

Data Collection. *1) Data on shoreline changes and mangrove area.* Changes in coastline and mangrove area originated from the quickbird high-resolution imagery with the accuracy of 0,6 m during 2005-2017. Data involve coastline length, area of abrasion and accretion, and the extent of mangrove that occurred among 2005-2017. Calculation of coastline length, extent of abrasion and accretion and the extent of mangrove were done by ArcGIS 10.3 software. The software was also employed to determine shoreline changes and mangrove area, supported to Indonesian earth map, time series mangrove area data on Semarang-Demak coastline 2005-2017, and Landsat images from 2005-2017. *2) Vegetation data*. In the research location, stand areas were subjectively determined by the density of mangroves (rare, medium, and high density). Then, transects were made. The length of the transect is 100 meters from the coast to land. Sampling was carried out at a distance of 0-20 m, 21-40 m, 41-50 m up to 100 m from the coastline and continued to determine the sampling area. Tree observations / data poles were taken by the quadratic method measuring 20 x 20 meters. To measure saplings, it is made smaller sized blocks (5 x 5 meters), while seedling data collection was from each plot measuring 2 x 2 meters (Hastuti et al., 2012). Further identification was done for mangrove species and quantities at each plot. In addition, observations of certain zones with special characteristics were done by descriptive methods. *3) Data on conservation efforts* is secondary data from non-profit organization in Bedono Village, Demak Regency.

Data Analysis on Shoreline Changes, Mangrove Area, Abrasion and Accretion

This analysis began by taking high-resolution imagery data (2005, 2010, and 2017) along the Semarang-Demak border which involved 5 villages including Trimulyo, Sri Wulan, Bedono, Timbulsloko and Surodadi. The locations are some villages affected by abrasion. The next stage was the determination of shoreline changes and mangrove area using radiometric correction to extract the information (Parman, 2010; Arief et al., 2011). Radiometric correction is employed to rearrange the reflected values recorded by sensors that have similar patterns to the reflection of an object and match the recording wavelength (Parman, 2010). Furthermore, the Landsat geometric data correction was also employed to compare coordinates and scale as well as the direction of the image and the map, which can then be stacked (Parman, 2010; Arief et al., 2011).

The next stage is on screen analogue digitizing. Further, analysis and calculation were done by integrating the results of digitization to identify the rate of shoreline change due to abrasion or accretion. Image processing steps for shoreline change as below (Figure 3).

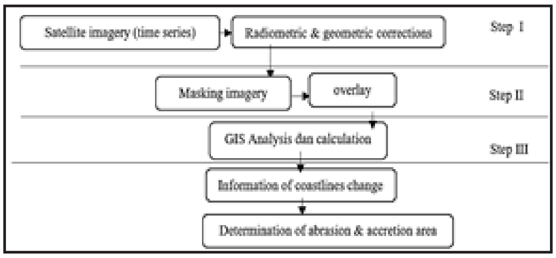

Figure 3. Steps of Image Processing

The calculation was then put in a matrix which informs year and the extent of abrasion and accretion to determine definite position of the observed area. The matrix provides summary of shoreline change from 2005-2017.

Vegetation data analysis. Vegetation in this study is all plants make up mangrove ecosystem which includes sample herbs, shrubs and trees. The plants were identified to determine the type or family and finally drew the species diversity in each area.

Analysis on mangrove conservation efforts. This data is explained by SWOT analysis in a matrix. In the matrix, alternative solutions on sustainable environmental managements for Semarang-Demak shoreline are given based on the strengths and weaknesses appeared. The matrix is briefly explained as follows.

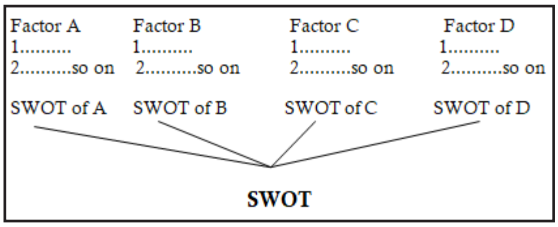

Figure 4. SWOT Analysis Matrix

The factor A is related to people's awareness in cultivating mangroves while the Factor B is parallel with the existence of mangrove management agencies. Further, the Factor C is connected to mangrove policies and the Factor D links to economic benefits of mangroves.

RESULTS AND DISCUSSION

Changes in Coastline and Mangrove Area in 2005-2017

Based on the mapping, the changes of coastline along the Semarang-Demak during 2005-2017 as Figure 5.

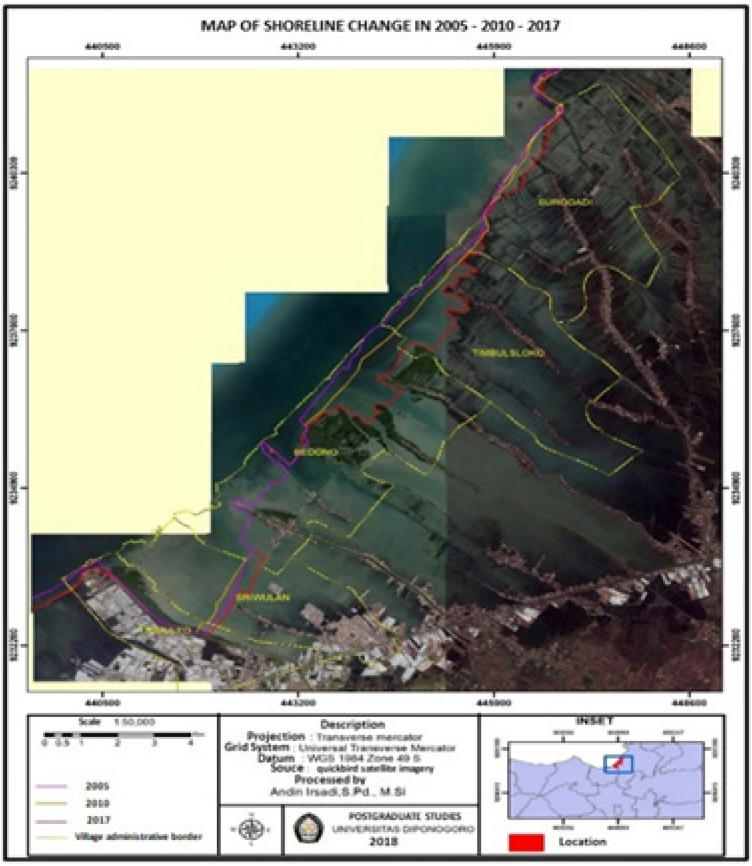

Figure 5. Map of Coastline Changes at the Semarang-Demak Border in 2005-2017

Based on the calculations, the coastline changes are as follows.

Table 1. Data on Shoreline Changes at the Semarang-Demak Border in 2005-2017

	Year	Shoreline (Km)	Changes in 2005 - 2010	Changes in 2010- 2017
1	2005	17.32	declined 0.49 km	
2	2010	16.83		inclined 3.30 km
3	2017	20.13		

Table 1 reveals that the borderline of Semarang-Demak experienced a long incline caused by the coast position which is getting juttered to the mainland. Beach changes happened due to the process of abrasion and accretion. The mapping with the quickbird satellite imagery shows that the area affected by abrasion is greater than the one affected by accretion. The results of the quickbird mapping also show that the area affected by abrasion is an open area and directly borders the sea. The abrasion and accretion data along Semarang-Demak border from mapping were as Figure 6.

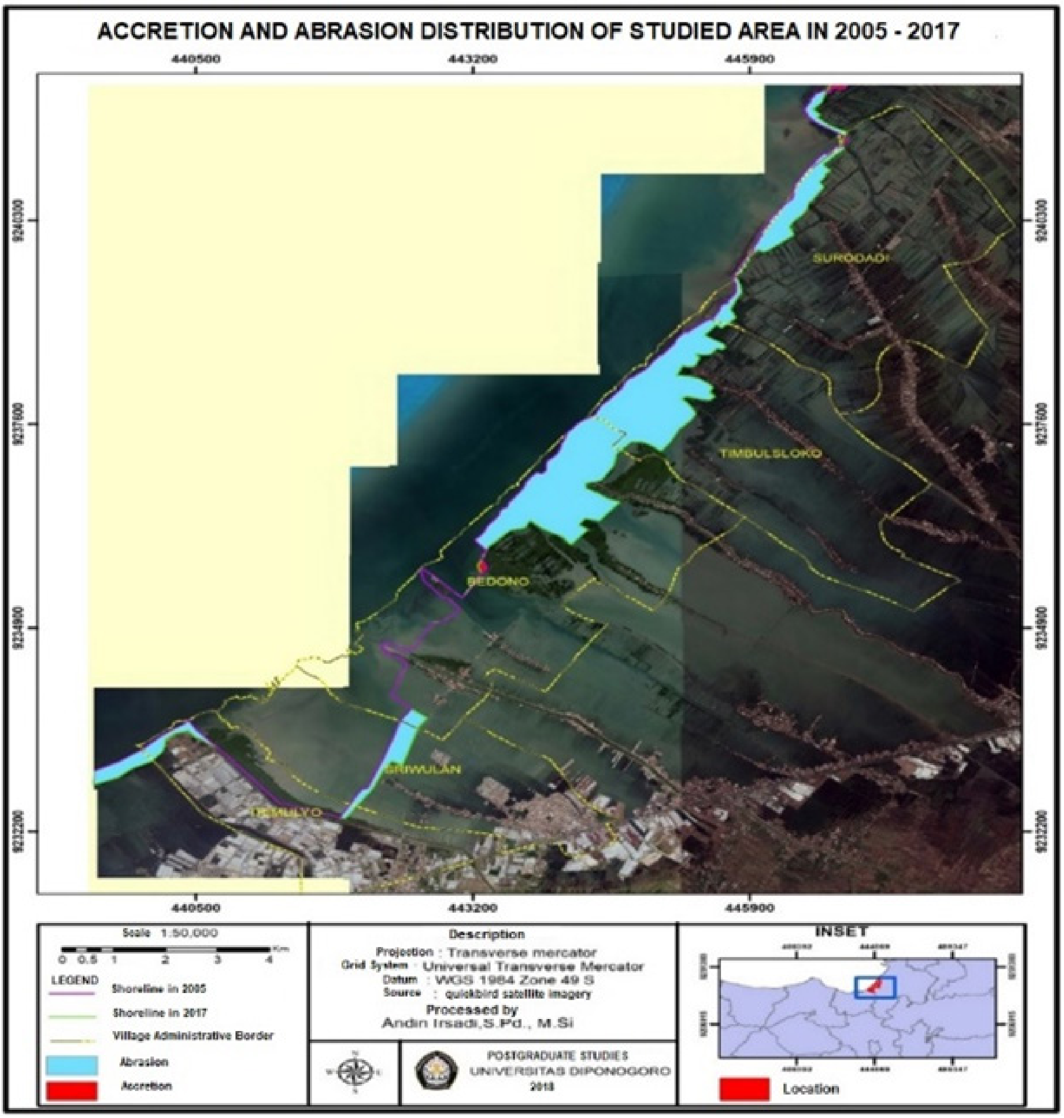

Figure 6. Distribution Map of Abrasion and Accretion along Semarang-Demak border in 2005-2017

The map of abrasion and accretion distribution (Figure 5) conveys that Trimulyo, Sriwulan, Bedono, Timbulsloko and Surodadi areas are affected by abrasion. In addition, Bedono village and Timbulsloko are areas with severe category abrasions. Based on the extensive abrasion and accretion calculations occurred along Semarang-Demak border in 2005-2017, the data in Table 2 are summarized.

Table 2. Extensive Changes in Abrasion and Accretion on the Semarang-Demak border in 2005-2017

	Year	Shoreline (km)	Abrasion area (ha)	Accretion area (ha)
1	2005	17.32	93.26	0.29
2	2010	16.83	217.93	2.77
3	2017	20.13	285.07	2.40

Table 2 implies that the abrasion of Semarang-Demak border is higher than the accretion process so that the process of depositing land naturally becomes harder. This also constricts land area in Sayung, Demak and areas that were previously used as dwellings became covered in water because of the abrasion (Asiyah, et al. 2015) The inhabitants decide to survive and deal with environmental conditions (Purnaweni et al., 2018) also to adapt to seawater inundation which sometimes enters homes, for example by raising houses level regularly (Marfai, 2012); or even evacuate to other places (Asiyah et al., 2015). A reason why the area in Sayung, Demak exposed to abrasion is that of its position, which is open without any natural or artificial protection and easily eroded when the waves approach the land.

Based on BMKG (Meteorology, Climatology, and Geophysical Agency) Semarang data, tides in 2013-2017 can be seen in Figure 7.

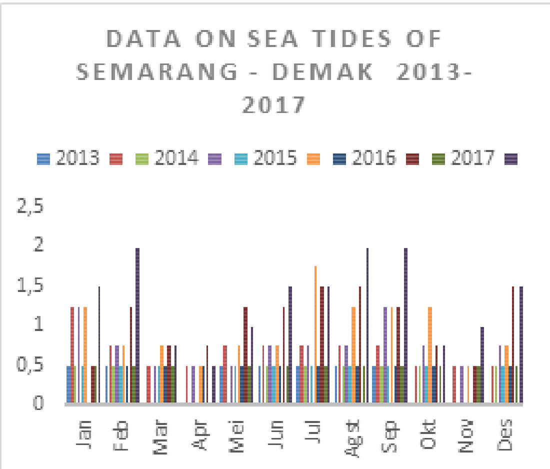

Figure 7. Tides in Semarang-Demak in 2013-2017

Based on Figure 6, there is a tendency for the tide to be higher during 2013 and 2017. This emphasises the need of overcoming abrasion by waves.

The Relationship between Coastline and Mangroves

The coastline is one of the most important linear features on the earth's surface, which displays dynamic properties. Coastline changes in an area can be resulted by natural factors such as currents, waves, storms, sea-level rise and coastal material types, some of which include sand mining, reclamation and land-use change (Alemayehu et al., 2014; Suniada, 2015). Thus, the shift in coastline will also cause the change of the mangrove forest area (Aulia et al., 2015). Considering the significance of coastline changes, it is necessary to detect changes and preventive actions to maintain sustainability in coastal areas (Temiz & Durduran, 2016), one of which was by planting mangroves.

Mangroves can substantially reduce the vulnerability of areas adjacent to the coast from inundation and erosion (Blankespoor et al., 2016). Mangroves also protect the land from waves, abrasion, storms and support for the life of biota (Soraya et al., 2012).

Mangrove ecosystems in the Semarang-Demak border, if they are traced by their types, are usually distinguished by 3 zones from sea to land. First, *Avicennia* zone (*Avicennia-Sonneratia*). It is located most out/far or closest to the sea. Surrounded by muddy soil which is slightly soft (shallow), with a little organic matter and rather high salt content. Second, mangroves zone (*Rhizophora*). It is at the back of *Avicennia* zone with deeper muddy soil. Third, other species zone. It is located farthest from the sea or closest to land.

Based on the distribution of mangroves along Semarang-Demak border, it is found that the mangrove species were dominated by the *Avicennia* and *Rhizophora*. Morphologically, the strong and dense roots of *Avicennia* and *Rhizophora* effectively grasp soil particles of land erosion. Mud from the land will be accumulated, and it continuously becomes sediment, such as in the east coast of Sumatera which is overgrown with mangroves. There will be an expansion of this kind of sedimentation around 2 cm/year (Purnobasuki, 2005). This fact shows that the importance of mangroves in the Semarang-Demak border, in this case, is inevitable and in line with the existing environmental conditions to overcome abrasion and expand the land area.

Some Efforts Made by Societies in Conserving Mangroves

Recognising the threats, the community and the government are trying to cope with various attempts, including constructing wave breakers and planting mangroves including *Avicennia* and *Rhizophora* since 2004. Both species are suitable and grow well in the border area Semarang-Demak. This can be seen from field data which shows that mangroves on the Semarang-Demak border are dominated by *Avicennia* and *Rhizophora* (Figure 8).

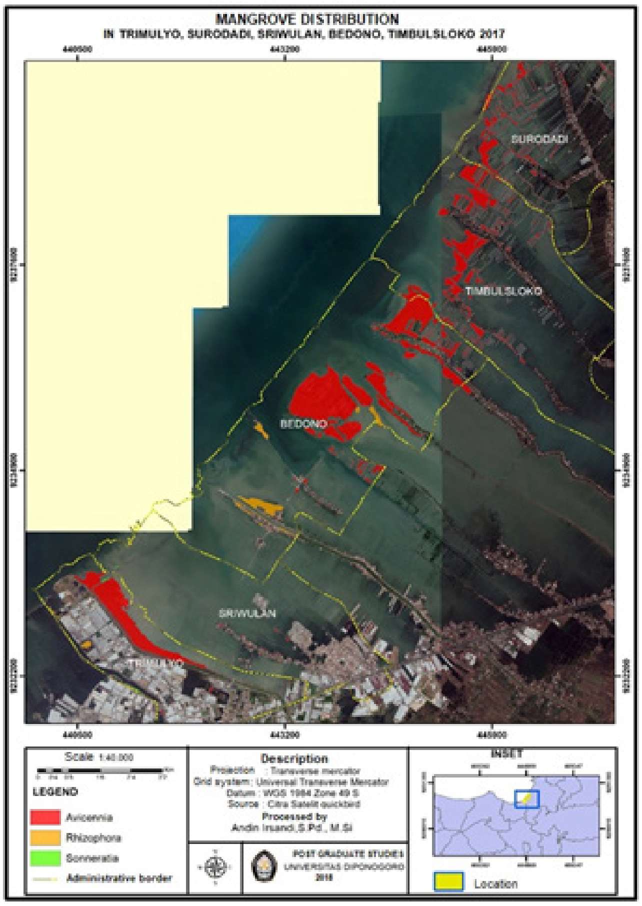

Figure 8. Mangrove Species Distribution in Semarang-Demak Border in 2017

Based on data from the "Bahari Mangrove Group" (a community that cares about mangrove conservation) various elements of the community are involved in planting mangroves both from local communities, government institutions, universities and schools both in Indonesia and other countries who care about environmental sustainability. Data on mangrove restoration that has been carried out in Bedono, Demak is presented in Table 3.

Table 3. Mangrove Planting Program by Year, Quantities, and the Executors (Bahari Mangrove Group, Bedono 2018)

Year	Planting Area	Quantities	Partnerships
2004	11 ha	13.750	OISCA-TMMP, DKP Demak, KKP Jakarta
2005	63 ha	81.000	OISCA-TMMP, CFP, OISCA academy Japan, SMK of fishery Demak, SDN 1,2,3 Bedono Demak, surrounding societies, LPP mangrove Bogor, DKP Demak, KKP Jakarta
2006	82 ha	115.000	OISCA-TMMP, CFP, OISCA academy Japan, SMK of fishery Demak, SDN 1,2,3 Bedono Demak, surrounding societies , LPP mangrove Bogor, DKP Demak, KKP Jakarta
2007	82 ha	122.000	OISCA-TMMP, CFP, OiSCA academy Japan, SMK of fishery Demak, SDN 1,2,3 Bedono Demak, surrounding societies, LPP mangrove Bogor, DKP Demak, KKP Jakarta

2008	41 ha	93.120	OISCA-TMMP, DKP Demak, KKP Jakarta
2009	15 ha	45.000	OISCA-TMMP, CFP, OISCA academy Japan, Unnes, IKIP PGRI Semarang, SMK of fishery Demak, SDN 1,2,3 Bedono Demak, surrounding societies, DKP Demak, KKP Jakarta
2010	10 ha	25.000	OISCA-TMMP, DKP Demak, KKP Jakarta
2011	23.5 ha	83.250	OISCA-TMMP, MFF, DKP Demak, KKP Jakarta
2012	16.5 ha	141.000	OISCA-TMMP, OISCA-DUNLOP, MFF, Undip, SMA 1 Demak, DKP Demak, KKP Jakarta
2013	18.4 ha	99.000	Kesemat - Undip, DKP Demak, KKP Jakarta, KLH Demak, KLH RI, OISCA-TMMP, MFF, OISCA-DUNLOP
2014	12.5 ha	45.750	OISCA-TMMP, MFF, DKP Demak, KKP Jakarta, KLH Demak, KLH RI, Kemendagri RI, STIFAR, Undip
2015	7.5 ha	58.700	OISCA-TMMP, OISCA-DUNLOP, PT. TOYOTA Indonesia, DKP Demak, KLH Demak, Kemendagri RI, Bapermas Demak, UGM, STIFARMING, Unnes, Undip

Note: KLH RI (*Kementerian Lingkungan Hidup Republik Indonesia*) = Indonesian Republic Ministry of Environment, KKP (*Kementrian Kelautan dn Perikanan)* = Ministry of Marine and Fisheries, LPP (*Lembaga Pengkajian dan Pengembangan*) mangrove = mangrove Assessment and Development Agency. DKP (*Dinas Kelautan dan Perikanan*) = Marine and Fisheries Department, Kemendagri (*Kementerian dalam Negeri*) = Ministry of Internal Affairs, Bapermas (*Badan Pemberdayaan Masyarakat*) = Community Empowerment Agency, MMF = Mangroves for the Future

Based on Table 3, it seems that all elements of society and government institutions both from the local and those from another country have contributed to sharing responsibility in preserving the environment. This effort has expanded mangrove area, the number of plants and the distribution of mangroves along Semarang-Demak coastal border. The mapping with satellite imagery shows a rise in the mangrove area in the Semarang-Demak coastal area from 2005 to 2017. The data on this area is different from the research by Faturrahmah & Marjuki (2017) which stated a slope in the number of mangroves in Demak during 2005-2017. This disclaimer is due to the different scope of the research area. Data on mangrove area along Semarang-Demak border during 2005-2017 is in Table 4.

Table 4. Data on Mangrove Area in 2005-2017

	Year	Shoreline (Km)	Changes in 2005 - 2010	Changes in 2010-2017
1	2005	90.63	Incline 40.94 ha	
2	2010	131.57		Decline 173. 19 ha
3	2017	304.76		

Table 4 indicates that mangrove area was inclined around 45% from 2005 to 2010 and about 132% from 2010 to 2017. It proves that there is the achievement of mangroves restoration. This success can be realized because of the active role of the communities in participating in environmental improvement programs at the Semarang-Demak border. The community participation is the key to success in ecosystem improvement (McDonald et al., 2016; Datta et al, 2012; Abdullah et al., 2014). But, since the mangroves currently exist are mostly from planting program, it is not rich in diversity.

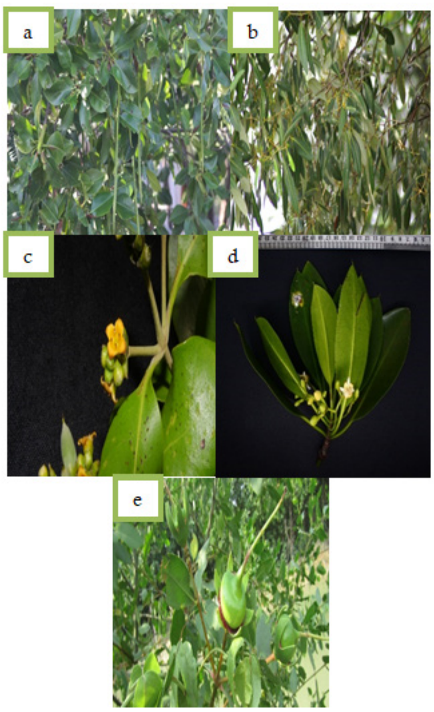

Figure 9. Mangroves Found at the Border Semarang-Demak (a. *R. mucronata*; b. *A. alba*; c. *A. marina*; d. *R. stylosa*; e. *S. casseolaris*)

The identification found five types of mangroves along the Semarang-Demak coastline, namely *Avicennia marina, Avicennia alba, Rhyzophora stylosa, Rhyzophora mucronata* and *Sonneratia casseolaris* (Figure 9). The calculation of species abundance shows that the Semarang-Demak border area is dominated by *A. marina.* It can be said that *A. marina* has good ability to utilise solar energy, nutrients/minerals and water and the ability to compete (Heriyanto & Subiandono, 2012). To sum up, an integrated effort is needed in all components on the Semarang-Demak coast to maintain the sustainability of mangroves. Integrated efforts involve the community, local government, and academics in the process of protecting and growing mangroves (Harty, 2009).

Based on the identification, it can be found that there are some strengths and weaknesses to the mangrove sustainability. In detail, the SWOT analysis of mangrove sustainability is explained in Table 5.

Table 5. Strengths and Weaknesses Analysis Of Mangroves Conservation Effort in Semarang-Demak Shoreline

	Strengths	Weaknesses	Alternative Rehabilitation
1	Awareness of planting mangroves	Community involvement is still limited	Need a greater participation of various institutions
2	There is an organisation concerning mangroves managements	The members of the organisation are mostly the olds (over 45 years old)	Need a reorganisation by recruiting young members
3	Some villages have regulations on mangroves management	Not all village has the same regulation	Need a kind of rule on mangroves for all villages
4	Mangroves areas are established as eco-tour	Some villages have not optimally utilised mangroves as eco-tour, or the eco-tour is not mainly promoted	Upgrade community interest for eco-tour by professional training

Table 5 shows the urgency to involve all components of the communities in mangrove sustainable management. The same rule is also required for all villages to optimize mangrove functions, not only as natural protection for abrasion but also giving economic value for the society.

The programs of mangrove management are also should be persistently done by engaging the community, local government, central government, and universities. Without the ongoing synergy, the mangrove conservation efforts are in vain, and the threat of shoreline abrasion will be continuously occurred.

CONCLUSION

Based on the quickbird satellite imagery analysis and calculations, the coastline along Semarang-Demak border was decline by 0.49 km during 2005-2010 and incline 3.30 km in 2010-2017. An abrasion prevention program has been carried out by constructing wave breakers and mangrove restoration by replanting. During 2005-2017, there had been an increase in mangrove area as proof of the achievement of the restoration program by the community, regional and central government, as well as government and private institutions. The further management program should be related to program sustainability, protection, care, and the development of mangroves to minimize abrasion.

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