Shoreline change analysis

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Shoreline Change Analysis Along Coast of Semarang-Demak, Indonesia for Sustainable Environmental Management

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This study would analyse 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

RI Government Regulation No. 51 of 2016 defines the shoreline 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. Also, this regulation 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.

The high rate of abrasion along Semarang- Demak beach finally changes the coastline. Some research proves that the shoreline in Sayung, Demak is decline over the years (Marfai, 2012; Ervita & Marfai, 2017). The wave is also responsible for the change and coast destruction. 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, 2008; Blankespoor *et al.*, 2016).

Mangroves are an ecosystem in the intertidal area connecting sea, brackish water, rivers and land. Mangroves exist in the tropics and subtropics in 250 LU and 250 LS. Mangroves are also associated with organisms and supporting environmental factors of its ecosystem (Sengupta, 2010) as at the Semarang-Demak beach border. However, the status of the mangrove ecosystem at the boundary is currently in problems.

One of the issues appears at the Semarang-Demak frontier, Indonesia was 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 is an important place to take refuge (shelter), spawn, lay eggs, grow the fauna associated with it (Sandilyan, 2014), absorb heavy metals (Kariada & Irsadi, 2014) and 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 widen mangrove areas (Chafid *et al.*, 2012). 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 residential, industry and so on (Irsadi *et al.*, 2017).

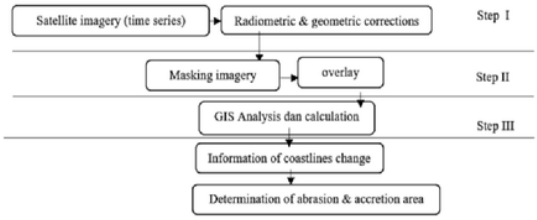
Based on previous research, mangroves of Demak in 2010-2015 decreased by an area of 68.17 ha (Faturrahmah & Marjuki, 2017). This degradation was due to abrasion in the coastal border or logging which would worsen mangrove species diversity. For this reason, the coastline change at the border of Semarang-Demak should always be monitored as relevant information for its sustainable environmental management.

METHODS

Changes in shoreline and mangroves area

This research began with taking high-resolution imagery data 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 digitising. Then, analysis and calculation were done by integrating the results of digitisation to identify shoreline change due to abrasion or accretion. Image processing steps for shoreline change as below.



Mangroves species

The data collection was done along Semarang-Demak border which was divided into three research locations. Administratively, the three locations are located in villages of Timbulsloko, Bedono and Trimulyo. The observed positions were grouped in three locations. The first location located in Timbulsloko village, Demak consisted of three research areas with 15 plots. The second location was in Bedono, Demak which included 2 research areas with 10. The third location was in Trimulyo, Semarang consisting of 2 research areas with 10 plots. So, the total data collection was 35 plots.

The locations were subjectively determined based on the density of mangroves for subsequent transects. The length of the transect was 100 meters from the coast to land. Samples were taken in each area at a distance of 0-20 m, 21-40 m, 41-50 m and so on. Next, the sampling area was determined. Vegetation data was observed by the quadratic method with a size of 20 x 20 meters for observation of trees/poles, then a smaller plot (5 x 5 meters) was used to measure saplings. The

seedlings data was from each plot measuring 2 x 2 meters.

RESULTS AND DISCUSSION

Changes in coastline and mangrove area

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

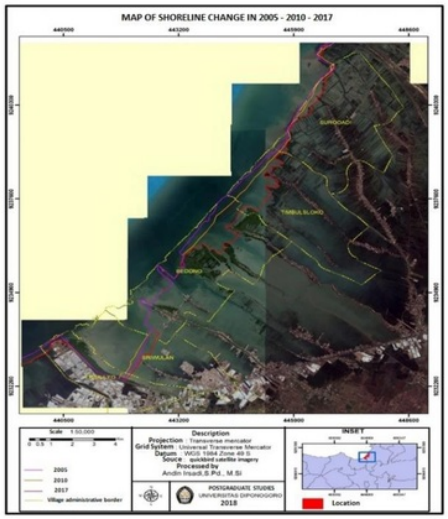


Figure 1. Map of coastline changes at the Semarang-Demak border in 2005-2017

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

Table 1. Data on shoreline changes at the Semarang-Demak border in 2005-2017

No	Year	Shoreline (Km)	Changes in 2005 - 2010	Changes in 2010- 2017
1	2005	17.32	declined 0.49	
2	2010	16.83	km	inclined 3.30
3	2017	20.13		km

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 satellite imagery shows that the area affected by abrasion is greater than the one affected by accretion. The results of 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 follows.

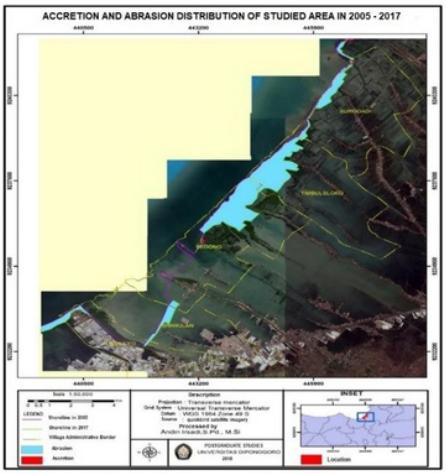


Figure 2. Distribution map of abrasion and accretion along Semarang-Demak border in 2005-2017

The map of abrasion and accretion distribution convey 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

No	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 shows 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. 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 move 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 3.

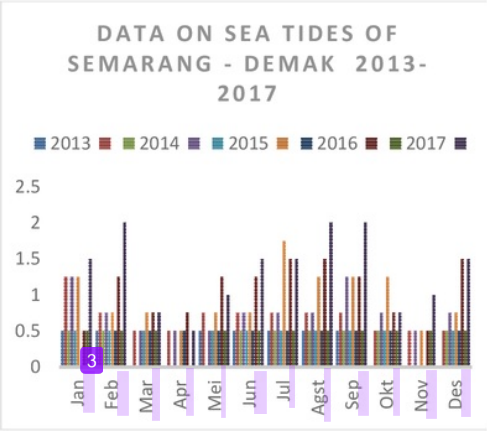


Figure 3. Tides in Semarang-Demak in 2013-2017

Based on Figure 3, 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 (Alesheikh *et al.*, 2007). 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 (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, 2012). Mangrove ecosystems in the Semarang-Demak border if traced by types, are usually distinguished by 3 zones from sea to land.

1. *Avicennia* zone (*Avicennia-Sonneratia*). 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.
2. Mangroves zone (*Rhizophora*). At the back of *Avicennia* zone with deeper muddy soil.
3. Other species zone. 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 there, 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 over time become sediment, such as 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 enlarge the land area.

Some efforts have been 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*. Based on data from the 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 planting that has been carried out is presented in Table 3.

Table 3. Mangrove planting program by year, quantities, and the executors

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 Jepang, SMK of fishery Demak, SDN 1,2,3 Bedono Demak, Masyarakat, LPP mangrove Bogor, DKP Demak, KKP Jakarta
2006	82 ha	115.000	OISCA-TMMP, CFP, OiSCA academy Jepang, SMK of fishery Demak, SDN 1,2,3 Bedono Demak, Masyarakat, LPP mangrove Bogor, DKP Demak, KKP Jakarta
2007	82 ha	122.000	OISCA-TMMP, CFP, OiSCA academy Jepang, SMK of fishery Demak, SDN 1,2,3 Bedono Demak, Masyarakat, 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 Jepang, Unnes, IKIP PGRI Semarang, SMK of fishery Demak, SDN 1,2,3 Bedono Demak,

Year	Planting Area	Quantities	Partnerships
			Masyarakat, 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 Kab. 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 Kab. Demak, KKP Jakrta, KLH Demak, KLH RI, OISCA-TMMP, MFF, OISCA-DUNLOP
2014	12.5 ha	45.750	OISCA-TMMP, MFF, DKP Demak, KKP Jakarta, KLH Kab. Demak, KLH RI, Kemendagri RI, STIFAR, Undip
2015	7.5 ha	58.700	OISCA-TMMP, OISCA-DUNLOP, PT. TOYOTA Indonesia, DKP Kab. Demak, KLH Kab. Demak, Kemendagri RI, Bapermas Demak, UGM, STIFARMING, Unnes, Undip

Based on Table 3, seems that all elements of society and government institutions both from the local and those from abroad have contributed to sharing responsibility in preserving the environment. This effort has enlarged 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

No	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. This proves the achievement of replanting mangroves. This success can be realized because of the active role of the communities in participating in environmental improvement program at the Semarang-Demak border. The community participation is the key to success in ecosystem improvement (Stone *et al.*, 2008). But, since the mangroves currently exist are mostly from planting program, it is not rich in diversity.

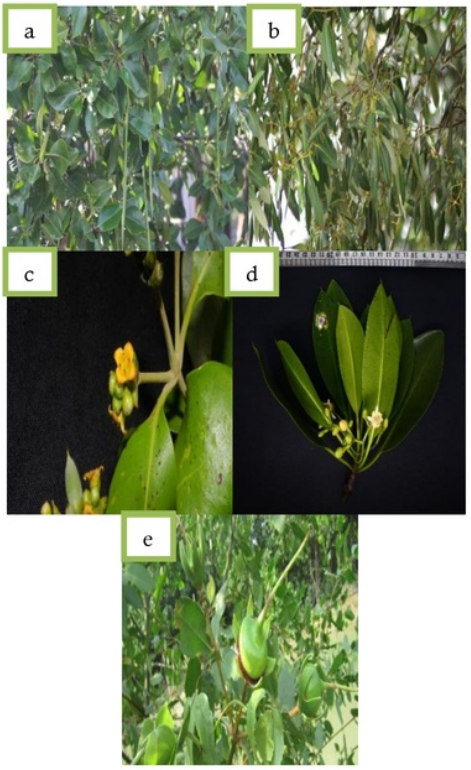


Figure 4. Mangroves found at the border Semarang-Demak (a. *R. mucronata*; b. *A. alba*; c. *A. marina*; d. *R. stylosa*; e. *S. casseolaris*)

An identification found five types of mangroves along the Semarang-Demak coastline, namely *Avicennia marina, Avicennia alba, Rhyzophora stylosa, Rhyzophora mucronata* and *Sonneratia casseolaris* (figure 4). 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). For this reason, 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, 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 are explained in Table 5.

Table 5. Strengths and weaknesses analysis of mangroves conservation effort in Semarang-Demak shoreline

No	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	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 utilised as eco-tour	Some villages have not optimally utilised mangroves as eco-tour, or the eco-tour is not mainly promoted	Boost community interest for eco-tour by professional training

Table 5 shows the existence of programs or activities that have been carried out among the community, local government, central government, and universities. Without the ongoing synergy, the mangrove conservation efforts are in vain. The care, protection and development of mangrove areas must be done immediately, especially the role of local communities, especially by the younger generation, in preserving mangroves. The members of community organisations concerning for mangroves are on average over 45 years, so regeneration of the members should be immediately done.

CONCLUSION

Based 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 replanting. During 2005-2017, there has been an increase in mangrove area as proof of the achievement of the planting 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 minimise abrasion.

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