The Evaluation of the Physical Condition in Coastal Area as a Result of Changes of Suspended Sediment (Case Study: Coastal Area of Surabaya and Gresik)

Pribadi, C. B.[1] and Hariyanto, T.[2]
Department of Geomatics Engineering, Institut Teknologi Sepuluh Nopember, Sukolilo-60111, Surabaya, Indonesia, E-mail: cheriebhekti@gmail.com[1], tgh_hary@yahoo.com[2]

Abstract
Indonesia as an archipelagic country, should have an advantage in the maritime sector. One important part of a country's maritime systems is a port. Coastal area is a transitional region and interaction between terrestrial and marine ecosystems. Coastal is affected by waves of sea water. The coast is also a zone that is the place of deposition of seawater erosion. The increase of coastal activities has an impact on changes in physical conditions, especially on changes in coastline and suspended sediment levels which are increased. Remote sensing methods with satellite imagery can be a solution for changes of monitoring coastline suspended sediment levels that occur along the coastal area. In this study, monitoring of changes in coastal conditions over a period of 15 years (2002-2017) had been carried out. The method used in this study uses remote sensing technology, namely the use of land and ocean separation algorithm and Total Suspended Sediment (TSS) algorithm methods.

1. Introduction

1.1 Background

Shipping has an important role in trade between countries. The ability of large vessels capable of transporting large quantities at low cost is an advantage. As a country that has thousands of islands, Indonesia should have an advantage in the maritime sector. One important part of a country's maritime system is a port. Ports become places of entry and exit of goods from within and outside the country. Madura Strait, a strait separating Java Island and Madura Island, is the most important route connecting Java and Madura. Various activities in Madura Strait, including Gresik sea port and Surabaya sea port (Tanjung Perak), Kali Lamong Sea Port are developed from Tanjung Perak port which occupies the Lamong Bay area of Surabaya, fisheries in Gresik, Madura (Bangkalan) and Surabaya, as well as the existence of Suramadu National Bridge which was built since 2003 and officially used for public in June 2009. Ferry lanes connect Madura Strait between Ujung Port (Surabaya) and Kamal Port (Bangkalan).

In Madura Strait waters, there are two estuarine streams for Bengawan Solo watershed located at the end of Gresik Regency and the Brantas Watershed in Porong River, where since 2006 the Porong River was also used as an alternative to sediment disposal Lapindo Porong Sidoarjo mudflow. According to MGI (Marine Geological Institute Indonesia) or Indonesian Marine Geology, the Brantas River innate sediment reaches 1.3 kg / m3, (meaning that in 1 M^3 of water there is a 1.3 Kg sediment) which is much smaller than the congenital sediment. The Bengawan Solo River sediment reaches 2.75 kg / m3. All activities mentioned above will certainly affect the quality of the environment in the Madura Strait, especially in terms of Total Suspended Soil (TSS) followed by changes in coastline.

In some locations, the Brantas River riverbed has degraded due to sediment carried from upstream which is smaller than the amount of scour capacity owned by the Porong River water flow. The conditions that occurred in the Brantas River also occurred on the Porong River before the discharge of Porong Mudflow to the Porong River. The base of the Porong River was generally degraded except for the river estuary, where the river base elevation was still above the riverbed of the Porong River (Harnanto, 2011).

Coastline is defined as the line of contact between land and the water body (Alesheikh et al., 2007). Coastline is one of the most important linear features on the earth surface, which has a dynamic nature (Winarso and Budhiman, 2001). Because of the dynamic nature of the water body and the coastal land, the shoreline changes all the time and it is never stable with either short-term or long-term positions (Lo and Gunasiri, 2014). Phenomenon of coastline changes due to sedimentation through processes such as coastal abrasion and accretion. Abrasion called coastal erosion around the coast can occur if sediment transport moves to a larger area than sediment transport that enters. Coastal erosion is usually followed by accretion (Fauzie, 2017). Accretion can result in precipitation in coastal area so that it can be close to river mouth and has an impact on flooding. While abrasion can result in changes in land area, as well as damage to existing infrastructure on land. Movement of the river mouth may be responsible for the complex trend in the erosion and accretion (Hashmi and Ahmad, 2018).

Problems related to abrasion and accretion which occur continuously in coastal areas result in imbalance of coastal conditions which lead to damage in the Coastal area (Hidayati, 2017). Remote sensing methods with satellite imagery can be a solution in this research, the problem for changes of monitoring coastline suspended sediment levels that occur along the coastal area, multitemporal satellite imagery that can be used from 2002 to 2017 to examine the problem, has a good multitemporal spatial resolution. Integration of the latest techniques of remote sensing with geographical information system (GIS) has been proven to be an extremely useful approach for the shoreline changes studies due to synoptic and repetitive data coverage, high resolution, multi-spectral database and its cost effectiveness in comparison to conventional techniques (Chand and Acharya, 2010).

2. The Methods

2.1 Study Area

The location of this study was the coastal area of Surabaya, East Java. which is located in a geographical position of 7°11′13″ South Latitude - 7°44′57″ South Latitude and 112°41′ 24″ East Longitude - 113°22′36″ East Longitude. The study area is presented in the following Figure 1.

Figure 1: The study area

2.2. Data Acquisition

The data used in this study are Landsat-7 satellite image data path/row: 118/065 in 2002 and Landsat-8 satellite image data path/row: 118/065 in 2017. The data in 2000 was used to determine the physical condition of coastal area and the state of TSS concentrations in the waters of the Porong river estuary before the Lapindo mud disaster occurred. The data in 2017 was used to determine the physical condition of coastal area and the state of TSS concentrations in the waters of the Porong river estuary before the Lapindo mud disaster occurred.The data in a period of 15 years was used to determine the major changes of physical condition and changes of TSS concentration that occured in the coastal area.

2.3 Radiometric Correction (Converting Digital Number Value to Reflectance Value)

Radiometric correction aims to correct pixel values to match what should normally consider atmospheric interference factors as the main source of error. The brightness temperature was calculated using the spectral radiance value obtained from the USGS number digital value. Radiometric correction for Landsat 7 was calculated by using the following equation:

$$L_\lambda = M_L Q_{cal} + A_L$$

Equation 1

Information:

L_λ = ToA radiance

M_L = RADIANCE_MULT_BAND_x, (where x equal to number band)

A_L = RADIANCE_ADD_BAND_x, (where x equal to number band)

Q_{cal} = nilai *Digital Number (DN)*

$$\rho = \frac{\pi L_2 d^2}{Esun\lambda cos\theta}$$

Equation 2

Information:

ρ = ToA reflectance

L_λ = ToA Radiance

d^2 = *Earth-Sun Distance in Astronomical Units*

$Esun\lambda$ = *Mean Solar Exoatmospheric Irradiances*

θ = Zenith angle

π = 3,141592654

According to Rahayu (2014), Landsat-8 data can be corrected radiometrically using the Top of Atmosphere correction (ToA) which includes ToA Reflectance and solar correction. ToA reflectance correction was calculated by converting the DN value to reflectance value. Based on (USGS in Rahayu, 2014), the conversion of equation for ToA reflectance was calculated by using the following equation:

$$\rho\lambda' = M_\rho Q_{cal} + A_a$$

Equation 3

Information:

$\rho\lambda'$ = ToA reflectance, without solar correction

M_ρ = REFLECTANCE_MULT_BAND_x, (where x equal to number band)

A_ρ = REFLECTANCE_ADD_BAND_x, (where x equal to number band)

Q_{cal} = value of *Digital Number* (DN)

Furthermore, the image is corrected by the sun angle to eliminate the difference in DN values caused by the position of the sun. The position of the sun on the earth changes depending on the recording time and location of the object being recorded. The solar correction with solar angles was calculated by using this following equation:

$$\lambda = \frac{\rho\lambda'}{(\cos(\theta SZ))} = \frac{\rho\lambda'}{(\sin(\theta SE))}$$

Equation 4

Information:

$\rho\lambda$ = TOA reflectance

θSE = *sun elevation*

θSZ = zenith angle of the sun

$\theta SZ = 90^o - \theta SE$

2.4 Atmospheric Correction

Atmospheric correction was carried out to reduce errors due to atmospheric effects and differences in the sun elevation angle and the distance of the sun-earth when receiving different data at a time. Atmospheric correction is also done to eliminate path radiance. It can be done one of them by the DOS (Dark Object Subtraction) method, which assumes that the digital value of the darkest object on the earth's surface must be zero. Atmospheric corrections were calculated by using the following equation:

$$\rho_{BoA} = \rho\lambda' - \rho_{min}$$

Equation 5

Information:

ρ_{BoA} = Reflectance BoA (mWatt cm^{-2} $sr^{-1}\mu m^{-1}$)

$\rho\lambda'$ = Reflectance ToA, without solar correction (mWatt $cm^{-2} sr^{-1}\mu m^{-1}$)

ρ_{min} = Minimum value histogram in *Region of Interest* (ROI)

The influence of atmosphere (fog) for some problems can occur and need to be repaired, so value can reflect the condition of the coastline clearly.

2.5 Land-Sea Masking

The main study areas are coastal and shallow waters, so it is necessary to separate the areas above the water (land, islands) by masking. The masking process is done first by looking for the range of maximum and minimum brightness values on the object. Decreasing brightness values occur at near infrared wavelengths around 1.4 - 2.7 µm, this does not occur in land objects. In these channels electromagnetic wave radiation does not penetrate the body of water (Lillesand et al., 2004). Bands with these wavelengths produce very dark brightness values on the image display, so that the boundary between the water and the land can be seen. This masking process uses NDWI (Normalized Difference Water Index) methods, green channels and NIR (Near Infrared) channels. NDWI is one of the simple and accurate band ratio methods for the demarcation and extraction of coast line. The NDWI is useful index for water body mapping, the interested ground object will be enhanced and other ground object will be inhibited correspondingly, so that the interested ground objects will be easier for extraction from back-ground ground objects (Du et al., 2001). The water body reflects low radiation and absorbs most of the visible to infrared wavelengths. This index uses the green and Near Infra-red bands of images and enhances the water information effectively (Pham and Prakash, 2018).

Remotely sensed imagery has long been used in water resources assessment and coastal management. These applications have involved the delineation of open water using thematic information extraction techniques. Remotely-sensed data were analyzed and integrated with vector-based data layers within a GIS to identify which residential land parcels had detectable surface water present (McFeeters, 2013). The Normalized Difference Water Index (NDWI) was first proposed by McFeeters in 1996 to detect surface waters in wetland environments and to allow for the measurement of surface water extent (McFeeters, 1996). NDWI was proposed by McFeeters (1996) to achieve this goal (Xu, 2006) and to identify non-urban surface water associated with wetlands. After atmospheric correction process had completed, and got the corrected reflectance value, the reflectance was changed to Rrs (Reflectance Remote Sensing). The RRS value is a derivative of the radiance and irradiance measurement using a bio-optical approach model (Budhiman, 2004). Rrs value was obtained from the following equation:

$$Rrs(\lambda) = Reflectance / \pi$$

Equation 6

After conversion of the reflectance value to Rrs value, new masking can be done. The separation of land and sea uses NDWI (Normalized Difference Water Index) algorithm with the following formula:

$$NDWI = \frac{RRSGreen - RRSNIR}{RRSGreen + RRSNIR}$$

Equation 7

Water features have positive values and thus they are enhanced, while vegetation and soil usually have zero or negative values and therefore they are suppressed (McFeeters 1996). NDWI is less sensitive to atmospheric effects than NDVI (Gao, 1996).

2.6 Raster to Vector Conversion

An image which is continuous in both spatial and spectral (colour intensity) domains is converted into a digital image by means of sampling and quantization (Gonzalez and Woods, 2002). Objects in vector models are composed of primitive shapes like points, lines and shapes with editable attributes like colour, fill and outline (Sharma, 2006). Raster to vector conversion is used to determine a coastline which can be calculated and overlaid and so it will be easier to do the analysis coastline changes due to abrasion.

2.7 Total Suspended Sediment (TSS)

In situ data, it is obtained by random sampling of sea water along coastal area of Surabaya City and Gresik. The seawater used as a sample for determining Total Suspended Sediment (TSS) is water which is taken at depth of 200 cm from sea level. The result of the seawater sampling is then calculated by using gravimetry method. Gravimetry is an examination of the amount of substances by weighting the results of the deposition reaction. The stages of measurement in gravimetry method include sedimentation, filtration, sediment washing, drying and weighting. TSS value can be calculated using the following equation:

$$TSS\ (Mg/L) = W1 - W0 / V \times 1000$$

Equation 8

Information:

W0 : Initial Weight (mg)

W1 : Final Weight (mg)

V : Volume sample (mL)

Water sampling in coastal waters was used as data of Total Suspended Solid (TSS) taken directly in accordance with the conditions of the waters in the coastal area. The water sampling was carried out using 24 points evenly distributed from the north coast of Surabaya to Lamong Bay, each point was taken at a distance of ± 1000 m between points. In this study, TSS value was also obtained from satellite image processing using an algorithm. The application of the algorithm was used to calculate TSS values in tropical waters whose characteristics resemble the Coastal Area of Surabaya. The algorithm is Syarif Budiman algorithm in 2004. The algorithm formula used this following equation:

$$TSS=7.9038 * \exp(23.942*Redkanal) \quad \text{Equation 9}$$

Whereas, redkanal is red band/red channel. In Landsat 7 we can find redknanal in Band 3 which have wavelength of 0.631-0.692 , in Landsat 8 we can find redknanal in Band 4 which have wavelength of 0.636-0.673.

3. Result and Discussion

The coastlines in the coastal area of Surabaya and Gresik in year 2002 to 2017 were obtained using the Normalized Difference Water Index (NDWI) algorithm, with band ratio using green band and Near Infa Red (NIR) band. Figure 2 show us that band ratio results from Landsat 7 satellite imagery in 2002, grey color in these figure is not as a land, but it is built-up land noise, it can occur due to many built-up land features which have positive values in NDWI image result, and they are present as noise in the NDWI image (Xu, 2006). The result still mix with many small non water information, land and water is easily confused with soil in NDWI, and form the noise (Yu et al., 2001). Figure 3 show us that band ratio results from Landsat 8 satellite imagery in 2017 in raster format. Figures 2 and 3 show us that difference in colors and patterns are obtained from the processing of land and sea masking, where the land area has a darker color than the sea area. The results of processing using the algorithm of land and sea masking then raster to vector conversion was conducted to get the coastline which was calculated and overlaid to analyse coastline changes. We can see the results of the conversion from raster to vector on Landsat 7 satellite imagery in 2002 and Landsat 8 satellite imagery in 2017 on Figure 4. Coastline changes due to accretion in coastal areas of Surabaya and Gresik can be known through Landsat 7 and Landsat 8satellite imagery using calculation method between the area of 2017 and 2002 where the accretion area is the blood area that leads to the sea due to sedimentation.

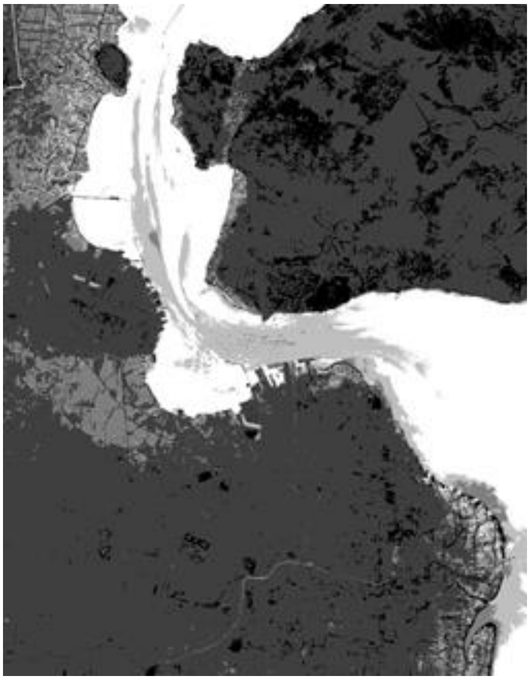

Figure 2: Land and Sea Masking in Year 2002

Figure 3: Land and sea masking in year of 2017

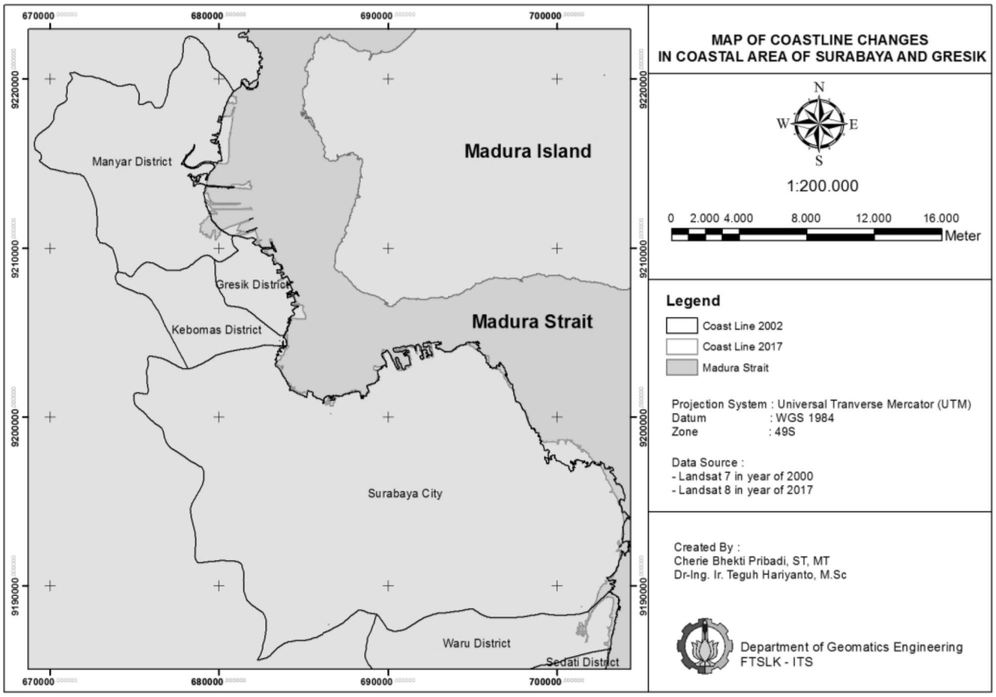

Figure 4: Map of coastline changes

Table 1: Accretion area

District	Area in 2002 (Km^2)	Area in 2017 (Km^2)	Coastline Changes (Km^2)	Accretion Area (Km^2)
Gresik	16.335	17.457	+1.122	1.304
Manyar	95.601	98.551	+2.950	3.934
Kebomas	29.405	29.463	+0.058	0.058
Surabaya City	348.959	349.110	+0.151	3.967
Total				9.262

Image processing results show the extent of accretion that occurs in coastal areas of Surabaya and Gresik presented in the following Table 1. The total area of accretion occurred in coastal areas of Surabaya and Gresik for 15 years is 9.262 km^2. With the greatest accretion occurring on the coast of Surabaya City amount 3.967 km^2, Manyar District amount 3.934 km^2, Gresik District amount 1.304 km^2, and the district with the smallest accretion is Kebomas District amount 0.058 km^2.

Figure 5 describes the distribution of areas that experience accretion which is the changes in the coastline to the high seas due to sedimentation from the land or river towards the sea. Accretion takes place due to the sediment deposition and the source of it is coastal area. The coastline can be changed due to erosion and accretion and accretion is caused by land reclamation projects. The result of accretion shows that the accretion area occurs in many industrial areas, where there is an increase in activities in these areas. In this study, TSS was calculated using the Syarif Budiman algorithm in 2004. The application of the algorithm was used to calculate TSS values in tropical waters whose characteristics resembled the coastal areas of Surabaya and Gresik. The application of the algorithm used Reflectance Remote Sensing (RRS) on band 4 (red band) Landsat 8 satellite imagery with a range of wavelengths (0.636-0.667 µm) and on band 3 (red band) Landsat 7 satellite imagery with a range of wavelengths (0.631-0.692 µm) due to the length, the waveform provided a good reflectance value for TSS. Figure 6 show the distribution of water sample points in the coastal waters.

The results of TSS processing using Syarif Budiman algorithms in 2004 conducted in 2002 and 2017, can be seen in Figure 7. Figure 7 shows the distribution of TSS concentration values in coastal areas of Surabaya and Gresik.

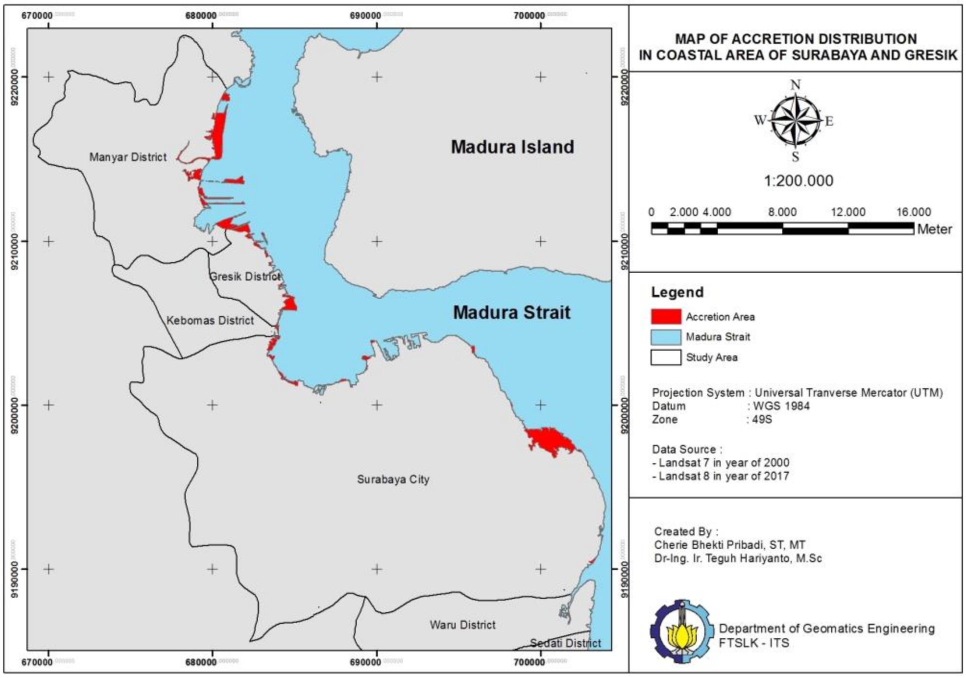

Figure 5: Map of accretion distribution

Figure 6: Data insitu water sample

In 2002 the value of TSS that dominates the coastal area is 15-30 mg / l, but the highest value in year 2002 amounts to 31.89 mg / l in coastal area. Figure 8 shows the distribution of TSS concentration values in the coastal areas of Surabaya and Gresik. In 2017 the value of TSS that dominates the coastal area is 30-45 mg/l, but the highest value in year 2002 amounts to 99.89 mg/l in coastal area. Changes in TSS concentration values for 15 years from 2002 to 2017 showed very significant results, where in 2017 the value of TSS concentrations increased in coastal areas. This can occur because of the increasing physical development carried out in coastal areas, in addition to the increase of human activities in the coastal area. Analysis of the status of water quality by the pollution index method is based on the TSS value referring to the Decree of the State Minister of Environment No. 115 Year of 2003 about Guidelines for Determination of the Status of Water Quality.

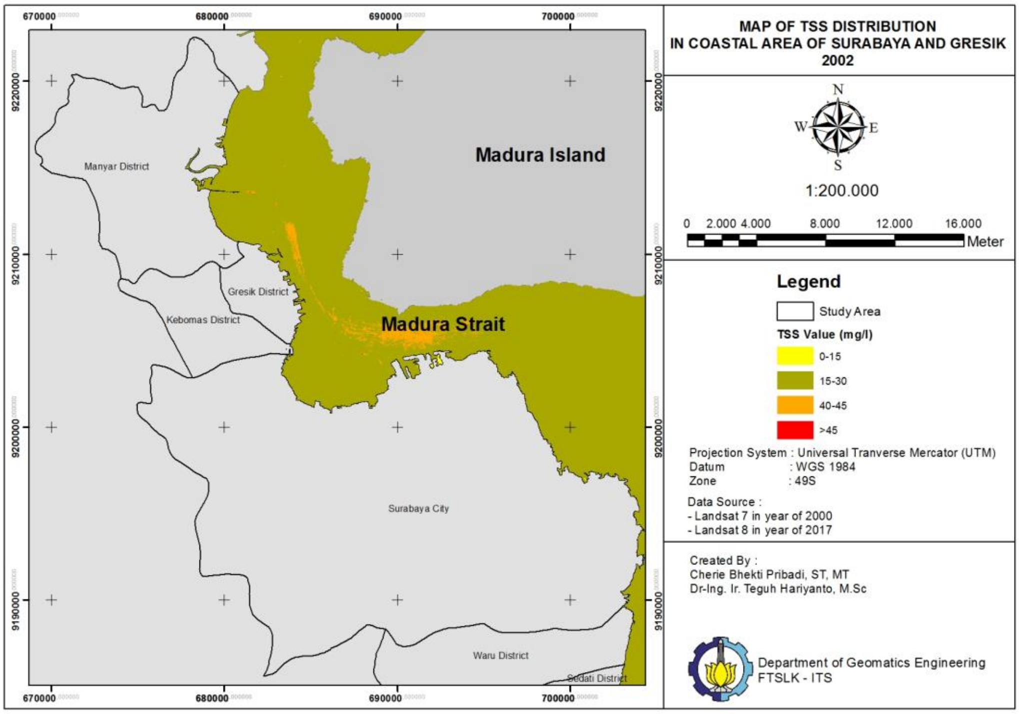

Figure 7: Map of TSS distribution 2002

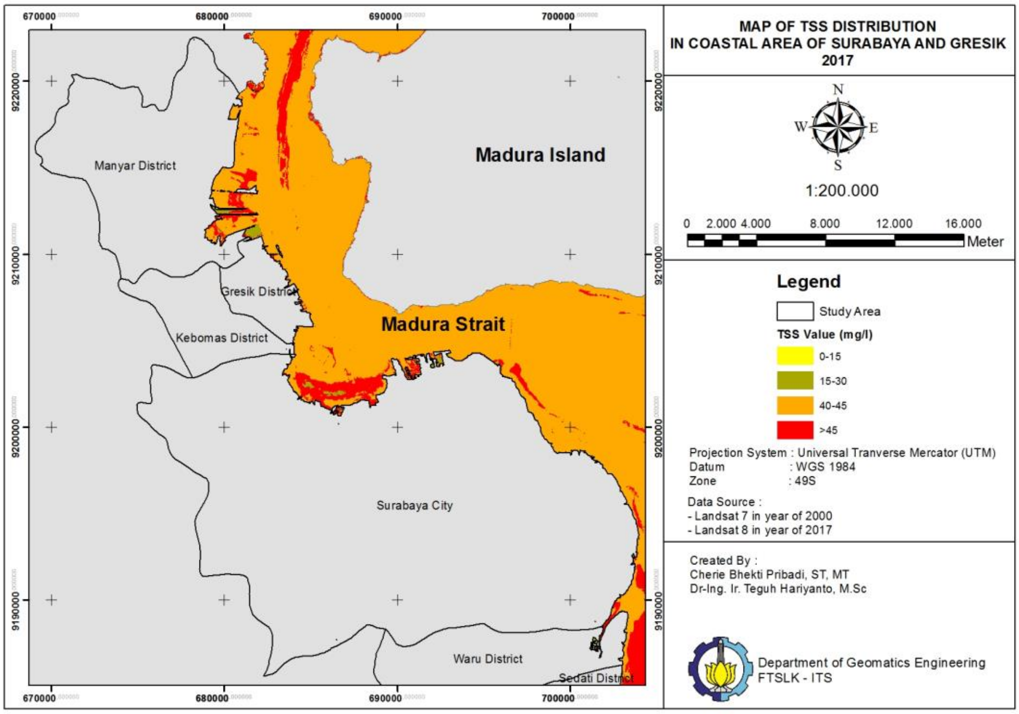

Figure 8: Map of TSS distribution 2017

This method uses the Pollution Index (IP) models, in which the average value and maximum value of the sample is needed. To get this value, the following formula is used:

$$PI=\sqrt{\frac{(X/Xmax)^2+(X/Xaverage)^2}{2}}$$

Equation 10

Information:
PI : Pollution Index
X : TSS value on sample point
Xmax : maximum TSS value on sample point
Xaverage : average TSS value on sample point

The following values were obtained based on the results of calculations using formula (10), so the results obtained are as follows (Table 2 and 3).

Table 2: Evaluation of pollution index value

Value	Description
0 ≤PI≤1	Quality Standart
1<PI≤5	Mild Pollutant
5 <PI≤10	Medium Pollutant
PI>10	Heavy Pollutant

Table 3: Result of pollution index

No	Pollution Index in 2002	Pollution Index in2017
1	0.8710	0.7425
2	0.9237	0.9463
3	0.8334	0.7397
4	0.9653	0.9902
5	0.8583	0.7650
6	0.9102	0.8635
7	0.9797	1.0444
8	1.0695	1.1531
9	0.9512	1.0405
10	0.9941	1.0798
11	0.9797	0.8755
12	0.9941	1.0479
13	0.8334	0.9977
14	0.9511	0.8096
15	0.9797	0.7449
16	0.9797	0.7421
17	1.0085	0.8961
18	0.9653	0.9276
19	0.9512	1.0401
20	0.9652	1.0475
21	0.9374	0.6459
22	0.8968	0.7759
23	0.9237	0.7406

Based on the results of data processing to determine the status of water quality with the pollution index method in accordance with the Decree of the State Minister of Environment No. 115 Year of 2003 about Guidelines for Determination of Water Quality Status, the average value is in the range of 0 ≤ pollution index ≤ 1 which means the water conditions of Coastal Area of Surabaya and Gresik meet the quality standards or in good condition. Some points show a pollution index value of 1 ≤ pollution index ≤5 which indicates that the waters are in mildly polluted conditions.

4. Conclusion

The result of this research indicates that the physical condition of coastal area can be monitored by coastline changes, coastline can be changed due to accretion. The greatest accretion occurring on the coast of Surabaya City amounts 3.967 km^2, Manyar District amounts 3.934 km^2, Gresik District amounts 1.304 km^2, and the district with the smallest accretion is Kebomas District amounts 0.058 km^2. Changes in TSS concentration values for 15 years from 2002 to 2017 showed very significant results, where in 2017 the value of TSS concentrations increased in coastal areas. This can occur because of the increasing physical development carried out in coastal areas, in addition to the increase in human activities in the coastal area. Water conditions of Coastal Area of Surabaya and Gresik meet quality standards or in good condition. Some points show a pollution index value of 1 ≤ pollution index ≤5 which indicates that the waters are in mildly polluted conditions.

References

Alesheikh, A., Ghorbanali, A. and Nouri, N., 2007, Coastline Change Detection Using Remote Sensing. *International Journal of Environmental Science and Technology*, Vol. 4(1). 61-66.

Budhiman, S., 2004, *Mapping TSM Concentrations from Multi Sensor Satellite Images in Turbid Tropical Coastal Waters of Mahakam Delta Indonesia*. Netherlands: Thesis ITC Enschede.

Chand, P. and Acharya, P., 2010, Shoreline Change and Sea Level Rise along Coast of Bhitarkanika Wildlife. *International Journal of Geomatics and Geosciences*, Vol. 1(3), 436-455.

Du, J., Huang, Y. S., Feng, X. and Wang, Z. L., 2001, Study on Water Bodies Extraction and Classification from SPOT Image. *Journal of Remote Sensing*, Vol. 5(3), 214-219.

Fauzie, A. K., 2017, Analysis of Short and Medium Term Coastal Abrasion and Accretion Rates Using GIS in Karawang, West Java. *CR Journal*, Vol. 3(2), 91-104

Gao, B., 1996, NDWI—A Normalized Difference Water Index for Remote Sensing of Vegetation Liquid Water from Space. *Remote Sensing of Environment*, Vol. 58(3), 257-266.

Gonzalez, R. C. and Woods, R. E., 2002, *Digital Image Processing*, Prentice Hall, 2nd ed.

Harnanto, A., 2011, Peranan Kali Porong dalam Mengalirkan Lumpur Sidoarjo ke Laut. Surabaya: Badan Pelaksana Penanggulangan Lumpur Sidoarjo.

Hashmi, S. G. M. D. and Ahmad, S. R., 2018, GIS-Based Analysis and Modelling of Coastline Erosion and Accretion along The Coast of Sindh Pakistan. *Journal of Coastal Zone Management*, 1-7.

Hidayati, N., 2017, *Coastal Dynamic*. Malang: UB Press

Lillesand, T., Kiefer, R. and Chipman, J., 2004, *Remote Sensing and Image Interpretation*. New York: John Wiley & Sons.

Kwong Fai A. L, and Chethika W. D. Gunasiri., 2014, Impact of Coastal Land Use Change on Shoreline Dynamics. *Journal of Environment Conservation and Technology*, 124-136. doi:10.3390/environments1020124

Mcfeeters, S. K., 1996, The Use of Normalized Difference Water Index (NDWI) in the Delineation of Open Water Features. *International Journal of Remote Sensing*, Vol. 17, 1425-1432.

Mcfeeters, S. K., 2013, Using the Normalized Difference Water Index (NDWI) within a Remote Sensing, *International Journal of Remote Sensing*, Vol. 5, 3544-3561.

Pham, B. T. and Prakash, I., 2018, Application of Simple Remote Sensing Techniques for the Detection and Extraction of Coastline-A Case Study of Diu Island, India. *Indian Journal of Ecology*, Vol. 45(4), 778-784.

Rahayu, Candra, D, S., 2014, Koreksi Radiometrik Citra Landsat-8 Kanal Multispektral Menggunakan Top of Atmosphere (ToA) Untuk Mendukung Klasifikasi Penutup Lahan. Seminar Nasional Penginderaan Jauh, LAPAN.

Sharma, O., 2006, A Methodology for Raster to Vector Conversion of Colour Scanned Maps. Technical Report No 240. Department of Geodesy and Geomatics Engineering, University of New Brunswick, Canada.

Winarso, G. and Budhiman, S., 2001, The Potential Application of Remote Sensing Data for Coastal Study, *Proc. 22nd. Asian Conference on Remote Sensing, Singapore*. Available on: http://www.crisp.nus.edu.sg/~acrs2001.

Xu, H., 2006, Modification of Normalised Difference Water Index (NDWI) to Enhance Open Water Features in Remotely Sensed Imagery. *International Journal of Remote Sensing*, Vol. 27((14)), 3025-3033. doi: 10.1080/01431160600589179.