The Study of Coastline Changing and Total Suspended Solid Distribution Based on The Remote Sensing Data in Teluk Lamong Multipurpose Port Terminal

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Abstract. Looking forward to the abovementioned conditions, this research is needed to elaborate on the effects of the reclamation to the marine resources in Teluk Lamong Multipurpose Port Terminal as the reclaimed product. In order to describe the impact of the port development, this study will analyze the shoreline changing, the current pattern modeling, as well as the Total Suspended Solid (TSS) modeling using the remote sensing data. The several numbers of expected objectives through this study are to get the set of scientific information on the shoreline changing in Teluk Lamong Multipurpose Port Terminal in the year of 2012 and 2020, to get the figure of current pattern in Teluk Lamong Multipurpose Port Terminal in the year of 2012 and 2020, and to elaborate TSS concentration through the modeling approach in Teluk Lamong Multipurpose Port Terminal in the year of 2012 and 2020. Hence, there is a set of methodologies and tools to cooperate with the information before and after the reclamation. The use of the Digital Shoreline Analysis System (DSAS) software to analyze coastline conditions. The using of Mike 21 to analyze the current pattern and TSS concentrations. In addition to the TSS analysis, it will also need a set of remote sensing data from the Google Earth Engine (GEE). The modeling and calculation give information about the End Point Rate (EPR) values and TSS values. The EPR values are 107.5 m/year, 59,625 m/year and 10,375 m/year. The TSS values are 0-20 mg/L, 20.1-40 mg/L, 40.1-80 mg/L, 80.1-120 mg/L and >120.1 mg/L. Moreover, the result shows the different values among the length of coastline, the current pattern, and TTS in the years 2012 and 2020. The difference in the coastline reaches 950 m at this latest 8 years. While it also brings the changing to the current pattern and sediment transport which show through its current velocity and sediment content per liter of seawater during high and low tide accordingly.
1. Introduction

In the coastal areas, there are interrelated ecosystems. A coastal ecosystem is a unit that interacts between organisms and the environment and jointly carries out their respective functions in the habitat [1]. Coastal ecosystems are a collection of biological (biotic) and non-biological (abiotic) components that are necessary for life and improving the quality of life [2]. Furthermore, the biological and non-living components are functionally related to each other and interact with each other to form a system. If there is a change in one of the existing systems, it will affect both the functional structure and its balance [3]. One form of linkage between ecosystems in coastal areas is the movement of river water, run-off, groundwater, and the various materials contained therein (nutrients, sedimentation, and pollutants) that will all lead to the coastal waters. With changes in coastal environmental conditions, it can change the coastal natural ecosystem and need to be adapted, for instances on the port development process through reclamation.

The development of the Lamong Bay Multipurpose Port can have an impact on the condition of the natural ecosystem around the coast due to the changes in environmental conditions from the coastal reclamation. The development of the Lamong Bay Multipurpose Port regarding reclamation has been described and legalized in Law Number 27 of 2007 article 34 of the Law No. 1 of 2014, concerning Management of Coastal Areas and Small Islands, explaining that reclamation means activities carried out by individuals in the context of increase the benefits of land resources from an environmental and socio-economic point of view by confining and draining the land. The reclamation has indeed received a reclamation permit through the Decree of the Minister of Transportation Number 4 of 1997 concerning the Granting of Permits to PT. Pelindo III for reclamation of coastal waters in the working environment of the waters of Tanjung Perak Port and Gresik Port. The development of the Lamong Bay Multipurpose Port can be affected by the coastal area where there will be changing the contours of the bottom of the waters and river estuaries.

The construction of PT. Lamong Bay Terminal is the Master Plan for the Acceleration and Expansion of Indonesia's Economic Development (MP3EI). Both of the construction and operation of PT. The Teluk Lamong Terminal are expected to reduce dwelling time at the Port of Tanjung Perak as the gateway to the economy of East Java and eastern Indonesia. Teluk Lamong Terminal is on the border of Surabaya City and Gresik Regency, precisely on Jalan Raya Tambak Osowilangaun KM 12 Surabaya, which is located at coordinates 07 ° 12'16.1 "LS and 112 ° 40'09.1" BT. The physical construction of the Lamong Bay Terminal began in 2010-2014 with a reclamation area for stage 1 covering an area of 38.86 hectares, stage 2 taking place in 2014-2016, stage 3 starting in 2016 completed in 2023. The construction of the Lamong Bay Terminal is the result of reclamation carried out due to the need for a development location and the absence of any area around the location. The Teluk Lamong Multipurpose Terminal was built as a development of the Tanjung Perak Port which is no longer sufficient to carry out various activities. Due to the limited land at Tanjung Perak Port, the port is developed in the shallow waters of Lamong Bay, Surabaya City. The development of Lamong Bay Port can change current and wave patterns which cause sedimentation in several areas. The area that has a high sedimentation effect is on the Lamong River, which is downstream of which there is raised land called Galang Island.

The knowledge of hydrodynamics is imperative to understand to determine the prediction of sediment distribution after reclamation. The results of models that have been validated and have shown a correlation or similarity to actual conditions in the field that can be used to predict the dynamics of the various processes in the coastal areas. Based on the description above, a study of the physical impact of the construction of the Teluk Lamong Multipurpose Terminal is needed to find out the impact of reclamation on environmental conditions around the location. Therefore, an analysis of shoreline changes was required to see the modeling of current patterns, modeling TSS based on remote sensing data to describe the impact before and after the construction of the Lamong Bay Multipurpose Port. Based on the problems that arose earlier, the objectives to be achieved in this study are:

- Conduct modeling analysis of current patterns at Lamong Bay Port before the 2012 reclamation and 2020 reclamation.
- Analyzing the distribution of TSS concentrations in Teluk Lamong Port before the 2012 reclamation and 2020 reclamation.
- Analyze shoreline changes at the Teluk Lamong Port before the 2012 reclamation and the 2020 reclamation post using satellite imagery.

2. Methodology

This research had been conducted at Teluk Lamong Multipurpose Terminal Port, located in the border area between Surabaya City and Gresik Regency, which is adjacent to two ports owned by PT. Pelabuhan Indonesia (PELINDO) III, namely Gresik Port to the west and Tanjung Perak Main Port to the east. The research location was chosen purposively (deliberately) based on the previous literature and information related to the existence of port development. Considering the Port Development will affect the condition of the coastal ecosystem and the livelihoods of coastal communities, it is necessary to study the impact of coastal resources on the development of the Teluk Lamong Multipurpose Terminal Port from the physical impact aspect. This research was location in Figure 1.

![Port of Teluk Lamong on 2012](image)

**Figure 1. Port of Teluk Lamong on 2012**

The implementation of this research is taken for one semester, while the research activities include:

- **Problem Formulation**, this stage is the identification of the problem, determinant, or focus of a study. The main problem of this research is the factors or impacts on coastal resources, namely, changes in the coastline, water flow patterns, TSS before and after the construction of the Teluk Lamong Multipurpose Terminal Port.
- **Literature Study**, this activity is carried out to collect information related to research in the form of theoretical concepts and relevant matters. Library sources are obtained from the internet, reports from related agencies, scientific articles, journals, media, books, and other documents.
- **Data Processing**, namely knowing the analysis of shoreline changes, modeling water flow patterns, and modeling TSS concentrations based on long sensing data before and after the construction of the Teluk Lamong Multipurpose Port.
- **Data Validation**, the implementation of data validation is an activity carried out to measure the accuracy of the modeling to be carried out.
- **Results and Discussion** are the process to analyze the results of processing data from Landsat 7 satellite imagery on March 5, 2012, and Landsat 8 on March 5, 2020, for shoreline change analysis, modeling of water flow patterns in 2012 and 2020 based on data from the Hydrographic and Oceanographic Center of the Indonesia Navy (DISHIDROS) and the Meteorology, Climatology and Geophysics Agency (BMKG), and TSS concentration modeling based on remote sensing data Sentinel 2A imagery dated March 5, 2020, the National Institute of Aeronautics and Space (LAPAN). The input from this data processing explains the correlation between the coastal conditions of the Teluk Lamong Multipurpose Port and the physical environmental conditions based on 2012 and 2020.
In the data management process, we need to analyze the impact study before and after the construction of the Teluk Lamong Multipurpose Port was carried out:

- Perform shoreline change analysis using DSAS software based on Landsat 7 satellite imagery data on March 5, 2012, and Landsat 8 on March 5, 2020.
- Determining the focus point of TSS research using remote sensing tools, namely Sentinel 2A satellite imagery recorded on March 5, 2020, then processed using Google Earth Engine at the LAPAN agency.
- Modeling the condition of the water flow pattern at the Port of Teluk Lamong Multipurpose Terminal based on wind, tidal, and bathymetry data processed using Mike 21 software.
- TSS modeling using Mike 21 software based on remote sensing data.

3. Results and Discussion

Changes in the coastline need attention considering that it has a major impact on social and environmental life in order to determine the possibility of using land in coastal areas optimally. Changes in coastline that cause changes in land use can be identified using a remote sensing approach. Through this remote sensing approach, it can be seen that changes in coastlines have an impact on changes in coastal land from time to time. Remote sensing technology is needed for the development of coastal areas because this technology can provide information on large areas without requiring a long time and is relatively easy. In this study, shoreline monitoring was carried out using the DSAS method. The method of calculating shoreline changes used in DSAS is Net Shoreline Movement (NSM) and End Point Rate (EPR). Observation of shoreline changes takes a time span before and after port reclamation using data dated March 2012 and 2019. The purpose of this study is to determine the trend of shoreline changes during the period before and after port reclamation and to predict future shoreline changes using DSAS.

3.1 Net Shoreline Movement (NSM)

analysis method by looking at changes in the distance between the longest coastline and the newest coastline. In the analysis using the NSM method, it will be seen that the value of changes in the shoreline that experience accretion and erosion, where accretion will be shown as a positive value and erosion is indicated by a negative value, calculated from the baseline. Based on the picture below, the Teluk Lamong Port area seen from the coastline in 2012 and 2019, has experienced a lot of accretion. The results of the NSM analysis above, there are 3 color variations that identify accretion, light blue color with the highest value around 670-950 m, red color with a moderate value of 470-530 m, and black color with a low value of 60-90 m.

![Figure 2. Net Shoreline Movement (NSM) Analysis](image)

3.2 End Point Rate (EPR)

shoreline change analysis by calculating the rate of shoreline change by dividing the results of the NSM analysis with time intervals of 2012 and 2019.
The results of the NSM analysis above, there are 3 color variations that identify accretion, light blue based on the area of the highest line change with an EPR value of 107.5 m / year, red color based on the area of moderate shoreline change with an EPR value of 59.625 m / year, and black color based on the region change in shoreline is low with an EPR value of 10.375 m / year.

3.3 Tidal Modeling Analysis

Data processing of current pattern modeling is based on Mike 21's 2012 and 2020 models based on BMKG tidal data and tidal analysis of data validation, as data validation and previous research flow data as data validation. Modeling of current patterns is useful for knowing current patterns in the study of the Teluk Lamong Port area. The simulation of this research model was carried out for 15 days on March 1, 2012 at 00.00 to March 15, 2012 at 23.00 for modeling before the construction of Lamong Bay Port and for 15 days on March 1 2020 at 00.00 to March 15 2020 at 23.00 for post-construction modeling Lamong Bay Port. The time interval for each timestep was taken 3600 seconds to produce 359 timesteps. Mike 21 modeling results & parameters:
Figure 6. Wind Data for 2012

Figure 7. Wind Data for 2020

Figure 8. Current pattern at low tide in 2012

Figure 9. Current pattern at low tide in 2020
based on the available data it can be seen that. The condition of the current flow in the observation area after modeling has changed from 2012 to 2020, so it can be indicated that the conditions of the seabed contour in the Lamong Bay reclamation area have changed.

### 3.3.1 Validation
Tidal conditions are generally analyzed using the harmonic analysis method, this method has a hypothesis that the tides are the sum of several wave components that have a certain amplitude and frequency. The analysis aims to obtain the amplitude and phase of the tidal components. Recording and tidal forecasting were carried out for 15 consecutive days with observation points of 7° 12'17" latitude and 112° 40'46" east longitude. The results of the observation of water height were then analyzed using the Admiralty method and verified using the Root Mean Square Error (RMSE) and Cost Function (CF) methods.

Calculation using the admiralty method, which is a calculation to find the value of amplitude (A) and phase difference ($g^0$) of the observation data for 15 or 29 pigs (observation days) and mean sea level (S0) which has been corrected (Smoothing). The following are tidal components of the 2012 admiralty method analysis results and 2020.

| Table 3. Tidal Component in 2012 |
|---|---|---|---|---|---|---|---|---|
| | S0 | M2 | S2 | N2 | K1 | O1 | M4 | MS4 | K2 | P1 |
| A Cm | 0.0 | 0.259 | 0.181 | 0.086 | 0.331 | 0.256 | 0.002 | 0.002 | 0.049 | 0.109 |
| $g^0$ | 282.07 | 179.70 | 30.07 | 104.52 | 67.42 | 147.06 | 282.48 | 179.70 | 104.52 |

The types of tides in the Madura Strait waters of 2012 according to Formzahl (F) numbers based on the tidal components in the table above.

$$F = \frac{(K1+O1)}{(M2+S2)}$$
$$= \frac{0.331+0.256}{0.259+0.181}$$
$$= 1.336$$

| Table 4. Tidal Component in 2020 |
|---|---|---|---|---|---|---|---|---|
| | S0 | M2 | S2 | N2 | K1 | O1 | M4 | MS4 | K2 | P1 |
| A Cm | 0.0 | 0.253 | 0.180 | 0.105 | 0.381 | 0.239 | 0.002 | 0.003 | 0.049 | 0.126 |
| $g^0$ | 249.03 | 189.46 | 4.63 | 125.04 | 4.21 | 157.48 | 256.17 | 189.46 | 125.04 |

Tidal types in the waters of the Madura Strait in 2020 according to the Formzahl (F) number based on the tidal components in the table above are as follows.

$$F = \frac{(K1+O1)}{(M2+S2)}$$
$$= \frac{0.381+0.239}{0.253+0.180}$$
$$= 1.433$$

Formzahl's numbers are 1.336 and 1.433, according to Table 5, they are classified as 0.25 <F <1.5 or a Mixed Tide Prevailing Semidiurnal.

| Table 5. Tidal Type |
|---|---|---|
| Value | Tidal Type | Phenomenon |
| 0 < F < 0.25 | Semi Diurnal Tide | In one day there are two times the tide and two low tides with almost the same height and the tides occur sequentially regularly |
| 0.25 < F < 1.25 | Mixed Tide Prevailing Semidiurnal | In one day there are two times the tide and two times the low tide, but the height and period are different. |
| 1.25 < F < 3 | Mixed Tide Prevailing Diurnal | In one day there is one high tide and one low tide, but sometimes temporarily there are two tides and two low tides with very different heights and periods. |
| F > 3 | Diurnal Tide | In one day there is one high tide and one low tide. |
Tidal Analysis in 2012 is used as a reference for verification of 2020 data. Quantitatively by calculating the number of errors that occur from each data can be calculated by:

\[
RMSE = \left( \frac{\sum(y_i - \hat{y}_i)^2}{n} \right)^{1/2}
\]  

RMSE : Root Mean Square Error  
\( y_i \) : data in 2012  
\( \hat{y}_i \) : data in 2020  
\( n \) : total data

Based on the results of the analysis and verification of tides obtained RMSE value of 0.253 or a level of confidence of 74.7%. Model verification is used to determine the accuracy of both wind data sources quantitatively by calculating the magnitude of errors that occur from each data. Wind speed verification uses a Cost Function (CF) statistical analysis. According to George et al. (2010), the calculation of the CF method can be done with formulas:

\[
CF = \frac{1}{N} \sum_{n=1}^{N} \frac{|D_n - M_n|}{\sigma_D}
\]  

with

\[
\sigma_D = \frac{1}{N} \sum_{n=1}^{N} (D_n - \bar{D})^2
\]

\( N \) is the amount of data; \( n \) is the \( n \) data; \( D \) is the 2012 data value; \( \sigma_D \) is the standard deviation; \( M \) is the 2020 data value; \( D ... \) is the 2020 average data and CF is the Cost Function. According to George et al. (2010), the criteria used are:

- \( CF < 1 \) = Very good
- \( 1 < CF < 2 \) = Good
- \( 2 < CF < 3 \) = Less
- \( CF > 3 \) = Not good

Based on the analysis, it is known that CF is obtained by 0.485. This means that verification of data for 2012 and 2020 is in the range of CF <1 or very good.

![Tide Comparison Field Observation and Modelling](image)

Figure 12. tide observation data 2017
3.4 TSS Modelling Analysis

The modules used in this thesis are three modules with two main modules. The hydrodynamic module and the mud transport module are the main modules that will be analyzed the simulation results, while the wave spectral module is used as a support module to add wave aspects in simulating the mud transport module. Simulation processing that is carried out requires input (input) data in accordance with the desired and required conditions. Oceanographic factors that affect the type of sediment and sediment distribution are tides, winds, waves and currents. Sediment distribution modeling uses current parameters generated by tides and the influence of waves. Sediment sample data is based on journals in 2017 with a density value of 1188 kg/m³, dry density 884 kg/m³ and a sediment concentration of (D50) 0.0738 mm. Initial studies have been carried out by PT. Pelindo III itself in implementing AMDAL in 2011 using the same modeling software, namely MIKE 21. The following are the results of sediment modeling in 2011:

![Figure 13. Wave Data Validation for 2012 and 2017](image)

![Figure 14. Wave Data Validation for 2020 and 2017](image)

![Figure 15. TSS Modelling in 2011 (PT. PELINDO III)](image)
Table 6. River Discharge and Sediment Concentration Data, 2011 [9]

| No | River    | 1 yearly discharge (m³/s) | 5 yearly discharge (m³/s) | Sediment Concentration |
|----|----------|---------------------------|---------------------------|------------------------|
| 1  | Krembangan | 3.6                       | 85                        | 0.0134                 |
| 2  | Lamong    | 19                        | 594                       | 0.0738                 |
| 3  | Mireng    | 19                        | 594                       | 0.0099                 |
| 4  | Sememi    | 4.3                       | 56                        | 0.0278                 |
| 5  | Brajangan | 3.6                       | 81                        | 0.0125                 |

From Table 6. We use it for parameter in Mike 21 Module. The TSS model simulation was carried out for 15 days on March 1, 2012 at 00.00 to March 15, 2012 at 23.00 for modeling before the construction of Lamong Bay Port and for 15 days on March 1, 2020 at 00.00 to March 15, 2020 at 23.00 for post development modeling of the Port Lamong Bay. The time interval for each timestep was taken 3600 seconds to produce 359 timesteps. TSS modelling result:

At high tide the water level in the sea causes the movement of water masses or towards the land and at the same time carries sedimentary material. At low tide, the water level on land is higher and results in the movement of currents toward the sea, in this condition the sediment material will be trapped by the presence of the Teluk Lamong Port building. The greater the mass of water entering the Port area, the greater the trapped sediment material will be. Likewise, at low tide, the outflow from Lamong Bay through the Lamong River area. The flow is quite large at high tide, but at low tide, the flow velocity in
the Lamong River and Galang Island areas becomes very small so that the transported sediment will be easily deposited and gradually cause silting.

| No | Condition during the 2012 Sediment Transport Observation | TSS (g/m³) |
|----|--------------------------------------------------------|------------|
| 1  | Low tide                                               | 360-400    |
| 2  | High tide                                              | 440        |

| No | Condition during the 2020 Sediment Transport Observation | TSS (g/m³) |
|----|--------------------------------------------------------|------------|
| 1  | Low tide                                               | 320-360    |
| 2  | High tide                                              | 325-350    |

3.5 Remote Sensing Data

Data processing from Sentinel 2A satellite imagery March 5, 2020 using google earth engine software which can produce TSS remote sensing output. The channels in Sentinel satellite image data processing are used to obtain the reflectance value which is used to estimate the TSS concentration value. The first stage, namely radiometric correction is carried out to eliminate errors in the sun elevation angle and the sun-earth distance. Radiometric correction is a process to eliminate noise that occurs due to the influence of the atmosphere and due to the systematic influence of image recording. The simplest method is the Dark Object Substraction (DOS) method. DOS assumed that the digital value of the darkest object on Earth's surface must be zero. In fact, the digital value of each channel (band) in a satellite image is not always zero.

Based on TSS remote sensing data, there are 5 assessment categories, namely very low (0-20 mg/L), low (20.1 -40 mg/L), moderate (40.1 -80 mg/L), high (80.1 -120 mg/L) and very high (> 120.1 mg/L). Very high conditions were found at the point where the Lamong River was discharged. High levels of TSS come from solid substances (sand, mud and clay) or particles suspended in water and can be in the form of living components (biotic) and inorganic particles. This causes the penetration of sunlight to the surface and the deeper part is not effective because it is blocked by suspended solids. The distribution of suspended solids in the sea, apart from being influenced by inputs from land through river flows, can also come from the air and displacement due to sediment resuspension due to erosion [4]. At Lamong Bay port, it is estimated that TSS will increase due to the eroded sand from the reclamation pile and port dredging to maintain the depth of the ship's anchor.

Figure 20. TSS Distribution Map 2014

Figure 21. TSS Distribution Map 2016
Based on the TSS remote sensing tables and figures, the highest value is at the point near the Teluk Lamong Port. In Situ data obtained in journals explain high TSS values at stations 2, 3, 4, 22 and 23 with values of 142 mg/L, 119 mg/L, 115 mg/L, 112 mg/L and 116 mg/L. When compared to remote sensing data in 2020 using GEE TSS software, the highest was 167 mg/L, 122 mg/L, 120 mg/L, 128 mg/L and 120 mg/L.

The accuracy test was carried out to validate the TSS result data from satellite image processing in 2020 using the Budiman algorithm, which then calculated the correlation by comparing the field survey data in the journal Analysis of Changes in Total Suspended Solid Concentration (TSS) in Lamong Bay Using Multitemporal Landsat Images by Sukojo, et al., [15]. It is used to see the closeness or goodness of image processing data. From the results of the validation test based on Figure 19, the correlation value is \( r = 0.94398 \) and the coefficient of determination \( R^2 = 81\% \) which indicates that the correlation between the results of extracting TSS values from images using Budiman's Algorithm is very strong \( (r \geq 0, 6) \) [5].

4. Conclusion and Suggestion

4.1 Conclusion

- There is a change in the pattern of current velocity around the Teluk Lamong terminal area which can cause changes in the contours of the seabed. At high tide conditions in 2012 the average current velocity was 0.3 m/s, while the average current velocity at tide in 2020 was 0.009 m/s. Likewise, during low tide, the average flow velocity in 2011 was 0.15 m/s, while the average flow velocity in 2020 was 0.01 m/s.
sediment occurs due to the impact of reclamation in the Lamong Bay area. In the simulation, it is known that the average TSS value in 2012 is 380 g/m³ (high tide) and 440 (low tide), while in 2020 the average TSS value in 2020 is 340 g/m³ (high tide) and 335 (low tide).

Based on the TSS remote sensing tables and figures, the highest value is at the point near the Teluk Lamong Port. In Situ data obtained in the journal explained the high TSS values at stations 2, 3, 4, 22 and 23 with values of 142 mg/L, 119 mg/L, 115 mg/L, 112 mg/L and 116 mg/L. When compared to remote sensing data in 2020 using GEE TSS software, the highest was 167 mg/L, 122 mg/L, 120 mg/L, 128 mg/L and 120 mg/L.

4.2 Suggestion

- With the presence of high sedimentation conditions in the Teluk Lamong Port area, based on modeling and remote sensing observations, maintenance is required for routine depth monitoring.
- If in depth monitoring, a change in depth is found that is no longer in accordance with the draft of the ship's voyage, it is necessary to do some prevention by dredging the port pool by the port authority as the party maintaining the port facilities.

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