Analysis of Total Suspended Solid at Merah Putih Beach, Bangkalan Regency

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Abstract. Total Suspended Solid (TSS) is the phenomenon of transporting solid particles both organic and inorganic on water column which can be an initial parameter in determining water quality. Merah Putih Beach is located in the Madura Strait, which has an active shipping pathway. We used the Gravimetric method to determine the concentration of TSS. We also applied the advances of remote sensing technology for Landsat-8 using Google Earth Engine and based on Jaelani algorithm. The algorithm is considered quite efficient because it only takes a short time and gets maximum results in TSS visualization. Merah Putih Beach has a TSS value 250 - 1508 mg/l. The result of validation for the algorithm estimation obtained an RMSE 866,51 mg/l and R square 0,1076. The advanced empirical modelling tests reveal the Polynomial mathematical equation had a smaller RMSE and a larger R square of 82,34 mg/l and 0.4468. The visualization results show a difference and have a value that is close to the actual TSS.

Keyword. TSS, gravimetric, remote sensing, landsat-8, efficient

1 Introduction

Total suspended solid (TSS) is solid particles suspended in water and comes from organic and inorganic materials. TSS is included in the first parameter in determining the initial condition of an environment, because high levels of TSS can reduce seawater quality. The source of this suspended sediment comes from particles carried by currents, either from rivers or from other places which then accumulate in one location [1], [2]. The study of this parameter is widely used in water quality studies where suspended particles affect water clarity and potentially reduce sunlight penetration which can have an impact on aquatic ecosystems. The Madura Strait is included in the type of semi-enclosed sea because it is flanked by two islands, namely the islands of Madura and Java [3]. This location has a high level of human activity, especially being an active shipping lane and there are other human activities that can have an impact on TSS concentrations [4].

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TSS is very important to be assessed periodically in order to maintain the existence of existing ecosystems for environmental sustainability [5], [6]. This assessment completed by testing water samples using existing suspended sediment analysis methods. Laboratory analysis of the TSS is a conventional method that utilizes the physical properties of the test parameters used filtering suspended particles at a certain particle size by the gravity and suitable filter paper [7]. The test takes a relatively long time but produces accurate concentration information. The method takes place in several stages including TSS sampling, sample testing, and data analysis. The data obtained is then calculated in order to obtain standardized units, namely mg/litter.

TSS in remote sensing is a method for analysing suspended sediment concentrations by applying satellite imagery as the medium of analysis. Remote sensing can be used efficiently and does not take much time and produces the amount of TSS concentration on a local, regional, and even global scale [8]. The application of remote sensing can be applied to determine temporal fluctuations in TSS concentration values [9] based on reflectance value for every bands which provided in the image data by applying the desired algorithm for modelling. This method has a disadvantages where the TSS estimation do not match or different to the actual conditions [10]. The limitation over the test for TSS become the point to applying multivariate empirical regression modelling which is expected to get the best results compare to the field data.

2 Material and Methods

2.1 Study Area

The current research was conducted at Merah Putih Beach, East Sukolilo, Bangkalan Regency, East Java, Indonesia. The study area is located at coordinates between longitudes 112°49.045' E to 112°49.420' E and 7°9.490' S to 7°9.755' S. The location are interesting due to a dynamic coastline and is directly adjacent to the Madura Strait which has a high level of shipping line activity. TSS sampling was conducted on October 6, 2024 at 14:00 WIB with 10 coordinate points along 675 meters that represent the TSS conditions at Merah Putih Beach. The distance between points used in this study varies based on the dynamic morphological conditions of the coastline (**Fig. 1.**). The sample was taken according to the availability of Landsat-8 image data at the United States Geological Survey (USGS) for method comparison.

Fig. 1. Map of Study Area

2.2 Data Collection

The data collection method was carried out by field observations and collected TSS samples at the study area. Sampling was required at predetermining coordinate points, called a total of 10 sampling points at one research location. Samples were taken using 1 litter sample bottles which were then labelled according to the sampling point code (MP1-MP10). The sampling method is expected to represent the TSS concentration and is used for comparison of remote sensing results regarding TSS that will be carried out. The samples that have been obtained are then analysed using the Gravimetric method with the Indonesian national standard [11]. Then the second data is the Landsat-8 image taken with the help of the Google Earth Engine (GEE) platform on October 6, 2024.

2.3 Methods

2.3.1 Processing In-situ data

The samples that have been obtained are then analysed using the Gravimetric method with the national standard of Indonesia [11]. The initial step of Gravimetric method is to dry the filter paper that has been labelled according to the sample and weighed as W1 and then place the filter paper in a vacuum and moistened using distilled water. The previously homogenized sample was then taken as much as 50 mL and filtered by vacuum until the sample empty. The filter paper has been used is then dried in an oven at 105°C around 2 hours and then weighed as W2. This stage is repeated until all stations have been analysed, but to minimize errors in the analysis, duplicates are required. Then to get the TSS concentration value, a calculation is needed with the following formula.

$$TSS\left(\frac{mg}{L}\right) = \left(\frac{W2-W1}{50}\right)1000 \quad (1)$$

2.3.2 Calculation of Total Suspended Solid (TSS)

The TSS remote sensing method is a stage in this research that utilizes Landsat 8 image data provided by the official USGS website and is processed using the Jaelani algorithm [12]. This algorithm uses band 2 and band 3 reflectance values to calculate TSS. Google Earth Engine (GEE) as a platform for analysing TSS. Before calculating the TSS concentration using the algorithm, atmospheric correction and radiometric calibration need to fixed to reduce the bias effect caused by reflected sunlight and other atmospheric objects. The results obtained are a model which has information of TSS concentration. The following is the algorithm used in the TSS remote sensing method.

$$TSS\ Jaelani\left(\frac{mg}{L}\right) = 1,5212\left(\frac{logRrs(\lambda 2)}{logRrs(\lambda 3)}\right) - 0,3698 \quad (2)$$

2.3.3 Statistical analysis and accuracy comparison of mathematical equations

The statistical method used in this study applies several stages. The first stage is to apply the data obtained to the ANOVA test with an alpha value of 0,05. This test is used to determine whether there is a significant difference between in-situ data and TSS remote sensing results at 10 sampling points. If the P-value is less than the predetermined alpha value, then there is a significant difference between the two data. The next stage is to conduct empirical regression modelling [13] which is used to determine the mathematical equations that allow it to be applied in TSS estimation. The following is the model used in this study, with variable (x) being the calculation value between band 2 and band 3 according to the algorithm of Jaelani [12].

a. linear. a(x) + b (3)

*b. exponential. a*e$^{b(x)}$* (4)

*c. logarithmic. a*ln(x) + b* (5)

d. polynomial. a(x)2 + b(x) + c (6)

The mathematical equation obtained is then used to estimate TSS with the reflectances data that has been obtained previously. The estimated data is then compared with the in-situ data to determine the R square and standard deviation values using the data analysis tools provided on the platform, while for the RMSE (Root Mean Square Error) value with the following formula, where the variable (n) is the amount of data; (y_i) is the in-situ TSS value; and ($\hat{y}_i$) is the estimated data value [14].

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{1}\left(y_i - \hat{y}_i\right)^2} \quad (7)$$

2.3.4 Estimating of Total Suspended Solid

This point is carried out by entering the best mathematical equation that has been obtained in the Google Earth Engine (GEE) script. Then the TSS estimation results that have been

obtained from GEE are compared with the results obtained by the Jaelani algorithm. This comparison can be seen how the difference between the two data visually and how the TSS concentration at the research location.

3 Result and Discussion

3.1 Result

The table below is a display of the data that has been obtained in the in-situ collection and the total suspended solid results calculated using Jaelani's algorithm. Sampling was carried out at 10 coordinate points and the X value is the calculation of the band 2 (blue) and band 3 (green) reflectance values based on the statistical test of Jaelani [12]. Total suspended solid analysis was carried out by gravimetric method based on SNI and obtained the highest result at point MP8 which is 1508 mg/L where the high TSS concentration is indicated by the turbidity. The lowest value at the research location is shown at station MP2 (250 mg/L) and has a clearer sample. The TSS calculation based on Jaelani's algorithm has a value that is very far from the in-situ data. TSS concentrations from laboratory testing obtained values between 1.30218 mg/L to 1.42077 mg/L. The difference is one of the attractions for the author to conduct research to compare the algorithm with advanced statistical methods.

Table 1. A Table of suspended sediment results based on in-situ and remote sensing data

Station	Lon	Lat	X	TSS (mg/L)	TSS Jaelani
MP1	112,817499	-7,160395	1,170506 1	450	1,41077
MP2	112,818310	-7,159938	1,056916 4	**250**	1,35547
MP3	112,819012	-7,159700	1,129307 2	642	1,34810
MP4	112,819998	-7,159489	1,166845 4	812	1,40521
MP5	112,820566	-7,159912	1,142382 3	1180	1,36799
MP6	112,821224	-7,160150	1,150618 8	574	1,38052
MP7	112,821934	-7,160220	1,099117 9	1014	1,30218
MP8	112,822494	-7,160494	1,133344	**1508**	1,35424
MP9	112,822982	-7,160872	1,124667 1	876	1,34104
MP10	112,823441	-7,161090	1,146864 7	634	1,37481

3.2 Statistical analysis and accuracy comparison of mathematical equations

ANOVA test results were conducted by comparing in-situ and remote sensing data. ANOVA shows a pattern of data displaying the frequency of the most frequently occurring data [16]. **Table 2** is the ANOVA result which is intended to determine how the data distribution

between in-situ and remote sensing. In this test, an alpha value of 0.05 has been set while the P-value is 0.00000632. The test found that the p-value is less than alpha, so it can be concluded that the remote sensing data has a significant difference with the in-situ data. In addition, the significant difference between the two data can be seen from the calculated F value (46.135540) which is more than the F crit (4.413873). The high difference also shows that further tests are needed to obtain TSS calculation results that are representative of field data.

Table 2. A table of ANOVA test on in situ data and modelling results

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3141359	1	3141359	46,1355	2,32E-06	4,41387
Within Groups	1225616	18	68089,78			
Total	4366975	19				

The graph in **Figure 2** is a scatter plot for comparing between in-situ data and reflectance values from the Landsat-8 OLI image, which then derives a mathematical equation for the calculation of TSS. The mathematical equation obtained was then used to calculate TSS with band 2 and 3 reflectance data that had been collected previously to obtain the TSS estimated from all algorithms. The estimated value was then tested using RMSE and R-square to determine the best mathematical equation for estimating the TSS concentration (**Table 3**). The results shown in **Table 3** are the calculation of statistical tests between in situ data and the estimated values obtained from each mathematical equation, while the TSS estimated value is obtained by the input of variable X which is the calculation of band 2 and 3 reflectance values. At this stage it can be seen that the algorithm with the final result close to the actual conditions is the algorithm that has the smallest RMSE value and R-square close to 1 [13]. These criteria are found in the polynomial model which has the highest RMSE value of 82.34 and the lowest R-square value of 0.4468.

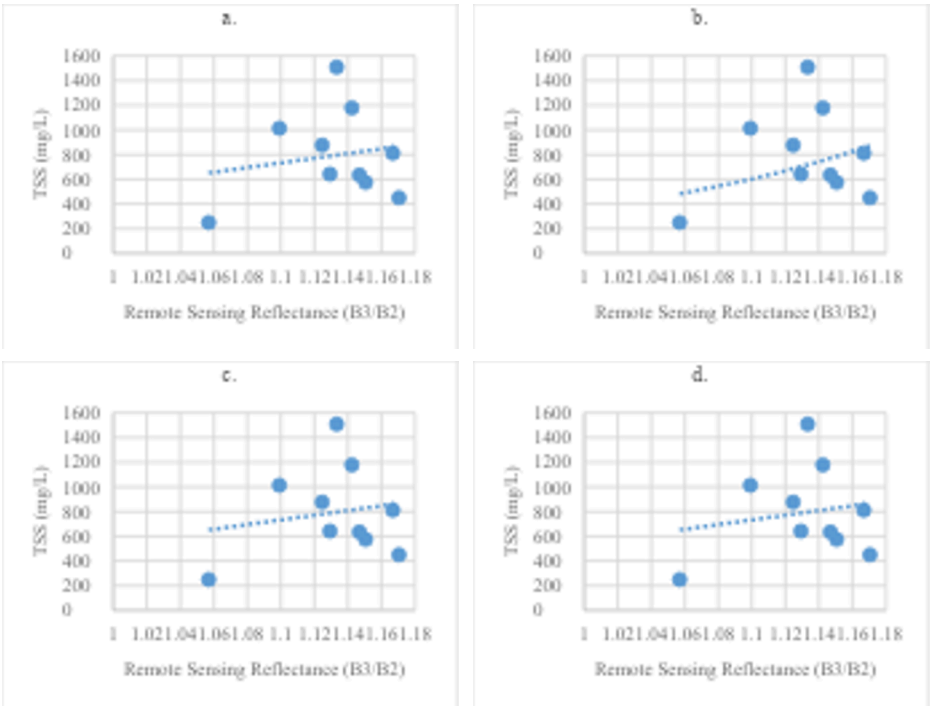

Fig. 2. Compared in-situ measured TSS Concentration and Reflectance Data with a.) Linear; b.) Exponential; c.) Logarithmic; and d.) Polynomial.

Table 3. A table of statistical test results on in situ data and modelling results

TSS	Mathematic Equation	RMSE	R^2	StDev
Jaelani	y = 1,5212x - 0,3698	866,51	0,1076	0,03173
Linear	y = 1900,1x - 1357	344,81	0,029	63,82221
Exp	$y = 1,9036e^{5,2339x}$	114,70	0,0118	116,4331
Log	y = 2249,6ln(x) + 515,88	108,82	0,0338	67,84088
Polynomial	**$y = -187960x^2 + 420971x - 234698$**	**82,34**	**0,4468**	**246,6702**

The calculation results are then plotted on a Taylor diagram which is a graphical display to show the representation of the estimation results against the observation data. The variables contained in the Taylor diagram are the Standard Deviation value and the correlation coefficient. The standard deviation used in this data uses a total suspended solid unit of mg/L and for the correlation coefficient value only uses a value range of 0 to 1. The observation point is located at StDev 369 mg/L and the correlation coefficient is 1, this is because the observation is used as a comparison with the estimation results using other mathematical equations. In accordance with the aim of knowing the mathematical equation that is closest to the observation results, it can be seen that the Polynomial calculation has a value closer to the observation reference [15]. The polynomial equation has a standard deviation value of 246.67 mg/L and a correlation coefficient of 0.6563. This shows that the

polynomial mathematical equation can be used to estimate the concentration of total suspended solid with results that are close to the actual conditions.

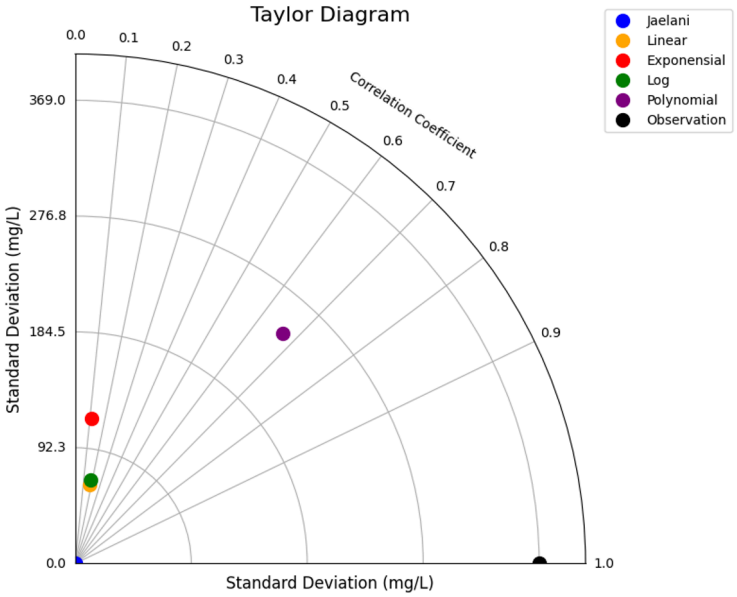

Fig. 3. Taylor Diagram.

Figure 4. is the result of estimating total suspended solid using Jaelani algorithm and polynomial mathematical equation? Both results still use the corresponding pixel data from the Landsat-8 image which is 30 meters so that the visualization of this research still needs to be smoothed. These results have differences where the results of the Jaelani algorithm have total suspended solid values between 1.2 mg/L to 1.8 mg/L, while the estimated results of the polynomial equation calculation range from -9999 mg/L to 1012 mg/L. This difference is also shown from the visualization results of the total suspended solid estimation where in the Jaelani algorithm the highest value shown in red is in the middle of the water, while at the edge has a low total suspended solid value. Visualization of suspended sediment estimation using the polynomial equation shows that the coastal edge has a high total suspended solid value, while the middle is relatively low.

This condition is in accordance with research by [3] conducted in the Madura Strait by comparing in-situ data and remote sensing results based on season. The study took samples at seven stations as in-situ data and coordinates for retrieving reflectance values from satellite imagery. Researchers obtained results showing that the value of TSS concentration in the middle of the Madura Strait has a low value, while on the coast has a higher value of TSS concentration. This is in accordance with the results of TSS estimation calculations using the mathematical equation obtained in empirical regression modelling, namely the polynomial equation. The R square value in this study is 0.4468 which is different from the results of the research by Cahyo [3] who got an R square of 0.6511. This R square value is included in the medium classification where the TSS estimation results are influenced by the reflectance value of 0.4468 or 44.68%.

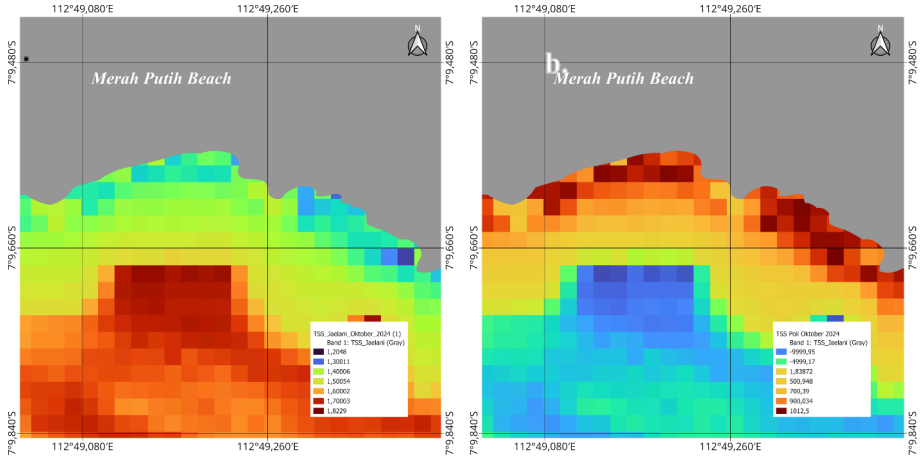

Fig. 4. Estimated results using a. Jaelani's algorithm; and b. Polynomial algorithm.

4 Conclusion

After observation at Merah Putih Beach, it was concluded that the total suspended solid (TSS) value was relatively high, ranging from 250 mg/liter to 1508 mg/liter. This study also showed that to determine the concentration of TSS, the remote sensing method can be utilized by calculating the reflectance value of satellite images. But after validation, the RMSE value of 866.51 mg/liter and R square of 0.1076 were obtained, indicating that the estimation results were still far from the field data. This study conducted further tests in the form of empirical modelling and found that the Polynomial mathematical equation had a smaller RMSE value and a larger R square than the use of the algorithm, namely 82.34 mg/l and 0.4468. The mathematical equation obtained was then run on Google Earth Engine to estimate TSS values. The visualization results show a difference to the initial visualization results and have a value that is close to the field TSS.

Acknowledgement

The author would like to thank the supervisor and members of the Oceanography Laboratory who have been supporting in completing this study both from funding and support in the administration and laboratory analysis.

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