Total Suspended Solids in Teluk Awur, Jepara using Red Reflectance from Landsat-8

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Abstract

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The coastal waters of Teluk Awur, Jepara are affected by human activities such as aquaculture, tourism, agriculture, and settlements. The increasing activities of humans on land will affect the input of suspended solids (TSS) into coastal waters through water runoff. The high TSS in the water column will affect the light intensity, disturbing the photosynthesis process and ecosystem. Its monitoring can be implemented through the use of remote sensing. This research aims to evaluate several TSS algorithms such as Wirasatriya, Budhiman, Ajiperwata, and Parwati algorithms, and develop a new algorithm through calibration of in situ data in July 2023 versus several reflectances in Landsat 8. The use of Budhiman algorithm has better performance than the others, however, the calibration result (new algorithm) is the best. The performance of the calibrated algorithm has a smaller error value with RMSE = 8.51, MAPE = 25.77%, and Bias = 7.52.TSS estimation from Landsat 8 satellite imagery with red band had a range of values of 30.56 - 62.55 mg/L (average 35.60 mg/L), while insitu data of TSS values weree 22.40 - 64.52 mg/L (average 32.69 mg/L). This research will be valuable information for using the right Landsat-8 algorithm for temporal and sustainable TSS monitoring. It can be used in abrasion monitoring and management in the Teluk Awur coastal waters of Jepara.

Keywords: *TSS, Algorithm, Landsat-8, Teluk Awur*

INTRODUCTION

The coastal water area is very vulnerable to land changes due to high human activities. Even though this area has high productivity and is a support area for the economy of the people like fisheries (aquaculture) and conservation areas. The environmental changes in coastal areas such as abrasion cause high turbidity and poor water quality (Adawiyah *et al*., 2021). The level of turbidity can be measured through the concentration of total suspended solids (TSS). One of the coastal waters in Jepara that is abrasion is Teluk Awur (Ibrahim *et al*., 2022). In addition to abrasion, the presence of aquaculture, settlements, and tourism around the coast has led to high land conversion which in turns can have an impact on TSS inputs. The feed and faecal residues released by aquaculture activities contribute to the high TSS in the water. Overall, TSS includes biotic (bacteria, phytoplankton) and abiotic (non-living detrital, clay, minerals) components. The presence of high TSS in waters will reduce the intensity of light [Wang *et al*., 2017; Balasubramanian *et al*., 2020] and interfere with photosynthesis. In addition, the presence of TSS in waters column is also a source of nutrients in the water column [Maslukah *et al*., 2020] which can cause eutrophication and as a source of pollutants (Pahlevan *et al*., 2022). Based on government regulations, the TSS value of waters that can still be tolerated for cultivation and conservation areas is below (<20 mg/L). Therefore, monitoring of TSS concentration must be carried out continuously.

. One of the approaches is water quality monitoring through the use of remote sensing. This method has the advantage that monitoring can be more efficient and effective as well as

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inexpensively (Saberioona *et al*. 2020). Research related to the distribution of suspended sediment in Teluk Awur, Jepara using remote sensing was previously carried out by Subardjo *et al*. (2020) and Maslukah *et al*. (2023). Subardjo's research only applied the algorithms developed from Syarif Budhiman's research (2004) without testing the model's accuracy in the research study area. Therefore, its validity is still questionable. While research by Maslukah *et al* (2023) explained that the use of algorithms from BKT waters does not apply to Awur Bay waters because it has a high bias and needs special algorithm development.

This research will evaluate several algorithm models using red reflectance from several previous researchers, including (1) Wirasatriya *et al*. (2023) in BKB Semarang river (2) Ajiperwata *et al*. (2023) in Tanjung Jati Jepara waters and (3) Parwati *et al*. (2010) in Segara Anakan waters, Cilacap. In addition, this study also developed its own algorithm by calibrating the in situ TSS against the reflectance from Landsat 8, namely λ1 (coastal aerosol), λ2 (blue), λ3 (green), λ4 (red), λ5 (near infrared), λ6 (short wave infrared 1) and λ7 (short wave infrared 2).

MATERIALS AND METHODS

This study was conducted in the coastal waters of Teluk Awur, Jepara Regency, Central Java, Indonesia with the coordinate boundaries of the area 110° 61' 72" to 110° 63' 96" E and -6° 64' 17" to -6° 61' 43" South Latitude (Figure 1). Sampling was conducted in July 2023 at 34 points (Figure 1).

Field samples in the form of seawater were taken as much as 1 liter at a depth of ±1 meter from sea surface. The water sample is then filtered and calculated using the gravimetric method to obtain the TSS value. The gravimetric method is a method of examining the amount of a substance which is determined by directly weighing the mass of the substance which is separated from other substances after filtration. Following research conducted by Delardi *et al*. (2019), to measure the TSS concentration value, the formula is used:

$$TSS = \frac{a-b}{c}\ mg/Liter$$

where: TSS (Total Suspended solid, in mg/L); a (mass of filter paper after filtering, in mg); b (mass of filter paper before filtering, in mg); c (volume of water sample, in liters).

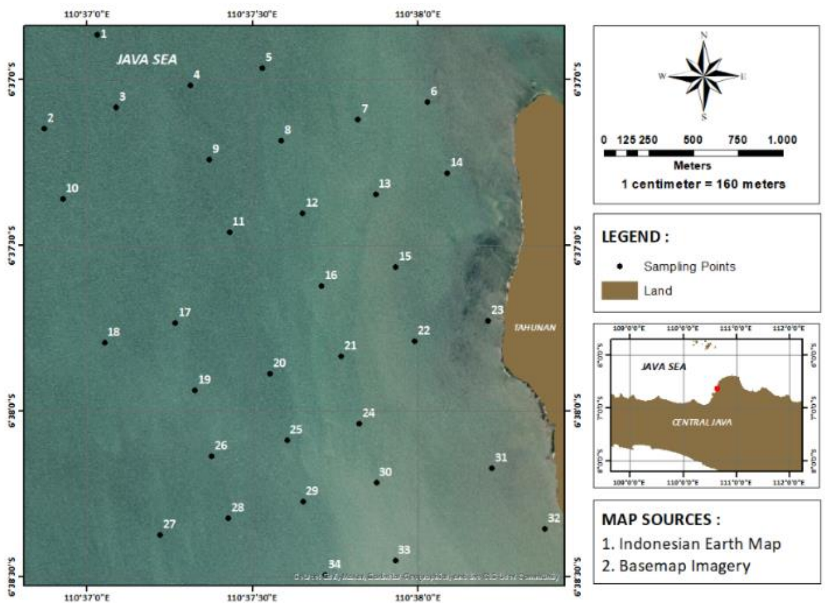

Figure 1. The location of the sampling area

Landsat 8 image data processing in this research uses ENVI 5.3 software. Landsat 8 images need to be corrected first, the corrections made are radiometric and atmospheric. Previously, for radiometric correction, the image was cropped using the Region of Interest (RoI) tool so that the processed image only focused on the research location (Jiyah *et al*., 2017). Next, object separation (masking) is carried out to give a value of 0 (zero) for objects that are not sea. Masking the image between waters and land is intended so that the spectral values from land do not influence the spectral values used in the interpretation process. Masking is done using the Near Infrared (NIR) reflectance.

Based on research by Ajiperwata *et al*. (2023) TSS concentration values from the reference algorithm are not close to field measurement values, a new algorithm will be developed between field data and satellite image data using Excel software. The new algorithm for TSS prediction is analyzed using a simple linear regression method using field TSS value data and Landsat 8 satellite image reflectance values. The prediction algorithm is obtained from band 1-7 reflectance values which have a resolution of 30 meters, this reflectance is λ1 (coastal aerosol), λ2 (blue), λ3 (green), λ4 (red), λ5 (near infrared), λ6 (short wave infrared 1) and λ7 (short wave infrared 2). This regression analysis will later obtain the coefficient of determination (R^2). Among the 7 bands used, the best band will be selected for the regression equation to be taken. If the R^2 value is +1 or close to 1 then variable x has a strong and positive influence on variable y and if the R^2 value is 0 or close to 0 then the effect is the opposite. This prediction algorithm model will then be tested for accuracy together with algorithms from previous research such as algorithms from the research results of Wirasatriya, *et al*. (2023), Budhiman, *et al*. (2004), Ajiperwata (2023), and Parwati, *et al*.(2010), respectively:

TSS (mg/L) = (1956.2*reflectance red) – 50.056
TSS (mg/L) = 8.1429*Exp(23.704* reflectance red)
TSS (mg/L) = (854.4*reflectance red) – 5.3743
TSS (mg/L) = 3.323*Exp(34.099* reflectance red)

The accuracy test was performed to determine the mean squared error (MSE) between the insitu TSS and the predicted TSS from satellite imagery. This test aims to determine the accuracy of the results of the TSS concentration value of the image processing algorithm on in situ data. This test is carried out with root mean square error (RMSE), mean absolute percentage error (MAPE), and relative bias error formula. The RMSE value and refractive error can be calculated using the formula previously used in the research of Millenia *et al*. (2021):

$$RMSE = \sqrt{\frac{1}{n}(X_{obs} - X_{pre})^2}$$

$$Bias = (X_{pre} - X_{obs})$$

Meanwhile, to calculate MAPE, it can be calculated using the formula previously used in the research of Saputra *et al*. (2023):

$$\boldsymbol{MAPE = \left(\frac{1}{n}\right)\sum_{i=1}^{n}\left|\frac{TSS_{predic-}\ TSS_{obs}}{TSS_{obs}}\right| x\,100}$$

RESULT AND DISCUSSION

One of the points to consider in the utilisation of imagery for water quality monitoring is the selection of a suitable algorithm for predicting concentrations. The use of previously developed algorithms is not always universally applicable to every coastal water (Kutser *et al*., 2018; Premkumar *et al*., 2021; Milenia *et al*., 2022; Faridzie *et al*., 2023). Therefore, regionally and locally based algorithms are needed to be more accurate.

In this study, we calibrated the in-situ data with Landsat-8 red reflectance data and tested the TSS retrieval algorithms of Wirasatriya, Budhiman, Ajiperwata, and Parwati, the results of which are shown in Table 1 and Table 2. The in-situ data used in this study was collected when the Landsat satellite was passing across the area of study, on 22 July 2023. The analysis of TSS in situ concentrations ranged from 22.40-64.52 mg/l (average 32.69 mg/l).

Based on Table 1, it is shown that the red reflectance (B4) shows the best performance as represented by the coefficient of determination (R^2) value of 0.3657. The scatter plot between red reflectance and in situ TSS is shown in Figure 2, which results in the model algorithm :
TSS (mg/L) = (547.31* Red reflectance) + 26,397

The predicted TSS values from the calibration process and the testing of several previous algorithms in the study area can be summarised in Table 2 and its accuracy values (RMSE, MAPE and Bias) are shown in Table 3.

Table 1. Regression models TSS insitu with reflectance Landsat-8

Band	Band Name	Regression Model	R^2
1	Coastal Aerosol	y = 279.75x + 27.66	0.0432
2	Blue	y = 172.17x + 28.561	0.0368
3	Green	y = 307.63x + 23.653	0.2234
4	Red	y = 547.31x + 26.397	0.3657
5	Near Infrared	y = 2497x + 4.37	0.3120
6	Short Wave Infrared 1	y = 1133.4x + 28.129	0.0325
7	Short Wave Infrared 2	y = 1639.9x + 23.11	0.0401

Table 2. The estimation of TSS concentration based on Landsat-8 imagery using different algorithms

Algorithms	Min (mg/L)	Max (mg/L)	Average (mg/L)
Wirasatriya	-30.56	43.42	-12.58
Budhiman	10.31	25.27	13.12
Ajiperwata	3.14	35.45	10.99
Parwati	4.67	16.95	6.72
From equation 3 (in this study)	30.56	62.55	35.60

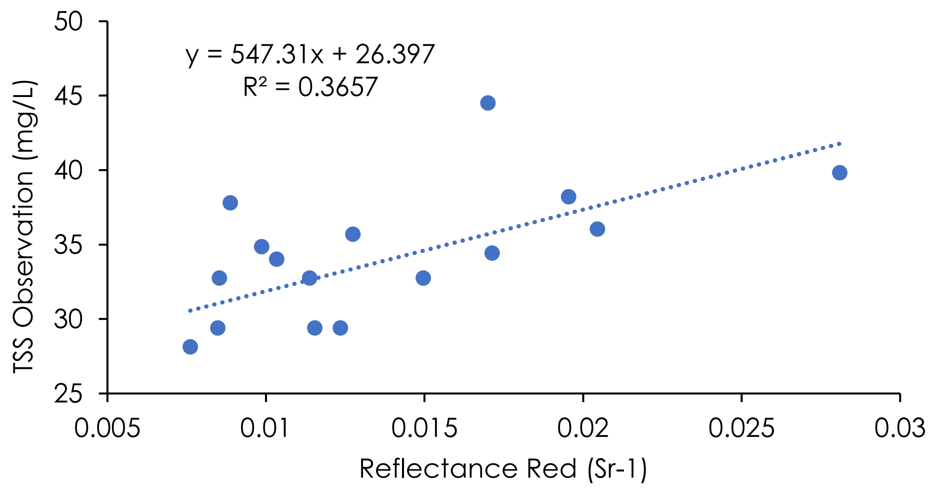

Figure 2. Scatter Plot of TSS observation versus reflectance red

The test results show that several previous regression models have quite large error values. Based on the results in Table 3, Wirasatriya's model has the highest error with RMSE, MAPE and Bias values respectively of 44.66, 148.82 and -41.94. Meanwhile, the lowest error value is in the regression model prediction with RMSE, MAPE and Bias values respectively of 8.51, 25.77 and 7.52. According to Sumari *et al*. (2020) an RMSE value close to 0 indicates that the resulting value is good. Meanwhile, the MAPE value is also needed as a reference in selecting an algorithm. The smaller the error value, the better the results obtained.

The application of new algorithm was chosen because it has the lowest error value when compared with the research algorithm of Wirasatya, Budhiman, Ajiperwata, and Parwati. These algorithms only use the red band or band 4 in their equations, this is by the prediction algorithm which also only uses the red band in its model equations. This is confirmed by Arief *et al*. (2017) who also used the red band to measure TSS estimates in Lampung Bay, the relationship between the red band and field data showed a fairly accurate value of 0.85. The red band on Landsat 8 has a spatial resolution of 30 meters with the ability to reflect visible color waves, so it can define conditions that occur in the waters, including concentrations for predicting TSS concentrations. So there is a relationship between satellite visible waves and concentration distribution values in waters (Liu *et al*., 2017).

To see the comparison between observed and predicted TSS concentration values, data validation was carried out on both values which can be seen in Figure 3. The prediction results using satellite imagery were also analyzed by making distribution maps which can be seen in Figure 4 and Figure 5. This analysis was carried out with the band math feature in ENVI software and then created in the form of a distribution map with ArcGIS software.

Table 3. Accuracy Test of Several Regression Models with Statistical Parameters

Reference	Satellite	RMSE (mg/L)	MAPE (%)	Bias
Wirasatriya	Sentinel 2	44.66	148.82	-41.94
Budhiman	Landsat 7	16.50	55.44	-16.23
Ajiperwata	Sentinel 2	19.43	64.15	-18.36
Parwati	Landsat 7	22.78	77.29	-22.63
New algorithm in the study	Landsat 8	8.51	25.77	7.52

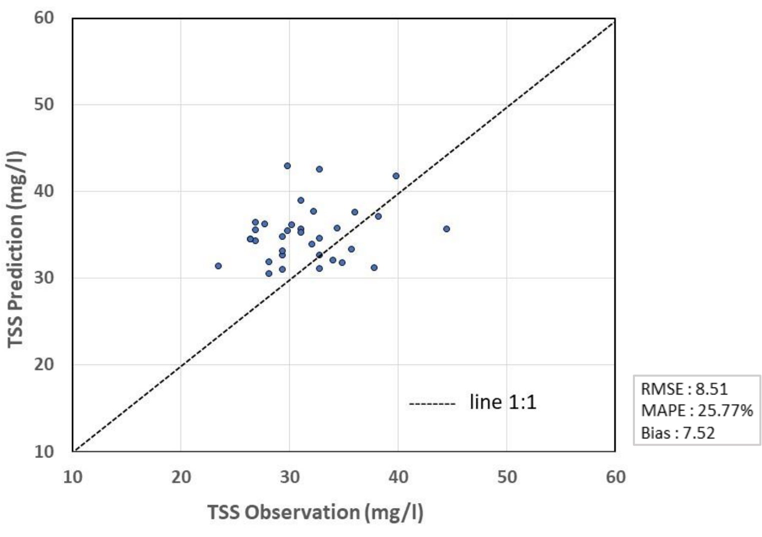

Figure 3. Validation of TSS from eq. (3) with TSS observation.

Figure 3 shows that, the calibration results using the red band, still have a high error value (RMSE=7, mg/L) and the predicted TSS overestimates the in situ data. However, the TSS prediction value from the calibration model in this study has a relatively small value compared to previous studies. The TSS prediction result using Landsat was 67.54 mg/L in the dry season (Subardja *et al*, 2020), while in the rainy season (October) it was 54.72 mg/L using Sentinel-2 (Maslukah *et al*., 2023). The results of the distribution of TSS concentrations in the field and satellite images can be seen in Figure 4 and Figure 5.

Based on Figure 4, TSS concentration values are classified into 3 classes. The classification of TSS values can be seen from the different colors shown on the map, the pale green color indicates that the TSS content is low, the lowest value has a value of 22.40 mg/l in the range of 20 - 40 mg/l, the light green color indicates a TSS value of 40 - 60 mg/l and the dark green color shows a value of 60 – 70 mg/l with the highest TSS value of 64.52 mg/l. The average TSS value for field data is 32.69 mg/l, shown in the value range of 20 – 40 mg/l in pale green. It can be seen that pale green dominates some of the colors in the classification of TSS values on the map. Meanwhile, the distribution of TSS concentrations predicted by the new algorithm can be seen in the following map.

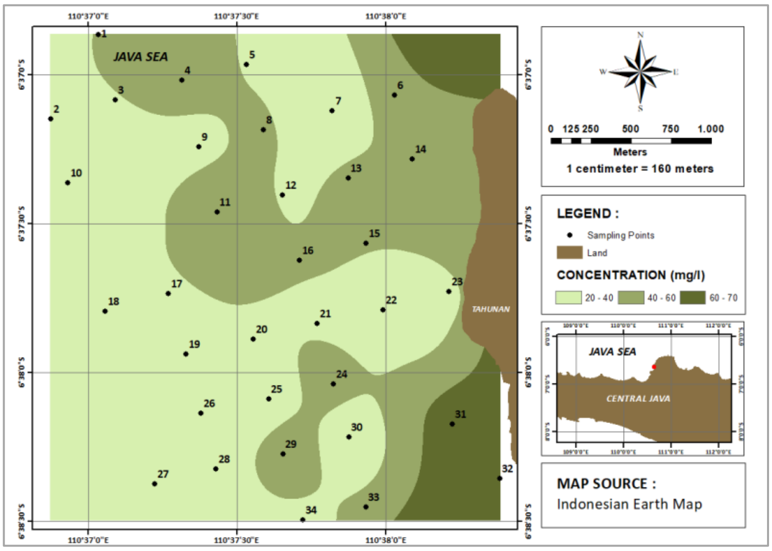

Figure 4. TSS Distribution Map Results from Field Observations on 22 July 2023

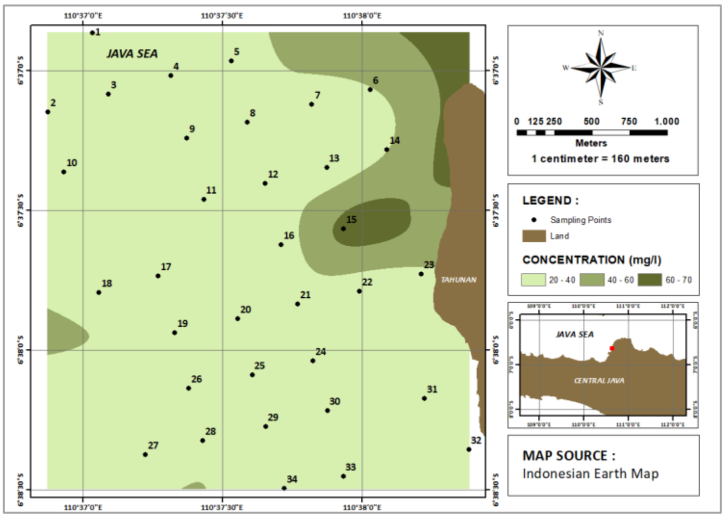

Figure 5. TSS Distribution Map from Landsat 8 Satellite Imagery on 22 July 2023

Based on Figure 5, the TSS concentration values predicted by satellite imagery are also classified into 3 classes. The classification of TSS values can be seen from the different colors shown on the map, pale green indicates that the TSS content is low, the lowest value has a value of 30.56 mg/l in the range of 20 - 40 mg/l, light green indicates a TSS value of 40 - 60 mg/l and the dark green color shows a value of 60 – 70 mg/l with the highest TSS value of 62.55 mg/l. The average TSS value for field data is 35.60 mg/l, shown in the value range of 20 – 40 mg/l in pale green. It can be seen that pale green dominates some of the colors in the classification of TSS values on the map. The results obtained from satellite image predictions are in accordance with the results from field data, although they still have a MAPE value error of 25.77%.

The distribution of TSS values is influenced by the location of the sampling points. Points that are near coastal areas will have a higher value because of the many activities such as the carrying of sediment material from land to water, water depth and human activity (Saputra *et al*., 2023). Teluk Awur coastal waters are used as a tourist attraction which will affect the concentration of TSS on the coast, the large number of tourist activities on the coast will cause more sediment material to be carried into the waters. Apart from that, the large number of tourist boats and fishing boats can also be one of the factors causing high concentrations of TSS on the coast. Meanwhile, in areas towards the open sea, the TSS concentration will tend to decrease because it is located far from these activities when TSS towards the high seas will also experience dilution due to seawater and will cause low TSS concentrations in the high seas area. In shallow waters, the orbital-orbital friction effect of wind-generated waves occurs, and causes resuspension of bottom sediments that add to the TSS of the water column. Andayani *et al*. (2020) explained that TSS tends to be high in flat and shallow waters.

Based on the results in Figure 4 and Figure 5, both results show a similar distribution, namely high TSS concentrations on the coast and low TSS concentrations in the open sea. Observations using remote sensing methods are quite promising to help assess TSS concentrations in the Teluk Awur coastal waters more efficiently. This method can be used when collecting data in the field is deemed not feasible, this could be due to weather factors, equipment limitations or monitoring fluctuations from year to year. Remote sensing methods can be used to review TSS fluctuations in the Teluk Awur coastal waters over a long period and of course with less time and material expenditure. The application of algorithms from the correlation of satellite image channels with field data can be used to facilitate the determination of the water quality of Teluk Awur coastal waters which can then be used to determine seawater quality standards (Indeswari *et al*., 2018).

CONCLUSION

The distribution of Total Suspended Solid (TSS) concentrations in the coastal waters of Teluk Awur can be predicted by remote sensing through algorithms derived from satellite image data. Previous algorithms such as Wirasatriya, Budhiman, Ajiperwata, and Parwati are unsuitable for application to Teluk Awur coastal waters. Thus, it is necessary to generate a new algorithm through the calibration process between field data and red reflectance data from Landsat images. The algorithm selected to predict TSS distribution has the equation, TSS = (547.31*Red reflectance) + 26.397 with RMSE, MAPE, and bias of 8.51 mg/L, 25.77%, and 7.52, respectively. The results indicate that the improved algorithm is suitable for describing the distribution of TSS concentrations in the coastal waters of Teluk Awur in July. The range of TSS values from image prediction was 30.56-62.55 mg/L (mean of 35.60), while the field observation was 22.40-64.52 mg/L (average of 32.69 mg/L). The pattern obtained shows that TSS values are high in the nearshore area and lower in the offshore area.

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