Monitoring coastal water quality using trios ramses hyperspectral reflectance data

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Abstract. The coastal area is very strategic as the center of national economic activity. Coastal areas that have strategic value from the potential of aquatic resources and environmental services, among others, are located on the northern coast of the Java Sea, one of which is Muaragembong. The Muaragembong coast in general has a problem of decreasing water quality. One of the water quality parameters that is often used to measure conditions in the field is Total Suspended Solid (TSS). Monitoring the concentration of TSS in a waters can be done through an approach, namely the development of an empirical model using remote sensing data. In addition to satellite imagery data, remote sensing data can also be performed by measuring the spectral reflection of an aquatic object using a tool called a radiometer. This study aims to build an empirical model using TRIO RAMSES data which is simulated into a combination of wavelengths from the Sentinel 2 and Landsat 8 bands to be able to estimate TSS concentrations in waters.The results showed that Reflectance Remote Sensing (Rrs) from TRIOS RAMSES data which was simulated into the wavelength range of Sentinel 2A image data was able to build an empirical model using multivariate band combinations. The results obtained on Sentinel 2 imagery show an R^2 value of 0.68 and RMSE 113.04 mg/L.

1. Introduction

Coastals are strategic areas for the center of national economic activity. This is because coastal areas have various potentials including renewable biological resources such as mangrove forests, coral reefs, seagrass beds, seaweed, fishery resources, maritime industry and services, potential for sea transportation and environmental services, and others [1]. Economic and development activities carried out by surrounding communities in coastal areas and the lack of integrated and sectoral management of coastal areas have made this area vulnerable to changes in the condition and quality of the environment, one of which is from the development sector [2]. Diverse human activities have resulted in a decrease in water quality due to the input of waste, both household and industrial waste that is increasing [3] as well as the process of abrasion and sedimentation in the North Coast of the Java Sea [4]. Other studies reported that abrasion and sedimentation processes also occur along the North Coast of the Java Sea, which has been studied, among others, by [5] that the erosion process in the southeastern part of Indramayu will continue to occur and develop seasonally which will accelerate changes in the coastline while The Cimanuk River delta is a place of accumulation of sedimentation. This is different from the results of [6] which analyzed the impact of port construction in Patimban resulting in shallowing of the water depth before and after construction. One of the water quality parameters that is often used to measure conditions in the field is Total Suspended Solid (TSS). Analysis of TSS concentrations in water locations requires a lot of measurement samples, a long time, and a lot of money, of course it needs to be done continuously to see the dynamics of changes that occur not to mention other physical, chemical and biological parameters to monitor changes in water quality. Remote sensing technology are developing rapidly to be used for environmental monitoring.

Monitoring TSS concentration in a water body can be done through an approach, namely empirical model building using remote sensing data. Previous research results shown medium resolution satellite data have been used to estimate TSS values in coastal waters. Remote sensing data in addition to satellite image data can also be done by measuring the spectral reflectance of an aquatic object using a set of tools called a radiometer. TriOS RAMSES is a spectral imaging radiometer for measuring radiance, irradiance, or scalar irradiance in the UV (ultraviolet), VIS (visible), and UV/VIS (ultraviolet/visible) ranges. The interaction of sunlight with an object will give a reflection reaction at a certain wavelength so that the reflectance results can identify the dominant phenomena and composition in a water object. TSS measurements have been widely carried out both through field measurements and developing linear models using satellite image data with in situ data (7; 8; 9; 10; 11).

The development of a linear model for estimating TSS concentration values using satellite image data experienced several obstacles, such as image data being covered by clouds and atmospheric corrections which usually resulted in overestimation. However, the development of empirical models is still a popular and easy alternative for estimating TSS concentrations in waters. Other remote sensing data capabilities are explored by adding spectral reflectance measurements of aquatic objects using radiometer data. TriOS RAMSES was used to build an empirical model using in situ measurement data and reflectance values (Rrs) generated at a certain wavelength range. TriOS RAMSES is used to build an empirical model using in situ measurement data and the resulting reflectance value (Rrs) at a specific wavelength range. Hyperspectral reflectance data describes the reflection of solar radiation in field conditions and can be simulated using satellite image data which is the sentinel 2A. The aim of this research is to build an empirical linear regression model from TSS in situ measurements with remote sensing reflectance (Rrs) from Trios Ramses which is converted and simulated at Sentinel 2A wavelengths.

2. Data and Methodology

2.1 Data

The research location was carried out on the North Coast of the Java Sea, namely parts of Jakarta Bay to the coast of Muara Gembong, Bekasi Regency (Figure 1). The waters of the Jakarta Bay and its surroundings, especially in the eastern waters of the Jakarta Bay to the coast of Muaragembong, have decreased water quality on the coast along the research location [12]. Water sampling and field spectral measurements were carried out on August 6 to 9, 2018 with a total sample of 50 data while the image data used were Sentinel 2A. The color of water objects was also considered at the study area. Trios Ramses data were simulated and converted into the spectral response of each band in each satellite sensor to be used. The conversion of reflectance from the Trios Ramses data into the spectral response of each satellite sensor is adjusted to the spectral response of each wavelength. Model building can also be done using linear regression of single bands or multivariant combinations of bands with in situ TSS values so that the best model is obtained. Sentinel 2 will carry an optical instrument payload that will sample 13 spectral bands: four bands at 10 m, six bands at 20 m, and three bands at 60 m spatial resolution. MSI sensor of Sentinel 2 covering 13 spectral bands (443–2190 nm), with a swath width of 290 km and a spatial resolution of 10 m (four visible and near-infrared bands), 20 m (six red edge and shortwave infrared bands) and 60 m (three atmospheric correction bands). Spectral response of Sentinel 2 satellite images can be seen in Figures 2.

The Research Location

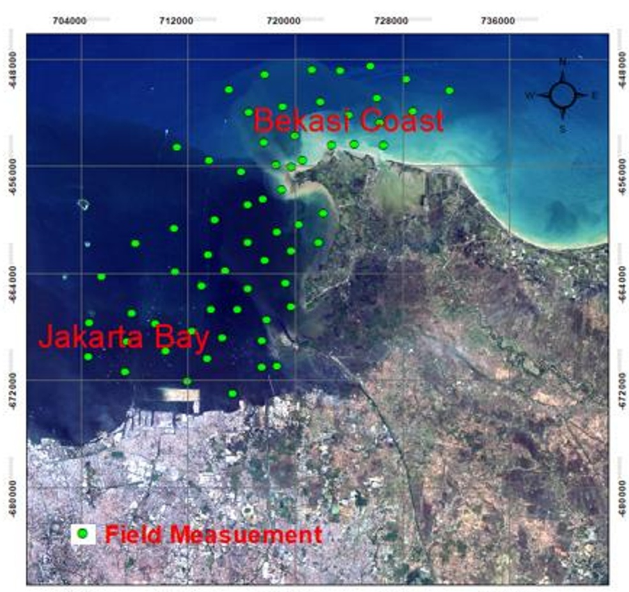


Fig 1. The Research Location

Table 1. Spesification of Sentinel 2 Wavelength

Bands	Central Wavelength (μm)	Resolution (m)
Band 1 - Coastal Aerosol	0.443	60
Band 2 - Blue	0.490	10
Band 3 - Green	0.560	10
Band 4 - Red	0.665	10
Band 5 - Vegetation Red Edge	0.705	20
Band 6 - Vegetation Red Edge	0.740	20
Band 7 - Vegetation Red Edge	0.783	20
Band 8 - NIR	0.842	10
Band 8A - Vegetation Red Edge	0.865	20
Band 9 - Water Vapour	0.945	60
Band 10 - SWIR – Cirrus	1.375	60

Band 11 - SWIR	1.610	20
Band 12 - SWIR	2.190	20

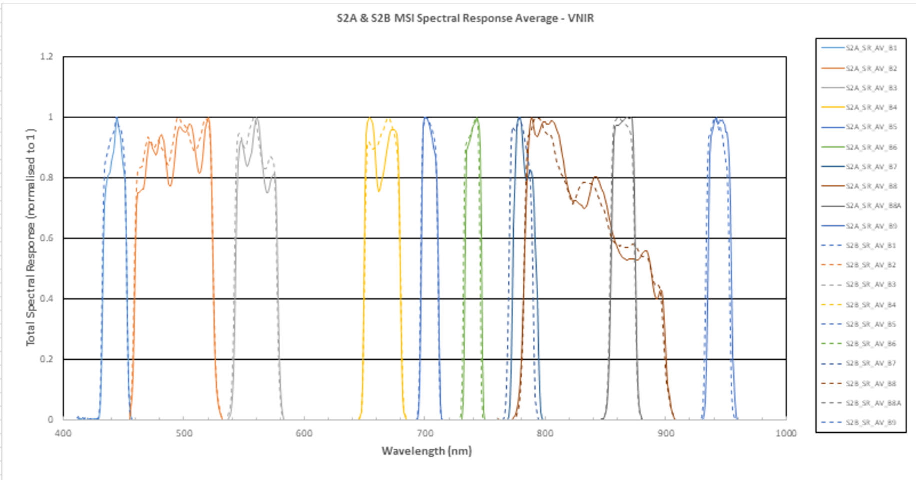


Fig 2. Spectral Response of Sentinel 2

2.2 Methodology

The development of the empirical model was carried out by simulating Rrs into energy recorded by a multispectral sensor in the form of a wavelength range in each Sentinel 2A image so that the reflectance formed is a relative spectral response. Then these values can be used to build a linear regression model by correlating the in situ TSS values with the reflectance obtained. The wavelength used can be a single band, a band ratio, a combination of two or more bands to get the next best model. The accuracy of the model is tested using RMSE. RMSE calculation to see that the variation in values produced by a model is close to the variation in observed values. The RMSE calculated in this study is a TSS concentration model with observed TSS. Calculating Rrs on Trios Ramses, remote sensing reflectance (Rrs) goes through several stages, first measuring the water leaving radiance using the formula:

$$L(w) = L(u) - 0.028 \quad (1)$$

Where: $L(w)$ is the water leaving radiance,
$L(u)$ is the upwelling radiance; and
$L(sky)$ is the radiance of the sky.

While the value of 0.028 is a constant from research results where this constant applies when the wind speed is 5m/sec. The use of this constant can change if the direction and speed of the wind can be known when measuring in the field. After obtaining the value of the water leaving radiance, the remote sensing reflectance can be calculated using the formula:

$$Rrs = L(w)/Ed \quad (2)$$

Where: Ed is the solar radiation value.

According to [13], the Rrs value needs to be corrected (eliminate errors) which may be caused by the presence of white light during measurement using the formula:

$$Rrs(Cor) = Rrs - (\alpha \times Rrs(780) - Rrs(720))/(\alpha-1) \quad (3)$$

Where: α is 2.35.

Accuracy testing is done by calculating RMSE. RMSE is a value that measures the deviation or deviation of a variable on an accepted value. the smaller the RMSE value of a sensor means the higher the accuracy of the sensor on palm reading. The RMSE value is calculated by the equation:

$$RMSE = \frac{\sqrt{\sum_{i=1}^{N}(Xi-Yi)^2}}{N} \quad (4)$$

Where: Xi : In situ TSS value;
Yi : Modeled TSS value;
N : number of data.

3. Results and Discussion

3.1 Spectral Reflectance of Water from Trios Ramses Hyperspectral

Spectral reflectance measurements were carried out on the water surface where the three sensors were installed on the ship so that the recording conditions were influenced by water conditions at the time of measurement. It is assumed that adjacent locations will tend to be homogeneous and have the same similarity as the surrounding location points. This is also to see changes/fluctuations that occur in TSS concentrations on the same day. The results of reflectance processing of spectral data from TriOS RAMSES are presented in the graphic image below.

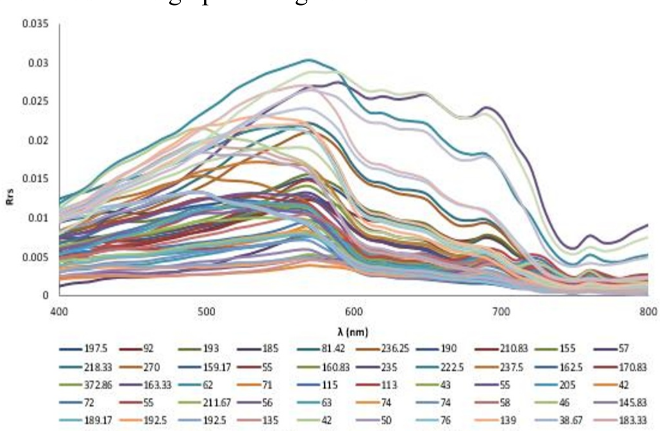
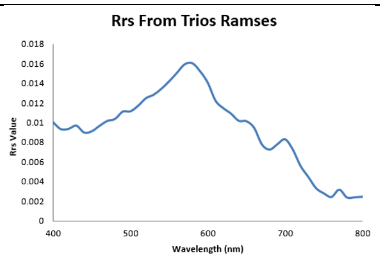
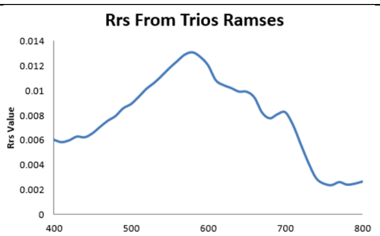
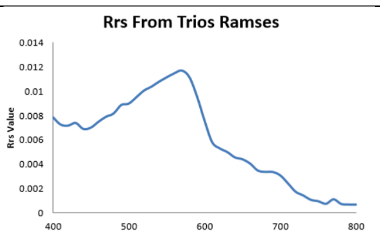
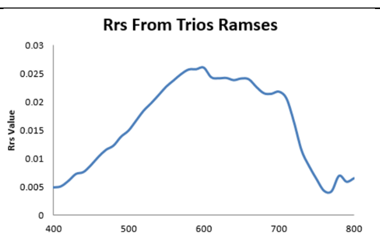
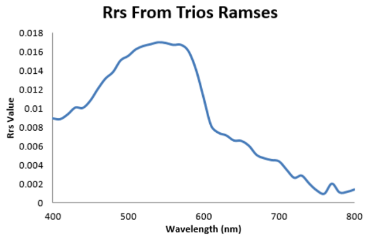
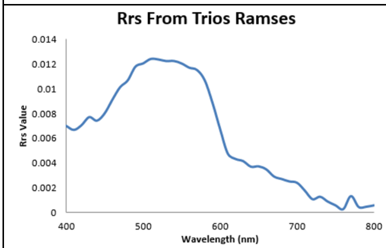
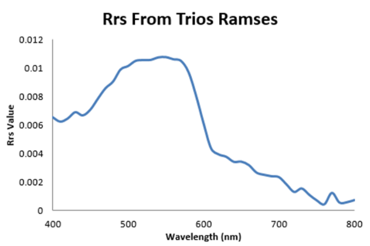
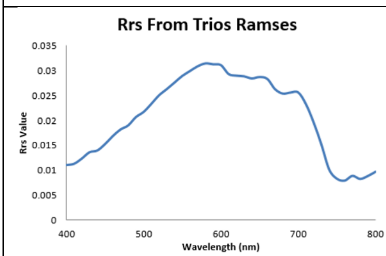
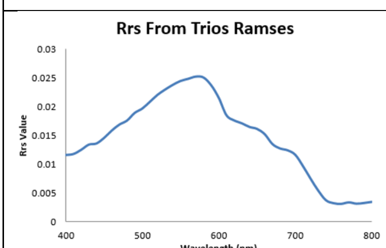


Fig 3. Spectral Data Graph from Trios Ramses

Based on the graphic results formed, it is clear that the spectral characteristics extracted from the Trios Ramses data show the spectral signature of the object under study, namely water. The spectral signature formed is in accordance with research that has been carried out previously that objects on the earth's surface have specific and different spectral response characteristics. The graph formed shows that there are two highest wave peaks at 570-580 and 670-690 nm, which shows that the graph is a water object that is still influenced by the presence of phytoplankton and also indicates an increase in TSS concentration values on the coast. Apart from that, the graph also shows waters in certain conditions where phytoplankton and the presence of yellow substrate still influence the condition of coastal waters.

Table 2. Water Color with Reflectance Response and TSS Concentration Value

Graph	TSS Value (mg/L)	Water Color
	197.5	
	92	
	155	
	235	

	237.5	
	42	
	211.67	
	186	
	62	

3.2 Empirical Model of Trios Ramses Data Conversion to Sentinel 2A

Empirical Model for Converting Trios Ramses Data to Sentinel 2 Imagery. The results of Reflectance remotesensing (Rrs) measurements from Trios Ramses are converted/simulated into the spectral response of each band on the satellite sensor. This simulation converts the single reflectance on the Trios Ramses into energy recorded by a multi-spectral sensor in the form of a wavelength range so that the value formed becomes a relative spectral response value. Empirical model development was also carried out using visible bands, namely blue, green and red, trying to find the best results through the use of single bands and multibands using linear regression models. In this study, band 1 shown is actually band 2 (blue); band 2 is band 3 (green); and band 3 is band 4 (red). Band 1 in Sentinel 2 is a coastal band with a different spatial resolution from the visible band, namely 60 m, so it is not used in the formulation of this model. The use of wavelength band values both individually and in combination with reflectance spectral responses plotted with TSS concentration values as shown in Figure 3 and in Table 1 is the selected regression model algorithm that has been created.

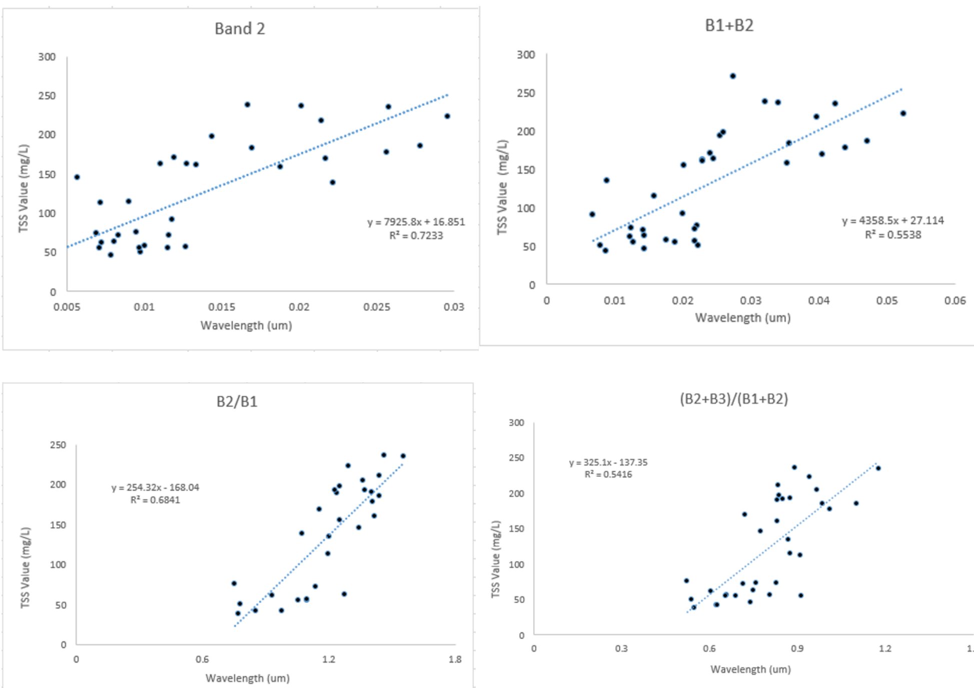


Figure 4. Spectral Response Reflectance Band Combination of Sentinel 2 on TSS Concentration Values

Table 3. Algorithm Models with Coefficient of determination (R^2) Values and Root Mean Square Error (RMSE) from different regressions for various combinations of Sentinel 2 wavelength bands

X	Regression Model	R^2	RMSE
B2	6814.7x+35.43	0.55	73.52
B1+B2	4358.5x+27.114	0.55	124.71
B2/B1	254.32x-168.04	0.68	113.04
(B2+B3)/(B1+B2)	325.1x-137.35	0.54	109.06

The results of building a regression model from Sentinel 2 found that using a combination of bands gives better results than using only a single band. The best single band model uses the green band. The blue and green bands provide better R^2 and RMSE values than the band combination using the red band. Similarly, the band ratio between the green and blue bands gives a better value than using the red band ratio. The highest coefficient of determination where R^2 is 0.68 and RMSE 113.04 in mg/L is in the algorithm model, namely, where Y = 254.32x-168.04 with X as green band/blue band. In the results of which estimated the TSS value in Shanmei Reservoir using Sentinel 2 and Landsat 8 data through a multivariate regression model, it was found that the use of blue and green bands could identify the TSS value in the reservoir even though the accuracy value was still poor. In contrast to the research of through the regression multivariant empirical model approach managed to model TSS concentrations quite well. In Table 3 the least effective band for building models is the blue band. The combination of bands on Sentinel 2 shows that the use of green bands is more prominent and dominates good results compared to blue and red bands. The model developed from this research still has a high RMSE value, this can be caused by measuring reflectance samples using Trios Ramses which is unstable because it is on a ship. The disturbance that occurs can cause the spectral measurements to be disturbed. The use of blue and red bands to build empirical models on satellite images has been widely developed. However, development continues to be carried out to obtain values that are close to the real situation so that water quality monitoring becomes reliable data.

4. Conclusion

Reflectance remote sensing from TriOS RAMSES data formed at the research location are a water object that is still influenced by phytoplankton. The high TSS concentration not all the water color will have a cloudy color.The linear regression model generated from Trios Ramses simulation into the range of wavelengths of Sentinel 2A shows that the use of the green band from single to ratio and in combination with other bands gives a values of R^2 values more better. The use of a combination of bands in image data, especially for aquatic objects, provides better results, presumably because the spectral response in satellite images cannot respond to more than one object sensitivity.

This research was funded by Pusfatja-LAPAN in 2018.

This research was supported by Syarif Budhiman and Ety Parwati for supporting and sharing knowledge related to TSS theory and remote sensing application of water bodies.

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