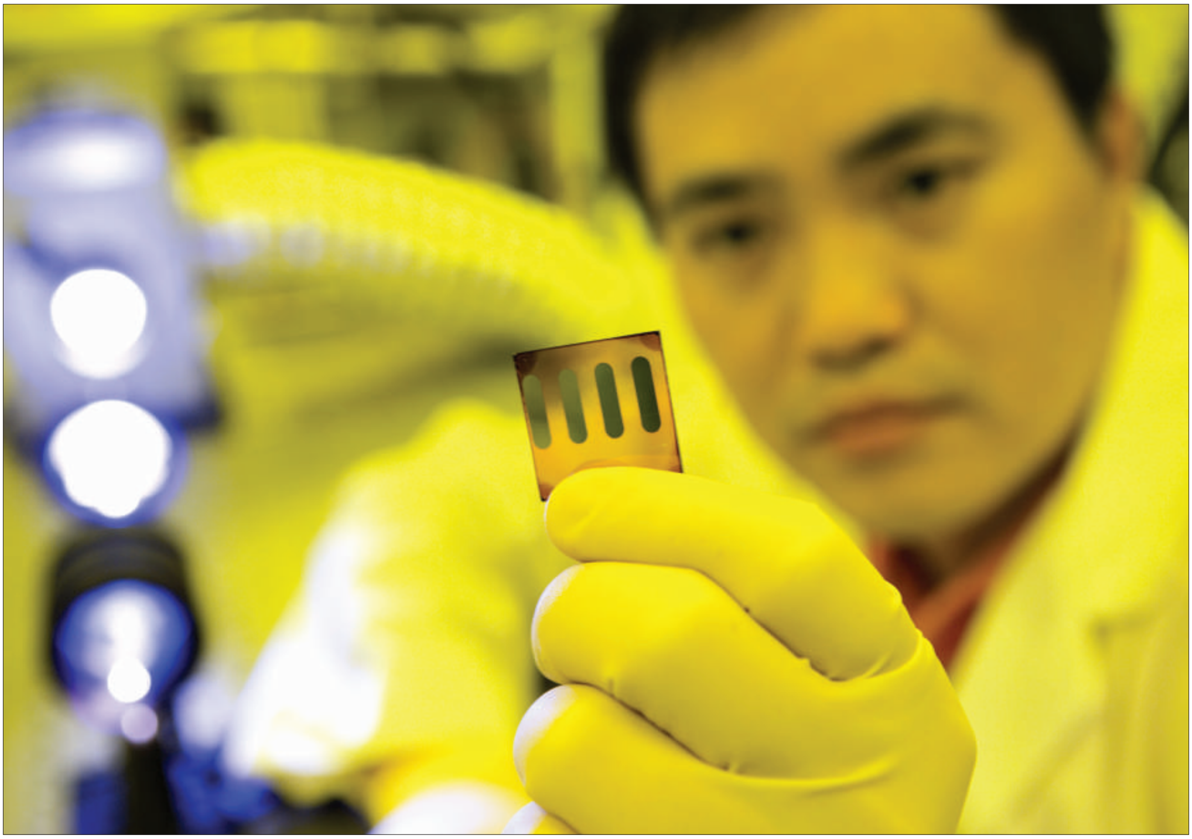

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Research Article

Analysis of Total Suspended Solids (TSS) at Bedadung River, Jember District of Indonesia Using Remote Sensing Sentinel 2A Data

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Abstract

Background and Objective: Clean water is an essential need for people to life. The quality assessment of water is very important to manage water resources to fulfill the needs. Remote sensing provides technology to assess water quality in the wide area effectively and quickly. The recent free and high resolution optical remote sensing satellite data is Sentinel 2A with 10 m spatial resolution. This study aims to detect water quality of the Bedadung River in the Jember District, Indonesia based on total suspended solids (TSS) values related to rainfall. **Materials and Methods:** Pre-processing data is conducted by geometric correction and radiometric correction. The next step is converting DN of pixels data into reflectance ToA. This converted data in then calculated to get TSS data. **Results:** The TSS values obtained were grouped into 4 classes that were declared from class 1 with the highest TSS value to grade 4 with the lowest TSS value. This maintains a logical effect that in the rainy season river water often becomes dirty because of the flow of rain into the river. The analysis of coefficient correlation between TSS and rainfall is 0.793. It means that TSS has positive correlation to rainfall. **Conclusion:** Based on calculated TSS values, the Bedadung's River is still good for water resources and they are positively related to the rainfall with correlation coefficient of 0.793.

Key words: Clean water, Bedadung, Sentinel 2A, TSS, remote sensing, rainfall, positive correlation

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Clean water is a limited and vulnerable resource but it is very important to support human life[1], for all development activities, health and environmental care. Clean water sources commonly used by residents in Indonesia are of lakes, rivers and ground water. In some places, river water is used as clean water for daily activities such as bathing, washing and even cooking.

Jember Regency has several major rivers and the Bedadung River is the largest river in Jember and passes through the city center[2]. The Bedadung River is the biggest take for the supply of raw water for PDAM Jember Regency[3], so the quality of the river water is very important to note. Monitoring of Bedadung River water quality has been performed by taking river water samples from several points and brought to the laboratory for testing. According to Giardino *et al.*[4] and Wang *et al.*[5], traditional analysis and laboratory testing using *in situ* measurements have been characterized and understood water quality parameters. This requires a large amount of time and cost if testing is carried out for long streams in which multiple samples are needed.

Remote sensing offers a faster and easier method for monitoring water quality[6], such as river water[7], lakes[8] and the sea[9]. Water quality parameters that can be monitored include TSS[10,11], water brightness and chlorophyll-a content[12]. If the river contains material that enters the land due to erosion, it will cause sedimentation. The presence of material due to erosion that enters the water will cause water turbidity and reduced light penetration[13]. Sediment material that enters the waters is known as total suspended solid (TSS). The main cause of total suspended solid in waters is the erosion of soil carried to the body of water.

One of the remote sensing satellite data that can be used for identification and monitoring of river water quality is Sentinel 2A data[7]. The data is good enough to be used because it has a good resolution of 10 m. Parameters in determining river water quality are chlorophyll-a content[4,14], suspended material[8,9,13,15,16] and distribution patterns by inserting algorithms in Sentinel 2A data. The use of sentinel data has the advantage of higher spatial resolution compared to widely used data such as Landsat[5,6,14] and MODIS[17].

The purpose of this study is to analyze water quality using TSS as a parameter related to river eutrophication by remote sensing methods. Water analysis is carried out in the Bedadung River in Jember district in 2019. Sentinel 2A multi temporal data are taken and processed to get the TSS values and then analyze the results. Relationship of TSS values to the rainfall in the related place are also statistically conducted.

MATERIALS AND METHODS

Study area: The study was carried out at the Bedadung River in Jember District, East java, Indonesia from January, 2019 to October, 2019. The map of research location is described in Fig. 1. The river of Bedadung is considered to be a focusing study area because it is still used as one of the water resource to be processed as clean water in Jember district of Indonesia.

Research data: The remote sensing satellite data used in this study are Sentinel 2A imageries that covers the study area in 5 different time and it has <10% of cloud cover. The acquired time of data are 21 April, 2019, 26 April, 2019, 20 June, 2019, 25 June, 2019 and 25 July, 2019. Those data are Earth observation mission from the Copernicus Programme that systematically acquires optical imagery at high spatial resolution (10-60 m) over land and coastal waters. Sentinel 2A data product is manage by European Space Agency (ESA). The Copernicus Sentinel-2 mission comprises a constellation of two polar-orbiting satellites placed in the same sun-synchronous orbit, phased at 180°C to each other. It aims at monitoring variability in land surface conditions and its wide swath width (290 km). The revisit time in the area of study is 12 days. Sentinel 2A data has12 spectral bands as shown in Table 1.

Pre-processing data: Pre-processing data conducted are geometric correction and radiometric correction. Geometric correction is performed to ensure that the image has no geometric distortions and it has been correctly laid in the appropriate coordinate system. In addition, radiometric correction is done to reduce errors in the digital numbers of image caused by the atmosphere condition. This process also does conversion of digital number into Top of Atmosphere (ToA) reflectance values. These values will be used in the calculation process to get TSS and chlorophyll-a content of water.

Sentinel 2 MSI L1C product provides the top of atmosphere reflectance (ρ_{TOA})[16], which is assumed to be the sum of Rayleigh reflectance (ρ_r), aerosol reflectance (ρ_a) and water-leaving reflectance (ρ_w):

$$\rho_{TOA} = \rho_r + \rho_a + t.\rho_w \quad (1)$$

where, t is the two-way diffuse atmospheric transmittance[18].

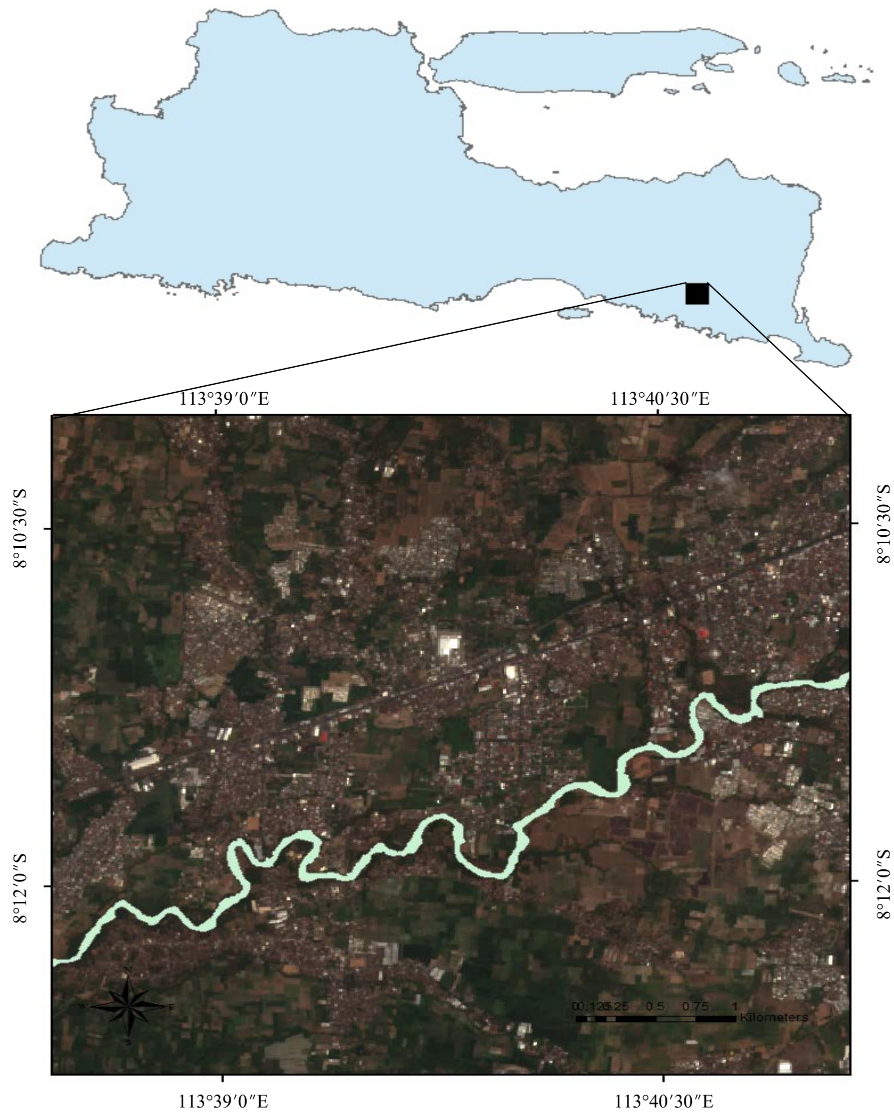

Fig. 1: Map of the study area

Images is processed from boundary of Indonesian province administration and true color composites of Sentinel 2A data

Table 1: Spectral bands of Sentinel 2A data

Sentinel-2 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

Table 2: TSS content and their related water quality impact to the ecosystem

Classes	TSS content (mg L^{-1})	Water ecosystem Impact
4	<25	No impact
3	25-80	Small impact
2	81-400	Medium impact/make fish un-healthy
1	>400	Bad/fish can be killed

Total suspended solids (TSS): TSS is one of parameters which is considered as water quality indicators[19,20]. Generally, clear water has low reflectance in the visible spectrum and has no reflection in near infrared (NIR) region, as it is absorbed by clear water. However, high reflectance measurements in red (600-700 nm) and NIR region (750-1400 nm) show a strong correlation with SS concentrations. A high concentration of suspended sediments blocks the transmittance to and from lower depths and therefore increases reflectance from the water surface. Similarly, high concentrations of chlorophyll (a photosynthetic pigment in phytoplankton and macroalgae) in water cause high reflectance in the green region (500-600 nm) and high absorption in the blue and red regions due to photosynthetic activity (Fig. 2)[21].

$$TSS\ (mg\ L^{-1}) = A^* \exp^{(S^*\ R(b1))}$$

$$TSS\ (mg\ L^{-1}) = 8.1744\ {}^*\exp^{(23.738^*\ band\ red)} \quad (2)$$

where, TSS is the total suspended solid (mg L^{-1}), A is the nilai konstanta rumus, S is the nilai konstanta sedimen (mg L^{-1}) and R (b1) is the irradiance reflectance input band red.

Water TSS content can affect to the water ecosystem especially to the life of the fish inside. The relationship of TSS values inside water and their impact to the fish ecosystem is described by Caspers[22] as shown in Table 2.

RESULTS

Total suspended solids (TSS): Data are processed along the Bedadung River channel that passes through 5 sub-districts in Jember Regency as previously mentioned. However, the following is shown the profile of TSS values for the Bedadung River which is only in the Rambipuji sub-district so that the TSS value level represented in color can be seen more clearly as shown in Fig. 2.

To be clearly described the pattern of TSS over the time and relationship to the rainfall, plots of TSS and rainfall over time are shown in Fig. 3a, b.

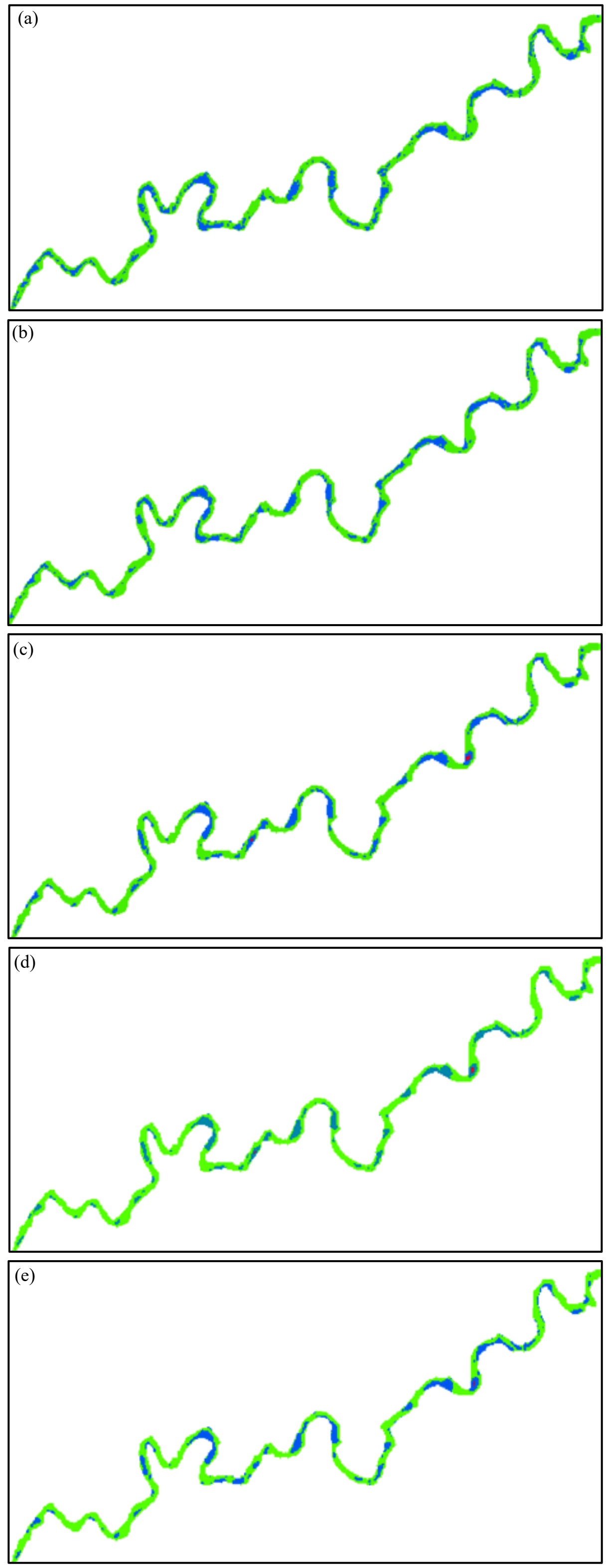

Fig. 2(a-e): Results of TSS value profiles in the Bedadung River at, (a) 21 April, 2019, (b) 26 April, 2019, (c) 20 June, 2019, (d) 25 June, 2019 and (e) 25 July, 2019

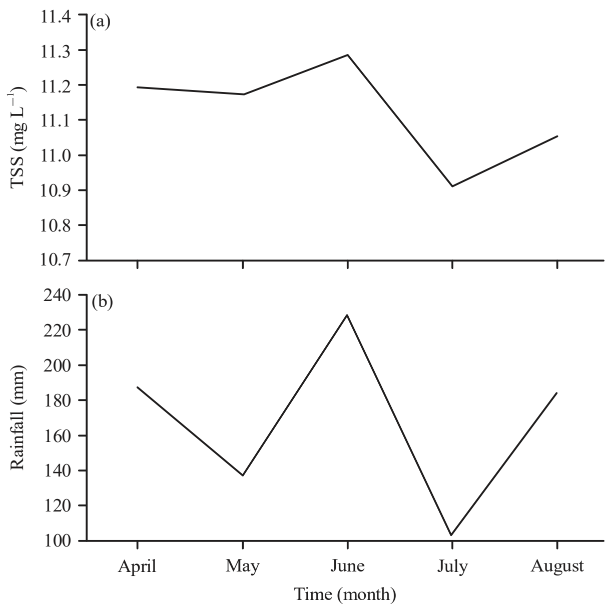

Fig. 3(a-b): (a) Plots of TSS values at Bedadung River and (b) Plots of rainfall that was measured at Ajung station (near Bedadung River) from April, 2019 to August, 2019

DISCUSSION

The main results of this study are determined values of TSS along the Bedadung River and the pattern of TSS along the time related to the rainfall measured from Weather station in Ajung near the study location. The TSS values obtained were grouped into 4 classes that were declared from class 1 with the highest TSS value to class or grade 4 with the lowest TSS value. With respects to the classification results, TSS values at Bedadung River are categorized in the class 4 (green) and class 3 (blue) as displayed in the Fig. 2(a-e). It can be considered that based on the TSS values, Bedadung River is laid in two best class which means that the Bedadung River water quality in the region is still good. Green class of TSS values look quite a lot for the data taken in April, while TSS values for June and July the majority of the water in the river is classified in class 3.

The Jember area still has a good vegetation cover[23] to maintain the availability of springs that flow into rivers. With so many sources of these springs, the cleanliness and quality of river water in Jember, especially Bedadung, is still well maintained.

A big vegetation cover also keeps a cool area in the sense that the ambient temperature is not too high[24]. The high ambient temperature can affect the quality and availability of clean water[25].

Moreover, the rainy season in the district of Jember generally takes place in October until April[26] while the dry season occur at intervals from May to October. In the rainy season, the land along the river side is potential to deal with erosion[27] especially in the area with lack of vegetation cover. Consequently, in the rainy season river water often becomes dirty because of the flow of rain into the river and also erosion. This is evident from the research data that in April, 2019 TSS values were classified in class 3 as possible because of the influence of the rainy season so that river water still receives quite a lot of contribution from the flowing rainwater. While in June and July the rain is almost no longer happening, the Bedadung River becomes better which is represented by a low TSS value and is classified into class 4.

The analysis of coefficient correlation between TSS and rainfall is 0.793. It means that TSS has positive correlation to rainfall. The positive correlation between TSS and rainfall indicate that increasing rainfall cause to increasing TSS value[28] in Bedadung River.

CONCLUSION

This study concludes that (1) TSS values in the Bedadung's River are small and reflecting the good water quality, so it is still good for fresh water fish's Life. (2) TSS values are positively correlated to the rainfall with correlation coefficient of 0.793.

SIGNIFICANCE STATEMENT

This study discovers the importance of water quality analysis of Bedadung River that can be beneficial to help the society and water management authority in Jember in their consideration of using this river as a water source to the life. This study will also help the researcher to uncover the critical areas of degraded land along Bedadung River side using satellite data that many researchers were not able to explore. Thus a new theory on quick and real time detection of river water quality may be arrived at.

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