Temporal detection of Total Suspended Solid (TSS) distribution in the southern area of Obi Island

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Abstract. The Halmahera Selatan Regency has many potential natural resources including mining potential, and nickel is one potential that can be found in Obi Island. The abundance of nickel in Obi Island also increases activities that cause various materials to enter the sea. The sediment materials entering the waters through land runoff are suspended sediment or Total Suspended Solids (TSS). Sentinel 2 satellite imageries could observed TSS concentration and its distribution in this research through visible and infrared channels. The distribution of TSS will be determined by using an algorithm, which uses the blue and green bands with corrected atmospheric reflectance format. Based on the data processing results, the distribution of TSS values in the southern area of Obi Island in 2023 was in the range of 4 - 874 mg/l that were divided into three groups of areas, represented by A area within the range of 4 – 874 mg/l, which describes the distribution of TSS in coastal areas without human settlements, B area within range of 4 - 237 mg/l which depicting TSS conditions at river estuaries, and group C area within range of 4 – 431 mg/l which illustrating TSS locations in coastal areas with human settlements.

1 Introduction

The Halmahera Selatan Regency has huge natural resources, such as forests, mangroves, plantations, marine fisheries, tourism, and mining potential including nickel, coal, gold, iron sand, geothermal, bacan stone, and oil. There is a significant mining potential, especially the nickel reserves on Obi Island, which correlates with the substantial income of the Halmahera Selatan Regency. Obi Island is part of the administrative region of Soligi Village, Obi Selatan Subdistrict, Halmahera Selatan Regency, Maluku Utara Province. The island is located at the

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intersection of four biogeographical regions: Bacan Island to the north, Maluku Province to the south (Seram Island), Sula Islands Regency to the west, and Papua Province to the east (Misool Islands). Obi Island stretches about 85 km from east to west and 45 km from north to south at its widest point, covering an area of approximately 2,542 km^2 [1].

The huge potential on Obi Island increases activities that cause the various materials to enter the sea. Materials entering the waters through runoff from the land can form suspended sediment in the water column, leading to turbidity and reducing light penetration in the water. Suspended sediment or Total Suspended Solids (TSS), remains suspended in the water due to the turbulence motion of the water, currents, or other factors. Total Suspended Solids (TSS) are particles or biotic components such as plankton and bacteria and also contain abiotic components such as detritus and solid substances that suspended in water [2]. The concentration of TSS in the sea waters is caused by the input of materials from the land, which are then carried to the sea through river flow. The distribution of TSS is influenced by the current speed, high current speed will move sediment that can affect the TSS value. Low current speeds tend to settle suspended sediment which might cause sedimentation [3]. The high concentration of total suspended solids in a water body leads to a decrease in oxygen, resulting in a decline in photosynthetic activity of both micro and macro marine plants [4].

The concentration and distribution of TSS can be observed through Sentinel 2 satellite imagery using visible channels. The visible bands (Blue and Green) are used to determine TSS by regression analysis of band ratio. The distribution patterns of TSS detected using remote sensing employ algorithms capable of transforming pixel values into estimates of TSS concentration [5]. Therefore, this research is conducted to determine the concentration and distribution of TSS in the southern area of Obi Island through Sentinel-2A and Sentinel-2B satellite imagery, serving as the primary data acquired in January, April, June, and October 2023. In this case, the TSS algorithm is utilized to assist in analyzing the distribution of TSS occurring in the southern area of Obi Island during each season. In this research, we used one of the common algorithms that can help us detect the TSS values by relying on the blue and green channels that are available in satellite image data.

1.1 Research methods

1.1.1 Research location

Observations of TSS distribution were conducted in the southern part of Obi Island. Data processing was carried out using Sentinel-2A and Sentinel-2B imagery, employing the algorithm [5]. The research focus is divided into three groups of areas, represented by A area which describes the distribution of Total Suspended Solids (TSS) in coastal areas without human settlements, B area which depicts TSS conditions at river estuaries, and C area which illustrates TSS locations in coastal areas with human settlements. The processing of TSS distribution using Sentinel 2 imageries data should be processed with the algorithm for calculating raster pixels and conducted in several stages, as referred to in Fig. 1.

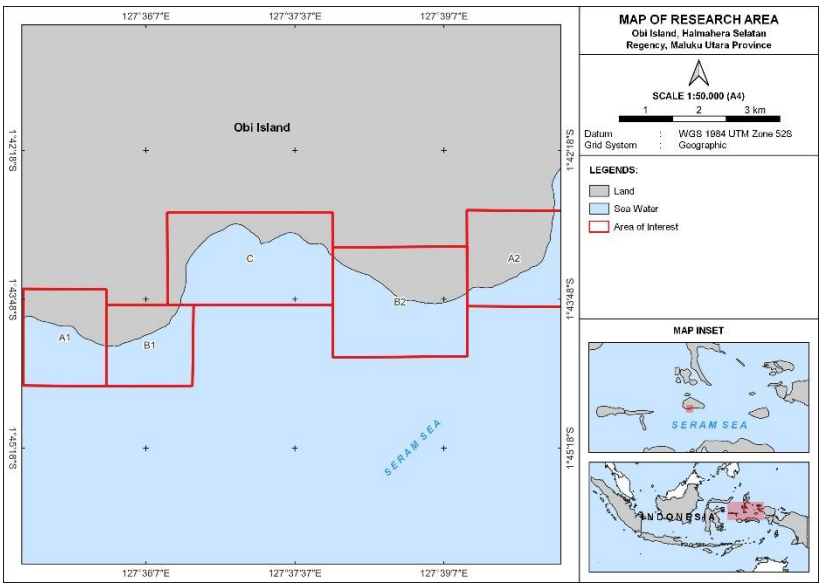

Fig. 1. Research Area

1.1.2 Data

The image data used in TSS processing was from Sentinel-2 imagery acquired on January 15, April 25, June 24, and October 22, 2023. The image data was downloaded through http://marine.copernicus.eu, followed by pre-processing before being processed using the relevant algorithm. Data specifications can be seen in Table 1. The use of Sentinel-2 imagery in processing this data is chosen due to its high spatial resolution of 10 meters, easy accessibility of the images, and a relatively straightforward and time-efficient data processing procedure.

Table 1. Satellite Image Data

Satellite	Acquisition Date (dd/mm/year)	Spatial Resolution (m)
Sentinel-2A	22-10-2023	10
Sentinel-2B	15-01-2023	10
Sentinel-2B	25-04-2023	10
Sentinel-2B	24-06-2023	10

1.1.3 Pre-processing

The pre-processing process was carried out using QGIS 3.24.2 software. In this stage, the downloaded Sentinel 2 images underwent a composite image process created with a combination of 5 channels (2, 3, 4, 5, and 8). Pre-processing involved atmospheric correction using the Dark Object Subtraction (DOS) method available in the Semi-Automatic Plugin

(SCP) tool [6]. Atmospheric correction is a step performed to eliminate the influence of air particles that cause the digital values of the image to increase proportionally to the content of certain particle values. This correction was used to restore the digital values of particles to their true values [7].

Geometric correction was done using a first-order polynomial coordinate transformation method, and projection adjustment was carried out using the Universal Transverse Mercator (UTM) projection system adapted to the research zone [7]. Radiometric correction processes include correcting effects related to the sensor to enhance contrast in the pixels of the image, making recorded objects easier to analyze. Radiometric corrections were performed using the Top of Atmosphere (TOA) method [2]. The main purpose of this radiometric calibration is to convert data in the image, typically stored in Digital Number (DN) format into radiance and/or reflectance. The method for calibrating DN values to Top of Atmosphere (TOA) reflectance is as follows [8]:

$$Sentinel\ 2\ TOA\ Reflectance = \frac{\mathrm{DN}}{10.000} \quad (1)$$

Description:
DN = Digital Number of each band in Sentinel 2 imagery

1.1.4 Masking

The image data that has been corrected can move to the masking stage. Masking is a process to separate the studied area from the non-studied area. In this stage, object separation (masking) in satellite imagery involves assigning zero values to objects that are not bodies of water. The image concealment between water and land is intended to ensure that the spectral values used in the interpretation process are not influenced by land spectral values. Masking at this stage is carried out using the Near-Infrared (NIR) band [5].

1.1.5 TSS algorithm

After the masking stage to separate land and sea areas, the next process conducted is to process image data by applying the TSS algorithm [5]. The algorithm used for calculating TSS has been conducted by comparing each band (Red, Green, Blue) ratio using simple mathematics operations. This algorithm assists in detecting the distribution of TSS in that particular area. The TSS algorithm is denoted as follows:

$$TSS(mg/l) = 3.7321 * (10 \wedge (12.543*(\lambda 3 + \lambda 4))) \quad (2)$$

Description:
λ 4 = Reflectance of Red Channel
λ 3 = Reflectance of Green Channel

2 Result and discussion

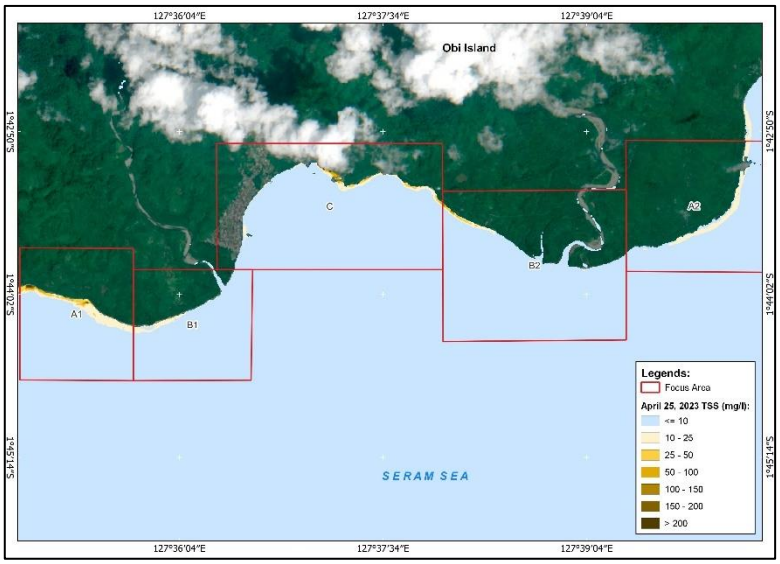

Fig. 2. Total Suspended Solid Distribution on January 15, 2023

The distribution of TSS values in the waters of the southern area of Obi Island on January 15, 2023 (Fig. 2), has a range of TSS values of about 4 - 588 mg/l, dominated in the coastal area in the focus area of A1 and C. All areas have 4 mg/l for the minimum TSS value that had been detected. The highest maximum TSS value was detected at 588 mg/l in the area of A1. Maximum TSS values in other areas are 39 mg/l in the B1 area, 204 mg/l in the B2 area, and 431 mg/l in the C area. In the C area, there is a settlement area and anthropogenic activities caused a high TSS value.

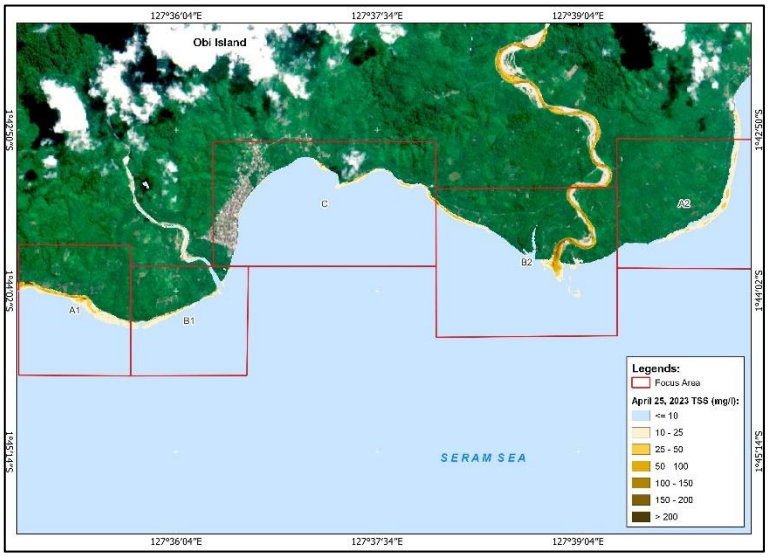

Fig. 3. Total Suspended Solid Distribution April 25, 2023

The estimation of TSS distribution on April 25, 2023 (Fig. 3), is predominantly in the range of 4 - 726 mg/l, dominated in the river and estuary in A1, A2, and B2 focus area. The A1 area has 4 mg/l for its minimum TSS value and 726 mg/l for the maximum TSS value. The A2 area has 4 mg/l for its minimum and 49 mg/l for its maximum, in the B1 area has 4 mg/l minimum TSS value and 237 mg/l for its maximum. The B2 area has 4 mg/l for the minimum value and 225 mg/l for the maximum value, while in C area has 4 mg/l for its minimum and 184 mg/l for its maximum value. TSS values dominate the river and estuary areas because suspended materials from land are carried by the river flow [10].

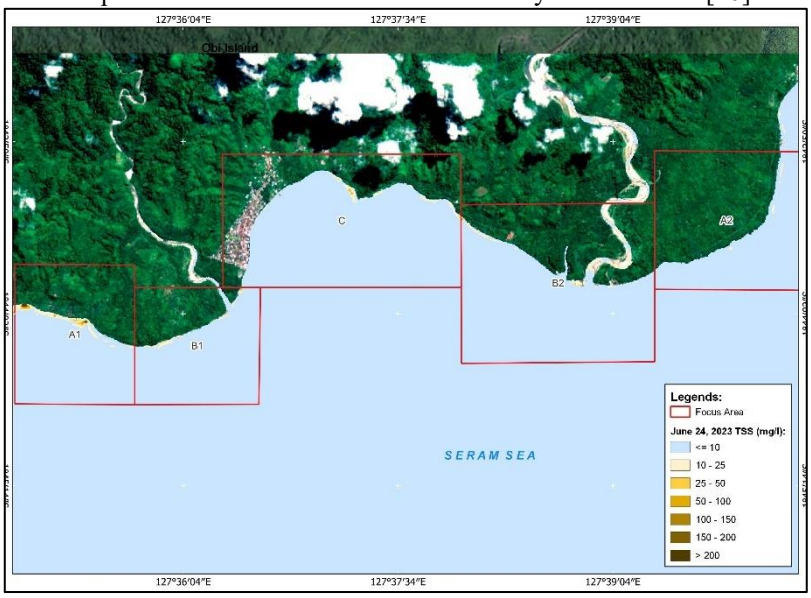

Fig. 4. Total Suspended Solid Distribution June 24, 2023

The range of TSS values on Juni 24, 2023 (Fig. 4), in the southern waters of Obi Island, distributed along the coastline, ranging from 4 - 875 mg/l. The A1 area has 4 mg/l for the minimum TSS value and 874 mg/l for the maximum value. A2 area has a minimum TSS value of 4 mg/l and 23 mg/l for the maximum value. The same minimum TSS value for other areas (B1, B2, and C) with the value of 4 mg/l, but different maximum TSS value for all those areas with 58 mg/l for B1 area, 126 mg/l for B2 area and 66 mg/l for C area. The distribution of TSS over the estuary area has a low value of TSS. TSS are distributed along the coastline in the A1 and C areas could be caused by the patterns of current movement during that month [11]. Meanwhile, from June to October, the dominant wind direction moves from the southern part of the earth towards the north and northeast, specifically towards the Northern part of Papua, with maximum speeds in the southern and southeastern parts of Halmahera Island [12]. This dominant wind direction caused the TSS to tend to be distributed along the coastline due to the movement of current patterns more toward the north.

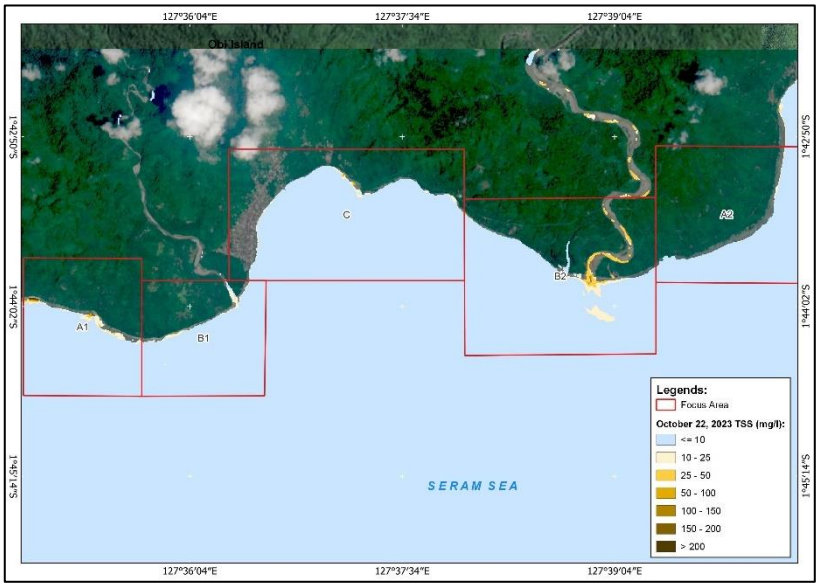

Fig. 5. Total Suspended Solid October 22, 2023

On October 22, 2023 (Fig. 5), the distribution pattern of TSS in the southern waters of Obi Island was caused by the river and dominated in the river and estuary area. The TSS value in the estuary has a range of 4 - 678 mg/l. The minimum TSS value for all those areas is the same with the value of 4 mg/l. The maximum TSS value that was detected in the A1 area is 678 mg/l, 25 mg/l in the A2 area, 44 mg/l in the B1 area, 94 mg/l in the B2 area, and 115 mg/l in the C area. The highest TSS value was detected in the A1 area.

Based on data processing, the concentration of TSS that found along the coastal area in the southern area of Obi Island with values ranging from 4 - 874 mg/l. In some areas, especially in estuary and river areas TSS is influenced by the input of materials from the land and carried through river flow [13]. On the other hand, the low TSS values in a certain area can be caused by dilution by seawater when the material reaches the coastal area. The multi-temporal distribution of TSS in the southern area of Obi Island result can be seen in Table 2.

Table 2. Multi-temporal TSS distribution

Times	Focus Area	TSS (mg/l)		
		Max	Min	Average
15/01/2023	A1	588.0	4.0	28.1
15/01/2023	A2	30.0	4.0	10.8
15/01/2023	B1	39.0	4.0	9.9
15/01/2023	B2	204.0	4.0	15.4
15/01/2023	C	431.0	4.0	17.1
25/04/2023	A1	726.0	4.0	31.0
25/04/2023	A2	49.0	4.0	14.0
25/04/2023	B1	237.0	4.0	11.9
25/04/2023	B2	225.0	4.0	36.2
25/04/2023	C	184.0	4.0	13.7
24/06/2023	A1	874.0	4.0	29.2
24/06/2023	A2	23.0	4.0	7.9

24/06/2023	B1	58.0	4.0	9.7
24/06/2023	B2	126.0	4.0	10.8
24/06/2023	C	66.0	4.0	10.6
22/10/2023	A1	678.0	4.0	30.3
22/10/2023	A2	25.0	4.0	8.6
22/10/2023	B1	44.0	4.0	10.0
22/10/2023	B2	94.0	4.0	18.6
22/10/2023	C	115.0	4.0	10.1

Based on the data process of the TSS variability, the four sets of data describe a wide range of TSS values. This variation is caused by different environmental conditions during those months, leading to varying TSS values. The distribution of TSS in the waters is also influenced by the patterns of current movement in that area. During calm current situations, sediments tend to settle up and make the initial high concentration of TSS decrease [14]. The high speed of currents in the waters also leads to an increase in TSS concentration because the water tends to undergo mixing. This mixing can lift the bottom materials, and it makes the water turbid. The patterns of current movement themselves can be caused by several factors such as wind direction, rainfall, differences in seafloor topography, and many more [15].

3 Conclusion

Remote sensing techniques using the images of satellites can be carried out to analyze TSS in remote and large areas, especially in small islands like Obi Island. The results of TSS distribution at different times using Sentinel-2 imageries in the southern area of Obi Island yield a range of TSS values between 4 to 874 mg/l. The patterns of TSS distribution in this area appear to be highly variable, this is due to the conditions of current patterns, wind, rain intensity, and anthropogenic conditions in the southern area of Obi Island.

The authors would like to express high gratitude to the Department of Marine Science and Technology also Nusantara Geosains Institut (NGI) and all colleagues who have helped with this research.

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