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The Spatial Analysis of Water Quality in Batang Natal River Estuary Area, Mandailing Natal Regency, North Sumatra

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ABSTRACT

Quoted from various sources, the Batang Natal river is currently in a very critical condition where this clear river has become extremely cloudy due to illegal gold mining activities along the riverbanks, especially starting from the upstream area. As a result, approximately 50 km along the river the water can no longer be used by the people who live along the river and it is estimated that there are 30 villages in the vicinity. The analysis was carried out in this area to see how the impact of mining activities in the upstream area that affects air quality and also the level of sedimentation seen from the final stop of the river, namely in the Batang Natal estuary area. This research utilizes spatial analysis with normalized different turbidity index (NDTI), normalized suspended material index (NMSI), and suspended sediment concentration (SSC) as the method. The results of data analysis show that the water quality at the final stop in the Batang Natal estuary area has decreased in their quality in the last 20 years where the water turbidity index shows a range of yield values from -0.129 to 0.490. The results of processed NMSI data show the distribution of solids in the area studied to increase the estuary and downstream areas of the river. The minimum value that appeared in 2000-2001 was 0.1450 and the maximum value was 0.5693. In 2010-2011 the value obtained is in the range of 0.1592 to 0.6280, while in 2020-2021 it is in the range of 0.2049 to 0.6985. The concentration of suspended sediment in the estuary area of Natal was at levels of 10.28 mg/L to 38.92 mg/L.

Keywords: Batang Natal River, Water Quality, NDTI, NMSI, SSC.

1. INTRODUCTION

Water is one of the main natural resources where every creature needs its existence to meet their needs, especially as a source of livelihood. Water according to Government Regulation Number 121 of 2015 concerning Water Resources Management states that water is all water found on, above, or below the ground surface, including sea water on land.

Water is also defined as a natural resource that has a very important meaning and function for humans as well as other living things such as animals and plants both on the surface and in the ground, in lakes and seas. The water in the cycle will evaporate up into the atmosphere, then form clouds, fall to form rain, then infiltrate into the earth or the earth's body, forming underground water, filling lakes and rivers and the sea and so on (Muhamad Erwin, 2008).

Natal is one of the districts located in North Sumatra Province at the coordinates of 0o10'-1o50' North Latitude and 98o10'-100o10 East Longitude with a total area of 6,620.70 km2 with a population in 2021 of 489,569 people as dense as 80 people/km2.

Batang Natal is one of the rivers in Mandailing Natal Regency which stretches for 70.50 km and passes through three sub-districts, namely Batang Natal, Lingga Bayu, and Batang Natal. Quoted from various sources, the Batang Natal river is currently in a very critical condition where this river which was previously clear has become cloudy due to illegal gold mining activities along the

riverbanks, especially starting from the upstream area. As a result, approximately 50 km along the river the water can no longer be used by the people who live along the river and it is estimated that there are 30 villages in the vicinity.

Gold mining activities without permits or abbreviated as PETI in this area are managed by the community using traditional methods, until since 2004, the gold mining has begun to be managed using machines, which are carried out both individually and in groups. This is because the Batang Natal river does have a fairly large gold reserve where the miners themselves have reached more than 430 people with a gold mining land processing capacity of more than 123 Ha (Deka Maita Sandi, 2018).

Gold mining activities in Batang Natal River are generally not legally enforceable. Coupled with the lack of crackdown on PETI (Unlicensed Gold Miners) in this area, it will certainly have a huge impact on water quality in the Batang Natal River from year to year. River water in this area to where it empties has decreased in quality due to pollution ranging from cleanliness problems, cloudy flowing water, to damage to the environment and ecosystems both around and in the river itself. Mine dredging can usually cause suspension due to particles flowing together with river water, causing sedimentation in the estuary area.

Clean water and proper sanitation are basic human needs that are one of the goals in sustainable development (Sustainable Development Goals (SDGs)), more precisely in the 6th goal which is in the environmental sector which aims to ensure the availability and management of water and sanitation. sustainable sanitation for all, and achieving quality and sustainability of water resources globally. Together with other SDGs, it is intended to help improve the quality of human life universally (Tortaja and Biswas, 2018).

Figure 1. Goal 6 SDGs

This study basically aims to see how the impact of mining activities in the upstream area of the river affects water quality and also the sedimentation rate seen from the final stop of river water, namely in the estuary area of the Batang Natal River.

2. EXPERIMENTAL

The analysis used in this research is taken from layered dimensions from the surface to the estimated content by utilizing the Normalized Difference Turbidity Index algorithm to see how clear the water flowing in the Batang Natal River from 2000 to 2021, Suspended Material Index (Normalized) Material Suspended Index), and the last is Suspended Sediment Concentration by utilizing cloudmasking Landsat 5 and 8 satellite imagery data.

The processing carried out to obtain data on river water quality analysis and sedimentation in the Batang Natal River estuary area utilizes cloud-based application technology with a programming language in the form of Google Earth Engine to obtain data and then analyze and layout using the Quantum GIS application.

a. Water Turbidity Index (Normalized Different Turbidity Index)

NDTI is an index that utilizes the response when water is clean and free of sediment has a low reflectance (>10%) in the green band and an increase in water turbidity reflects a higher reflectance in the red band (Islam and Sado, 2006).

This technique is used to produce quality turbidity levels as low, medium, and high turbidity concentrations with a minimum value of -1 and a maximum of 1. The higher the value, the lower the turbidity level, and vice versa.

The formula used is:

$$\text{NDTI} : \frac{(\text{red band} - \text{green band})}{(\text{red band} + \text{green band})}$$

b. Suspended Material Index (Normalized Material Suspended Index)

NMSI is an algorithm that can analyze suspended material in water by estimated and normalized based on the spectral reflectance in the channel in the visible wave range including blue, green and red channels (Nguyen et al, 2020).

The range of values in this algorithm is between -1 to 1 where the lower value corresponds to clear water and minimal suspended material, and vice versa.

The formula used is:

$$\text{NMSI} : \frac{(\text{red band} + \text{green band} - \text{blue band})}{(\text{red band} + \text{green band} + \text{blue band})}$$

c. Suspended Sediment Concentration

SSC measurements were carried out to evaluate the concentration of sedimentary solids by utilizing the correlation coefficient between the red and green bands of 0.53, where based on Sutari et al, 2020 the regression of these values resulted in the SSC equation as follows:

30.03 * (red band/green band)

Correlation matrix for log spectral values of each band/band ratio and log SSC:

	SSC	blue	green	NIR	red	$\frac{blue}{green}$	$\frac{blue}{red}$	$\frac{blue}{NIR}$	$\frac{green}{red}$	$\frac{green}{NIR}$	$\frac{red}{NIR}$	$\frac{NIR}{green}$	$\frac{green-red}{2}$	$\frac{red/green}{2}$	$\frac{red}{blue}$	$\frac{red}{green}$
SSC	1.00															
blue	0.22	1.00														
green	0.39	0.88	1.00													
NIR	0.22	0.68	0.62	1.00												
red	0.49	0.84	0.96	0.61	1.00											
$\frac{blue}{green}$	-0.29	0.42	-0.06	0.25	-0.07	1.00										
$\frac{blue}{red}$	-0.53	0.05	-0.36	-0.04	-0.50	0.79	1.00									
$\frac{blue}{NIR}$	-0.12	-0.09	-0.10	-0.79	-0.13	0.01	0.09	1.00								
$\frac{green}{red}$	-0.53	-0.44	-0.51	-0.38	-0.74	0.06	0.65	0.15	1.00							
$\frac{green}{NIR}$	0.00	-0.24	-0.07	-0.83	-0.10	-0.37	-0.21	0.93	0.11	1.00						
$\frac{red}{NIR}$	0.16	-0.11	0.08	-0.71	0.12	-0.38	-0.40	0.87	-0.19	0.96	1.00					
$\frac{NIR}{green}$	0.00	0.24	0.07	0.83	0.10	0.37	0.21	-0.93	-0.11	-1.00	-0.96	1.00				
$\frac{green-red}{2}$	0.43	0.87	0.99	0.62	0.98	-0.06	-0.41	-0.11	-0.60	-0.08	0.10	0.08	1.00			
$\frac{red/green}{2}$	0.53	0.44	0.51	0.38	0.74	-0.06	-0.65	-0.15	-1.00	-0.11	0.19	0.11	0.60	1.00		
$\frac{red}{blue}$	0.53	-0.05	0.36	0.04	0.50	-0.79	-1.00	-0.09	-0.65	0.21	0.40	-0.21	0.41	0.65	1.00	
$\frac{red}{green}$	0.53	0.44	0.51	0.38	0.74	-0.06	-0.65	-0.15	-1.00	-0.11	0.19	0.11	0.60	1.00	0.65	1.00

Figure 2. Spectral Value Correlation Matrix for Logarithm SSC

3. RESULTS AND DISCUSSION

From the data processing, several facts were found related to evidence of water quality pollution where the management of the water turbidity index obtained through processing from Google Earth Engine was processed using QGIS, the range of values obtained through continuous linear interpolation categorization so that the combination of the three monitored images showed a range of values. result from -0.129 to 0.490. The higher the value, the lower the turbidity of the water. The results of the analysis show that the level of water turbidity tends to increase, especially around river estuaries and also river bodies which are marked by the intensity of the red hue that is increasing and is getting closer to 2021 (figure 6). This shows that the trend of activity upstream, especially related to mining activities, is also indicated to be increasing, marked by increasingly cloudy water reaching the downstream area and the estuary of the Batang Natal River.

The results of the histogram of the turbidity index data in 2000-2001 show a high range of values at 0.30 to 0.35 which means that the turbidity that occurs in the Batang Natal estuary is still mostly low. Meanwhile, the lowest value which indicates a high level of water turbidity is at the limit of -0.05.

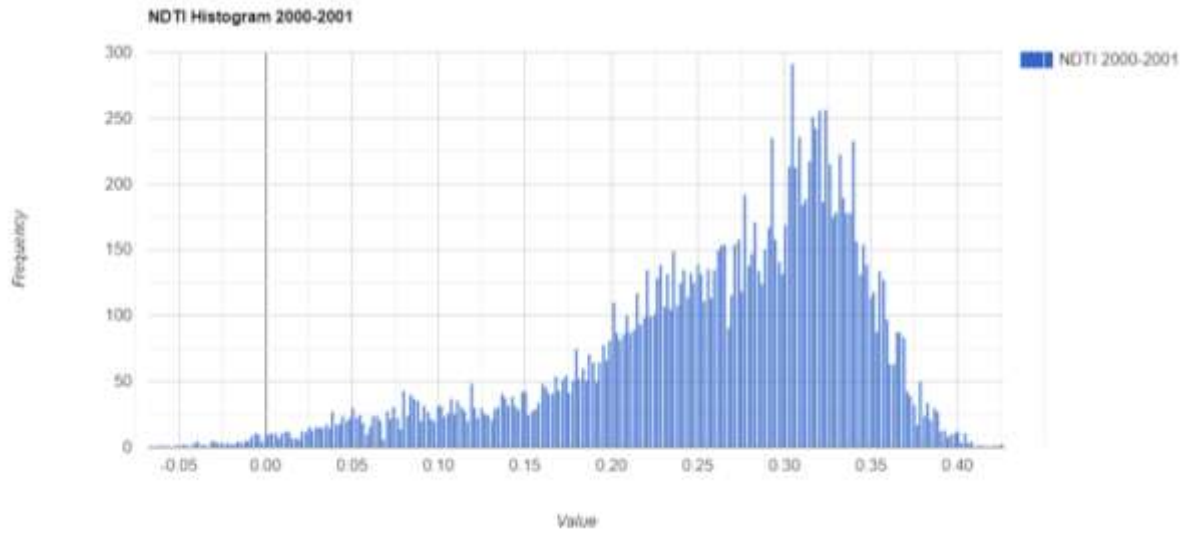

Figure 3. Histogram of Water Turbidity Index Data 2000 - 2001

The results of the histogram of turbidity index data in 2010-2011 have started to show a wide range of high values to a value of 0.20 which indicates that the turbidity of the water in the Batang Natal estuary area has begun to increase in turbidity.

The minimum value which indicates a high level of turbidity is still at the limit of -0.05.

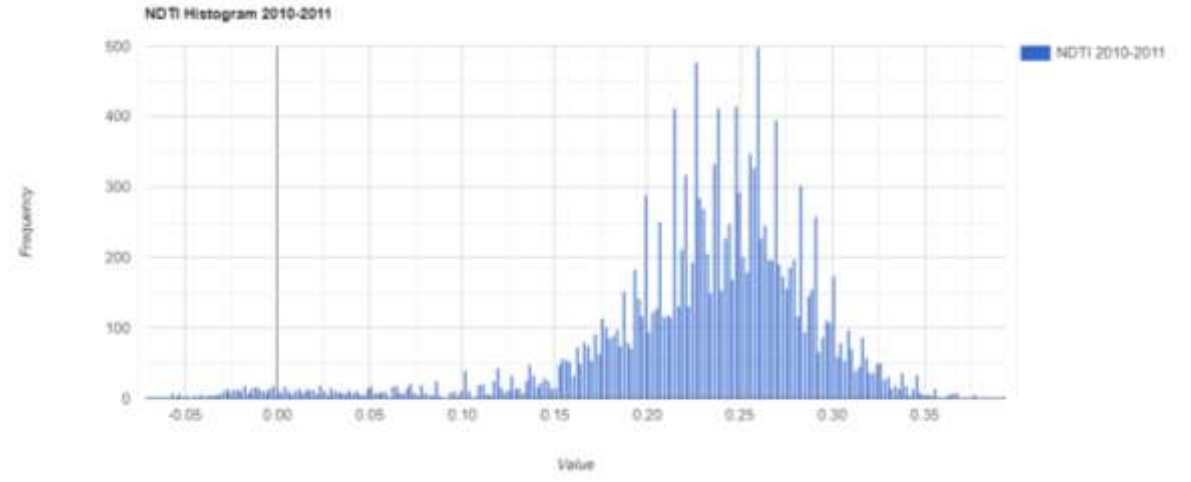

Figure 4. Histogram of Water Turbidity Index Data 2010 – 2011

The histogram value of the water turbidity index data in 2020-2021 itself has a fairly even and continuous distribution where the high value which indicates clear water in the range of values of 0.3 to 0.4 is indicating the clarity of the sea water off the Batang Natal estuary, while the low value indicates the value in the water. The cloudy ones are also evenly distributed and the range of values also widens to a value of -0.1

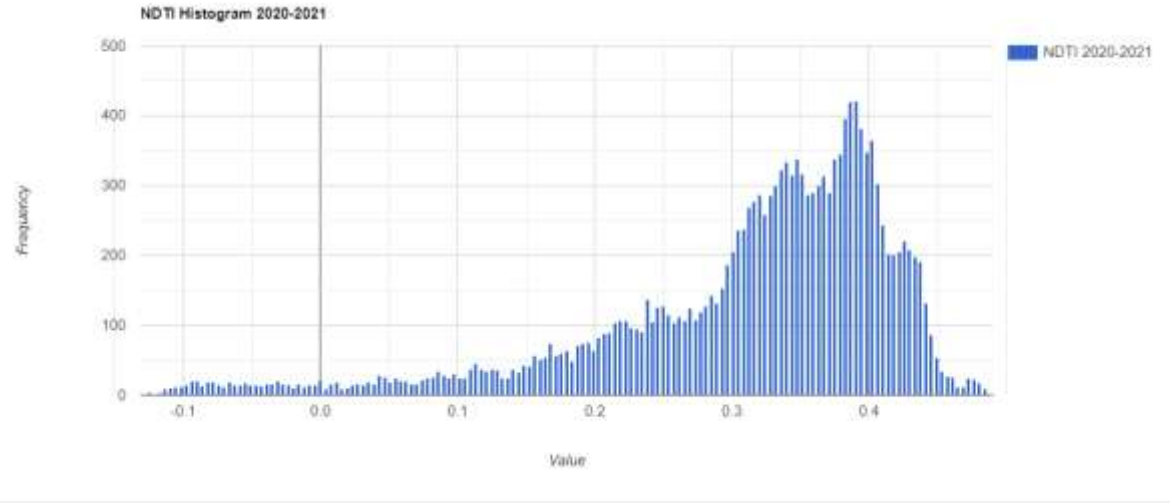

Figure 5. Histogram of Water Turbidity Index Data for 2020 – 2021

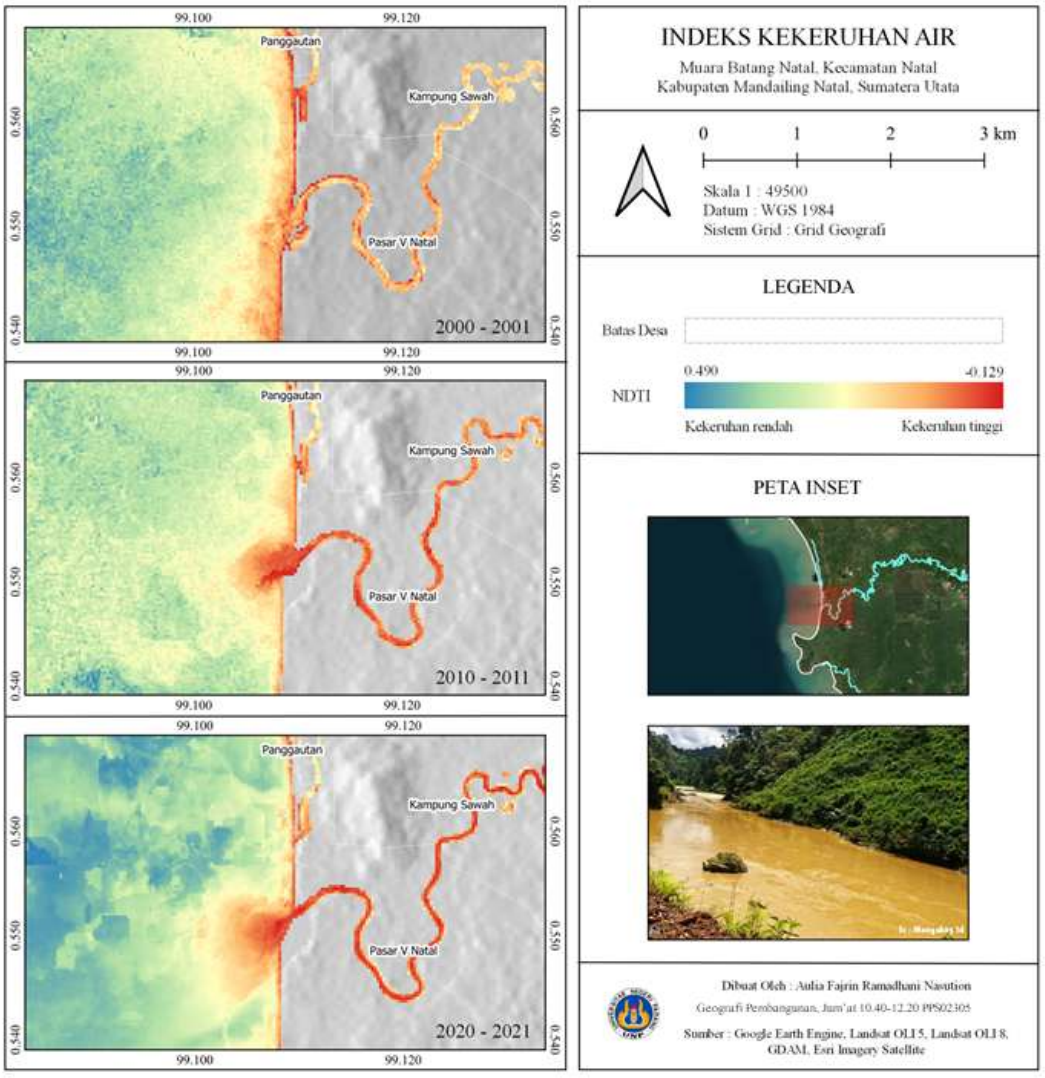

Figure 6. Water Turbidity Index Map

The suspended material index is closely related to the distribution of the suspension of solid material in the liquid material as well as the solid load of mud and waste carried by the water current.

The results of processed NMSI data show that the distribution of solids in the area under study is increasingly concentrated in the estuary and downstream areas of the river. The minimum value that appeared in 2000-2001 was 0.1450 and the maximum value was 0.5693. In 2010-2011 the value obtained is in the range of 0.1592 to 0.6280, while in 2020-2021 it is in the range of 0.2049 to 0.6985

Areas with higher values correlate with higher suspended material conditions in the studied waters. Suspended material in the Batang Natal River estuary area shows the highest value in 2020-2021 (figure 7) where this indicates the increasingly intense pollution that occurs in this area.

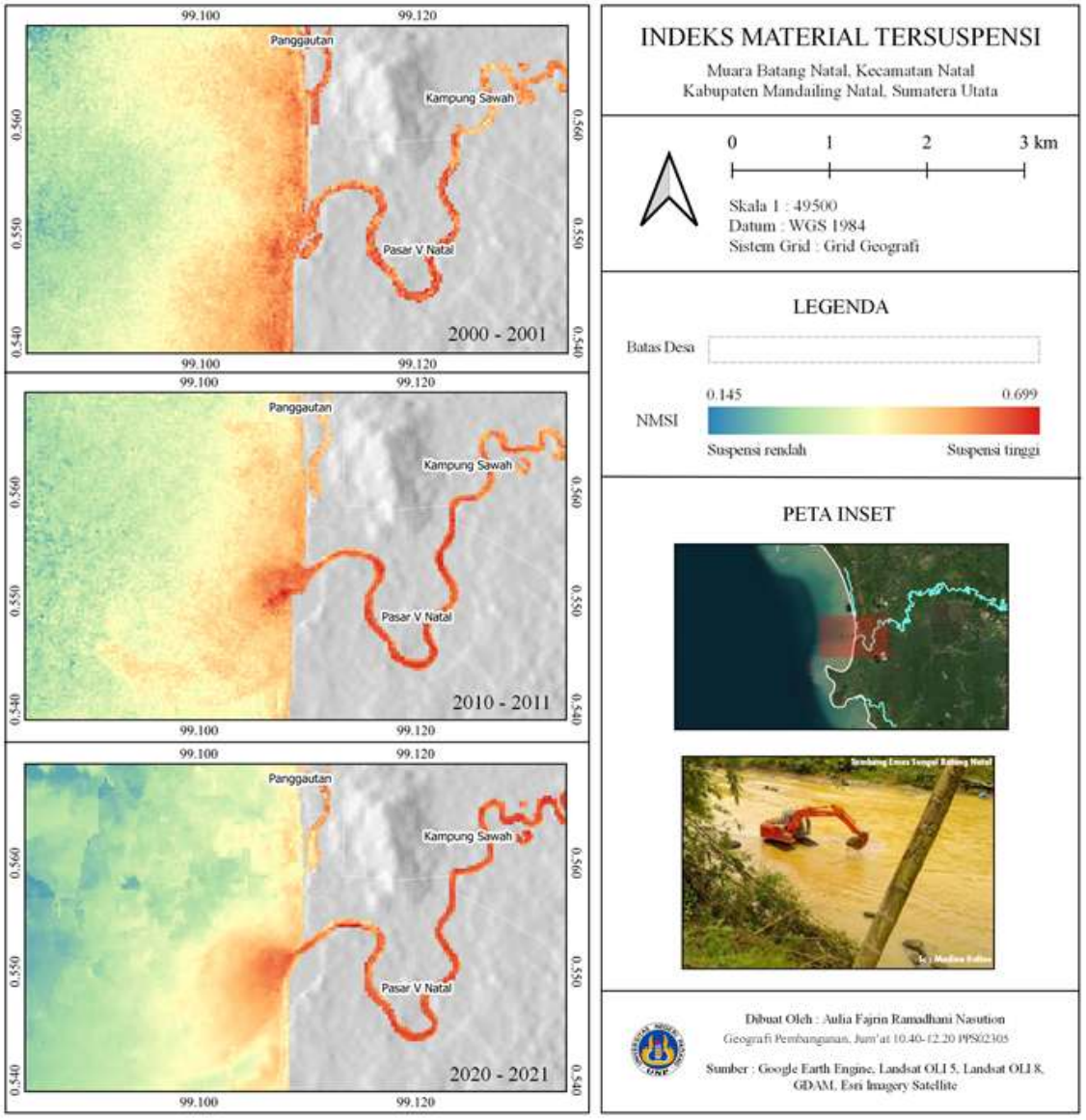

Figure 7. Suspended Material Index Map

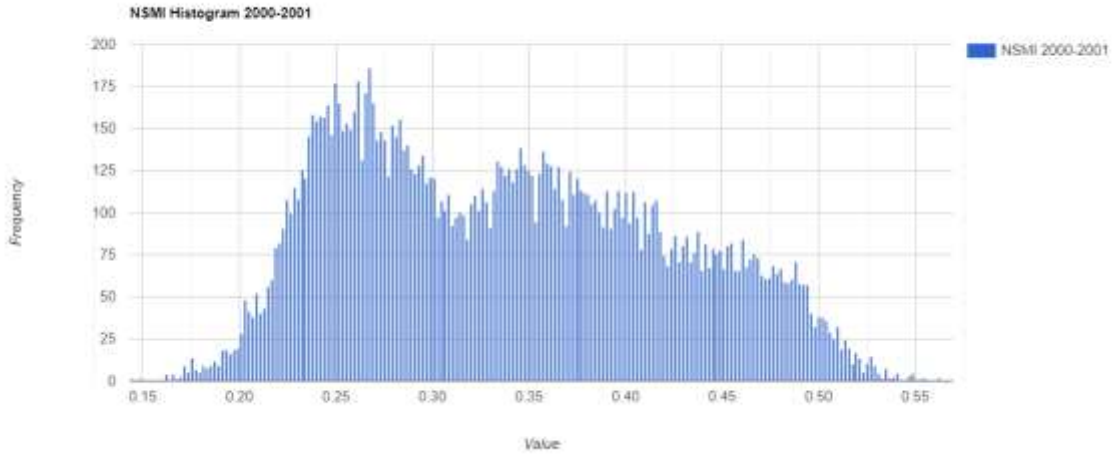

Figure 8. Histogram of Suspended Material Index Data 2000 – 2001

Histogram data from the index of suspended material in 2000-2001 shows the highest distribution is at a value of 0.25 to 0.30 which indicates that the water quality is still generally good. Where the distribution of data with high values indicating that water tends to have been suspended is still very low with a narrow distribution that only reaches the range of 0.55.

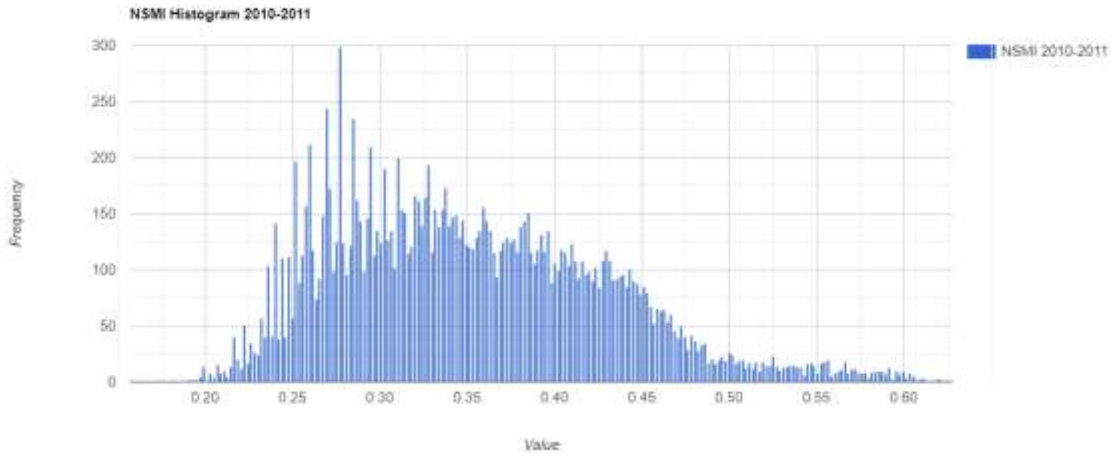

Figure 9. Histogram of Suspended Material Index Data for 2010 – 2011

Histogram of suspended material index data for 2010-2011 shows the highest and even distribution in the range of 0.25 to 0.45. The range of values with a fairly high default estimate of suspended material is in the range of 050-0.60 which tends to be evenly and densely distributed.

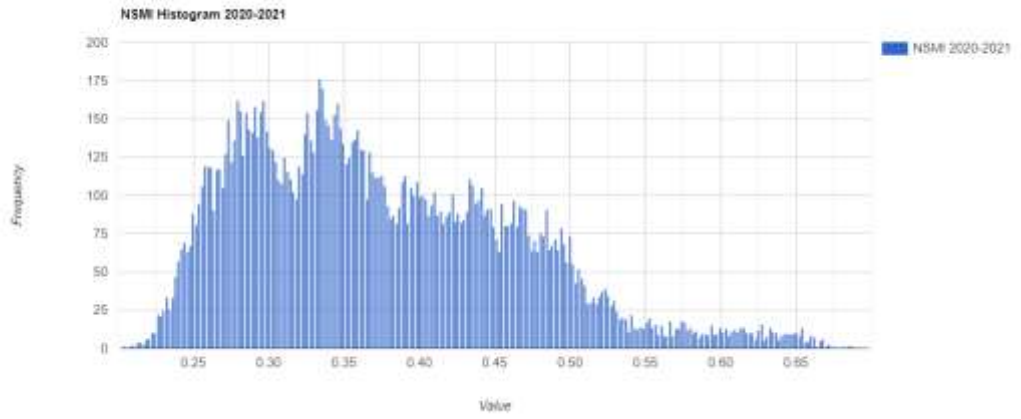

Figure 10. Histogram of Suspended Material Index Data for 2020 – 2021

Most of the suspended material in 2020-2021 is in the range of values from 0.25 to 0.50 where most of these values are spread in the sea area off the Batang Natal estuary. Suspended material that begins to be contained in densely water is seen to be evenly distributed in the range of high values of 0.55 to widening to 0.65 values.

Furthermore, the results of processing the distribution of suspended sediment concentration or called SSC. Sedimentation is an event of deposition of rock that has been transported by hydropower or wind (Anwas, 1994). When erosion occurs, water can carry rocks from water bodies on land to the sea. When the transport strength is reduced, the rock is deposited in the watershed. Associated with mining activities in Batang Natal, can accelerate this sedimentation case.

The sedimentation process itself includes the process of erosion, transportation or transportation, deposition, and compaction (Soewarno, 1991)SSC processing was carried out to see the concentration of suspended sediment in the estuary area of the Batang Natal River to support the previous methods (NDTI and NMSI) so as to generate data that was correlated with previous findings.

The turbidity of the water in the processed NDTI is closely related to the solids of the material that are carried away by the water detected by the NMSI method. The results of both are related to the deposition of material carried by the water, especially at the bottom of the studied waters. It can be seen on the map that the detected sediment deposits are also increasingly centered on the estuary area with a time span that is getting closer to 2021. Likewise, river bodies which look increasingly dense with sediment deposits that appear. The results of this processing more specifically can be seen in the following table

Tahun	Min	Max
2000-2001	12.048 mg/L	34.269 mg/L
2010-2011	13.039 mg/L	34.537 mg/L
2020-2021	10.280 mg/L	38.920 mg/L

The concentration of suspended sediment on the following map can be seen in its distribution where when the color is redder on the map, the concentration of suspended sediment is considered high, and vice versa.

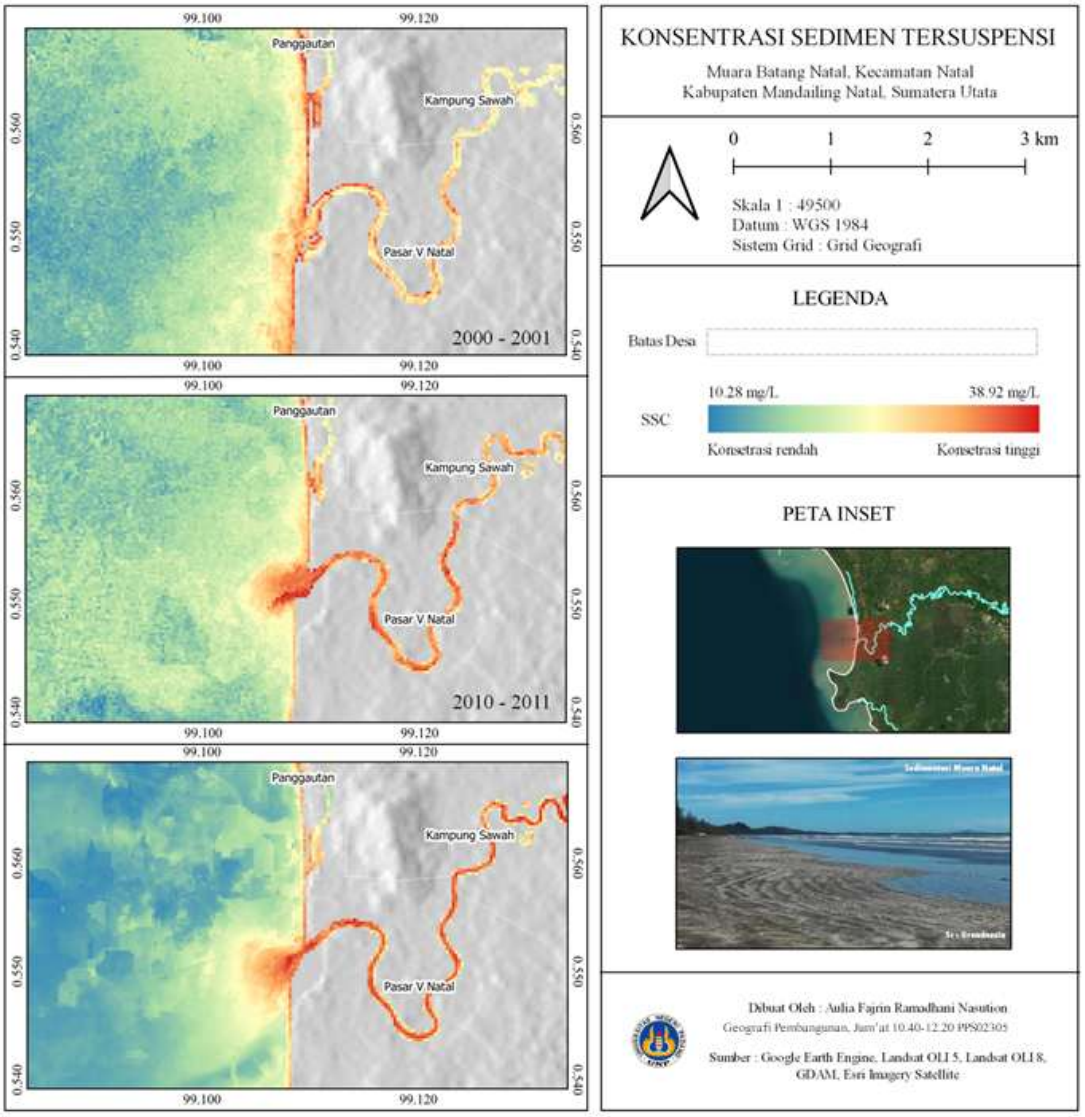

Figure 11. Suspended Sediment Concentration Map

4. CONCLUSION

Batang Natal is one of the rivers in Mandailing Natal Regency which stretches for 70.50 km and passes through three sub-districts, namely Batang Natal, Lingga Bayu, and Batang Natal. Quoted from various sources, the Batang Natal river is currently in a very critical condition where this river which was previously clear has become cloudy due to illegal gold mining activities along the riverbanks, especially starting from the upstream area so that the water in the river cannot be used by the community at that time. generally to meet their daily needs.

Clean water and proper sanitation are basic human needs which are one of the goals in sustainable development (Sustainable Development Goals. The results of data analysis show that the water quality at the final stop in the Batang Natal estuary area has decreased in quality in the last 20 years where the water turbidity index shows a range of yield values from -0.129 to 0.490. The results of processed NMSI data show that the distribution of solids in the area under study is increasingly concentrated in the estuary and downstream areas of the river. The minimum value that appeared in 2000-2001 was 0.1450 and the maximum value was 0.5693. In 2010-2011 the value obtained is in the range of 0.1592 to 0.6280, while in 2020-2021 it is in the range of 0.2049 to 0.6985. The concentration of suspended sediment in the estuary area of Natal was at levels of 10.28 mg/L to 38.92 mg/L. On the evidence of the decline in water quality in the Batang Natal case, the authors suggest that the government and the surrounding community pay more attention to the problem of river pollution, especially due to the presence of PETI activities on the riverbanks. Conservation actions need to be carried out seriously so that there is no inequality in meeting the needs of clean water for the surrounding community.

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