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WATER QUALITY OF BATANG MERAO WATERSHED AND IMPLEMENTATION OF LANDSAT 8 OLI/TIRS FOR THE TRANSPARENCY OF LAKE KERINCI WATERS

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Abstract This research aims to analyse the water quality of the Batang Merao watershed and the implementation of the algorithm model from Landsat 8 OLI/TIRS for the transparency of Lake Kerinci waters. The method used is descriptive quantitative, which is used to obtain measured data on water quality using the Pollution Index (IP) method based on the Decree of the State Minister for the Environment (KEPMENLH) No. 115/2003, PP No. 82/2001, and PP No. 22/2021, as well as the kriging method from an algorithm of the Landsat 8 OLI/TIRS for Total Suspended Solid (TSS) concentrations with the transparency of the waters of Lake Kerinci. Based on the test results of water samples in the Batang Merao DAS showed that several water quality parameters exceeded the class II water quality standard PP No. 82/2001, which covers DO, BOD, and oil & fats parameters. The relationship between TSS concentration and water transparency of Kerinci Lake has a high coefficient of determination, reaching 0.8344; this indicates the transparency of Kerinci Lake is around 2 m or less. This means that the waters of Lake Kerinci have lower transparency.

Keywords: Water quality, watershed, transparency, Landsat, Lake Kerinci.

Introduction

Lake Kerinci was formed from a tectonic fault process in the Bukit Barisan pathway, which is one of the areas with great potential (Poedjopradjitno, 2012; de Maisonneuve *et al*., 2019; Hermon *et al.*, 2021), but its sustainability is being threatened by sedimentation and eutrophication processes originating from the catchment area. The Lake Kerinci catchment area has a very fertile soil type and is sensitive to erosion, so it is easily eroded by rainfall and then carried by the river flow into the lake. The high water slope and very intensive land management, which has not yet implemented a conservative farming system, have triggered a high rate of sedimentation that enters the lake. This is also influenced by the existence of 10 rivers, which are the inlets for the water supply at Lake Kerinci.

The potential for water supply for Lake Kerinci, which is quite guaranteed throughout the season, is related to the existence of the Kerinci Seblat National Park (TNKS), which is a conservation region of protected forest with an area of nearly 1.5 million ha (MacKinnon *et al.*, 2019). de Maisonneuve *et al.* (2019) add that this lake has an area of 46 km^2, with an average lake depth of 97 m, a water volume of 1.6 million m^3, and is located at an altitude of 787 m above sea level.

The river system that flows into the Kerinci Lake region can be classified into two (2) groups, namely: 1) The river system which is the source of inlet water for Lake Kerinci, namely the Batang Merao watershed which is part of the Kerinci lake catchment area, Kerinci river, Tebing Tinggi river, Siulak or Merau river, Kapur river, and Jujun river; and 2) The river system which is the source of the lake's outlet water, namely the Merangin watershed which is part of the Batanghari sub-watershed. The

Merangin River is a river that comes out of Lake Kerinci, and its water resources are utilised for the Regional Drinking Water Company (PDAM) and the Merangin Hydroelectric Power Plant (PLTA). The upstream of the Batang Merao watershed is in the highlands of the Kerinci volcano, which crosses Sungai Penuh City and empties into Lake Kerinci. Research by Firdaus & Nakagoshi (2013) explains the management of the Batang Merao watershed has faced various problems, including the large number of sand or stone mining activities upstream and land use change from agricultural land to settlement land. In addition, some people activities utilise the riverbank areas for livestock activities. Putra *et al.* (2024) and Hermon *et al.* (2019) add sand mining activities can result in changes in land use to open land and cause high levels of erosion.

In addition, Putra *et al.* (2017) also added that water utilisation activities in the upstream area would have an impact on the downstream watershed in the form of changes in water storage and control of water release in the downstream area, in the form of changes in water quantity and water quality. The existence of people activities that throw waste into rivers and runoff from rice field activities and the presence of illegal mining causes water quality to exceed river water quality standards. The limited availability of clean water has been felt by the people in several river areas of the Batang Merao watershed, such as in Koto Dumo Village, Rawang Sub-district. The people use polluted Batang Merao river water to meet their daily water needs, such as bathing, washing, and toilets.

According to the report results of the Environmental Performance Information Document (DIKPLHD) Sungai Penuh City 2018 in Putra *et al.* (2019); Ningsih *et al.* (2020); Hermon *et al.* (2021) show there has been a decrease in water quality with an increase in the value of the IP of the Batang Merao watershed, namely 0.86 (not polluted) in 2014 to 1.49 (lightly) in 2017. Based on these problems, the researchers determined indicators of monitoring the pollution load of water quality in the Batang Merao watershed and Lake Kerinci, which had an impact on environmental sustainability. Given the problems in the Lake Kerinci area are quite complex, and there are still few studies, it is necessary to carry out an analysis so that the catchment area and river in the Batang Merao watershed can be utilised according to their designation and the people's water needs can be fulfilled and sustainable. This research aims to analyse the water quality of the Batang Merao watershed and the implementation of the algorithm model from Landsat 8 OLI/TIRS for the transparency of Lake Kerinci waters.

Methods

This research was conducted in the Batang Merao watershed, which is located in Kerinci Regency and Sungai Penuh City-Jambi Province (Figure 1). The area of the Batang Merao watershed is 679692.21 ha, with the main river being the Batang Merao, with a length of ± 53.63 km. The research was conducted in June 2022. An analysis of water quality in the Kerinci Lake region was carried out based on data on water brightness and total suspended solids (TSS).

A quantitative descriptive method (Keeler *et al.,* 2012) was used to obtain measurable data from monitoring river water quality in the Batang Merao watershed. Descriptive methods to determine the water quality of Lake Kerinci using the kriging method from an algorithm of the Landsat 8 OLI/TIRS for TSS concentrations with the transparency of the waters of Lake Kerinci with the data used in this research are primary data. Primary data were obtained from sampling data and results of water quality testing in the Batang Merao watershed, which are three sample points and two sample points in Lake Kerinci waters (Figure 1). At the same time, the analysis uses a reliable discharge approach (Q80) (Purnaditya & Asyiah, 2021).

Sampling points were determined by the sample survey method, namely dividing the research area into several parts that were considered to represent the research area.

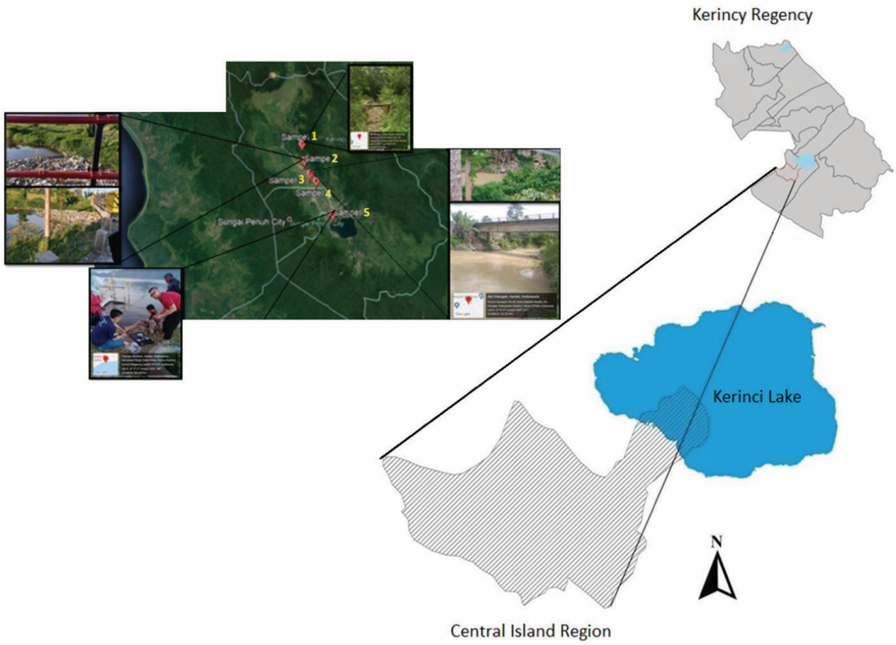

Figure 1: Field survey location map in research

Sampling points are determined based on the characteristics and forms of utilisation of water resources and people activities around the watershed. Water quality sampling was carried out using the grab sample method, and duplicate samples were taken for a total of 5 samples. Meanwhile, the analysis of water quality data for water quality status is carried out using the PI method. This is based on the Decree of the State Minister for the Environment (KEPMENLH) No. 115/2003 concerning "Guidelines for Determining Water Quality Status", Government Regulation (PP) No. 82/2001 concerning "Management of water quality and control of water pollution", and the Republic of Indonesia Government Regulation (PP) No. 22/2021 concerning "Environmental Implementation and Management for National Water Quality Standards" (Melinda *et al.,* 2021; Anggraini & Wardhani, 2021). This method is used to determine the level of pollution from pollutant sources on the quality of waters for a specific designation, both for the entire body of water or part of water (river).

The next step is a measurement of TSS concentrations using water samples taken from lake waters with different locations and water transparency using Secchi Disk Transparency (SDT). Then, all data is analysed and correlated to obtain a correlation algorithm between TSS and lake water transparency. Measurements of TSS and water transparency were carried out in Lake Kerinci waters on 1-2 June 2022 to obtain TSS concentrations in a varying range of values (low to high TSS concentrations).

The reclassification of Landsat 8 OLI/TIRS for TSS was carried out to classify images of TSS concentrations and simplify the process of interpretation and calculations in classification. The application from the Van Hengel and Spitzer Algorithms is carried out by looking for matrix components from previously processed images to obtain a depth index (Sukmono *et al.,* 2022). To obtain absolute depth, modelling is carried out between the depth index as x and the depth of field as y. So, the best depth algorithm modelling is obtained, namely the polynomial regression model 3 with an R^2 value of 0.7127 and an RMS error of 1.2929. For more details, the bathymetry (depth) of Lake Kerinci is presented in Figure 2, which originates from the work of de Maisonneuve *et al.* (2019).

To know the level of truth of the algorithm results, spatial validation is carried out between field data and image data. Spatial analysis is carried out by calculating the difference between the field data and the image and then calculating the standard deviation. To calculate the deviation from the field data and image data as a whole, the field data is raster interpolated using the Kriging method (Dewata & Putra, 2021).

Results

Water Discharge and Surface Run-off Coefficient

Calculation of water availability begins with finding the minimum discharge. The minimum debit data for the last 3 months have been obtained from the Secondary Data of the Environmental Office of Kerinci Regency. They are then sorted from the largest to the smallest discharge data. Water availability is calculated using a water balance using the reliable debit formula (Q80) (Hidayat & Ferdina, 2019). Based on the results of the discharge calculation, the availability of river water in the Batang Merao watershed is 20.12 m³/second (Figure 3). Maximum and minimum discharge fluctuations can be used as indicators of land use quality. The occurrence of discharge fluctuations affects the value of the River Regime Coefficient (RRC) (Rachman *et al*., 2021), which is a comparison between Q_{max} and $_{Qmin}$.

The land use Changes of the Batang Merao watershed are expected to have an impact on the run-off water coefficient and water quality of Lake Kerinci. The run-off coefficient increases when there is development of land cover and decreases as vegetation conservation improves. Utilisation of land cover will lead to changes in

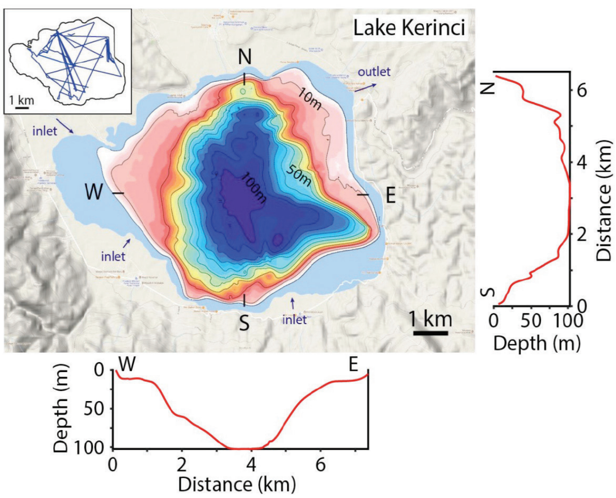

Figure 2: Bathymetry (depth) map of Lake Kerinci (de Maisonneuve *et al.,* 2019)

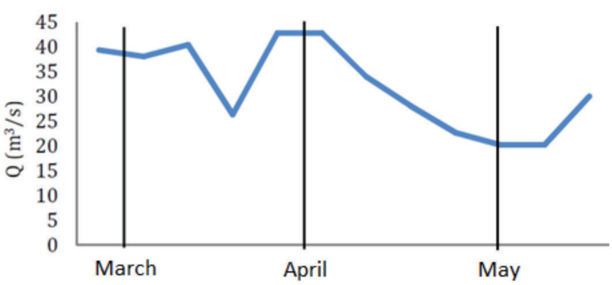

Figure 3: River discharge in the Batang Merao watershed from March to May 2022

land use with a tendency to be more watertight, causing puddles and thick surface water run-off, which can cause high water discharge and flooding. The results of calculating the surface run-off coefficient values in the Batang Merao watershed during the periods of 2018, 2019, and 2021 (Figure 4) with an algorithm using Landsat 8 OLI/TIRS 2020-2021, which represent catchments in the Kerinci Lake region show that the average value of the run-off coefficient has remained relatively unchanged. Still, for catchments in settlement areas and plantations, there is an increase in run-off value.

The results of calculating the average surface run-off coefficient during the 2018, 2019, and 2021 periods are shown in Table 1, where the surface run-off coefficient has increased from 0.420 in 2018 to 0.427 in 2019 and 0.437 in 2021. An increase in the flow coefficient causes a decrease in water absorption into the ground, which eventually increases the amount of ground run-off. In the next stage, it causes an increase in water discharge and soil erosion in the catchment area.

Water Quality

The water quality of the Batang Merao watershed was determined using the Water Quality Test Kit Professional 8 in One EC-900 on samples taken from five (5) points originating from the Batang Merao watershed and Lake Kerinci. The Batang Merao watershed has not yet been assigned according to the river class. Based on Government Regulation (PP) No. 82/2001 (Arthana *et al.,* 2021), if water quality standards at water sources have not been and are not set, then class II water quality criteria apply. Then, it can be used for water recreation infrastructure/facilities, cultivation of freshwater fish, animal husbandry, water for irrigating plantations and/or other uses that require the same quality of water as that user. The results of testing the river quality of the Batang Merao watershed can be seen in Table 2 and Figure 5.

The results of testing samples of river water in the Batang Merao watershed showed that several water quality parameters exceeded the class II water quality standard PP No. 82/2001, which covers DO, BOD, and oil & grease

Figure 4: Changes in catchment run-off coefficient, a) 2018, b) 2019, and c) 2020

Table 1: Coefficient of surface run-off of the Batang Merao watershed in 2018-2021.

Year	2018	2019	2021
Average run-off coefficient	0,420	0,427	0,437

Table 2: Results of testing the water quality of the Batang Merao watershed

Parameter	Water Quality Standard (Class II)	Unit	Sampling Ppoint				
			1	2	3	4	5
PHYSICS							
Temperature	-	°C	21	25	22	22	24
Turbidity	-	NTU	2,76	69,3	39,7	39,7	35,6
TSS	50	mg/L	41	157	42	42	34
INORGANIC CHEMISTRY							
pH	6-9	-	7,92	8,16	7,52	7,52	7,51
BOD	3	mg/L	7,06	16,7	15,09	15,09	13,49
DO	4	mg/L	5,78	4,96	3,27	3,27	4,61
MICROBIOLOGY							
Fecal Coli	1000	Amount/100	10	24	24	15	38
Total Coli	5000	mL	>1600	>1600	>1600	>1600	>1600
ORGANIC CHEMISTRY							
Oils & Fats	1000	µg/L	2400	1200	5600	2500	8100

parameters. The results of the TSS parameter water quality analysis showed a significant increase in concentration from sampling point 1 of 41 mg/l to 157 mg/l at point 2, 42 mg/l at points 3-4, and 34 at point 5. Based on PP 82/2001 Class II of 50 mg/l, the water quality conditions of the Batang Merao watershed, when viewed from the TSS parameter sample 2, exceed the water quality standard value. A significant increase in TSS concentration occurred at location 2, which was influenced by sand and rock mining activities around the sampling location. The high concentration of TSS at that location was caused by the addition of particulates in the form of silt and fine sand, the residue from washing sand that was wasted into the river. Ghosh *et al.* (2023) explained that the greater volume of sand taken will increase the concentration of TSS and the more turbid the water will be. Mining activities can increase the rate of erosion and adversely affect fisheries.

The results of testing the BOD concentration in the Batang Merao watershed showed values ranging from 7.06-16.7 mg/l, as shown in Figure 5. BOD concentrations at all points did not meet the class II water quality standard value of 3 mg/l. The high concentration of BOD in the research area indicates that there are people who still use the Batang Merao watershed as a final disposal site for household domestic liquid waste and a place for bathing and washing. In some areas, latrines are still found along the Batang Merao watershed, and sewage from household activities is directly discharged into the water bodies. In addition, the high concentration of BOD at several points is also influenced by the sampling factor, which is carried out during the dry season so that the available river water discharge is very small. Still, the pollution load from domestic waste that enters water bodies is quite large.

The highest concentration of BOD was at sampling point 2, which was 16.7 mg/l, while the lowest concentration was at sampling point 1, 7.06 mg/l. The high concentration of BOD is also influenced by the presence of sewerage channels for household liquid waste that is discharged directly into water bodies without prior treatment. The people still use the river for toilets and garbage disposal. Bai *et al.* (2022) added that water conditions that accommodate waste from settlements and/or industrial waste without treatment often exceed 200 mg/l. Determining the water quality status of the Batang Merao watershed uses the IP method (Nurrohman *et al.*, 2019; Suriadikusumah *et al.*, 2021; Putra *et al.*,

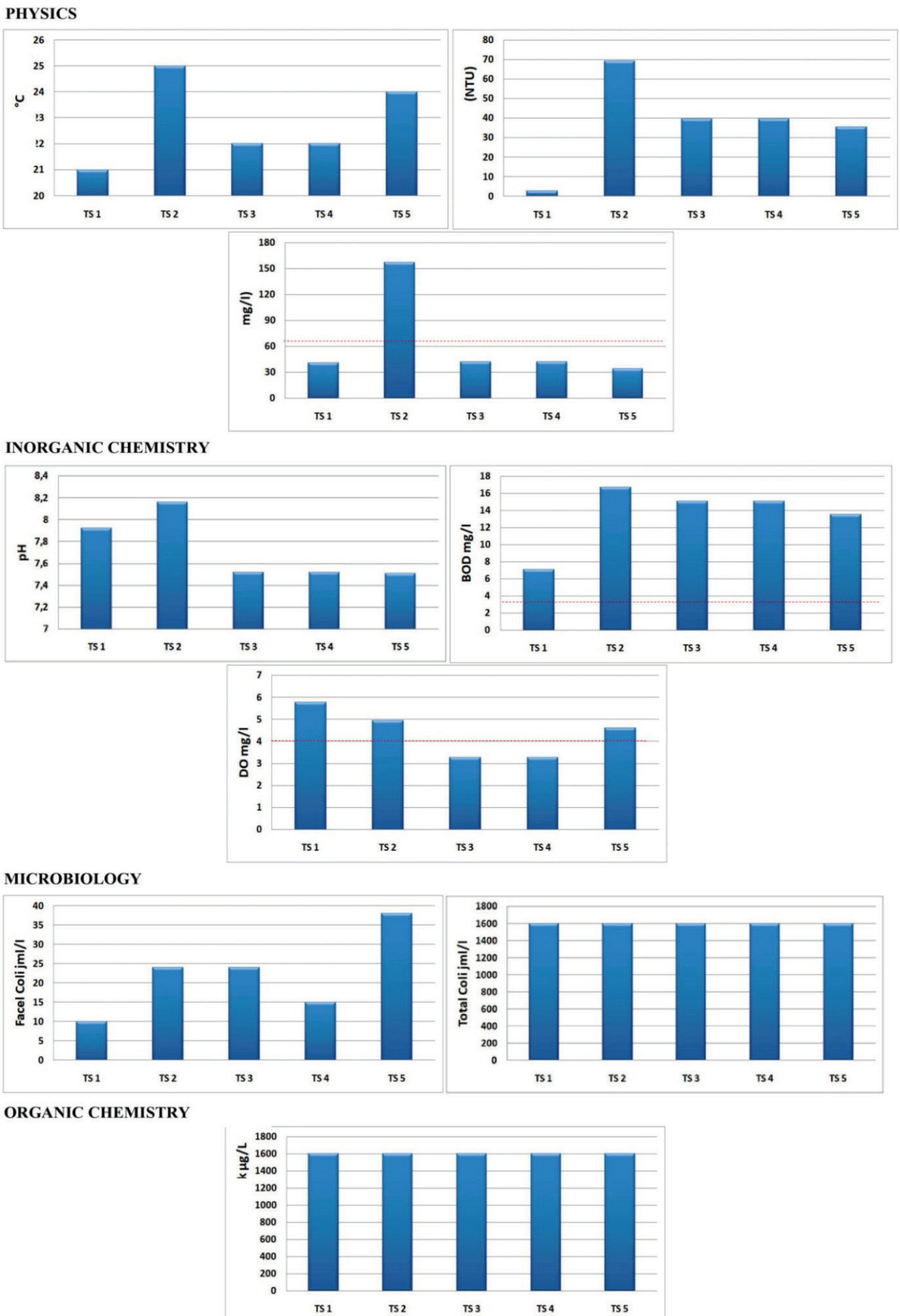

Figure 5: Graph of water quality monitoring results for the Batang Merao watershed

2022). Water quality parameters compared with class I, II, III, and IV water quality standards PP No. 82/2001 (Ajiwibowo *et al.*, 2019; Dewata, 2019). Water quality status is determined by the IP method following KEPMENLH No. 115/2003 concerning "Water Quality Status". In determining the status of water quality, the parameters used in calculating the pollution index are TSS, pH, BOD, DO, Fecal Coli, Total Coli, oil, and grease. The results of calculating the pollution index at each sampling point can be seen in Table 3 below.

Modelling the Water Quality Distribution of Kerinci Lake

The relationship between TSS concentration and water transparency is an exponential model (Wirabumi *et al.,* 2021) and has a high coefficient of determination, reaching 0.8344. The developed water transparency algorithm is applied to Landsat 8 OLI/TIRS data to obtain the distribution of water transparency in Lake Kerinci waters. Figure 6 shows a model of TSS distribution and water transparency in Lake Kerinci using Landsat 8 OLI/TIRS. Lake Kerinci waters have low concentrations of TSS in the middle of the lake region and high concentrations of TSS along the lake borders.

The highest TSS concentrations along the lake boundary are believed to be due to soil erosion in watersheds that are carried from rivers to the lake water and soil erosion that occurs along the lake region. As mentioned in the previous discussion, there is an inverse correlation between water transparency and TSS concentration in Lake Kerinci. Wahyono (2012) states that, in general, most of the water in Lake Kerinci is less than 2 m clear, although the water transparency is greater than 2 m in the central part of the lake. There are several sand pits around Lake Kerinci due to sand mining around Lake Kerinci. The presence of sand mining areas is thought to increase water turbidity and reduce the water transparency of Lake Kerinci.

Table 3. Pollution Index (IP) of the Batang Merao watershed.

Sample	PI in Each Class of Water							
	Class I		Class II		Class III		Class IV	
	Value	Criteria	Value	Criteria	Value	Criteria	Value	Criteria
TS 1	3.03	Lightly	2.41	Lightly	2.09	Lightly	0.44	Meet standards
TS 2	7.25	Medium	6.65	Medium	5.53	Medium	1.25	Lightly
TS 3	3.95	Lightly	3.45	Lightly	3.4	Lightly	1.07	Lightly
TS 4	4.26	Lightly	3.64	Lightly	2.54	Lightly	1.38	Lightly
TS 5	7.8	Medium	7.2	Medium	6.12	Medium	0.9	Meet standards

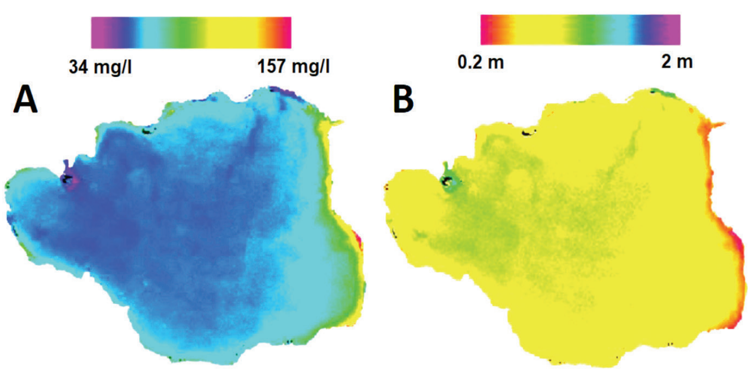

Figure 6: Model of TSS distribution and water transparency in Lake Kerinci

All sampling data for the Kerinci Lake waters show an inverse relationship between TSS and water transparency. TSS concentration increases with decreasing water transparency, while water transparency has different values for each TSS concentration value. The TSS concentration values ranged from 34 to 157 mg/l, and the water transparency ranged from 0.2 m to 2 m. Based on the measured data, the water in Lake Kerinci is known to have low water transparency. increase. The measured data are then recalculated using the Kriging method in an ArcGIS application (Dewata & Putra, 2021) to obtain the mean and variance of water transparency at each TSS concentration value. The results are shown again in Figure 6, showing that water transparency is inversely proportional to TSS concentration. A study by Ballantine *et al*. (2014), Hannouche *et al*. (2017), and Hermon *et al.* (2022) stated that TSS is linearly correlated with turbidity and that TSS and turbidity are inversely related to water transparency. Therefore, the correlation between his TSS and water transparency found in this study yields the same results as in previous publications.

The damage to the Kerinci Lake ecosystem is poorly understood by the relevant parties, partly because they do not understand the boundaries of the hydrological system and the lake's very complex water system, which has a very high intensity and duration of rainfall. As a result of this lack of understanding, development carried out in upstream areas often causes damage downstream (in Lake Kerinci). This condition reflects the lack of integration of water resource management system policies from upstream to downstream.

The increase in the amount of sediment carried by water flows from rivers to Lake Kerinci is a big and important problem. Apart from that, many studies have explained that the large floods that occur every year in Kerinci have transported large amounts of sediment that always end up in Lake Kerinci. So that Lake Kerinci does not become a "sediment trap" or even a dead lake, water catchment area management must be carried out in an integrated manner.

The decline in environmental quality in the Kerinci Lake area needs to be addressed immediately so that it does not have a further impact on the quality of the lake ecosystem or the sustainability of the community's economic activities. For this reason, rescue actions taken need to involve the government, community, and private sector, as well as within an integrated spatial scope, integrated into a single ecosystem.

Another event that is affected (apart from erosion and sedimentation) is inaccurate land use in the lake water catchment area, resulting in land damage in the catchment area, namely flooding. The term flood in this paper is the overflow of water that cannot be accommodated by the river body (flash flood, flash flood, torrent). In hydrology, the term flood also means a hydrograph peak, which is not always associated with a disaster. Floods are a bitter story in wet tropical regions. After the dry season passed, during which there were quite large changes in the ecological, economic, and social conditions of the communities around the lake, the rainy season occurred with high intensity, which caused new disasters in the form of floods and landslides with large impacts.

In the concept of watershed management (watershed management, catchment area, drainage/river basin), a watershed is an area limited by topography, where rainwater that falls in the area flows into tributaries or sub-watersheds, leading to the main river that flows into a lake or the sea. So, theoretically, all areas on the earth's surface are divided into watershed areas, where the upstream and downstream areas have close hydrological connections. On-site ecological degradation in upstream areas has an off-site impact in downstream areas (lakes). Therefore, watersheds as lake catchment areas are hydrological units that are ideal for use as planning, management, and monitoring units for natural resources, especially water resources.

Conclusions

Based on the analysis of river discharge data from the Batang Merao watershed in March-May 2022, water availability in the Batang Merao watershed is 20.12 m^3/second, covering domestic, non-domestic, agricultural, animal husbandry, and fisheries needs. The availability of water in the Batang Merao watershed has not been able to meet the total water needs of the people in the Batang Merao watershed, with a water deficit of 4.01 m^3/second. Based on the IP value, the water quality status of the Batang Merao watershed is in a lightly polluted condition caused by pollution from domestic sewage, livestock waste, mining activities (sand and rock mining), and agricultural run-off. The algorithm developed in this study has a high coefficient of determination, reaching 0.834. The implementation of the algorithm for Landsat 8 OLI/TIRS shows that the water transparency in Lake Kerinci is around 2 m or less. This means that the waters of Lake Kerinci have lower water transparency.

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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