WATER CLARITY MAPPING IN KERINCI AND TONDANO LAKE WATERS USING LANDSAT 8 DATA

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Abstract. Land conversion occurred in the lake catchment area caused the decreasing of water quality in many lakes of Indonesia. According to Lake Ecosystem Management Guidelines from Ministry of Environment, tropic state of lake water is one of parameters for assessing the lake ecosystem status. Tropic state can be indicated by the quantity of nitrogen, phosphorus, chlorophyll, and water clarity. The objective of this research is to develop the water quality algorithm and map the water clarity of lake water using Landsat 8 data. The data were standardized for sun geometry correction and atmospheric correction using Dark Object Subtraction method. In the first step, Total Suspended Solid (TSS) distributions in the lake were calculated using a semi empirical algorithm (Doxaran et al., 2002), which can be applied to a wide range of TSS values. Secchi Disk Transparency (SDT) distributions were calculated using our water clarity algorithm that was obtained from the relationship between TSS and SDT measured directly in the lake waters. The result shows that the water clarity algorithm developed in this research has the determination coefficient that reaches to 0,834. Implementation of the algorithm for Landsat 8 data in 2013 and 2014 showed that the water clarity in Kerinci Lake waters was around 2 m or less, but the water clarity in Tondano Lake waters was around 2 – 3 m. It means that Kerinci Lake waters had lower water clarity than Tondano Lake waters which is consistent with the field measurement results.

Keywords: *lake water, SDT, TSS, tropic state, water clarity*

1 INTRODUCTION

Lake is a water resource that must be preserved because it has many benefits for human life. Recently, the existence of the lakes have been degraded due to land conversion in the lake catchment area, coupled with waste disposal that flowed into the waters of the lake as a result of population growth, residential areas and industrial development in the catchment area. These conditions caused many lake ecosystem problems, such as eutrophication, water supply, reducing, increasing the acidity of the lake water, sedimentation, and decreasing the biodiversity. This problem would potentially lead to disaster and disrupt people's lives around the lake.

The Ministry of Environment has issued the Guidelines for Lake Ecosystem Management. It describes that some parameters affect the status of lake catchment area's ecosystem, lake border area's ecosystem and lake water area ecosystem (Moe, 2008). Changes in these parameters over time can be an indicator that the catchment area and the lake ecosystem, are good, threatened or damaged. Therefore, monitoring the change of these parameters is very important to support the lake management activities in Indonesia. According to Lake Ecosystem Management Guidelines from the Ministry of Environment, trophic state of lake waters is one of the parameters for assessing the lake water ecosystem status. Trophic state of lake waters indicates the fertility level of waters as a result of a variety of nutrients that enter into the lake waters. The high fertility of waters will lead to rapid growth of algae (algae bloom), and it will cause the death of fish due to the reducing of dissolved oxygen content in the lake water. Tropic state can be indicated by the quantity of nitrogen, phosphorus, chlorophyll, and water clarity. When the value of each parameter in the lake waters exceeds or is less than a certain threshold value, the trophic state of lake waters will be classified in a particular class, such as good waters (oligotrophic and mesotrophic), threatened waters (eutrophic) or damaged waters (hypertrophic) as shown in Table 1-1.

Utilizations of satellite remote sensing data for monitoring the trophic state indicated parameters have been done by some researchers, such as Brezonik *et al.,* (2002) that mapped the water quality parameters (chlorophyll and water transparency) in lake waters of the United States, and Li *et al.*, (2004) presented the result that lake monitoring can be performed for various sizes of the lake using a different spatial resolution of satellite data. Furthermore utilizations of satellite data were not only within the scope of research and model development, but it has entered into a phase of data utilization for supporting the operational activities of water quality and lake trophic state monitoring. Brezonik *et al.*, (2002), Liu *et al.,* (2007) and Powell *et al.,* (2008) have created models for mapping, water quality parameters (chlorophyll, water transparency, temperature and suspended solids) and also for mapping the trophic state of lake waters using Landsat TM/ ETM+. Those models have been operationally implemented to monitor the condition of some lakes in the United States and Canada.

Utilization of satellite data for monitoring the lake ecosystem in Indonesia was still a few studies and it was difficult to be continued until the operational level. This was due to the standardization of data processing procedures was not done yet, so the information obtained were not consistent. It caused the generated algorithm model tends to be implemented only for specific data and specific location. The objective of this study was to develop a water clarity algorithm model and then implemented the algorithm to map the water clarity of lake waters using Landsat 8. This paper is the improvement of our previous study that presented in Porsec 2014 (Trisakti et al., 2014).

Table 1-1: Trophic state classes of lake waters (Permen KLH, 2009)

Trophic State	**Mean Concentration**			
	Total N (mg/l)	**Total P (mg/l)**	**Chlorophyll-A (mg/l)**	**Water Clarity (m)**
Oligotrophic	≤ 650	< 10	< 2	> 10
Mesotrophic	≤ 750	< 30	< 5	> 4
Eutrophic	≤ 1900	< 100	< 15	≥ 2,5
Hypertrophic	> 1900	≤ 100	≥ 200	< 2,5

2 MATERIALS AND METHODOLOGY

2-1 Location and Data

The study area is Tondano Lake in North Sulawesi Province and Kerinci Lake in Jambi Province (Figure 2-1), which were included in the 15 priority lakes in the national lake rescue program in the period of 2010 to 2014 (MoE, 2011). The data used in this research were Landsat 8 data, with acquisition date 2nd June 2013 for Kerinci Lake and 14th July 2014 for Tondano Lake. Another data were TSS and water clarity measurement data collected from the Tondano Lake in July 2012 and from Kerinci lakes in August 2013.

2-2 Research Method

The work was divided into four stages: data standardization, water clarity algorithm development, Total Suspended Solid (TSS) mapping and water clarity mapping. Flowchart of this research is shown in Figure 2-2.

In the data standardization stage, Landsat 8 data were corrected for sun geometry correction and atmospheric correction. Sun geometry correction aims to correct the error of spectral pixel value due to the influence of solar lighting position (Trisakti and Nugroho, 2012). Correction process was done by changing the digital pixel values into radian values (radiation from the object to the sensor) and then change the radian values into reflectance values. On the other hand, atmospheric correction was conducted by assuming the existence of a dark object on the earth's surface that will absorb all the energy of electromagnetic waves, so there is no reflection or scattering of electromagnetic waves from the object into the sensor. It means that if the object pixel in the image has a value, the value is not from the object scattering, but the atmospheric scattering, so it must be removed.

A dark object in the data was assumed to be happening in deep areas of lake waters. The correction was done by finding the minimum pixel value in each band, the minimum pixel values in each band were assumed as a dark object (scattering from deep water), then the minimum values were used to subtract the pixel value of each band in the entire data, so that the minimum pixel value of each band becomes zero.

Tondano Lake, North Sulawesi Kerinci Lake, Jambi

Figure 2-1: Study area of Tondano Lake and Kerinci Lake

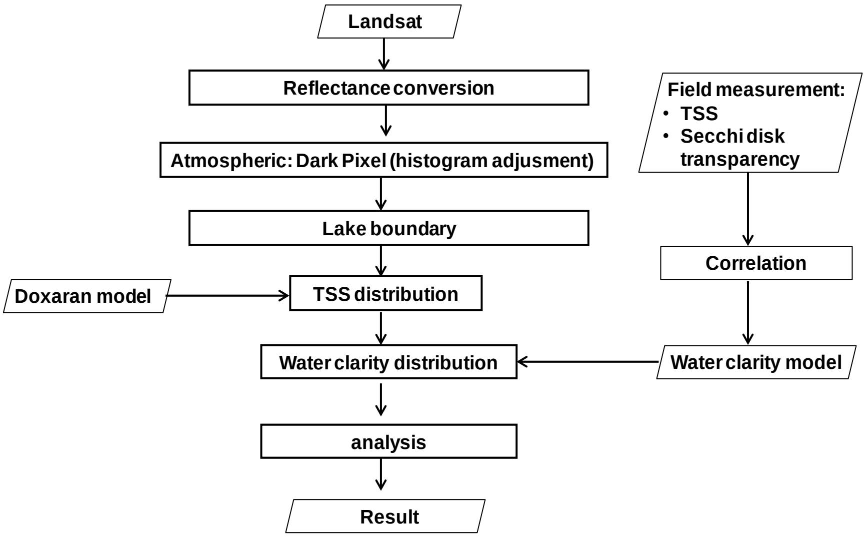

Figure 2-2: Flowchart of water clarity mapping

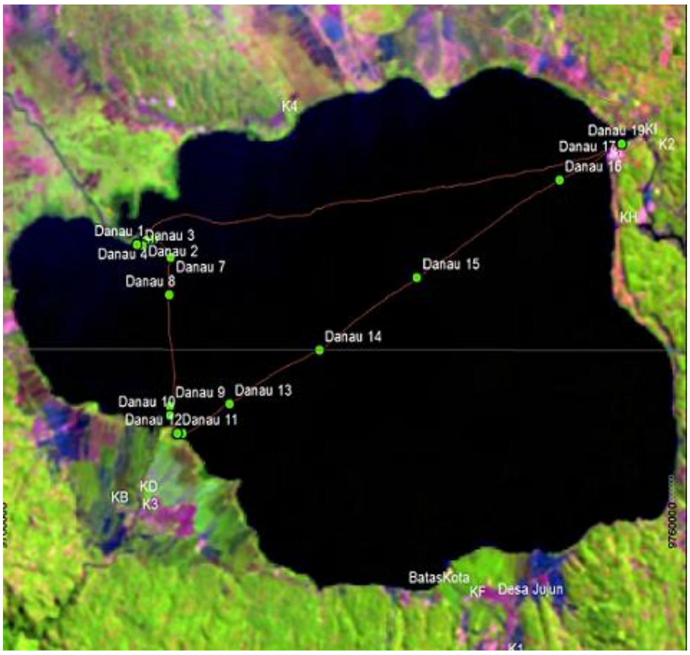

Figure 2-3: Sampling locations of TSS and water clarity measurements (15 locations as shown with green dot point)

The next stage is to build a water clarity algorithm model based on field measurement data. Measurements were conducted to measure TSS concentration by using a water sample taken in lake waters for different location and to measure the water clarity by using SDT in the same location as TSS measurement. The measurements were conducted in two locations, Kerinci Lake and Tondano lake. Figure 2-3 shows sampling locations of TSS and water clarity measurement in Kerinci Lake waters. Furthermore, the results of TSS and water clarity measurements in Tondano Lake waters in July 2012, and the results of TSS and water clarity measurements in Kerinci Lake waters on August 2013 were combined (total of 39 measurement samples), then all the data were analyzed and correlated to getting the correlation algorithm between TSS and water clarity of the lake waters. Figure 2-4 shows the photos of the TSS and water clarity measurements.

(a) TSS measurement (b) Water Clarity measurement

Figure 2-4: TSS and water clarity measurement

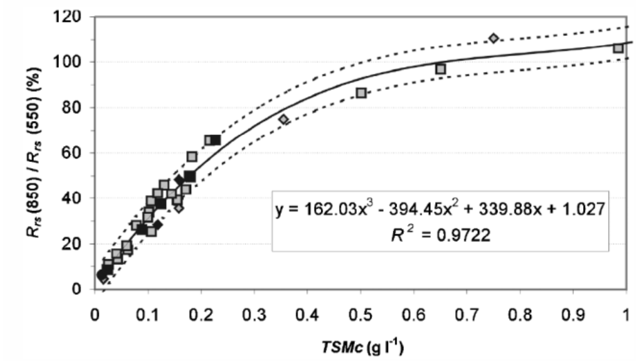

Figure 2-5: Semi empirical TSS algorithm developed by Doxaran *et al.* (2002)

TSS was mapped using semi-empirical algorithm model developed by Doxaran et al. (2002). Figure 2-5 shows the TSS algorithm, which was developed by making the correlation between TSS with the ratio of Near Infrared band and Green band (NIR/Green). The TSS algorithm was built based on the Spectroradiometer measurements in wide ranges of TSS concentrations (10-1000 mg/l), and then it was applied to the satellite data (Landsat and SPOT). Furthermore, the water clarity algorithm obtained from this study was used to map the water clarity distribution in the study area, and the then distribution values of water clarity were analyzed.

3 RESULTS AND DISCUSSION

TSS and water clarity measurement were conducted in Tondano Lake waters in 1-2nd June 2012, and in Kerinci Lake waters with 4th -5th July 2013. As shown in Figure 2-3, Sampling locations were distributed over the lake waters, which were mainly performed in the river mouth. These locations were selected to obtain TSS concentration in varies range values (low to high concentration of TSS).

In the first survey, 25 samples of TSS concentration and water clarity were measured, while in the second survey, 14 samples of TSS concentration and water clarity were measured. The total collected samples were 39 samples. All data were combined and plotted in Figure 3-1. The red dots are samples taken from the Tondano Lake waters, and the blue dots are samples taken from the Kerinci Lake waters. The data showed an inverse relationship between TSS and water clarity. TSS concentration increases as the water clarity decreases. Another fact shows that water clarity had variable values at each TSS concentration value. TSS concentration in both lakes ranged from 4 mg/l to 18 mg/l. The water clarity of the Lake Tondano waters ranged from 0,2 m (20 cm) to 2,5 m (250 cm), while the water clarity of the Lake Kerinci waters ranged from 0,2 m to 2 m. Based on the measurement data, it is known that Kerinci Lake waters had lower water clarity than Tondano Lake waters.

Furthermore, the distribution data in Figure 2-5 were recalculated to obtain average and deviation value of water clarity at each TSS concentration value. The results were re-plotted in Figure 3-2, and it shows that water clarity has an inverse correlation with TSS concentration. The correlation between TSS, turbidity and water clarity have been reported in some publication (Wei, 2007; Ballantine et al., 2014; Hannouche et al., 2012). TSS has a linear correlation with turbidity (Hannouche et al., 2012), and TSS and turbidity have an inverse correlation with water clarity (Wei, 2007; Ballantine et al., 2014). So, the correlation of TSS and water clarity found in this research has the same result with those previous publications. The relationship between TSS concentration and water clarity is the exponential model as shown in Equation 1, and it has high determination coefficient reaching to 0,8344. The developed water clarity algorithm was applied in Landsat 8 data to get the water clarity distribution in the lake waters of Kerinci and Tondano Lakes.

$$SDT\ (cm) = 375.71\ e^{-0.123\ TSS} \quad (3\text{-}1)$$

Figure 3-3 shows TSS distribution and water clarity distribution in the Kerinci Lake waters using Landsat 8 in 2nd June 2013. Kerinci Lake waters had a low TSS concentration in the center part of lake area, and high TSS concentration along the lake shoreline area. The highest concentration of TSS along lake shoreline area was thought due to soil erosion in catchment area carried by rivers into the lake waters as well as soil erosion that occurred along the lake shoreline area. As mentioned in the previous discussion, water clarity in Kerinci Lake waters had an inverse correlation with TSS concentration. The water clarity was greater than 2 m in the center part of lake waters, but in general, most of the Kerinci Lake water had water clarity less than 2 m.

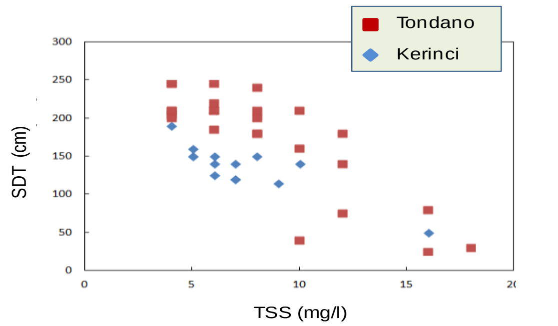

Figure 3-1: Measurement data of TSS and water clarity in Kerinci and Tondano Lake waters

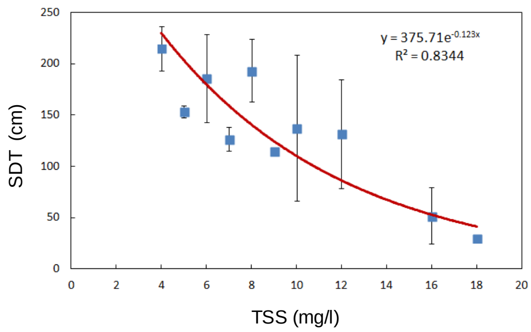

Figure 3-2: Relationship between TSS and water clarity in exponential model

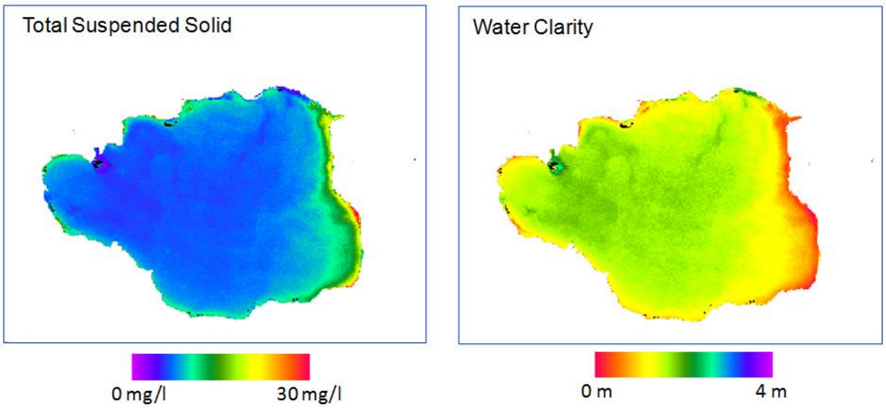

Figure 3-3: TSS and water clarity distribution in Kerinci Lake waters using Landsat 8 (2nd June 2013) in Jambi Province

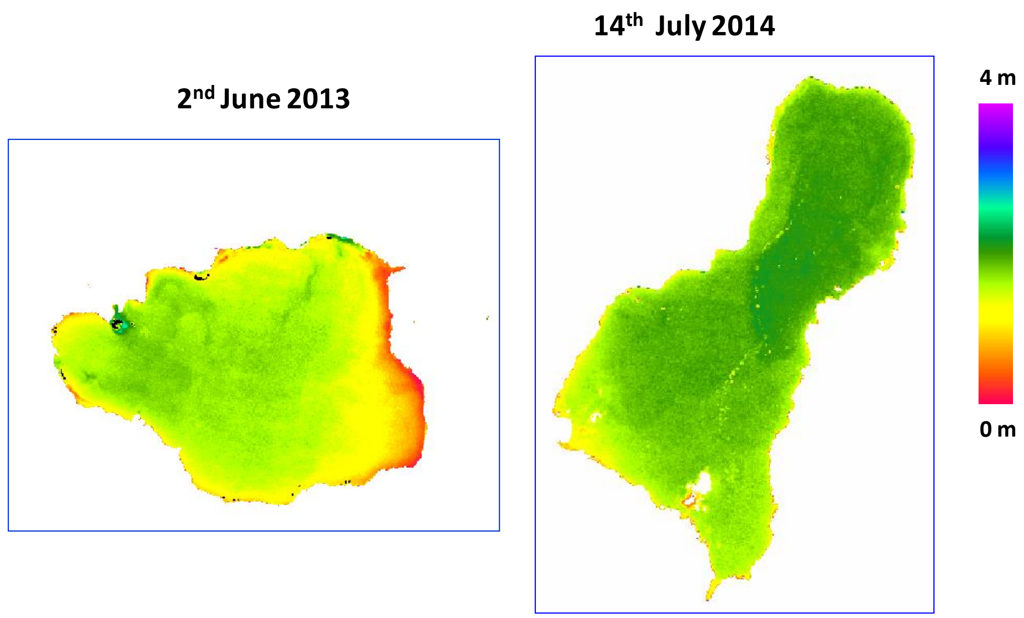

Figure 3-4: Comparison of water clarity in Kerinci Lake waters in Jambi Province (left) and that in Tondano Lake waters in North Sulawesi Province (right)

Figure 3-4 shows a comparison of water clarity in the Kerinci Lake waters and water clarity in Tondano Lake waters. The water clarity in Tondano Lake waters had values ranging from 2 m to 3 m, but in some parts of Tondano Lake waters had water clarity less than 2 m. Comparing to Tondano Lake waters, Kerinci Lake waters had lower water clarity. It indicates that the quality of Tondano Lake waters was still better compared to Kerinci Lake waters. This result is consistent with the results obtained from our field measurement which indicates that the water clarity in Tondano lakes was higher than that in the Kerinci Lake (Figure 3-1). This water clarity of Tondano Lake was also confirmed by the result from another researcher (Sudarmaji et al. 2012) who reported that based on the field measurement in 2010, the water clarity in Tondano Lake was about 2-3 meter. Further Wahyono (2012) explained that one profession of people who lives near Kerinci Lake was sand miner, so there were several sand mining area located in surrounding Kerinci Lake. The existentialists of sand mining areas were thought to increase the water turbidity and decrease the water clarity of the Kerinci Lake waters.

4 CONCLUSION

The developed algorithm this research has the high determination coefficient that reaches to 0,834. Implementation of the algorithm for Landsat 8 data in 2013 and 2014 showed that the water clarity in Kerinci Lakes waters was around 2 m or less, but the water clarity in Tondano Lake waters was around 2 – 3 m. It means that Kerinci Lake waters had lower water clarity than Tondano Lake waters. This result is consistent with the results obtained from field measurement and information reported from the previous publication.

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