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Multi-Temporal Chlorophyll-A Monitoring in Lake Matano and Towuti Using Landsat 8 OLI Imagery

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Abstract

Lake Matano and Towuti are two of 15 lake priorities in Indonesia. For conservation purposes, a routine water quality monitoring from satellite is needed. In this study, 11 scenes of Landsat 8 data were processed to produce chlorophyll-a concentration as an indicator of water quality condition on these two lakes. The result showed that water quality in Lake Matano and Towuti were in low cholorphyll-a condition with chlorophyll-a concentration ranged from 0.000– 2.298 mg/m^3, 0.000-2.236 mg/m^3, respectively. The accuracy of estimated Chlorophyll-a in these two lakes were affected by an inaccurate of atmospheric corrected data. To improve the accuracy, a more accurate atmospheric correction algorithm for Landsat 8 was still required.

Keywords: Water Quality Monitoring, Chlorophyll-a, Landsat-8, Multi-temporal monitoring, Matano, Towuti

1. Introduction

As an in-land water ecosystem environment, Lake is vital for human life. Not only as source of drinking water and water resources for daily purposes, lake is additionally utilized as a water transportation medium, irrigation, tourism, and fisheries. The eccesive use of lake and its surrounding area causing the ecosystem condition of the lake encountering progressively overwhelming degradation to date (Bunkei Matsushita, Wei Yang, Lalu Muhamad Jaelani, Fajar Setiawan, & Takehiko Fukushima, 2016; Fukushima T., Matsushita B., Oyama Y., 2014; Haryani, 2013; L. M. L. M. Jaelani, Matsushita, Yang, & Fukushima, 2013).

In Indonesia, the efforts to save the ecosystem of 15 lake priorities are intended to restore, preserve and maintain the functionality of lake based on the principle balance of the ecosystem and the carrying capacity of the environment (Kementerian Lingkungan Hidup Republik Indonesia, 2011).

To save lake ecosystem condition from heavy degradation, a regular monitoring of lake water quality parameters such as chlorophyll-a (chl-a), colored dissolved organic matter (CDOM) and total suspended solid (TSS), become an urgently needed by considering the spatially and temporally heterogeneity aspects of lake water (Bunkei Matsushita et al., 2016; L. M. Jaelani et al., 2016; Matsushita, Jaelani, Yang, Oyama, & Fukushima, 2015). A lack of conventional sampling technique for monitoring remote and wide area of lake was overcame by untilization of remote sensing technique (Gholizadeh, Melesse, & Reddi, 2016; Haji Gholizadeh, Melesse, & Reddi, 2016; Liu, Islam, & Gao, 2017). The objective of this study was to extract Chlorophyll-a concentration from remotelly sensed data as an indicator of water quality on Lake Matano and Towuti by implementing an existing parameter retrieval algorithm for 4 years Landsat 8 data.

2. Methods

2.1 Study Area

Lake Matano (2.494º S; 121.369º E) and Lake Towuti (2.799º S; 121.51º E) are situated in East Luwu Regency, South Sulawesi Province. With the depth of 595 m (203 m is under sea level), Lake Matano (area of 164.08 km^2) is the eighth deepest lake in the world and the deepest lake in Asia region. Near this lake, there is Lake Towuti with an area of 561.08 km^2 (the second largest lake in Indonesia after Lake Toba in North Sumatera) with a depth of about 200 meters. Both are freshwater ecosystems that stream into the Larona and Malili Rivers (Indonesia's Ministry of Maritime Affairs and Fisheries & Kementrian Kelautan dan Perikanan, 2011; L. M. Jaelani, Setiawan, & Matsushita, 2015; LIPI, 2016).

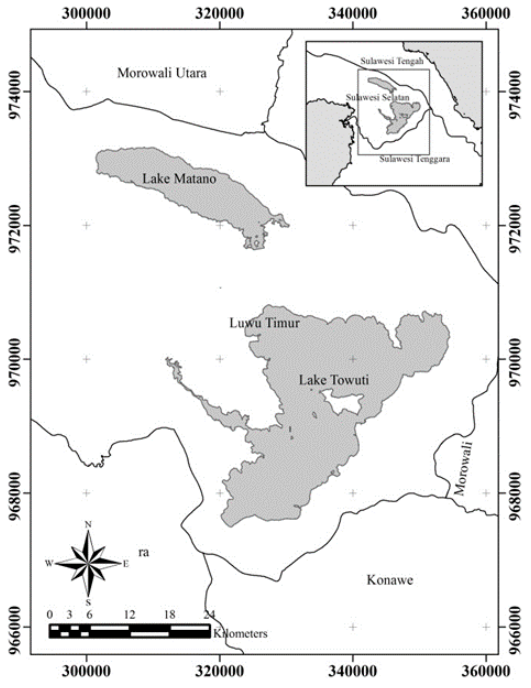

Figure 1. Study Area: Lake Matano (top), Lake Towuti (bottom)

2.2 Tools and Data

The data used in this research were 11 scenes of Landsat 8-OLI data acquired within 2013 and 2016. The digital number was callibrated and atmospheric corrected by NASA to produce surface reflectance. This Landsat 8 product was publicly availabe at ESPA website (https://espa.cr.usgs.gov/) and earth explorer (https://earthexplorer.usgs.gov/) . In this study, all data were processed using SNAP and ArcGIS software.

2.3 Research Methods

At the first processing step, an uncalibrated surface reflectance of Landsat 8 was calibrated in order to produce remote sensing reflectance *Rrs(λ)* by dividing all data with 10,000 and π. Theoretically, all *Rrs(λ)* should be valued within the range of 0.0 and 1.0. To avoid an invalid result in calculation, other value less than 0.0 was set into 0.00001 and value greater than 1 was set to 1.0.

For estimating Chl-a concentration, a Chl-a retrieval algorithm developed by Jaelani (L. M. Jaelani, Setiawan, Wibowo, & Apip, 2015) that was developed by using in-situ Chl-a collected on Lake Matano and Lake Towuti as well as its in-situ apparent optical parameter was used.

This algorithm was implemented using Landsat 8 and Sentinel 2 data:

$$\log(Chl-a) = -0.9889\frac{Rrs_{(\lambda_4)}}{Rrs_{(\lambda_5)}} + 0.3619 \text{..... (1)}$$

Rrs(λ_4) and Rrs(λ_5) are remote sensing reflectance of Landsat 8 at band 4 and 5, respectively.

3. Results and Discussion

The spatial and temporal distribution of Chl-a concentration was presented in Figure 2. The highest Chl-a concentration (green color) occurred in shallow water areas (e.g. near bank area), while a very low concentration (red) occurred in the deep waters (e.g. central lake). This condition was because in the shallow waters there are many suspensions that result in ineffective photosynthesis process one of which high water turbidity value (Sumich, 1992). Thus, the intensity of light is very small. This is inversely proportional to the increasingly large TSS values in shallow water areas. The Chl-a concentration in Lake Towuti and Matano as estimated from multi-temporal data of Landsat 8 (2013-2016) was ranged from 0.0 to 2.3 mg/m^3. Following the study of Wetzel (2001) that classified the waters by its water constituents, It was indicated that both Lakes were in natural or oligotrophic waters type. As presented in Table 2, the highest average concentration of Chl-a occurred on May 30, 2016 (1.666 mg/m^3) and the lowest on October 19, 2015 (0.169 mg/m^3). Chl-a concentrations generally reached the peak values in the dry season (April-October) and the lowest in the rainy season (November-May). One reason is, in dry season the intensity of light penetrating waters is very high and shows the relationship with the dynamics of Chl-a concentration in these waters. The intensity of the light will cause chlorophyll to effectively process photosynthesis (Abigail, Zainuri, Tisiana, Kuswardani, & Setiyo, 2015).

Table 1 Chl-a Concentration (in mg/m^3) in Lake Matano and Towuti

Date	Min	Max	Ave.	Std
20/04/2013	0.000	2.300	0.488	0.662
13/10/2013	0.000	2.301	0.497	0.746
29/10/2013	0.000	2.299	1.418	0.872
14/09/2014	0.000	2.300	0.950	0.888
15/07/2015	0.000	2.300	1.171	0.870
17/09/2015	0.000	2.298	0.819	0.785
19/10/2015	0.000	2.299	0.169	0.431
20/11/2015	0.000	2.299	0.384	0.551
7/1/2016	0.000	2.299	0.319	0.571
30/05/2016	0.000	2.300	1.666	0.717
3/9/2016	0.000	2.299	0.561	0.682

However, in this study, in October the concentration was fluctuate. This happens because October is the month of transition from dry to rainy season. The changing conditions of seasons in Indonesia in recent years were also uncertain. Temporally, the Chl-a concentration in Lake Matano and Towuti were very varied and fluctuate. In Lake Matano, the average distribution of Chl-a was quite high in the dry season of July 15, 2015, September 14, 2014, September 17, 2015. While the lowest distribution occurred in the rainy season and the transition period (April 20, 2013 and October 19, 2015). For the highest concentration occurred at sample of point 16 (shallow waters) on October 13, 2013 with a value of 2.298 mg/m^3 and the lowest of 0.00 mg/m^3 was scattered at several points (shallow waters, deep,

inlet area). In Lake Towuti, the average Chl-a concentration was high in the dry season between October 29, 2013 and May 30, 2016. While the lowest concentration was occurred in the rainy season and the transition period (January 7, 2016; October 19, 2015; and November 20, 2015). The highest Chl-a concentration occurred at sample point of 10 (inlet area) on October 13, 2013 (2.297 mg/m^3) and the lowest concentration (0.00 mg/m^3) spread on shallow waters and inlet area. The chl-a

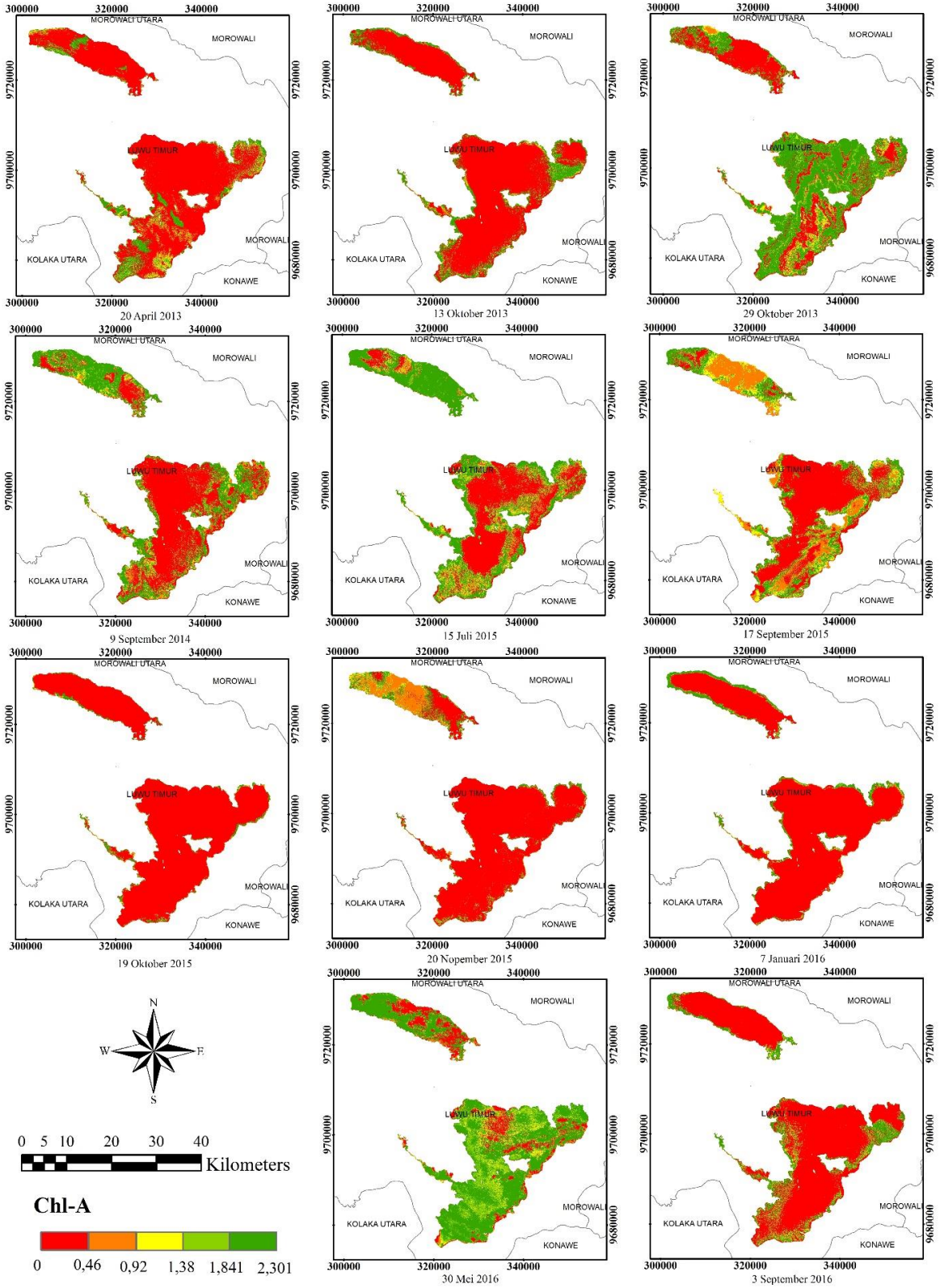

Figure 2. Chl-a Distribution Map

concentration produced from atmospheric corrected data of Landsat remained some strange values on inlet area (shallow and turbid water) and central lake (deep and clear water). On inlet area, a negative value of $Rrs(\lambda_4)$ and $Rrs(\lambda_5)$ made chl-a algorithm retrieval produced 0.236 mg/m3. While on central lake, the negative value of $Rrs(\lambda_5)$ (and $Rrs(\lambda_4)$>1.00) produce Chlorophyll-a concentration of 0.000 mg/m^3. This condition indicated that an inaccurate Chlorophyll-a concentration was affected by an inaccurate of atmospheric corrected data as found by Jaelani at al (2015). Then, to improve the accuracy, a more accurate atmospheric correction algorithm for Landsat 8 was required.

6. Conclusion

We have processed 11 scenes of remotely sensed data of Landsat 8 to obtain Chlorophyll-a concertation as water quality in Lake Matano and Towuti. The result showed that water quality in Lake Matano and Towuti were in low chl-a concentration with the value ranged from 0.000-2.298 mg/m^3 and 0.000-0.236 m^3, respectively. This result still similar with chl-a estimating using Sentinel-2 data where the Chl-a ranged from 0-2.3 mg/m^3 (L. M. Jaelani & Ratnaningsih, 2018).

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