

## Spatial and Temporal Analysis of Water Quality Parameter using Sentinel-2A Data; Case Study: Lake Matano and Towuti

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**Abstract**— Lakes are very important for human life in term of ecology and hydrology as the sources of fresh water, the ecosystem of aquatic life and control system to the local micro-climate. Lake Matano and Towuti in South Sulawesi Province are two of 15 priority lakes in Indonesia that need to be preserved from degradation. For preservation purposes, a routine water quality monitoring from the satellite is needed. Currently, there are many satellite images that can be used for extracting water quality parameters such as TSS, Chl-a, and CDOM. In this research, we implemented the use of medium resolution optical satellite image to extract more detail information from lake waters. We have processed remotely sensed data acquired by Sentinel 2 sensor to obtain these water quality parameters. The result showed that water quality in Lake Matano and Towuti were in healthy condition with TSS, Chl-a and CDOM ranged from 1 - 60 mg/m<sup>3</sup>, 0-2.3 mg/m<sup>3</sup> and 0.010 -0.170 m<sup>-1</sup>, respectively.

**Keywords**— TSS, Chl-a, CDOM, water quality

### I. INTRODUCTION

Lake is an inland water ecosystem which is very important for human life. In addition to be a source of drinking water and water resources for everyday purposes, the lake is also used as a source of industrial raw water, water transportation, irrigation, tourism, and sources of protein from fisheries. Utilization of the multisector and the existence of activity in the area around the lake causing the ecosystem condition of the lake experiencing increasingly heavy degradation to date [1]–[4].

In Indonesia, efforts to save the lake ecosystem is intended to restore, preserve and maintain the functionality of lake based on the principal balance of the ecosystem and the carrying capacity of the environment through some programs. The programs include management of lake ecosystem, utilization of lake water resources, systems development for lake information, monitoring and evaluation, preparation for climate change adaptation and mitigation, capacity building, and increasing community roles and sustainable financing[5].

Lake Matano and Lake Towuti are two of 15 priority lakes in Indonesia located in South Sulawesi Province [6]. Lake Matano has a depth of 595 m, or the bottom of the lake is at 203 m under sea level. It is known as the eighth deepest lake in the world and the deepest lake in Southeast Asia. The area of this lake is 16,408 hectares with an axis extending 28

km in the east-west direction. Not far from this lake, there is Lake Towuti with an area of 56,108 hectares (the second largest lake in Indonesia) with a depth of about 200 meters. Both are freshwater ecosystems that flow into the Larona and Malili Rivers [7].

To save lake ecosystem condition from heavy degradation, a regular monitoring of lake water quality such as chlorophyll-a (Chl-a), colored dissolved organic matter (CDOM), secchi disk depth (SDD), turbidity, total suspended solids (TSS), surface temperature, total phosphorus (TP), sea surface salinity (SSS), dissolved oxygen (DO), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) become an urgently needed by considering the heterogeneity aspects of lake water, both spatially and temporally. Remote sensing technology that has experienced rapid development has a vital role in supporting and covering the lack of conventional sampling techniques [8]–[10].

The objective of this study was to monitor the water quality (i.e., TSS, Chl-a, and CDOM) of Lake Matano and Towuti with spatial and temporal aspects using Sentinel-2A data.

### II. MATERIAL AND METHOD

#### A. Tools and Data

The data used in this research were 2 scenes of Sentinel-2 data (T51MUT and T51MUS) with an acquisition date of November 2015, February 2016, March 2016, August 2016,

October 2016, December 2016, February 2017 and April 2017. All data were processed using SNAP and related software.

### B. Research Method

At the first processing step, a raw data of Sentinel 2A was corrected from atmospheric effect using a tool of Sen2Cor. This tool is a processor in SNAP software for converting Sentinel-2 product Level 1C to Level 2A, performing atmospheric correction and cirrus correction. The main function of Sen2Cor is to produce bottom-of-atmospheric (BOA) reflectance from top-of-atmospheric data. The output product format is equivalent to Level 1C product (i.e., JPEG 2000) with three different resolutions of 60, 20 and 10 m [11]. BOA reflectance then calibrated by dividing with  $10,000 * \pi$  to produces remote sensing reflectance ( $R_{rs}(\lambda)$ ) [12].  $R_{rs}(\lambda)$  of related bands were inputted into corresponding TSS, Chl-a and CDOM algorithms.

For estimating TSS from  $R_{rs}(\lambda)$ , the Landsat 8 -TSS algorithm developed by Jaelani [13] was modified following band characteristic of Sentinel 2 data. This algorithm was developed based in-situ measured TSS data collected on Poteran and Gili Iyang waters as well as its corresponding in-situ  $R_{rs}(\lambda)$ .

$$\log(\text{TSS}_{\text{Jaelani}}) = 1.5212 \left( \frac{\log R_{rs}(\lambda_2)}{\log R_{rs}(\lambda_3)} \right) - 0.3698 \quad (1)$$

$R_{rs}(\lambda_2)$  and  $R_{rs}(\lambda_3)$  are remote sensing reflectance of Sentinel 2 at band 2 and 3, respectively.

For estimating Chl-a concentration, a Chl-a retrieval algorithm developed by Jaelani [6] using in-situ Chl-a collected on Lake Matano and Lake Towuti, as well as its in-situ  $R_{rs}(\lambda)$ , was used. This algorithm was implemented using Landsat 8:

TABLE I  
WATER QUALITY PARAMETERS AT THE CENTER OF LAKE MATANO  
(2.484150764S , 121.3539268E)

Date	Chl-a (mg/m <sup>3</sup> )	TSS (g/m <sup>3</sup> )	CDOM (mg/m <sup>3</sup> )
14-Nov-15	0.17546	15.9375	0.126959
2-Feb-16	0.260839	12.3292	0.082466
3-Mar-16	0.849682	14.171	0.106585
30-Aug-16	0.544841	9.394	0.027488
29-Oct-16	0.288234	12.3203	0.08257
8-Dec-16	0.612032	10.0125	0.067023
16-Feb-17	0.7959	17.6777	0.17021
17-Apr-17	0.817335	8.6933	0.010379

$$\log(\text{Chl-a}_{\text{Jaelani}}) = -0.9889 \left( \frac{R_{rs}(\lambda_2)}{R_{rs}(\lambda_3)} \right) + 0.3619 \quad (2)$$

$R_{rs}(\lambda_4)$  and  $R_{rs}(\lambda_8)$  are remote sensing reflectance of Sentinel 2 at band 4 and 8, respectively.

The CDOM algorithm used in this study was the Mannino algorithm [14]. This algorithm was based on in-situ data collected on Northeast US Coast and its corresponding MODIS data.

TABLE II  
WATER QUALITY PARAMETERS AT THE CENTER OF LAKE MATANO  
(2.484150764S , 121.3539268E)

Date	Chl-a (mg/m <sup>3</sup> )	TSS (g/m <sup>3</sup> )	CDOM (mg/m <sup>3</sup> )
14-Nov-15	0.191911	15.9074	0.131979
2-Feb-16	0.177577	12.9258	0.087681
3-Mar-16	0.73697	12.0919	0.073813
30-Aug-16	1.45922	9.87501	0.036643
29-Oct-16	0.248026	13.3807	0.097131
8-Dec-16	0.310219	10.232	0.049837
16-Feb-17	0.305802	12.9053	0.091698
17-Apr-17	0.135291	10.8564	0.057182

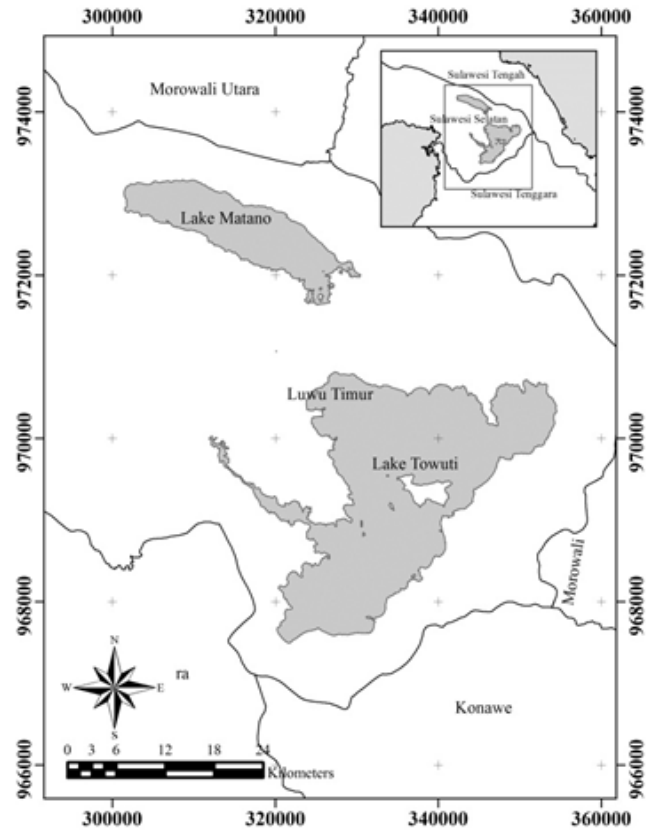


Fig. 1 Study area

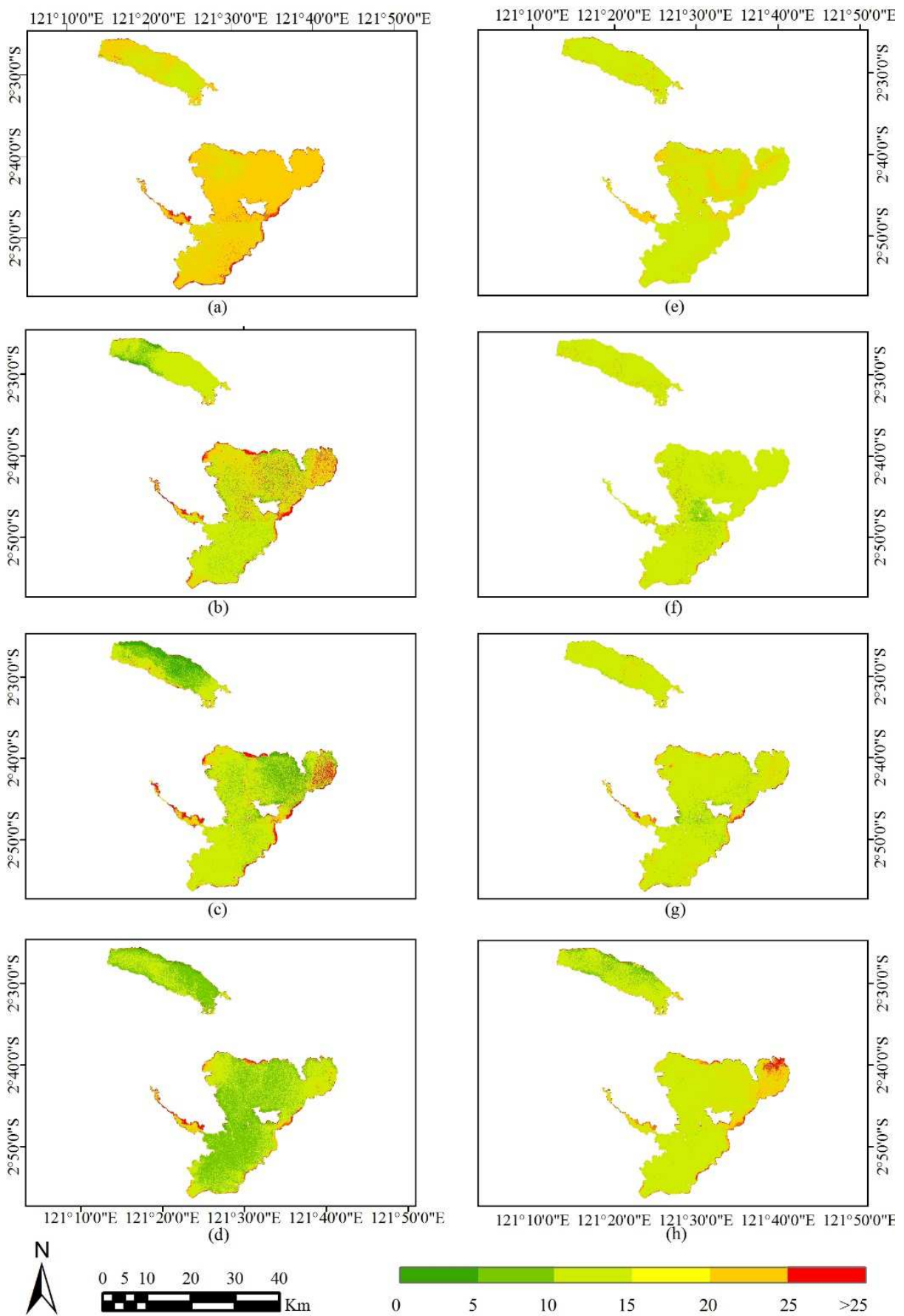


Fig. 2 TSS Concentration map (a) November 2015, (b) February 2016, (c) March 2016, (d) August 2016, (e) October 2016, (f) December 2016, (g) February 2017, (h) April 2017

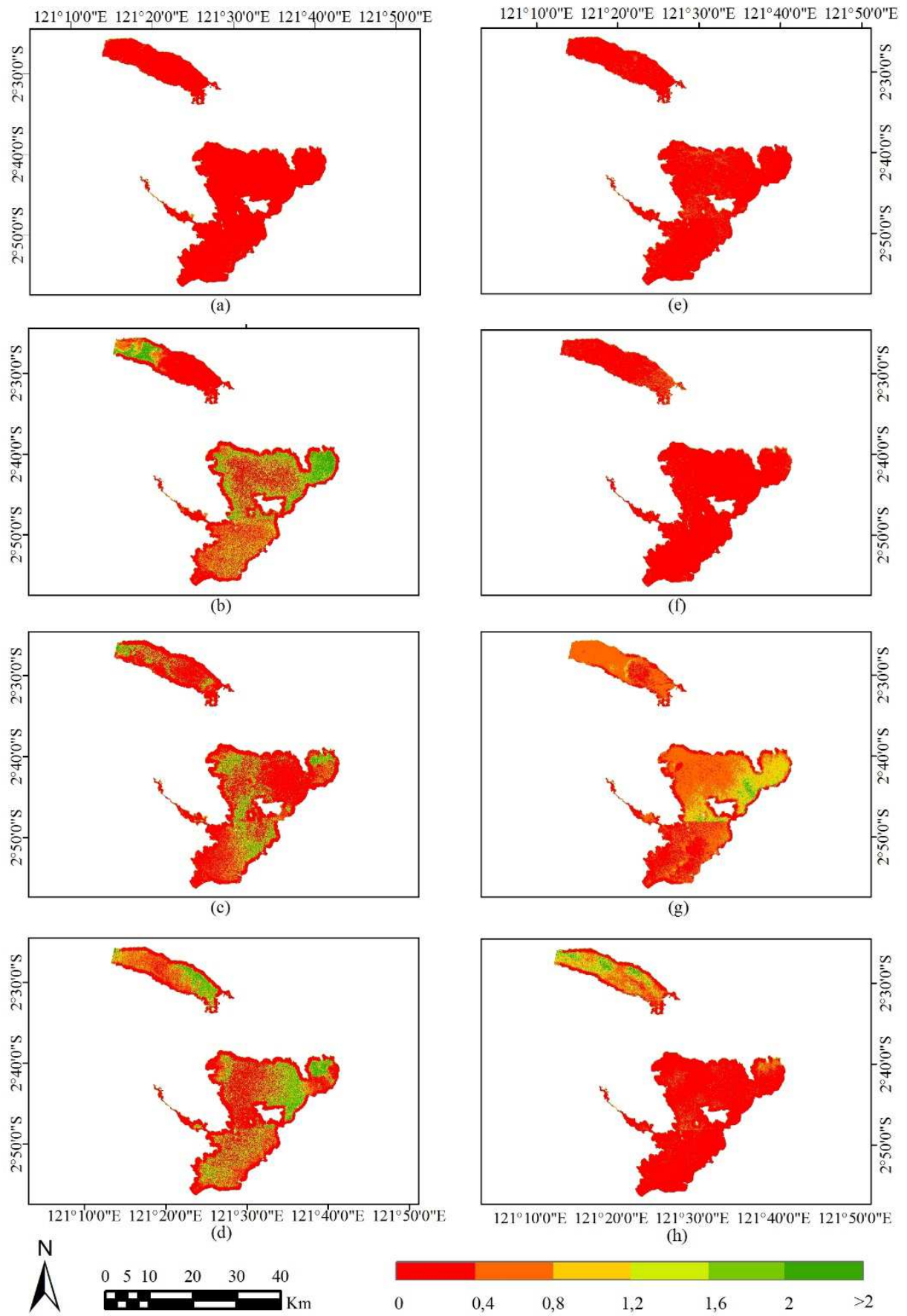


Fig. 3 TSS Concentration map (a) November 2015, (b) February 2016, (c) March 2016, (d) August 2016, (e) October 2016, (f) December 2016, (g) February 2017, (h) April 2017

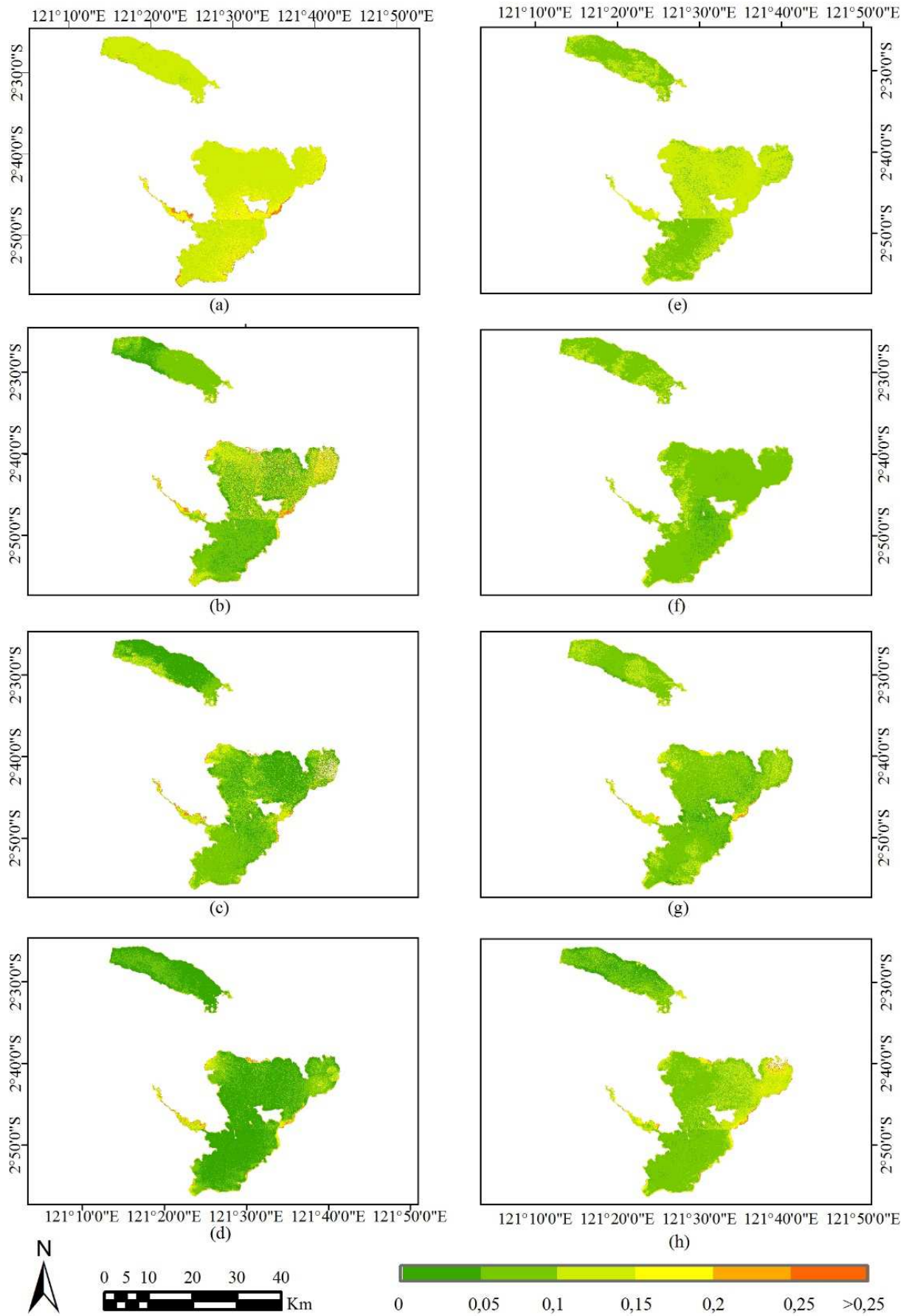


Fig. 4 CDOM concentration map (a) November 2015, (b) February 2016, (c) March 2016, (d) August 2016, (e) October 2016, (f) December 2016, (g) February 2017, (h) April 2017



$$\text{CDOM}_{\text{Maninno}} = -0.0736 \ln \left( \frac{\log R_{rs}(\lambda_2)}{\log R_{rs}(\lambda_3)} \right) - 0.1736 \quad (3)$$

$R_{rs}(\lambda_2)$  and  $R_{rs}(\lambda_3)$  are remote sensing reflectance of Sentinel 2 at band 2 and 3, respectively.

### III. RESULTS AND DISCUSSION

#### A. Total Suspended Sediment

Estimated TSS concentration calculated using Equation (1) was presented in Table 1 and 2. The highest value occurred in February 2017 for Lake Matano with TSS of 17.678 mg/m<sup>3</sup> and in November 2015 for Lake Towuti with TSS of 15.907 mg/m<sup>3</sup>. The lowest value occurred in April at Matano lake (8,693 mg/m<sup>3</sup>) and lake Towuti in August (9.875 mg/m<sup>3</sup>).

Overall calculation result, TSS concentration ranged from 1 - 60 mg/m<sup>3</sup>. However, TSS of 25 to 60 mg/m<sup>3</sup> were very rare, and those values occurred on shallow water conditions. Figure 1. showed the highest concentration of TSS in shallow waters close to the lake bank and inlet water stream while the lowest concentration occurred in the center of the lake.

In general, the concentration of TSS in Lake Towuti and Matano was no negative effect on the lake ecosystem. According to Alabaster and Lloyd [15], the value of TSS <25 mg/m<sup>3</sup> does not affect fisheries. The values of 25 - 80 mg/m<sup>3</sup> is slightly influential. The value highest than 81 mg/m<sup>3</sup> is harmful to fisheries.

#### B. Chlorophyll-a

The concentration of chlorophyll-a estimated by Sentinel-2 data from November 2015 to April 2017 showed that Lake Towuti and Matano were in natural or oligotrophic waters condition. According to Wetzel [16], oligotrophic lakes have a chlorophyll-a range of 0.3 - 3 mg/m<sup>3</sup>. In this study, the same conclusions obtained from research on chlorophyll-a concentration in Lake Towuti conducted by Sulastri et al. [17] with Chl-a of 0 - 0.415 mg/m<sup>3</sup>. Our result by using Sentinel-2 data has Chl-a ranged from 0-2.3 mg/m<sup>3</sup>.

On the observation of chlorophyll-a as presented in Table 1 and 2, the highest Chl-a on Lake Matano occurred in March 2016 and the lowest in February 2016. On Lake Towuti, the highest concentration occurred in August 2016 and the lowest in April 2017. The concentration of Chl-a has the highest value in summer (October - April), the lowest is in winter (May - September) [18]. Because in the summer the intensity of light in the waters is very high and shows the relationship with the dynamics of chlorophyll-a concentration in these waters. The intensity of the light will cause chlorophyll to process photosynthesis effectively [19]. The condition of the dry season in Indonesia in 2016 and then experienced a wet dry season, only 26 percent of the region of Indonesia that suffered drought [20]. It can be concluded that the seasons cannot be a determinant of the increase or decrease of Chl-a.

The distribution map of chlorophyll-a can be seen in Figure 3. The figure showed the highest distribution of Chl-a were in the deepwater region and low concentration on shallow waters. On shallow waters, many suspensions resulted in an ineffective process of photosynthesis [21].

This condition contrasted with the increasing concentration of TSS in shallow water areas.

#### C. Colored Dissolved Organic Matters

The highest CDOM concentrations occurred in February 2017 for Lake Matano and in November 2015 for Towuti with the CDOM of 0.170 m<sup>-1</sup> and 0.132 m<sup>-1</sup> respectively. The lowest CDOM of 0.010 m<sup>-1</sup> in April 2017 for lake Matano and 0.037 m<sup>-1</sup> in August 2016 for Lake Towuti.

CDOM concentration was driven by season. CDOM vary seasonally, with higher values in spring due to melt-water run-off from rivers [22] and higher photo-bleaching of CDOM in summer [23].

### IV. CONCLUSION

We have processed remotely sensed data acquired by Sentinel 2 sensor to obtain water quality parameters such as TSS, Chl-a, and CDOM. The result showed that water quality in Lake Matano and Towuti were in healthy condition with TSS, Chl-a and CDOM ranged from 1 - 60 mg/m<sup>3</sup> 0-2.3 mg/m<sup>3</sup> and 0.010 -0.170 m<sup>-1</sup>.

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