Application of Landsat 8 OLI Image and Empirical Model for Water Trophic Status Identification of Riam Kanan Reservoir, Banjar, South Kalimantan

A N Saputra1*, P Danoedoro2 and M Kamal3

1Remote Sensing Masters Program, Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, 55281
2Department of Geographic Information Science, Remote Sensing Program, Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, 55281
3PUSPICS, Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, 55281

aswin.geografi@gmail.com

Abstract. Remote sensing has a potential for observing, mapping and monitoring the quality of lake water. Riam Kanan is a reservoir which has a water resource from Riam Kanan River with the area width of its watershed about 1043 km². The accumulation of nutrient in this reservoir simultaneously deteriorates the condition of waters, which can cause an increasingly growth of harm micro algae or Harmful Algal Blooms (HABs). This research applied Carlson’s trophic status index (CTSI) at Riam Kanan Reservoir using Landsat-8 OLI satellite image. The Landsat 8 OLI image was recorded on 14 August 2016 and was used in this research based on its surface reflectance values. The result of correlation test shows that band 3 of the image as coefficient of chlorophyll-a parameter, channel 2 as coefficient of phosphate, and band ratio of SDT as coefficient of SDT. Based on the result of modelling using CTSI, the majority scale of CTSI score at Riam Kanan Reservoir is between 60 to 70 in medium eutrophic class. The class of medium eutrophic at Riam Kanan Reservoir potentially emerges the threat both of the improvement of water fertility and the reduction of water quality. Improvement of the fertility is apprehensive since it can trigger an explosion of micro algae which will endanger the ecological condition at the area of Riam Kanan Reservoir.

Keywords: Landsat-8 OLI, Eutrophic, Carlson’s trophic status index, HABs

1. Introduction
A rising of eutrophication at Riam Kanan Reservoir waters will cause another effect that is the growth of the potential of HABs (Harmful Algal Blooms) [1]. It is because of the rate of eutrophication, which keeps on rising; make the growth of the micro algae type of Microcystis sp. also increases [2]. Eutrophication level that always keeps rising every year does not only increase the potential of HABs, but also causes the negative effect on ecological condition of reservoir, such as massive death of millions fish because of ammonia poisoning. That case is not added yet by potential of danger when HABs is happened. The danger which will be emerged is not only to the ecology of the reservoir but also to the...
humans around the reservoir who use it for their daily life. Thus, it is important to know the distribution level of eutrophication that potentially happens to HABs at Riam Kanan Reservoir waters.

An increasing of nutrient in the reservoir comes from some sources. Generally, the resource of the nutrient comes from inlet area of the reservoir, while the source of water of the reservoir comes from inlet area that consists of some stream branches. The potential source on increasing the nutrients and pollution in the reservoir are waste from the population, industry, agricultural, and livestock.

The use of remote sensing image to observe waters quality especially for eutrophication study and *Harmful Algal Blooms* (HABs) to map the distribution has been widely used [3][4][5][6]. The previous research concerning of HABs was done more on using image with higher spectral resolution on lower spatial resolution. Observation of waters land quality needs remote sensing image with bigger spatial resolution. The use of Landsat-8 OLI is tended to fulfil the need.

2. Methodology

This research was done at Riam Kanan Reservoir which has the wide 9.200 ha on flood water, and 1200 million m³ volume on normal water. Riam Kanan Reservoir is a reservoir which has a water resource from Riam Kanan River with the wide of watershed is 1043 km². Riam Kanan Reservoir or Pangeran Mohammad Noor Reservoir is located in Aranio sub district, Banjar Regency, South Kalimantan. In this research, the data which was used was 1T level data that has been geometrically corrected automatically and the atmosphere disturbance has been also removed. Image conversion as the TOA reflectance value was done based on algorithm which was issued by United States Geological Survey (USGS), then was followed by relative atmospheric correction using the dark object subtraction (DOS) to generate image with surface reflectance value. The next process was image masking process which was limited to only cover land area and masking area based on the range of the pixel value on water and land as well by utilizing a range value of transformation of NDVI.

![Figure 1. Research area](image)

The result of image on masking then was being extracted by pre field primary data. Data extraction was done through the processing of digital image using spectral transformation with band ratio method. Band ratio method was used algorithm that has been generated by previous research on each parameter to be measured in the field which included transparency of Secchi Disk [7], that is:

$$\ln(\text{SDT}) = \frac{B1}{B3}(1.3083) + B1(-0.0631) + (-1.2937)$$  

(1)
Clorophyll-a with algorithm [8] :

\[ \ln(\text{Chl}) = 9.82(TM1 - TM3)/TM2 \]  

(2)

and algorithm for total of phosphor [9] :

\[ \ln(\text{TP}) = -21.45(TM3/TM2) - 14.42(TM1/TM3) + 42.99(TM1) + 27.1 \]  

(3)

Where:

- \( \ln(\text{SDT}) \) = Natural logarithm from the depth of Secchi Disk transparency
- \( \ln(\text{Chl}) \) = Natural logarithm from chlorophyll-a
- \( \ln(\text{TP}) \) = Natural logarithm from total of phosphor
- TM1 = Reflectance value band 1 Landsat-5 TM
- TM2 = Reflectance value band 2 Landsat-5 TM
- TM3 = Reflectance value band 3 Landsat-5 TM

The result of transformation of band ratio would then be overlaid in which the result was used as a tentative map of the research and was used to determine the distribution of the sample. The sample was taken by stratified random sampling method based on classification of overlay result.

Furthermore, the score of content on each parameter in the field would be tested by accuracy test of the score from resulted image. Besides using the resulted image of band ratio between parameter of trophic status, image and real band were also included to be correlated to the score in the field. The highest input correlation then was tested by accuracy test of content score on each parameter in the field. Based on accuracy test above, then regression test was done between content score in the field and image score for spatial modelling to be done empirically. The image result of empirical modelling then was combined based on trophic status index by [10] so that it was obtained the trophic status at Riam Kanan Reservoir.

3. Results and Discussion

3.1. Statistical Analysis of Trophic Parameter

Empirical modelling was done by using statistical analysis between the pixel value of image on a tentative map parameter and the result of field measurement. Statistical analysis was used linear regression analysis. The result of sampling in the field then tested in the laboratory for the parameters of total phosphor and chlorophyll-a. The result of parameter in the laboratory and in the field then was converted into natural logarithm. The distribution for each sample was tested using normality test of sampling then was correlated between sample score and pixel value by using SPSS software.

In the correlation which was done to chlorophyll-a, the most important predictor was on band 3 (\( r = 0.46 \)) compared to alogarithm on initial estimation. Whereas for SDT, there were three predictors which have the same important correlation (\( r = 0.28 \)); however, predictor alogarithm 2 was taken as an initial alogarithm in spectral transformation to estimate the initial distribution. On phosphate, the most influential predictor was on band 2 (\( r = 0.48 \)) compared to alogarithm on initial estimation.

Accuracy test was also done between content score of chlorophyll-a (mg/L), phosphate (mg/L), and SDT (m) in the field and the predictor which has the highest correlation on each parameter. Based on the accuracy test, it is obtained that the score of chlorophyll-a RMSE is higher than the score of other RMSE.

| Parameter                        | RMSE    |
|----------------------------------|---------|
| Chlorophyll-a                    | 0.011760836 |
| Phosphate                        | 0.529959  |
| Transparency of Secchi Disk      | 1.13172707 |

Source: Analysis of Data (2016)
Then, on the result of linear regression statistical analysis of data showed that there was a low determinacy coefficient between the result of field data for chlorophyll-a and reflectance value on the green band of Landsat-8 OLI image. This was possible since water of reservoir has already mixed with the rainwater. In addition, it was also possible since the peak of productivity of micro algae in the water reservoir has already passed.

![Chlorophyll-a](image1)

**Figure 2.** Graphic of linear regression of chlorophyll-a parameter  
Source: Analysis of Data (2016)

Regression and correlation on phosphate on Figure 3 were compared to chlorophyll-a showed that there was an increasing of phosphorus content which was compared to a decreasing of chlorophyll-a. There was a possibility that the peak of micro algae productivity occurred between 14 August (image recorded) and 15 September (field measurement) then the number of micro algae declined. This possibility was strengthening by the result of a high regression (R) and determinacy (R²).

![Phosphate](image2)

**Figure 3.** Graphic of linear regression of phosphate parameter  
Source: Analysis of Data (2016)

The result of regression on SDT as shown in Figure 4 showed the level of sun translucency in water that relatively correlated with regression result and analysis of phosphate regression. Therefore, there was a possibility of low connection of reservoir permeability and the level of total phosphor in the water of reservoir.

\[ y = 55.244x + 1.2547 \]
\[ R^2 = 0.2555 \]

\[ y = -178.95x + 7.3518 \]
\[ R^2 = 0.2535 \]
3.2. Analysis of Carlson Trophic Status
The result of regression which was done on each parameter, then was being modelled for trophic status of reservoir water by using trophic status index by [10] that was developed based on 3 parameters, they are chlorophyll-a, total of phosphor, and transparency of Secchi Disk with the formulas as follows:

a. TSI for water transparency

\[ TSI\ (SD) = 60 \times 14,41 \times \ln \text{Secchi depth (m)} \]  

(4)

b. TSI for total of phosphor

\[ TSI\ (TP) = 14,42 \times \ln \text{Total Phosphorus (µg/L)} + 4,15 \]  

(5)

c. TSI for chlorophyll-a

\[ TSI\ (CA) = 9,81 \times \ln \text{Chlorophyll a (µg/L)} + 30,6 \]  

(6)

Carlson’s Trophic State Index

\[ (CTSI) = \frac{[TSI\ (SD) + TSI\ (TP) + TSI\ (CA)]}{3} \]  

(7)

The calculation of Carlson’s trophic status index used the image of empirical modelling result to obtain the trophic status map of Riam Kanan Reservoir. The resulted map is the combination of 3 parameters, they are chlorophyll-a, phosphate, and SDT. The score which is obtained from the calculation index, results the majority of scale score between 60 and 70. The average scores which are obtained from the calculation are fit to trophic status class that are explained in Table 2.

| Score | Trophic Status | Explanation |
|-------|----------------|-------------|
| <30   | Ultraoligotrophic | The fertility of waters is very low. The water is clear, has a high soluble oxygen concentration along year, and reaches hypolimnion zone. |
| 30 – 40 | Oligotrophic | The fertility of waters is low. The water is clear, and there might be anoxic limitation on hypolimnetic zone periodically (DO=0). The fertility of waters is medium. The brightness of the water is in moderate condition, there is an increasing of anoxic changing in hypolimnetic zone, aesthetically it still supports for water sport activities. |
| 40 – 50 | Mesotrophic | |

Figure 4. Graphic of linear regression of SDT parameter

Source: Analysis of Data (2016).
50 – 60 Light Eutrophic
The fertility of water is high. Decreasing in water brightness, hypolimnetic zone is anoxic, there are problems of water plant, only fish that can live in warm water, it supports water sport activities, but needs a treatment.

60 – 70 Medium Eutrophic
The fertility of water is high. Dominated by blue green algae, a clumping is occurred and water plant’s problems are occurred extensively.

70 – 80 Heavy Eutrophic
The fertility of water is high. Heavy *blooming algae* are occurred and water plant forms a layer, such as hyper eutrophic condition.

>80 Hyper eutrophic
The fertility of water is high. Algae clumping are occurred, the death of fish is frequently occurred, water plant is slightly dominated by algae.

---

**Figure 5.** The Distribution of trophic status at Riam Kanan Reservoir
Based on the score that resulted by adjusting to the table of Carlson trophic classification, it is obtained that trophic status at Riam Kanan Reservoir is in medium trophic status. According to [10] area of water that has a medium trophic status is categorized as a high fertility area. This area of water has been dominated by blue green toxic micro algae. The dominated of micro algae has been very extensive and the clumping has been also occurred. The area of water in this condition has a high potential of the explosion of harmful micro algae population or Harmful Algal Blooms (HABs).

4. Conclusions

Based on the result of calculation by using Carlson’s trophic status index, it is obtained that generally; the water condition at Riam Kanan Reservoir is in medium eutrophic status. Trophic status improvement which is occurred at Riam Kanan Reservoir is potentially cause a threat of water fertility improvement as well as water quality reduction. It is feared that the improvement of water fertility can trigger an explosion of micro algae population that will be very harmful to the ecological condition in the reservoir area.

Through the use of method and process which are used in the research, it is also known that the use of band ratio is not always has a high correlation on particular water area. The score of surface reflectance on image has the similarity score to the score of trophic parameter content in the field. Therefore, the use of band ratio can be only used as an approach to the initial estimation of each parameter sampling in the field.

References

[1] Effendi H 2003 Telaah kualitas air: Bagi Pengelolaan Sumber Daya Dan Lingkungan Perairan (Jakarta: Kanisius).
[2] Brahmana S S, Y Summarriani and F Ahmad 2010 Kualitas Air dan Eutrofikasi Waduk Riam Kanan di Kaliman Selatan Prosiding Seminar Nasional Limnologi V Puslitbang Sumber Daya Air, Bandung.
[3] Matthews M W, S Bernard and K Winter 2010 Remote sensing of cyanobacteria-dominant algal blooms and water quality parameters in Zeekoevlei, a small hypertrophic lake, using MERIS Remote Sensing of Environment 114(9) pp 2070-2087.
[4] Stumpf R P and M C Tomlinson 2007 Remote sensing of harmful algal blooms In Remote sensing of coastal aquatic environments pp 277-296 Springer Netherlands.
[5] Kahru M, O P Savehuk and R Elmgren 2007 Satellite measurements of cyanobacterial bloom frequency in the Baltic Sea: interannual and spatial variability Marine Ecology Progress Series 343 pp 15-23.
[6] Barale V, J M Jaquet and M Ndiaye 2008 Algal blooming patterns and anomalies in the Mediterranean Sea as derived from the SeaWiFS data set (1998–2003) Remote Sensing of Environment 112 (8), pp 3300-3313.
[7] Kloiber S M, P L Brezonik, L G Olmanson and M E Bauer 2002 A procedure for regional lake water clarity assessment using Landsat multispectral data Remote Sensing of Environment 82(1) pp 38-47.
[8] Brivio P A, C Giardino and E Zilioli 2001 Determination of Chlorophyll Concentration Changes in Lake Garda Using an Image-Based Radiative Transfer Code for Landsat TM Images International Journal of Remote Sensing 22(2-3) pp 487-502.
[9] Wu C, J Wu, J Qi, L Zhang, H Huang, L Lou and Y Chen 2010 Empirical Estimation of Total Phosphorus Concentration in The Mainstream of The Qiantang River in China Using Landsat TM Data International Journal of Remote Sensing 31(9) pp 2309-2324.
[10] Carlson R E 1977 A Trophic State Index for Lakes (Minneapolis: Limnology Research Center, University of Minnesota).
[11] Badan Pusat Statistik Kabupaten Banjar 2008 Kabupaten Banjar Dalam Angka Kabupaten Banjar.
[12] Department of Interior 2015 Landsat 8 (L8) Data Users Handbook Version 1.0 (South Dakota: USGS).
[13] Dillon P J and Rigler F H 1974 The phosphorus-chlorophyll relationship in lakes *Limnol. Oceanogr* **19**(5) pp 767-773.

[14] Irianto W Eko and Anong Sudarna 1996 Karakteristik Beban Pencemaran Limbah Penduduk di Bandung dan Yogyakarta *Buletin PUSAIR, Media Kegiatan Penelitian Keairan* (V) No: 21 pp 15-35.

[15] OECD 1982 *Eutrophication of Waters: Monitoring, Assessment, and Control*. Organization for Economic and Co-operative Development, Paris, France.

[16] Prasad A G D and Siddaraju 2012 *Carlson’s Trophic State Index for The Assessment of Trophic Status of Two Lakes in Mandya District*. Pelagia Research Library, Department of Environmental Sciences, University of Mysore, Karnataka, India, 3 pp 2992-2996.