MULTITEMPORAL ANALYSIS FOR TROPHIC STATE MAPPING IN BATUR LAKE AT BALI PROVINCE BASED ON HIGH-RESOLUTION PLANETSCOPE IMAGERY

Rahma Nafila Fitri Sabrina[1]* and Sudaryatno[1]

[1]Department of Geographic Information Science, Faculty of Geography, Universitas Gadjah Mada, Bulaksumur, Yogyakarta 55281, Phone. (0274) 6492340 Fax. (0274) 589595

*e-mail: rahmanafilafs98@gmail.com

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Abstract. Remote sensing data for analyzing and evaluating trophic state ecosystem problems seen in Batur Lake is an approach that is suitable for water parameters that cannot be observed terrestrially. As the multitemporal spatial data used in this study were extensive, it was necessary to consider the effectiveness and efficiency of the processing and analysis, therefore R Studio was used as a data processing tool. The research aims to (1) map the trophic state of Batur Lake multitemporally using PlanetScope Imagery ; (2) assess the accuracy of the trophic state model and apply it to another temporal data as a Spatial Big Data; and (3) understand the trophic state impact on the water quality of Batur Lake based on physical factors and the lake's chemical concentration (sulfur concentration). The research shows that the trophic state of Batur Lake is in good condition, with an ultraoligotrophic state as the majority class, based on the mean Trophic State Index (TSI) value of 9.49. The standard errors of each trophic state parameter were 0.010 for total phosphor, 0.609 for chlorophyll-a, and 0.225 for Secchi Disk Transparency (SDT). The multitemporal model demonstrates that the correlation between the increase of trophic state and mass fish death cases in Batur Lake is existent.

Keywords: *Freshwater Lakes, Ultraoligotrophic, TSI Carlson, Sulfur Bursts, Remote Sensing*

1 INTRODUCTION

Water is the most important source of life for all organisms on earth and is found in exceptionally large quantities. 70% of the earth's surface is covered by water, of which 97.2% is in the form of oceans/seawater, with 2.15% formed by glaciers and ice, 0.61% by groundwater, 0.009% by freshwater lakes, and the remaining 0.031% by inland seas, soil moisture, the atmosphere and rivers (Nace, 1967). Water is a resource that can be utilized by humans in various sectors, including tourism, agriculture, industry, the environment, and households. Approximately 80% of surface water was used in a home daily basis (NGWA, 2020).

One supply of freshwater is from lakes. At present, many lakes are experiencing problems due to disruption to the catchment area, which causes the degradation of the lake such as siltation (sedimentation), lake narrowing, growth in the intensity of water hyacinth, decreased water volume, increased lake water temperature, and a decrease in water quality. One of the lakes in Indonesia currently experiencing such ecosystem problems is Lake Batur, located in Kintamani, Bangli Regency, Bali Province. At The 1st Conference of National Lakes Indonesia (KNDI I) in 2009, it was declared that Lake Batur was one of the 15 National Priority Lakes (MoE, 2011), meaning the government needed to develop a policy to save it.

Because of the large area of the lake, the use of remote sensing data to analyze

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and evaluate its ecosystem problems is a suitable research method that can take into account parameters around the lake that cannot be seen terrestrially. In addition, the method can also accelerate the research process because the required samples are determined according to their level of accuracy. In the studies by Z.Y. Avdan, Kaplan, Goncu, and U. Avdan (2019); Trisakti, Suwargana, and Parsa (2015); Marpaung, Faristyawan, Purwanto, Wikanti, Suhada, Prayogo, and Sitorus (2020); and Arief (2015); it can be seen that remote sensing images can also be used to extract several water quality parameters, for example, electrical conductivity (EC), total dissolved solids (TDS), water transparency, water turbidity, Dissolved Oxygen (DO) concentration, suspended particular matter (SPM) and chlorophyll-a. The expected benefits of this research are in establishing how to map the trophic state of Lake Batur multitemporally by extracting information from PlanetScope Remote Sensing imagery, ascertaining the trophic state effect on Lake Batur water quality conditions, and finding the accuracy level of trophic state modeling using R Studio as a processor for Spatial Big Data. In addition, the study is expected to be used as a reference for similar research in the future.

PlanetScope is high-resolution imagery with a 3 meter spatial resolution produced by Planet Labs Inc. The study used PlanetScope Ortho Scene Lake Batur regional images, covering a total of ten recording dates from 2020 to 2017. Mapping was made using the Carlson Trophic State Index (TSI) method, consisting of three trophic state parameters, namely total phosphorus, chlorophyll-a, and Secchi Disk Transparency (SDT). The model was obtained from the results of the regression between the field data with pixel values of input band (single band images, band ratios, or Principle Component Analysis (PCA) bands) that have the highest correlation value. The models were performed to the image of the fieldworks time to gain the standard errors of each trophic state and then applied to nine other images using the R Studio application.

The mass fish mortality was the result of a complex process of organic matter accumulation both in the bottom and the water column. In the early stages, due to the accumulation of organic matter on the bottom of the waters, there is a formation of the large anaerobic layer (Garno et al., 1999), followed by the formation of toxic compounds such as H_2S and NH_3. Under certain conditions, there will be "turn over" which encourages the rise of a water column that does not contain oxygen (anaerobic) and threatens many fish in net cages (Lukman et al., 2013). This case of mass fish mortality could also be affected by the trophic state of the lake.

2 MATERIALS AND METHODOLOGY

2.1 Location and Data

Lake Batur is located in Kintamani District, Bangli Regency, Bali Province (Figure 2-1). It is in the old caldera of Mount Batur, an active volcano that is subject to the volcanic activity of the Pacific Ring of Fire. Lake Batur is located at Latitude 8°13'-8°18'S and Longitude 115°22'-115°26'E, with an elevation of 1,080m above sea level (Radiarta & Sagala, 2012). The area of Lake Batur is 15.9km^2, with a maximum depth of 88m (World Lakes, 2005).

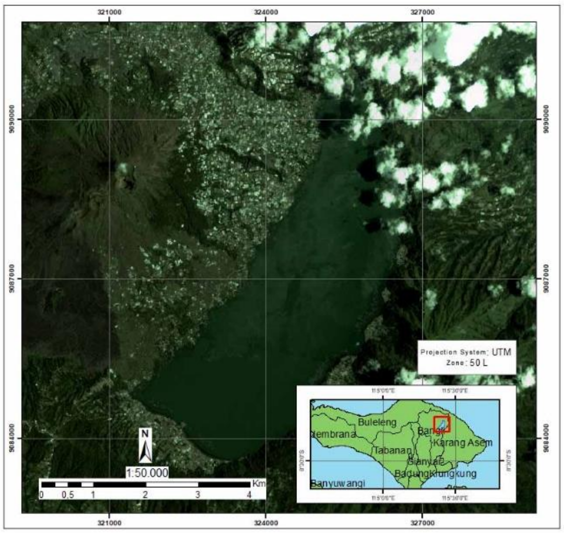

Figure 2-1: Research Location Map (ArcGIS Basemap)

The data used for the research were:

a. Landuse vector data acquired in March 2018 on Bangli Regency and Karangasem Regency, Bali Province from InaGeoportal opensource,

b. PlanetScope Lake Batur area 2020 image;

c. PlanetScope imagery from 2017-2020 (recording dates 13 February 2020, 29 January 2020, 2 September 2019, 25 February 2019, 8 July 2019, 14 November 2018, 2 April 2018, 15 July 2017, 17 April 2017 and 13 March 2017);

d. River flow vector data acquired in March 2018 on Bangli Regency and Karangasem Regency, Bali Province from InaGeoportal opensource;

e. Lake Batur boundary vector data acquired from visual interpretation of PlanetScope imagery on January 2020;

f. Field sample data, field checklist, and laboratory test results of total phosphor and chlorophyll-a, acquired on 26 February 2020.

2.2 Data standardization

River and land use data were obtained from InaGeoportal opensource on Bangli Regency and Karangasem Regency, Bali Province. The river vector data used were in the form of line data, while land use vector data were in the form of polygon data. Lake Batur boundary vector data were obtained by visual interpretation of the PlanetScope 2019 image of the NIR spectral band, assisted by true color composite from the on-screen digitization results using the ArcGIS software.

The Planet Scope imagery that was used as a reference in determining the sample points, standardized by mosaicking process, masking, and sunglint correction (an image correction process to reduce the error in image spectral values caused by wavy water surfaces as a result of tide or water current effects (Hedley et al., 2005)). In addition, processing with spectral band maths was conducted to obtain an index value that represented the level of each parameter determining the trophic state. The image mosaic process was performed to combine several scenes covering the study area. The process employed ENVI 5.1 software to produce image scenes that covered the entire Lake Batur area. Transformation of PlanetScope imagery to produce images with index values that represent the level of each parameter include SDT (Secchi Disk Transparency), chlorophyll-a content, and total phosphorus, refers to the regression results obtained by Musfiroh (2019), assuming that the resulting accuracy was in accordance with standards for being able to produce sample map.

2.3 Methods

The sample point was based on the results of the transformation of TSI with PlanetScope imagery in February 2020. The transect sampling method was used to determine the sample point at intervals of 1 km and covered the whole class of TSI transformation. Field activities were conducted to collect water samples of total phosphorus and chlorophyll-a for laboratory testing, as well as the measurement of in situ data such as SDT and a dataset obtained with a water quality checker (WQC) tool.

The correlation test is a statistical technique used to test the presence or absence of a relationship, and the direction of the relationship, between two or more variables (Sami'an, 2008). The extent of the relationship between these variables is expressed as a correlation coefficient, with a value between -1, 0, and +1. A strong relationship is expressed by -1 and +1, whereas if each of the variables has no relationship at all, then the correlation coefficient is 0. The correlation sought in this study was the relationship between the independent variable, in the form of image pixel values, and the dependent variables, in the form of total phosphorus concentration, chlorophyll-a concentration, and SDT value. A correlation test for each parameter was performed using the bootstrap method in the IBM SPSS 24 application. This process used 14 sample models with four single PlanetScope spectral bands, 12 band ratios, and 16 Principal Component bands to be tested. The input spectral bands were considered significant and passed the correlation test if the lower and upper bootstrap values had values not equal to 0. If the bootstrap had a negative lower and a positive upper value, or otherwise, there was a possible relationship between the two variables with a determinant coefficient of 0, or no relationship at all, it could be determined that the input spectral band did not pass the correlation test.

Regression analysis aims to find the factors that might influence trophic state distribution. This study was conducted to produce a regression equation for each parameter, which was then used to model the estimated trophic state level of Lake Batur. The analysis was performed by regressing every single input spectral band with the value of each independent variable (total phosphorus, chlorophyll-a, and SDT) value. The best regression of the input spectral band was then used to model the value of Carlson's TSI parameters.

The TSI value was calculated using an algorithm developed by Carlson (1977), which uses three parameters as its variables, namely the total values of phosphorus, chlorophyll-a, and water clarity. These were obtained from the results of the remote sensing data extraction recorded at the same time as the field activities in February 2020. The calculation results were then divided into seven classes according to the lake trophic state classification categories based on Carlson's Trophic State Index shown in Table 2-1.

Table 2-1: Lake Trophic State Classification

TSI Value	Trophic State
>30	Ultraligotrophic
30-40	Oligotrophic
40-50	Mesotrophic
50-60	Mild Eutrophic
60-70	Moderate Eutrophic
70-80	Heavy Eutrophic
>80	Hypereutrophic

Source: Laksitaningrum et al. (2017)

Accuracy tests were conducted based on RMSE (Root Mean Square Error) to assess the difference between the field data used for the regression and those that were not. The lower the RMSE value, the lower the deviation or shift in the value of each parameter. The RMSE value was obtained from the standard error estimation algorithm as follows:

$$\delta_{est} = \sqrt{\frac{\sum(Y - Y')^2}{N - 2}} \quad (2\text{-}1)$$

δ_{est} = Standard error of estimation

Y = Field measurement results
Y' = Estimated results
N = Sample count

The multitemporal data modeling aimed to obtain Lake Batur trophic state information multitemporally using big data from nine recording dates of PlanetScope images, with modeling used for the field regression imagery. The R scripts used before PCA were used for image cropping processing, image masking, and band ratio calculations. R Studio processing after PCA was performed to model the image of the PCA results in order to obtain information on the distribution of trophic state parameters used for the Carlson TSI transformation. In this process, a CTSI classification plot image was obtained from the three parameters and the final result of Carlson TSI image processing.

The multitemporal analysis was made by taking into account the TSI value graph obtained from each sample point in the complete image of the trophic state modeling results using R Studio within a 3 year period of the PlanetScope image being acquired. The resulting graph was then analyzed by considering the incidence of sulfur bursts (dead fish masses) and drought cases that had occurred in Lake Batur based on information from media news.

3 RESULTS AND DISCUSSION

The Planet Scope imagery used consisted of a total of ten acquisition dates, 13 February and 29 January 2020; 2 September, 25 February, and 8 July 2019; 14 November and 2 April 2018; and 15 July, 17 April, and 13 March on 2017. The PlanetScope imagery acquired on 29 January 2020 was used for the TSI transformed pre-field image, and imagery acquired 13 February 2020 was used for mapping the trophic state was from 13 February 2020. The chosen imagery was considered based on the availability of qualifying PlanetScope images with minimal cloud cover and area coverage completeness.

The distribution of the sample points using the transect sample method had interval distances between each sample of 1 km (Figure 3-1). Field testing including water sampling and collection of in-situ data was performed on February 26, 2020. A total of 20 samples were obtained, with a composition of 15 model samples and five validation samples. Water sampling was divided into two types, namely the total phosphorus sample and the chlorophyll-a sample. The sampling was conducted simultaneously at each predetermined sample point.

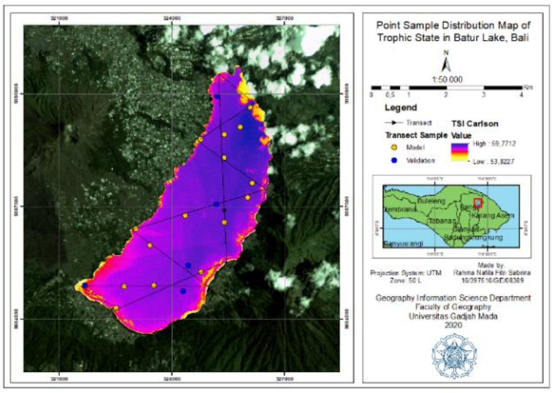

Figure 3-1: Map of Distribution of Final Field Sample Points for Lake Batur Trophic State (Data Processing, 2020)

Other in-situ water parameters obtained in the field activities besides SDT data were temperature, pH, salinity, TDS, and conductivity. The temperature of the water sample increased during sunny weather and around 12.00 when the sun was directly above, but decreased when it was rainy. Water pH tended to have a constant high value of around 8.5 and up to 8.8. Salinity, TDS, and conductivity value had an alteration quantity due to the precipitation during the fieldwork. Salinity content was very low at 1.1 to 1.3 ppt, with electrical conductivity ranging from 1776 to 1883 µS/cm and TDS from1.16 to 1.34 ppt.

Statistical analysis was performed so that the value and accuracy of the modeling could be accounted for. The analysis included a bootstrap test, correlation test, and regression test. Otherwise, Principal Component Analysis (PCA) process and band ratios statistical analysis is also applied to the images for analyzing the spectral pixel bands value in conjunction with each single PlanetScope Imagery band.

A description of the correlation for each parameter with pixel values that passed the bootstrap test can be seen in Tables 3-1 to 3-3. The PC number refers to the order of the PCA processing result.

Table 3-1: Correlation Test of Total Phosphorus

Band	Correlation	Bootstrap Value	
		Lower	Upper
PC3	0.530	0.047	0.857
PC7	-0.302	-0.623	-0.110
PC11	-0.311	-0.600	-0.149
PC14	-0.356	-0.672	-0.212

Source*:* Data Processing, 2020

Table 3-2: Correlation Test of Chlorophyll-a

Band	Correlation	Bootstrap Value	
		Lower	Upper
PC14	0.843	0.129	0.966

Source*:* Data Processing, 2020

Table 3-3: Correlation Test of Secchi Disk Transparency

Band	Correlation	Bootstrap Value	
		Lower	Upper
PC11	0.579	0.431	0.945
PC15	-0.342	0.896	-0.154

Source*:* Data Processing, 2020

Regression analysis was performed to determine the factors that might influence the distribution of the trophic state parameters. In this study, it was conducted to produce a regression model or equation for each parameter, which was then used to model the estimated trophic state class of Lake Batur. The analysis was made by regressing the input band (single band, band ratio, or PC band) with the value of each dependent variable (total phosphorus, chlorophyll-a, and SDT values).

Total phosphorus regression analysis was applied to the band that had the best (highest) correlation value, namely PC3. The coefficient determination (R^2) was obtained from the scatter plot between the pixel value and the 14 total phosphorus values in the field. The R^2 was equal to 0.281. This value was low, being strongly influenced by the overall phosphorus data, with the majority of the values being 0.01 mg/l. The formula obtained with the help of Microsoft Excel to make the model was y = 0.0004x + 0.018, where y is the total image of phosphorus transformed and x is the PC3 band. The minimum value of the image pixels was -0.193, and the maximum was 1.06, with an average value of 0.018. Noise or interference contained in the pixels, such as background images, pixels damaged by transformation, error correction, or noise that did originate from the initial PlanetScope imagery from both sensors and atmospheric effects, greatly affected the results of the transformation.

Chlorophyll-a regression analysis was applied to the spectral band that had the highest correlation value, namely PC14. A model that could represent the chlorophyll-a parameter with the independent variable was this band. The coefficient of determination resulting from the regression was 0.710. The combined coefficients that produced the model-making formula were y = 2143.145x + 0.767, where y is the image of the transformed chlorophyll-a and x the PC14 band. The minimum value of the image pixels was -31.67, with a maximum value of 135.90, and an average of 0.767.

SDT regression analysis was also applied to the spectral band that had the highest correlation value, namely PC11. The result of this regression analysis led to two models that could represent the SDT parameter, with the suitable variables being the PC11 and PC7 bands.

The first model of this regression had a coefficient of determination of 0.335, while that of the second was 0.703. The model used for mapping the distribution of SDT was that which had the highest coefficient value, namely the second. The combined coefficients that produced the formula for constructing the second model were $y = 105.568x_1 + 459.664x_2 + 1.419$, where y was the transformed image of *Secchi Disk*, x_1 was the PC7 band, and x_2 was the PC11 band. The minimum image pixel value was -248.79, the maximum 26.59, with an average value of 1.42.

Lake Batur trophic state mapping was performed to obtain information about the distribution of trophic state classes with the Carlson TSI index. The results of the total phosphorus distribution obtained from the previous modeling were converted using equation TSI-TP= 14.42 x Ln [TP] + 4.15, where [TP] is the input spectral band resulting from the distribution of all the phosphorus parameters. The total trophic state in the overall Lake Batur area (Figure 3-2) shows that the lake was in the ultraoligotrophic class, which is characterized by a dark green shading shown in Figure 3-2 that almost covers the whole lake area. As for the locations shown in white, this indicates that in these areas the TSI value could not be visualized because it was not classified in the seven classes. The low TSI class of total phosphorus was proportional to the total value of phosphorus in Lake Batur, which was also relatively low, in the range of 0.01 mg/l to 0.082 mg/l. The maximum TSI value for total phosphorus was only 5.

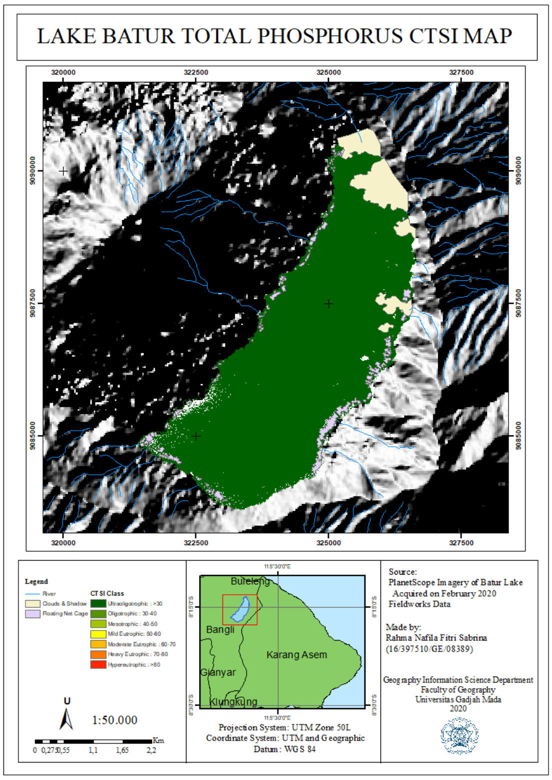

Figure 3-2: Map of Lake Batur Total Phosphorus CTSI (Data Processing, 2020)

The Lake Batur chlorophyll-a TSI class was dominated by the ultraoligotrophic and oligotrophic classes. The results of the chlorophyll-a distribution obtained from the previous modeling were converted using the equation TSI-Chl-a = 30.6 + 9.81 x Ln [Chl-a], where [Chl-a] is the input spectral band (resulting from the distribution of the chlorophyll-a parameter). The chlorophyll-a trophic state class as shown in Figure 3-3, at the edge of Lake Batur and in the middle of the lake, had a lower class compared to the edge of the lake. In the area where floating net cages were built, most of the water was in the oligotrophic CTSI class with a TSI value of 30-40, shown in green in Figure 3-3. The ultraoligotrophic class which had a TSI value of less than 30 was spread in the central and southern parts of the lake.

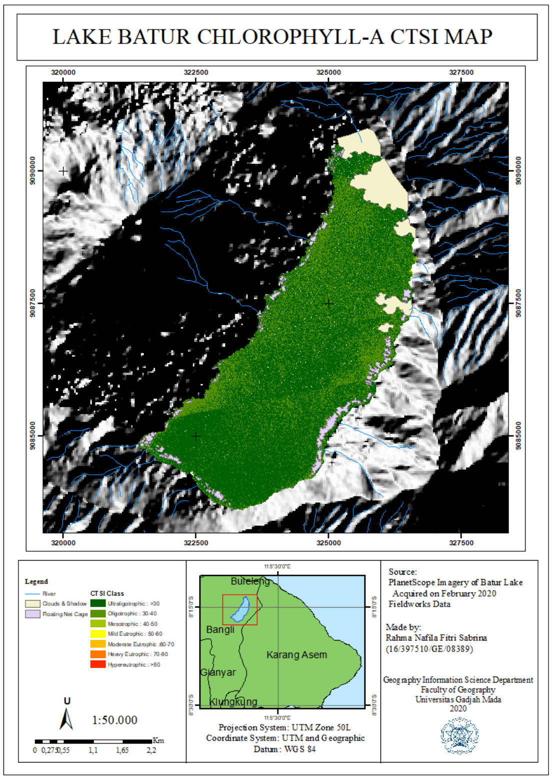

Figure 3-3: Map of Lake Batur Chlorophyll-a CTSI (Data Processing, 2020)

The results of the SDT parameter distribution obtained from the previous model were converted using equation TSI-SD = 60 - 14.41x Ln [Secchi], where [Secchi] is the input band (layer input of the SDT parameter distribution results). The TSI of the SDT Lake Batur class (Figure 3-4) was dominated by mild eutrophic, moderate eutrophic, and mesotrophic classes. In the area where the floating net cages were built, the distribution of the trophic state was low, namely the mesotrophic class symbolized by light green pixels around the edge of the lake near the floating net cages in Songan A Village. As for classes that had high TSI values, such as moderate eutrophic and heavy eutrophic, these were scattered around the floating cages in the southwestern part of the lake. The varied distribution of SDT eutrophication classes spread throughout the lake shows that the presence of the floating net cages did not greatly affect the quality of the lake waters in terms of its SDT trophic state.

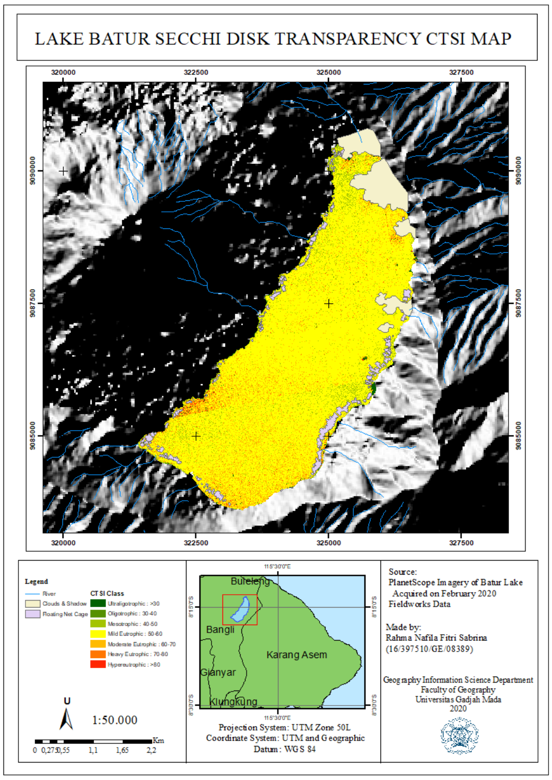

Figure 3-4: Map of Lake Batur Secchi Disk Transparency CTSI (Data Processing, 2020)

The results of the distribution of the trophic state class estimates with the Carlson TSI index were obtained by calculating the average of the three CTSI maps previously produced. Each layer was converted by using the Carlson TSI equation, TSI = [(TSI - TP) + (TSI - Chl a) + (TSI - SD)] / 3. The trophic state class with the Lake Batur TSI Carlson index was dominated by the ultraoligotrophic class, as shown in Figure 3-5. However, overall the condition of Lake Batur could be categorized as not experiencing eutrophication, with an ultraoligotrophic class area covering an area of 12.07 km^2 and an average TSI value of 9.49 (Figure 3-5). Even though this Carlson TSI class shows that lake water fertility was relatively low, if it were left continuously subject to human activity and high floating net cage production without any attempt to improve the quality of the water, this could lead to algae blooming, as occurred in Lake Maninjau (Yulianto, 2017).

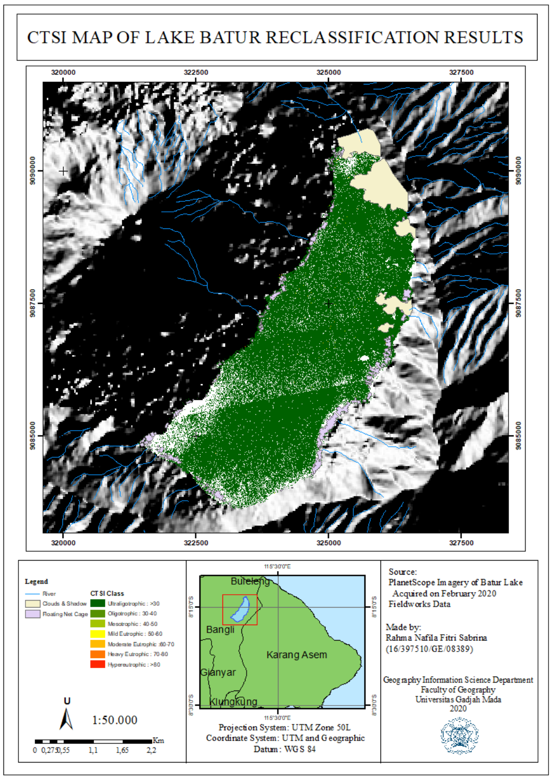

Figure 3-5: CTSI Map of Lake Batur Reclassification Results (Data Processing, 2020)

Accuracy assessment was conducted to assess the difference between the field data used for regression and the transformed images used for estimating the distribution of the trophic state parameters. The method used for this was based on RMSE (Root Mean Square Error).

The accuracy assessment for the parameters of total phosphorus was made by testing the image of the transformation of PC3 for modeling total phosphorus using three validation samples. The resulting standard error was 0.010, while the estimated value of the image (RMSE) had an error probability of 0.010 mg/l. The accuracy of this modeling had a maximum value of 76.97% and a minimum of -65.79%. This accuracy value showed a very large error, which exceeded the negative linear level of percent.

The accuracy test for the chlorophyll-a parameter was conducted by testing the image of the transformation of PC14 for modeling chlorophyll-a using three validation samples. The resulting standard error was 0.609, while the estimated value of the image (RMSE) had an error probability of 0.609 mg/m^3. The accuracy of this modeling had a maximum value of 47.74% and a minimum of -30.19%. This accuracy value also displayed a large error, as seen from the minimum value which exceeds a negative linear level and a maximum value that is still below 50%, but better than the accuracy of the total phosphorus parameter content.

Accuracy assessment for the SDT parameters was made by examining the image of the transformation results of PC7 and PC11 for modeling SDT using four validation samples. The resulting standard error was 0.224, while the estimated value of the image (RMSE) had an error probability of 0.609 mg/m^3. The accuracy of this modeling had a maximum value of 83.34% and a minimum of 82.42%. This accuracy value shows a small error and very good accuracy, with the accuracy value exceeding 70%.

The multitemporal data modeling aimed to obtain Lake Batur trophic state information multitemporally using big data from nine PlanetScope Imagery acquisition dates and modeling used for the imagery of 13 February 2020. The model show the level trophic state of 1 to 7, where 1 was ultraoligotrophic, 2 was oligotrophic, 3 was mesotrophic, 4 was mild eutrophic, 5 was moderate eutrophic, 6 was heavy eutrophic, and 7 was hypereutrophic.

The value obtained of the distribution of the trophic state of the total phosphorus in Figure 3-6 was dominated by ultraoligotrophic classes, but with different distributions. This can be seen from the values shown in the legend, which only rise to class 1, with other areas unclassified. This trophic state class was in the same class on all dates, but with different distributions.

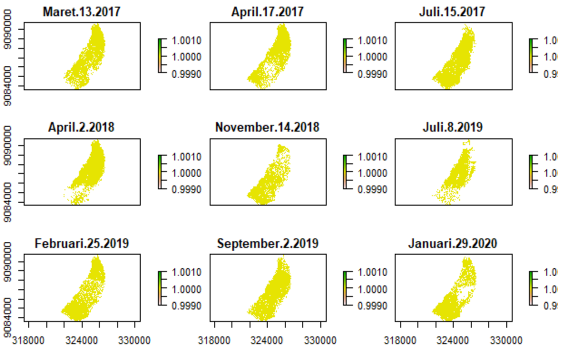

Figure 3-6: Plot Map Distribution of Total Phosphorus Trophic State (Data Processing, 2020)

The distribution values of the chlorophyll-a trophic state classes are dominated by ultraoligotrophic and oligotrophic classes. In Figure 3-7, it can be seen that the trophic state of the chlorophyll-a class was quite low in the trophic state class; i.e., in the ultraoligotrophic to mild eutrophic classes. This can be seen from the chlorophyll-a value, which tended to be low in the Lake Batur area. However, it is shown that in some parts of the lake there are signs of mild eutrophication. Figure 3-7 shows that the oligotrophic state displayed a spreading distribution over the whole lake during the wet season (Dec-Feb). On the other hand, in the dry season (May-Aug) the trophic state declined.

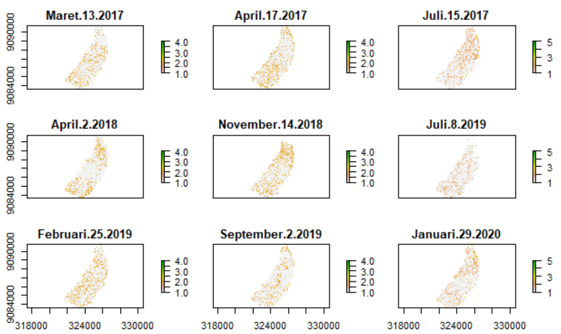

Figure 3-7: Plot Map Distribution of Chlorophyll-a Trophic State (Data Processing, 2020)

The distribution value of the TSI Carlson of SDT is dominated by mild eutrophic classes. In Figure 3-8, it can be seen that the SDT trophic state class was at various levels, namely from the ultraoligotrophic class to the hypereutrophic class. However, in some locations there were some parts of the lake showed signs of severe eutrophication, and some were still in the mesotrophic class. The highest classes were generally located in the north, which could be due to the mining of sand in Songan A Village (Nada et al., 2017). The distribution of SDT trophic state classes on each recording date shows a high distribution, especially in July 2017, November 2018, July 2019, and January 2020. On the other hand, the lowest classes were in March 2017 and September 2019. Figure 3-8 shows that the ultraoligotrophic, oligotrophic, and to a low extent the mesotrophic states displayed a spreading distribution over a whole lake during the wet season (Dec-Feb). On the other hand, in the dry season (May-Aug) the trophic state increased into eutrophication.

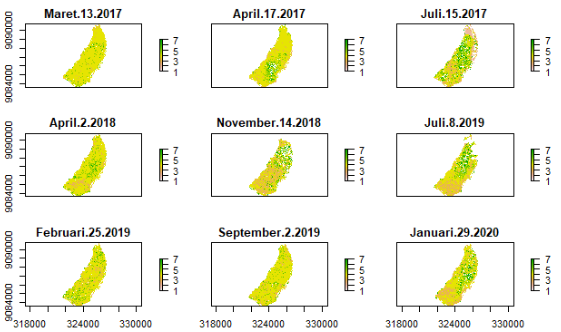

Figure 3-8: Plot Map Distribution of SDT Trophic State (Data Processing, 2020)

From Figure 3-9, it can be seen that Lake Batur was at various trophic state class levels, namely from the ultraoligotrophic class to the mild eutrophic class, but that in November 2018 and September 2019 it was in the lowest trophic state class, the oligotrophic. The distribution of Lake Batur trophic state classes on each recording date shows an increase in distribution in April 2017, July 2019, and January 2020, whereas a decline occurred in November 2018 and September 2019. There was no difference between each season in the trophic state distribution of Batur Lake.

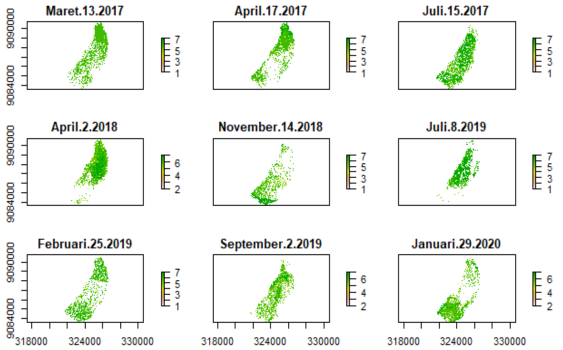

Figure 3-9: Plot Map Distribution Lake Batur Trophic State (Data Processing, 2020)

The CTSI graph in Figure 3-10 was produced from the data representation of the average TSI value of each mapped parameter, as well as the total TSI final results. There were fluctuations in the average trophic state index on each date within the three years from 1 March 2017 to 1 December 2019. The graph was then linked to events in Lake Batur, namely fish mortality and drought. Fish deaths occurred on 13 July 2019, 13 March 2018, 13 July 2017, and 7 February 2017, and took place almost every year, encouraged by the volcanic activity of Mount Batur, with sulfur bursts at the bottom of the lake. The use and management of land around the lake could also be a factor having a big impact on the problems of sedimentation and the mass death of fish, especially the high intensity of the use of organic fertilizers, resulting in very high sedimentation rates caused by runoff during the rainy season. Mass fish mortality is shown by dark blue vertical lines and the drought which occurred on 19 August 2019 is shown by a green vertical line.

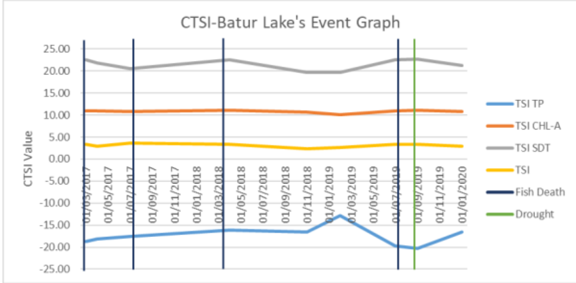

Figure 3-10: Graph of fluctuation in CTSI value affected by Lake Batur's Event (Data Processing, 2020)

The increase of the trophic state index was followed by a decline that occurred on dates of mass fish deaths. The fluctuation's line near the date of the mass fish mortality tends to show the peak of the trend. This can be seen that the peak approaches almost every line of the conjunction between the occurrence of sulfur bursts (mass fish deaths) and the CTSI values. This is comparable with the possibility of volcanic eruptions, which also increase the trophic state, or it could also be affected by poor handling of the floating net cages. The Beggiatoa bacteria which are generally located in fresh water and the mud layer of the lake when sulfide concentrations increase can oxidize the sulfur contained in the lake's bedrock in the form of sulfides, with the help of the nitrates stored in its vacuoles (Dodds & Whiles, 1958).

The increase in the TSI class also occurred during the lake drought event, when the peak of the chart trend was on the date of the drought. This may have occurred due to the presence of mixed sediments, which could increase the turbidity of the lake water when overflow occurred after the drought. The plants that were planted when the land width increased on the border of the lake could affect the levels of phosphorus from fertilizers and chlorophyll-a from the plants.

4 CONCLUSION

Batur Lake trophic state classes were mapped with PlanetScope images in

February 2020, resulting in ultraoligotrophic trophic states, with an average TSI value of 9.49. TSI SDT achieved the highest accuracy, of 83.36%, while the highest accuracy of the parameters of total phosphorus and chlorophyll-a were -65.79% and 76.97% respectively. The increase in the trophic state of Batur Lake was triggered by sulphur bursts at the bottom of the lake as well as by bacteria that can oxidise sulfur using nitrate nutrients, facts based on the graph (Figure 3-10) of the relationship between mass dead fish (sulfur bursts) and drought, and the CTSI values in Lake Batur.

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AUTHOR CONTRIBUTIONS

Multitemporal Analysis For Trophic State Mapping in Batur Lake at Bali Province Based on High-Resolution Planetscope Imagery. Lead author: Rahma Nafila Fitri Sabrina, Co-Author: Sudaryatno.

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