Water Quality Monitoring of Shallow Lakes Through Google Earth Engine

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Abstract. *This work focuses on the monitoring of water quality parameters in Trasimeno lake, a shallow water body located in central Italy, in the period 2015-2022. To this aim ad hoc Google Earth Engine (GEE) based routines are implemented to analyse data from Sentinel 2 multispectral images. The spatial distribution of turbidity and chlorophyll-a concentration can be derived through the spectral band ratio method: a semi-empirical approach expressed by the mathematical ratio between the reflectance of two or more spectral bands. Two normalized indices are considered: NDTI - Normalized Difference Turbidity Index and NDCI Normalized Difference Chlorophyll-a Index. The results show an increasing trend both for turbidity and Chlorophyll-a concentration over time, highlighting a light worsening in Trasimeno lake quality status.*

Keywords. Sentinel 2, NDTI, NDCI, turbidity, chlorophyll

University of Maribor Press

DOI https://doi.org/10.18690/um.4.2023.51
ISBN 978-961-286-783-6

1 Introduction

Recent scenarios and current conditions of climate change express particular concern for the continued increase in drought, which necessarily leads to water shortages and water pollution. Trasimeno lake is a shallow body, with no tributaries or emissaries, lying on a poorly permeable bed. Due to its characteristics, the water level varies greatly, as a result of local rainfall an inverse correlation between lake water level and water quality is observed: when water level decreases, parameters such as chlorophyll concentration and turbidity increase [1]. The Chlorophyll-a (Chl-a), belonging to the phytoplankton class of Optically Active Constituents (OACs), is closely associated with algae and their constituents present in the water column; like other chlorophyll pigments; it absorbs solar energy at wavelengths in the Blue and Red regions while reflects light at wavelengths in the Green region.

The turbidity and the suspended sediments belong to the class of non-algal particles which influence the reflectance of incident solar radiation; varying the response in Visible and NIR waves. [2]

These two water quality parameters are extracted and analysed by means of remote sensed data, Sentinel 2, managed in GEE environment.

The Sentinel-2 satellite is a Copernicus mission including a constellation of two polar-orbiting satellites placed in the same sun-synchronous orbit at a mean altitude of 786 km, phased at 180° to each other: Sentinel-2A launched on 23 June 2015, Sentinel-2B launched on 7 March 2017. Both Sentinel-2 platforms are equipped with a multi-spectral sensor that acquires 13 spectral bands with 12-bit radiometric resolution

GEE is a platform for browsing and processing a huge amount of satellite imagery and geospatial datasets, it has very high computational power. Users can access and analyze data using JavaScript API in Earth Engine Code Editor, an Interactive Development Environment (IDE) where it is possible to implement your own script and view real-time processing results.

2 Materials and methods

The turbidity and chl-a concentration analysis on Lake Trasimeno is carried out through two normalized indices NDTI - Normalized Difference Turbidity Index and NDCI - Normalized Difference Chl-a Index:

$$\mathrm{NDTI}=\frac{\rho_{red}-\rho_{green}}{\rho_{red}+\rho_{green}} \quad (1)$$

$$\mathrm{NDCI}=\frac{\rho_{redEdge1}-\rho_{red}}{\rho_{redredEdge1}+\rho_{red}} \quad (2)$$

where the Red and Green reflectance correspond to B4 and B3 bands respectively; while RedEdge1 reflectance corresponds to B5. The spatial resolution of these three bands is 10m for B3 and B4, 20m for B5; then in the computation of NDCI the B4 band is resampled, upscaling in our case from 10 to 20 m. Both indices are normalized and are related to water quality parameters as follows: NDTI ranges from -1 to 1 and represent clear and very turbid water, respectively [1];

NDCI values close to -1 indicate an optically transparent water body, while for values between -0,3 and 0,5 there is a moderate to high algal biomass, and finally for values close to 1 the algal bloom conditions are extremely intense. [3]

The script implemented in the GEE for water quality analysis provides the following step:

1. Selection of the Sentinel-2 MSI image collection;
2. Application of filters to define study area and time period, in our case Lake Trasimeno and a period between 10-20 July of each year from 2015 to 2022;
3. Application of dedicated cloud cover filter to search for the image with the lowest cloud cover (less than 5%) in the specified time period;
4. Implementation of spectral band ratio method to calculate the normalized indices NDTI and NDCI for each year;
5. Export of the result in GeoTiff format.

3 Turbidity and Chlorophyll-a results

The turbidity spatial distribution and chl-a concentration of Lake Trasimeno are computed by considering sentinel-2 data acquired in mid-July of each year between 2015 and 2022; the script automatically selects the least cloudy images of the reference period
for all images, NDTI and NDCI indices are computed in GEE and mean values for turbidity and chl-a concentration are extracted (Tab. 1).

Table 1. Average NDTI and NDCI values with reference to the least cloudy images from Sentinel-2 between July 10 and 20, 2015 to 2022.

Image date	NDTI (average value)	NDCI (average value)
11 July 2015	-0.33	-0,12
18 July 2016	-0.32	-0,06
13 July 2017	-0.30	-0,11
10 July 2018	-0.31	-0,09
20 July 2019	-0.32	-0,10
12 July 2020	-0.18	-0,06
12 July 2021	-0.17	-0,04
14 July 2022	-0.14	-0,02

The results show an increasing trend of turbidity over time, from a value of −0.331 (in 2015) to a value of −0.144 (in 2022). The average NDTI value increases slightly from 2015 to 2017, decreases in 2018 and increases again from 2019 to 2022.

Similarly, the NDCI results outline an increasing trend of chl-a concentration, starting from a value of −0.12 (in 2015) to −0.02 (in 2022).

4 Conclusion

The work examines the potentials of Sentinel 2 imagery managed in GEE in mapping Chl-a concentrations, turbidity, and detecting in this way possible algal blooms. Moreover, time-series analysis showed that both parameters increased especially in drought period, suggesting the need for political strategies to reach a good quality status.

As already mentioned in the introduction, there is an inverse correlation between the water level of the Lake and the concentration of Chl-a and Turbidity; therefore, any strategy to mitigate the water level decrease can also be considered advantageous for preserving the quality of the Lake, such as careful water replenishment from the reservoirs of the adjacent basins (Casanova and Montedoglio) [1].

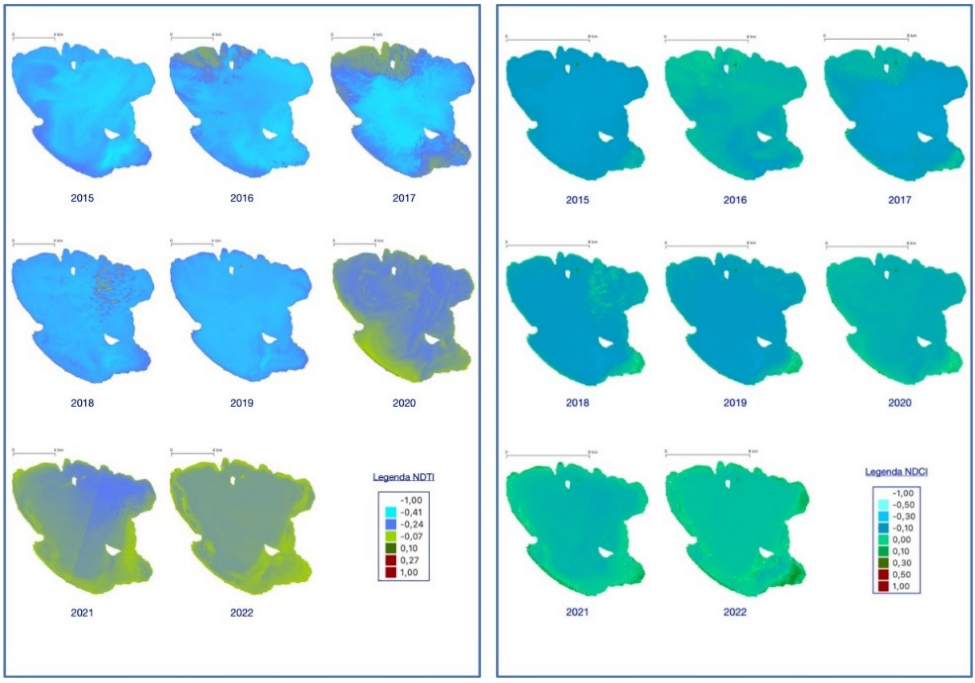

Figure 1. NDTI (left) and NDCI (right) of lake Trasimeno in the middle days of July, from 2015 to 2022.

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