



## Satellite-derived trophic index to support management of small and medium-sized lakes

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The trophic index is one of the most important indicators for primary production and potential anthropogenic eutrophication of lakes. In Germany, It is calculated from measured phosphorus concentration, visibility and chlorophyll-a content in water samples collected during the productive period between April and October. These parameters are monitored for most lakes > 50 ha, which are covered by the Water Framework Directive. Monitoring typically occurs only at a low interval of several years, making it difficult to distinguish trends in lake water quality from natural annual variations. Moreover, no information is available for small lakes < 50 ha, thus excluding a high proportion of lakes from trophic state monitoring.

In the presented work, we investigated the extent to which satellite data are able to fill these gaps. There are many indices for real-time water monitoring based on satellite images from the Copernicus Sentinel-2 program. Based on this existing know-how, the reliability of satellite-based trophic index assessment was validated along the following questions:

- which bands of the Sentinel-2 images are best suited for estimating trophic state?
- how does the data need to be temporally aggregated within a season?
- is one pixel of a lake sufficient to reliably describe the trophic state of a lake, so small lakes can be included in the assessment?

The investigation was based on 294 lakes in Brandenburg, Germany. Monitored trophic index from the years 2018 to 2022 was correlated with satellite information for one pixel, chosen randomly in the center of each lake. The trophic index based on in-situ measurements is best calculated from monthly values. Similarly, satellite-derived indices were first averaged monthly and then seasonally (April to October in Germany).

Results show that Bands 2 and 5 of the Copernicus Sentinel-2 Mission are best suited to describe the differences of trophic state. The developed *Normalized Difference Trophic Index* (NDTrI) is based on single image indices which are defined as:

$$NDTrI_{image} = \frac{B5 - B2}{B5 + B2}$$

Band 5 describes the near infrared reflectance at 705 nm, band 2 the reflectance of blue light at 490 nm. In oligotrophic lakes, band 2 reflectance usually dominates and the index is below zero. The resulting NDTrI was found to be highly correlated with the in-situ data for the available years (Pearson correlation coefficient per year between 0.83 and 0.92). The data are available at an annual resolution, which is three times more frequent than the conventional analysis. This allows a much more reliable trend analysis, which can be used to monitor the success or lack of water quality management more quickly. The feasibility of the methodology, using only one pixel for each lake, indicates that thousands of small lakes can be included in the remote monitoring without much effort.

A first sensitivity analysis has shown that the classification is more reliable for eutrophic water bodies than for oligotrophic ones. Further factors influencing the accuracy of the method and potentials of trend as well as seasonal analysis will be investigated in the European Horizon projects AD4GD and ProCleanLakes.