Mon25-009

Monitoring of eutrophication of lakes in Volyn Polissya (on the example of Lake Turske)

V. Fesyuk** *(Lesya Ukrainka Volyn National University)*, ***I. Moroz *(Lutsk National Technical University)*, ***M. Fedonyuk*** *(Lutsk National Technical University)*, ***S. Polianskyi*** *(Lesya Ukrainka Volyn National University)*

SUMMARY

The article considers of example of studying the current state of eutrophication for one of the lakes of Volyn Polissya (Turske Lake) using modern remote sensing methods. Eutrophication causes significant damage to the ecosystems of the Volyn Polissya lakes. The use of the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Algae Index (NDAI) allowed us to find out the peculiarities of the development of eutrophication processes in the lake in different years. The use of statistical methods of analysis made it possible to assess the closeness of the relationship between the weighted values of NDVI and the water surface temperature of Lake Turske. It has been established that the intra-annual variation of the NDVI and NDAI indices is characterized by an increase from May to August and a further decrease in values by the end of the year. Among the factors affecting the level of eutrophication, the most important are water temperature, nutrient supply (phosphorus, nitrogen) and morphological features of water bodies (area, depth, volume, shape of the basin).

Introduction

Lake eutrophication is a serious environmental problem. It occurs when excessive amounts of nutrients, especially nitrogen and phosphorus compounds, enter water bodies. The most significant natural causes of eutrophication are: natural aging of water bodies, seasonal fluctuations in water temperature, nutrient washout from coastal areas during rains, the vital activity of aquatic organisms and decomposition of their remains, and shore erosion. Recently, however, the impact of anthropogenic factors on this process has been increasing. The most important of these are: fertilizer runoff from agricultural land, untreated wastewater discharge, soil erosion in lake catchments, precipitation containing pollutants, urbanization, etc. The consequences of eutrophication are: "blooming" of water due to the massive growth of algae, deterioration of water quality for drinking water supply, death of fish and other aquatic organisms, and degradation of biodiversity. Effective eutrophication control involves controlling the use of fertilizers in agriculture, treating wastewater before it is discharged into water bodies, creating coastal protection strips, mechanical removal of excess vegetation, water aeration, bioremediation, etc. However, in order to detect and respond to a problem in a timely manner, it is necessary to have high-quality and timely information about the state and course of biological processes in a water body. This requires environmental monitoring of water bodies. Since there are many lakes within Volyn Polissia, it is not feasible to cover all lakes with a network of regular observations. This task can be solved using remote sensing methods.

There are many examples in the scientific literature of the use of remote methods to monitor the eutrophication of natural and artificial reservoirs. For example, Zhou, J., Leavitt, P. R., Zhang, Y., & Qin, B. (2022) investigate the features of anthropogenic eutrophication of shallow lakes, Lin, S.-S. S., Shen, S.-L., Zhou, A., & Lyu, H.-M. (2021) formulated approaches to assess and manage lake eutrophication, in Suresh, K., Tang, T., van Vliet, M. T. H., Bierkens, M. F. P., Strokal, M., Sorger-Domenigg, F., & Wada, Y. (2023) Proposed water quality indicators for assessing freshwater lake eutrophication. The article by Abell, J.M., Özkundakci, D., Hamilton, D.P., & Reeves, P. (2020) is more applied and aims to develop restoration measures for shallow lakes affected by eutrophication. The possibility of using remote sensing methods to study water eutrophication is substantiated in Tomchenko, O. (2014), Fedorovsky, O., Khyzhnyak, A. & Tomchenko, O. (2021), and for the conditions of Volyn Polissia – Fesyuk, V., Polianskyi, S. & Kopytyuk, T. (2022). The peculiarities of estimating vegetation indices are highlighted in Fedoniuk M., Kovalchuk I., Fesyuk V., Kirchuk R. & Merlenko I.M. (2021). In our work, we also set out to assess the level of eutrophication of individual lakes in Volyn Polissia, which differ in origin, size, hydroecological status, and modern economic use.

Method and Theory

Remote sensing methods were used to study the lakes of Volyn Polissya. Namely, the calculation of difference vegetation indices NDVI and NDAI. NDVI is a normalized difference vegetation index. It reflects the state of vegetation through the red and near-infrared spectra. The range of values is (-1; 1). NDAI – normalized difference algo index. Determines the presence of algae through the ratio of spectral channels. Based on the results of the calculation, maps of the distribution of indices on the surface of the lakes were constructed. For this purpose, the online platform EO Browser and satellite images of the Sentinel-2 mission for different years were used. They were filtered by cloud cover (less than 20%). Atmospheric correction was taken into account. Statistical analysis of the dynamics of vegetation indices for different periods and calculation of correlation coefficients between the values of the indices and water temperature were calculated in MS Excel. The results of statistical calculations and graphical constructions were analyzed in the context of the lake type by origin, its size, depth, water quality and hydroecological condition.

Results

In recent years, NDVI has been widely used to assess the degree of eutrophication of water bodies. This is facilitated by the ability to differentiate NDVI values from an image. This makes it possible to identify separate areas of water and shores covered with vegetation. Within the water surface, it is also possible to identify separate areas that differ in vegetation intensity. Their area and distribution vary with the seasons and depend primarily on water temperature and distance from the shore, when concentric zones of vegetation are formed. NDVI provides certain information about the state of the reservoir. High NDVI values (>0.3-0.5) indicate dense floating vegetation, such as duckweed. This is a sign of a high level of eutrophication. Moderate NDVI values (0.1-0.3) indicate surface growth of algae or microorganisms. Negative or close to zero NDVI values correspond to clean water without vegetation. Negative values help to identify clean areas of a water body and compare them to areas with positive NDVI values. Observing changes in NDVI (e.g., from -0.2 to -0.1) over time can indicate the onset of eutrophication.

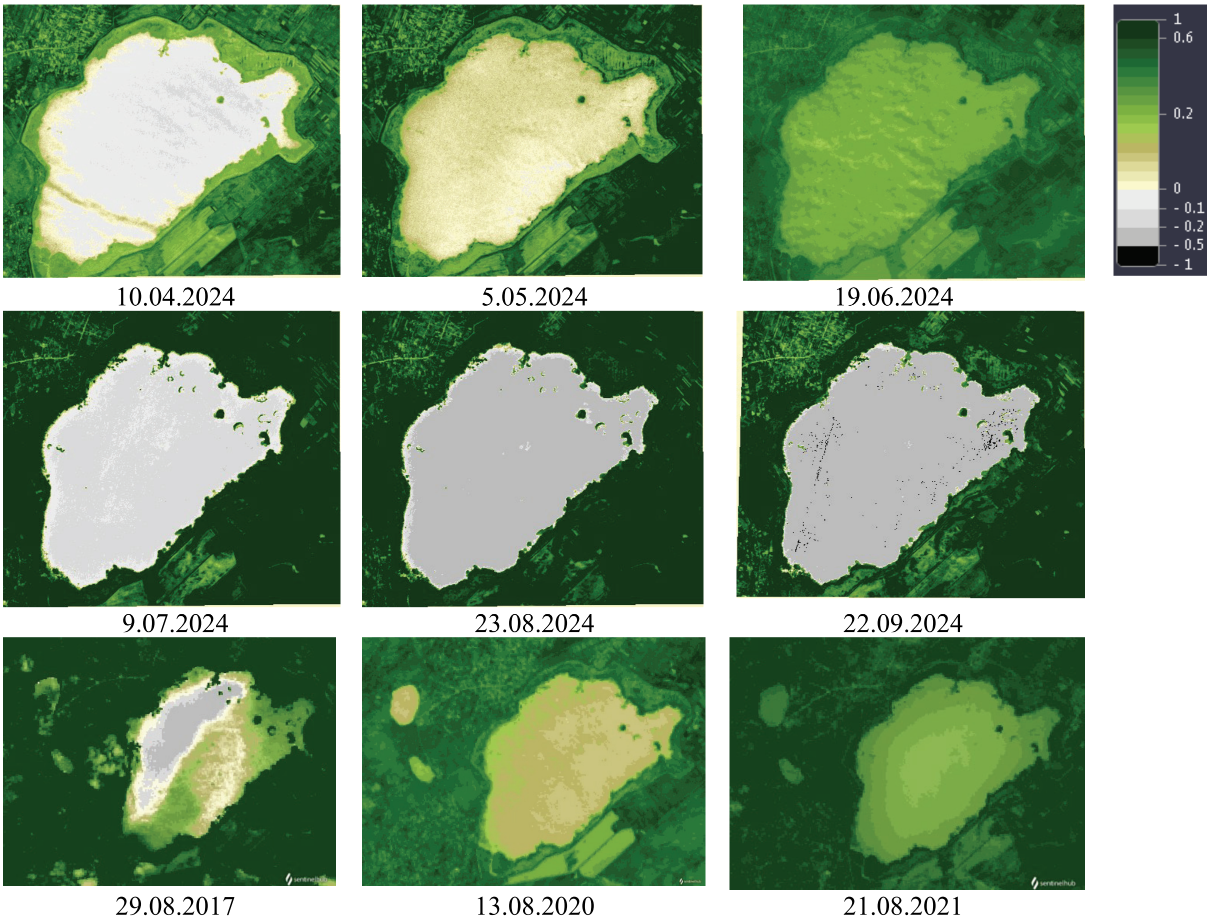


Figure 1 *NDVI index values on Sentinel-2 satellite image fragments for Lake Turske for different dates according to sentinel-hub.com.*

Let's consider the features of eutrophication processes on the example of Lake Turske (Fig. 1). The anthropogenic impact has significantly changed its watershed. The key role in these changes has been played by drainage works, development of settlements and agricultural activities. The Turska and Zabolotivska drainage systems operate in the catchment area. The lake is not just under their influence. It is a reservoir of the Turska drainage system, built in 1964-65. Reclamation work in this region has a long history. More than 150 years ago, the Tursk Main Canal was built to receive water from the reclamation system. Therefore, the lake is subject to intense eutrophication (Fig. 1). These processes begin in the spring. In summer, their intensity increases. The following pattern is evident: in May, eutrophication is practically absent. The NDVI for the lake surface is -0.1-0.2, and in some areas even -0.2-0.5. In June, the NDVI values increase, and some areas of the lake surface appear with positive NDVI values. In some years, these areas have different sizes. For example, in 2017-18, these were rather small areas, mainly in the central part of the lake, near the eastern and northern shores, and in 2019-2021, these areas already occupy significant areas, in particular, in 2019 - 20% of the water surface area, in 2020 - 50%, in 2021 - more than 70%. In 2023-24, their area was much smaller. The lower part of Fig. 1 shows fragments of images of the lake in August in different years. They clearly demonstrate the maximum scale of eutrophication processes. Starting in September, the intensity of eutrophication decreases and the lake water is purified.

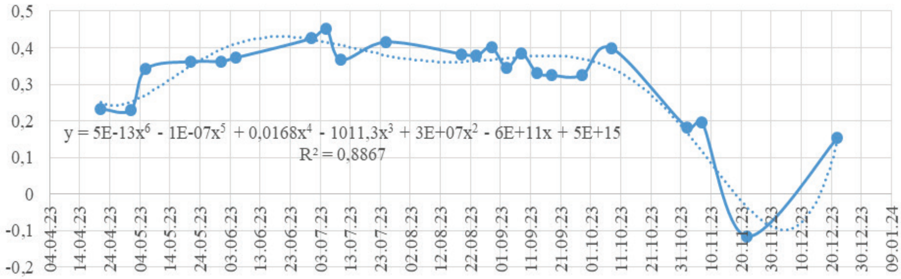


Figure 2 *The dynamics of the NDVI index for Lake Turske in 2023 according to sentinel-hub.com.*

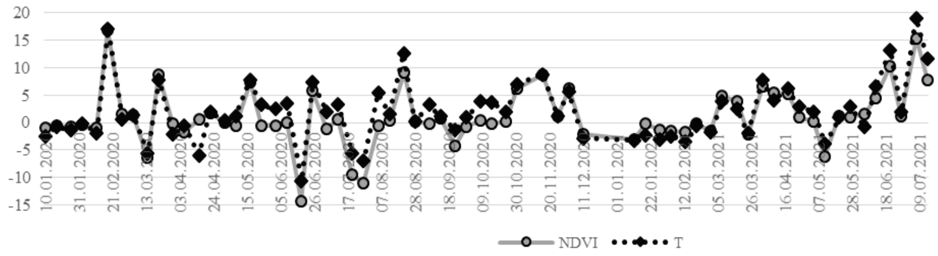
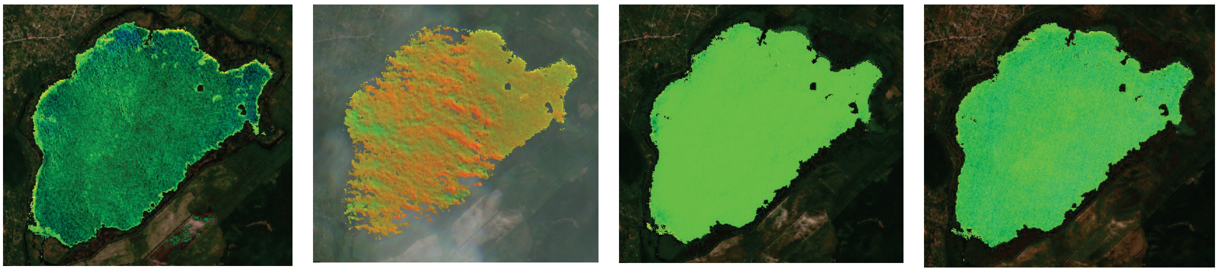


Figure 3 *Comparison of the dynamics of weighted NDVI values and water surface temperature of Lake Turske for 2020-21 according to sentinel-hub.com.*

For example, during 2023 (Fig. 2), the NDVI values for the lake were in the range (-0.11; 0.45). Index values greater than 0.3 indicate a high level of eutrophication and were typical from May 5 to October 21.

Among the factors affecting the level of eutrophication, the most important are water temperature, nutrient inputs (phosphorus, nitrogen) and morphological features of water bodies (area, depth, volume, and shape of the basin). Fig. 3 shows a comparison of the dynamics of the weighted NDVI values and water surface temperature of Lake Turske in 2020-21. The graph confirms the conclusion that eutrophication is most strongly correlated with water temperature. The calculated correlation coefficient is 0.88. This is a fairly high correlation.

Other indices are also used to study lake eutrophication. Fedorovsky, O., Khyzhnyak, A., Tomchenko, O. (2021) proposed to use the NDAI (Normalized Difference Algae Index) index for this purpose. The density of vegetation or algae in water is displayed in different colors (Fig. 4). Blue color indicates water, turquoise color indicates areas with lower density of aquatic plants or algae, bright green color indicates medium density of algae, yellow areas indicate the highest density of these species. Muddy water is colored brown, red or purple in proportion to the amount of turbidity. The NDVI index allows to identify aquatic plants and algae in water bodies, as it highlights these areas, while the rest of the territory is visualized in natural colors (True Colors). The results of the analysis of satellite images by the NAI index (Fig. 4) correlate well with the NDVI. The intra-annual course of the NDAI index is also characterized by an increase from May to August and then a decrease in values by the end of the year.



20.05.2024 19.06.2024 9.07.2024 7.09.2024

Figure 4 *NDAI index values on Sentinel-2 satellite image fragments for Lake Turske for different dates according to sentinel-hub.com.*

Conclusions

Eutrophication causes significant damage to the ecosystems of Volyn Polissia lakes. To monitor lake eutrophication, it is advisable to use the NDVI and NDAI indices, which are closely correlated. It is also advisable to combine the analysis of index distribution maps with statistical processing. In particular, with the calculation of correlation coefficients between NDVI values and water temperature. Using this approach will ensure the objectivity and efficiency of the analysis, allow forecasting changes in the eutrophication and hydroecological state of the lake, planning and implementing effective and timely measures to prevent eutrophication and improve water quality. The complex of remote monitoring methods will differ for each individual lake. The composition of the methods depends on the morphological and topological features of the reservoir, its origin, stage of development, intensity of economic development and anthropogenic impact, current hydroecological state and other factors affecting the course of eutrophication processes in the reservoir.

References

Abell, J. M., Özkundakci, D., Hamilton, D. P., & Reeves, P. (2020). Restoring shallow lakes impaired by eutrophication: Approaches, outcomes, and challenges. Critical Reviews in Environmental Science and Technology, 52(7), 1199-1246.

Fedoniuk, M., Kovalchuk, I., Fesyuk, V., Kirchuk, R & Merlenko, I. (2021). Differences in the assessment of vegetation indexes in the EO-Browser and EOS LandViewer services (on the example of Lutsk district lands). Conference Proceedings, International Scientific Conference "Geoinformatics-2021", URL: https://eage.in.ua/?page_id=2414

Fedorovskyi, O. D, Khyzhniak, A. V., & Tomchenko, O. V. (2021). Assessment of the aquatic environment quality of urban reservoirs using system analysis methods based on remote sensing data integration. Space Science and Technology, 27(5), 11-18. (In Ukrainian).

Fesiuk, V. O., Polianskyi, S. V., & Kopytiuk, T. V. (2022). Methodology and practical implementation of remote sensing data application for monitoring of water bodies eutrophication (on the example of Lake Turske). Scientific Notes of Ternopil Volodymyr Hnatiuk National Pedagogical University. Series: Geography, (1), 159-166. (In Ukrainian).

Lin, S.-S., Shen, S.-L., Zhou, A., & Lyu, H.-M. (2021). Assessment and management of lake eutrophication: A case study in Lake Erhai, China. Science of The Total Environment, 751, 141618. Suresh, K., Tang, T., van Vliet, M. T. H., Bierkens, M. F. P., Strokal, M., Sorger-Domenigg, F., & Wada, Y. (2023). Recent advancement in water quality indicators for eutrophication in global freshwater lakes. Environmental Research Letters, 18(6), 063004.

Tomchenko, O. V. (2014). Use of space information from remote sensing and ground-based observations for integrated assessment of ecosystem services of the Kyiv reservoir based on the hierarchy analysis method. Space Science and Technology, 20(5), 41-49. (In Ukrainian).

Zhou, J., Leavitt, P. R., Zhang, Y., & Qin, B. (2022). Anthropogenic eutrophication of shallow lakes: Is it occasional? Water Research, 221, 118728.