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Investigation of Surface Water Dynamics Using the NDCI and NDTI Remote Sensing Indices

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SUMMARY

This study investigated surface water dynamics using the NDCI and NDTI remote sensing indices, enabling the tracking of the spatiotemporal dynamics of pollution in the Desna and Seim rivers within Chernihiv Oblast, caused by the influx of suspended matter from the Seim River in Sumy Oblast. The application of remote sensing indices is one of the most effective approaches for detecting, monitoring, and analyzing environmental changes. These indices enable the operational observation of anthropogenic impacts, ecological assessment of territories, and tracking of the spatial distribution of environmental pollution. Furthermore, the use of remote sensing indices complements traditional methods for monitoring surface water conditions. In 2024, it was found that the spectral characteristics of surface waters – specifically in the Seim River and the Desna River within Chernihiv Oblast – significantly deteriorated, indicating increased turbidity and suspended matter concentration. The results of the study showed that as of September 3, 2024, NDTI values fluctuated between 0 and 1. This indicated the presence of suspended matter over significant areas of the Desna River after its confluence with the Seim River. The affected zone extended from the "Lavryk" Zoological Nature Monument to the village of Makoshyno in Chernihiv Oblast, where river biota mortality was recorded. At the same time, the analysis of satellite imagery subsets using the NDTI as of September 5, 2024, demonstrated a significant decrease in NDTI values to a range between -0.6 and 0.2. This indicated a reduction in suspended matter concentrations and a gradual improvement of the aquatic environment of the Desna and Seim rivers within Chernihiv Oblast. The obtained results demonstrate the feasibility of using remote sensing data for early pollution detection, assessment of its scale, and monitoring of recovery processes in aquatic ecosystems.

Keywords: Surface water bodies; Normalized Difference Turbidity Index; Normalized Difference Chlorophyll Index

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Introduction

Remote sensing indices provide an effective method for detecting environmental changes, monitoring anthropogenic impacts, and tracking spread of pollution. Furthermore, these indices complement traditional surface water monitoring methods. In late August 2024, a mass fish kill was recorded in the Seim River. As a result, the water in the river became turbid, turned black in color, and emitted an ammonia odor. Subsequently, the entire mass of pollution gradually migrated downstream into the Desna River. A potential cause of this pollution is the release of ammonia-containing substances from the territory of the Russian Federation (Patoka, 2024). Therefore, in this study, an investigation of surface water dynamics was conducted using remote sensing indices to record spatiotemporal changes in the spread of pollution on satellite imagery.

Method and Theory

Investigations into the dynamics of the state of surface water bodies using remote sensing indices are presented in previous works (Plichko et al., 2022; Zatserkovnyi et al., 2019). Therefore, to analyze both the spatial and temporal changes in the spread of pollution in surface waters on satellite imagery, the spectral indices NDCI and NDTI were used. The NDCI (Normalized Difference Chlorophyll Index) is a spectral index used to assess chlorophyll concentration in water bodies and detect the intensity of phytoplankton development. The index is based on the difference in reflectance between the red and red-edge spectral bands, which provides increased sensitivity to the bio-optical properties of water, even under turbid conditions. NDCI values increase with rising chlorophyll-a concentrations, which may indicate the development of eutrophication processes and algal blooms. The index has a formula for Sentinel-2 (Mishra & Mishra, 2012):

$$\boldsymbol{NDCI} = \frac{(\boldsymbol{R_{RedEdge} - R_{Red}})}{(\boldsymbol{R_{RedEdge} + R_{Red}})} \quad (1)$$

where $R_{RedEdge}$ is the brightness value of the reflected electromagnetic radiation from the red-edge spectral band, and R_{Red} is the brightness value of the reflected electromagnetic radiation from the red spectral band.

The NDTI (Normalized Difference Turbidity Index) is a spectral index used to assess the turbidity of water bodies by analyzing light reflectance in the visible and infrared spectra. The index allows for the quantitative characterization of the concentration of suspended particles in water. It has a formula for Sentinel-2 based on reflectance in the red (0.61–0.68 µm) and green (0.5–0.59 µm) bands according to the formula (NDTI Algorithm Specification, 2025):

$$\boldsymbol{NDTI} = \frac{(\mathbf{R_{Red} - R_{Green}})}{(\mathbf{R_{Red} + R_{Green}})} \quad (2)$$

where R_{Red} is the brightness value of the reflected electromagnetic radiation from the red spectral band, and R_{Green} is the brightness value of the reflected electromagnetic radiation from the green spectral band.

To detect changes in surface water conditions, subsets of satellite imagery acquired from the Sentinel-2A satellite were analyzed for the period 2023–2025, covering cloud-free days at spatial resolutions of 10 m and 20 m (ESA, n. d.).

The Desna River within Chernihiv Oblast was chosen as the object of study. It is the second-largest tributary of the Dnipro River by catchment area (after the Prypiat River); its length is 1030 km, of which 575 km are located in Ukraine, and its catchment area is 88.9 thousand km². Additionally, a part of the Seim River within Chernihiv Oblast was studied. It is a left tributary of the Desna River. Its length is 714 km, of which 250 km are located in Ukraine, and its catchment area is 27.5 thousand km² (Surface waters, 2000).

Results

The surface water dynamics, investigated using the NDCI and NDTI spectral indices on satellite imagery, are presented in Fig. 1-3.

As shown in Figure 1, the NDCI values from April to October 2023 fluctuated between 0 and 0.7. Elevated values were concentrated near the banks due to the presence of riparian vegetation. In contrast, satellite images from April to October 2024 showed NDCI values ranging from -1 to 1. In these images, NDCI values increased in the near-bank zone similarly to the satellite images from April-August 2023. However, a significant increase was recorded in the middle of the channel after the confluence with the Seim River in the satellite imagery subset from September 3, 2024. This was caused by the presence of significant concentrations of suspended matter entering from the Seim River in Sumy Oblast. Conversely, in the satellite images from April – October 2025, the NDCI values fluctuated in the range from 0 to 0.7, they were observed only in the near-bank zone, indicating that the state of the Desna River within Chernihiv Oblast had returned to a stable condition.

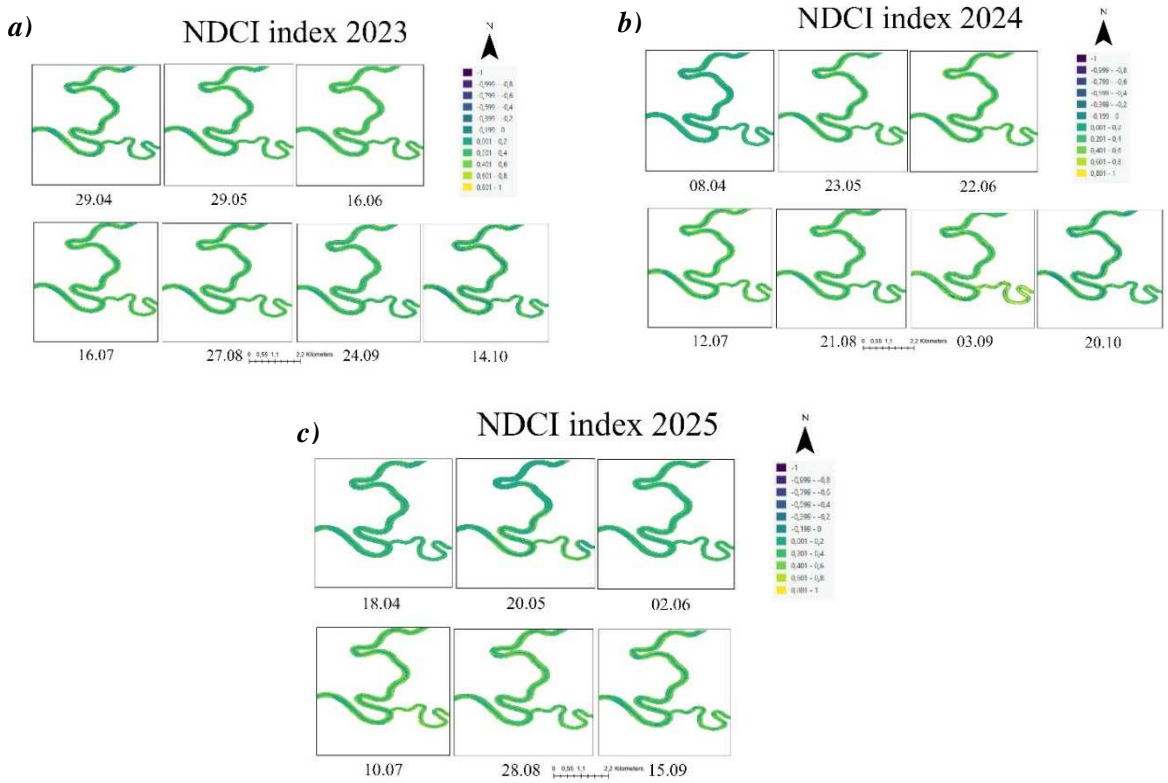

Figure 1. *Assessment results for water transparency dynamics in the Desna River using the NDCI: a) 2023; b) 2024; c) 2025*

The next step was calculating the NDTI to map suspended matter in surface waters in more detail (Figure 2). From April to October 2023, the values in the images ranged from 0 to 0.1, occupying insignificant areas within the riparian territory. In the satellite imagery subsets from April–October 2024, a significant increase in the area of suspended matter was observed. As can be seen in Figure 2, the NDTI values for September 3, 2024 (Figure 3) fluctuated in the range from 0 to 1, indicating the presence of suspended matter that was observed over significant areas in the Desna River after its confluence with the Seim River, specifically near the "Lavryk" Zoological Nature Monument, and spread to the village of Makoshyno in Chernihiv Oblast, where river biota mortality was recorded *(Patoka, 2024).* In contrast, as early as September 5, 2024, no significant concentrations of suspended matter were recorded in the satellite images using the NDTI, and the values fluctuated in the range from -0.6 to 0.2. Similar values were also traced for the NDCI. Furthermore, from April – October

2025, the highest NDTI values were recorded in the range from 0 to 0.23; this indicates that the state of the Desna River within Chernihiv Oblast returned to a stable condition.

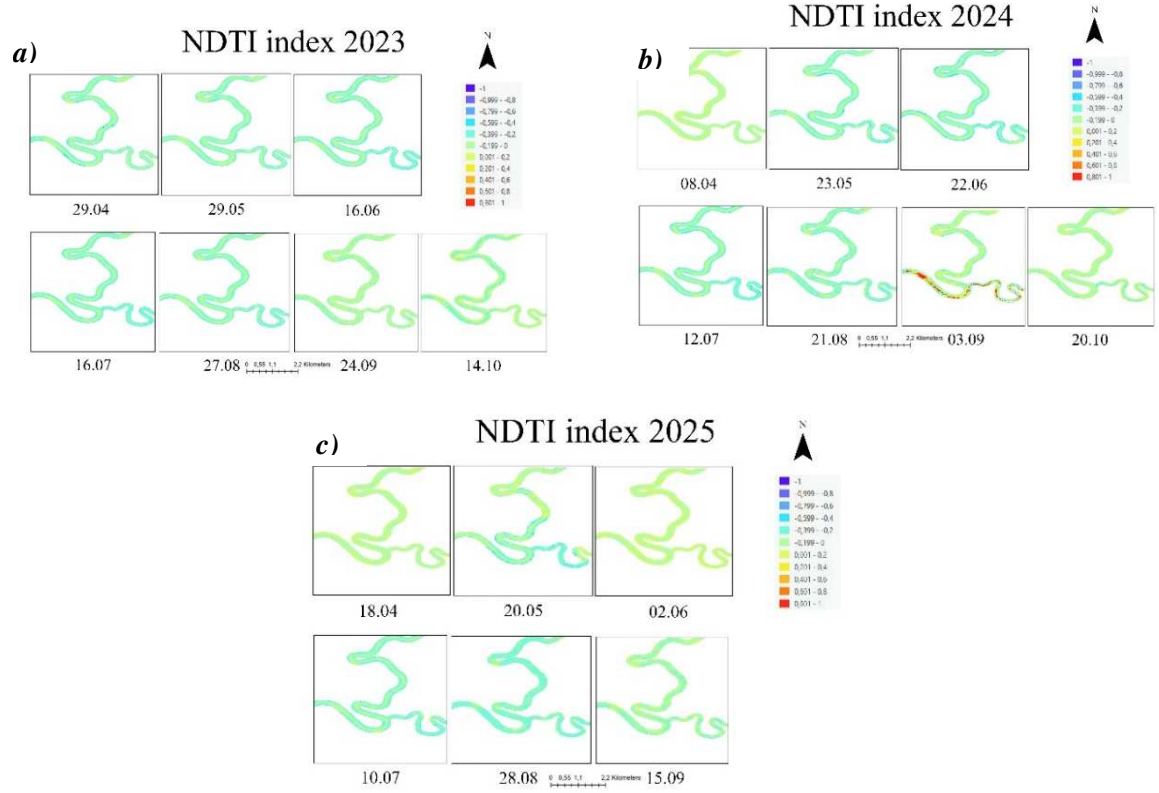

Figure 2. *Assessment results for water transparency dynamics in the Desna River using the NDTI: a) 2023; b) 2024; c) 2025*

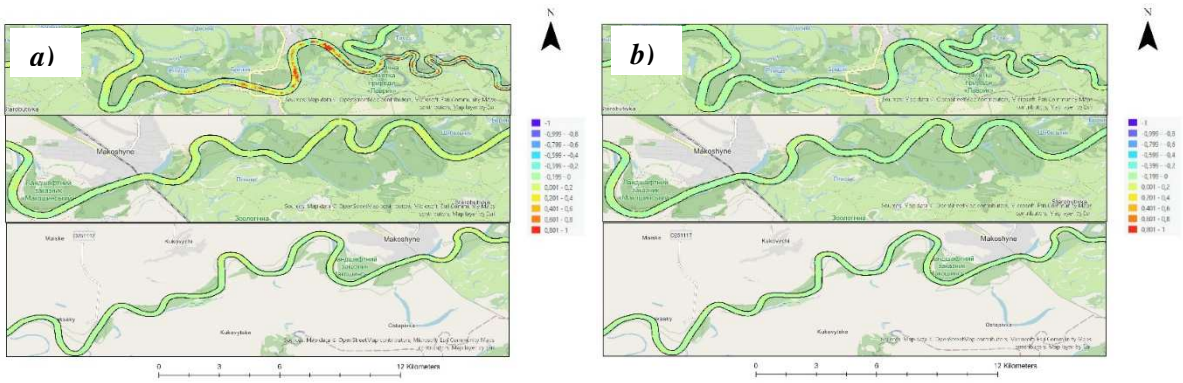

Figure 3. *Assessment results for the dynamics of changes in water transparency in the Desna River using the NDTI: a) 03.09.2024; b) 05.09.2024*

Conclusions

This study confirmed the effectiveness of using the NDCI and NDTI remote sensing spectral indices to investigate surface water dynamics. This approach enabled the tracking of spatiotemporal pollution dynamics in the Desna and Seim rivers within Chernihiv Oblast, caused by the influx of suspended matter from the Seim River in Sumy Oblast.

In 2024, a significant deterioration in the spectral characteristics of surface waters – specifically the Seim and Desna rivers within Chernihiv Oblast – was observed, characterized by an increase in turbidity and suspended matter concentration.

A comparison of the satellite imagery analysis results using the NDCI and NDTI spectral indices for 2023, 2024, and 2025 showed that in 2025, the spectral indicators returned to values close to background levels, indicating a gradual recovery of the condition of the Desna and Seim rivers within Chernihiv Oblast. The obtained results demonstrate the feasibility of using remote sensing data for the early detection of pollution, assessment of its scale, and monitoring of aquatic ecosystem recovery processes.

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