ГЕОІНФОРМАТИКА

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SPATIAL ANALYSIS OF THE FLOODED LAND AREA OF THE KHERSON REGION NATURE RESERVE USING REMOTE SENSING DATA

(Представлено членом редакційної колегії д-ром геол. наук, ст. дослідником О.І. Меньшовим)

Background. *The ongoing war in Ukraine has become the largest armed conflict in the world in the last decade, causing unprecedented destruction and devastation of the country's natural landscapes. The disaster caused by the explosion at the Kakhovka hydroelectric power station inflicted irreparable damage to the ecologically important and valuable lands of the Kherson region natural reserve. The aim of the work was to study the flooded land areas of the natural reserve of the Kherson region, Ukraine, which were affected by the collapse of the Kakhovka hydroelectric power station dam, using remote sensing data.*

Methods. *The paper highlights the features of using remote sensing (RS) for geoinformation modeling of the impact of the Kakhovka hydroelectric power station dam collapse on the lands of the Kherson region natural reserve. In addition, data from the Ministry of Environmental Protection and Natural Resources of Ukraine, Open Street Map, and Landsat 8 satellite images were used for the work. The method of geoinformation modeling in the QGIS, Sentinel Hub, and ArcGIS environments was used for data processing.*

Results. *The study found that more than 80 % of the area was flooded in half of the studied nature reserves (19). In this study, special attention was paid to the Nyzhniodniprovsky National Nature Park, which is the largest in area and is actually located on the front line. The area of flooding was 89 %, which indicates the extent of damage caused by the flooding. This paper describes the algorithm for processing geospatial data, Landsat. To analyze the changes that the park's landscapes have undergone, changes in vegetation indices were assessed.*

Conclusions. *The paper concludes that there is a pressing need for further monitoring and development of comprehensive measures for the rehabilitation of the affected areas. It is proposed to use the modeling results to plan measures for the protection and restoration of natural complexes affected by human-made disasters. These results will serve as the basis for further research, which will include studying the dynamics of changes in the state of the land areas of the nature reserve. This approach will allow a more accurate assessment of the consequences of the disaster event and the development of effective measures for the restoration and preservation of these lands.*

Keywords: *flooded lands, RSE, Kakhovka reservoir, nature reserve lands.*

Background

Armed conflicts and hostilities negatively impact the environment, infrastructure, and human lives. Modern wars have a greater impact on ecosystems than previous, less industrialized wars, due to the greater potential of modern weapons to cause environmental damage (Tignino, 2011). Consequences of war can manifest both directly, as damage to water resources and contamination by weapon residues, and indirectly, as increased frequency or intensity of destructive processes. Such processes can occur naturally, for example, erosion, or anthropogenically (e.g., industrial pollution). Water supply and treatment facilities, water distribution and sewage systems often become direct and indirect victims of war (Francis, 2011).

On February 24, 2022, Russia launched a full-scale invasion of Ukraine, an event that triggered unprecedented destruction and devastation of the country's natural landscapes (Tomchenko et al., 2023). The Kherson region, like the country's other regions, faced enormous problems caused by the use of military force by the aggressor country. The south of Ukraine had long been known to suffer from a shortage of water resources, with the Kherson region being no exception. That is why, in the late 1950s, the Kakhovka Reservoir was created by constructing the Kakhovka Dam on the Dnieper in order to improve local water supply and meet the needs of agriculture, industry and energy.

In June 2023, however, the Russian occupation troops destroyed the Kakhovka Dam, using damage to civilian infrastructure as a weapon against Ukraine. This disastrous event has become a problem of special scientific interest, highlighted in numerous studies by researchers, ecologists, and public activists. The Kakhovka Dam destruction inflicted great damage to the region, affecting water management, agriculture, as well as the lands of the nature reserve, which

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make an important component of the land cover in the Kherson region. Moreover, these lands are both a regional jewel and an attraction for tourists, which, in turn, have an impact on the economy of the region (Afanasyev, 2023).

The impact of the Kakhovka hydropower plant (HPP) demolition on the lands of the Kherson region is a major issue because land is an important natural resource of the country; therefore, it is necessary to monitor and analyze changes in land use and land cover for territorial development planning, ensuring sustainable development, and preserving biodiversity (Vyshnevskyi et al., 2023).

One of the most adverse effects of warfare on land cover is the destruction or damage to agricultural lands, forests, water bodies, and other natural areas (Tsiupa, & Plichko, 2023). Military operations, the use of heavy weapons and explosive devices can lead to soil destruction, water pollution, and the destruction of forest cover (Strokal et al., 2023). Being an important natural resource, the lands of the nature reserve play a role in both regional and national economy, as well as contributing to the development of ecosystems and biodiversity of nature.

Literature Review. Floods are natural phenomena that are an integral part of the hydrological cycle. Most floods are caused by the interaction between extreme unexpected weather events and the geohydrological characteristics of the catchment (relief, land use, geomorphology, and human intervention). In order to fully understand the consequences of the explosion at the Kakhovka HPP and develop a system of measures for remedying them, one should carefully study the results of research on similar topics in other countries (Kastridis et al., 2021).

The experience gained by the colleagues from Brazil, who are investigating the problem of vegetation degradation in their study, is of great use to this research. They applied an improved method based on NDVI values obtained from satellite images and tested in the Uberaba River Basin Environmental Protection Area (Valle Júnior et al., 2019).

Flooding, in terms of its development dynamics and territorial distribution, is the most prevalent among exogenous geological processes in Ukraine. This is a complex process, which is characteristic mainly of economically developed territories. Flooding affects more than 2 thousand cities, towns, and rural settlements with a population of up to 16 million inhabitants. Flood threats have become particularly high in Mykolaiv (52 % of the total area of the region), Odessa (40 %), and Kherson (36 %). Among urbanized territories facing the greatest risk of flooding are the Dnipropetrovsk, Donetsk, Zhytomyr, and Odessa regions (Tymochko, 2009).

Of interest is also the method of assessing the benefits of a flood warning system, as well as the method of assessing flood hazard zones, which was applied to the Koyliaris River basin in Greece. The implementation of this idea may help to mitigate the adverse effects of flooding now that the water level of the Dnieper River is no longer stable after the collapse of the dam (Kourgialas, & Karatzas, 2011).

In recent years, world scientific publications have paid close attention to the topic of human-induced flood damage. In papers on water pollution due to infrastructure damage (Mason et al., 2011; Biswas, 2000), the authors report extensive damage to treatment facilities as an example of human-made disasters. For instance, in Afghanistan, the irrigation system was seriously damaged during military operations, which resulted in the loss of viable agricultural land and biodiversity, and is still contributing to the loss of livelihoods and food security (Hussona, 2019).

In a recent paper on a flood disaster caused by a dam failure (Latrubesse et al., 2020), the authors used Sentinel-1 and Shuttle Radar Topography Mission (SRTM) imagery to determine the extent of the flooded areas. Analysis of satellite imagery, supported by field observations, showed that the flood inundated an area of ~46 km^2 of villages and farmland in the Wang Ngao River, a tributary of the Mekong River basin.

A study by Tavus et al. (2022) analyzed the extent of flooding and damage caused by the Sardoba Dam breach, which flooded parts of Uzbekistan and Kazakhstan. As a result of the dam breach, large areas were flooded, posing a serious threat to human lives, settlements and agricultural areas, the natural environment, etc. The authors recommended that a combination of Sentinel-1 and Sentinel-2 data be applied for flood mapping.

Scientists from the Institute of Land Use of the NAAS, Ukraine (Dorosh et al., 2023) developed a methodology for determining the areas of flooded lands affected by the collapse of the Kakhovka HPP dam and the area downstream of the Kakhovka reservoir. The methodology involved the use of satellite imagery, geoinformation technologies, and artificial intelligence technologies. The study results showed that the total area of flooding, according to ESA WorldCover land cover classes, was about 65 thousand hectares.

Another paper (Vyshnevskyi et al., 2023) examined the flooding of large areas caused by the Kakhovka dam destruction, including numerous settlements, agricultural lands, and natural ecosystems. The authors concluded that the collapse of the dam would lead to a shutdown of water supply to irrigation systems, which, in turn, would have a catastrophic impact on agriculture in southern Ukraine.

A study conducted by Magas et al. (2023) also analyzed the hydrological conditions of the Dnieper-Bug estuary region deriving from the collapse of the Kakhovka HPP dam and assessed its impact on the water resources and territories of Ukraine's southern regions. The major resulting hydrological phenomena observed included flooding of territories, destruction of civil infrastructure, residential buildings and households in the settlements, industrial and agricultural facilities, restriction of access to drinking water, deterioration of the ecological and epidemiological situation, destruction of the top soil, damage to vegetation, destruction of unique biodiversity, and loss of human lives.

The impact of military operations on freshwater resources and water infrastructure during the first three months of the war in Ukraine was analyzed in a paper by Shumilova et al. (2023), whose results showed that much of the water infrastructure, such as dams on reservoirs, water supply and water purification systems, and underground mines, were damaged or are currently under threat from military operations. A number of papers revealed major negative effects of military operations on the state of water bodies and their quality (Strokal, & Kovpak, 2022; Khan, 2022). Although considerable amount of research has been devoted to human-made flooding events, few attempts have been made to analyze the long-term effects of the Kakhovka HPP accident on the lands of the Kherson region nature reserve.

The purpose of the study is to investigate the lands of the Kherson region nature reserve flooded as a result of the explosion at the Kakhovka hydroelectric power station, using remote sensing data.

The object of the study is the lands of the nature reserve of the Kherson region, Ukraine.

The Kherson region nature reserve includes natural territories and objects (biosphere reserves, national natural parks, reserves) and artificially created objects (botanical

gardens, dendrological and zoological parks, and monuments of landscape art). These objects, depending on their ecological, historical, cultural and scientific value, are of national or local importance (Ministry of Environmental Protection…, 2020).

Methods

To achieve this goal, Landsat 8 satellite images taken on June 9, 2023 were used. One of the best ways to determine the area of flooding is to calculate the Normalized Difference Water Index (NDWI), proposed by McFeeters in 1995. The NDWI relies on the contrast between reflected near-infrared and visible green light to enhance the presence of these water bodies, effectively minimizing the visibility of soil and terrestrial vegetation features (McFeeters,1995).

To determine the condition of the park after the dam breach, the Normalized Difference Vegetation Index (NDVI) was used:

$$NDVI=(NIR-RED)/(NIR+RED)$$

The result produced by the formula is a value ranging from –1 to +1. If reflectance is low (or values are low) in the red channel and high in the NIR channel, this will generate a high NDVI value, and vice versa. In general, the NDVI is a standardized way to measure healthy vegetation. High NDVI values are indicative of healthier vegetation. On the contrary, low NDVI values are associated with lower density or lack of vegetation (EOS Data Analytics, 2022).

The next step was to convert the raster data (the NDWI index) to vector. For each polygon of the created vector, the corresponding value of the source class or each pixel of the raster is recorded in the attribute table (Raster to Polygon, 2021) (Fig. 1).

In addition, in this study, we used data from the Ministry of Environmental Protection and Natural Resources of Ukraine on the ecological state of the territories of the Kherson region for 2020, which provides a detailed account of the composition and area of the NPF lands. The actual area of the NPF lands as of 2020 was obtained from the environmental passport of the Kherson region (Ministry of Environmental Protection…, 2020). Data from the Open Street Map cartographic portal was used to overlay the NPF layer on satellite images. The method of geoinformation modeling in the QGIS, Sentinel Hub, ArcGIS environment was used to process the data.

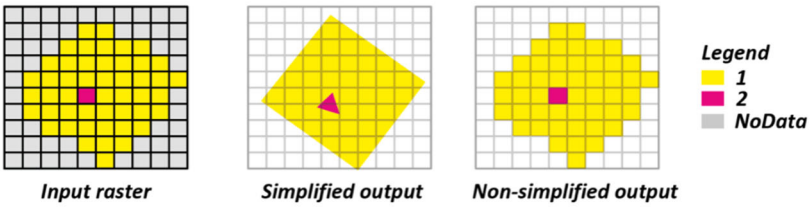


Fig. 1. Raster to vector conversion with various simplified settings

Results

Figure 2 presents a classified (reduced) NDWI Landsat 8 image as of June 9, 2023, i.e. the day when the flood reached peak values. It was found that the most flooded areas were those located on the left bank of the Dnieper River, in the area of Hola Prystan. Furthermore, the expansion of the Inhulets River bed became noticeable, which in turn led to an increase in water levels in the villages of Inhulets, Ulyanivka, Darivka, and Yasna Polyana (Fig. 2).

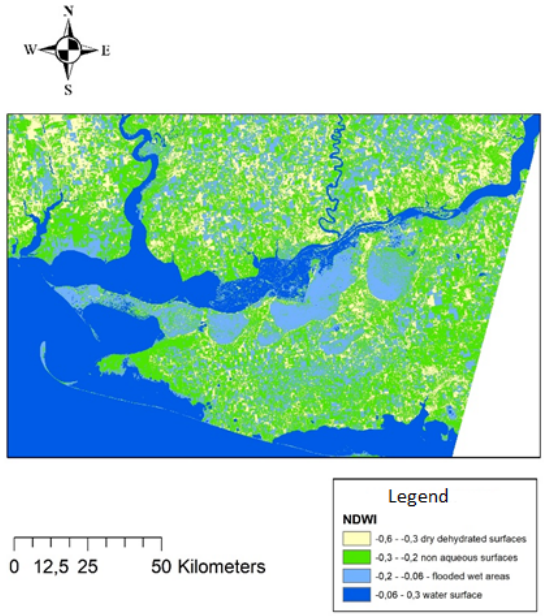


Fig. 2. NDWI water index of the flooded area according to Landsat 8 images as of June 09, 2023

To identify the lands of the nature reserve that were affected by flooding, Landsat 8 images were downloaded, the NDWI index was converted into vector format, after which the intersection of the NDWI layer and the reserve layer was found using ArcGIS tools. The next step in the analysis of the obtained data and Open Street Map data was to calculate the area of the flooded reserve lands (Table 1).

Table 1 presents the effects of the explosion at the Kakhovka HPP on the areas of land of the Kherson region nature reserve. The landmarks that suffered the most severe damage from flooding included: the Tsiurupynskyi Sosnovyi Bir ("Pine Forest") protected area of local importance, 95 % of which was flooded; Kozatske Dzherelo, a hydrological natural monument of local importance – 89 %; the part of Hopry Lake hydrological monument of local importance – 97 %; Bilozerski Dzherela, a hydrological monument of local importance – 94 %; and Ozero Solyane ("Salt Lake") Hydrological Reserve of national importance – 97 %. Among the least affected areas, on the other hand, were the Korsunskyi General Zoological Reserve of local importance and Hopry Sanatorium Park, a park-monument of landscape art of local importance, with a flooded area of 18 % and 14 %, respectively. These data indicate a number of serious issues caused by the dam collapse, considering the importance of the lands of the Kherson region natural reserve for both the economy and the development of ecosystems and biodiversity of nature. As a result of the blast, rare ecosystems have been lost, and a large number of rare plant and animal species inhabiting the reserve are under threat of extinction.

Figure 3 shows a map of the location of the objects of the Kherson region nature reserve where the area of flooding was more than 85 %.

Table 1

Comparison of land areas of the Kherson region natural reserve fund before and after flooding

№	Name of the object	Area, ha	Area of inundation, ha	%, flooding
1	Aleksandrivskyi Landscape Reserve, of national importance	989.827	626.44	63
2	Shiroka Balka Botanical Reserve, of local importance	114.312	95.3	83
3	Sophiivskyi Botanical Reserve, of local importance	204.074	161.811	80
4	Inguletskyi Iyman ("Estuary") Botanical Reserve, of local importance	50.022	37.584	75
5	Korsunskyi General Zoological Reserve, of local importance	3,390.228	619.179	18
6	Bakaiskyi Zholob General Zoological Reserve, of local importance	1,627.117	1,010.714	62
7	Bobrove Ozero ("Beaver Lake") Landscape Reserve, of local importance	49.351	43.631	88
8	Tsiurupynskyi Sosnovyi Bir ("Pine Forest") Protected Tract, of local importance	284.77	269.90	95
9	Ponyativske Poselennya Zmii ("Snake Settlement") Zoological Natural Monument, of local importance	5.613	3.758	67
10	Krynkivske Poselennya Bobriv ("Beaver Settlement") Zoological Natural Monument, of local importance	5.758	2.848	49
11	Kozatske Dzherelo Hydrological Natural Monument, of local importance	0.018	0.016	89
12	Bilozerski Dzherela ("Springs") Hydrological Natural Monument, of local importance	0.039	0.037	94
13	Part of Hopry Lake Hydrological Natural Monument, of local importance	5.009	4.858	97
14	Shaby Botanical Reserve, of local importance	20.33	18.311	90
15	Nyzhniodniprovskyi National Nature Park	82,850.50	73,955.82	89
16	Bakaiskyi Forest Reserve, of national importance	411.797	188.35	46
17	Ozero Solyane ("Salt Lake") Hydrological Reserve, of national importance	122.264	118.12	97
18	Hopry Sanatorium Park, park-monument of landscape art of local importance	17.994	2.45	14
19	Stanislavskyi Landscape Reserve, of national importance	659.271	526.454	80

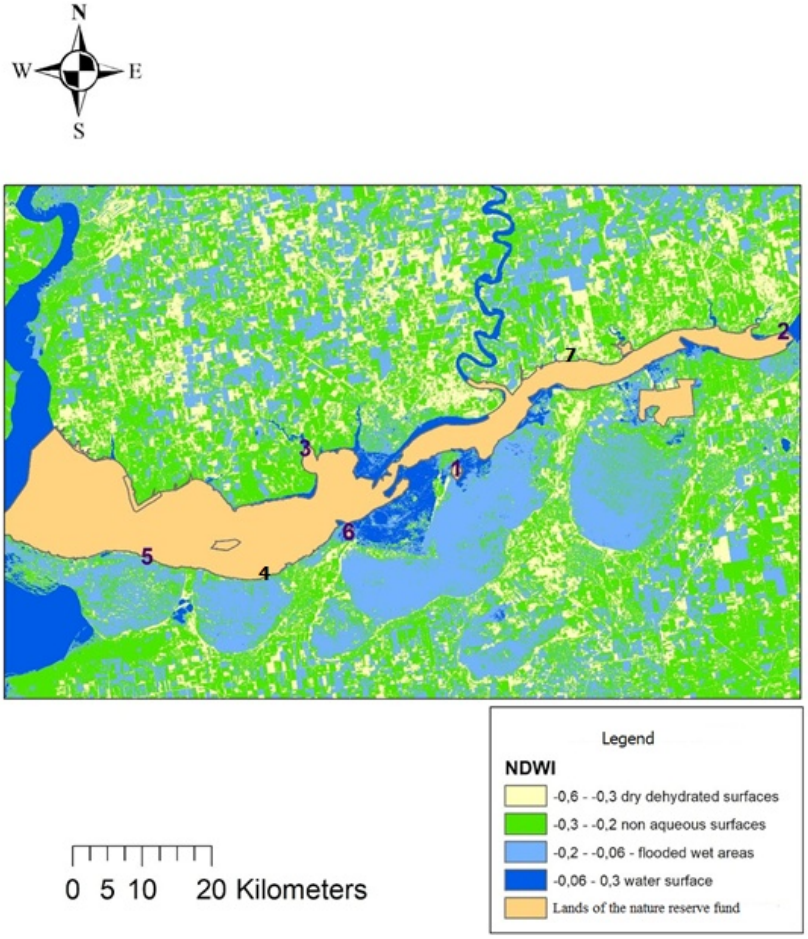


Fig. 3. Map of the nature reserve features with more than 85 % of the area flooded.
The map details the following nature reserve features marked with numbers:
1 – Tsiurupynskyi Sosnovyi Bir ("Pine Forest") Protected Tract of local importance;
2 – Kozatske Dzherelo Hydrological Natural Monument of local importance; 3 – Bilozerski Dzherela ("Springs") Hydrological Natural Monument of local importance; 4 – the part of Hopry Lake hydrological monument of local importance;
5 – Shaby Botanical Reserve of local importance; 6 – Ozero Solyane ("Salt Lake") Hydrological Reserve of national importance;
7 – Nyzhniodniprovskyi National Nature Park

In this paper, special emphasis is placed on the study of the Nyzhniodniprovskyi National Nature Park, which is the largest in area and is actually located on the current front line. There is no access to the territory, with the left bank still occupied by the enemy and the right bank recaptured. The river basin, with 50 islands in it, is the territory of the park, the direct combat zone where the front line passes. Hence, the use of remote sensing data is feasible (Hordiichuk et al., 2024).

The ecosystem of the national park suffered critical damage after the explosion of the dam at the Kakhovka HPP. In the first days after the explosion, the water rose by 6 meters 15 centimeters throughout the territory of the national park and all the living organisms that inhabited the area, including the Red Book flora and ichthyofauna, were all washed away (Tomchenko et al., 2023). According to the Ministry of Environmental Protection and Natural Resources of Ukraine, the flooding of the territory destroyed the habitat of more than 1,000 species of flora and 1,140 species of fauna (Ministry of Environmental Protection, 2020).

Analysis of the data obtained revealed an area of 73,955.8 hectares of the park territory inundated. By contrast, before the dam destruction, the total park area measured 82,850.506 hectares. The percentage of flooding reached nearly 90%, which indicates the scale of the tragedy caused by Russia's military actions (Fig. 4).

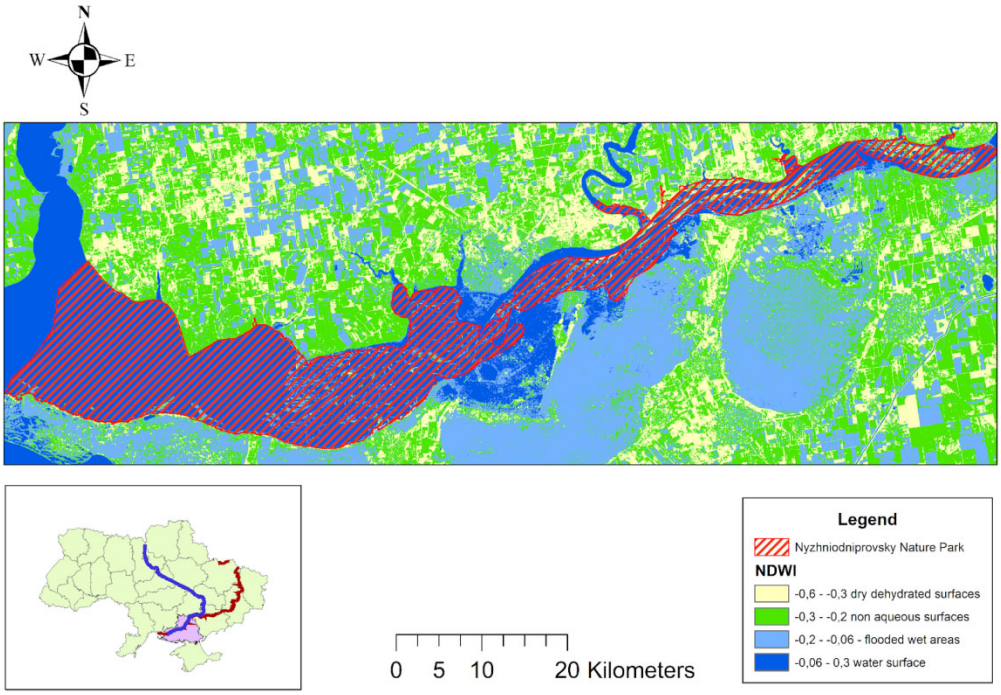


Fig. 4. Territory of the Nyzhniodniprovsky National Nature Park (park territory and flooded area)

The next step was to study the change in the NDVI vegetation index values during the flood peak and after it (according to Landsat 8 data). To compare the index values, 15 dates closest to the flooding period were taken, of which 8 main ones were placed on the graph (Fig. 5).

Figure 5 shows uniform NDVI index values until June 3, 2023, which show little fluctuation within the period. However, after June 8, 2023, a rapid decrease in the index value is noticeable, which may indicate the flood peak. After that, the index values begin to increase, showing slight fluctuations. This suggests that the water level became unstable, with a sudden increase on certain dates in some areas of the park. Therefore, the damage caused could be assessed as rather extensive. However, the graph shows that the NDVI values nearly reach the values observed before the accident. Thus, the park's ecosystem is gradually recovering.

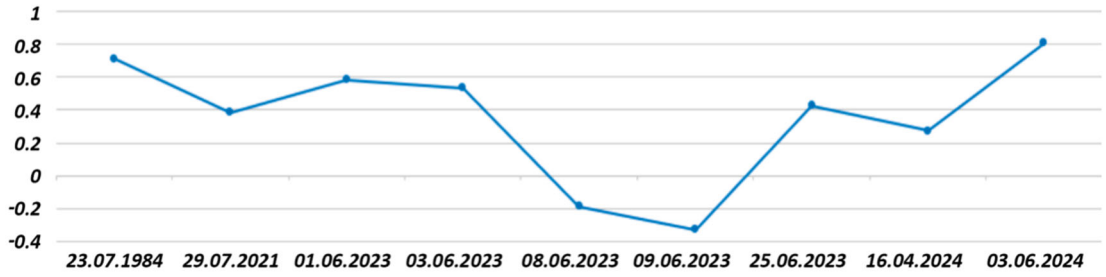
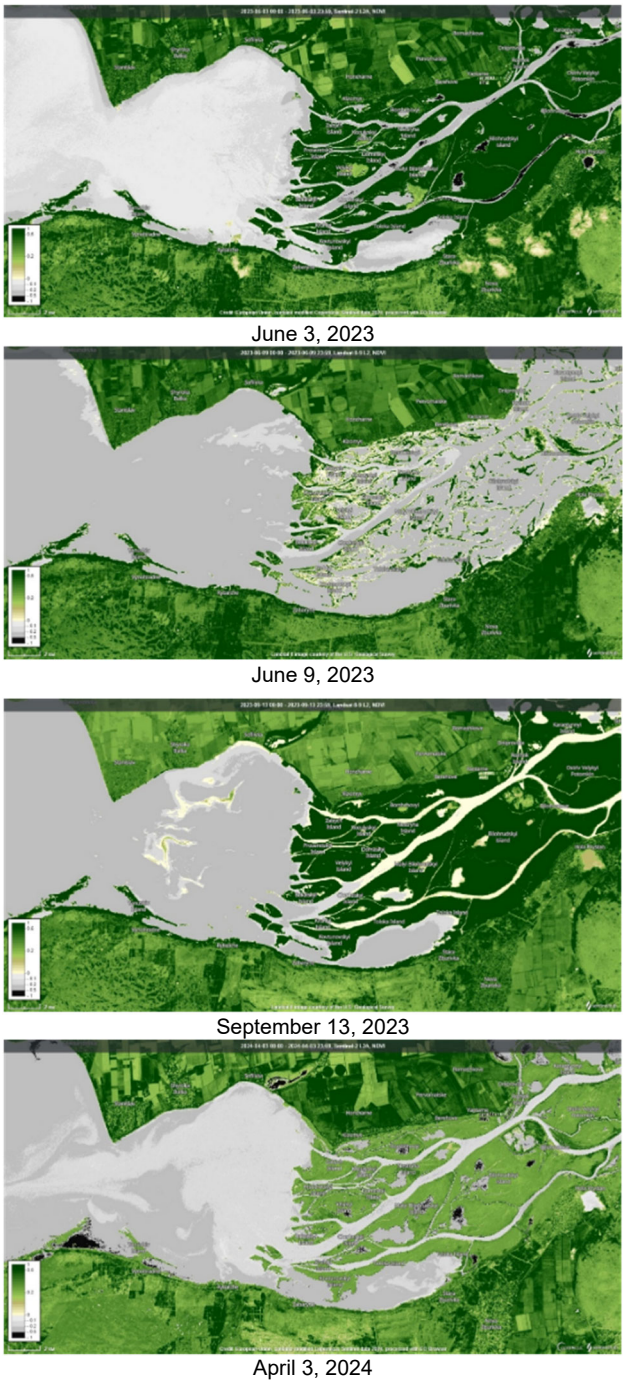


Fig. 5. Changes in NDVI values during and after the flood peak (based on Landsat 8 data)

Fig. 6 shows the dynamics of the NDVI index change before and after the accident. A significant decrease in the vegetation index values is observed. This may indicate extensive damage to vegetation due to flooding and a subsequent decline in the groundwater level due to a drop in the water level in the Kakhovka reservoir. Thus, the areas that previously had a higher moisture regime are being drained.



June 3, 2023

June 9, 2023

September 13, 2023

April 3, 2024

Fig. 6. NDVI index values obtained using Landsat 8 images

Discussion and conclusions

Using satellite images and geographic information systems (GIS), an analysis of changes in the state of the land areas of the Kherson region nature reserve after the destruction of the Kakhovka HPP was conducted. During the study, 19 nature reserve objects were analyzed, among which the most affected by flooding were the Tsiurupynskyi Sosnovyi Bir ("Pine Forest") protected area – 95 %; the Kozatske Dzherelo hydrological natural monument – 89 %, the Bilozerski Dzherela hydrological monument – 94 %, the part of Hopry Lake hydrological monument – 97 %, the Ozero Solyane ("Salt Lake") Hydrological Reserve – 97 %, and the Nyzhniodniprovskyi National Nature Park – 90 %.

In this study, special attention is paid to the Nyzhniodniprovskyi National Nature Park, due to the economic, natural, and cultural value of the protected area, the percentage of its affected area, and the park's having actually become the zone of combat. According to the results of the study, changes in the NDVI vegetation index values were observed during the peak flood period and after it, with the lowest index values recorded on June 8 and 9, 2023. However, since June 25, 2023, NDVI values have been increasing, which suggests that the park's ecosystem is gradually recovering.

The results obtained show the devastating impact of the Kakhovka Dam collapse on the local environment, which may lead to the disruption of ecosystems, loss of biodiversity

and natural resources, as well as a threat to the life and health of the local population.

To restore the damaged ecosystems and prevent similar tragedies in the future, a number of solutions suggested should include a detailed survey of the affected areas, the development of an ecological restoration plan, the provision of international assistance, and the strengthening of international law.

These results could make the basis for further research, which will focus on the dynamics of changes in the state of the lands of the nature reserves. This approach will ensure a more comprehensive assessment of the effects of the disastrous event on the lands and the development of effective measures for their restoration and preservation.

The flooding triggered by the dam destruction is also likely to have a detrimental impact on the coastal ecosystems. For example, the slopes of the Dnieper River valley may be eroded due to increased erosion activity and changes in the water flow regime. This can lead to soil erosion and damage to vegetation. The sudden rise in water levels led to the flooding of large areas of the floodplain, the destruction of vegetation and increased riverbank erosion. After the water recedes, the soils will be subject to erosion, salinization and pollution, which will lead to their degradation and a decrease in fertility for a long period.

Changes in the coastline of the Dnieper River and floodplain lakes, soil erosion, and other factors may reduce the attractiveness of the NNP and adjacent areas for recreation. However, an integrated approach to the restoration of these areas will allow creating new conditions adapted for ecotourism, bird watching, and other types of recreation on the site of the former floodplains.

A drop in prices for land plots adjacent to the National Nature Reserve may be predicted, as the areas that have been flooded or are subject to intense erosion tend to lose their value for recreation and construction. In addition, changes in the riverbed, water regime, erosion, bank redevelopment, instability of the level of surface and ground water will cause some areas to lose their commercial value. The destruction of infrastructure, such as roads, bridges, and communications, may reduce interest in purchasing land for commercial or residential purposes.

Authors' contribution: Iryna Stakhiv – conceptualization, formal analysis, methodology, writing (original draft); Vitalii Zatserkovnyi – conceptualization, data validation, writing (reviewing and editing); Mauro De Donatis – data validation, writing (reviewing and editing); Tetiana Pastushenko – writing (reviewing and editing); Sofiya Hordiichuk – formal analysis, data validation; Tetiana Malik – formal analysis, data validation.

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ПРОСТОРОВИЙ АНАЛІЗ ПЛОЩ ПІДТОПЛЕНИХ ЗЕМЕЛЬ ПРИРОДНО-ЗАПОВІДНОГО ФОНДУ ХЕРСОНСЬКОЇ ОБЛАСТІ ЗА ДАНИМИ ДИСТАНЦІЙНОГО ЗОНДУВАННЯ ЗЕМЛІ

Вступ. ***Війна, яка триває в Україні, стала найбільшим збройним конфліктом у світі за останнє десятиліття, що спричинив безпрецедентні руйнування та спустошення природних ландшафтів країни. Катастрофа, спричинена вибухом на Каховській ГЕС, завдала непоправної шкоди екологічно важливим і цінним землям природно-заповідного фонду Херсонської області. Метою роботи було дослідження площ підтоплених земель природно-заповідного фонду Херсонської області, що постраждали внаслідок руйнування дамби Каховської ГЕС за допомогою даних дистанційного зондування Землі.***

Методи. ***Висвітлено особливості використання дистанційного зондування (ДЗ) для геоінформаційного моделювання впливу наслідків підриву дамби Каховської ГЕС на землі природно-заповідного фонду Херсонської області. Також для роботи використано дані Міністерства захисту довкілля та природних ресурсів України, Open Street Map, супутникові знімки Landsat 8. Для оброблення даних застосовано метод геоінформаційного моделювання в середовищі QGIS, Sentinel Hub, ArcGIS.***

Результати. ***В ході дослідження встановлено, що понад 80 % площі затоплення зазнала половина із досліджуваних природно-заповідних об'єктів (19). В роботі особливу увагу приділено Національному природному парку "Нижньодніпровський", який є найбільшим за площею і фактично розташований на лінії бойового зіткнення. Площа затоплення склала 89 %, що говорить про шкоду, яку спричинило затоплення. У тексті описано алгоритм обробки геопросторових даних, Landsat. Для аналізу змін, що зазнали ландшафти парку, оцінено зміни вегетаційних індексів.***

Висновки. ***В роботі зроблено висновок про необхідність подальшого моніторингу та розробки комплексних заходів з реабілітації постраждалих територій. Запропоновано використовувати результати моделювання для планування заходів із захисту та відновлення природних комплексів в умовах таких техногенних катастроф. Отримані результати стануть підґрунтям для подальших досліджень, що включатимуть вивчення динаміки змін стану площ земель природно-заповідного фонду. Такий підхід дасть змогу більш повно оцінити наслідки події та розробити ефективні заходи для відновлення та збереження цих земель.***

Ключові слова: ***підтоплені землі, ДЗЗ, Каховське водосховище, природно-заповідний фонд.***

Автори заявляють про відсутність конфлікту інтересів. Спонсори не брали участі в розробленні дослідження; у зборі, аналізі чи інтерпретації даних; у написанні рукопису; в рішенні про публікацію результатів.

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