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GIS AS A TOOL FOR DETERMINING THE CONSEQUENCES OF NEGATIVE ANTHROPOGENIC INFLUENCE

ГІС ЯК ІНСТРУМЕНТ ВИЗНАЧЕННЯ НАСЛІДКІВ НЕГАТИВНОГО АНТРОПОГЕННОГО ВПЛИВУ

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Abstract. *The work is devoted to the application of GIS technologies in the modeling of flood research processes caused by negative anthropogenic influence. The considered technology of geoinformation provision of modern models of the formation of a flood monitoring system with an assessment of the consequences of flooding on the basis of open spatial data. The methodology and results of flood risk assessment modeling based on DZZ and GIS technologies are presented. Using the example of an abnormally high level of flooding in the studied territory, a web application was created with a graphic demonstration of the flooded territory, a display of information about all objects in the area affected by the flood, a selection of infrastructure objects damaged by the flood and a display of the result of the flood impact analysis.*

Keywords*: GIS technologies, remote sensing of the Earth, monitoring, web application, risk assessment.*

Introduction.

The present of modern science shows fundamental changes that are associated with the growing volume of data in free access, the emergence of modern algorithms for their processing and analysis. With the development of information technologies, traditional terrestrial methods of information collection are almost not used, they are replaced by technologies of remote sensing of the Earth (DSR) and geographic information systems (GIS), which ensure high efficiency of data acquisition and processing. Objects and processes described in GIS are a part of everyday life, and almost every decision made is conditioned by one or another spatial factor. Nowadays, the use of GIS technologies contributes to the solution of complex applied problems in various spheres of human activity [1]. GIS technologies together with physical-mathematical models for the study of various processes and phenomena have become the main tool for studying nature as a result of the negative anthropogenic impact on it. The information provision of emergency situations requires the involvement of a large volume of various information from various sources, data analysis and their presentation in an accessible form to the management of relevant institutions in a short time for making management decisions.

The purpose of this study is to develop a web application for flood monitoring with an assessment of the consequences of flooding. This will make it possible to ensure wide coverage of potentially dangerous areas, high accuracy of results, because objective and timely monitoring information is necessary for solving the tasks of restoring damaged areas.

Main part.

In order to ensure the appropriate living conditions of the population in the territories affected by floods and increase the level of environmental safety of these territories, it is necessary to determine the extent of the impact of flooding processes in a timely manner, which makes it possible to quickly respond to them by making appropriate management decisions. Modern flood forecasting systems at the national and regional levels operate on the basis of GIS technologies.

It is known that methods of monitoring the environment can be divided into 2 groups: contact measurement methods and DZ methods [2]. Today, modern GIS technologies are an effective tool in solving water resource management issues [3-4]. The process of active implementation of GIS technologies in hydrology is presented in works [5-6]. In studies [7-10], the process of data preparation for modeling and management of water resources, which later became standards, was considered.

Space images from the Landsat 8 OLI satellite are used to create graphic maps. These images can be obtained from the open electronic resource http://earthexplorer.usgs.gov. Atmospheric correction of the images is carried out, the digital number is converted into the surface reflection coefficient, the normalized wetness index (NDWI) is decomposed into a binary raster layer, where the water surface classes and other classes are separated by a threshold value, which is calculated using the Otsu method and is similar to the discriminant analysis method Fisher. The optimal threshold is obtained from the solution of system (1):

$$\begin{cases} \sigma^2 = P_{nw}\left(M_{nw} - M\right)^2 + P_w\left(M_{nw} - M\right)^2, \\ M = P_{nw}M_{nw} + P_w M_w, \\ P_{nw} + P_w = 1, \\ t^* = ArcMax\left\{P_{nw}\left(M_{nw} - M\right)^2 + P_w\left(M_{nw} - M\right)^2\right\}, \end{cases} \quad (1)$$

where σ – interclass dispersion of water and other classes, M – average value NDWI, P_{nw} – the probability of classes that are not related to water, P_w – probability of water, M_{nw} – class average without water, M_w – the average value of the water class.

It is also important to consider harvest periods from land for agricultural activities, as the model may erroneously include them in the flood zone. For this, the basis for uninhabited lands should be prepared using the normalized vegetation index NDVI, which we obtain from a satellite image according to formula (2):

$$NDVI = \frac{NIR - RED}{NIR + RED}, \quad (2)$$

where NIR – amplitude of reflection in the near-infrared region of the spectrum, RED – amplitude of reflection in the red region of the spectrum.

For the accuracy of the results, the normalized difference water index NDWI is still calculated, the threshold value for which is found using the Otsu method and system (1) with the replacement of water and non-water by vegetation and non-vegetation. A threshold value is used to classify layers based on binary. As a result, on the basis of the received data and the received layers, an intersection search operation is carried out and the inundation zone according to danger, damaged areas of land and geographical objects are distinguished.

Spatial data based on GIS packages for a geometric approach using multi-criteria analysis are used to model flood hazard areas. The impact of the criteria is calculated using the Analysis Hierarchy Method (AHP). The method is based on a semi-quantitative approach, which makes it possible to evaluate the impact of criteria depending on their importance for the occurrence of flooding. Ukraine has its own criteria (table 1).

Table 1. Criteria for influencing flood formation

Parameters	Accumulation of water	The possibility of a shower	Height	Depth Soil water	Land use	Flow coefficient	Incline	Geology
Accumulation of water	1	2	2	3	5	7	7	9
The possibility of a shower	0,5	1	1	3	4	5	6	7
Height	0,5	1	1	2	3	5	5	7
Depth soil water	0,33	0,33	0,5	1	3	4	5	6
Land use	0,2	0,25	0,33	0,33	1	2	4	5
Flow coefficient	0,14	0,2	0,2	0,25	0,05	1	3	5
Incline	0,14	0,17	0,2	0,2	0,25	0,33	1	3
Geology	0,11	0,14	0,14	0,17	0,2	0,2	0,33	1

For each matrix, you need to find the consistency coefficient (CR), which is calculated according to the formula:

$$CR = \frac{CI}{RI}, \quad (3)$$

where RI is an index that depends on the number of criteria and CI is a consistency index calculated by the formula:

$$CI = \frac{\lambda_{\max}}{n-1}, \quad (4)$$

where $\lambda_{\max}$ – the maximum value of the comparison matrix, n – total number of criteria. For a detailed selection of more problematic places on the map, you need to break down the criteria into categories.

After calculating the effect of the parameters, it is necessary to calculate the force of the flood on the landscape. For this, the flood danger index is used, which is calculated according to the formula:

$$FHI = \sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij} w_i, \quad (5)$$

where FHI – flood danger index, *m* – the number of categories of criteria, *n* – the total number of criteria, r_{ij} – rating of the *i*-th parameter for the *j*-th category, w_i – influence of the *i*-th parameter.

The developed web application is created for desktop personal computers on Windows operating systems and has the following functionality:

- graphic demonstration of the flooded territory;
- display of information about all objects in the area affected by the flood;
- allocation of infrastructural facilities damaged by the flood;
- display of the result of flood impact analysis.

In the web application, you can open an interactive map (Figure 1) with an image of the studied area with the necessary layers (flooding area, mountain streams, rivers with a width of more/less than 3 meters, lakes), display all damaged geographical objects at once (Figure 2). The territory of western Ukraine - the basin of the Dniester River in 2020 - was chosen for the study.

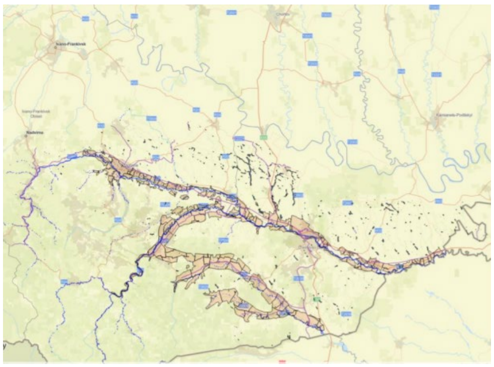

Figure 1 – Image of the Western region from Ukraine

Figure 2 – Image of the Western region of Ukraine with damage

The application also helps the user find information about all settlements, rivers and bridges in this area, assess the risks of flood impact and calculate the damage caused. Figure 3 presents flood risk assessment graphs. They are interactive and allow you to manipulate them.

This web application will be useful for the leadership of the country/region/district, as well as for the state service of Ukraine for emergency situations, as it will increase the level of providing responsible persons with operational and reliable information for assessing the scale of floods and planning measures to reduce their negative consequences.

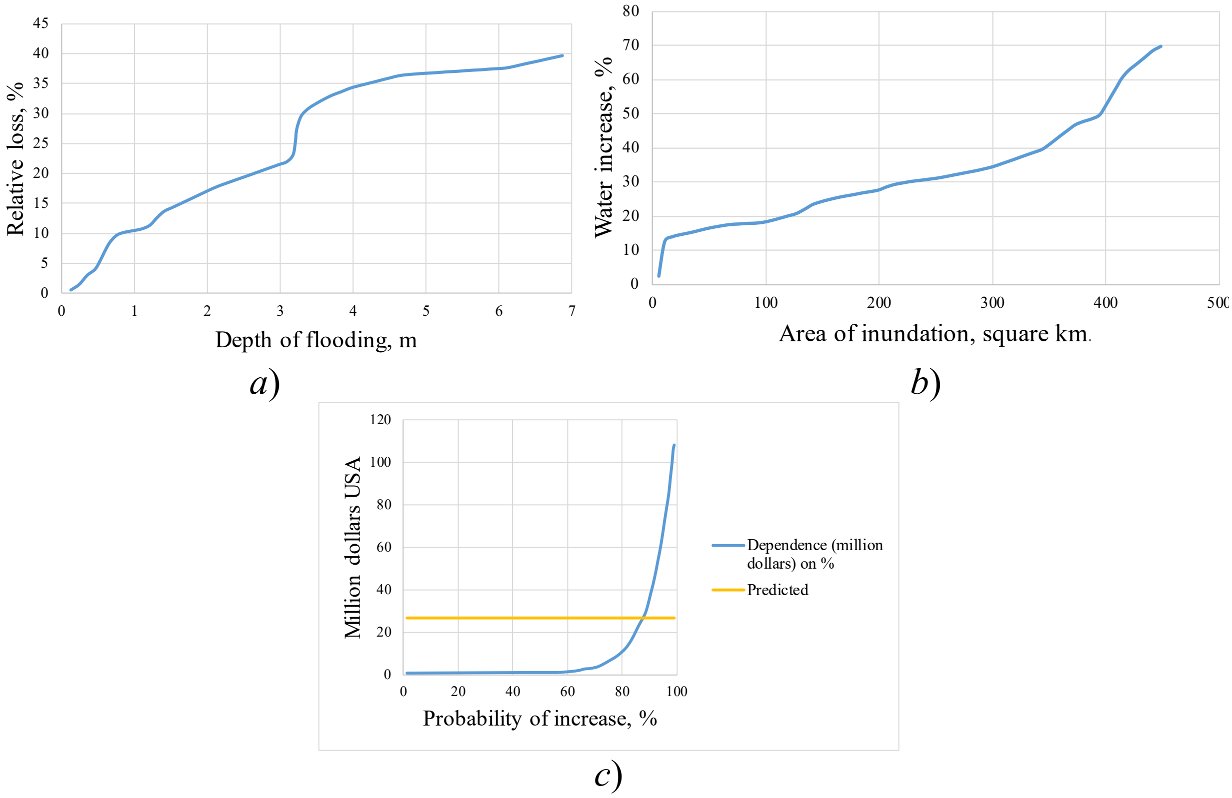

Figure 3 – Flood risk assessment:

a) the standard dependence of object damage on the depth of flooding,

b) the dependence of the flooded area on the increase of water in the river,

c) the dependence of the probability of an increase in total damage from a flood.

Conclusion.

The developed web application allows you to quickly diagnose inundation zones due to floods and assess the consequences of flooding. This software product is quite flexible and versatile, it can be easily adapted for use not only in assessing the consequences of floods, but also in their forecasting and prevention.

A promising direction for improving the application is the introduction of artificial intelligence, which would make it possible to more efficiently and accurately analyze flooded areas, assess damages, add 3D modeling of the process of flooding land and settlements, as well as prepare recommendations for specific areas where flood prevention measures are carried out.

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Анотація. *Робота присвячена застосуванню ГІС-технологій при моделюванні процесів дослідження повеней, спричинених негативним антропогенним впливом. Розглянута технологія геоінформаційного забезпечення сучасних моделей формування системи моніторингу повеней з оцінкою наслідків затоплення на основі відкритих просторових даних. Представлена методика та результати моделювання оцінки ризиків повеней на основі ДЗЗ та ГІС-технологій. Для створення графічних карт використовуються космічні знімки супутника Landsat 8 OLI. На прикладі аномально високого рівня повеней на досліджуваній території створено веб-додаток з графічною демонстрацією затопленої території, відображенням інформації про всі об'єкти в зоні впливу повені, виділенням інфраструктурних об'єктів, що зазнали шкоди внаслідок повені та відображенням результату аналізу впливу від повені. Додаток допомагає знайти користувачеві інформацію про всі населені пункти, річки й мости в цій зоні, оцінити ризики впливу від повені та порахувати завдані збитки. Даний програмний продукт є досить гнучким та універсальним, він може бути легко адаптованим для застосування не тільки для оцінки наслідків повеней, а й для їх прогнозування та попередження.*

Ключові слова: *ГІС-технології, дистанційне зондування Землі, моніторинг, веб-додаток, оцінка ризиків.*

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