GEOGRAPHICAL INFORMATION SYSTEM IN ECOLOGY: ANALYSIS AND PERSPECTIVES

SISTEMUL INFORMAȚIONAL GEOGRAFIC ÎN ECOLOGIE: ANALIZA ȘI PERSPECTIVE

ГЕОГРАФИЧЕСКИЕ ИНФОРМАЦИОННЫЕ СИСТЕМЫ В ЭКОЛОГИИ: АНАЛИЗ И ПЕРСПЕКТИВЫ

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ABSTRACT

The study provides analysis of implementation the Geographical Information System in the field of ecology and natural resource management. Using the Geographic Information System, it is possible to simulate the development of various accidents and natural and man-made disasters. For example, the consequences of hurricanes, volcanic eruptions or oil spills, as well as the influence of permanent pollutants. The article provides several Case studies of using the GIS technologies in solving environmental problems, one of the illustrative examples was implemented with the participation of the author of this article.

Keywords: *Geographic Information System, ecology, natural resource management, permanent pollutants.*

În studiul este efectuată analiza implementării Sistemului Informațional Geografic în domeniul ecologic și gestionarea resurselor naturale. Cu ajutorul Sistemului Informațional Geografic este posibil să simulăm dezvoltarea diverselor accidente și dezastre naturale și celor provocate de om. De exemplu, consecințele uraganelor, erupțiilor vulcanice sau a scurgerilor de petrol, precum și influența poluanților permanenți. Articolul oferă câteva studii de caz privind utilizarea tehnologiilor GIS în rezolvarea problemelor ecologice, unul dintre exemplele ilustrative a fost implementat cu participarea autorului acestui articol.

Cuvinte cheie: *Sistemul Informațional Geografic, ecologie, managementul resurselor naturale, poluanți permanenți.*

В исследовании представлен анализ применения Географической информационной системы в области экологии и управления природными ресурсами. С помощью Географической информационной системы можно моделировать развитие различных аварий, природных и техногенных катастроф. Например, последствия ураганов, извержений вулканов или разливов нефти, а также влияние постоянных загрязнителей. В статье приводятся несколько примеров применения ГИС-технологий при решении экологических проблем, один из показательных примеров был реализован при участии автора статьи.

Ключевые слова: *Географическая Информационная Система, экология, управление природными ресурсами, постоянные загрязнители.*

INTRODUCTION

Today, the world community is facing an acute task of preventing the ecological crisis, strengthening nature protection and the competent use of its not endless resources. According to a report from the European Environment Agency (EEA), every eighth death in Europe is associated with air pollution, noise, as well as poor water quality and exposure to chemicals [1]. Overall, 13% of deaths in Europe can be attributed to poor ecology. The poor and the vulnerable are hardest hit. The researchers found that 630,000 premature deaths in the EU each year were

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associated with environmental factors. Air pollution is the cause of 400,000 deaths a year, noise pollution is 12,000 deaths, the rest of the cases were associated with extreme weather conditions such as heat.

Poor people are most affected by air pollution and extreme weather conditions (heat or extreme cold). This has to do with where they live, go to school and work. As a rule, these are urban areas located near heavy traffic. The main conclusion of the study authors from the Icahn School of Medicine, Mount Sinai Medical Center in New York: "Pollution is much more than an environmental problem. It is a deep and pervasive threat that affects many aspects of human health and well-being."

The authors of another large-scale study, conducted by the World Health Organization, UNICEF and the authoritative scientific journal The Lancet, also concluded that the biggest risk factor, such as air pollution, contributed to about 6.5 million premature deaths worldwide [2]. This includes pollution from both external sources, such as gas emissions, and from within households, such as indoor combustion of wood or coal.

The second most important factor, water pollution, has resulted in 1.8 million deaths, while workplace pollution is associated with 800,000 deaths worldwide. Around 92% of these deaths occurred in poor countries, with emerging economies such as India (fifth in pollution deaths) and China (16th) particularly affected. Russia is ranked 60th, with 8.6% of pollution-related deaths. This is significantly better than many of its neighbors: Ukraine in 85th place, Belarus - in 90th place. In the United States - more than 5.8%, or 155 thousand deaths can be attributed to pollution. In Britain, about 8%, or 50,000 deaths, are estimated to be related to pollution. Thus, the United Kingdom is in 55th place out of 188 countries in the ranking, after the USA and many European countries, including Germany, France, Spain, Italy and Denmark.

According to Dr. Penny Woods of the British Lung Association: "Air pollution has reached critical levels around the world, and the situation in the UK is worse than in many countries in Western Europe and the United States."

EEA experts have measured the content of fine particles in the air, that is, microscopic dust in 323 cities in Europe. PM particles pose the greatest health hazard of all other air pollutants, as this dust settles in the lungs and causes serious respiratory and circulatory problems.

In the city with the dirtiest air, which is recognized as the Polish Nowy Sacz, the average annual PM content in the atmosphere was about 27.3 μg / m3 - at the European limit of the norm of 25 μg / m3. The cleanest air in Europe was found in Swedish Umeå - only 3.7 μg / m3. Good air quality was also recorded in the city of Funchal, located on the Portuguese island of Madeira, in the capital of Estonia, Tallinn, in the Norwegian Bergen.

According to the EEA report, air quality in Europe has improved significantly over the past decade, thanks in part to reductions in emissions from the transport and energy sectors.

The countries of Eastern Europe suffer from poor ecology. If the death rate in Norway and Iceland is 9%, then in Albania it reaches 23%, and in Bosnia and Herzegovina - 27%, and the highest rate is in Romania - 19%.

GIS is an effective tool for environmental research. Geographic information system (GIS) is a software and hardware complex capable of storing and using (showing, analyzing, managing) data describing objects in space, managed by special personnel. GIS uses a special type of information - spatial (geographic) and associated databases, this information can be social, political, environmental or demographic, that is, any information that can be displayed on a map. GIS is the best way to store information about a piece of land or sea. GIS can help make management more efficient, promote scientific work and protection of the territory, which is carried out in all specially protected natural areas, regardless of their area [7].

GIS technologies are widely used in ecology and nature management for mapping and analyzing the state of environmental objects. The use of geographic information systems allows you to quickly receive information upon request and display it on a map basis, assess the state of the ecosystem and predict its development. With an integrated approach, typical for ecology, one usually has to rely on generalizing characteristics of the environment, as a result of which, the volumes of even the minimum sufficient initial information should undoubtedly be large. Otherwise, the validity of actions and decisions can hardly be achieved. However, the simple accumulation of data is also, unfortunately, not enough. These data should be easily accessible, systematized according to the needs. The grouping of data in the desired form, their proper display, comparison and analysis entirely depend on the qualifications and erudition of the researcher, the approach he has chosen to interpret the accumulated information. At the stage of processing and analyzing the collected data, a significant, but by no means the first, place is occupied by the technical equipment of the researcher, including hardware and software suitable for solving the problem. As the latter, modern powerful technology of geographic information systems is increasingly being used all over the world.

GIS in Ecology was set up by Dr. Colin MacLeod in 2011 with the aim of making GIS as accessible as possible by providing in-person training courses, online training courses, books, advice and consultancy for ecologists by ecologists.

The emergence and rapid development of GIS was predetermined by the richest experience in topographic and, especially, thematic mapping, successful attempts to automate the mapping process, as well as revolutionary advances in the field of computer technology, informatics and computer graphics.

The idea of depicting data using different layers on a series of basemaps and relating things spatially, geographically, arose long before the advent of computers. Even during the War of Independence in the United States, French cartographer Louis-Alexander Berthier, when creating a map of the Battle of Yorktown (1781), used transparent flip plates, on which troop movements were represented. In the mid-19th century, the Atlas for the Second Report of the Representatives of the Irish Railways superimposed maps of population, traffic flows, geology, and topography on a single basemap. In September 1854, physician John Shaw used a cholera fatality map overlaid on a map of central London to find the source of the epidemic, which turned out to be a contaminated well - one of the earliest examples of geographic analysis.

Possibilities to applied GIS in ecology. The use of geographic information systems allows you to quickly receive information upon request and display it on a map basis, assess the state of the ecosystem and predict its development [3].

GIS capabilities applicable in ecology [4]:

- input, accumulation, storage and processing of digital cartographic and environmental information,
- building thematic maps based on the received data, reflecting the current state of the ecosystem,
- study of the dynamics of changes in the ecological situation in space and time, construction of graphs, tables, diagrams,
- modeling the development of the ecological situation in various environments and studying the dependence of the state of the ecosystem on meteorological conditions, characteristics of pollution sources, values of background concentrations,
- obtaining comprehensive assessments of the state of environmental objects based on heterogeneous data.

An illustration of how the real world is represented in a GIS project as a series of data layers, each of wich contains information about a specific real world characteristic. Due to the way that the data layers are "stacked" or overlaid on top of each other, the information in diferent layers can be joined together based on their spatioal relationships - as indicated by the black arrows (Figure 1).

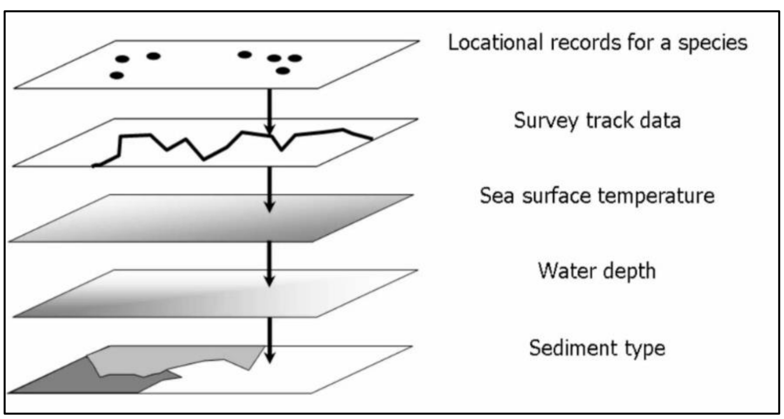

Figure 1. Examples of possible data layers in a GIS project.

Source: *[5]*

The basic concept of GIS is very simple. Normal databases primarily consist of a series of tables which can be linked together to allow the data within them to be extracted, compared or manipulated based on values in different fields or columns in them. However, normal databases have great difficulty in manipulating data in a spatial context.

A GIS is generally created using specialist GIS software, and such software usually provides a series of tools which allow you to not only create, manipulate and edit data layers, but also to investigate the spatial relationships between them in a variety of ways. Therefore, the GIS software that you use is a key component of any GIS project. However, different GIS software may contain different tools, and some are better at some tasks than others. As a result, it is important that, where possible, you choose GIS software which is appropriate to your requirements.

The aim to do this using the type of language that ecologists can understand, and by showing them specifically how to use GIS to do the everyday tasks ecologists need to know in order to quickly start using GIS in their research (Figure 2).

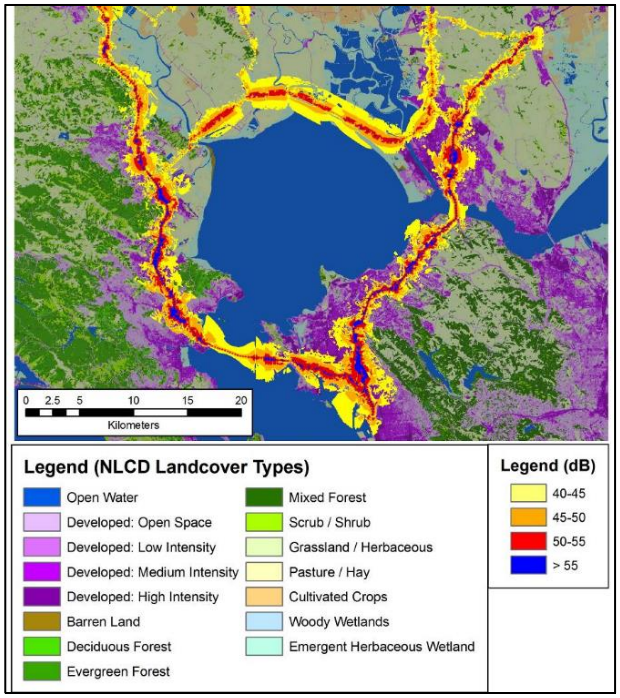

Figure 2. GIS map.

Source: *[5], [8]*

GIS can work with two significantly different types of data - vector and raster. In a vector model, information about points, lines and polygons is encoded and stored as a set of X, Y coordinates (in modern GIS, a third is often added - a spatial and a fourth, for example, a time coordinate). The location of a point (point object), for example, a discharge point of a utility company or a settlement, is described by a pair of coordinates (X, Y). Linear features such as roads, rivers, or pipelines are stored as X, Y coordinate sets. Polygon features such as river watersheds, land parcels, or service areas are stored as a closed coordinate set.

The vector model is especially useful for describing discrete objects and is less suitable for describing continuously changing properties such as population density or object availability.

The raster model is optimal for working with continuous properties. A raster image is a set of values for individual elementary components (cells), it is similar to a scanned map or picture. Both models have their own advantages and disadvantages.

Modern GIS can work with both vector and raster data models.

GIS-based software applications used in research. GIS technologies are used to carry out comprehensive environmental monitoring. There are many GIS-based software applications tailored to meet environmental challenges. For example, the following software tools are used: ArcGIS, BelGIS, MapInfo, Surfer, Map 2000, Quantum GIS (QGIS), etc.

➢ ArcGIS is a family of geoinformation software products of the American company ESRI. They are used for land cadastres, in the tasks of land management, registration of real estate objects, systems of engineering communications, geodesy and subsoil use and other areas.

➢ The BelGIS software module is distinguished by the simplicity and convenience of the vectorization process, and also provides the ability to overlay tabular information from the database on the map.

➢ Mapinfo software has the ability to register and display raster maps in formats: .gif, .ipg, .tiff, .pcx., Bmp, .tga, .bil, .sid, .pgn, .wmf, .psd, as well as import graphics: DXF, DWG, ARC / INFO, ESRI SHAPE, Atlas GIS, Intergraph / MicroStation DGN, ASCII (.mif, .mmi, .mbi).

- Mapinfo supports spherical projections and allows automatic thematic mapping.
- Surfer software is a tool for building three-dimensional models, which conveniently presents the technology for creating digital elevation models.
- GIS Map 2000 provides the user with a powerful tool for developing applied tasks Gis ToolKit, which allows you to create your own GIS using various high-level programming languages.
- The QGIS program is available for most modern platforms (Windows, Mac OS X, Linux) and combines support for vector and raster data, and is also able to work with data provided by various map web servers and many common spatial databases [2]. QGIS has one of the most developed Internet communities in the open GIS environment, and the number of developers is constantly increasing, which is facilitated by the availability of good documentation on the development process and a user-friendly architecture. QGIS has a wide range of functions for generating maps.

Practical significance. The practical implementation of GIS in ecology will be presented by two Case studies - one of them is based on global data and carried out by a world known organization IQAir which strives to empower change and contribute to a sustainable path to better air, and the second Case study is carried out with the participation of the author of this article.

Case study 1. New data from the global air quality data platform IQAir, published in the 2019 World Air Quality Report and on an interactive global map, showcases the impact of COVID-19 quarantine and behavior change on global particulate matter (PM2.5) levels [6]. IQAir collaborats with like-minded organizations in the fight against air pollution. As a technology partner of the United Nations Environmental Program, UN Habitat, and Greenpeace.

The 2019 World Air Quality Report brings together PM2.5 data from 106 countries collected from government ground stations and a growing network of certified non-governmental air quality sensors owned by organizations and individuals. These data represent the world's largest air pollution database.

An interactive map shows the average PM2.5 emissions for over 5,000 cities worldwide (Figure 3).

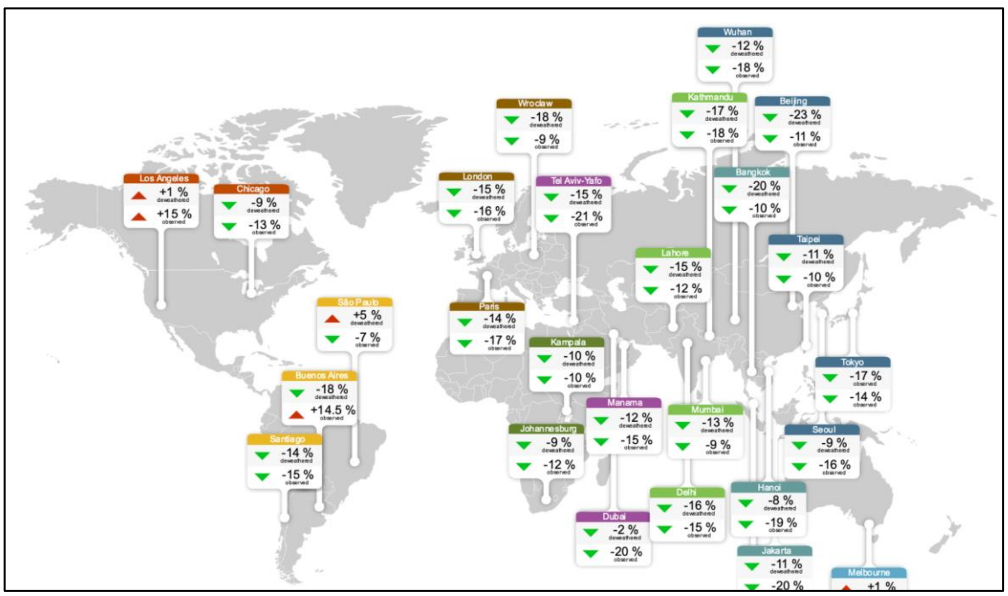

Figure 3. Global map of annual PM2.5 exposure by city with available data in 2020.

Source: *IQAir World Air Quality Report 2020 [6]*

Based on the sample, Singapore (-25%), Beijing (-23%) and Bangkok (-20%) have the strongest reductions in PM2.5 emissions. Sao Paulo (+ 5%), Los Angeles (+ 1%) and Melbourne (+ 1%) have the largest increases in PM2.5 emissions since 2019 - all three cities were affected by wildfire seasons. significantly affected the average annual PM2.5 emissions.

Case study 2 (own research). Author of this article participated in 2020 in research dedicated suitability of environment for a green space in Moldova. Using the GIS-based software application - ArcGIS platform that allows to combine raster imagery with other types of geographic data in analytic models. ArcGIS contains thousands of analysis operators that can provide statistical information, and moving the model and flying over the created surfaces will help to find the most and least suitable areas for the activities.

The forest change analysis tool estimates the overall reduction in forest cover in a specific area and also shows results for different land cover classes. Modeling the suitability of environment for a green space is a classic GIS and image analysis task described in this story map (Figure 4). The raw data from multiple sensors are pooled and georeferenced, allowing land-use planners to identify locations for green space corridors that will ensure their long-term survival.

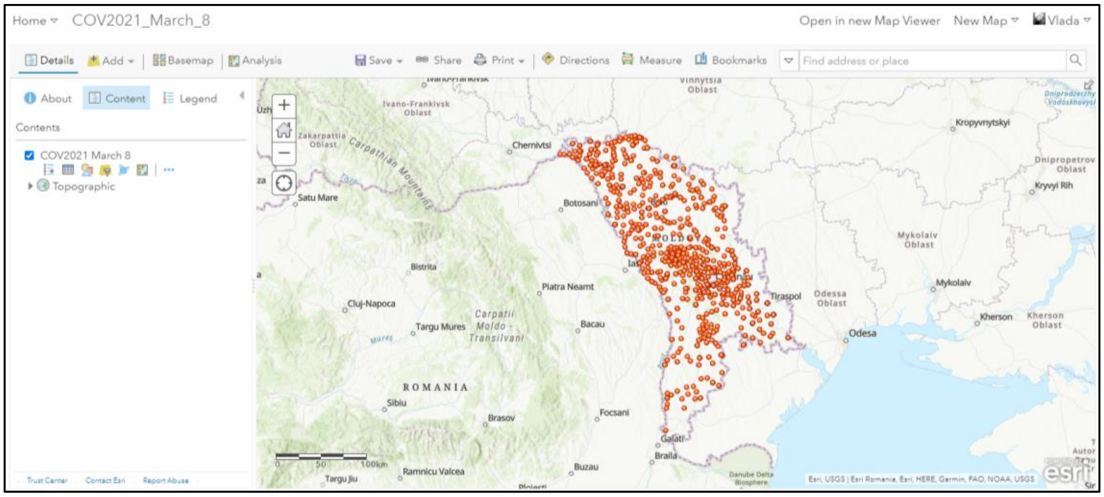

Figure 4. Modeling-map of suitability of environment for a green space with available data.

Source: *elaborated by the author*

CONCLUSIONS AND PERSPECTIVES

Increased attention is paid to environmental problems all over the world. Environmental problems often require immediate and adequate actions, the effectiveness of which is directly related to the promptness of processing and presenting information. With an integrated approach, typical for ecology, one usually has to rely on generalizing characteristics of the environment, as a result of which, the volumes of even the minimum sufficient initial information should undoubtedly be large. Otherwise, the validity of actions and decisions can hardly be achieved. However, the simple accumulation of data is also, unfortunately, not enough. These data should be easily accessible and systematized according to needs. It is good if it is possible to connect heterogeneous data with each other, compare, analyze, simply view them in a convenient and visual form, for example, by creating on their basis the necessary table, figure, map, diagram. The grouping of data in the desired form, their proper display, comparison and analysis entirely depend on the qualifications and erudition of the researcher, the approach he has chosen to interpret the accumulated information. At the stage of processing and analyzing the collected data, a significant, but by no means the first, place is occupied by the technical equipment of the researcher, including hardware and software suitable for solving the problem. As the latter, modern powerful technology of geographic information systems is increasingly used all over the world [9].

Over the past five decades, GIS has evolved from a concept to a science. The phenomenal evolution of GIS from a rudimentary tool to a modern, powerful IT platform for understanding and planning our world. Today, GIS empowers people to create their own data layers on interactive maps to help solve real-world problems. GIS has also evolved into a medium for data exchange and collaboration in virtually every area of human endeavor. Today, hundreds of thousands of organizations around the world share their work and create billions of maps every day to tell stories, find patterns, and make predictions.

Thanks to the transition to network and cloud computing, integration with information in real time via the Internet of Things, GIS has become a platform suitable for almost any field of human activity. As our world faces the challenges of population growth, diminishing natural resources and environmental pollution, GIS will play an increasingly important role in how we understand and address these challenges. GIS will serve as a vehicle for the exchange of solutions using a common mapping language.

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