

THE USE OF GIS FOR ECOLOGICAL AND LANDSCAPE LAND MANAGEMENT OF HUMAN SETTLEMENTS

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Abstract: The issue of forming an analytical and informational base for management decisions in the field of land affairs is particularly relevant given the global trend of systemic social transformations. It requires active implementation of the latest information technologies. The study aims to comprehensively analyze the aspects of using geographic information systems (GIS) for ecological and landscape land management of human settlements. The research was carried out using general scientific methods of cognition: logical and structural analysis, induction and deduction, comparison, abstraction, specification, generalization, and formalization. The article investigates the basics of GIS and variations of their implementation in the field of land management. It highlights the main provisions and algorithmic structure of the process. The authors described the typical features of modern GIS technologies and their capabilities in the spheres of mapping, monitoring, and other aspects of land management. The main problems, challenges, and achievements of the GIS utilization process are considered. It has been determined that the effective utilization of GIS capabilities is a promising priority area for optimizing the land utilization system. The practical significance of the findings of this paper is manifested in the feasibility of using them in developing suitable programs to improve the efficiency of ecological and landscape land management of settlements. Also, the study's results can be used to form a universal effective model of GIS technologies application during the process of land utilization management.

Keywords: Purpose or intended use, Mapping, Sustainable development, Process automation, Spatial analysis, Modeling.

1 Introduction

The land relations system's prospective development significantly increases the requirements for information support of management decisions on the territorial organization of land use. This includes ecological and landscape land management of the human settlements. The rapid development of geographic information systems with various functionality marks the current stage of land use and land relations system development. Their significant advantage lies in integrating diverse sources and methods of information processing. This allows for effective assessment and forecasting of the situation, as well as for making appropriate management decisions. Such a concept helps optimize land management processes in the territories of human settlements, particularly in the ecological and landscape aspects. It ensures the synergistic development of various spheres of life.

Numerous scientific publications by contemporary Ukrainian and foreign scholars are devoted to the study of this topic. Some scholars study the functionality of GIS in the land management system (Chen, 2022). Others address the concept of GIS technology. The concept includes the creation of multilayer electronic maps. The basic layer of these maps describes the geographical aspects of the territory. Each subsequent layer defines one of the vectors of the functional state of the territory (Tretiak et al., 2022). The problem of the practical utilization of GIS during ecological and landscape land management is thoroughly studied in the works of modern scientists (Liu et al., 2023). Currently, technologies created based on geographic information systems are used in urban planning design work. Usually, the urban cadaster contains informative registers and results of an analytical assessment of the settlements' territories (Vardopoulos et al., 2023).

Despite the significant scientific value of the research papers released, there are still some aspects left unresolved. The issue of forming an algorithm for the successful implementation of modern GIS capabilities in the ecological and landscape land management system remains understudied and requires further research.

The article aims to analyze the modern innovative capabilities of GIS in the sphere of ecological and landscape land management of the human settlements' territories.

2 Literature Review

The scientific and methodological basis for the study was set by researchers who focused on aspects of implementing geographic information technology tools in the ecological and landscape land management system, as well as the problems of digital transformation of land use and finding ways to solve them.

Scientific journals contain numerous publications on the topics studied in this paper. Some aspects of GIS mechanisms regarding the transformation of the land use system at the municipal level are considered in the studies of modern scientists (Degerli & Çetin, 2022; Liu et al., 2022). Among the most recent publications, we should highlight the studies by Gabriele M., Brumana R., and Previtali M. (2023), Kazemi F. and Hosseinpour N. (2022). The authors substantiate the principles of effective implementation of GIS tools in modern global digitalization processes. At the same time, some scientists like Yu J., Zeng P., Yu Y., Yu H., Huang L., and Zhou D. (2022) emphasize the need for proper preventive preparation of society for the dynamics of management processes in land management within settlements.

Xu L., Liu X., Tong D., Liu Z., Yin L., and Zheng W. (2022) identified the main conceptual principles of effective GIS implementation. In addition, some works by Abdel Rahman M. (2023) emphasize the need to pay special attention to the opportunities opening up in land management due to geographic information system technologies. At the same time, Battisti F., Campo O., and Manganelli B. (2022) draw attention to the complexity of implementing some aspects of GIS tools in the modern world.

Despite the significance of the scientific and practical achievements of scholars on the subject, it is necessary to note the need to develop scientific research toward the effective implementation of GIS technologies in the ecological and landscape land management system of human settlements.

3 Materials and Methods

While working on the research, we employed various general scientific methods of cognition. They include methods of analysis, synthesis, abstraction, induction and deduction, comparison, specification, and formalization.

The theoretical and methodological background of the study is based on numerous articles in specialized journals, conference proceedings, monographs, and the results of practical and analytical developments of contemporary scholars.

The study was carried out taking into account the principles of comprehensive research and a systematic approach. The complexity principle allowed us to analyze the research object as a system with a corresponding set of interconnections.

The methods of analysis and synthesis were applied to identify the factors and stages of development of the object under study and its key elements. The method of comparison was used to highlight the specific features of GIS application during land management of human settlements. The deductive method was employed while formulating proposals for optimizing management processes in ecological and landscape land management. The induction method was used to identify prognostic indicators of the development of the studied object.

The method of abstraction was applied to formulate theoretical generalizations, identify the main concepts and categories, and

draw conclusions. The general scientific method of formalization was used to identify priority vectors for optimizing the system of ecological and landscape land management of human settlements using GIS technologies. This method was also employed to structure the principles, priorities, and functions of GIS.

The method of concretization was applied to prove the feasibility of using GIS tools during land use reforms. It was also used to identify priority solutions for optimizing the system of ecological and landscape land management of human settlements.

4 Results

Geographic information systems are currently positioned as the most effective tool for understanding and describing the dynamic geographic environment. These systems are widely used to solve many problematic aspects related to the use of spatially distributed information arrays to ensure environmental safety and sustainable development of territories. At the same time, GIS can be effectively used to analyze environmental and landscape monitoring data, create digital maps, and analyze the dynamics of the situation in regional land use and its prognostic study (Battisti et al., 2022). In developed countries, the use of GIS has become widespread and popular.

GIS is a complex, multi-component system characterized by the use of specific methods of spatial data analysis. In synergy with measures to generate, accumulate, process, and present spatially coordinated information, such a system forms the basic principles of geographic information systems technology.

Another result of such integration was the emergence of geographic information mapping. It is an automated information and cartographic modeling of natural and socio-economic geosystems based on GIS and relevant databases. At the same time, GIS-based maps can be both analytical and predictive or reflect the targeted zoning of the territory (Abdel Rahman, 2023). GIS technologies are also used for operational mapping in real-time. This allows for an adequate level of information and the ability to influence the process. Such functional maps are mainly created to inventory objects, respond quickly to adverse processes, monitor their dynamics, and provide forecasting analytics.

Currently, electronic cadasters are being created using GIS tools as an alternative to the State Land Cadaster. They simplify the functioning of land relations and regulate the state of land in populated areas. The introduction of such cadasters will allow for the optimization of the management of investment projects and environmental and landscape land management. The creation of a unified system of state cadasters is considered a priority. It is necessary to provide an adequate information base for the implementation of socio-economic processes in settlements, environmental monitoring, and preventive prevention of irrational use of resources (Mathenge et al., 2022).

As a result, the use of GIS is associated with the actualization of spatial and analytical operations in the ecological and landscape land management of settlements, in particular, buffering (Čustović et al., 2021). The buffer zones are sanitary protection zones, security zones, and zones of identified restrictions. Modern GIS tools allow the formation of buffer zones automatically.

Implementation of GIS for ecological and landscape land management of the settlements' territories is effectively manifested in cartometric functions that include measures for measurement operations (Li, 2022). Other popular aspects of GIS application in the land management process include network analysis. This analysis is carried out to determine the optimal network route or zones of influence on network objects by other objects, as well as 3D analysis and modeling of spatial tasks.

Such a model is a mathematical or visual way of describing objects, processes, or phenomena that are impossible or

impractical to observe directly. The creation of a spatial model is a process of analyzing the characteristics of various factors for each location, which is used to solve spatial issues (Papaskiri et al., 2021). The organization of sustainable land utilization of the settlements' territories involves the development of such models of landscape land management that could ensure the synergy of economic potential development together with the level of environmental safety. In this case, the top priority should be a balance between the use and reproduction of land resources and strict control over the observance of such a balance.

It is necessary to emphasize another comparatively new function of GIS in the system of ecological and landscape land management of settlements. In particular, such a function is a decision support function in administration, planning, and design activities.

The results of the effective use of GIS in such functionality include:

- optimal decisions on urban planning projects;
- proper geographic information support for emergencies;
- application of artificial intelligence technologies;
- leveling the human factor in risky situational choices.

The GIS makes it possible and affordable to create a flexible and adaptive decision-making coordination function. Through the processing of informative databases, such a supporting system allows for static, dynamic, and predictive analysis of the situation (Liu & Cheng, 2020).

Furthermore, it is advisable to implement a system of monitoring environmental parameters through GIS. It allows timely identification of problem areas and recording of environmental violations in the use of land resources. Also, modeling tools can be used to determine the necessary algorithm of measures to offset the effects of destructive processes.

Thus, it can be argued that the use of geographic information technologies in developing and implementing ecological and landscape land management programs for human settlements provides an opportunity to effectively assess parameters in real-time while simultaneously allowing for predictive analytics. The advantage of using GIS in this case is the ability to integrate statistical methods, geoinformation and digital modeling, and business graphics methods. Together, they allow identifying a specific type of information as the basis for a management decision.

The integration and unification of diverse spatial information on ecological and landscape land management of human settlements into the spatial data infrastructure is implemented using GIS through generalization procedures, conceptual communication, and extrapolation of data processing results. The information processed in this way forms models of objects in the form of thematic maps, digital dynamics models, vector images, and 3D models. This considerably simplifies and optimizes the land management process (Chen, 2022).

At the same time, geoinformation data is characterized by the time factor. It allows for analyzing the specifics of the ecological and landscape aspects of land use at a particular point in time, identifying trends in future dynamics, and assessing changes in territorial characteristics over certain periods.

Therefore, it is advisable to form geoinformation support bodies for municipalities to optimize the ecological and landscape land management of the populated areas. This will minimize the cost of GIS implementation and significantly increase the level of efficiency of using spatial data arrays. Furthermore, the municipal GIS should integrate vector and raster data, information from online mapping services, and attribute information, reflecting logical and functional system interaction between separate components.

5 Discussion

The issue of using geographic information systems for ecological and landscape land management of populated areas is studied by many scientists in the modern scientific school. Scholars of current scientific directions (Choi, 2020) argue that through mapping, GIS allows the following activities:

- to form detailed spatial analytics of territories;
- to assess the properties of environmental objects;
- to reflect the real situation of territories.

Some scientific papers consider the need to update the information support of GIS technologies for the optimal implementation of local management processes (Sisman & Aydinoglu, 2020). Modern scientists' research shows the effectiveness of the use of GIS tools to optimize management processes (Kumar, & Khan, 2021).

According to research by Jia J. (2021), the rejection of outdated technologies and action algorithms in favor of GIS, as well as the use of innovative technologies, are priorities at the present stage of the transformation of ecological and landscape land management of human settlements.

The studies by Nowak M., Dziób K., Ludwisiak L., and Chmiel J. (2020) emphasize the need to optimize the efficiency of managing the potential of settlements and also substantiate the need to create a unified state strategic concept for ecological and landscape land management of settlements. According to some scholars (Paul et al., 2020), such a concept should level socio-economic disproportions of settlements by regulating their natural resource potential, considering geographical features. Modern studies highlight the need to identify optimal approaches to land use management based on the ecological and landscape approach (Nuriddinov et al., 2022). Wang (2023) focuses on the need for synergy between territorial and land management.

In addition, scientists are considering the possibility of using GIS as an effective management tool that can provide systematic monitoring of the ecological and landscape conditions of populated areas to identify and assess the dynamics, prevent destructive processes, and eliminate the consequences (Opara et al., 2020).

Based on research findings, it can be argued that there is currently a need for coherence between the adoption of measures to manage the ecological and landscape development of territories and the functional use of land resources. They are both components of the natural ecosystem, means of production, territorial structural unit, and real estate object.

Based on the results obtained in this research and the conclusions of the authors in the aforementioned studies, it is possible to insist on the expediency of using geographic information systems in the management of ecological and landscape land management. The main task of such management is to create appropriate conditions for dynamic and balanced territorial development, rational use of natural resources, and preventive environmental protection. Under current conditions, geographic information systems can serve as the basis for effective territorial management in human settlements. The methodological basis for data formalization in GIS usually includes digital terrain modeling. It integrates the processes of accumulating primary information, its modeling, processing, and document generation. Thus, it can be argued that GIS tools should be effectively used when it is necessary to take into account, process, and display geographically dispersed information.

Based on the results of this study and the conclusions of the authors mentioned above, we can predict the growing role of digital optimization tools in the successful implementation of public administration policy transformation. This approach will significantly increase the productivity of management decisions,

introduce innovative management capabilities, and ensure compliance with the requirements of sustainable development.

6 Conclusion

In this paper, we managed to analyze the aspects of GIS technologies implementation in the system of ecological and landscape land management of human settlements. During the study, it was found that the effective use of geographic information systems is a basic prerequisite for intensifying the efficiency of land use management. The main functions of GIS during the implementation of territorial management of land resources have been highlighted.

The article succeeded in summarizing the main issues of using modern geographic information technologies and outlining ways to solve them. It has been established that one of the main features of GIS technologies is the vast possibilities for processing geodetic data arrays.

Based on the results obtained in this study, we have proposed priority vectors for further research on the topic. Also, we argued the need to organize the availability and systematization of practical information on the possibilities of using GIS in municipal management processes.

A practical approach to the introduction of geographic information technologies into the system of ecological and landscape land management of the settlements' territories involves a set of modern methods that can ensure an increase in the level of productivity of communication and integration processes. It should be based on the implementation of a development strategy formed on the principles of sustainable development as an integral part of the management paradigm.

The research has shown that the use of GIS technologies for addressing land management issues allows for initiating fundamental changes in the field of ensuring effective management decisions.

There is a need for further research into the possibilities of using GIS tools to develop and implement optimal programs for improving the efficiency of ecological and landscape land management of human settlements.

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