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MODERN DIGITAL TECHNOLOGIES IN LAND MANAGEMENT SYSTEMS

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Annotation. *Modern development of society is impossible without effective management of natural resources, among which land resources play a key role. Land is the basis of economic activity, a source of food security and an integral element of ecological balance. In this regard, there is a need to improve land management systems, especially in the context of the rapid development of digital technologies and the globalisation of information processes.*

The use of digital technologies, such as geographic information systems, remote sensing, big data and blockchain, creates new opportunities for effective monitoring, analysis and forecasting of land use changes. These tools help to ensure transparency of cadastral records, reduce the risks of abuse in land relations, and increase the accuracy and speed of management decision-making. At the same time, there is a growing demand for the integration of such technologies into management systems, which requires scientific justification and practical implementation.

In the face of growing challenges related to urbanisation, climate change and land degradation, digital technologies are an important tool for supporting sustainable development. In Ukraine, where a significant portion of land resources is in a state of environmental hazard and management systems often remain outdated, the introduction of modern digital solutions is not only promising but also urgent.

Thus, this article focuses on the current issues of integrating digital technologies into land management systems, which is essential for increasing their efficiency, transparency and sustainability. This study is aimed at identifying new approaches to solving land use problems adapted to modern challenges and needs of society.

Key words: *digital technologies, geographic information systems, remote sensing, land management, sustainable development.*

Actuality

Modern societal development is impossible without effective management of natural resources, with land resources holding a key position. Land serves as the foundation of economic activity, a source of food security, and an integral element of ecological balance. In this regard, there is a growing need to improve land resource management systems, particularly in the context of rapid advancements in digital technologies and the globalization of information processes.

The use of digital technologies such as geographic information systems (GIS), remote sensing, big data, and blockchain creates new opportunities for effective monitoring, analysis, and forecasting of land use changes. These tools enable transparency in cadastral records, reduce risks of misuse in land relations, and enhance the accuracy and efficiency of decision-making processes. At the same time, the increasing demand for integrating such technologies into management systems necessitates scientific substantiation and practical implementation.

Amid growing challenges related to urbanization, climate change, and land degradation, digital technologies play a crucial role in supporting sustainable development. In Ukraine, where a significant portion of land resources is under ecological threat and management systems often remain outdated, the implementation of modern digital solutions is not only promising but also an urgent necessity.

Thus, this article addresses the pressing issues of integrating digital technologies into land resource management systems, which is critical for improving their efficiency, transparency, and sustainability. This study aims to identify new approaches to solving land use problems that are adapted to contemporary challenges and societal needs.

Analysis of the latest scientific research and publications

The problems of development and automation of land management systems have been studied by such scientists as P. Putsentailo, N. Khoma, S. Babiy, V. Dankevych, P. Oukes, M. Van Andel, E. Folmer, R. Bennett, R. Lemmen, C. Lemmen, etc.

The majority of recent publications have concluded that technologies that allow efficient use of land resources and reduce environmental losses, while contributing to increased and sustainable production, are essential for achieving food security. Some existing tools and technologies, such as Geographic Information System (GIS), Remote Sensing (RS), Global Positioning System (GPS), Artificial Intelligence (AI), Big Data, Analytics and Internet of Things (IoT) play an important role in achieving this goal and, when combined with other information data, provide data-driven information for targeted land management.

At the same time, the issue of widespread implementation of modern digital technologies in land management systems is relatively new and poorly understood.

The purpose of the article is to highlight scientific and methodological approaches to the formation of modern digital technologies in land management systems.

Materials and methods of scientific research

The theoretical and methodological basis of the study is modern conceptual

approaches to the problem of introducing modern digital technologies in land management systems. It is proposed to use a set of methods aimed at collecting, processing and analyzing data, as well as at assessing their impact on management decision-making.

In the process of studying the introduction of modern digital technologies into land management systems, an interdisciplinary approach is used that combines the methods of geoinformation analysis, mathematical modeling, as well as comparative and empirical analysis.

The integration of digital technologies contributes to increasing transparency and efficiency in the field of land management, which meets the current challenges of sustainable development.

The results

Analyzing the works of domestic scientists, it should be noted that study [1] defines information support for land resource management as a comprehensive process of collecting, processing, and presenting data necessary for making management decisions regarding land use at various administrative-territorial levels.

Information and digital support for land relations play a crucial role in improving regulatory frameworks and significantly influence the development of the land market, which officially commenced in 2021.

The efficiency of land resource management largely depends on the quality of information support. The primary factors determining its success include the relevance, reliability, accessibility, and timeliness of information; the speed of data collection and processing; technical infrastructure and the adoption of GIS technologies; the completeness of data on land resources; and adequate funding for information systems. Digital land management systems have the potential to create integrated information platforms for assessing the quality and location of agricultural lands, based on inventory, productivity analysis, and geographic features. These systems also support the finalization of land market reforms for agricultural lands, improve land relations, attract loans secured by land, and enhance the efficiency of the agricultural sector.

Special attention in research is given to the implementation of digital technologies in agricultural enterprises. For example, the application of GIS and GPS systems enables the automation of management processes, cost reduction, and improvement of agrotechnical indicators.

The works of V. Dankevych and Ye. Dankevych [2] highlight a wide range of opportunities offered by modern information technologies in land management and land use. Their studies address aspects such as the use of GIS, remote sensing, and land data management systems to optimize the allocation and use of land resources. The authors provide examples of practical applications of digital tools aimed at reducing costs and increasing land use efficiency.

The digitization of land cadastres, as well as the introduction of Big Data and artificial intelligence technologies, opens up new opportunities for analyzing large datasets, effective land-use planning, and monitoring changes. Integrating the public through digital platforms promotes transparency and openness in land management processes, reduces corruption risks, and ensures the accessibility of electronic services. This approach modernizes land resource

management and contributes to achieving sustainable development goals.

The authors conclude that information innovations in land resource management play a critical role in improving the economic efficiency of Ukraine's agricultural sector. Digital technologies, particularly geographic information systems and precision farming systems, not only optimize resource use and minimize environmental impact but also significantly increase productivity and profitability in agriculture. Such intensive adoption of information technologies promotes rational and transparent land resource management, providing vital support in addressing food security challenges and ensuring economic stability.

The adoption of innovations and the Internet of Things (IoT) in agriculture plays a pivotal role in enhancing the economic efficiency of land resource management for agricultural enterprises. These technologies facilitate the collection, analysis, and utilization of large datasets to optimize agricultural production, reduce losses, and improve productivity. The introduction of a geoinformation vegetation index module is just one innovation that enhances production efficiency and supports the sustainable development of the agricultural sector. The realization of such projects requires joint efforts from industry stakeholders and academic institutions, but their potential to create a modern, efficient, and sustainable agro-industrial complex is substantial.

Using modern geoinformation technologies, particularly geoinformation vegetation index modules, represents an important step toward achieving the goals of sustainable agricultural development. These innovations, aimed at optimizing production and reducing losses, have the potential to increase the economic efficiency of land resource management for agricultural enterprises. The integration of these technologies into the agricultural sector requires collaborative efforts from the government, businesses, and academic institutions. This approach will enable the creation of an effective management system that accounts for current trends and industry needs, contributing to its sustainable development.

The implementation or modernization of information systems often begins with data modeling. In the field of land resource management, as in other industries, this process is complex: intricate laws and regulations, lengthy technological processes, distributed organizational responsibilities, various coding systems and data formats, as well as the need to comply with the LADM ISO 19152 standard.

Transitioning from the system concept to its realization is an indirect path. The Netherlands' example [3], specifically the principle of Domain-Driven Design (DDD) in cadastral organization, demonstrates an approach applicable to broader land management. This approach helps overcome implementation complexity by adopting a flexible methodology that focuses on problematic areas related to business involvement, rather than being restricted solely to technical aspects. By selecting subdomains and addressing interactions between them, the scope of implementation becomes less overwhelming. At the business and process levels, challenges exist in resolving issues between these subdomains.

The strategy for developing a new system focuses on viewing transactions as events, which more accurately reflects actual registration actions (Zevenbergen, 2002; Vos and Roes, 2020). An

event-oriented approach offers opportunities to transcend state-centric systems and enhances traceability, functionality, and interoperability of cadastral systems.

This enables scalable implementation of LADM. An event-based approach aligns particularly well with document-based registration systems but also proves beneficial for title-based systems. On a technical level, the "Cadastre" case demonstrates that data modification becomes more straightforward using standard formats such as XML, JSON, and GML. Furthermore, event sourcing improves interoperability and operationalization through loosely coupled systems with independent models, software, and platforms.

Modern digital technologies, such as GIS and artificial intelligence (AI), play a crucial role in improving land resource management. The use of digital twins, which are virtual models of physical objects, offers opportunities for real-time monitoring, analysis, and forecasting of land use changes. This enhances managerial decision-making, resource use efficiency, and reduces environmental impacts. In Ukraine, such practices are in their infancy, making it important to study international experience and assess the potential for adapting these technologies to local realities.

An analysis of international practices shows that the introduction of digital twins in land resource management brings significant advantages. For example, in the United Kingdom, the "Universal Digital Twin" project created a universal digital twin for collecting, managing, and analyzing land use data. This twin integrates geospatial information and allows for scenario modeling to predict the impact of different land-use options on ecosystems and energy resources.

In South Korea, digital twins are actively used to optimize land resource management. For instance, a pilot project in Jeonju integrates physical and digital data into a unified system to support policy decisions. Using digital twins enables monitoring of urban land, environmental conditions, and comprehensive analysis of urban infrastructure development scenarios.

Digital twins are also crucial in modern agriculture for improving land use efficiency. Combining digital twins with GIS and AI provides precise monitoring and forecasting tools, enabling better decision-making. These technologies help optimize water and chemical use, increase yields, and reduce greenhouse gas emissions.

Based on the analyzed practices and studies of domestic and international scientists, a framework of modern digital technologies to be implemented in land resource management systems has been developed (fig.).

The main software products that can be implemented in land management systems are the following: ChatGPT, DeepSeek, Tableau, ArcGIS Pro, Google Cloud, AWS, Azure, Confluence, AR application, etc.

The integration of modern digital technologies into land management systems is an important stage of their modernization, which contributes to the transparency, efficiency and sustainability of management processes.

Analyzing large amounts of data using machine learning and artificial intelligence algorithms opens up new opportunities for predicting changes in land use, identifying soil degradation risks, and developing climate change adaptation strategies.

Successful examples of using digital twins in the UK and South Korea

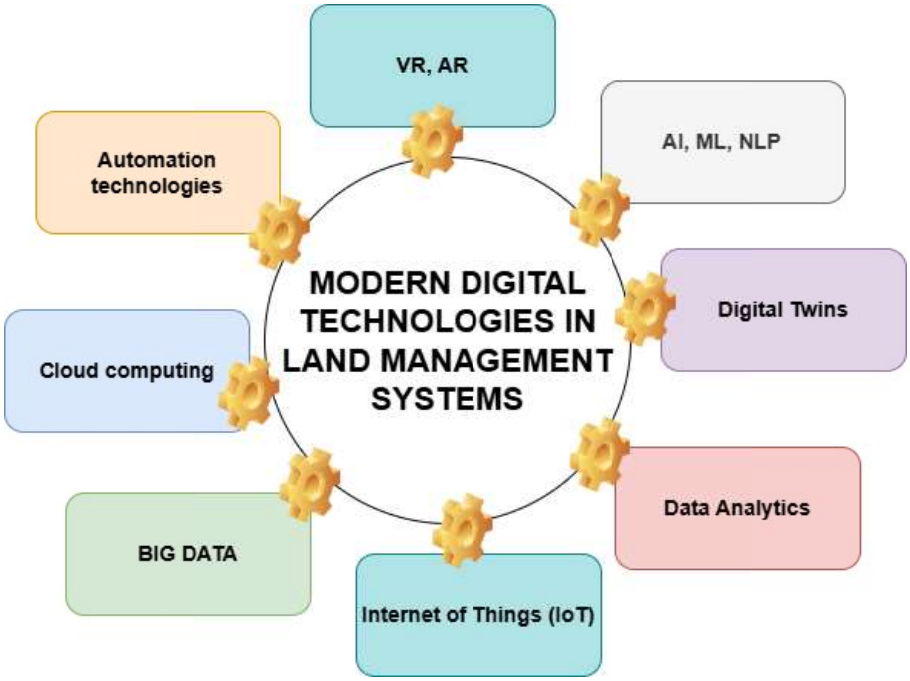

Fig. 1. Scheme of modern digital technologies to be implemented in land management systems

Source: author's

demonstrate the prospects of integrating these solutions into land management processes. Ukraine can adapt these practices to improve the management of agricultural and urban land.

The key areas for the introduction and development of digital technologies in land management systems should be as follows:

- Development of a national strategy for the digitalization of land management, taking into account international experience.

- Use digital twins to integrate data from different sectors, including environmental, social and economic aspects of land use.

- Creation of innovative platforms for public engagement in land management, which will increase transparency.

In the medium term, digital technologies will play a key role in creating sustainable land management systems. Adapting them to Ukraine's conditions will become the foundation for rational land use, food security, and economic stability.

Conclusions and perspectives

Thus, the integration of GIS and AI into the creation of digital twins is a promising area for Ukraine, especially in the context of sustainable development. The use of these technologies will significantly improve the efficiency of land management, ensure the rational use of land, increase the transparency of management processes and minimize risks. Given the successful experience of the UK, where digital twins serve as a universal tool for analyzing and forecasting land use, and South Korea, which is actively implementing digital twins to optimize urban land management, Ukraine may consider adapting such solutions to its needs. Integrating GIS and AI into the process of creating

digital twins will help Ukrainian managers ensure that decisions are informed and improve the quality of planning. Thus, digital twins can become the basis for more efficient land management, contributing not only to the economic but also to the environmental sustainability of the country in the long run.

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СУЧАСНІ ЦИФРОВІ ТЕХНОЛОГІЇ У СИСТЕМАХ УПРАВЛІННЯ ЗЕМЕЛЬНИМИ РЕСУРСАМИ

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Анотація. *У статті розглянуто вплив сучасних цифрових технологій на ефективність систем управління земельними ресурсами. Особливу увагу приділено аналізу ключових інновацій, таких як геоінформаційні системи (ГІС), дистанційне зондування Землі (ДЗЗ) та блокчейн-технології, які стають основою для оптимізації процесів моніторингу, обліку та використання земельних ресурсів. Автори акцентують увагу на їх потенціалі щодо підвищення прозорості, точності та швидкості прийняття управлінських рішень.*

Дослідження охоплює практичні аспекти застосування цифрових інструментів у різних сегментах управління земельними ресурсами, таких як кадастрові обліки, регулювання землекористування та вирішення земельних спорів. Наведено приклади впровадження цифрових технологій у країнах світу та в Україні, що демонструють успішний досвід автоматизації обробки великих обсягів просторових даних. Окремо розглянуто питання інтеграції цифрових рішень у існуючі законодавчі та інституційні рамки.

Автори дослідили потенціал використання штучного інтелекту та великих даних у сфері управління земельними ресурсами. Зокрема, підкреслено важливість застосування алгоритмів машинного навчання для прогнозування змін у землекористуванні, визначення ризиків деградації ґрунтів та підтримки сталого розвитку. Також відзначено роль автоматизованого аналізу супутникових даних у моніторингу екологічного стану земель.

Окремий акцент зроблено на викликах та обмеженнях, що постають перед впровадженням сучасних цифрових технологій. Серед них – недостатня цифровізація державних органів, обмежений доступ до високоякісних даних, а також ризики кібербезпеки. Наголошено на необхідності розроблення національної стратегії цифрової трансформації управління земельними ресурсами з урахуванням міжнародного досвіду.

У підсумку зазначено, що інтеграція цифрових технологій у системи управління земельними ресурсами сприяє їх модернізації та підвищує ефективність управлінських процесів. Стаття містить рекомендації для органів влади, наукових установ і бізнесу щодо подальшого розвитку та впровадження цифрових рішень для досягнення більш раціонального використання земельного фонду.

Ключові слова: *цифрові технології, геоінформаційні системи, дистанційне зондування Землі, управління земельними ресурсами, сталий розвиток.*

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