SUSTAINABLE DEVELOPMENT OF LAND USE IN URBAN AGGLOMERATIONS: TRAINING OF SPECIALISTS IN THE FIELD OF LAND CADASTRE

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INTRODUCTION

Sustainable development is a key direction of modern global policy, aimed at ensuring economic growth, social justice and preserving natural resources for future generations. In this context, the issue of efficient land use in urban agglomerations is of particular importance, as the growth of urbanization and the increasing demand for land resources create numerous challenges. One of the most important tasks is to ensure a balance between infrastructure development, environmental protection and meeting the socio-economic needs of the population.

Effective land management in urban agglomerations largely depends on the quality of work of specialists in the field of land cadastre. It is such specialists who play a crucial role in ensuring transparency and validity of land use decisions, as well as in the implementation of sustainable development strategies. In addition, the modern stage of development of geodetic measurements, which is an effective tool for filling the land cadastre, opens up new opportunities for improving their preparation, in particular through the introduction of artificial intelligence (AI). Automation of the processes of collecting and processing geodetic data using unmanned aerial vehicles and machine learning algorithms provides high accuracy, speed and efficiency.[1]

This allows minimizing the impact of the human factor, reducing errors and optimizing the costs of work, especially in difficult or inaccessible conditions. The integration of AI also helps to predict changes in the terrain, which is important for the development of infrastructure projects and effective management of territories. In this context, the relevance of training specialists in the field of land cadastre is significantly increasing. Their competence should include not only traditional knowledge, but also skills in working with the latest technologies, such as geographic information systems and automated data collection methods.

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[1] Малащук О. Автоматизація геодезичних вимірювань за допомогою штучного інтелекту. *Наука і техніка сьогодн*і. 2024. № 11(39). С. 949–961.

However, the modern training of such specialists faces numerous challenges, in particular due to the constantly increasing requirements for the amount of knowledge, skills and competencies necessary for effective work in conditions of rapid technological changes and the regulatory environment.

The issues considered by the authors of the section are the analysis of modern approaches to sustainable land use of urban agglomerations and the determination of the role of training specialists in the field of land cadastre to ensure effective management of territories. Particular attention is paid to the impact of new technologies, such as geographic information systems (GIS), digital platforms and innovative methods of land resource assessment, on the formation of professional competencies.[2]

The purpose of writing this section is to identify the main areas of improving the training of specialists in the field of land cadastre to ensure sustainable development of land use in conditions of urbanization and the integration of environmental, economic and social aspects into the process of land resources management.

1. The role of the land cadastre in the sustainable development of urban agglomerations

The land cadastre is the main tool for effective land use management in urban agglomerations. It plays an important role in ensuring the rational use of land resources, sustainable development of urban areas and increasing transparency in decision-making. It should be noted that urban agglomerations are characterized by high population density, complex infrastructure and various types of land use, which creates significant pressure on land resources and requires accurate accounting, analysis and planning. It is the maintenance of the land cadastre that provides:

1. Land accounting and monitoring. Thanks to cadastral data, it becomes possible to systematically record land plots, including their location, area, legal status and purpose. This allows you to prevent chaotic development, control land use in accordance with urban planning documentation and avoid conflicts between users.

2. Planning and zoning of territories. The land cadastre is the basis for spatial planning, zoning of urban areas and the development of master plans. It helps to determine development priorities, establish the boundaries of residential, commercial, industrial and recreational zones.

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[2] Новаковська І. О. Сучасні проблеми землевпорядної освіти. Роль соціального та емоційного інтелекту як найважливіших soft-skills XXI століття в освітньому процесі: матеріали всеукраїнського науково-педагогічного підвищення кваліфікації (Одеса: 6 березня – 16 квітня 2023). Одеса, 2023. С. 304–307.

3. Effective resource management. Cadastral data contribute to optimizing the use of land resources, ensuring their economic, environmental and social balance. This is especially important for urban agglomerations, where every square meter of land has a high value.

4. Attracting investments. Transparency of cadastral data is an important factor in attracting investors. Access to reliable information about land plots minimizes the risks associated with the purchase or lease of land and facilitates the implementation of infrastructure projects.

Urbanized areas face a number of challenges that require a clear regulatory framework. Ukrainian legislation provides mechanisms for ensuring sustainable land use. However, for urban agglomerations, it is important to consider certain aspects (Fig. 1)

Legal regulation of the formation of sustainable land use in urbanized areas is usually based on a set of laws, regulations, rules and recommendations aimed at ensuring efficient land use, rational urban planning and infrastructure development taking into account sustainable development and environmental preservation.

Planning complexity	Spatial planning should integrate economic, environmental and social priorities
Protection of ecological zones	Legislation should ensure the protection of green areas, water bodies and nature reserves from excessive urbanization
Land market transparency	Effective regulation of land purchase and sale promotes investment and prevents corruption
Innovative approaches	The use of geographic information systems (GIS) and modern technologies in cadastral accounting contributes to effective monitoring and analysis of land resources

**Fig. 1. Legal aspects of the formation and development
of urban agglomerations**

In Ukraine, these are: the Land Code, the Civil Code, the Water Code, the Forest Code; the laws of Ukraine "On the Regulation of Urban Planning Activities", "On Land Management", "On the State Land Cadastre", "On the National Geospatial Data Infrastructure", "On Environmental Protection", "On Subsoil", "On the Protection of Atmospheric Air", "On the Protection and Use of Flora and Fauna", "On Cooperation of Territorial Communities", "On Local Self-Government in Ukraine", "On Amendments to Certain Laws of Ukraine Regarding the Determination of Territories and Administrative Centers of Territorial Communities", "On Voluntary Association of Terri-

torial Communities", etc.; Resolution of the Verkhovna Rada of Ukraine "On the Formation and Liquidation of Districts" [3].

From September 1, 2022, amendments to the state building codes came into force: "DBN B.1.1-13:2021 Composition and content of urban planning documentation at the state and regional levels", "DBN B.1.1-14:2021 Composition and content of urban planning documentation at the local level", "DBN B.2.2-3:2021 Composition and content of the historical and architectural reference plan of a settlement", "DBN A.2.2-1:2021 Composition and content of environmental impact assessment materials (OVNS) (BN01:6644-7432-9782-8367, Order of the Ministry of Regional Development No. 366 dated 12/30/2021). To replace DBN A.2.2-1-2003", "DBN V.1.2-8:2021 Basic requirements for buildings and structures. Hygiene, Health and Environmental Protection (BN01:5791–7254-6353-7623, Order No. 366). To replace DBN V.1.2-8-2008 Basic requirements for buildings and structures. Safety of human life and health and protection of the natural environment", etc.

It should be noted that the domestic legislation currently does not clearly define the concept of "agglomeration" and clear criteria that would help establish its boundaries, and the term "agglomeration" has no direct relation to the existing administrative-territorial structure of Ukraine.

It should be noted that the land cadastre is not only a technical register, but also a strategic tool for the sustainable development of urban agglomerations. Effective legal regulation of land use should be based on modern approaches to planning, transparency, innovation and adherence to the principles of sustainable development. This will allow creating cities that will be comfortable for the lives of current and future generations (Fig. 2).
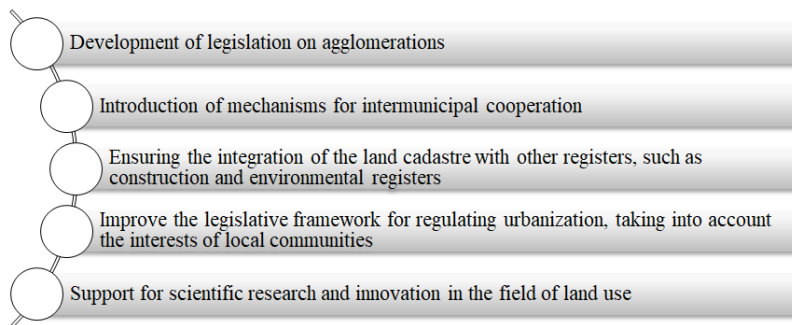
Fig. 2. Legal ways to achieve sustainable land use

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[3] Кулинич П. Ф., Новаковська І. О. Особлива охорона земель України як основного національного багатства: теоретико-правові аспекти. *Землеустрій, кадастр і моніторинг земель*. 2022. № 2. С. 97–106.

Land use within agglomerations is one of the key aspects of modern urban development. Agglomerations, as centers of economic, social and cultural activity, face numerous challenges associated with the interaction of different categories of land users. Given the diversity of interests of different categories of land users within agglomerations, conflicts between them are inevitable. However, they can be minimized by integrating environmental, social and economic interests into the processes of planning and management of territories [4].

mpetent planning, public participation and business responsibility to society are key elements for ensuring harmonious coexistence of all land use participants. Only through a balance of these interests can sustainable development be achieved, which will become the basis for comfortable and efficient life within agglomerations.

However, sustainable land use planning of large agglomerations is a difficult task, as they include complex problems related to urbanization, ecology, economy and social aspects.

The main steps and principles for sustainable land use planning can be:

Analysis of territory use. It is important to carefully analyze the territory of the agglomeration, taking into account the presence of natural resources, ecosystems, environmental features and geographical constraints.

Determination of priorities. Setting the main goals and priorities for the development of the agglomeration, including ensuring housing needs, preserving green areas, developing industry and infrastructure.*Інтегрований підхід*. Planning should take into account all aspects of sustainability, such as the environmental, social and economic dimensions. An integrated approach avoids conflicts between different land use requirements.

Zoning. Dividing an area into functional zones can help avoid conflicts between different types of activities, such as residential, commercial, industrial and green zones.

Land use. The principle of land use is to make the most efficient use of available resources and minimize waste.

Green building. Incorporating green building principles into the planning process can help reduce the negative impact of development on the environment and ensure the creation of healthy and sustainable communities.

Efficient transport infrastructure. Developing efficient and sustainable transport infrastructure can help reduce congestion, air pollution and reliance on road transport.

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[4] Новаковська І. О., Митяєв М. М., Байрачний О. Л. Детальний план території як інструмент сталого розвитку. *Наукові інновації та передові технології (Серія «Економіка»)*. 2024. № 7(35). С. 666–676. DOI:

Conservation of natural resources. Planning should consider the conservation of water resources, soils and natural ecosystems to ensure environmental sustainability.

Citizen participation. It is important to involve local residents, the business community and experts in the planning process to take into account diverse needs and opinions.

Monitoring and evaluation. After the plan is implemented, it is recommended to establish a monitoring and evaluation system to track results, identify problems and make necessary adjustments.

Sustainable land use planning in large agglomerations requires cooperation between different stakeholders and consideration of different aspects of sustainable development.

According to Article 2 of the Law of Ukraine "On Regulation of Urban Planning Activity"[5], "planning and development of territories is the activity of state bodies, local self-government bodies, legal entities and individuals, which provides for:

1) forecasting the development of territories;

2) ensuring rational settlement and determining the directions of sustainable development of territories;

3) substantiation of land distribution by purpose;

4) mutual coordination of state, public and private interests during planning and development of territories;

5) determination and rational mutual location of residential and public development zones, industrial, transport, recreational, environmental, health, historical and cultural and other zones and objects;

6) establishment of the development regime of territories on which urban development activities are planned;

7) development of urban development and design documentation, construction of objects;

8) reconstruction of existing buildings and territories;

9) preservation, creation and restoration of recreational, environmental, health territories and objects, landscapes, forests, parks, squares, individual green spaces;

10) creation and development of engineering and transport infrastructure;

10-1) creation of an obstacle-free living environment for people with disabilities and other low-mobility population groups;

11) monitoring of development;

12) maintenance of the urban planning cadastre;

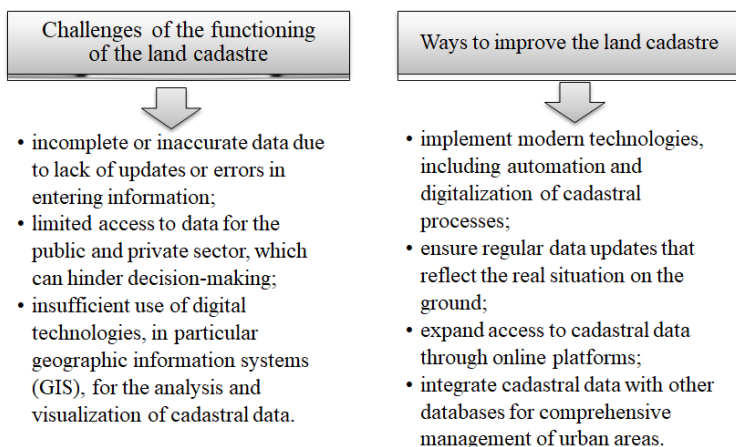13) control in the field of urban planning.

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[5] Про регулювання містобудівної діяльності: Закон України від 17 лютого 2011 р. № 3038-VI / Верховна Рада України. URL: https://zakon.rada.gov.ua/laws/show/3038-17#Text (дата звернення: 26.11.2024).

However, it should be noted that the land cadastre is an integral component of the above-mentioned steps to achieve sustainable development and effective land use management in urban agglomerations. Its development and improvement will contribute to the rational use of land resources, ensure transparency, and support sustainable development.

In today's conditions, when urbanization is gaining momentum, the role of the land cadastre as a basic land management system will only grow.

However, despite the obvious advantages, there are certain challenges in the functioning of the land cadastre (Fig. 3).

Challenges of the functioning of the land cadastre	Ways to improve the land cadastre
• incomplete or inaccurate data due to lack of updates or errors in entering information; • limited access to data for the public and private sector, which can hinder decision-making; • insufficient use of digital technologies, in particular geographic information systems (GIS), for the analysis and visualization of cadastral data.	• implement modern technologies, including automation and digitalization of cadastral processes; • ensure regular data updates that reflect the real situation on the ground; • expand access to cadastral data through online platforms; • integrate cadastral data with other databases for comprehensive management of urban areas.

Fig. 3. Challenges in the functioning of the land cadastre and ways to improve it[6]

The cadastre is the basis for making informed decisions, as it provides accurate and up-to-date information about land resources, their use, ownership, and legal status.

In the context of modern challenges such as urbanization, climate change, demographic pressure and economic instability, the need for effective use of cadastral data is becoming increasingly evident. An integral part of sustainable territorial management is the integration of cadastral data into spatial planning.

It not only contributes to more efficient use of land resources, but also helps to solve complex socio-economic and environmental problems.

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[6] Новаковська І., Береза О. Столичне землекористування: проблеми та шляхи їх вирішення згідно з концепцією сталого розвитку. *Наукові інновації та передові технології. Серія «Економіка».* 2023. № 5. С. 404–414.

Modern technologies, state support and active participation of communities are key factors for the successful implementation of these processes.

In the modern world, where digital technologies are shaping new realities in resource management, the introduction of innovations in cadastral systems is becoming one of the key tasks for ensuring sustainable development. However, one of the most important barriers to this is the technical obsolescence of existing systems. In many countries, including Ukraine, the cadastral infrastructure is still based on outdated technologies that cannot ensure the integration of modern solutions. The lack of a single platform for managing land data and rights to it complicates access to information and its updating, creating chaos and inconsistency between different institutions. Of particular relevance

No less important is the aspect of cybersecurity. The digitization of cadastral data carries risks of unauthorized access and loss of information, especially when it comes to confidential data. In addition, the current legislation in many countries does not meet the modern challenges of the digital age, slowing down the implementation of new technologies.

A rather serious challenge for maintaining a land cadastre in the context of sustainable development was the full-scale invasion of the aggressor country into the territory of Ukraine. Military actions have a large-scale and long-term impact on land use and land cadastre, creating challenges that can change the spatial organization of territories, disrupt economic activity and complicate post-conflict recovery. Taking into account the consequences of the war from February 24 to June 1, 2022, the damage caused to the sectors covered by the RDNA is estimated at about 97 billion US dollars[7].

The main aspects of the impact include the destruction of infrastructure, the loss of cadastral data and the violation of land boundaries.

Military actions often lead to the destruction of transport routes, irrigation systems, water pipelines, energy networks and other infrastructure facilities. Table 1. This makes it impossible to use land resources normally and significantly reduces their productivity. For example, destroyed roads make it difficult to access agricultural land, which reduces the efficiency of agricultural production. In addition, damage to engineering structures can cause soil degradation through flooding, erosion or pollution (Table 1).

War is often accompanied by the destruction or loss of land information. Electronic databases, paper archives, and geospatial data can be lost through shelling or deliberate actions[8].

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[7] Новаковська І., Бавровська Н. Інформаційне забезпечення грошової оцінки земель: навч. посіб. Київ : Видавничий центр НУБіП України, 2023. 368 с.

[8] Ukraine: Rapid Assessment of Damage and Recovery Needs. August 2022, World Bank, Government of Ukraine, European Commission. 269

Total damage and losses by sector as of June 1, 2022 (USD billion)[8]

Sector	Damage caused	Share,%	Losses
Housing	39,2	4,0	13,3
Education	3,4	3	0,5
Healthcare	1,4	1	6,4
Culture and Tourism	1,1	1	19,3
Agriculture	2,2	2	28,3
Energy	3,0	3	11,7
Transport	29,9	31	26,1
Environmental Protection, Nature Management and Forestry	2,5	3	0,7

This creates significant difficulties in restoring property rights, managing land resources, and conducting any economic transactions. The lack of accurate data makes planning impossible and creates the basis for land conflicts. [9] Military operations change the physical and legal boundaries of land plots. The construction of military facilities, mining of territories, mass resettlement of the population or illegal development significantly complicate the identification and management of land resources. After the war, this can lead to long-term conflicts between owners, the state and communities. Despite the difficulties, the prospects for digitalization of cadastral systems are impressive. Automation of land registration and monitoring will significantly reduce bureaucratic processes, reduce the human factor and minimize errors. GIS and remote sensing data provide high-precision analysis of land resources, opening up the possibility of effective planning and management.

The implementation of blockchain technologies will allow creating a reliable data storage system that will be protected from forgery and interference. This will also contribute to transparency in land relations, reducing the risks of corruption. The use of artificial intelligence to analyze cadastral data creates new opportunities for predicting changes in land use and making rational decisions. On the other hand, the integration of citizens into the land management process through online platforms will promote openness and public involvement. We should not forget about international experience. For example, Estonia's success in creating a digital cadastre can serve as a reference point for other countries.

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[9] Digital Public Administration Factsheet. 2023. Estonia. URL: https://interoperable-europe.ec.europa.eu/sites/default/files/inlinefiles/DPA_Factsheets_2023_Estonia_vFINAL.pdf.

After all, the transparency of cadastral systems makes regions more attractive for investment, stimulating economic development. The implementation of digital technologies in cadastral systems is a complex but necessary process for creating a modern, effective and transparent land management system. Yes, the staff shortage remains a serious problem. Working with technologies such as geographic information systems (GIS), blockchain, and artificial intelligence (AI) requires specialists, which are currently in short supply. In addition, digitalization requires significant financial resources. Not every region, especially in conditions of economic instability or war, can afford modernization. The challenges that arise along the way serve not as obstacles, but as growth points, stimulating the search for innovative solutions. The prospects promise not only technical progress, but also profound socio-economic changes that will contribute to the sustainable development of society.

2. Training specialists in the field of land cadaster to ensure sustainable development
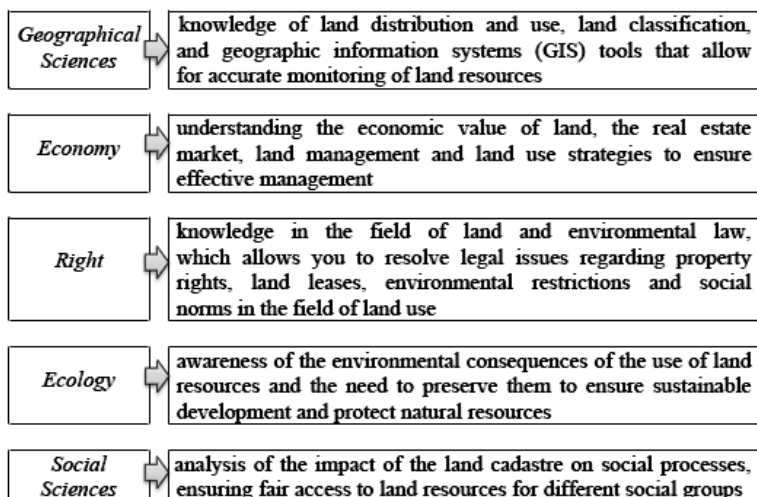
Sustainable development is a global goal for many countries, and the land cadastre is an important tool in achieving this goal. In this context, special attention should be paid to the training of specialists in the field of land cadastre, because only professionals who have comprehensive knowledge and skills are capable of effectively managing land resources. To do this, it is necessary to introduce an interdisciplinary approach to the process of training specialists, which allows ensuring their ability to work with various aspects of the land cadastre, including environmental, economic, social and legal issues.

The key to the training of modern specialists in the field of land cadastre is an interdisciplinary approach. It involves combining knowledge from different disciplines, which allows creating a comprehensive understanding of the problems that arise in the field of land management (Fig. 4).

An interdisciplinary approach to training specialists in the field of land cadastre is necessary to ensure sustainable development. [10] The combination of knowledge from geography, economics, law, ecology and social sciences allows to create a holistic vision of land processes and ensure effective management of land resources. To achieve sustainable development, it is necessary not only to optimize land use, but also to preserve natural resources for future generations, which is impossible without competent and versatile specialists in the field of land cadastre.

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[10] Дорош Й. М., Мартин А. Г., Новаковська І. О. Розвиток землевпорядної науки в Україні: історія, сучасність, перспективи. *Вісник аграрної науки.* 2021. № 4(99). С. 67–76.

Geographical Sciences	⇨	knowledge of land distribution and use, land classification, and geographic information systems (GIS) tools that allow for accurate monitoring of land resources
Economy	⇨	understanding the economic value of land, the real estate market, land management and land use strategies to ensure effective management
Right	⇨	knowledge in the field of land and environmental law, which allows you to resolve legal issues regarding property rights, land leases, environmental restrictions and social norms in the field of land use
Ecology	⇨	awareness of the environmental consequences of the use of land resources and the need to preserve them to ensure sustainable development and protect natural resources
Social Sciences	⇨	analysis of the impact of the land cadastre on social processes, ensuring fair access to land resources for different social groups

Fig. 4. Key elements of an interdisciplinary approach to training modern specialists in the field of land cadaster

The requirements for the competences of training specialists in the field of land cadastre to ensure sustainable development include technical, legal and environmental aspects that must be taken into account for effective management of land resources in the context of modern challenges of sustainable development (Table 2).

In general, a specialist in the field of land cadastre must have integrated knowledge of technical, legal and environmental aspects in order to work effectively in conditions of sustainable development, ensuring the rational use and protection of land resources for future generations.

Thus, one of the key areas of development of modern technologies that are actively being introduced into land management is the automation of geodetic measurements[11].

Automation of geodetic measurements using artificial intelligence is a modern direction in the development of geodesy, which allows to significantly increase the efficiency of data collection and processing, minimize the impact of the human factor, as well as improve the accuracy and speed of work. The introduction of artificial intelligence (AI) technologies into geodetic processes creates new opportunities for measurements, data processing and monitoring of territories. One of the key advantages of automating geodetic

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[11]Новаковська І. О., Жолкевський П. Ф., Іщенко Н. Ф. Геодезія: навч. посіб. Київ: НАУ, 2021. 232 с.

measurements is the use of drones and unmanned aerial vehicles (UAVs) equipped with high-resolution sensors and cameras. Thanks to them, data collection over large areas is possible in a short time. Drones connected to AI systems can automatically fly along specified routes, collect topographic information and send it to central systems for further processing. This allows to significantly reduce measurement time compared to traditional methods that require the direct participation of specialists on the ground.

Table 2

**Requirements for the competences of training specialists
in the field of land cadastre to ensure sustainable development**

№	Type of competence	Competency characteristics
	Technical competencies	
1.	Geographic Information Systems (GIS):	knowledge of the principles of working with GIS for analyzing and monitoring land resources, mapping and creating digital maps of land plots
	Cartography and remote sensing:	the ability to use technologies to collect and process land data, assess their condition, and predict changes in land use
	Land cadastre data management:	skills in processing, storing and updating land cadastre data in digital systems
	Spatial analytics:	ability to conduct land use analysis, identify problems and potential for sustainable development of territories
2	*Legal competences*	
	Knowledge of legislation in the field of land relations:	familiarity with the main laws and regulations that regulate the use, protection and management of land resources (e.g., land code, environmental protection laws, cadastre and registration of land rights)
	Legal aspects of land management:	understanding of land rights regulation mechanisms, including issues of ownership, lease, land allocation, land disputes and conflict resolution
	Environmental standards and requirements:	knowledge of standards for environmental assessment of lands, their protection and sustainable use.
3.	*Environmental competencies*	
	Environmental Impact Assessment (EIA):	ability to conduct environmental research and assess the impact of land use on the environment
	Natural resource management:	knowledge of the principles of sustainable land management, including land management, biodiversity conservation, and restoration of degraded lands
	Green technologies and innovations:	knowledge of innovative approaches to sustainable land use, such as renewable energy sources, energy-efficient construction, and environmentally friendly agricultural production methods

AI is also used to automatically interpret data obtained from drones, including satellite images, aerial photographs, and laser scans. These algorithms help to recognize objects, identify changes in the terrain, and detect potential hazards, such as soil erosion or landslides.

Automated data processing is one of the most important elements of modern geodesy. Traditional methods of processing large amounts of data are time-consuming and require highly skilled specialists. Artificial intelligence allows you to automate this process through machine learning and deep learning algorithms. These algorithms are able to quickly analyze large amounts of data, identify patterns, and make predictions based on the results obtained. One of the main advantages of using AI is the ability to self-learn.

Algorithms used to process geodata are able to improve their results with each new data set, making them more accurate and reliable.

This is especially important for geodetic measurements in difficult conditions, where errors in traditional methods are possible. One of the key problems in geodetic measurements is the errors that arise due to the influence of external factors, such as weather, terrain or technical limitations of equipment. Artificial intelligence algorithms can minimize errors by automatically correcting data and adapting to changing conditions during information collection. For example, algorithms can automatically correct the coordinates of objects based on the analysis of past data or predict possible errors based on previous measurements.

AI also allows you to increase the accuracy of measurements through more detailed data analysis. Automated analysis systems use deep learning algorithms that can recognize small details in the terrain that can be ignored during traditional analysis. The integration of artificial intelligence with GIS provides a new level of automation of geodetic measurements. Geographic information systems allow you to collect, store, analyze and visualize spatial data, which is the basis for decision-making in geodesy, construction, land management and other industries. Using AI to process this data significantly increases the speed and accuracy of analysis.

Automated GIS systems based on AI can track changes in the terrain or in the condition of infrastructure facilities in real time. For example, these systems can be used to monitor the condition of bridges, dams or other critical facilities that require constant monitoring. Thanks to artificial intelligence, such systems can detect even minor changes and warn about possible risks, which allows you to avoid accidents or destruction[12]

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[12] Дегтяренко Д. О., Оболонков Д. Ф. Цифрові методи автоматизації геодезичних вимірювань у реконструкції будівель. *Збірник наукових праць ДонНАБА*. 2024. № 4. С. 11–16.

Despite all the advantages, the implementation of artificial intelligence in geodetic measurements faces certain challenges.

Firstly, it is the high cost of equipment and software. For the effective operation of AI-based systems, modern computing resources and specialized software are required, which may be inaccessible to small companies or individual specialists.

Secondly, there is a problem of insufficient personnel qualifications. The use of AI requires knowledge not only in the field of geodesy, but also in the field of programming and working with big data. Training specialists capable of working with such systems takes time and resources.

Another important challenge is the issue of data security. Geodetic measurements are often used for territory management, infrastructure construction or monitoring environmental changes, so it is important to ensure that the collected data is protected from unauthorized access or loss.

Bing the coming years, the use of artificial intelligence in geodetic measurements will become the standard for large infrastructure projects and territory management.

AI technologies will not only improve the accuracy and speed of data collection, but will also provide the ability to predict changes in the terrain or the state of objects. This will open up new opportunities for the design, construction and monitoring of various territories. Thus, the automation of geodetic measurements using AI is an important step in the development of modern geodesy. It allows you to increase the efficiency of work, reduce costs, improve the accuracy of results and minimize the impact of the human factor on the measurement process.[13]

In the context of training specialists, the automation of geodetic measurements using artificial intelligence (AI) opens up new opportunities for improving educational programs.

In particular, educational institutions should integrate disciplines that cover the basics of working with modern automated geodetic systems, AI algorithms, machine learning and big data processing into their curricula.

This will allow students to acquire the necessary competencies to work with innovative technologies, such as automatic object recognition, terrain change prediction and data accuracy analysis. In addition, it is important to develop skills in interpreting the results obtained using AI and applying them to make effective decisions in geodetic projects.
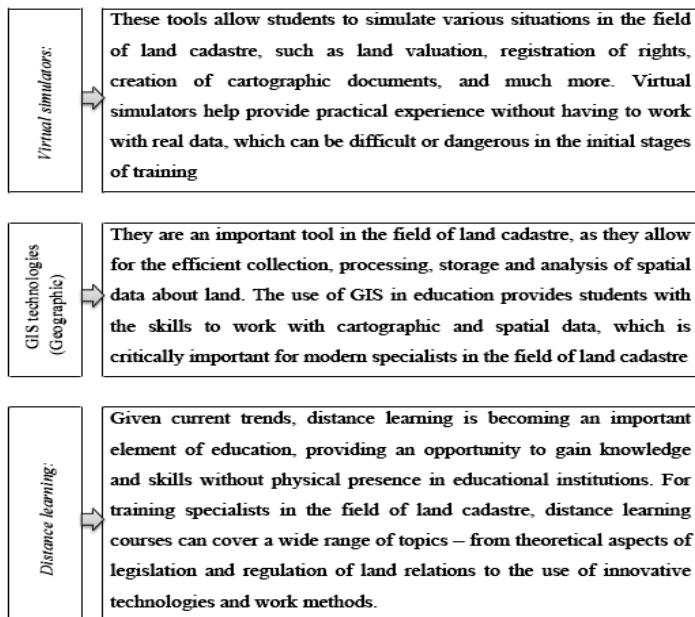
The development of digital laboratories, simulation platforms and access to real geodata will be a key element in the training of highly qualified specialists who are able to adapt to modern challenges in the field of geodesy. Thus,

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[13] Бровенко Д. О. Програмні засоби для автоматизації геодезичних вимірювань у землеустрої. *Технічний вісник України*. 2021. С. 85–92.

automation not only changes approaches to measurements, but also forms new requirements for professional education, ensuring the training of a new generation of specialists.

Educational programs and innovative teaching methods, such as virtual simulators, GIS technologies and distance learning, play an important role in training specialists in the field of land cadastre, which provides not only a high level of theoretical training, but also provides practical skills necessary for effective management of land resources in conditions of sustainable development (Fig. 5).

Virtual simulators:	These tools allow students to simulate various situations in the field of land cadastre, such as land valuation, registration of rights, creation of cartographic documents, and much more. Virtual simulators help provide practical experience without having to work with real data, which can be difficult or dangerous in the initial stages of training
GIS technologies (Geographic)	They are an important tool in the field of land cadastre, as they allow for the efficient collection, processing, storage and analysis of spatial data about land. The use of GIS in education provides students with the skills to work with cartographic and spatial data, which is critically important for modern specialists in the field of land cadastre
Distance learning:	Given current trends, distance learning is becoming an important element of education, providing an opportunity to gain knowledge and skills without physical presence in educational institutions. For training specialists in the field of land cadastre, distance learning courses can cover a wide range of topics – from theoretical aspects of legislation and regulation of land relations to the use of innovative technologies and work methods.

Fig. 5. Educational programs and innovative training methods for training specialists in the field of land cadastre

As a result of such educational programs (Fig. 5), specialists receive the necessary training for effective land resource management, taking into account the principles of sustainable development, which includes environmental protection, rational use of land resources, and optimization of cadastral activity processes.[14]

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[14] Новаковська І. О., Мединська Н. В., Бавровська Н. М. Інвестиційний аналіз: навч. посіб. Київ: Видавничий центр НУБіП України, 2024. 368 с.

Ensuring the accuracy and efficiency of cadastral work is critical for land management, especially in conditions of martial law and post-war reconstruction:

The importance of the cadastre for sustainable development in conditions of war and post-war reconstruction:

• cadastral work is the basis for the proper use of land resources, effective management of the territory and the restoration of infrastructure after the war;

• during the war, cadastral data allow to identify damaged areas, plan restoration and assess property losses;

• in the post-war period, the cadastre will be needed for the restructuring of land ownership, clarification of land boundaries, and organization of land reform.

Challenges for specialists in the field of land cadastre during war are:

• access to traditional cadastral databases often disappears due to the destruction of infrastructure or occupation of territories;

• it is important to ensure the mobility of specialists and the ability to work in the field, quickly and effectively restoring important data;

• problems with using modern information technologies due to limited access to the Internet or equipment.

The role of practical training and advanced training of specialists:

• theoretical knowledge is important, but without real experience of working with cadastral data in conditions of changing territorial boundaries or destruction of infrastructure, they will not be effective;

• practical training should include the use of modern technologies, such as geographic information systems (GIS), remote sensing of the earth for data collection and analysis;

• practical courses and trainings for cadastral specialists can provide skills for working in extreme conditions, such as using field maps, drones for data collection in combat zones or in affected areas[15].

Software solutions and tools for professional development:

• development of specialized training programs and courses that would include methods of managing cadastral data during and after the war;

• implementation of distance learning for specialists, which allows to improve their qualifications in conditions of limited access to resources.

• implementation of the latest tools for territory management, which allow to take into account wartime changes in cadastral data.

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[15] Novakovska I., Gunko L. Conceptual principles of land protection in context of sustainable development. Kyiv, 2024. 288 p.

The role of advanced training of specialists in the post-war period:

• After the war, it is necessary to carry out a large-scale restructuring of cadastral data, as many territories have undergone changes as a result of hostilities. Specialists must have the skills to restore data, update it, and also know how to work in conditions of large information volumes.[16, 17, 18]

• improving the skills of specialists in the field of cadastre will become an important component for stabilizing and developing the economy, as the restoration of land resources and their effective use will be of key importance for the restoration of infrastructure and development of territories[19].

This also provides an opportunity to develop new methods of training and adaptation of personnel to modern conditions, to create integrated approaches to cadastre management in times of crisis.

Also, in the context of high-quality specialists in the field of land cadastre, important cooperation between educational institutions, local governments and business is an important component for the development of the economy, social stability and innovation. Such cooperation has several key areas (Fig. 6).

Thanks to such cooperation, it is possible to achieve comprehensive development of the region's economy, create a favorable environment for business development, and improve the quality of education and employment.

CONCLUSION

Sustainable development of land use in urban agglomerations is one of the key challenges of modern society, requiring the integration of economic, environmental and social aspects into the process of territorial management. The land cadastre is a strategic tool that ensures transparency, accuracy and efficiency of land management. In modern conditions, the introduction of innovative technologies, such as geographic information systems (GIS) and artificial intelligence algorithms, opens up new opportunities for automating the processes of data collection and analysis, reducing the impact of the human factor and increasing the accuracy of decisions.
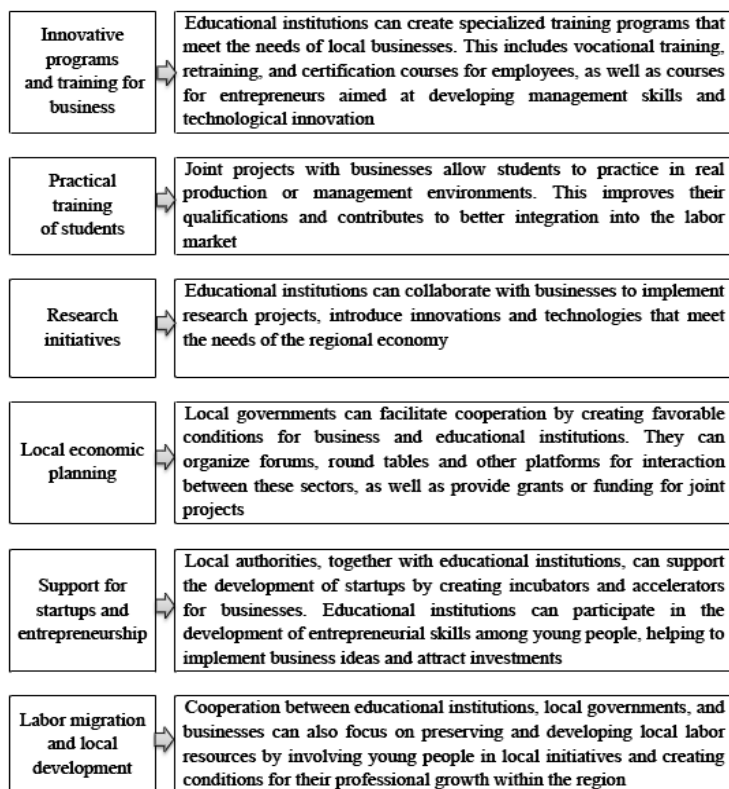
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[16] Кисельникова В. С., Лоцман О. О. Автоматизовані системи обробки геодезичних даних у містобудуванні. *Науковий журнал «Архітектура та містобудування».* 2023. № 2. С. 29–35.

[17] Новаковська І. О., Близнюк В. В., Береза О. В. Стале землекористування в умовах формування міських агломерацій: виклики та перспективи. *Наукові інновації та передові технології (Серія «Економіка»).* 2024. № 6(34). С. 928–941.

[18] Новаковська І. О., Бавровська Н. М. Трансформація земельно-кадастрового обліку кількості та якості земель в Україні в умовах повоєнного відновлення. *Землеустрій, кадастр і моніторинг земель.* 2023. № 2. С. 51–63.

[19] Новаковський Л. Я., Євсюков Т. О., Новаковська І. О. Управління землекористуванням: проблеми охорони основного національного багатства. *Землеустрій, кадастр і моніторинг земель.* 2022. № 1. С. 4–17.

Innovative programs and training for business	Educational institutions can create specialized training programs that meet the needs of local businesses. This includes vocational training, retraining, and certification courses for employees, as well as courses for entrepreneurs aimed at developing management skills and technological innovation
Practical training of students	Joint projects with businesses allow students to practice in real production or management environments. This improves their qualifications and contributes to better integration into the labor market
Research initiatives	Educational institutions can collaborate with businesses to implement research projects, introduce innovations and technologies that meet the needs of the regional economy
Local economic planning	Local governments can facilitate cooperation by creating favorable conditions for business and educational institutions. They can organize forums, round tables and other platforms for interaction between these sectors, as well as provide grants or funding for joint projects
Support for startups and entrepreneurship	Local authorities, together with educational institutions, can support the development of startups by creating incubators and accelerators for businesses. Educational institutions can participate in the development of entrepreneurial skills among young people, helping to implement business ideas and attract investments
Labor migration and local development	Cooperation between educational institutions, local governments, and businesses can also focus on preserving and developing local labor resources by involving young people in local initiatives and creating conditions for their professional growth within the region

Fig. 6. Key aspects of cooperation between educational institutions, local governments and business in training specialists in the field of land cadaster[20],[21]

Military operations in Ukraine increase the relevance of the topic due to significant challenges for land management, including the loss of cadastral data, damage to infrastructure and changes in territorial boundaries. However, these challenges also open up opportunities for the modernization

[20] Новаковська І. О., Бавровська Н. М., Іванченко В. А. Перспективи інвестиційної привабливості України в умовах повоєнного відновлення. *Актуальні питання у сучасній науці.* 2024. № 5(23). С. 137–149. DOI: https://doi.org/10.52058/2786-6300-2024-5(23)-137-149.

[21] Ладиченко В., Мединська Н., Новаковська І., Яринко Б. Правові аспекти захисту земель як національного багатства України в умовах агресії: міжнародні та національні підходи. *Національні інтереси України.* 2024. № 3(3). С. 210–224. DOI: https://doi.org/10.52058/3041-1793-2024-3(3)-210-224.

of cadastral systems, their digitalization and increasing the role of communities in management processes.

An important component of achieving sustainable development is the training of specialists in the field of land cadastre, who must possess interdisciplinary knowledge, including technical, legal, economic and environmental competencies. The introduction of modern educational methods and technologies will contribute to the formation of personnel capable of effectively responding to the challenges of the time and ensuring the rational use of land resources for current and future generations.

SUMMARY

The authors considered the issue of sustainable development of land use in urban agglomerations in the context of integrating economic, environmental and social aspects of land management. Particular attention is paid to the role of the land cadastre as a strategic tool for ensuring rational use of territories, transparency in decision-making and preventing conflicts between different land users.

The article highlights the impact of innovative technologies, in particular geographic information systems (GIS) and artificial intelligence algorithms, on the optimization of cadastral accounting and monitoring processes of territories. The challenges that arise in the field of land use in conditions of military operations are considered, in particular the loss of cadastral data, violation of land boundaries and destruction of infrastructure.

The need to improve the training of specialists in the field of land cadastre is emphasized by introducing an interdisciplinary approach, modern teaching methods and practical training. This will allow creating an effective land management system that will contribute to the sustainable development of urbanized territories.

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