International Information and Engineering Technology Association
Advancing the World of Information and Engineering

Instrumentation Mesure Métrologie
Vol. 23, No. 3, June, 2024, pp. 183-191
Journal homepage: http://iieta.org/journals/i2m

Scientific Foundations of Application of New Effective Technologies in Land Surveying Studies (On the Example of Talgar District, Almaty Region)

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https://doi.org/10.18280/i2m.230301

Received: 22 March 2024
Revised: 24 May 2024
Accepted: 4 June 2024
Available online: 21 June 2024

Keywords:
geodesy, geoinformation technology, resource management, terrain, artificial intelligence

ABSTRACT

The study aims to develop and scientifically outline the methodology and technological innovations in land surveying aimed at optimizing the processes of land registration, planning, and sustainable land use. The methods used include analytical, statistical, functional, deductive, and synthetic approaches. In the course of the study aimed at developing the scientific basis for the application of new technologies in land surveying studies in Talgar district of Almaty region, modern technologies were analyzed, as well as their potential. In the last ten years, the land management system has undergone a process of renewal, modernization, and digital transformation, including the introduction of information and communication technologies. The main objective of this process is to simplify the search, collection, and structuring of information in the field of land management and cadaster, as well as to improve the interaction between different agencies involved in land management. Such technologies can be distributed registry systems (blockchain), big data processing, neurotechnology, and artificial intelligence. The potential of these technologies in the context of improving land administration was explored.

1. INTRODUCTION

The research relevance of this topic is determined by the fact that effective land management plays an important role in agriculture and natural resource management, especially in agrarian regions such as the Talgar district of the Almaty region. New technologies in land management can significantly improve the accuracy and efficiency of studies, which in turn contributes to increasing crop yields, optimizing land use, and ultimately improving the economic sustainability of the region [1]. This study provides a scientific basis for introducing innovative approaches to land management, which can lead to improved livelihoods for rural residents and increased agricultural productivity in the area.

The research problem is that modern land management processes require improvement and optimization to better manage limited land resources as well as to achieve sustainable development. Despite existing technological advances, there is a need for scientific justification and methodology development for more accurate land records, planning, and land management. The effective integration of these technologies, as well as consideration of social and environmental aspects, remain challenges that require serious research to ensure more accurate and sustainable land management in the future.

According to the study by Alpyspayeva et al. [2], modern geodesy and geoinformation technologies provide unique opportunities for more accurate and efficient land management, which is important for the rational use of land resources. The study did not consider the social and environmental aspects of the impact of modern technologies on land management and sustainable land use, despite their significant influence on decision-making in this area. Jangarasheva et al. [3] emphasized that the study of the scientific basis of sustainable land use allows for consideration of the impact of human activity on natural ecosystems and the development of strategies for biodiversity conservation. The technological aspects of the integration of modern geodetic and geoinformation technologies for more effective implementation of biodiversity conservation strategies in the context of sustainable land use were not considered.

Following the study of Zhaksybaeva et al. [4], the integration methodology of modern technologies into cadastral processes reduces bureaucratic barriers and improves access to information on land plots. The study did not cover legal and data confidentiality issues related to the integration of modern technologies into cadastral processes, although these aspects are critical to ensuring the protection of property rights and the confidentiality of information on land plots. Turganaliyev et al. [5] note that the development of new technologies raises issues of confidentiality and data protection, which require the development of reliable legal mechanisms. The technical and security aspects of the introduction of modern technologies in the field of land management have not been investigated, although they are of critical importance, and it is required to develop appropriate legal and technical measures to ensure information security.

The study conducted by Toleubekova et al. [6] highlights that Geographic Information System (GIS) application and modelling of land use changes help to create more resilient and sustainable urban environments. The study did not consider aspects of social interaction and public involvement in sustainable urban planning processes, despite their important influence on the creation of viable and sustainable urban environments. Ualieva and Maydirova [7] raised the important issue that effective land management is important for economic development, as land plays a key role in infrastructure and production processes. The aspects related to the environmental consequences of land management and its impact on the natural environment have not been considered, despite their importance for sustainable development and environmental conservation.

Although there is much potential for the development of scientific underpinnings for the application of new technologies to land surveying, there is also considerable opposition and differing opinions. Critics argue that, particularly for smaller towns or rural regions with tighter budgets, the hefty costs of deploying cutting-edge technological like GIS, remote sensing, and artificial intelligence (AI) may outweigh any possible advantages [8]. Concerns regarding data privacy and the possibility of abusing the comprehensive land record capabilities made possible by these technologies also exist. Furthermore, some stakeholders support a more well-rounded strategy that combines cutting-edge technology advancements with conventional wisdom and community engagement [9]. They contend that data-driven technology might not be able to adequately capture the social, cultural, and environmental circumstances unique to each place, and that this is why sustainable land management is necessary.

This study offers fresh insights into the use of contemporary technologies in land management and surveying. While individual technologies have been the subject of previous research, there hasn't been an integrated strategy that concurrently makes use of several cutting-edge technology. Through bridging these different technological domains, the research offers a novel blueprint for constructing cyber-physical "digital twin" systems that can precisely model the physical terrain of land while permitting safe data exchange, automated analytics, and economical decision assistance. In addition, the study's unique approach takes into account the socio-economic, legal, and environmental implications of using these technologies for land administration in the case study location in an ethical manner.

The study aims to provide a set of special methods and innovative technologies in the field of land management to improve the efficiency of land accounting, planning, and the sustainable use of land resources.

2. MATERIALS AND METHODS

The analytical method was used to examine the data collected during the survey in a more detailed and systematic manner and to identify hidden patterns and relationships between the various land parameters. This required a thorough and methodical investigation to uncover opportunities for accounting and planning procedure optimization as well as insights into current land management practices. The statistical method was used to conduct more in-depth and objective data research, which helped to identify significant trends and statistical patterns in land use. This research contributed to the identification of potential areas for optimization of land planning and accounting processes, which in turn contributed to more rational use of land and resources.

By applying the functional method, the key functions and roles of land within different land projects and sites were identified. Examining the precise goals, objectives, and specifications for the land's use was part of this process. This consideration of the functions of land enabled better tailoring of site planning and utilization to specific needs and objectives, which in turn helped to create more effective and sustainable land solutions. The structural-functional method helped in detailing the interrelationships between land management elements and their impact on the organization of the area. This included describing the interactions and roles of the various land project components, allowing for the optimization of land use patterns, and enhancing the viability and sustainability of land management techniques.

The deduction method was used to systematically investigate the available knowledge and draw conclusions from the available evidence. It ensured a complete evaluation and analysis of all pertinent data from which to form inferences, as opposed to drawing conclusions based on scant evidence. This, in turn, contributed to a more accurate and informed determination of the best strategies and solutions for land management and sustainable land management. By applying the synthesis method, the diverse aspects and elements of land management and technology, such as surveying data, GIS mapping, urban planning models, blockchain, and AI, were brought together to create a holistic and integrated view of the processes of land records, planning, and sustainable land management. This method facilitated the development of more effective and integrated approaches to problem-solving, which ultimately improved the overall efficiency and sustainability of land administration.

The research conducted is a comprehensive analysis covering various aspects. This study's choice of analytical and statistical techniques was influenced by the requirement to thoroughly investigate the complex terrain of land surveying and management procedures. Together, these methodological approaches offered a strong basis for tackling the research goals, making use of the advantages of different qualitative and quantitative approaches to fully examine the problem domain, spot areas where technology could be used to help, and create recommendations based on science for incorporating new technologies into land surveying procedures. Both theoretical and practical aspects were investigated in detail, thus providing a comprehensive overview of the topic at hand. The theoretical component included a literature review and theoretical aspects related to the subject of the study. The practical component included data collection and analysis, case studies, or process studies in real-life settings. Methodology development for the application of new technologies in land management in Talgar district includes a comprehensive analysis of natural and agrarian conditions, a literature review of existing methodologies, expert advice, mathematical modelling of the interaction of new technologies with local conditions, pilot testing, and economic analysis. This process provides a scientific basis for the introduction of new technologies and an understanding of their impact on agrarian and environmental aspects in the Talgar district, contributing to sustainable agricultural development and reducing negative environmental impacts. All these components together contributed to a more complete understanding of the research topic and the formation of relevant conclusions.

But a strong dependence on secondary data sources could add biases or mistakes that affect how reliable the results are. Furthermore, the absence of primary data gathering methods such as surveys or field observations hinders the study's capacity to encompass complex viewpoints and firsthand experiences from a range of stakeholders engaged in land surveying and management procedures. This can result in a lack of knowledge about the real-world difficulties and environmental aspects that affect how new technologies are implemented successfully. Moreover, the study's implications for practical applications may be weakened by the lack of thorough empirical testing or pilot studies assessing the suggested technology solutions.

The Talgar district of the Almaty region was selected due to its geographical and land use diversity, encompassing agricultural lands, pastoral areas, mountainous terrain, forests, and natural reserves. The district's designated natural reserves and sanctuaries require environmental conservation. Obstacles to traditional land surveying include insufficient geodetic networks, old cadastral records, and poor terrain accessibility. In addition, the district administration's plans for infrastructure improvements, urban growth, and economic development call for careful spatial planning and efficient use of available land. Using modern technology could help with this intelligent planning and monitoring of the effects of development. The study's goal is to create a thorough scientific methodology that can be applied to the distinct socio-economic and environmental conditions of this diversified neighborhood.

Based on the findings, recommendations and suggestions were formulated to improve land management processes and sustainable land use. These recommendations have practical value and can be used in real land management projects and solutions. Thus, the study has had an important impact on practice and scientific knowledge in the field, and its results can contribute to more effective land management and sustainable development of territories.

3. RESULTS

Technological progress introduces new dynamics in the field of land management. Modern advances in information technology and geographic information systems, the availability of GPS technology, and the use of powerful computers, peripherals, and digital cartography provide the government with effective tools to manage the resources and characteristics of land. This significantly increases the scope of land management studies in land transformation and expands the opportunities for the use of modern geodetic equipment in land planning design processes [10]. Land management is an important and multidimensional direction in land resources management, which requires continuous improvement and innovation and is defined as the procedure for managing land resources to guarantee best use and conservation, including planning, registration, and use. Effective land management requires a clear understanding and the operationalization of several key concepts. The main objective is to manage sustainable land use, which means meeting present demands while protecting the land's potential for future productivity and reducing environmental damage. Since inaccuracies can spread through different land management operations, the accuracy of geographic data, property boundaries, topography models, and other land information is crucial. In order to complete land administration activities swiftly, affordably, and with the fewest mistakes possible, efficiency is also essential. These fundamental ideas of land management, when combined, set the stage for utilizing cutting-edge scientific techniques and technology in this field.

In the Talgar district of the Almaty region, it was considered important to develop a scientific basis for the application of new technologies in the field of land management. Talgar district is a vast territory with a variety of land types, from agricultural fields to natural reserves (Figure 1). This diversity requires accurate and up-to-date methods for land management, land records, and monitoring of changes in the landscape. In this context, the development of a scientific basis for the application of new technologies is of paramount importance.

Figure 1. Talgar city topographic survey

One of the most promising technologies worth considering is GIS. GIS provides the ability to visualize and analyze spatial data, which is especially useful in the case of land management. They can be used to create electronic maps, optimize land distribution, and track changes in land use [11]. GIS allows for more accurate delineation of site boundaries while considering various factors such as topography, ecological environment, and landscape. Another important new technology is the use of remote sensing and satellite data for land monitoring [12]. These techniques provide information on the condition of land with high accuracy and without the need for a direct physical presence on site. This is especially important in remote areas, such as the Talgar district, where the accessibility of land plots may be limited by difficult terrain and climatic conditions. However, the introduction of new technologies requires scientific justification and adaptation to the specific conditions of the Talgar district. Research and development in this area may include identifying optimal GIS methods for analyzing land data in this region, creating models for predicting changes in land use, and determining optimal remote sensing parameters [13]. A trained human resource base and cooperation with scientific and educational institutions are also important for the successful implementation of new technologies in land management in the Talgar district. It is important to provide training for specialists capable of working with new technologies and to promote research aimed at adapting them to the specific needs of the region.

Practice confirms that achieving increased productivity and improved quality of design and research studies in the field of land management is quite possible with the use of modern information technologies and the organization of land management processes, including computer equipment and modern software [1-7]. What distinguishes these technologies from traditional methods based on the experience and intuition of specialists and expert judgement is their ability to provide integrated solutions to tasks including planning, accounting, analysis, and design at a higher level of quality. These technologies also reduce the time required to complete design studies, significantly improve the quality of projects, and simplify the labor of designers by allowing them to focus on the more creative aspects of design. The establishment and maintenance of land cadastral systems are complex tasks, as they play a key role in assessing public resources and controlling their use. There are no unpopulated or unassigned areas on the Earth's surface, and it is therefore important to account for every piece of land. Standard paper-based methods are not able to provide complete coverage of the entire surface area of the Earth. This means that not all parcels of land can be accounted for completely and accurately. Therefore, the use of GIS technologies provides high-quality cartographic material that covers the entire Earth's territory and ensures more accurate and comprehensive cadastral studies [14].

Historically, geodetic surveys and land-use plans were created on the ground for specific areas, such as rural areas, and rarely used computer processing [15]. When such data is entered into the computer, there are problems with accuracy, correspondence, and connecting different territorial units. Often, the coordinates of the pivot points that were recorded in the technical reports and then entered into the computer do not match those calculated by the computer. This is due to the impact of the so-called "human factor." Inaccurate line measurement data can lead to errors in the calculation of areas. Even with correct and accurate geodetic surveys, errors have occurred in the creation of graphic materials. Since all outlines on the territory are interconnected, inaccurate representation of at least one line can lead to distortion of adjacent areas on the map. The creation of digital maps based on such materials can lead to significant distortions with displacements of up to 10-20 meters compared to the actual position of contours on the ground [16]. Given the low quality and accuracy of the source materials themselves, when converting existing cartographic materials into digital format, the error in the plan can reach 30 meters, which can lead to the displacement of contours and their arbitrary rotation. Soil maps that currently exist are often of even lower quality and accuracy [17].

The use of available cartographic data in the land management process is limited and can be applied at a limited scale, most often in the form of land surveying schemes. To achieve a more accurate and realistic picture, almost complete geodetic surveying is required, which is time-consuming and costly. In many cases, there are no points in the state geodetic network, which leads to the necessity of creating their own geodetic reference network, which often extends over more extensive areas than administrative boundaries. In this context, the use of GIS technologies, including GPS systems, seems to be a more economically feasible solution. An ideal way out of this situation could be the use of rigid-based orthophoto maps as a reference substrate in the creation of digital maps with accurate georeferencing [18]. This would allow a more accurate comparison of existing land survey data with the rigid spatial base provided by aerial orthophotos. In areas with complex topography, which should be considered in land surveying studies, it is advisable to use large-scale topographic maps and stereo photographs to create accurate terrain relief [19]. In conclusion, it is important to emphasize that although GIS technology is actively used in various countries, its potential is much broader than just the creation of interactive maps and data visualization described in the projects studied.

Effective land management requires accurate and organized information on land plots and related rights [20]. Currently, the existing systems of registration of land plots and their rights are far from perfect. The use of blockchain technology can contribute to the creation of a unified registration and cadastral registration system. The main idea of blockchain technology is the presence of a decentralized database with distributed information available only to verified participants. Such participants may include government agencies, cadastral engineers, and local government specialists. The information stored in the blockchain is provided with cryptographic protection, which guarantees its inaccessibility and the impossibility of tampering. Each verified participant in the system can access the data and verify its authenticity. In a consecutive chain of blocks, it is possible to store information about transactions, changes in the status of the object, and imposed restrictions, which are formalized in the form of a register. It should be noted that making changes in one block automatically leads to corresponding changes in all other blocks, and there is no need to manually change information in each of them.

The introduction of blockchain technology into the real estate cadaster sector helps to optimize operational processes and reduce the time required to complete and register real estate transactions. It also helps to increase the reliability and transparency of registration procedures and reduce the risk of fraud, which is achieved through the use of cryptographic methods to protect the system. Nowadays, one of the key tasks is to process vast amounts of data, which include cartographic, statistical, land surveying, and cadastral information [21]. Every hour, real estate sale and purchase transactions are registered, and remote sensing of the Earth is carried out, which leads to the creation of new cartographic materials. These processes have a significant impact on making informed management decisions in the field of land resource management and their effective management. In this regard, the use of big data processing technologies seems to be very promising. The term "big data" covers a variety of structured and unstructured data in large volumes, and specialized software tools are required for their processing. The main characteristics of big data technologies include a significant amount of information, the high speed of their generation and processing, as well as a variety of formats and types of data.

The application of big data in land management at the municipal level offers the following benefits:

(1) Automated collection of extensive cartographic, textual, photographic, and video information from various sources on a single platform with subsequent structuring and systematization of this information.

(2) The possibility of making informed decisions based on structured information covering various aspects of management, including quantitative and qualitative changes in

the land fund, trends in its transformation, and spatial development.

(3) Accelerating the decision-making process, increasing its validity and efficiency.

Among modern digital technologies that can be applied to land surveying, real estate cadaster, and land management, AI represents a significant potential. AI is the ability of computer systems to mimic the cognitive processes of the human mind, including learning, analysis, and decision-making. Through the use of mathematical functions and logic, computer systems can emulate the processes of assimilating new information and making informed decisions based on analysis. The application of AI in land management provides an opportunity to extend the functionality of geographic information systems in land monitoring and land survey operations. This includes automating the classification of graphical information and providing decision support based on classification data. In addition, it makes it possible to solve the tasks of assessment, diagnosis, and forecasting with higher efficiency, providing faster creation of development scenarios based on input data, creation of three-dimensional models of territories, and reduction of time and resource costs [22, 23].

The digital twin paradigm and the cyber-physical systems theoretical framework are compatible with the integrated usage of all these technologies. Cyber-physical systems enable bidirectional data flows between the digital and physical realms by closely integrating computational and physical processes. The term “digital twin” describes the process of building an extensive virtual duplicate of a real-world object or setting. GIS provides the fundamental digital representation of the actual land parcels and geography in the context of land management [24]. This digital landscape model can incorporate multidimensional datasets such as sensor data, satellite imagery, demographic data, and so on, thanks to big data analytics. Then, using AI and machine learning approaches, this integrated data corpus can be automatically mined for insights, patterns, and predictions. Blockchain offers a decentralized, safe system for tracking the source of data that goes into the digital twin and for managing transactions. The reliability of the digital twin can be preserved by registering land ownership records, zoning changes, environmental monitoring data, and other updates immutably on the blockchain.

However, orchestrating this technological convergence is theoretically and practically challenging. In terms of theory, integrating the various data models, processing processes, and output representations that are employed by each technology area seamlessly requires the establishment of strong interoperability standards and data integration frameworks. Geographical data employs unique standards to depict spatial relationships, whereas blockchain technologies depend on distributed consensus models and cryptographic primitives. Structured and unstructured sensor data, images, and machine learning techniques can all be ingested and analyzed; however, mappings are required to reconcile these data types with traditional GIS data models [25]. Another major issue is scalability, since the amount of spatial data, the quantity of blockchain transactions, and the range of data sources all grow exponentially with geographic coverage. To avoid performance bottlenecks, research on distributed computing paradigms, data partitioning techniques, and parallelization approaches is necessary. When it comes to property tenure, ownership rights, and financial transactions, privacy and security assurances are crucial. Although blockchain ensures data integrity, theoretical advancements in encrypted computing are necessary to maintain privacy.

Active implementation of modern digital technologies is proposed to increase the efficiency and effectiveness of the work of state and local government bodies in the field of land resource management. This includes the use of big data technologies to ensure the preservation and structuring of information obtained as a result of land surveying, as well as to control this process. For the effective organization of state expertise in land survey documentation and supervision of cadastral engineers, it is proposed to apply blockchain technology, which will ensure reliable control over the actions of specialists. To improve the determination of cadastral value and state cadastral valuation, it is proposed to use AI to automate the collection and analysis of data, which will allow for quick and accurate calculation of the value of real estate. Finally, it is proposed to apply big data technologies to the territory of municipalities to systematize information on land plots and improve the efficiency of services provided. These modern digital technologies are gaining increasing popularity in Kazakhstan and have significant potential. Land management at the regional level involves a complex hierarchical interaction between state authorities, local self-government, and various legal entities and individuals. In this regard, the use of advanced digital technologies such as blockchain, big data, and AI facilitates faster, technically sound, and cost-effective decision-making in land management [26].

Land management assumes a significant role in ensuring the wise use and protection of land. Using technical, economic, and legal approaches, it promotes sustainable and economically sound use of land resources, as well as effective territory planning and production allocation. This process is integrated into the economic system and is a complex mechanism depending on the nature of production relations and the form of land ownership. The following conclusions follow from the analysis of this process: the assessment of the economic efficiency of land management requires consideration of economic laws and the development of appropriate evaluation indicators; when calculating efficiency, it is necessary to highlight the contribution of land management and compare it with costs, ensuring the comparability of indicators; it is also important to take into account the effectiveness of activities carried out before the completion of the project, as well as the cost of the formation and maintenance of fixed and working capital, related to compensation for losses and environmental protection.

From a methodological point of view, it is important to distinguish between actual and estimated land management performance. Actual efficiency is assessed to evaluate the actual cost results, establish a systematic control of the project’s progress in the process of the author’s supervision, and, if necessary, adjust. Estimated (design) efficiency is considered in the development of land surveying schemes and projects, as well as in the implementation of specific land surveying measures. When determining actual efficiency, the actual organization of the territory is compared with what was envisaged in previously developed projects, as is the analysis of reported indicators in comparison with the design and normative values. The actual efficiency of land management helps to determine the real results and the level of usefulness for social development. Actual efficiency reaches its maximum level at the full completion of the project but may vary during the course of the project depending on various conditions. Actual and estimated efficiencies may diverge for several reasons (Table 1).

Table 1. Comparison of actual and estimated land management efficiency

Aspect	Actual Efficiency	Estimated Efficiency
Timing	Depends on the impact of natural and economic factors, which may vary	Assessed at project completion based on planned production rates
Scope	Considers only completed activities	Considers all planned capital investment activities
Inputs	Depends on actual costs and commissioning times	Assessed based on averaged norms
Conditions	Accounts for actual production conditions	Compares estimated and base periods

The results of the research have important implications that go beyond the field of land management and surveying. The effective fusion of technologies such as digital modelling, remote sensing, and GIS shows the field's adaptability and promise for use in a range of mapping and spatial analytic scenarios. Scholars in this domain may expand on the methods presented in this work to investigate novel approaches for precise terrain mapping, land use change identification, and three-dimensional geographic data visualization. Furthermore, the study's conclusions about using AI and big data analytics to process massive amounts of geographical data may open doors for interdisciplinary partnerships with academics in data science and computer science.

4. DISCUSSION

The topic of the development of scientific bases for the application of new effective technologies in land surveying is important and relevant in the modern world. Land management is a process that involves the creation, updating, and management of information about land resources, and it concerns not only agrarian but also urban and suburban areas. This discussion considers the significance of the development of new technologies in land management and their impact on this field. The introduction of modern technologies in land management greatly simplifies data collection and processing. GIS technologies allow collecting, storing, and analyzing geodata in a convenient form. This makes the land management process more efficient and allows for more informed decision-making [27]. The application of new technologies, such as AI, can automate many processes in land management. AI can be used to classify and analyze geodata, as well as to determine the cadastral value of real estate. This reduces the time spent on routine tasks and reduces the likelihood of errors.

According to the results of recent studies by de Vries [28], in 2021 there were significant trends in the introduction of new geospatial technologies in spatial planning and land management. These trends are related to the digitalization and automation of processes in organizations involved in land management and spatial planning. One of the key trends has been the active use of geographic information systems in spatial planning and land management. GIS allows efficient storage, analysis, and visualization of geodata, which becomes the basis for informed decision-making. Many countries and regions have started the transition to digital cadasters and maps, which simplifies access to land information and ensures transparency in this area [29]. These results support the above study, as the introduction of new geospatial technologies has significantly improved the efficiency and accuracy of spatial planning and land management processes. It has also contributed to more transparent and open land management. These trends are likely to continue and develop in the future, improving land management and spatial planning practices.

Referring to the definition of Abdukadirova and Yokubov [30], the use of geographic information systems in land fund research is becoming an integral part of modern land management and cadastral practice. GIS provides powerful tools for the collection, storage, analysis, and visualization of geospatial data, which significantly simplifies the process of land resource research and management. These findings are consistent with the thesis presented in the previous section. One of the key advantages of using GIS in land research is the ability to integrate a variety of data. GIS allows land parcel data, geodata, cadastral information, soil composition information, climatic data, and many other parameters to be combined into a single geospatial environment. This provides researchers with a wide range of information to analyze land resources in greater depth.

Sazonova et al. [31] determined that technologies for digital modelling of spatial information about the territory represent an important tool for the analysis and planning of land resource use. Digital models can be used to create virtual representations of geographical objects, landscapes, and the infrastructure of a territory. These models can include information on elevation, depth, population density, climatic conditions, and many other parameters. Analyzing the results obtained, as well as the findings, one of the key benefits of digital modelling is the ability to analyze different scenarios for the development of the territory. Planners and researchers can create and modify virtual models to assess the environmental and social impacts of different decisions [32]. This allows for more informed decision-making in the fields of urban planning, land management, and ecology. Thus, digital modelling of spatial information about the territory plays an important role in modern spatial resource management and planning.

Kansanga et al. [33] identified that collaborative farmer learning and the adoption of sustainable land management practices have the potential to significantly improve agriculture and rural development in general. It is an approach that promotes the sharing of knowledge and experience among farmers and also involves the adoption of modern practices and techniques aimed at better utilizing land resources. It can be agreed that shared learning and adoption of sustainable land management practices contribute to improved agricultural productivity and sustainability, which is important for both farmers and society as a whole.

van de Ven et al. [34] demonstrated that land use and land requirements have a significant impact on solar energy emissions. Switching to solar energy as a source of electricity is becoming increasingly popular, and this could potentially lead to a change in the way land is utilized. The solar panels required to collect solar energy require a significant amount of space to accommodate. This means that large tracts of land may be required to establish solar farms and provide sufficient power. Despite the findings, land requirements may change, and this may affect land use. Farmers or landowners may decide to dedicate a portion of their land to installing solar panels, which will contribute to the production of clean energy. However, this may also entail changes in land use, requiring a more flexible and sustainable approach to land planning and management. Thus, the potential land requirements associated with solar energy development can bring significant changes to the landscape and land infrastructure, requiring balanced and environmentally sustainable solutions [35].

As noted by Alam et al. [36], a blockchain-based land rights management system is an innovative and promising approach to recording and protecting property rights and land resources. Blockchain is a distributed and trusted registry that enables the establishment and confirmation of land rights, as well as the recording of transactions and events related to them. One of the key advantages of such a system is transparency. All data is stored in the blockchain and can be accessed by all participants, which eliminates the possibility of fraud and disputes over land rights. This research confirms the results of the current study. Blockchain also helps improve the efficiency of land administration. It can automate the processes of verification and registration of property rights, reducing bureaucratic burdens and time delays. In addition, a blockchain-based land rights management system can be particularly useful in developing countries, where double registration and falsification of title documents are common problems. It provides an opportunity to create a more transparent and reliable land registration system, which can help boost economies and reduce land conflicts.

The development of new technologies and methods in land management can contribute to a more detailed and accurate understanding of land resources. This is particularly important in the face of increasing urbanization and climate change. Modern remote sensing techniques, such as the use of drones and satellites, allow for more detailed site surveys and monitoring of changes on land parcels. Tools and techniques, such as GIS, AI, and remote sensing, can make the land surveying process more accurate, faster, and more affordable. However, there are also challenges when introducing new technologies into land management. The introduction of new technologies requires attention to staff training. Hence, it is important to ensure that personnel are available and trained to work with these technologies. It is also necessary to consider issues of data privacy and security when using GIS.

5. CONCLUSIONS

The development of scientific foundations for the application of modern efficient technologies in land surveying is critical for improving land management and rational use of the territory. Modern technologies such as geographic information systems, blockchain, and AI are transforming the approach to land management and land records. An important outcome of research in this area is to ensure the accuracy and reliability of land data. GIS enables the creation of highly accurate maps and digital terrain models, which significantly improves the quality of land registries and simplifies spatial planning. Blockchain creates a transparent and reliable system for recording land ownership, which prevents fraud and disputes. The use of AI to analyze cadastral value assessment data reduces errors and increases the efficiency of the process.

Blockchain technology creates a system of land title records characterized by transparency and reliability. This system significantly reduces the risk of fraud and disputes by preventing unscrupulous transactions and ensuring trust in ownership data. The introduction of AI to analyze cadastral value assessment data is important. This technology can reduce the probability of errors and increase the efficiency of the land valuation process. The automation of this task makes it possible to determine the market value of land plots more accurately and quickly. These new technologies contribute to saving time and resources, as well as improving the quality of land work. They also play an important role in sustainable land management and in maintaining environmental sustainability. Overall, the development of a scientific basis for the application of modern technologies in land surveying helps to ensure more efficient and sustainable land management, which is a key element of modern, sustainable urban and rural environments.

There are still certain limitations that should be acknowledged. Firstly, the research’s primary focus is the Almaty region’s Talgar district, which may restrict the findings’ applicability to other areas with distinct topographies, environments, and socioeconomic situations. Furthermore, the study skips over the unique technical difficulties and data security issues that come with integrating blockchain and AI into land management systems. These elements may make it more difficult for the suggested solutions to scale and be widely used. Furthermore, a detailed examination of the economic viability and cost-benefit analysis of implementing these technologies is lacking, which is essential for stakeholders and policymakers to make well-informed decisions. Future studies ought to work towards carrying out more extensive pilot projects in various areas to verify the suitability of these technologies. Comprehensive evaluations of cybersecurity threats, data governance structures, and economic viability are also necessary.

To address potential regulatory impediments and make sure the suggested solutions are in line with regional laws, cultural norms, and society’s values, collaboration with legal experts, lawmakers, and community stakeholders is advised. In addition, it is advisable to conduct cost-benefit analyses and economic feasibility studies in order to assess the long-term financial sustainability and return on investment of implementing these cutting-edge technologies, especially in environments with limited resources. Practically speaking, the results highlight the necessity of capacity-building and training initiatives to provide land surveyors, cadastral authorities, and other pertinent staff with the know-how required to operate and maintain these systems. Collaborations between educational establishments and technology suppliers could enable the exchange of knowledge and the creation of customized learning materials.

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