THE SIGNIFICANCE OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES IN CARTOGRAPHIC AND CADASTRAL ACTIVITIES AND PROSPECTS FOR THEIR ADVANCEMENT

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ABSTRACT

This article analyzes the implementation of artificial intelligence (AI) technologies in cartography and cadastral activities, examining their practical significance and future prospects. The study investigates the application of machine learning, deep learning, computer vision, and generative AI technologies in geospatial domains, drawing on international scientific literature and Uzbekistan's national experience. Research findings demonstrate that AI technologies are creating significant opportunities in automated land boundary detection, digitization of cadastral data, land use mapping, and modernization of land management systems. At the same time, challenges related to data quality, accuracy, legal regulation, and a shortage of qualified personnel were identified. The article analyzes state policy in Uzbekistan and international experience, outlining future development prospects.

Keywords: artificial intelligence, cartography, cadastre, GeoAI, machine learning, deep learning, geospatial data, land use mapping, UAV, remote sensing, convolutional neural network, boundary detection, land administration.

1. INTRODUCTION

The twenty-first century represents an era of digital technological revolution, a process that encompasses all fields of science and practice. Cartography and cadastral activities have not remained untouched by these transformations: traditional manual methods are increasingly being replaced by modern digital solutions, in particular, artificial intelligence technologies.

Problem Statement: Land resources constitute one of the most vital assets of any state. The poor quality and outdatedness of cadastral and cartographic data, the predominance of paper-based documentation, and the slowness of traditional methods represent the core challenges that must be addressed in today's land management systems. The fact that more than 70 percent of the world's population lack formally registered land rights [4] underscores the global scale of this problem.

Research Objective: To analyze the principal directions and significance of AI technology use in cartography and cadastral activities, to identify existing limitations, and to define future development prospects for Uzbekistan.

Research Tasks:

- To examine the primary application domains of AI technologies in cartography and cadastre;
- To analyze the current situation and state policy in Uzbekistan;
- To identify problems and limitations in the implementation of these technologies;
- To develop recommendations for future directions of development.

Limitations: This article draws primarily on international scientific literature published between 2022 and 2026, as well as official documents of the Republic of Uzbekistan. Due to limited empirical data, some conclusions were formulated on the basis of comparative analysis.

Article Structure: The article comprises an abstract, introduction, literature review, methodology, main findings (application directions in cartography and cadastre), Uzbekistan's experience, problems and limitations, improvement prospects, recommendations, and conclusion.

2. LITERATURE REVIEW

International scientific literature examining the application of artificial intelligence in cartography and cadastre has grown sharply in recent years. This section reviews the most significant studies relevant to the topic.

2.1. GeoAI and Artificial Intelligence in Cartography

Zhang et al. (2024), in their published article on reviewing AI methodology and practice for land use/land cover mapping in the era of remote sensing big data, analyze semantic segmentation models for land use mapping and demonstrate the effectiveness of neural networks [1].

Li et al. (2025), in their article "Artificial Intelligence in Earth Science: A GeoAI Perspective," present the Prithvi-EO geospatial AI foundation model. This model demonstrated high performance in disaster mapping, multi-temporal land use classification, and above-ground biomass estimation [2].

Petitpierre et al. (2024) demonstrated in their research that AI technologies differ fundamentally from traditional cartographic technologies — enabling the creation of maps without explicitly programmed rules and, in some instances, surpassing human intelligence [7].

2.2. Artificial Intelligence and Cadastre

Research presented by Hosseini, Atazadeh, and Rajabifard (2025) at FIG Working Week emphasizes that artificial intelligence is recognized as one of the strategic parameters for modernizing cadastral systems. Studies on transitioning from 2D machine-unreadable formats to fully digital 3D models are analyzed [3].

Marzougui et al. (2025) present a deep learning-based spatial pattern modeling technique. Using the Inception-V3 model, high accuracy scores were achieved in classifying 10 types of land cover, with an accuracy of 0.9943 and validation accuracy of 0.9850 [4].

Cetl et al. (2022) investigated the possibility of updating cadastral boundaries using deep learning in image-based mapping. In tests conducted in rural areas of Slovenia, a precision score of 0.71 was achieved based on a CNN architecture [8].

3. RESEARCH METHODOLOGY

This research is based on comparative analysis and systematic literature review methods. The study analyzed 15 primary sources published between 2022 and 2026 in internationally ranked scientific journals (Scopus, Web of Science) and at international conferences (FIG Working Week, CVPR).

The GeoAI concept, the IMRAD article structure, and the Land Administration Domain Model (LADM) served as the theoretical basis. Data on Uzbekistan were drawn from official reports of the Cadastre Agency and Presidential decrees.

The analysis was carried out in three stages: (1) collection and selection of literature; (2) thematic classification by principal directions; (3) assessment of applicability to Uzbekistan's conditions.

4. RESULTS

4.1. Principal Application Directions of Artificial Intelligence in Cartography

Research findings indicate that artificial intelligence is applied in cartography across three principal directions.

4.1.1. Automated Analysis of Remote Sensing Data

Modern satellites (Sentinel-2, Landsat) transmit vast volumes of multispectral data. AI technologies are fundamentally transforming this process: in the field of land use/land cover (LULC) classification, accuracy has been significantly improved through the use of convolutional neural networks (CNN) and Random Forest (RF) algorithms. In the case of Ravenna, Italy, it has been demonstrated that LULC classification accuracy can be further improved by tuning the hyperparameters of RF and SVM classifiers [15].

In the field of generative AI, the Sat2Cap model developed by researchers at the University of Washington enables the synthesis of satellite imagery based on text prompts [9]. GeoAI models are also widely used in monitoring natural disasters, deforestation, and urban growth.

4.1.2. Automated Map Design and Cartographic Creativity

Generative AI (GenAI), including large language models (LLM) and diffusion-based image generation models, is opening new possibilities in cartography. Multimodal LLM-based systems such as CartoAgent and MapGPT are being used to automate map style transfer and evaluation [6].

4.1.3. High-Precision Mapping with UAVs and Drones

Unmanned aerial vehicle (UAV/drone) technologies, used in conjunction with AI, have enabled automated extraction of cadastral boundaries from orthophotos, generation of point clouds and digital surface models (DSM), and accurate topographic mapping even in small towns.

4.2. The Significance of Artificial Intelligence in Cadastral Activities

4.2.1. Automated Detection of Cadastral Boundaries

Identifying the boundaries of land parcels is traditionally a time-consuming and labor-intensive process. In a study conducted by Slovenian researchers, a neural network based on a modified CNN architecture successfully detected boundaries in the rural areas of Ponova Vas and Odranci with precision scores of 0.71 and 0.61 respectively [8]. These neural networks also assist in extracting digital cadastral data from archived, scanned documents.

4.2.2. Digitization of Paper-Based Data

Computer vision technologies vectorize old paper cadastral plans, while Natural Language Processing (NLP) technologies enable the extraction of land-related information (owners, boundaries, legal restrictions) from document texts. Victoria (Australia) state's Digital Cadastre Modernization program is cited as a successful example of this approach [3].

4.2.3. Optimization of Land Redistribution

Genetic algorithms make optimal decisions taking into account the shape, size, and value of land parcels. The Artificial Bee Colony (ABC) algorithm analyzes subdivision variants and selects the optimal solution. LSTM neural networks assist in modeling the decision-making process based on time-series data [5].

4.2.4. 3D Cadastre and Intelligent Query Systems

Modern cities feature multi-story buildings and complex ownership structures. Classical 2D cadastre cannot reflect this complexity. AI facilitates the integration of the Land Administration Domain Model (LADM) with Building Information Modeling (BIM), with 3D

property boundaries recorded in digital format. The system presented by Hosseini et al. (2025) enables automated querying and information retrieval from cadastral plans [3].

5. DISCUSSION

5.1. Uzbekistan's Experience and State Policy

In Uzbekistan, significant steps and initiatives are being implemented to introduce AI technologies in the field of cartography and cadastre. In 2024, the Cadastre Agency reviewed 187 technical projects and 148 technical reports related to geodesy and cartography. By December 1, 2024, cadastral maps of more than 485 populated areas had been corrected, representing approximately 47 percent of the total number [14].

By Decree No. PQ-358 of the President of the Republic of Uzbekistan, dated October 14, 2024, the "Strategy for the Development of Artificial Intelligence Technologies until 2030" was approved [12]. The strategy's principal directions include: establishing a big data platform by September 1, 2025; allocating interest-free credit of 50 million US dollars; and creating the "Center for the Development of Artificial Intelligence and the Digital Economy."

5.2. Problems and Limitations

The following principal problems were identified in the course of the research:

- **Data Quality and Sufficiency:** AI models require high-quality and complete training data. In Uzbekistan, a significant portion of cadastral data is still stored in paper format or has not been updated for many years.
- **Accuracy and Reliability:** Accuracy is critically important in the cadastral domain. When current CNN models yield F1 scores of 0.54–0.60, this is not considered sufficient for land boundary detection [8].
- **Legal Regulation:** The legal force of decisions made on the basis of AI, and the "black box" problem, remain serious challenges in the cadastral field.
- **Shortage of Qualified Personnel:** Specialists with comprehensive knowledge in geoinformatics, machine learning, and land law remain very scarce.
- **Infrastructure and Financial Resources:** Establishing high-performance computing infrastructure (GPU clusters, cloud computing) and large-scale storage systems requires substantial financial investment.

5.3. Prospects for Improvement

Based on the analysis conducted, the following principal development directions were identified:

- **Geospatial Foundation Models:** Models such as Prithvi-EO hold a significant advantage over traditional task-specific models through their ability to adapt to diverse geospatial tasks [2].
- **3D and 4D Cadastral Systems:** Future cadastral systems will record not only surface objects but also subsurface and airspace objects in 3D format. 4D cadastre models the historical condition of land parcels along the time axis.
- **Blockchain and AI Integration:** This enables the immutable storage of land rights registries and the automation of land transactions through smart contracts.
- **Crowdsourcing-Based Data Collection:** When data collected via smartphones is combined with AI models, it enables real-time updating of cadastral data.

- **International Cooperation:** Standardization of AI technologies based on FIG and ISO/TC 211 geoinformatics standards is intensifying. Uzbekistan must engage more actively in these processes [3].

6. RECOMMENDATIONS

Short-Term Recommendations (1–2 years):

1. Develop a national program for the digitization and standardization of existing cadastral data;

2. Introduce specialized training courses and preparation programs in GeoAI;

3. Pilot cadastral update systems based on UAV and AI in selected regions;

4. Establish cooperation mechanisms between the Cadastre Agency and IT organizations.

Medium-Term Recommendations (3–5 years):

5. Create a national geospatial data platform for Uzbekistan;

6. Develop the regulatory and legal framework for transitioning to a 3D cadastral system;

7. Update large-scale land use maps through integration of satellite and UAV data;

8. Join international GeoAI research collaborations.

Long-Term Prospects (5–10 years):

9. Introduce a fully automated 4D cadastral system;

10. Create a transparent land registry based on blockchain-AI integration;

11. Establish a real-time cadastral update system based on citizen science.

7. CONCLUSION

The application of artificial intelligence technologies in cartographic and cadastral activities has today transitioned from scientific hypothesis to practical necessity. The research conducted has led to the following principal conclusions:

- GeoAI technologies are bringing revolutionary changes to automated land boundary detection, cadastral data digitization, and land use mapping.
- Through its "Strategy for the Development of Artificial Intelligence Technologies until 2030," Uzbekistan is taking important steps in line with this global trend.
- To achieve successful results, it is necessary to build a high-quality data infrastructure, train qualified personnel, establish an appropriate regulatory and legal environment, and strengthen international cooperation.
- The future of cartographic and cadastral activities appears as a synthesis of traditional geodetic knowledge and artificial intelligence — a synthesis that serves the equitable and transparent management of land resources, economic development, and environmental sustainability.

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