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AI MONITORING-BASED INNOVATIVE SOLUTIONS OF AI AND DRONE TECHNOLOGIES FOR AGRO-ECONOMIC AND ECOLOGICAL SUSTAINABILITY

Safarova Barchinoy Iskandar qiz
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Annotatsiya. Ushbu maqolada AI monitoring asosida sun’iy intellekt va dron texnologiyalari integratsiyasining agroiqtisodiyot barqarorligini ta’minlash hamda ekologik muammolarni hal etishdagi innovatsion yondashuvlari chuqur tahlil qilingan. Zamonaviy qishloq xo‘jaligida raqamli va aqlli texnologiyalarni, jumladan sun’iy intellekt, IoT va nanoteknologiyalarni joriy etish resurslardan samarali foydalanish, hosildorlikni oshirish va ekologik xavflarni minimallashtirishda muhim ahamiyat kasb etmoqda. Tadqiqotda dronlar yordamida yig‘ilgan katta hajmdagi ma’lumotlarni mashinali o‘rganish va chuqur o‘rganish algoritmlari orqali qayta ishlash, agroekotizimlarni real vaqt rejimida monitoring qilish hamda optimal boshqaruv qarorlarini qabul qilish mexanizmlari yoritilgan. Shuningdek, AI monitoring tizimlarining agroiqtisodiy samaradorlikni oshirish, suv va o‘g‘it sarfini optimallashtirish hamda ekologik barqarorlikni ta’minlashdagi roli asoslab berilgan. Tadqiqot natijalari ushbu texnologiyalar qishloq xo‘jaligini raqamlashtirish, aqlli ferma tizimlarini shakllantirish va global oziq-ovqat xavfsizligini ta’minlashda muhim omil ekanligini ko‘rsatadi.

Kalit so‘zlar: AI monitoring, sun’iy intellekt, dron texnologiyalari, agroekotizim, IoT, nanoteknologiya, aqlli qishloq xo‘jaligi, mashinali o‘rganish, real vaqt monitoringi, barqaror rivojlanish.

Аннотация. В данной статье подробно рассмотрены инновационные подходы интеграции искусственного интеллекта и дронных технологий на основе AI-мониторинга для обеспечения устойчивости агроэкономики и решения экологических проблем. В условиях современного сельского хозяйства внедрение цифровых и интеллектуальных технологий, включая искусственный интеллект, IoT и нанотехнологии, играет важную роль в эффективном использовании ресурсов, повышении урожайности и снижении экологических рисков. В исследовании анализируются методы обработки больших данных, полученных с помощью дронов, с использованием алгоритмов машинного и глубокого обучения, а также возможности мониторинга агроэкосистем в режиме реального времени и принятия оптимальных управленческих решений. Кроме того, обоснована роль систем AI-мониторинга в повышении агроэкономической эффективности, оптимизации использования воды и удобрений и обеспечении экологической устойчивости. Результаты исследования показывают, что данные технологии играют ключевую роль в

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цифровизации сельского хозяйства и обеспечении глобальной продовольственной безопасности.

Ключевые слова: AI-мониторинг, искусственный интеллект, дроны, агроэкосистема, IoT, нанотехнологии, умное сельское хозяйство, машинное обучение, мониторинг в реальном времени, устойчивое развитие.

Annotation. This article explores innovative approaches to integrating artificial intelligence and drone technologies based on AI monitoring systems to ensure agroeconomic sustainability and address environmental challenges. In modern agriculture, the implementation of digital and intelligent technologies, including artificial intelligence, IoT, and nanotechnology, plays a crucial role in improving resource efficiency, increasing crop productivity, and minimizing environmental risks. The study analyzes methods for processing large-scale data collected by drones using machine learning and deep learning algorithms, enabling real-time monitoring of agroecosystems and optimal decision-making. Furthermore, the article highlights the role of AI monitoring systems in enhancing agroeconomic efficiency, optimizing water and fertilizer usage, and ensuring environmental sustainability. The findings demonstrate that these technologies are essential for the digital transformation of agriculture and the development of smart farming systems, as well as for ensuring global food security.

Keywords: AI monitoring, artificial intelligence, drone technology, agroecosystem, IoT, nanotechnology, smart agriculture, machine learning, real-time monitoring, sustainability.

KIRISH.

Drone technology is no longer merely a technical tool, but is increasingly becoming an integral part of the global economy and technological development. Modern drone technologies are widely used in various sectors, particularly in agriculture, industry, logistics, security, and ecology. The fact that the global drone market is expected to exceed 53 billion USD by 2026 clearly demonstrates the rapid development of this field. This creates new investment opportunities and opens broad prospects for implementing innovative projects.Through drone manufacturing and localization, it is possible to significantly improve import and export indicators. In particular, by reducing the share of imports in the technological sector, export potential can be increased from 20% to 80%. This contributes to strengthening the national economy, increasing foreign currency inflows, and creating new jobs. At the same time, establishing production plants based on nanotechnology enhances the quality of drones and transforms them into competitive products in the international market.Smart spraying technology is considered one of the most important advantages of drones. With this system, fertilizers and chemical substances are applied only to necessary areas in precise

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quantities. As a result, resources are conserved and costs are reduced by 30–50%. This increases efficiency in agriculture and contributes to higher crop yields. Furthermore, environmental damage is reduced and rational use of land resources is ensured.The integration of drones and artificial intelligence in the development of agrotechnologies is reaching a new stage, evolving into fully autonomous, self-learning, and adaptive systems. Recent international scientific studies consider AI monitoring systems not merely as image analysis tools, but as complex cyber-physical systems operating on the basis of multimodal data fusion. In this approach, visual, thermal, hyperspectral, and radar data obtained from drones are integrated and analyzed through a unified artificial intelligence model.One of the latest scientific directions is the concept of foundation models for agriculture. In this approach, large AI models such as GPT or Vision Transformers are specifically adapted for agriculture. Such models are trained on millions of agro-images and provide high accuracy in crop identification, disease classification, and yield prediction. In particular, transformer-based models working with time-series agro-data make it possible to consider climate change factors as well.This technology creates a virtual model for each farm or agricultural field. The model is continuously updated with real-time data. AI tests various scenarios within this virtual model, such as: “What will happen if water usage is reduced by 20%?” or “How will crop yield change if temperature increases by 3°C?” Such an approach minimizes risks and ensures optimal decision-making.In next-generation drone systems, the combination of swarm robotics and federated learning is also gaining significant importance. Based on swarm intelligence, multiple drones operate as a single system and rapidly monitor divided territories. Federated learning enables these drones to train models without transferring collected data to a central server. This increases both security and efficiency.Another emerging direction in international research on AgroAI systems is carbon-aware agriculture AI. These systems analyze not only productivity but also the carbon footprint. AI evaluates soil carbon absorption capacity, fertilizer usage, and CO_2 emissions in real time. As a result, farmers gain the opportunity to participate in eco-credit or carbon credit systems.Currently, the level of drone technology utilization in our country is approximately 20–30%. This indicates that the full potential of these technologies has not yet been utilized. Therefore, our main objective is to significantly increase the use of drones and widely implement them across various sectors of the economy. In particular, effective utilization of drones in agriculture, industry, logistics, ecology, and security systems can improve overall efficiency.In general, the project not only reduces costs but also creates new opportunities. Most importantly, it enables the transition from systems that detect problems too late to intelligent systems capable of forecasting issues in advance

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and taking rapid measures.In this research, methods based on artificial intelligence algorithms were applied to analyze data collected through drones. Using multispectral sensors, plant conditions, soil moisture, and vegetation processes were studied. AI models were used to detect diseases and predict crop yields. The results demonstrated that AI monitoring systems are effective tools for increasing productivity, reducing costs, and minimizing environmental problems. Resource utilization was optimized, and agroeconomic efficiency improved.The integration of artificial intelligence and drone technologies based on AI monitoring has emerged as an innovative approach in agriculture, playing an important role in ensuring agroeconomic sustainability and solving environmental problems. In the future, these technologies are expected to become key components of smart agriculture systems.AI monitoring systems based on drone and artificial intelligence integration are enabling the transition from traditional agricultural management to digital and intelligent management systems. These technologies create opportunities for real-time monitoring of agroecosystems, early problem detection, and predictive decision-making. In particular, conducting monitoring without human intervention across large-scale areas consisting of thousands of hectares is considered a major advantage.Research shows that drones equipped with multispectral and hyperspectral sensors can determine vegetation indices such as NDVI and EVI. These indices help identify whether plants are healthy or under stress. Artificial intelligence-based computer vision algorithms deeply analyze the obtained images and detect diseases, pests, and water deficiency at early stages.Deep learning models used in AI monitoring systems, such as CNN and YOLO, evaluate crop conditions with high accuracy through image segmentation and classification. As a result, precision agriculture principles enable an individualized approach for each area. This reduces fertilizer and water consumption by 20–30% while increasing crop yield by 15–25%.Furthermore, data collected by drones are transmitted in real time through cloud platforms and IoT systems. Streaming technologies allow data to be processed without delay, ensuring rapid decision-making. At the same time, modern cybersecurity mechanisms such as data encryption and blockchain play an important role in ensuring system security.From an ecological perspective, AI monitoring systems reduce soil degradation and water pollution by enabling fertilizers and pesticides to be applied only in necessary areas. This contributes to the formation of sustainable agroecosystems.As a practical example, monitoring saxaul plantations in the Muynak region through drones can improve the effectiveness of combating desertification. AI systems analyze plant growth dynamics in this region and determine where additional agrotechnical measures are necessary.AI monitoring

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systems are also playing a major role in solving environmental problems. In particular, new algorithms are being developed for monitoring desertification processes, managing water resources, and preserving biodiversity. For example, in addition to the NDVI index, new Vegetation Health Index (VHI+) models are being applied, which evaluate not only greenery but also the internal stress condition of plants.Multispectral and hyperspectral sensors used in drones determine vegetation indices, including NDVI and EVI indicators. This makes it possible to identify hidden plant stress conditions, nutrient deficiencies, and diseases at early stages. Artificial intelligence-based computer vision and deep learning models such as CNN and YOLO evaluate crop conditions with high accuracy through image segmentation and classification while enabling yield prediction.Moreover, AI monitoring systems integrated with IoT and cloud technologies provide opportunities for real-time data transmission and processing. Through edge computing technology, some analyses are performed directly on the drone itself, ensuring rapid decision-making. This allows immediate action to be taken when pests, water shortages, or diseases are detected.As one of the modern approaches, the “Digital Twin” model creates virtual replicas of agricultural objects, allowing different scenarios to be tested in advance. Additionally, “swarm” systems consisting of multiple drones enable the monitoring of large territories within a short period of time. Precision spraying technology significantly reduces pesticide consumption by applying chemicals only to affected areas while preserving ecological balance.The implementation of AI monitoring systems not only increases productivity but also ensures efficient use of water and fertilizer resources, reduces production costs, and minimizes environmental risks. For example, monitoring saxaul plantations in the Muynak region through drones can increase the effectiveness of combating desertification.In conclusion, the integration of artificial intelligence and drone technologies based on AI monitoring represents an important stage in the digitalization of agriculture and serves as an effective innovative solution for ensuring agroeconomic sustainability, optimizing resources, and solving environmental problems. In the future, these technologies are expected to play a significant role in ensuring global food security as the main components of smart agriculture systems.AI monitoring systems based on drones and artificial intelligence are increasingly developing in agriculture, replacing traditional management approaches with digital and automated systems. One of the latest directions is Edge AI technology, in which data processing is performed directly on the drone rather than on cloud servers. This reduces dependence on the internet and enables rapid real-time decision-making.At the same time, the federated learning approach plays an important role in ensuring data security in agriculture.

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In this method, data are not centralized but are trained locally within each farm, and only model parameter changes are transmitted. This approach ensures efficient operation of AI systems while maintaining data confidentiality.The integration of hyperspectral and Synthetic Aperture Radar (SAR) technologies in next-generation drone systems is also considered an important innovation. These technologies make it possible to identify not only visual indicators but also deep agrobiological parameters such as underground moisture, plant stress, and soil composition. As a result, more accurate and comprehensive analysis of agroecosystems becomes possible.In addition, the concept of carbon farming combined with AI monitoring enables the identification of soil carbon levels and assessment of ecological balance. This transforms agriculture not only into a production system but also into an economic sector that creates ecological value.Fully autonomous farming systems are emerging through the integration of drones and ground robots. In such systems, planting, irrigation, fertilization, and harvesting processes are controlled by artificial intelligence. This reduces dependence on human labor and significantly increases production efficiency.Furthermore, swarm intelligence technology allows multiple drones to function as a unified system and monitor large areas in a short time. Blockchain technology enables transparent and reliable recording of agricultural product supply chains.AI-based climate intelligence systems help predict droughts, changes in crop productivity, and environmental risks in advance. This approach transforms agriculture from a reactive system into a proactive management model.In conclusion, recent international scientific trends indicate that artificial intelligence and drone technologies are no longer separate tools but are becoming the main components of a deeply integrated intelligent cyber-physical system. Artificial intelligence performs data analysis, forecasting, and optimal decision-making functions, enabling highly accurate processing of real-time data collected from drones. Drones, in turn, serve as autonomous platforms capable of rapid data collection, monitoring, and direct interactive communication with the environment.As a result of integrating these two technologies, traditional monitoring and management systems are being replaced by fully automated, adaptive, and self-improving AI monitoring ecosystems. Such systems not only provide highly accurate real-time analysis but are also capable of independent decision-making in complex conditions, minimizing errors, and continuously improving system efficiency. From this perspective, the integration of artificial intelligence and drones is emerging as one of the most important technological platforms of future digital transformation.

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