Shabatura Tetiana
Doctor of Economic Sciences, Chief Researcher,
Institute of Climate-Oriented Agriculture
of the National Academy of Sciences
Yakovenko Alla
PhD in Economics, Associate Professor,
Senior Researcher of the Department of Geoinformation Technologies
and Economic Research,
Institute of Climate-Oriented Agriculture
of the National Academy of Sciences
Stepanova Margarita
PhD in Economics, Head of the Department of Geoinformation
Technologies and Economic Research,
Institute of Climate-Oriented Agriculture
of the National Academy of Sciences

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THE USE OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES FOR PREDICTING CLIMATE THREATS AND THEIR IMPACT ON AGROECOSYSTEMS

The integration of artificial intelligence (AI) into climate threat prediction has become indispensable due to the escalating impacts of climate change on agriculture. Climate adversities, such as droughts, floods, and extreme temperature variations, significantly diminish crop yields, posing a severe threat to global food security. AI technologies facilitate the real-time analysis of extensive datasets, encompassing weather patterns and soil conditions, thereby enabling precise climate risk forecasts and providing critical insights for optimizing crop management.

This application is particularly pertinent to agroecosystems, where resilient farming practices are imperative to counter unpredictable environmental changes. For instance, in 2020, the United Nations estimated that climate change-related disruptions could reduce global agricultural productivity by up to 17% by 2050 [1]. However, AI-driven solutions have demonstrated the potential to mitigate these effects. According to a study by PwC [2], AI applications in agriculture could boost global GDP by up to $4.4 trillion by 2035, through enhanced crop management and productivity improvements.

In addition, countries with substantial agricultural sectors, such as Ukraine, are well-positioned to harness AI to bolster adaptation strategies and support sustainable agricultural practices. Ukraine, which is one of the world's largest grain exporters, has seen variable climatic conditions impact its agricultural

output. By leveraging AI, Ukraine can enhance its predictive capabilities and develop robust frameworks to ensure food supply stability, even under increasingly erratic climatic conditions. Thus, the use of AI in agriculture not only increases the efficiency of crop management but also contributes to broader socio-economic development by securing food supplies and fostering sustainable practices.

Having studied the scientific achievements of foreign scientists, we can summarize the main conclusions regarding the opportunities presented by the integration of artificial intelligence into agricultural ecosystems (Table 1).

Table 1

Opportunities for the integration of artificial intelligence into agricultural ecosystems

Opportunity	Description
Climate Threat Prediction	AI systems can process extensive climate datasets to identify trends and predict potential climate risks, enabling data-driven decision-making for farmers in crop planning and management. This predictive capacity helps reduce the impact of extreme weather on agricultural yields. For example, by anticipating droughts, AI systems can prompt the implementation of water-efficient irrigation methods, reducing water use and safeguarding crop resilience against water scarcity [3].
Precision Farming	Precision agriculture powered by AI harnesses advanced machine learning to process extensive data streams from sensors, drones, and satellite imagery, delivering rapid insights into soil health, crop status, and pest infestations. This approach enables precise application of resources such as fertilizers, pesticides, and water, maximizing efficiency and lowering ecological impact. Empirical evidence suggests that adopting precision agriculture can lead to yield increases of up to 30%, while simultaneously reducing input costs by 15-20%. This dual benefit, both economic and environmental, underscores the value of AI in fostering sustainable agricultural practices, enhancing productivity, and optimizing farm profitability [3; 4].
Automated Machinery	AI-driven tractors and harvesters improve efficiency and reduce labor costs by automating key tasks like planting and harvesting with high precision. The agricultural robotics market is projected to grow at a 22.8% CAGR, reaching USD 20.6 billion by 2025, driven by demand for scalable, efficient solutions to labor challenges [3; 4].
Enhancing Crop Management	AI can enhance crop management by using intelligent systems to monitor plant health and predict potential disease outbreaks. Machine learning algorithms can detect early indicators of disease, enabling timely interventions that minimize crop losses and boost yields. For instance, AI applications in plant pathology have been shown to lower disease-related crop losses by 20-40%, offering a significant improvement in both crop quality and productivity. By identifying threats early, these systems support more sustainable farming practices and reduce reliance on reactive measures [4].

Sustainable Practices	AI technologies play a pivotal role in advancing sustainable agriculture by enabling precise resource management and reducing waste, which is essential for optimizing agricultural productivity while conserving environmental resources. For example, the CropX system, developed by the agtech firm CropX, leverages real-time soil moisture and weather data to adjust irrigation levels based on specific crop needs. Studies indicate that this system reduces water use substantially, aligning with sustainability goals while enhancing crop yields. Similarly, Blue River Technology, a division of John Deere, has introduced See & Spray, an AI-powered system using computer vision to identify weeds and apply herbicides with precision. This technology minimizes chemical use by up to 90%, contributing to both cost efficiency and environmental protection by reducing pesticide exposure. In the field of livestock management, Cainthus, an agri-tech company, has developed an AI-driven system for continuous monitoring of cattle health and behavior. Using computer vision, it tracks individual animals to enable timely interventions, thereby improving welfare standards and production efficiency.
Socio-Economic Impact	The implementation of artificial intelligence in the agricultural sector brings substantial socio-economic benefits, especially for developing nations. By boosting agricultural productivity and enhancing resource efficiency, AI can play a crucial role in ensuring food security, reducing poverty, and fostering rural development. In countries such as Ukraine, with significant agricultural industries, AI technologies can strengthen the resilience of agroecosystems and promote sustainable economic growth [5].
Data-Driven Decision Making	Artificial Intelligence enables sophisticated data-driven decision-making processes by meticulously analyzing both historical and real-time datasets to yield actionable insights for agricultural practitioners. By integrating information from diverse sources, including meteorological predictions, soil sensor readings, and market dynamics, AI systems can provide recommendations for optimal planting and harvesting schedules, crop selection, and resource distribution. This approach not only augments farm productivity and profitability but also mitigates the risks associated with climate variability and market volatility, thereby fostering more resilient and efficient agricultural practices [6].
Predictive Maintenance of Equipment	Artificial Intelligence, incorporating innovative technologies such as Machine Learning (ML), the Internet of Things (IoT), and Predictive Analytics, can be strategically utilized to monitor and forecast the maintenance needs of agricultural equipment. By thoroughly examining sensor-generated data, AI systems, particularly those employing Machine Learning techniques, can detect early indicators of equipment degradation, anticipate potential failures, and schedule maintenance activities proactively. This approach to predictive maintenance not only minimizes equipment downtime but also extends the machinery's operational lifespan and reduces overall maintenance costs. Consequently, this enhances the efficiency and sustainability of agricultural operations. Through these advanced technological applications, the agricultural sector can foster more resilient and productive farming practices [7].

The integration of AI in predicting climate risks for agroecosystems offers substantial benefits but also raises key concerns, highlighted by prior research. One central issue is the potential overreliance on AI-based predictions, as noted in recent studies. Even minor inaccuracies in algorithmic models can mislead essential agricultural decisions, heightening risk exposure [8]. Additionally, effective AI systems depend on vast, high-quality datasets; however, data scarcity, especially in developing regions, reduces predictive accuracy. Consequently, only well-funded agricultural sectors may effectively utilize AI, potentially widening the digital gap between large and small farming operations.

Ethical and privacy issues further complicate data ownership concerns. Researchers have noted that farmers often lack control over the data collected from their fields, raising alarms about its potential misuse by third parties. Furthermore, the considerable energy demands necessary to process large AI datasets may conflict with sustainable development goals. Studies suggest that these environmental trade-offs challenge the purported benefits of AI in enhancing agricultural sustainability. Therefore, addressing these challenges is crucial for realizing AI's full potential in agriculture while mitigating its economic and environmental impacts.

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