ISSN 2957-1898 Print
ISSN 2957-2096 Online

ACADEMIA POLONICA

SCIENTIFIC JOURNAL OF POLONIA UNIVERSITY
PERIODYK NAUKOWY AKADEMII POLONIJNEJ

74 (2026) nr 1

CZESTOCHOWA 2026

Periodyk Naukowy Akademii Polonijnej, Częstochowa, 2026, 74 (2026) nr 1, s. 308.

PARTNERZY / PARTNERS

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ISSN 2957-1898 Print
ISSN 2957-2096 Online

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CONTENTS

LANGUAGE, CULTURE, COMMUNICATION

HEALTH, ENVIRONMENT, DEVELOPMENT

TECHNOLOGY, CREATIVITY, IMPLEMENTATION

DIGITALISATION OF TECHNOLOGIES AND TECHNOLOGICAL EQUIPMENT IN UKRAINIAN AGRICULTURE: OPPORTUNITIES AND PROSPECTS FOR DEVELOPMENT

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Summary

The article defines the current level of digitalisation in agriculture in Ukraine and in the world in the context of the global trend towards digital transformation of the agro-industrial complex. The article analyses the indicators of digitalisation of the agricultural sector by regions of the world, highlights the advantages and problems of digital technologies implementation, and identifies prospects for further development of the industry. Detailed information is provided on the need for and economic importance of digitalisation of the agro-industrial complex, in particular in the context of losses and structural transformations caused by a full-scale military invasion. The key technologies of digital transformation, such as artificial intelligence, the Internet of Things, big data, blockchain, robotics, drones and nanotechnology, are considered from the perspective of their practical application in agricultural production, food and processing industries. The author substantiates the impact of digitalisation on the transformation of management functions and decision-making algorithms in digital agricultural production. It is established that the use of digital technologies in the agro-industrial complex is a competitive advantage both in the development of production processes and in improving the efficiency of industry management. The author emphasises that in wartime, digitalisation is gaining strategic importance as a tool for restoring and adapting the industry. Thanks to digital transformation, the agricultural sector is becoming high-tech and competitive not only at the national but also at the international level.

Key words: agriculture, artificial intelligence, Internet of Things, blockchain, robotics, drones, nanotechnology, precision agriculture.

DOI https://doi.org/10.23856/7434

1. Introduction

The modern agro-industrial complex is on the verge of a technological revolution, which experts define as the "fourth industrial revolution" or "digital revolution in agriculture". This transformation is the latest stage in the evolution of the industry, which opens up fundamentally new opportunities to meet the growing food needs of the world's population in the face of limited natural resources. The relevance of the study is driven by the fact that digitalisation is

rapidly changing the fundamentals of the economy, labour and social relations in all sectors, including agricultural production and the food and processing industry.

The Food and Agriculture Organisation of the United Nations (FAO) predicts that the global digital agriculture market will grow by an average of 11.3% between 2022 and 2027, which demonstrates the global nature of the phenomenon under study. Despite the significant potential of Ukraine's agricultural sector, the level of its digitalisation remains insufficient compared to the world's leading countries, which underlines the scientific and practical significance of this study.

The purpose of the study is to comprehensively analyse the current state and prospects of digitalisation of technologies and technological equipment in Ukrainian agriculture, identify the benefits and challenges of this process, and justify the priority areas for the introduction of digital solutions in agricultural production. To achieve this goal, the following research objectives have been set: to characterise the essence of the digitalisation of the agricultural sector and key technological tools; to conduct a comparative analysis of the level of digitalisation of agriculture in different regions of the world; to study the impact of digital technologies on the transformation of production and management processes; to substantiate the prospects for digitalisation of the Ukrainian agro-industrial complex.

The methodological basis of the study is based on the methods of systematic analysis and synthesis, comparative and statistical analysis, generalisation of scientific sources and the regulatory framework in the field of digital technologies and agricultural production. The logic of the material presentation involves the transition from theoretical foundations and conceptual framework to the analysis of world experience, the state of digitalisation in Ukraine and the prospects for the development of the industry.

2. Conceptual framework of digital agricultural production

The digital economy is a system of economic activity based on digital technologies and associated with e-commerce, digital goods and services, and the distribution of products through digital channels. Digital agriculture is an industry that uses digital technologies and proprietary methods of automated production. These concepts are closely interrelated, as the development of the digital economy creates demand for technological solutions for the agricultural sector, and the agricultural sector is one of the key markets for digital economy products.

It is important to distinguish between the concepts of mechanisation, automation and digitalisation. Mechanisation is the re-equipment of industry to replace manual labour with machine labour. Automation is a method of performing production tasks using technology, which allows processes to be implemented faster and cheaper while reducing errors. Whereas automation improves existing production methods, digitalisation transforms the product itself, the relationships between customers and suppliers, and the positioning of the enterprise as a whole. The digitalisation of business processes can include automation as one of its tools, as well as artificial intelligence and other modern technological solutions, replacing humans in routine and dangerous functions.

The following areas are among the key digital technologies that determine the modern face of agricultural production.

Table 1

Key digital technologies in agricultural production

Technology	Definition	Application in agriculture	Expected effect
Artificial intelligence (AI)	Software systems that reproduce human cognitive abilities based on machine learning and analysis of large data sets	Agricultural operations management, plant disease detection, yield forecasting	Fast decision-making, reduction of crop losses
Internet of Things (IoT)	A network of physical objects with embedded devices to interact with each other and the external environment	"Smart sensors for monitoring soil, climate and plant health	Eliminating human involvement in routine operations, restructuring production processes
Big Data	An ever-increasing flow of diverse data from numerous sources that requires specialised processing methods	Analytics of production processes, forecasting, market and government support assessment	Access to previously inaccessible information, improving management efficiency
Blockchain	A distributed ledger that stores information about participants' transactions in the form of a "blockchain"	Traceability of food supply chains, protection of property rights, secure payments	Transparency and security of operations, increasing consumer confidence
Robotics	Applied science to create automated technical systems.	Sowing, harvesting, spraying, crop monitoring	Significant reduction in the need for manual labour, increased accuracy of operations
UAV / Drone	Remotely controlled or autonomous unmanned aerial vehicles of various designs and purposes	Aerial photography of fields, precise application of fertilisers and plant protection products, real-time monitoring of crops	Reducing the cost of agrochemicals, prompt identification of problem areas
Nano	Methods of research and synthesis of substances by manipulating individual atoms and molecules	New packaging materials, nanofertilisers, targeted delivery systems for agrochemicals	Increasing the efficiency of fertilisers, reducing the environmental impact

3. Global experience of digitalisation of the agricultural sector

An analysis of global experience in the digitalisation of agriculture shows significant regional differences in the pace and scale of technology adoption. The general trend is towards digital agri-food systems where resource management is optimised, personalised and based on real-time data *(Bezpartochnyi et al., 2022).*

In North America (USA and Canada), the use of satellite imagery for crop monitoring has become widespread. American and Canadian farmers use data from satellites, unmanned aerial vehicles, and analytical platforms to optimise crop conditions *(McFadden et al., 2023)*. The level of digital technology adoption in these countries is 30-50%, while the level of precision farming methods application reaches 60-80% *(CAPI, 2025).*

In Europe, about 70% of fertiliser applicators and sprayers, as well as a significant share of sowing equipment, are equipped with precision farming technologies *(Fountas et al., 2020),* with the highest adoption rates in Western Europe - the Netherlands, Germany, Switzerland and the UK *(Petrović et al., 2024)*.

In the Asia-Pacific region, Australia, New Zealand, and Japan have made significant progress. In particular, in China, the level of mechanisation (automation) of planting and harvesting in China has increased from about 30% in the early 2000s to about 70% today *(Yang et al., 2023: 17)*. In contrast, Southeast Asian countries have limited access to technology and infrastructure *(Kozono et al., 2025).*

In Latin America, primarily in Brazil and Argentina, the technological transformation of the agricultural sector has received active government support (Monsalve et al.) Precision farming, genetic improvement of crops, and robotics are being actively implemented here *(Segretin et al., 2025).*

In Africa, the level of agricultural digitalisation remains lower than in other regions, mainly due to financial constraints *(FAO and ITU, 2022).* At the same time, there is a growing interest in mobile technologies: digital mobile platforms are operating in Burkina Faso, Cameroon, Ethiopia, Ghana, Kenya, Nigeria, Kenya, Ethiopia, and Zambia, among other countries *(Gakuru, 2009).*

4. Digital transformation of the Ukrainian agro-industrial complex

Agribusiness is the economic engine of Ukraine: it not only contributes to the development of the national economy, but also traditionally forms the basis of the country's gross domestic product *(Stepenko, 2021).* However, the full-scale military invasion of the Russian Federation has caused unprecedented losses to the agricultural sector: the occupation of farmland, destruction of production infrastructure, destruction of machinery and processing facilities, disruption of supply chains, and rising operating costs have significantly reduced the industry's production potential. In such circumstances, the digitalisation of the agricultural sector is gaining strategic importance not only as a tool for increasing competitiveness in international markets, but also as a mechanism for restoring and adapting the industry to new realities.

Despite the objective difficulties of wartime, the level of digitalisation of the agricultural sector in Ukraine is still inferior to leading countries that fully exploit the benefits of digital technologies. It should also be borne in mind that the hostilities have exacerbated the existing territorial disparities: the level of development of digital technologies in the land use sector among different business entities differs depending on the region, the scale of the enterprise, and the proximity to the war zone.

In the context of post-war recovery, digitalisation is becoming a key factor in the sector's restructuring *(Stegney, 2022).* "Digital transformation can stimulate dynamic efficiency and support both gradual and radical disruptive innovations in the production and sale of goods, services, processes, strategies and organisation of all economic processes" *(Panchenko, 2023)*. Reducing production costs and improving the quality and competitiveness of products through the efficient use of limited resources in wartime is of particular relevance and defines the main goal of digitalisation of Ukraine's agricultural sector at the present stage *(Mandych et al., 2022).*

Digitalisation in agriculture involves the collection of large amounts of data from numerous sensors installed in fields and on farms, from agricultural machinery, meteorological stations, and satellites *(Huang et al., 2018).* The analytical processing of these data sets allows

to obtain previously unavailable information, increase the efficiency of agricultural production management, identify patterns that improve economic performance, and optimise communication with consumers and external partners *(Horváth et al., 2019).*

Digital technologies make it possible to perform many production tasks remotely, while significantly improving work in the field. The key benefits of implementing digital solutions in agricultural production include: increased speed of data collection and processing; improved accuracy of all technological processes; increased production efficiency and reduction of waste; reduced need for manual labour and reduced risks for agricultural machinery operators; simplified risk forecasting and optimised accountability; and support for sustainable development principles.

The implementation of a digital quality and traceability monitoring system for agricultural products involves all authorised bodies involved in the production process and provides quantitative and qualitative records along the entire chain - from field to consumer. Full monitoring within the traceability system paves the way for higher quality standards for agricultural products and directly affects both the range and geography of processed food supply. The introduction of such a system will also help attract investment in the sector and expand export potential.

The seasonality of agricultural production remains a constraint on the industry's development, but digitalisation can partially mitigate this factor through predictive modelling, automation of production processes and rapid response to changing conditions.

5. Transformation of management functions in digital agricultural production

In the context of digitalisation, organisational management functions are undergoing fundamental changes. Forecast scenarios for the development of production, implemented with the help of artificial intelligence, are beginning to play a key role. The function of monitoring production processes is also being transferred to automated control systems based on artificial intelligence (Fig. 1).

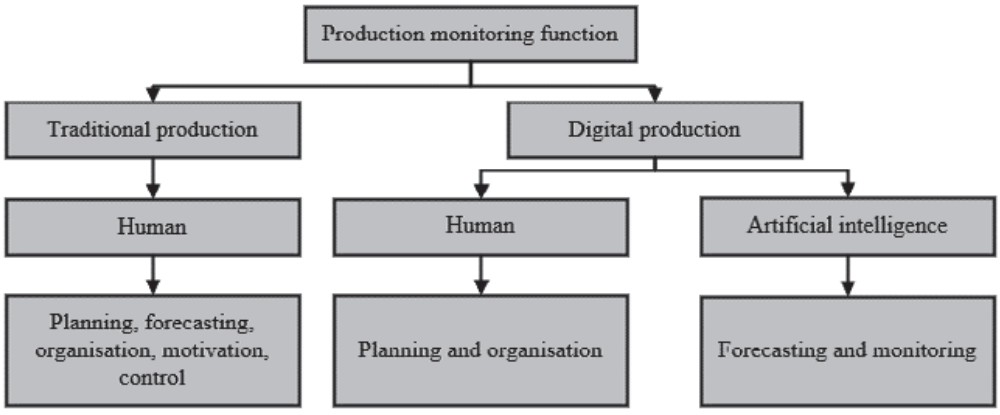

Fig. 1. Production monitoring function

Thanks to industrial robotics and digitalisation, the function of directly motivating employees in terms of routine tasks is losing its importance, as the automated control system is designed from the outset to achieve the best possible result. Measures aimed at automating the monitoring of agricultural products allow for the control of the entire life cycle of production and sales of agricultural products.

In the digital environment, the new management paradigm leads to a reduction and modification of the management decision-making algorithm. Whereas earlier decision-making in agricultural production was based mainly on the subjective experience of an agronomist or manager, now the precise use of huge amounts of data from sensors and analytical systems allows decisions to be made with mathematical precision. The information network is analysed and processed in real time, and the manager or specialist receives the results of the analysis, recommendations and possible options for further action.

The transformed algorithm for making management decisions at a business entity is shown in Figure 2.

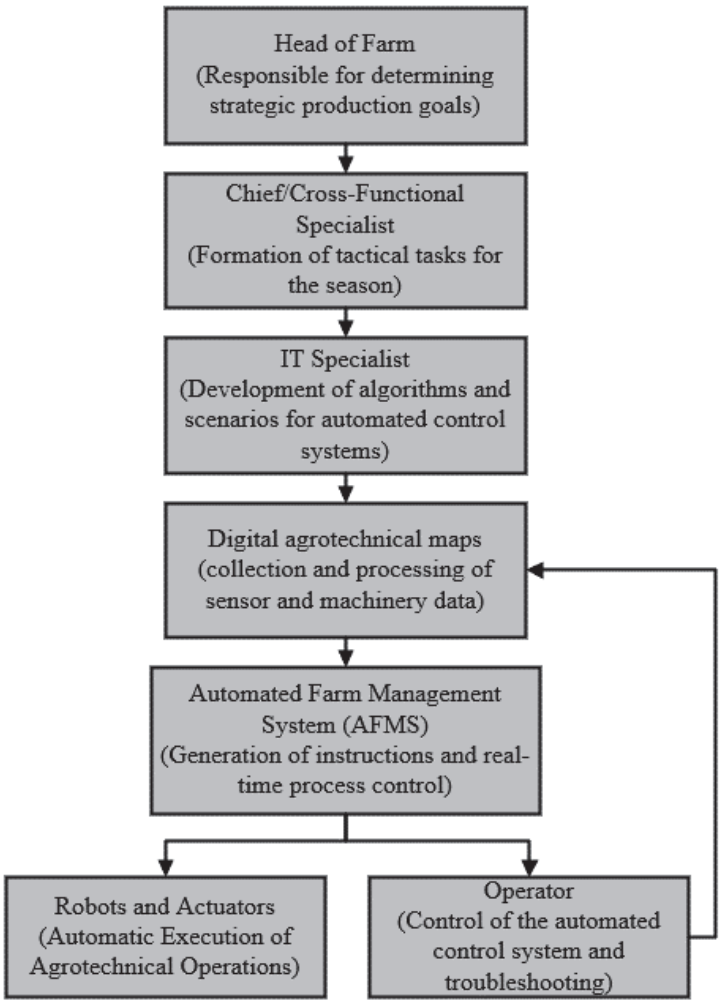

Fig. 2. Algorithm for making management decisions at a business entity

The head of the farm sets strategic goals. On their basis, the chief specialist or cross-functional specialist determines tactical tasks for the season, for the implementation of which the IT specialist develops algorithms or scenarios for the automated farm management system. As sensors, actuators and the control unit are connected to a single network, the system becomes "intelligent" and can automatically generate instructions for robots. IT specialists create digital agrotechnical maps for crops based on the collected data. In this case, the operator's function is not to manage the production process itself, but to monitor the operation of the automated system in order to quickly eliminate faults.

Of particular importance is the introduction of technologies that replace manual labour with machines and automated systems in production processes. Over time, in order to protect human health and minimise the human factor, the level of labour involvement in physically demanding and hazardous operations will decrease. At the same time, digitalisation does not displace people from agricultural production, but frees them from daily, monotonous and dangerous processes, redirecting their efforts to managerial, analytical and creative tasks. The effect of these processes is also to reduce emissions and optimise the use of material resources, which is in line with the goals of sustainable development.

6. Conclusions

Based on the results of this study, the following generalisable conclusions can be drawn.

First, digitalisation is the main direction of agricultural development in the 21st century. From harvesting to sowing, from mechanical tools to automated systems, revolutionary innovations are taking the agricultural sector to a whole new level. Digital technologies are transforming every segment of the agri-food supply chain, transforming traditional agriculture into a high-tech sector.

Secondly, robotic systems, sensors, field controllers and data processing systems form the basis of digital agricultural production. Monitoring and surveillance systems, neural networks and machine learning algorithms remotely control production processes, significantly reducing the need for manual labour and changing management approaches.

Third, the digitalisation of the agricultural sector is of strategic importance for Ukraine's economy. Thanks to the implementation of digitalisation programmes, the domestic agricultural sector has sufficient potential to rise to a new quality level and become a driver of the national economy. The main goals of this process are to increase yields and labour productivity, reduce production costs, ensure food security, stabilise climatic conditions for production and prevent soil degradation.

Fourth, digitalisation requires not only the introduction of new production technologies but also a complete overhaul of the management system. The managerial hierarchy is being inversed: an automated management system becomes the subject of tactical decision-making, and the main goal of management is transformed into preventing crises and ensuring the continuity of production processes.

Fifth, an important condition for the success of digital transformation is overcoming existing barriers: the high cost of technology implementation, the lack of qualified IT specialists in the agricultural sector, and the need to adapt the education and training system to the needs of digital agricultural production. In the context of the military invasion, these challenges take on an additional dimension: the destruction of production infrastructure and the outflow of skilled personnel due to mobilisation and forced migration significantly complicate the implementation of digitalisation programmes. At the same time, digital technologies can partially compensate for the shortage of human and material resources through remote control of production processes, precision agriculture in the de-occupied territories, and the attraction of international technical and financial assistance as part of agricultural sector recovery programmes.

Further research in this area could focus on developing methodological foundations for assessing the economic efficiency of digital technologies in Ukrainian agribusinesses, analysing the regulatory environment for the digitalisation of the agricultural sector, and studying the pedagogical aspects of training digital agricultural production specialists within the higher

education system. Particular attention should be given to studying the impact of digital technologies on agricultural processing and food production technologies, as this is a promising area for further research.

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