



DIGITAL TRANSFORMATION IN AGRICULTURAL ENTREPRENEURSHIP IN BULGARIA: A LITERATURE REVIEW AND DIRECTIONS FOR FUTURE RESEARCH

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ABSTRACT

PURPOSE: This article aims to systematically review and analyze scientific publications on the digitalization of the agricultural sector and entrepreneurial practices in Bulgaria, driven by the increasing importance of digital transformation for economic efficiency and competitiveness in agribusiness. **METHODS:** A systematic search, selection, and analysis of publications were conducted across international and national scientific databases, including Google Scholar, ResearchGate, ScienceDirect, Web of Science, and Scopus, considering articles in both Bulgarian and English. **RESULTS:** The review identifies and presents the main trends, opportunities, and challenges related to the implementation of digital technologies within Bulgarian agribusiness. **CONCLUSIONS:** The article concludes by outlining key directions for future research, contributing to an enhanced understanding and optimization of digital processes in the Bulgarian agricultural sector.

Keywords: digital transformation, agricultural entrepreneurship, literature review, future research, agribusiness, digital technologies

INTRODUCTION

Globally and across Europe, digital transformation is fundamental to modern agricultural progress. However, Bulgaria's agrarian sector lags technologically and structurally behind other EU nations in its digitalization efforts (1). Digitalization provides tools to enhance efficiency, sustainability, and traceability in agricultural production, particularly in light of limited natural resources, demographic pressures, and climate change. The Ministry of Agriculture of the Republic of Bulgaria published the "Strategy for Digitalization of Agriculture and Rural Areas 2019–2027," which lays the foundation for the systematic application of innovations in the sector (2).

However, the implementation of digital solutions is uneven and influenced by a number of structural factors such as a lack of infrastructure and limited access to financing

(1). Digitalization in Bulgaria is still at a low level compared to the EU average, and its application is concentrated in certain regions and large farms (3).

The purpose of this article is to provide a systematized overview of scientific sources regarding digitalization in the agricultural sector and agricultural entrepreneurship in Bulgaria, identifying key trends, challenges, and directions for future research.

METHODS

This literature review employed a systematic and structured approach to identify, evaluate, and synthesize scholarly publications, policy documents, and statistical data relevant to the digital transformation of the agricultural sector in Bulgaria. The data collection process began with extensive searches across multidisciplinary databases including Scopus, Web of Science, ResearchGate, and Google Scholar, as well as institutional repositories of the Bulgarian Ministry of Agriculture, the European Commission, and Eurostat. Search queries were developed using Boolean operators ("AND" / "OR") to combine

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keywords such as “digital transformation,” “precision agriculture,” “smart farming,” “IoT,” “AI,” “Bulgaria,” and “EU agricultural policy.” The search was limited to sources published between 2019 and 2024 to capture the most recent developments, particularly those influenced by the current cycle of EU funding and innovation initiatives. Documents were included if they were published in English or Bulgarian and demonstrated empirical or analytical relevance, including peer-reviewed articles, policy briefs, and statistical reports. Sources were excluded if they lacked focus on Bulgaria, were published prior to 2019, or did not contain substantive analytical content. An initial pool of over 120 documents was identified, with titles and abstracts screened for relevance, followed by full-text review of 55 shortlisted materials. The final selection for in-depth synthesis comprised 22 references, organized thematically to reflect the historical evolution of agricultural policy, technological trends, economic impacts of digitalization, and key challenges and future directions for the sector. This analytical process enabled the extraction of patterns, policy gaps, and critical factors influencing the pace and scope of digital transformation in Bulgarian agribusiness.

RESULTS AND DISCUSSION

HISTORICAL CONTEXT

The evolution of agricultural entrepreneurship in Bulgaria has unfolded through several key stages. During the period of a centrally planned economy, agriculture was dominated by collective farms, which, while ensuring scale and mechanization, suppressed individual initiative and innovation (4). The transition to a market economy after 1989 led to the disintegration of these collective structures, land restitution, and the establishment of small and big, fragmented farms (5). The lack of coordination, institutional support, and financing significantly hindered the sector's sustainable development.

With Bulgaria's accession to the EU in 2007, integration with the Common Agricultural Policy began, providing opportunities for subsidies, investments, and rural development programs. This gradually created the prerequisites for the modernization and digitalization of production processes (6, 7). Despite these developments, digitalization in Bulgarian agriculture is progressing unevenly – predominantly in large farms, while small ones lag due to a lack of knowledge, capital, and

human resources. According to a study, only about 14% of agricultural producers in Bulgaria utilize modern digital technologies, with the share being higher among farms sized between 5,000 and 10,000 decares. These larger farms are the most innovative due to economies of scale and better access to investments. In contrast, small-scale producers often lack sufficient resources and, frequently, the technical literacy to integrate precision agriculture technologies, sensors, or digital management platforms.

A survey that covers 260 agricultural producers indicates that only 4% of them plan real investments in digitalization, while 86% would invest no more than 10% of their revenues in such technologies. At the same time, among the anticipated benefits of digitalization, respondents highlight increased efficiency (22%), reduced costs (17%), and improved management (16%). Despite these potential benefits, the level of digitalization varies significantly across different agricultural sub-sectors, farm types, and regions of the country. A significant portion of digitalization funding remains within the sphere of private investments, and at the national level, there is a lack of comprehensive statistics on the degree of achieved digitalization, which complicates policy planning. This underscores the need for targeted public support – through training, incentives, and the creation of appropriate infrastructure – especially to support small and medium-sized farms, which are at the greatest risk of exclusion from the digital transition process. According to NSI data, the share of individuals in Bulgaria using the internet for interaction with public institutions increased from 17.8% in 2015 to 26.9% in 2020, indicating growing digital penetration among agricultural holdings as well. Despite this trend, the digital divide remains clear – especially in less developed rural regions, where access to the internet and digital services is limited both physically and in terms of digital skills. (8, 9)

ECONOMIC BENEFITS OF DIGITALIZATION IN AGRIBUSINESS

Digital transformation in agribusiness generates a range of economic benefits related to increasing efficiency, reducing costs, and enhancing competitiveness. By implementing smart technologies, agricultural holdings can precisely manage their resources, utilizing real-time data to optimize production and curtail operational losses. The integration of

innovations such as artificial intelligence, IoT, satellite monitoring, and automated irrigation systems leads to resource savings and better forecasting of market needs (10, 11).

The use of digital tools like farm management systems, sensors, and drones enables comprehensive crop monitoring, soil analysis, and yield forecasting. Research indicates that farms applying smart technologies achieve up to 17% higher profit per decare compared to traditional agricultural practices (12). This improvement stems from both reduced losses due to inefficient use of fertilizers and water, and more effective planning of production cycles.

Digitalization also enhances market access through e-commerce and blockchain platforms, which are particularly crucial for organic farming and exports. Utilizing digital channels shortens the supply chain, allowing producers a direct connection with consumers and enabling them to achieve higher added value. Blockchain technologies contribute to traceability, prevent fraud, and increase trust in organic products, simultaneously leading to a higher value for the produce (13).

The automation of administrative processes (declarations, applications, subsidies) through electronic platforms saves significant resources for farmers. Furthermore, digitalization supports innovation – new business models, agri-services, and equipment-sharing platforms are being created, opening up opportunities for employment and youth entrepreneurship in rural areas (14).

TECHNOLOGICAL TRENDS IN AGRICULTURAL DIGITALIZATION

Agricultural digitalization in Bulgaria is developing at an accelerated pace under the influence of global technological transformations in the information and communication technology sector. It leads to fundamental changes in the functioning of agricultural holdings, as digital tools are being implemented in more and more links of the agricultural chain – from production to market realization. Among the leading directions of digital innovations are precision agriculture, artificial intelligence (AI), the Internet of Things (IoT), blockchain solutions, automation, and cloud technologies. These technologies create new opportunities for collecting, processing, and analyzing agricultural

information, which supports the making of timely and informed management decisions. (14). Precision agriculture, through the use of GPS navigation, soil moisture sensors, meteorological stations, and geospatial data, enables the precise application of resources – fertilizers, water, and pesticides – in the exact quantity and at the exact location. This not only increases yields but also reduces the negative impact on the environment. For instance, intelligent irrigation systems, based on embedded sensors and climatic models, can reduce water consumption by up to one-third while simultaneously improving the biological efficiency of plants. (11)

The integration of IoT in agriculture expands the possibilities for remote control and monitoring of machinery, crops, and livestock. Automated irrigation systems, feeders, and microclimate control systems in greenhouses are managed in real-time via mobile applications, providing flexibility and optimizing operations. Data collected through sensor networks is transmitted in real-time to central cloud platforms, where it is processed and visualized for management purposes. (15)

Artificial intelligence (AI) and machine learning algorithms are actively integrating into planning, forecasting, and diagnostic processes. Software solutions utilize satellite imagery and drone data to identify crop diseases at an early stage, enabling the application of targeted and timely measures. AI is also employed for yield modeling, risk management, and dynamic supply chain planning. (10, 16)

Blockchain technologies offer a new paradigm in ensuring transparency, traceability, and trust in the agri-food chain, especially in the context of organic farming and sustainable production. By utilizing decentralized digital ledgers, blockchain allows for the recording of every stage of the agricultural production and logistics process – from soil preparation and seeds used, to harvesting, processing, transport, and final sale. Each transaction or activity is recorded as a unique, timestamped block that cannot be altered or deleted, thereby ensuring a high level of information security and reliability.

This technology is particularly effective in supporting certified organic products, where it is necessary to prove the origin of raw materials, cultivation methods, adherence to standards, and the absence of synthetic additives.

Furthermore, blockchain significantly facilitates international trade by providing access to digital certificates of quality and origin, reducing administrative burdens, and mitigating the risk of fraudulent documents.

The application of blockchain in the agricultural sector also contributes to reducing fraudulent practices, improving cooperation among value chain participants – farmers, processors, logistics operators, and traders – and increasing trust from the end consumer, who now seeks not only quality but also transparency regarding the origin and journey of the food they consume. (17)

Automation through the use of drones, autonomous tractors, and agricultural robots significantly reduces the need for manual labor. These technologies are particularly useful in hard-to-reach terrains or in cases of labor shortages. They perform activities such as sowing, fertilizing, and spraying with high precision and minimal time and resource expenditure. (12)

Cloud-based farm management systems offer centralized control over the production process, real-time analytics, warehouse management, and financial reporting. With access via mobile devices and the internet, farmers can make decisions remotely, based on objective data and forecasts. This makes production more flexible, sustainable, and prepared for climatic and market challenges. Furthermore, these systems facilitate seamless data integration from various sources, including sensors, drones, and weather stations, providing a holistic view of farm operations. They also enable better collaboration among team members and agronomists, allowing for shared insights and more informed strategic planning. The ability to store and process vast amounts of data in the cloud supports advanced predictive analytics, helping farmers anticipate challenges and optimize resource allocation for maximum efficiency and profitability. (16)

CHALLENGES TO DIGITAL TRANSFORMATION IN THE AGRI-SECTOR

Digitalization in crop production and plant protection in Bulgaria faces several key challenges that hinder its widespread adoption. Firstly, infrastructural limitations are particularly pronounced – only 2.7% of rural areas have high-speed internet connectivity, which makes the use of IoT, cloud platforms,

and precise management systems practically impossible for a large proportion of agricultural producers. The second significant barrier is the low level of digital skills among farmers, with less than one-third of the population possessing basic computer literacy, which impedes the adoption and effective use of digital technologies in the agricultural sector. In addition, the lack of institutional coordination between farmers, public administration, and scientific organizations hinders the creation of an integrated digital ecosystem necessary for the sustainable application of innovations. Developing policies and educational programs that address these structural deficits and encourage the transfer of knowledge and technology to agricultural producers. (17)

Financial limitations represent the third major challenge. The implementation of technologies requires significant investments, especially in automated systems, GPS devices, and management software. There is a lack of targeted microfinancing instruments accessible to small and medium-sized farmers, and the expected return on investment is often uncertain in the short term. This leads to low motivation among agricultural producers for technological investments. (12, 18)

An institutional deficit also exists, representing a significant barrier to the successful implementation of digital technologies in the agri-sector. There is a lack of sustained coordination among public institutions, the private sector, and the scientific community—an interaction that is crucial for the creation and application of effective innovation policies. The absence of effective coordination among state structures, agricultural producers, and research organizations leads to fragmented efforts and low efficiency in technology implementation. Policies in this area are often formulated without sufficient interaction with farmers, making them difficult to apply and distant from the sector's real challenges. Additionally, the absence of standardized and mutually compatible digital solutions creates serious obstacles when integrating various management and monitoring systems. The lack of a comprehensive digital ecosystem that unifies technologies, data, and institutions into a single platform hinders automation, analysis, and management decision-making processes. These institutional deficits not only slow down the adoption of innovations but also limit the

economic and environmental benefits of digitalization in the agri-sector. (17, 18)

FUTURE DIRECTIONS: AREAS FOR RESEARCH AND POLICY RECOMMENDATIONS

Future research should focus on analyzing the economic return on digitalization across different sub-sectors of the agricultural economy, with a particular emphasis on small and medium-sized agricultural holdings, which often remain outside the scope of high-tech solutions due to a lack of resources and expertise. It is necessary to develop regionally adapted models for digital transformation that reflect differences in infrastructure, access to financing, and levels of digital literacy. (17) At the policy level, it is recommended to establish a national coordinating body to manage and synchronize digitalization processes in the agri-sector. Such a body could unite the efforts of the public sector, the academic community, and businesses, creating a platform for cooperation, sharing best practices, and accelerating the implementation of innovations. Additional attention should be paid to professional training and upskilling of agricultural producers, especially in the context of introducing complex digital solutions. The establishment of demonstration farms, technological hubs, and regional training centers could not only enhance knowledge but also practically demonstrate the benefits of innovations in a real-world environment. Such initiatives are already being piloted in some EU countries and could be adapted to Bulgarian conditions. According to a number of studies, public-private partnerships play a significant role in the process of technology transfer, know-how, and best practices, creating a bridge between scientific developments and daily farming activities (19). Furthermore, access to financing remains critical for small and medium-sized agricultural holdings, which often lack sufficient own capital to implement digital technologies. More active mobilization of resources from European and national programs, aimed at innovation, digitalization, and rural infrastructure development, is necessary (20). In this regard, the European Agricultural Fund for Rural Development and other targeted mechanisms should be strategically utilized to promote digital transformation through simplified financing schemes, microcredits, and subsidies adapted to the needs of different types of farmers. It is also important that these instruments are accompanied by consulting and

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administrative support, so that access to them is not limited by bureaucratic obstacles (21). Such needs have also been noted in international analyses, which emphasize that technological modernization in rural areas is impossible without active support for financing, training, and logistical infrastructure (22).

CONCLUSION

This study aimed to analyze the processes of digital transformation in agricultural entrepreneurship in Bulgaria, presenting a systematized overview of scientific publications, strategic documents, and empirical data. The analysis outlined three key areas: leading technological trends, institutional and structural challenges, and the potential for economic sustainability and growth through digital solutions.

It was established that digitalization is progressing at varying speeds, with large farms leading in the application of precision agriculture, IoT technologies, drones, autonomous machinery, and blockchain platforms. These innovations contribute to more efficient resource utilization, increased yields, and product traceability. At the same time, however, small and medium-sized agricultural producers remain outside the transformation process due to limited access to financing, a lack of digital competencies, insufficient technical support, and infrastructural deficits.

The proposals derived from the analysis include the establishment of a national coordinating body for digitalization in the agri-sector, the development of regionally adapted models for digital transformation, and the strengthening of public-private partnerships for technology transfer. Investments in professional training, demonstration farms, and technological hubs are also necessary to accelerate the practical implementation of digital solutions.

From a scientific perspective, future research should focus on an empirical analysis of the impact of digitalization on productivity, profitability, and environmental sustainability across different agricultural sub-sectors. A more in-depth assessment of the return on technological investments is needed within the context of various farm types and regional characteristics.

A limitation of the current study is its review nature, primarily based on secondary sources.

Nevertheless, the presented results provide a conceptual framework and an analytical basis that can guide future empirical and policy efforts towards an effective and inclusive digital transformation in Bulgarian agriculture.

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