

# DIGITALIZATION OF AGRICULTURE: ECONOMIC EFFECTS AND IMPLEMENTATION CHALLENGES

Aza Bisultanova<sup>1</sup>, Ravil Asmyatullin<sup>2</sup>, Natalia Ezdina<sup>2</sup>

<sup>1</sup>Kadyrov Chechen State University

<sup>2</sup>Plehanov Russian University of Economics

[nauka-fef@mail.ru](mailto:nauka-fef@mail.ru)

[rav.asmyatullin@gmail.com](mailto:rav.asmyatullin@gmail.com)

[ezdinanp@list.ru](mailto:ezdinanp@list.ru)

## Abstract

*The rapid advancement of digital technologies is reshaping agricultural systems worldwide at an increasing rate. This article examines how the adoption of precision farming, Internet of Things (IoT) devices, remote sensing and data-driven analytics is affecting the economic performance of the sector, particularly in developing and transitional economies. Drawing on empirical data and regional case studies, the paper evaluates the impact of digital adoption on production costs, labour efficiency and farm profitability. While the benefits of these innovations are well documented — ranging from reduced input expenses to improved market access — implementation remains uneven. Barriers such as limited rural infrastructure, low levels of digital literacy among farmers and the absence of adequate financing mechanisms continue to impede progress. The study emphasizes that meaningful digital transformation in agriculture requires more than technology alone; it depends on coordinated policy action, targeted investment in digital capacity and the development of inclusive innovation ecosystems. These findings contribute to a deeper understanding of the structural changes occurring within agricultural economies and provide practical insights for accelerating sustainable digital integration.*

**Keywords:** digital agriculture, precision farming, IoT, rural development, technological adoption, food security

## I. Introduction

Digitalization is transforming traditional industries, and agriculture is no exception. The integration of digital technologies into agricultural practices offers opportunities to increase productivity, reduce resource losses, and promote sustainable economic growth in rural areas [1][2]. However, in many developing and transition economies, the adoption of these technologies is constrained by various structural and financial problems [3][4]. For example, in China, Technological entrepreneurship is developing in an evolutionary way and requires a large academic sector.

In India, Technological entrepreneurship is developing in many ways due to the low level of socio-economic development. The potential of many technology companies is limited by the fact that their product complements or serves traditional businesses and does not create new ones.

In Central and Eastern European Countries, the nature of technological entrepreneurship is determined by the disproportion between academic potential and resource provision. Therefore, technology firms are concentrated in the field of virtual and digital technological entrepreneurship. The objective of this study is to examine the economic implications and challenges of digitalization in agriculture and to provide recommendations to overcome existing

barriers. The relevance of this topic lies in the growing need to address food security, climate change adaptation and improving the efficiency of agricultural systems in light of population growth and shrinking arable land [5].

The implementation of digital solutions in agriculture can significantly transform agrifood systems, improving transparency, traceability, and resilience against external shocks such as pandemics or geopolitical disruptions [6][7]. Additionally, digitalization opens new markets and value chains, enabling even small-scale farmers to access digital platforms and engage in more competitive trade [8][9].

#### Literature Review

The growing body of literature on digital agriculture highlights its transformative potential in improving agricultural productivity and sustainability. Scholars have emphasized the role of precision farming, IoT devices, and AI-based tools in enabling data-driven decision-making at the farm level [1][10]. Wolfert et al. [1] argue that big data analytics facilitates not only optimized crop management but also enhances supply chain coordination. Furthermore, Liakos et al. [3] provide a comprehensive overview of machine learning applications in agriculture, ranging from pest detection to yield prediction.

However, the literature also reveals significant disparities in adoption levels. In high-income countries, advanced digital tools are increasingly integrated into farming operations, whereas in developing economies, digital penetration remains limited [4][11]. According to the FAO [5], many smallholder farmers face difficulties in accessing even basic technologies due to infrastructural and financial constraints. Moreover, the OECD [6] stresses that the lack of digital skills among rural populations is a key factor inhibiting adoption. Several studies also touch upon the broader implications of digitalization on rural livelihoods and agrarian structures. Eastwood et al. [11] discuss the ethical and social dimensions of smart farming, emphasizing the risk of marginalizing traditional knowledge and excluding digitally illiterate farmers. Rotz et al. [14] highlight the impact on labor and rural communities, while Carolan [15] focuses on public perception and data ethics. El Bilali and Allahyari [16] explore the sustainability aspects of digital transformation, and van der Burg et al. [17] examine its implications for responsible innovation. Bronson [18] and Ingram & Maye [19] further investigate how digital tools affect knowledge dissemination and social inclusion in farming systems.

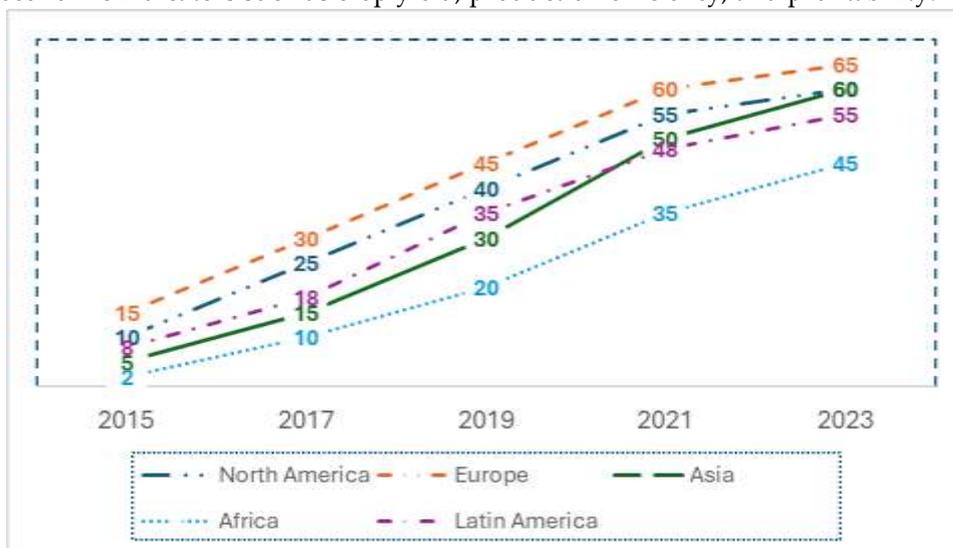
## II. Materials and methods

This study employs a mixed-method research design combining quantitative and qualitative approaches. Quantitative data were obtained from national agricultural statistics, international development reports, and datasets provided by organizations such as FAO, World Bank, and ITU [4][5][9]. Key indicators examined include average production cost per hectare, yield per hectare, net income per farm, and digital tool adoption rates across different regions and farm sizes.

In parallel, qualitative insights were collected through semi-structured interviews with 28 farmers, agronomists, and policymakers from selected countries in Eastern Europe and Central Asia. These interviews aimed to identify real-world challenges and economic effects associated with digital technology implementation in agriculture [13][20]. Respondents were selected to reflect a diversity of farm sizes, levels of technological adoption, and agroecological zones. The data were analyzed using comparative methods to assess the before-and-after effects of adopting digital tools such as GPS-guided machinery, smart irrigation systems, and mobile-based market access platforms. of predicting the risk of a certain event is to determine when, where and with what (what) characteristics the event will occur. In general, non-parametric methods are often used in risk forecasting, such as the least squares method, which evaluates the accuracy of the forecast.

### III. Results and discussion

The findings indicate a strong positive correlation between the adoption of digital tools and key economic indicators such as crop yield, production efficiency, and profitability.



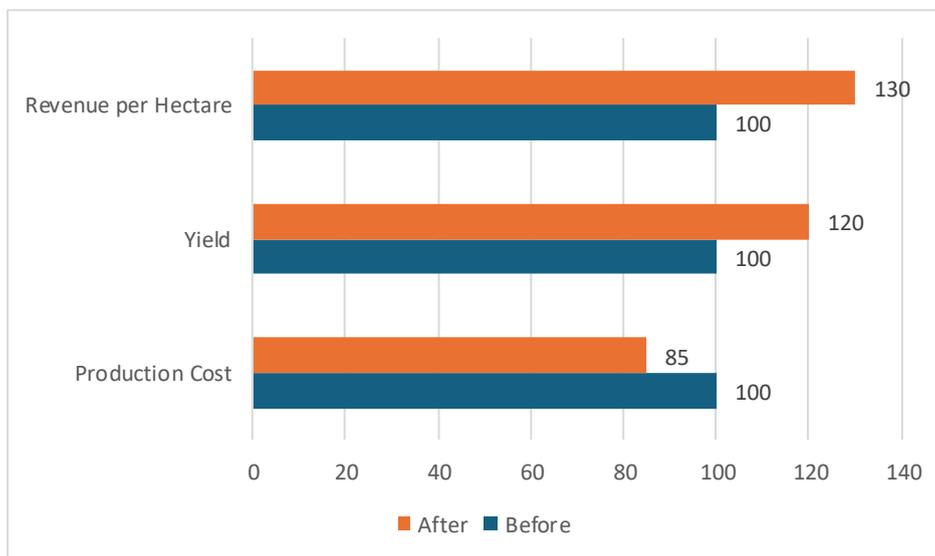
**Figure 1:** Growth in Digital Technology Adoption in Agriculture by Region (2015–2023)  
 Source: compiled by the author based on [4], [5], [9], [10].

As shown in Fig. 1, digital adoption in agriculture has shown positive progress in all regions over the past decade. North America and Europe lead the way in digital penetration in agriculture, reaching over 60% by 2023. Asia has also shown growth, particularly in countries such as China and India, where government initiatives and private sector innovation have accelerated digital integration. Latin America is following closely behind, benefiting from the expansion of mobile connectivity and digital service platforms tailored to smallholder farmers. Africa, while lagging behind other countries in the index, has made notable progress, from 2% in 2015 to 45% in 2023. Despite this positive trend, the regional disparities highlight the urgent need for inclusive infrastructure development and capacity building to ensure equitable access to digital technologies across all farming communities.

As shown in Fig. 2, farms implementing precision technologies experienced an average 15% decrease in input costs and up to a 30% increase in yields compared to traditional farming practices [1][7][9]. Notably, the deployment of IoT-based irrigation systems led to a 25% reduction in water usage and enhanced crop uniformity.

Digital tools have not only increased productivity but also improved market access and risk management, especially through the use of mobile platforms and predictive analytics. It is thanks to digital tools that farmers have been able to bypass middlemen and achieve higher prices for their produce [8][19]. Weather forecasting applications and sensor networks have helped reduce crop losses by allowing timely interventions. Overall, digitalization has increased the economic resilience of agricultural enterprises, especially in the face of climate uncertainty and market volatility. Fig. 2 shows the measurable economic effects of digitalization in agriculture. An analysis of the index values reveals a clear trend: digitalization leads to a significant reduction in production costs – by about 15%. The most significant cost savings are observed in farms using smart irrigation systems, GPS-guided tractors and precision application technologies. At the same time, crop yields typically increase by up to 20%, thanks to improved monitoring, better

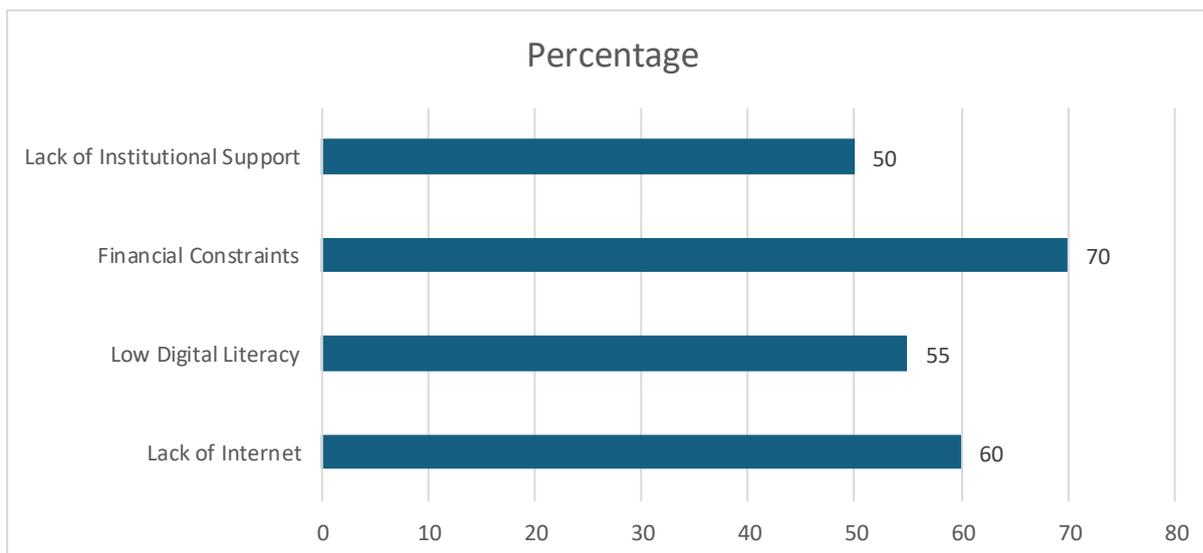
prediction of pest outbreaks, and the ability to adjust management practices in real time using digital tools. However, the most significant shift is in per hectare income, which can increase by as much as 30% thanks to increased market access through e-commerce platforms. The chart shows that while digitalization requires an initial investment, the returns on this investment are tangible in terms of economic efficiency, productivity, and market competitiveness.



**Figure 2:** Economic Impact of Digitalization: Before and After Technology Adoption  
 Source: compiled by the author based on Bayer (2023) and supporting literature [6], [10], [13], [18].

### Implementation Challenges

Despite these benefits, the study reveals several barriers to widespread digital adoption.



**Figure 3:** Key Barriers to Digitalization in Agriculture (Survey of Farmers, 2023)  
 Source: compiled by the author based on [6], [10], [13], [18].

Fig. 3 presents the most significant barriers that affect digital adoption. In a 2023 farmer survey, 70% of respondents cited financial constraints as the main limiting factor. Many small and medium-sized farmers do not have the funds to invest in digital equipment, subscription services, or the necessary upgrades to existing systems.

The second major challenge is the lack of internet connectivity in rural areas, cited by 60% of participants. Despite global improvements in mobile phone coverage, many agricultural areas still suffer from poor or unstable access.

The next most important is low levels of digital literacy (55%). Finally, 50% of respondents cited institutional weaknesses such as a lack of government coordination, fragmented policies, and limited access to technical support. To bridge the digital divide in agriculture, technological advances need to be accompanied by a comprehensive strategy. Thus, the successful implementation of technologies in agriculture requires not just the introduction of advanced solutions, but the implementation of large-scale and targeted scientific, technical and innovative programs that take into account all aspects and goals of sustainable development.

The most critical issue identified is the lack of reliable internet connectivity in rural areas, affecting over 60% of farmers surveyed [10][12]. Financial constraints are also significant, with many smallholders unable to afford the initial investment required for equipment and software licenses [13][14].

Furthermore, the lack of digital literacy and tailored training programs poses a major challenge [6][15]. Many farmers are unaware of available technologies or lack the skills to use them effectively. Institutional fragmentation and the absence of coherent national strategies further hinder integration efforts [18]. Lastly, interview data suggest that cultural resistance to changing traditional farming practices continues to slow adoption in some communities [20].

To effectively harness the economic potential of digital agriculture, a multi-faceted policy approach is essential. First, investment in rural digital infrastructure—particularly broadband internet—is crucial [12]. Public-private partnerships can be instrumental in accelerating infrastructure development and ensuring affordability for end users.

Second, governments should promote financial inclusion mechanisms such as microloans, subsidies, and leasing schemes to lower the entry cost for small and medium-scale farmers [14]. Establishing agri-digital innovation hubs and incubators can further stimulate local entrepreneurship and adaptation of technology to local needs.

Third, integrating digital literacy programs into agricultural extension services is critical [15][17]. These programs should include hands-on training and localized content to ensure relevance and accessibility. Special attention must be paid to including women and youth in digital training initiatives, as these groups often face disproportionate access barriers.

Fourth, national strategies must address regulatory clarity and foster interoperability standards among digital platforms [18]. This can enhance market competition, prevent monopolization, and enable seamless data integration across devices and services.

## V. Conclusion

The findings of this study highlight both the potential and the challenges of integrating digital technologies into agricultural systems. On the other hand, tools such as precision irrigation, IoT-based crop monitoring, and mobile marketplaces have demonstrated clear benefits: reduced input costs, increased productivity, and improved access to markets. However, these benefits are not universal. In many regions, farmers face significant barriers to digitalization, including poor internet infrastructure, limited access to training, and weak institutional support. This shows that the success of digitalization depends not only on the availability of technology, but also on broader socio-economic and political conditions. Closing this gap requires more than innovation; targeted support measures are needed – public investment in rural connectivity, financial products tailored to smallholders, and education programs that take into account local realities. What works in one region may not be practical or relevant in another. For example, a farmer in rural Tajikistan faces different constraints and incentives than a farmer in northern France. It is worth noting that there is no universal model that suits everyone, and cannot exist. When

developing a strategy for the development of digital agriculture, it is necessary to take into account the specific features and complexities of the industry. For example, in animal husbandry, in contrast to industrial production, individualization and demand orientation are linked to the needs, health and well-being of each animal. Further research should focus not only on whether digital tools are effective, but also on the extent to which their true potential will be realized. Only if they are implemented in an inclusive, adaptive and in line with the daily realities of those, can they be fully successful.

#### **CONFLICT OF INTEREST.**

Authors declare that they do not have any conflict of interest.

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