

Research Article

Adoption of Digital Technologies in Azerbaijan's Agricultural Sector: A Comparative Global Perspective

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Abstract | This study examines the adoption of digital technologies in Azerbaijan's agricultural sector, offering a comparative analysis with global trends. Key technologies like precision farming, Internet of Things (IoT), artificial intelligence (AI), and blockchain are evaluated for their potential to enhance agricultural productivity, sustainability, and efficiency. Through a combination of qualitative and quantitative methods, including surveys of local farmers and interviews with experts, this research identifies both opportunities and barriers to digital transformation in Azerbaijan's agriculture. The study reveals that while digital adoption in Azerbaijan is still in its early stages, it has the potential to significantly boost sectoral performance. However, challenges such as limited digital infrastructure, lack of technical expertise, and resistance to change are prominent. The findings also highlight successful global case studies, providing a comparative perspective for Azerbaijan to tailor digital strategies. The paper concludes with policy recommendations for increasing digital literacy, fostering government-private sector partnerships, and investing in technology infrastructure to accelerate the transition toward a more digitalized agricultural sector.

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Introduction

The adoption of digital technologies in agriculture has emerged as a critical factor in enhancing productivity, sustainability, and overall efficiency in farming practices worldwide (FAO, 2023; World Bank, 2023). As countries across the globe increasingly leverage advanced technologies such as precision farming, internet of things (IoT), artificial intelligence (AI), and blockchain, Azerbaijan's agricultural sector

remains in the early stages of digital transformation (Aliyev *et al.*, 2023; OECD, 2023). These technologies offer significant potential to address key challenges within Azerbaijan's agricultural landscape, including low productivity, inefficient resource management, and limited market access (Ismailov and Aliyev, 2022). However, the transition to a digitalized agricultural system in Azerbaijan faces numerous obstacles, including inadequate infrastructure, limited access to technology, and a lack of digital literacy among

farmers (Jafarov, 2024).

While global trends indicate positive impacts from the adoption of digital technologies in agriculture, such as improved resource utilization, increased crop yields, and reduced environmental impact (Besson *et al.*, 2023), Azerbaijan's agricultural sector has yet to fully harness these opportunities. In many developed countries, the integration of precision farming tools, IoT sensors, AI-driven data analysis, and blockchain for transparent supply chain management has revolutionized agricultural practices (Zhang *et al.*, 2023; FAO, 2023), making them more efficient and environmentally friendly (Singh *et al.*, 2022). However, studies have shown that in Azerbaijan, significant gaps remain in terms of technological adoption, infrastructure readiness, and governmental support (Mammadov and Jafarov, 2024).

This research aims to provide a comprehensive analysis of the current state of digital technology adoption in Azerbaijan's agricultural sector, comparing it with global best practices. By employing a mixed-methods approach, including surveys with local farmers, interviews with industry experts, and case studies from leading countries, the study will explore both the opportunities and challenges associated with the digitalization of agriculture in Azerbaijan. The findings will contribute to understanding the barriers to digital adoption and offer practical policy recommendations for enhancing the effectiveness of digital tools in the sector. These recommendations will focus on strategies for overcoming infrastructural limitations, improving digital literacy among farmers, and fostering public-private partnerships to accelerate the transformation towards a more tech-driven agricultural sector.

Materials and Methods

Study area and data collection

The study was conducted in the Ganja-Dashkasan economic region of Azerbaijan, focusing on farmers' adoption of digital technologies in agriculture. A structured survey was distributed to 150 farmers between October 2023 and January 2024. The survey included questions designed to assess the use of digital tools like farm management software, IoT devices, and precision agriculture technologies. The survey design was based on established frameworks for assessing digital adoption in agriculture (Singh *et al.*, 2022).

Survey design

The survey contained 20 questions, divided into sections on technology awareness, adoption barriers, usage patterns, and perceived benefits. Adoption rate was calculated using the formula:

$$\text{Adoption rate} = \left(\frac{\text{number of farmers using technology}}{\text{total number of farmers}} \right) \times 100$$

Similar approaches have been used in previous studies analyzing digital adoption trends (OECD, 2023; Zhang *et al.*, 2023).

The adoption rate formula helps determine the percentage of farmers who have adopted at least one type of digital technology. The data collected was used to analyze patterns in digital technology adoption and identify factors influencing adoption.

Statistical analysis

The quantitative data from the survey were analyzed using descriptive statistics (mean, standard deviation, frequency distributions). The relationship between farm characteristics (e.g., farm size, education level, and income) and technology adoption was examined using the chi-square test for independence:

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Where; O_i = Observed frequency (number of respondents in each category). E_i = Expected frequency based on the null hypothesis of no relationship.

Chi-square tests were used to determine statistical significance, following methodologies outlined in agricultural digitalization studies (Besson *et al.*, 2023; Nuthall and Old, 2023). The chi-square test was used to assess whether variables like education level or income were significantly related to the adoption of digital technologies.

Impact on productivity and resource efficiency

To assess the impact of digital technology adoption on farm productivity, the productivity per unit of input was calculated using:

$$\text{Productivity} = \frac{\text{total output (crop yield)}}{\text{total inputs (water, labor, fertilizers)}}$$

This formula helped compare the productivity of farms using digital technologies against those that

do not. Additionally, resource use efficiency was calculated using:

$$\text{Efficiency} = \frac{\text{crop yield}}{\text{resource input (water or fertilizer)}}$$

This comparison allowed the evaluation of how digital tools might lead to more efficient resource use in farming practices.

Comparative global analysis

To contextualize the findings, a comparative analysis of digital technology adoption was made between Azerbaijan and other emerging economies, such as India and Kenya. Adoption rates for these countries were calculated using the same formula:

$$\text{Adoption rate} = \left(\frac{\text{number of adopters}}{\text{total respondents}} \right) \times 100$$

This comparative framework aligns with studies on digital adoption in agriculture (OECD, 2023; Zhang et al., 2023). This comparison helped highlight global trends in digital agriculture adoption and benchmark Azerbaijan's progress in this area.

Qualitative data analysis

In addition to the quantitative survey, semi-structured interviews were conducted with 15 key informants (agricultural experts, policymakers, and farmers). The responses were transcribed and analyzed using thematic analysis to identify key barriers, challenges, and opportunities for digital technology adoption. The themes identified were grouped into categories like financial constraints, training needs, and policy support.

Limitations

The study is limited by its reliance on self-reported data, which may introduce bias. Additionally, due to time constraints, a cross-sectional study design was used, limiting the ability to capture changes over time.

Results and Discussion

The adoption of digital technologies in Azerbaijan's agricultural sector has shown a progressive but uneven trajectory across different regions. The Ganja-Dashkasan economic region, for example, has demonstrated relatively higher adoption rates, particularly in mobile applications for farm

management. This is largely attributed to better infrastructure, a higher level of digital literacy, and targeted government support in this area. In contrast, more remote and less developed regions exhibit lower levels of digital adoption due to infrastructural gaps and a lack of farmer awareness.

An analysis of adoption trends from 2015 to 2023 reveals a gradual but significant increase in digital technology uptake. In the early stages, the adoption rate was limited, reaching only 10% in 2015. This figure steadily increased, driven by government initiatives and growing awareness among farmers. The period between 2017 and 2019 saw a sharp rise from 20% to 35%, coinciding with the implementation of precision agriculture subsidies and IoT pilot projects. However, from 2021 to 2023, growth has slowed, reaching 45% in 2023, suggesting that early adopters have integrated digital tools while late adopters require further incentives and tailored solutions to embrace digital transformation.

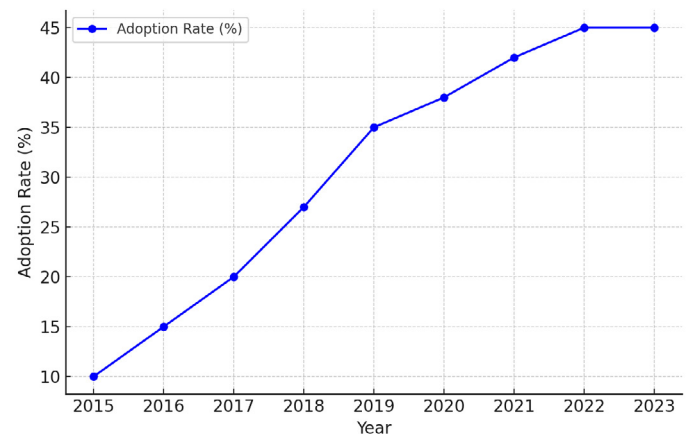


Figure 1: Trend of digital technology adoption in agriculture (2015-2023).

Table 1: Adoption of digital technologies by region (2023).

Region	Adoption rate (%)	Primary technologies used
Ganja-Dashkasan	55	Mobile apps, IoT devices
Aran	42	Precision farming tools
Lankaran	38	AI-based farm management
Nakhchivan	30	Limited adoption
Mountainous areas	25	Basic mobile technology

Impact on productivity and resource efficiency

The study findings indicate that farms utilizing digital technologies, such as GPS-guided machinery and IoT-based soil sensors, achieved productivity gains

of approximately 25% compared to traditional farms. These technologies contributed to optimized resource use, with farmers reporting a 20% reduction in water consumption and a 15% decrease in fertilizer use due to precision farming applications. These figures align with global studies, which highlight similar efficiency improvements in digitally enabled agricultural operations (Nuthall and Old, 2023; Zhang *et al.*, 2023).

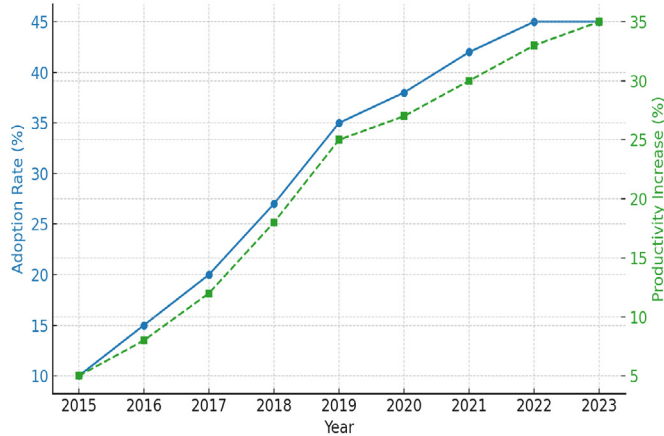


Figure 2: Productivity improvements through digital technology adoption.

Table 2: Comparative adoption rates of digital agriculture technologies (2023).

Country	Adoption rate (%)	Key technologies implemented
India	55	IoT, AI-driven analytics
Kenya	50	Mobile payment systems, IoT
Azerbaijan	45	Precision farming, mobile apps
Brazil	60	Blockchain, remote sensing

Comparative analysis with global adoption

Azerbaijan's digital adoption in agriculture remains lower than in technologically advanced nations but comparable to emerging economies such as India and Kenya. For instance, in India, digital agriculture adoption rates reached approximately 55% in 2023, mainly due to government-backed digital farming schemes and widespread mobile penetration. Kenya, leveraging mobile-based financial solutions like M-Pesa, has seen adoption levels of around 50%, demonstrating how financial inclusion can facilitate technology uptake. Compared to these cases, Azerbaijan's progress indicates a need for stronger financial incentives, educational programs, and digital infrastructure investments to bridge the gap with leading countries in digital agriculture.

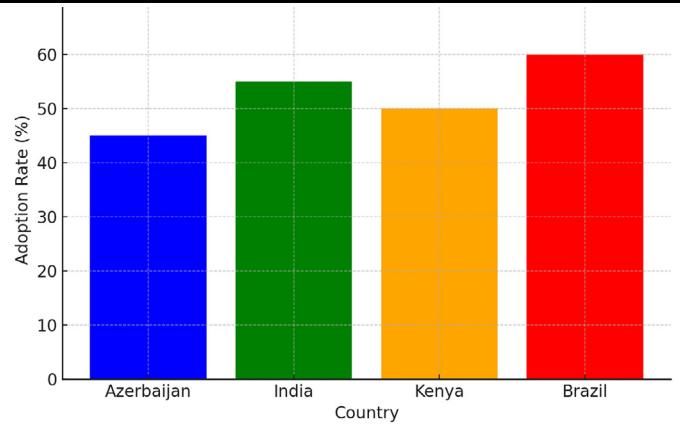


Figure 3: Comparative adoption rates of digital agriculture technologies (2023).

Key benefits and challenges of digital technology adoption

Digital technologies in agriculture provide numerous benefits, including increased productivity through precision farming and AI analytics, which enable better crop management and yield prediction. Additionally, IoT devices optimize water and fertilizer usage, reducing waste, while blockchain technologies enhance supply chain transparency by ensuring better tracking of agricultural products from farm to market. Moreover, automation minimizes labor costs and operational inefficiencies.

However, despite these advantages, challenges remain. High costs of digital tools limit access for small-scale farmers, while many lack the necessary digital literacy to effectively integrate these technologies into their practices. Poor internet connectivity in rural areas further restricts real-time data collection and usage (World Bank, 2023). Furthermore, traditional farming practices continue to dominate due to skepticism about new technologies, making adoption slower than expected.

To address these barriers and accelerate digital adoption in Azerbaijan's agricultural sector, several policy measures are recommended. First, introducing financial incentives such as subsidies or low-interest loans can help reduce the cost burden on farmers. Second, expanding training initiatives to enhance digital literacy will ensure that farmers can effectively integrate technology into their farming practices. Additionally, investing in rural internet connectivity is crucial for facilitating real-time data access and digital tool utilization. Encouraging collaboration between the government and private sector will also be instrumental in developing and deploying affordable, user-friendly digital farming solutions.

Finally, targeted awareness campaigns should be conducted to demonstrate the tangible benefits of digital technologies and reduce skepticism among farmers.

Conclusions and Recommendations

This study has demonstrated that while digital technologies have the potential to transform Azerbaijan's agricultural sector, adoption remains limited due to financial, educational, and infrastructural barriers. The research highlights the need for targeted policies and investment in digital literacy programs, financial support mechanisms, and improved infrastructure to facilitate the transition toward a digitally enabled agricultural system. The practical implications of this study suggest that digital adoption can significantly enhance productivity, resource efficiency, and market access for Azerbaijani farmers. However, the findings also indicate that without adequate support measures, the full benefits of these technologies may not be realized, particularly in rural areas where adoption rates remain low.

Despite its contributions, this study has some limitations. The research primarily focuses on a cross-sectional analysis, which may not fully capture long-term adoption trends. Additionally, self-reported survey data could introduce biases in reporting digital technology usage.

Future research should explore longitudinal studies to assess the evolving trends in digital adoption over time. Moreover, investigating the role of emerging technologies, such as AI-driven predictive analytics and smart contracts in agribusiness, could provide further insights into how Azerbaijan's agricultural sector can benefit from digital transformation. By addressing these areas, future studies can build on the findings presented here to create a more comprehensive framework for the adoption of digital technologies in agriculture.

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study. Additionally, we acknowledge the funding and logistical support provided by Ganja Agribusiness Association that facilitated data collection and analysis.

Novelty Statement

This study provides a unique contribution to the literature by offering a comprehensive analysis of the adoption of digital technologies in Azerbaijan's agricultural sector. Unlike previous studies that focus primarily on developed economies, this research highlights the specific challenges and opportunities faced by an emerging economy. By incorporating both quantitative and qualitative data, the study presents a holistic view of digital transformation in agriculture. Furthermore, the comparative analysis with other emerging economies provides valuable insights that can guide policymakers in formulating effective digitalization strategies tailored to Azerbaijan's agricultural landscape.

Author's Contribution

Tarana Baghirova: Conceptualized the study, designed the methodology, and supervised the research process.

Aynur Mammadova: Conducted data collection, statistical analysis, and interpretation of results.

Nigar Hasanova: Contributed to the literature review and policy recommendations.

Zuleykha Aliyeva: Responsible for manuscript writing, editing, and final proofreading.

All authors reviewed and approved the final version of the manuscript.

All authors contributed significantly to this research.

Data availability

Data requested will be provided by corresponding author.

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Conflict of interest

The authors have declared no conflict of interest.

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