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SMART AGRICULTURE AND DIGITAL TECHNOLOGY ADOPTION: EVIDENCE FROM AZERBAIJAN

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Summary. *It is impossible to imagine our modern era without electronic services and digital technologies. Therefore, among the strategic tasks of our time, as well as many complex issues, as well as increasing the economic efficiency of ICT in the agricultural sector, intensifying the application of digital technologies, increasing productivity in all areas of activity due to these technologies, and making additional contributions to solving the efficiency problems of the agricultural sector as a whole is more of a priority.*

In the world, the processes of active use of "smart" technologies have risen to the maximum attractive level for most countries, and as a result, ICT technologies are being applied in leading fields of activity. Among the selected approaches and measures related to digitization of the agricultural sector and increasing the economic efficiency of the use of information technologies, providing necessary technological assistance to entrepreneurial and economic structures, providing advice and organizing training for the organization of effective use of ICT, modeling the use of natural resources, including land and water resources, preparation of targeted action programs, forecasting of climate changes, etc. directions are more requested.

These mentioned problems and tasks are a sufficient priority for Azerbaijan. It is for this reason that the article paid special attention to the issues of increasing the economic efficiency of information and communication technologies in the agricultural field in accordance with the goals of the "Strategic Roadmap for the development of telecommunications and information technologies in the Republic of Azerbaijan" as well as "Azerbaijan 2030: National Priorities for socio-economic development". Because the agrarian sphere is an important economic sphere of strategic importance for Azerbaijan.

Key words: *innovation, investment, digital technologies, "smart" mechanisms, diversification, economic resources.*

In the context of increasing global risks and uncertainties, the diversification and sustainable development of Azerbaijan's national economy require the implementation of well-grounded mechanisms and continuous institutional reforms. In this regard, agriculture, as one of the key sectors of the economy, necessitates modernization in line with contemporary challenges, including the intensification of production processes, improvement of management mechanisms, and efficient use of available resources. Traditional approaches to economic regulation have proven insufficient under new global conditions, making the adaptation of innovative and digital solutions an essential requirement.

One of the priority directions in this transformation is the adoption of information and communication technologies (ICT). The development of ICT in Azerbaijan is reflected in relevant strategic roadmaps, which define short-, medium-, and long-term goals for digital transformation. Although certain progress has been achieved—such as the establishment of e-government services, digital platforms, and electronic service packages—the pace of ICT diffusion remains uneven, particularly in rural and regional areas where access to high-speed internet and digital infrastructure is limited. This constraint is especially evident among small and medium-sized enterprises, including agricultural producers, whose ICT adoption is often hindered by traditional practices, limited awareness, insufficient skills, and lack of training. [1].

The application of ICT in agriculture offers significant opportunities, including enhanced farm productivity, real-time monitoring of crops and livestock, efficient resource management, and improved decision-making through data-driven tools such as remote sensing and drone technologies. However, the effective use of these technologies requires not only financial resources, but also appropriate legal frameworks, regulatory mechanisms, and institutional support. Issues related to the legal use of digital tools, data security, and standardization remain critical challenges.

Since the restoration of independence, Azerbaijan has implemented comprehensive agrarian reforms aimed at improving land use efficiency and strengthening the legal foundations of agricultural development. The adoption of key legislative acts, including the Law of the Republic of Azerbaijan “On the Basics of Agrarian Reform” (1995) and the Law “On Land Reform” (1996), laid the groundwork for restructuring the agrarian sector in line with international experience. In the current stage, integrating ICT into agriculture represents a logical continuation of these reforms and a crucial factor in enhancing productivity, sustainability, and competitiveness of the sector.

Following the launch of Azerbaijan’s oil strategy, large-scale structural reforms were gradually implemented across the national economy, with the agrarian sector emerging as one of the areas demonstrating substantial socio-economic returns. The rational utilization of agricultural land, targeted state support for small and medium-sized farmers, land distribution mechanisms, and the simplification of administrative procedures contributed to measurable improvements in agricultural productivity. Tax incentives and other support instruments encouraged the establishment of new agricultural enterprises and facilitated the expansion of processing capacities.

As the country’s independent agrarian policy evolved, the development of a comprehensive legal framework became a central priority. Ensuring food security—particularly with regard to grain and wheat production—was identified as a strategic objective. In this context, the adoption of the Law of the Republic of Azerbaijan “On Grain” in 2000 established institutional and regulatory foundations for supporting grain production, attracting private investment, and introducing modern agricultural technologies. Subsequent legislative acts, including temporary tax exemptions for agricultural producers, the introduction of leasing mechanisms, and preferential financing instruments, further strengthened incentives for production growth and investment activity. [2].

From the early 2000s onward, the modernization of agriculture increasingly incorporated the application of information and communication technologies. Policy measures aimed at technology transfer, human capital development, and digitalization of production and marketing processes gradually recognized ICT as a key driver of efficiency. The need to reduce post-harvest losses, optimize supply chains, and improve market access highlighted the importance of electronic tools and platforms. In this regard, the adoption of the Law “On Electronic Commerce” in 2005 provided a legal basis for digital transactions and the use of electronic resources in agricultural trade.

A significant turning point in the digital transformation of the agrarian sector occurred with the Presidential Decree of April 16, 2014, which focused on improving sectoral governance and accelerating institutional reforms. The establishment of the Electronic Agriculture System within the Ministry of Agriculture enhanced transparency, strengthened management efficiency, and expanded access to electronic services. The subsequent development of an integrated electronic agricultural information system enabled more effective data management, supported innovation diffusion, and facilitated evidence-based decision-making. [4].

Overall, the progressive integration of ICT into agriculture has contributed to improving productivity, modernizing management practices, and reinforcing cooperative relations within the sector. In this context, the adoption of the Law “On Agricultural Cooperation” in 2016 played an important role in revitalizing cooperative structures and aligning agricultural development with contemporary digital and institutional standards.

At the current stage, the primary objective of agricultural development in Azerbaijan is the effective integration of farms, agricultural entrepreneurs, cooperatives, public associations, and individual producers into coordinated and efficient economic structures. Achieving this goal requires the formation of sustainable collectives, the extensive application of modern high technologies, and the

prioritization of ICT-based operational mechanisms. Such an approach reflects contemporary development requirements and responds to the growing complexity of agricultural production systems.

The active engagement of the state in regional development—through continuous field visits, infrastructure development, targeted financial allocations, and the adoption of relevant presidential decrees—has significantly contributed to increasing economic activity in rural areas. These measures have also laid a solid foundation for the expansion of digital technologies and strengthened demand for transparency, accountability, and inclusiveness, which are essential elements of an information-based society. [5].

The implementation of the State Program for the Development of the Information Society (2016–2020) played an important role in stimulating civil society participation, identifying structural challenges, and supporting the emergence of new sources of economic growth. In parallel, the establishment of the Agrarian Research Center in 2018 marked a transition toward evidence-based and scientifically grounded agricultural development. Institutional reforms were further strengthened through the creation of new organizational structures aimed at improving supply chains, reducing inefficiencies in product distribution, and enhancing market regulation, while simultaneously emphasizing the role of ICT in modern governance models.

Improving access to information, promoting the adoption of innovative technologies, and expanding agrarian services have become key priorities for increasing productivity and minimizing production losses. In this context, the establishment of the Agrarian Services Agency in 2019 significantly expanded advisory, technical, and digital support services for agricultural producers, particularly in rural regions.

Agriculture remains a high-risk sector due to climatic uncertainties, natural disasters, and market volatility, which often constrain investment activity. The development of transparent and efficient agricultural insurance mechanisms is therefore essential for mitigating risks and encouraging the adoption of advanced technologies. The adoption of the Law “On Agricultural Insurance” in 2019 created new opportunities for protecting farmers against losses and enhancing investment confidence, thereby indirectly supporting the diffusion of ICT-based solutions.

A new dimension of agricultural modernization has emerged following the liberation of previously occupied territories. The establishment of the Karabakh and Eastern Zangezur economic regions, both characterized by substantial agricultural potential, has enabled the implementation of pilot projects based on smart technologies. Infrastructure reconstruction, the development of industrial parks, smart village initiatives, and digitally driven agrarian projects indicate that ICT will play a decisive role in the economic revitalization of these regions. [6].

The challenges posed by the COVID-19 pandemic, climate change, land degradation, and increasing global food demand further highlight the necessity of ICT-driven agricultural development. Automated livestock farms, precision irrigation systems, digital monitoring platforms, and data-based management models offer viable solutions for improving efficiency, reducing losses, and ensuring sustainability. International experience confirms that smart agriculture contributes to productivity growth, cost optimization, and profitability enhancement.

Despite significant industrial and energy-sector development, Azerbaijan remains a country with a strong agrarian character, where a substantial share of the population resides in rural areas. Agriculture plays a crucial role in employment, food security, and poverty reduction. However, global warming, resource constraints, and demographic pressures impose new demands on the sector, requiring a transition toward science- and technology-based growth models.

In this context, digitalization—understood as the integrated application of ICT across agricultural production, management, and distribution—emerges as a strategic tool for enhancing resilience, sustainability, and competitiveness. The adoption of smart technologies enables more accurate forecasting, preventive decision-making, efficient resource use, and environmentally responsible production practices. Consequently, accelerating ICT adoption in agriculture is not only a technological choice but also a strategic necessity for ensuring long-term food security and inclusive economic development in Azerbaijan.

Given agriculture's strategic significance, ongoing agrarian reforms in Azerbaijan must increasingly leverage modern information and communication technologies (ICT). Digitalization has already fostered structural improvements in the sector, including stabilized investment levels, heightened competition among producers, and wider adoption of ICT tools across the agro-industrial complex. Simultaneously, the rapid accumulation of data has created a pressing need for advanced analytical systems capable of precise information processing and evidence-based decision-making, particularly in rural areas. [7].

Innovation adoption in agriculture is not merely beneficial but essential. Beyond ensuring food production, the sector underpins rural development, employment generation, income growth, and social stability. Harnessing digital technologies accelerates agricultural advancement while generating multiplier effects across the economy: diversifying economic activities, reinforcing the non-oil sector, enhancing export potential, stimulating regional economic activity, and promoting innovative entrepreneurship.

Effective ICT deployment, however, depends on robust digital infrastructure, including high-speed internet access in rural and remote areas. While Azerbaijan has begun developing the conceptual and institutional foundations for ICT integration, further efforts are necessary to adapt global best practices to national priorities. Sustained public investment, policy consistency, and inter-institutional coordination are therefore critical for fully realizing ICT's potential across the economy, particularly within agriculture.

ICT expansion also contributes to reducing import dependency, strengthening food security, and increasing resilience against global challenges such as climate change, resource scarcity, and population growth. Digital technologies facilitate precision agriculture, automated management, optimized resource allocation, and minimized production losses, promoting sustainable and environmentally responsible growth. [8].

Comprehensive economic diversification and innovation-driven development require a holistic approach that combines investment-friendly policies, regional ICT infrastructure, and human capital development. Training skilled specialists and enhancing digital literacy among agricultural producers is as important as establishing physical infrastructure, since technological investments are only as effective as the human capacity to utilize them. [9].

In today's global economy, sustainable development and competitiveness are inseparable from ICT. Digitalization has become a transformative force, reshaping production, management, and market dynamics. In agriculture, ICT enables real-time monitoring, risk management, productivity optimization, and proactive decision-making under uncertain conditions. [11]

Azerbaijan's strategic policy documents since the mid-2010s underscore digital transformation as a national priority across all sectors, including agriculture. These policies emphasize the adoption of electronic services, data-driven governance, and digital integration within production and processing activities, recognizing agriculture as a sector where ICT adoption yields significant socio-economic returns.

Currently, new development models and region-specific strategies are increasingly necessary for agricultural planning, particularly in rural and reconstructed territories. Expanding access to ICT tools, networks, and digital platforms in farms, agro-processing facilities, and villages can enhance management efficiency. Implementing smart management systems, remote monitoring, and data-based resource optimization represents a practical path toward intensified and sustainable agricultural development.

Achieving these goals requires that ICT development remain a national priority, supported by investments in innovation ecosystems, digital infrastructure, and technology markets. Establishing ICT-driven technoparks, agro-industrial zones, agricultural clusters, and special economic zones can accelerate the diffusion of digital solutions and reinforce the role of smart agriculture within Azerbaijan's long-term economic strategy.

Currently, Azerbaijan has established 51 agrarian parks, with several more in the process of formation across the country. These parks benefit from ten-year tax and customs concessions. While

these measures represent a progressive approach, many of the existing agroparks remain similar to conventional farms and agricultural enterprises. A key reason for this limited differentiation is the underutilization of ICT mechanisms.

The approach to digital technologies is gradually becoming conceptual, shifting focus from central state structures to regional and local units, private sector participants, and state-owned enterprises. Expanding ICT usage across these levels has become a priority. Achieving this requires assessing the current national situation in the context of global changes and risks and identifying effective strategies to enhance the economic efficiency of ICT in the agricultural sector—particularly in territories recently liberated from occupation, which will be addressed in the final section.

There is an urgent need to increase productivity, optimize resource use, and update agricultural mechanisms by integrating globally tested and proven technologies. International experience highlights various approaches, and their adaptability to Azerbaijan's context will be further discussed later. Looking forward, the country should enter a more advanced phase of economic reforms and technological innovation. Beyond the oil and gas sector, other economic sectors should be modernized, ICT adoption deepened, and digital mechanisms intensified. [3]

Modeling the agricultural sector's activities to develop more profitable and efficient mechanisms is critical for increasing profitability. Existing stereotypes and inefficiencies must be addressed systematically. The agricultural sector should not be perceived solely as reliant on subsidies or preferential support, even though such practices exist globally. Azerbaijan, operating within a market economy framework, must prioritize efficiency. Accordingly, the sector should adopt technological innovations and ICT tools to optimize costs, balance incomes among production participants, and create additional incentives for food production. Achieving this requires intensifying institutional and structural reforms, updating regional economic priorities, and aligning them with current challenges. It also demands integrating digital mechanisms, "smart" technologies, and innovation-driven approaches to unlock added value and financial resources while contributing to broader economic and social development.

In the liberated Karabakh and Eastern Zangezur economic regions, large-scale infrastructure development and socio-economic rehabilitation are underway. Projects include constructing industrial and agro-processing parks, developing the Araz Valley Economic Zone, restoring electricity, water, and gas supply systems, building residential areas, and expanding transport infrastructure, including Fuzuli International Airport and planned Zangilan and Lachin airports. The Zangezur Corridor, connecting Azerbaijan to the Nakhchivan Autonomous Republic, also forms a strategic component of regional development. Within these initiatives, prioritizing ICT-based mechanisms in the agricultural sector is crucial for enhancing efficiency, accelerating employment recovery following population resettlement, and expanding the sector's economic role in regional development. [12].

State programs, including the "State Program for Socio-Economic Development of the Regions of the Republic of Azerbaijan for 2019–2023," emphasize increasing economic activity, particularly within the non-oil agricultural sector, modernizing it through high technologies, and improving productivity. Likewise, Azerbaijan's "National Priorities for Socio-Economic Development 2030" [February 2, 2021] underscore post-pandemic priorities such as accelerating socio-economic development, enhancing economic security under global risks, ensuring food security, and diversifying the national economy. The efficient use of high technologies, including ICT, is central to achieving these goals [12][10].

Productive use of digital technologies enables efficient resource utilization, greater diversification of agricultural activities, and enhanced performance across production areas. Key measures include scientific land management, cultivation of high-quality seed varieties, adoption of productive machinery and techniques, and optimization of technological processes. Furthermore, the active application of ICT in all areas of agricultural activity—including information collection, systematization, processing, software development, automation, and electronic service provision—creates additional incentives for improving efficiency, increasing transparency, and fostering better operational conditions for agricultural enterprises.

Conclusion and Suggestions

The study analyzed the priorities and mechanisms for increasing the efficiency of ICT in agriculture, highlighting both theoretical approaches and practical applications. Given the strategic role of the agricultural sector in ensuring food security and socio-economic development, the integration of ICT remains a critical factor for modernizing the sector.

Key findings and recommendations are as follows:

1. ICT use in agriculture is still at an early stage, and there is a need to expand its role through sustainable and innovative mechanisms.
2. Comprehensive measures are required to optimize production processes, reduce losses, improve competitiveness, and align state policies with modern challenges.
3. Leveraging global ICT experiences and “smart” technologies can enhance investment attractiveness, efficiency, and innovation in the sector.
4. Production resources, machinery, technologies, and methodological approaches should be systematically assessed to maximize productivity from raw materials to processed products.
5. Expanding ICT infrastructure—including broadband Internet, advanced digital tools, and information systems—will diversify economic benefits and create new sources of added value.
6. Digital platforms such as e-services, e-commerce networks, and e-export portals can increase efficiency, stimulate production, and integrate resources into the value chain.
7. High-tech projects in Karabakh and Eastern Zangezur demonstrate the potential of ICT; pilot projects in all regions can support the wider adoption of productive technologies.
8. Establishing “smart” management systems, agribusiness centers, specialized production complexes, and incentives for private and foreign investments will further enhance ICT-driven development in agriculture.

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