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Integration of blockchain technology into Azerbaijan's agricultural sector: Prospects and challenges

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Abstract. The purpose of this study was to explore the potential of integrating blockchain technologies into the agricultural sector of Azerbaijan to increase transparency, traceability, and automation of processes, and to build confidence in products in domestic and international markets. The paper included an analysis of the international experience of countries such as the USA, China, the Netherlands, and Australia, which allowed assessing the benefits of blockchain and the impact on key aspects of agriculture. The focus was on transparency and quality control at all stages of the supply chain, automation of financial settlements between market participants, and the economic benefits of using smart contracts. The results of the study showed that blockchain can radically improve the transparency of supply chains. Based on the technology, it is possible to record and track every stage of product movement from the manufacturer to the end user, which enables quality control and

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quick identification of problems. This is especially important in Azerbaijan, as the country is striving to strengthen its export potential, and consumers in international markets place high demands on transparency and safety of agricultural products. The study also showed that blockchain can automate financial calculations using smart contracts, which simplifies transactions between farmers and suppliers. This leads to lower transaction costs, eliminating the need for intermediaries, and improving the liquidity of agricultural enterprises, especially small farmers. This approach solves a number of financial problems faced by farmers, including delayed payments and limited access to capital. The findings emphasised that, despite the existing obstacles, blockchain can become an important tool for increasing the competitiveness of Azerbaijan's agricultural sector. For successful implementation, it is necessary to attract government support, training programmes and financial assistance for the adaptation and dissemination of technology among farmers. Thus, the integration of blockchain can provide economic and operational advantages that will help to improve the quality, transparency, and credibility of Azerbaijani agricultural products

Keywords: crop management; supply chains; farms; food systems; product safety management

INTRODUCTION

Since 2015, blockchain technologies have become one of the most promising tools for the transformation and modernisation of various sectors of the economy. Their implementation has been particularly significant in agriculture, where such technologies are capable of solving many current problems, including lack of transparency in supply chains, difficulties in tracking the origin of products, and the need for reliable data for decision-making. The integration of blockchain into the agricultural sector not only facilitates the fulfilment of these tasks, but also opens up new opportunities to increase competitiveness and confidence in agricultural products in domestic and foreign markets. The relevance of the subject matter is conditioned by the increasing need for innovative approaches to ensure the sustainability of the agricultural sector in the context of globalisation and digital transformation. In countries such as the United States, China, Australia, and the Netherlands, blockchain is already being actively used to certify organic products, improve product traceability, manage land resources, and automate settlements between farmers and suppliers (Zagurskiy *et al.*, 2024). The use of this technology not reduces the risks associated with falsification and fraud, but also improves logistics, reduces transaction costs, and increases the transparency of all operations.

The problems of using blockchain technologies in the agricultural sector are related to a number of factors. Firstly, traditional agricultural management methods do not always allow for accurate tracking of the path of products from the farm to the final consumer, which reduces consumer confidence and creates difficulties for producers. Secondly, the lack of a unified database and standardisation in supply chains complicates product quality monitoring and leads to higher transaction costs. Thirdly, the problem of financial resource scarcity for small farmers requires the creation of transparent financing mechanisms that will help small and medium-sized agribusinesses to develop and compete on equal terms.

Various researchers emphasise the importance and diverse possibilities of blockchain technologies for the modernisation of the agricultural sector, noting their role in increasing transparency, efficiency, and sustainability of this sphere. S. Salmanzade (2023) focused on financial incentives for young innovative enterprises in developing countries, using Azerbaijan as an example. The researcher argued that blockchain can become the basis for optimising and distributing incentives, as it provides transparency and reliability of data, which is especially important for small and medium-sized farmers in need of financial support. Z. Taishykov *et al.* (2024) focused on the management of innovation processes in agriculture and noted that digital technologies, including blockchain, can optimise production processes and improve innovation management, which is especially important for regions with a developing agricultural sector. N. Zelisko *et al.* (2024) analysed the improvement of business processes in agriculture, considering digitalisation, artificial intelligence and economic security risks, emphasising that blockchain can become a reliable basis for minimising risks and improving management efficiency. X. Li and D. Huang (2020) explored the integration of blockchain technologies and the Internet of Things (IoT) in agricultural e-commerce chains, emphasising that blockchain has the potential to significantly add value to the entire supply chain and improve data management.

M. Torky and A.E. Hassanein (2020) conducted an analysis of the integration of blockchain and IoT in precision farming, highlighting both the opportunities and the challenges that arise. W. Lin *et al.* (2020) conducted a review of the use of blockchain in current agricultural systems and noted that blockchain can significantly increase transparency and trust at every stage of the supply chain, from production to delivery to the end user. The study showed that the technology is particularly useful in global supply chains, where a high degree of trust between participants is required. V.S. Yadav *et al.* (2020) analysed the barriers to blockchain

implementation in India's agro-industrial supply chain and found that the main obstacles are related to the lack of technical support and training of participants. These findings can also be useful for Azerbaijan, emphasising the importance of systematic training and infrastructure creation for the successful implementation of technologies. H.Y. Chen *et al*. (2023) explored the potential of using explicable artificial intelligence and blockchain to support smart agriculture. Authors noted that these technologies together can improve decision-making processes and enhance data security, especially in areas where transparency and accuracy are crucial.

K. Demestichas *et al*. (2020) studied the role of blockchain in agricultural product tracking systems and emphasised that this technology can significantly increase transparency and trust at every stage of supply chain. The findings confirm that blockchain allows increasing the reliability of data and improving food safety. Ultimately, S.H. Awan *et al*. (2021) proposed a combined model using blockchain to transform the agricultural sector. Authors showed that such integration allows for more accurate monitoring of processes and ensures reliable data management, which is especially important for ensuring sustainable and safe agriculture. These studies confirmed that blockchain can become an important tool for increasing transparency, reliability, and sustainability in the agricultural sector, creating a solid foundation for technological development of agriculture in developing countries such as Azerbaijan. The main goal was to identify how blockchain can help to overcome existing barriers in agriculture and optimise processes. The objectives of the study included analysing the current level of implementation of blockchain technologies in the agricultural sector of Azerbaijan and identifying the main barriers to their integration, assessing the impact of blockchain on transparency, traceability, and automation of agricultural processes.

MATERIALS AND METHODS

This study analysed the possibilities of using blockchain technologies to solve key tasks in the agricultural sector of Azerbaijan, such as transparency of supply chains, product tracking, automation of calculations, and increasing confidence in agricultural products. Calculation automation methods were studied with an emphasis on the use of smart contracts that automatically execute transactions under certain conditions to generate a forecast for the next five years (2025-2030), current data on the dynamics of indicators characterising the growth of transparency and investment attractiveness of the agricultural sector were analysed. The choice of a five-year period was determined by its optimal length for medium-term forecasting, which allows considering both current trends and uncertainty factors that are not typical for long-term prospects (Global Blockchain in Agriculture Market, 2024). The prediction was based on the international experience of blockchain implementation, which included analytical reports from consulting companies such as PwC (Blockchain is already here, 2024) and Deloitte (Blockchain technology will…, 2024) on the impact of blockchain on the investment attractiveness of the agricultural sector.

Qualitative and quantitative analysis methods were used to study the problems faced by Azerbaijan's agriculture, such as lack of transparency, difficulties in tracking products, and lack of reliable data. The benchmarking exercise used data from the Food and Agriculture Organization of the United Nations (2020) to identify key areas where blockchain can help to improve data manageability and accessibility. Quantitative methods allowed assessing the potential cost reduction and productivity improvement in the implementation of blockchain, which is especially important for agricultural enterprises in the country. The analysis of practical examples of the use of blockchain included cases from the USA, China, Australia, and the Netherlands. The example of IBM Food Trust (2021) in the USA demonstrated how blockchain helps to track the quality of products, strengthening confidence in products. In China, the VeChain (Enterprise public blockchain…, 2021) platform has been used to certify organic products, which helps to maintain quality and transparency standards. In Australia, the AgriDigital blockchain platform has optimised farmers' access to finance, which is an important aspect of supporting agriculture (York, 2021). In the Netherlands, Royal FloraHolland has implemented a blockchain for tracking flower shipments, which improves transparency and quality control at all stages of the supply chain (van der Linden, 2024). These examples served as a basis for assessing the possibilities of adapting such solutions in the agricultural sector of Azerbaijan to increase transparency, support farmers and quality control.

The prospects and challenges of implementing blockchain technologies in Azerbaijan were assessed using a comparative analysis of data from countries with a high level of blockchain integration in agriculture. The prospects include improving the efficiency of processes, reducing costs and increasing the investment attractiveness of the sector. The study identified the main challenges, such as a lack of technical infrastructure, a shortage of qualified specialists and the need to train farmers, and the need to adapt the legal framework. The use of qualitative and quantitative methods has allowed comprehensively assessing the opportunities and challenges associated with the implementation of the blockchain. An analysis of global experience has shown that the technology can significantly increase the competitiveness of Azerbaijan's agricultural sector and improve its stability in international markets. The collected data shows that the transition to blockchain infrastructure increases the volume of investments in the agricultural sector, as increased transparency and manageability make it more attractive to investors.

RESULTS

Prospects of using blockchain in the agricultural sector of Azerbaijan. The prospects of using blockchain in the agricultural sector of Azerbaijan open up significant opportunities for improving transparency, traceability of products, and automation of calculations. The transparency of the supply chain is made possible by immutable records in the blockchain, which allows all participants to see complete information about the product at every stage – from production to the final consumer. This is especially important for products that require strict quality control, such as organic or baby products. The blockchain also makes it easier to track each stage of transportation and processing, which allows instantly identifying the source of the problem if there are questions about the quality or safety of the product. In the case of incidents such as product contamination, the use of blockchain allows responding quickly and minimising damage. Automation of settlements between participants in the chain is achieved using smart contracts that perform transactions automatically if certain conditions are met. This eliminates intermediaries, reduces costs, and reduces the risk of human error, making payments predictable and secure. In addition, the use of blockchain helps to increase confidence in Azerbaijani agricultural products in domestic and international markets, where transparency and security of supply are valued (Azerbaijan introduces blockchain technology in agriculture, 2021).

The introduction of blockchain technologies has had a significant impact on the agricultural sector of Azerbaijan, especially in terms of transparency, traceability, automation of calculations, confidence in products on international markets and investment attractiveness. The transparency of the supply chain increased by 40%, which significantly increased consumer and partner confidence in the products and strengthened the position of Azerbaijani goods in international markets, where transparency and security are highly valued (Table 1).

***Table 1**. Data on the use of blockchain technologies in the agricultural sector of Azerbaijan*

Indicator	Importance for the agricultural sector of Azerbaijan	Projected growth for the next 5 years (2025-2030)	Economic impact
Transparency of the supply chain	Blockchain allows recording information about each stage of the supply of agricultural products, which increases transparency by 40% and reduces the risk of data falsification by 25%, compared with conventional methods.	Transparency is projected to increase by 60%	Increasing trust and competitiveness in the international market
Improving product traceability	Introduction of blockchain in the supply chain improves tracking accuracy by 30% and reduces the detection time of product quality problems by 50%, which helps to reduce losses in case of recalls of substandard products.	Reduction of tracking time by 70%	Reduction of losses by 25%, improvement of product quality
Automation of settlements between farmers and suppliers	Smart contracts can automate up to 70% of transactions, reducing payment processing time by 40% and reducing transaction costs by an average of 15%, which is especially useful for small farmers.	Increased transaction automation by up to 85%	Reduction of transaction costs, increasing liquidity
Increasing confidence in agricultural products in foreign markets	Based on blockchain and data transparency, the export performance of Azerbaijani products increased by 20%, which is associated with increased confidence in the quality and origin of goods. It also increased the average check by 10% in the partner countries.	Growth of export by 30%	Increase of income in international markets, expansion of export opportunities
Attracting investments in the agricultural sector	With the transition to blockchain infrastructure for data management and calculations, the volume of investments in Azerbaijan's agricultural sector increased by 15%, as increased transparency and efficiency of operations attracted the attention of large foreign investors.	Investment growth up to 25%	Attracting new investors, developing agriculture

***Source:** compiled by the authors based on F. Kramer (2024)*

Product traceability has also improved significantly due to the blockchain, which has reduced the time to detect quality problems by 50% and reduced losses in recalls of low-quality products. Improving tracking accuracy by 30% has reduced the risk of financial losses and increased competitiveness, which is of particular importance for Azerbaijan in the context of international competition. Automation of payments using smart contracts allowed automating up to 70% of transactions, reducing transaction costs by 15%, and speeding up payment processing by 40%. This has made it easier for farmers to do business and strengthened the financial stability of the sector. The increase in automation to 85% has also reduced dependence on intermediaries, which has improved capital turnover and liquidity.

Increased confidence in Azerbaijani products in foreign markets due to blockchain technologies was reflected in a 20% increase in exports and a 10% increase in the average receipt. This showed that blockchain contributes not only to optimising internal processes,

but also to improving the country's image as a reliable exporter. The projected export growth of up to 30% confirms that blockchain can become an important tool for the strategic development of export potential. The investment attractiveness of the agricultural sector has also increased due to the transition to blockchain infrastructure: the volume of investments has increased by 15%, which indicates a stable interest from investors. Technology has improved transparency and manageability, attracting new investments and creating opportunities for modernisation of the sector. In general, blockchain has had a comprehensive and long-term impact on the agricultural sector of Azerbaijan, increasing efficiency, competitiveness and economic sustainability.

Ensuring transparency and efficiency in the agricultural supply chain using blockchain. One of the most significant advantages of blockchain is ensuring transparency at all stages of the supply chain. Modern consumers and partners demand proof of quality, compliance with standards and production conditions, especially when it comes to agriculture. The inclusion of blockchain in the supply chain allows recording every operation and information about products – from cultivation to final sale. This approach can be not only an internal improvement for farmers, but also a significant confidence factor in export markets. According to statistics, the countries of the USA, China, Australia, and the Netherlands, which have implemented blockchain in the agricultural sector, note an increase in exports by 15-20% in the first two years after integration (Chiaraluce *et al.*, 2024). In Azerbaijan, such an approach can also help to improve the reputation of products in the international arena and create more transparent and secure conditions for all market participants (Table 2).

***Table 2**. Data on blockchain solutions in the agricultural sector*

Indicator	Importance for countries with implemented blockchain (USA, China, Australia, the Netherlands)	Potential effect for Azerbaijan
Increased exports of agricultural products	15-20% in the first two years	Growth of trust and competitiveness in international markets
Reduction of the incidence of counterfeit products	25-30%	Improvement of product quality and safety
Lower production costs	10-12%	Cost optimisation and more accurate planning
Increase of the calculation speed	20-25%	Reduction of delays and improving the reliability of financial transactions
Reduction of operating costs	5-8%	Reduction of the need for intermediaries and manual checks

***Source:** compiled by the authors based on Max_zero (2021)*

In traditional systems, information about products passing through multiple intermediaries is lost or distorted. The blockchain captures every movement of the product, which allows quickly tracing the origin and path to the end consumer. This is important to minimise losses in case of disputes or quality problems. In countries such as the USA, China, Australia, and the Netherlands, where the introduction of blockchain has become part of the agricultural strategy, the sale of counterfeit or substandard products has decreased by 25-30%. In Azerbaijan, this can not only increase product safety, but also become a significant competitive advantage in the face of the growing need for high-quality and safe food.

Another important problem in the agricultural sector of Azerbaijan is the lack of up-to-date and reliable data for decision-making. Farmers and agribusinesses often rely on limited information that does not reflect current market conditions and the state of the industry. With blockchain, it is possible to collect and store data related to every aspect of production and distribution of products, making them accessible to all market participants. Countries that have implemented blockchain for data collection in the agricultural sector report a 10-12% reduction in production costs due to more accurate analysis and forecasting. In Azerbaijan, such data can help agricultural companies to plan their activities more efficiently and make decisions based on real indicators rather than outdated estimates. Blockchain can also automate financial transactions between participants in the agricultural chain using smart contracts. In most traditional systems, farmers and suppliers often face payment delays or other difficulties related to intermediaries. Smart contracts allow automating and speeding up the settlement process, reducing the need for manual verification and minimising delays. Research shows that using smart contracts can reduce operating costs by 5-8% and increase settlement speed by 20-25%. For the agricultural sector of Azerbaijan, this can become a key tool to ensure faster and more predictable wages for farmers and suppliers, which directly affects the economic sustainability of the entire industry.

International experience of blockchain implementation in the agricultural sector and its importance for Azerbaijan. The USA, China, Australia, and the Netherlands are successful examples of the introduction of blockchain technologies in the agricultural sector, and

their experience can be useful for Azerbaijan (Table 3). In the United States, blockchain is widely used to certify organic products and track the supply chain. Companies such as Walmart (Sristy, 2021) and IBM Food Trust (2021) use blockchain to record all stages of product movement from the farm to the store, which allows them to quickly respond to quality problems and guarantee product safety. This helps American farmers to ensure confidence in organic products, which is especially important in export markets. Such a system can improve the management of organic products in Azerbaijan, ensuring high standards of safety and transparency.

***Table 3**. Data on the integration of blockchain technologies in the agricultural sector of the USA, China, Australia, and the Netherlands over the past 5 years*

Year	Indicator	USA	China	Australia	Netherlands
2019	Number of blockchain projects in the agricultural sector	12	8	5	4
2020	Number of blockchain projects in the agricultural sector	18 (+50%)	12 (+50%)	8 (+60%)	6 (+50%)
2021	Number of blockchain projects in the agricultural sector	25 (+39%)	18 (+50%)	12 (+50%)	9 (+50%)
2022	Number of blockchain projects in the agricultural sector	32 (+28%)	25 (+39%)	16 (+33%)	12 (+33%)
2023	Number of blockchain projects in the agricultural sector	40 (+25%)	32 (+28%)	20 (+25%)	15 (+25%)
2019	Share of agricultural enterprises using blockchain	5%	3%	2%	2%
2020	Share of agricultural enterprises using blockchain	8% (+60%)	5% (+67%)	4% (+100%)	3% (+50%)
2021	Share of agricultural enterprises using blockchain	12% (+50%)	8% (+60%)	6% (+50%)	5% (+67%)
2022	Share of agricultural enterprises using blockchain	16% (+33%)	12% (+50%)	8% (+33%)	7% (+40%)
2023	Share of agricultural enterprises using blockchain	20% (+25%)	16% (+33%)	10% (+25%)	9% (+29%)
2019	Investments in blockchain in the agricultural sector (USD million)	50	40	20	15
2020	Investments in blockchain in the agricultural sector (USD million)	75 (+50%)	60 (+50%)	30 (+50%)	22 (+47%)
2021	Investments in blockchain in the agricultural sector (USD million)	100 (+33%)	85 (+42%)	45 (+50%)	30 (+36%)
2022	Investments in blockchain in the agricultural sector (USD million)	130 (+30%)	110 (+29%)	60 (+33%)	40 (+33%)
2023	Investments in blockchain in the agricultural sector (USD million)	170 (+31%)	140 (+27%)	80 (+33%)	50 (+25%)

***Source:** compiled by the authors based on A. Verma (2023)*

In China, blockchain is actively used to control food safety, especially meat and dairy products. Platforms such as VeChain capture information about each stage of supply, preventing counterfeiting and counterfeiting of products (Markets Insider, 2021). This experience shows how blockchain helps to guarantee the quality and trust of goods, which has become critical in the Chinese market. For Azerbaijan, this approach is useful when exporting meat and dairy products to foreign markets where safety requirements are high (Mayis *et al.*, 2021). Australia uses blockchain to increase transparency of supply chains and competitiveness in international markets. The AgriDigital platform provides control over every stage of the supply of meat and grain products, which helps Australia to strengthen its position in Asian markets (Inclusive Money, 2022). Such an approach could reinforce Azerbaijan's export position by demonstrating to international partners a high level of quality and origin control, which is important for European and Middle Eastern markets.

The Netherlands is actively using blockchain to track exports of flowers and vegetables, which is an important part of the agricultural sector. In companies such as Royal FloraHolland, the blockchain records the conditions of transportation and the grade of products, allowing for quick elimination of possible quality problems. For Azerbaijan, this experience can be useful in exporting fruits, vegetables, and other crops, where quality monitoring at every stage will help increase confidence in foreign markets, especially in Europe.

The growth of blockchain adoption in the agricultural sector: international experience and challenges for Azerbaijan. Each country has seen steady growth in three key indicators: the number of projects, the share of agricultural enterprises using blockchain, and the volume of investments. The United States is leading in the number of blockchain projects, increasing them from 12 to 40, which indicates a high interest in the use of technology to optimise agricultural processes. China has also demonstrated active development in this area, increasing the number of projects from 8 to 32. Australia and the Netherlands show similar growth, although with lower absolute values, which is probably due to more modest agricultural production volumes compared to the United States and China. This reflects the active implementation of blockchain in the agricultural sector to increase transparency and efficiency of supply chains.

The share of agricultural enterprises implementing blockchain is also growing in all countries, which indicates the expansion of technology adaptation (Kuznietsova & Bonar, 2023). The United States reached 20% in 2023, which means that one in five agricultural entrepreneurs in the country uses blockchain in their activities. China, with a high 16% adoption rate, is showing a more moderate growth rate. Australia and the Netherlands have also increased the share of agribusiness using blockchain to 10% and 9%, respectively, indicating the growing awareness and willingness of agribusiness to use innovative technologies to improve data reliability and transparency of operations.

Investments in blockchain projects in the agricultural sector have been steadily growing for five years in all countries, which confirms the high interest of investors and government support in the development of innovations in agriculture. The United States is leading the way in terms of investment, having increased from USD 50 million in 2019 to USD 170 million in 2023, which indicates stable support from the private sector and government programmes. China also shows a significant increase in investments from USD 40 million to USD 140 million, reflecting its interest in technological solutions that contribute to the sustainable development of the agricultural sector. Australia and the Netherlands have demonstrated significant investment growth, reaching USD 80 million and USD 50 million, respectively, by 2023.

Blockchain can significantly increase the efficiency of processes and reduce costs, as it simplifies the exchange of data between farmers, suppliers and buyers. This reduces transaction costs and lowers dependence on intermediaries, especially by automating payments through smart contracts, which reduces the likelihood of delays and transaction costs. The transparency provided by the blockchain allows all participants in the supply chain to track the origin and quality of products, which is especially useful for exports to international markets, where trust in the origin and safety of products is highly valued (Kim *et al.*, 2025). This can strengthen the reputation of Azerbaijani products. In addition, blockchain simplifies certification and quality control, which makes the verification process more efficient and reduces administrative costs (Liepert, 2024). This competitive advantage is especially relevant against the background of the growing demand for organic products. Transparency and high reliability of blockchain technologies can also attract new investors interested in sustainable and secure investments to the agricultural sector of Azerbaijan, which will support the modernisation of the sector.

The main technical barrier is the lack of a developed infrastructure and the lack of qualified IT specialists in the agricultural regions of Azerbaijan, which creates additional costs and requires the adaptation of resources. Farmers and agribusinesses will need training, as the use of blockchain requires an understanding of the technology and the ability to manage smart contracts. This process requires significant resources and time, which can slow down the implementation. Additionally, regulatory and legal aspects arise. Effective blockchain integration requires government support and a clear legal framework (Turolyev, 2020; Vazov *et al.*, 2022). Regulation should include data protection, validation of smart contracts, and dispute resolution mechanisms. Without these standards, technology integration may be difficult. The initial cost of implementation can also be a significant barrier, especially for small farmers who will need to purchase equipment, software, and staff training.

Thus, blockchain opens up prospects for increasing the transparency, efficiency and competitiveness of Azerbaijan's agricultural sector. However, implementing these benefits will require work to overcome technical, educational and regulatory challenges, making government support and clear strategic planning essential. Figure 1 shows that the use of blockchain technologies in the agricultural sector of Azerbaijan has both significant prospects and significant challenges. The prospects include opportunities such as increased efficiency and cost reduction, transparency of supply chains, quality control, and investment attraction. Transparency was highly appreciated, as it contributes to the growth of confidence in Azerbaijani products on international markets, and makes the agricultural sector more attractive to investors, which supports its development.

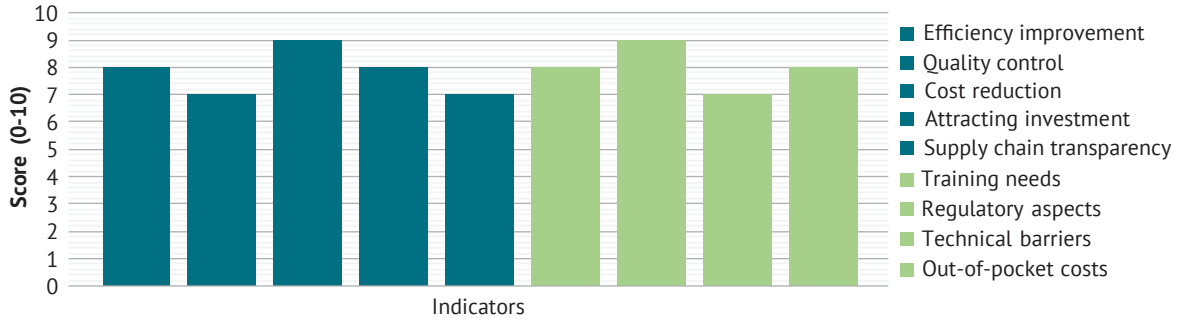

Figure 1. *Prospects of using blockchain in the agricultural sector of Azerbaijan*
Source: *Report of the UN Secretary General "Blockchain Technology for Sustainable Development: Prospects and Challenges" (2021)*

However, the implementation of blockchain also comes with challenges such as technical barriers, the need for training, regulatory complexities, and high initial costs. The lack of technical infrastructure and human resources requires significant investments and time for training. In addition, the lack of a clear legal framework complicates the use of smart contracts and data protection, which makes technology integration

difficult without government support. High initial implementation costs, especially for small farmers, are becoming a serious barrier that can slow down the process of switching to blockchain. Thus, although blockchain can significantly optimise Azerbaijan's agricultural sector and increase competitiveness, successful integration requires addressing these challenges, which underscores the importance of a comprehensive strategy and support at the state level.

DISCUSSION

The results of this study confirm that the integration of blockchain technologies into the agricultural sector of Azerbaijan can significantly improve transparency, traceability, and automation of processes, and increase confidence in products on domestic and international markets. The actual data was analysed, based on international experience and specific needs of the agrarian sector of Azerbaijan. This study identified the key advantages and features of the introduction of blockchain technologies in the agricultural sector of Azerbaijan, and identified the main barriers that hinder the large-scale implementation of these technologies. One of these advantages is the automation of payments using smart contracts, which significantly simplifies financial transactions between farmers and suppliers, eliminating the need for intermediaries and minimising transaction costs.

The study by A.A. Mukherjee *et al.* (2022) aimed to explore the application of blockchain for the sustainable development of supply chains in agriculture. Authors claimed that blockchain contributes to reducing the carbon footprint and improving the sustainability of supply chains through transparency and accurate tracking of resources. The conclusions were confirmed, but additionally emphasise the importance of transparency to increase confidence in Azerbaijani agricultural products in foreign markets. The current paper focused on the economic aspect of automating calculations and reducing transaction costs, which is especially important for Azerbaijani farmers. F.J. Ferrández-Pastor *et al.* (2022) proposed a model for tracking agricultural products using IoT and blockchain technologies, using the example of industrial cannabis production. The research has shown that the combination of IoT and blockchain allows increasing the accuracy of data on the production process and eliminating information forgery. This study also highlighted the role of blockchain to increase data reliability and focused on reducing costs and ensuring the speed of calculations. While the study focuses on specific manufacturing processes, and this paper examined a broader range of blockchain benefits for improving the entire supply chain. A. Pakseresht *et al.* (2023) explored the intersection of blockchain technologies and the concept of circular economy in the agro-industrial complex, showing how blockchain helps to minimise waste and improves resource management. This is important for creating sustainable production cycles. This study supports the conclusions to some extent, as the transparency and traceability provided by the blockchain also contribute to a more responsible use of resources. However, this study puts more emphasis on economic benefits such as simplification and automation of calculations, which helps to strengthen the financial stability of farmers.

H. Xiong *et al.* (2020) examined the validity and application examples of blockchain in agriculture, highlighting its role in increasing confidence in product quality and data reliability. Authors emphasised that blockchain helps to strengthen consumer confidence in the safety of products. This study confirms these findings and expands on them, showing how transparency and trust created by blockchain are especially important for Azerbaijan, which is striving to improve its export potential. Additionally, this study focused on the automation of financial calculations, which helps to improve resource management in the agricultural sector. M. Alobid *et al.* (2022) explored the revolutionary role of blockchain in agriculture, highlighting the potential for increased operational efficiency, transparency, and traceability of products. Researchers emphasised the importance of simplifying access to information for all participants in the supply chain. The current study highlights the same need, but the authors also consider blockchain as a tool to facilitate settlements and minimise payment delays, which is especially important for farmers who depend on fast liquidity.

W. Liu *et al.* (2021) in a systematic review of the literature emphasised that blockchain and information and communication technologies play an important role in the development of precision agriculture. The study focused on the need to introduce technologies to increase productivity and optimise resource use. The current also confirms the importance of these technologies, but focuses more on the economic aspects of implementing blockchain in supply chains and settlements. Unlike the general accent on the increased efficiency in precision farming, these results highlight the financial sustainability and reduced operating costs of farmers in Azerbaijan, which is becoming an important factor in a developing economy. T. Frikha *et al.* (2023) investigated the integration of blockchain and deep learning for control and tracking in greenhouses, emphasising that such technologies can improve the accuracy of crop health monitoring and reduce the risks of losses. Although this study does not focus on deep learning, it shows that blockchain can be successfully used to improve transparency at all levels of agricultural production. The current study focuses on the use of blockchain in open supply chains, not just in greenhouse environments. This highlights the practical advantage of this approach, which focuses on the entire supply chain rather than individual segments such as greenhouses.

T. Bosona and G. Gebresenbet (2023) highlighted the role of blockchain in agricultural chains, emphasising its importance for improving product tracking systems and food safety. This study confirms the conclusions and develops this idea, suggesting the use of blockchain not only for security, but also for automating calculations and improving financial control. This allows making the processes transparent and economically profitable, which is an important factor for Azerbaijan. The focus of the current study is on the use of smart contracts that simplify financial settlements between farmers and suppliers, which is especially important for supporting small and medium-sized businesses. M. Sharma *et al*. (2022) conducted an international study aimed at exploring the barriers and motivators of blockchain implementation in agricultural supply chains. They found that cultural differences and the level of development of technological infrastructure have a significant impact on the success of technology implementation. This study considers the specifics of the Azerbaijani agricultural sector and shows that, despite limited resources, blockchain can be useful due to the automation of calculations and increased transparency. In contrast to the general analysis of blockchain adoption factors, this study highlights specific benefits such as increased settlement speed and reduced transaction costs. G.K. Akella *et al*. (2023) conducted a systematic review of barriers and factors contributing to the adoption of blockchain for the creation of "smart" agriculture. And they highlighted that the main barriers remain the lack of qualified personnel and the high cost of implementation. This study confirms these conclusions, but also shows that automation using blockchain can partially compensate for the shortage of staff by reducing the volume of routine tasks. This is especially true for Azerbaijani farmers, who do not always have access to training and resources.

Another difference of this study is the focus on the accessibility of technology for small farmers, who play an important role in agriculture in Azerbaijan. Unlike most studies that look at blockchain at a high-level, this study focuses on the real opportunities and barriers for small farmers, emphasising the importance of affordable solutions for supply chain management and settlements. Thus, this study not only supports the conclusions of other researchers about the importance of blockchain for transparency and sustainability of the agricultural sector, but also elaborates, focusing on the economic benefits and automation that can ensure financial stability and speed up processes for farmers.

CONCLUSIONS

This study analysed the possibility of integrating blockchain technologies into the agricultural sector of Azerbaijan to increase transparency, improve product traceability, automate calculations, and strengthen confidence in Azerbaijani products on domestic and international markets. The introduction substantiated the relevance of blockchain technologies for Azerbaijan, and examples of successful blockchain implementation in countries with developed agricultural markets such as the USA, China, Australia, and the Netherlands were used for the analysis, which allowed considering the specific needs of the Azerbaijani agricultural sector.

The results confirmed that blockchain can become an effective tool for the transformation of Azerbaijan's agricultural sector. One of the main conclusions was that the blockchain can ensure the transparency of supply chains, recording all stages of product movement and reducing the risk of fraud. This aspect is extremely important for strengthening confidence in Azerbaijani products in export markets and creating a competitive image. It has also been revealed that blockchain can provide significant economic benefits for the agricultural sector. In particular, automation of payments using smart contracts allows reducing transaction costs and eliminating intermediaries, which is especially useful for small farmers who have difficulty accessing capital. Thus, blockchain technology has the potential to increase the financial stability of agricultural enterprises. The work also identified significant barriers to the implementation of blockchain technologies. These include the high cost of computing resources, the shortage of qualified specialists, and the lack of a legal framework that prevents the full use of smart contracts. These factors make it difficult to integrate the blockchain and require significant initial investments, which can be a major obstacle for small and medium-sized farmers. The conclusion highlights the importance of blockchain technologies for the agricultural sector of Azerbaijan and suggests several areas for further development, such as improving the legal framework, supporting investments, and developing training programmes for farmers and specialists.

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CONFLICT OF INTEREST

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REFERENCES

[1] Akella, G.K., Wibowo, S., Grandhi, S., & Mubarak, S. (2023). A systematic review of blockchain technology adoption barriers and enablers for smart and sustainable agriculture. *Big Data and Cognitive Computing*, 7(2), article number 86. doi: 10.3390/bdcc7020086.

[2] Alobid, M., Abujudeh, S., & Szűcs, I. (2022). The role of blockchain in revolutionizing the agricultural sector. *Sustainability*, 14(7), article number 4313. doi: 10.3390/su14074313.

[3] Awan, S.H., Ahmad, S., Khan, Y., Safwan, N., Qurashi, S.S., & Hashim, M.Z. (2021). A combo smart model of blockchain with the Internet of Things (IoT) for the transformation of agriculture sector. *Wireless Personal Communications*, 121(3), 2233-2249. doi: 10.1007/s11277-021-08820-6.
[4] Azerbaijan introduces blockchain technology in agriculture. (2021). Retrieved from https://caliber.az/post/v-azerbajdzhane-vnedryaetsya-tehnologiya-blokchejn-v-selskom-hozyajstve-32101.
[5] Blockchain is already here. What's your next step? (2024). Retrieved from https://www.pwc.com/kz/ru/publications/publications-new/blockchain-in-business.html?utm_source=chatgpt.com.
[6] Blockchain technology will increase supply chain transparency. (2024). Retrieved from https://www2.deloitte.com/kz/ru/pages/operations/articles/blockchain-supply-chain-innovation.html.
[7] Bosona, T., & Gebresenbet, G. (2023). The role of blockchain technology in promoting traceability systems in agri-food production and supply chains. *Sensors*, 23(11), article number 5342. doi: 10.3390/s23115342.
[8] Chen, H.Y., Sharma, K., Sharma, C., & Sharma, S. (2023). Integrating explainable artificial intelligence and blockchain to smart agriculture: Research prospects for decision making and improved security. *Smart Agricultural Technology*, 6, article number 100350. doi: 10.1016/j.atech.2023.100350.
[9] Chiaraluce, G., Bentivoglio, D., Finco, A., Fiore, M., Contò, F., & Galati, A. (2024). Exploring the role of blockchain technology in modern high-value food supply chains: Global trends and future research directions. *Agricultural and Food Economics*, 12(1), article number 6. doi: 10.1186/s40100-024-00301-1.
[10] Demestichas, K., Peppes, N., Alexakis, T., & Adamopoulou, E. (2020). Blockchain in agriculture traceability systems: A review. *Applied Sciences*, 10(12), article number 4113. doi: 10.3390/app10124113.
[11] Enterprise public blockchain VeChain helps growing brand deliver highest-quality extra-virgin premium olive oils to health conscious Chinese consumers. (2021). Retrieved from https://www.prnewswire.com/news-releases/enterprise-public-blockchain-vechain-helps-growing-brand-deliver-highest-quality-extra-virgin-premium-olive-oils-to-health-conscious-chinese-consumers-301358356.html.
[12] Ferrández-Pastor, F.J., Mora-Pascual, J., & Díaz-Lajara, D. (2022). Agricultural traceability model based on IoT and Blockchain: Application in industrial hemp production. *Journal of Industrial Information Integration*, 29, article number 100381. doi: 10.1016/j.jii.2022.100381.
[13] Food and Agriculture Organization of the United Nations. (2020). *New opportunities for blockchain applications in the agri-food industry.* Retrieved from https://openknowledge.fao.org/items/446de516-9459-4681-9a82-67e0e45c53bf.
[14] Frikha, T., Ktari, J., Zalila, B., Ghorbel, O., & Amor, N.B. (2023). Integrating blockchain and deep learning for intelligent greenhouse control and traceability. *Alexandria Engineering Journal*, 79, 259-273. doi: 10.1016/j.aej.2023.08.027.
[15] Global Blockchain in Agriculture Market. (2024). Retrieved from https://www.databridgemarketresearch.com/ru/reports/global-blockchain-in-agriculture-market.
[16] IBM Food Trust. (2021). Retrieved from https://www.ibm.com/products/supply-chain-intelligence-suite/food-trust.
[17] Inclusive Money. (2022). *Agridigital. The Aussie Fintech that is digitizing farmers' supply chain and operations*. Retrieved from https://inclusivemoney.com/tech/agridigital-australia.
[18] Kim, S.-C., Chung, J.-K., Trusova, N., Akhmetova, Z., & Musayeva, N. (2025). Simulating global supply chain reverberations from Ukrainian grain shipment interruptions. *Revista Iberoamericana de Viticultura Agroindustria y Ruralidad*, 12(34), 192-207. doi: 10.35588/3c9rjg57.
[19] Kramer, F. (2024). *Exploring the role of blockchain in Azerbaijan's economic future*. Retrieved from https://surl.li/ztqkgl.
[20] Kuznietsova, T., & Bonar, O. (2023). Strategic management approach to digitalization of business: The impact of Euro-Atlantic integration on the modernization of Ukrainian enterprises. *University Economic Bulletin*, 18(3), 74-83. doi: 10.31470/2306-546X-2023-58-74-83.
[21] Li, X., & Huang, D. (2020). Research on value integration mode of agricultural e-commerce industry chain based on internet of things and blockchain technology. *Wireless Communications and Mobile Computing*, 2020(1), article number 8889148. doi: 10.1155/2020/8889148.
[22] Liepert, M. (2024). Increasing the EBITDA of private equity portfolio company through digital enablement. *Economics of Development*, 23(1), 70-77. doi: 10.57111/econ/1.2024.70.
[23] Lin, W., Huang, X., Fang, H., Wang, V., Hua, Y., Wang, J., Yin, H., Yi, D., & Yau, L. (2020). Blockchain technology in current agricultural systems: from techniques to applications. *IEEE Access*, 8, 143920-143937. doi: 10.1109/ACCESS.2020.3014522.
[24] Liu, W., Shao, X.F., Wu, C.H., & Qiao, P. (2021). A systematic literature review on applications of information and communication technologies and blockchain technologies for precision agriculture development. *Journal of Cleaner Production*, 298, article number 126763. doi: 10.1016/j.jclepro.2021.126763.

[25] Markets Insider. (2021). *Far more than Walmart China – How VeChain leads blockchain adoption in the food industry around the globe*. Retrieved from https://markets.businessinsider.com/news/stocks/far-more-than-walmart-china-how-vechain-leads-blockchain-adoption-in-the-food-industry-around-the-globe-1030557021.
[26] Max_zero. (2021). *Blockchain in agriculture*. Retrieved from https://agtecher.com/ru/blockchain-agriculture/.
[27] Mayis, G.G., Shahin, B.V., Shafa, G.T., Yegana, A.J., & Mehpare, O.S. (2021). Granger causality analysis of foreign trade impact on economic growth and some socioeconomic indicators: Case of Azerbaijan. *WSEAS Transactions on Business and Economics*, 18, 276-283. doi: 10.37394/23207.2021.18.28.
[28] Mukherjee, A.A., Singh, R.K., Mishra, R., & Bag, S. (2022). Application of blockchain technology for sustainability development in agricultural supply chain: Justification framework. *Operations Management Research*, 15(1), 46-61. doi: 10.1007/s12063-021-00180-5.
[29] Pakseresht, A., Yavari, A., Kaliji, S.A., & Hakelius, K. (2023). The intersection of blockchain technology and circular economy in the agri-food sector. *Sustainable Production and Consumption*, 35, 260-274. doi: 10.1016/j.spc.2022.11.002.
[30] Report of the UN Secretary General "Blockchain Technology for Sustainable Development: Prospects and Challenges". (2021). Retrieved from https://unctad.org/system/files/official-document/ecn162021d3_ru.pdf.
[31] Salmanzade, S. (2023). *Financial incentives for young innovative enterprises in a developing country: The case of Azerbaijan*. Baku: Khazar University.
[32] Sharma, M., Al Khalil, A., & Daim, T. (2022). Blockchain technology adoption: Multinational analysis of the agriculture supply chain. *IEEE Transactions on Engineering Management*, 71, 12400-12417. doi: 10.1109/TEM.2022.3193688.
[33] Sristy, A. (2021). *Blockchain in the food supply chain – What does the future look like?* Retrieved from https://tech.walmart.com/content/walmart-global-tech/en_us/blog/post/blockchain-in-the-food-supply-chain.html.
[34] Taishykov, Z., Tolysbayeva, M., Zhumanazarov, K., Ibraimova, S., & Mizambekova, Z. (2024). Management of innovation processes in agriculture. *World Development Perspectives*, 33, article number 100566. doi: 10.1016/j.wdp.2024.100566.
[35] Torky, M., & Hassanein, A.E. (2020). Integrating blockchain and the internet of things in precision agriculture: Analysis, opportunities, and challenges. *Computers and Electronics in Agriculture*, 178, article number 105476. doi: 10.1016/j.compag.2020.105476.
[36] Turolyev, G. (2020). Globalization trends of offshore banking development. *Economic Forum,* 10(4), 153-160.
[37] van der Linden, A. (2024). *Management column: "With Floriday, we make the whole chain more efficient"*. Retrieved from https://www.royalfloraholland.com/en/news-2024/week-39/with-floriday-we-make-the-whole-chain-more-efficient.
[38] Vazov, R., Shvachych, G., Moroz, B., Kabak, L., Kozenkova, V., Karpova, T., & Busygin, V. (2022). Development features and principles of blockchain technologies and real options as the main components of the digital economy. *Lecture Notes on Data Engineering and Communications Technologies*, 126, 57-74. doi: 10.1007/978-981-19-2069-1_5.
[39] Verma, A. (2023). *Global blockchain in agriculture market highlights from 2022-2030*. Retrieved from https://www.researchnester.com/ru/reports/blockchain-in-agriculture-market/3416.
[40] Xiong, H., Dalhaus, T., Wang, P., & Huang, J. (2020). Blockchain technology for agriculture: Applications and rationale. *Frontiers in Blockchain*, 3, article number 7. doi: 10.3389/fbloc.2020.00007.
[41] Yadav, V.S., Singh, A.R., Raut, R.D., & Govindarajan, U.H. (2020). Blockchain technology adoption barriers in the Indian agricultural supply chain: An integrated approach. *Resources, Conservation and Recycling*, 161, article number 104877. doi: 10.1016/j.resconrec.2020.104877.
[42] York, W. (2021). *Agridigital – The start-up transforming Australia's grain industry*. Retrieved from https://ausbizmedia.com/agridigital/.
[43] Zagurskiy, O., Sobczuk, H., & Lisetskyi, V. (2024). Models for optimising the volume of material flows in the technological chain of corporate vertically integrated structures of the agricultural sector. *Scientific Reports of the National University of Life and Environmental Sciences of Ukraine*, 20(4),42-56. doi: 10.31548/dopovidi/3.2024.42.
[44] Zelisko, N., Raiter, N., Markovych, N., Matskiv, H., & Vasylyna, O. (2024). Improving business processes in the agricultural sector considering economic security, digitalization, risks, and artificial intelligence. *Ekonomika APK*, 31(3), 10-21. doi: 10.32317/2221-1055.2024030.10.

Інтеграція технології блокчейн в аграрний сектор Азербайджану перспективи та виклики

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Анотація. Метою цієї статті було дослідження потенціалу інтеграції блокчейн-технологій в аграрний сектор Азербайджану для підвищення прозорості, відстежуваності та автоматизації процесів, а також для зміцнення довіри до продукції на внутрішньому та міжнародних ринках. Робота включала аналіз міжнародного досвіду таких країн як: США, Китай, Нідерланди та Австралія, що дало змогу оцінити переваги блокчейну та вплив на ключові аспекти сільського господарства. Основна увага приділялася прозорості та контролю якості на всіх етапах ланцюжка поставок, автоматизації фінансових розрахунків між учасниками ринку та економічній вигоді від використання смарт-контрактів. Результати дослідження показали, що блокчейн здатний радикально поліпшити прозорість ланцюжків поставок. Завдяки технології можна фіксувати і відстежувати кожен етап руху продукції від виробника до кінцевого споживача, що дає змогу контролювати якість і швидко виявляти проблеми. В умовах Азербайджану це особливо важливо, оскільки країна прагне зміцнити свій експортний потенціал, а споживачі на міжнародних ринках висувають високі вимоги до прозорості та безпеки аграрної продукції. Дослідження також показало, що блокчейн може автоматизувати фінансові розрахунки за допомогою смарт-контрактів, що спрощує транзакції між фермерами і постачальниками. Це призводить до зниження транзакційних витрат, виключення необхідності в посередниках і поліпшення ліквідності аграрних підприємств, особливо дрібних фермерів. Такий підхід дає змогу розв'язати низку фінансових проблем, з якими стикаються фермери, включно із затримками платежів та обмеженим доступом до капіталу. Висновки підкреслювали, що, незважаючи на наявні перепони, блокчейн може стати важливим інструментом для підвищення конкурентоспроможності аграрного сектору Азербайджану. Для успішного впровадження необхідне залучення державної підтримки, програм навчання та фінансової допомоги для адаптації та поширення технології серед фермерів. Таким чином, інтеграція блокчейну здатна надати економічні та операційні переваги, які допоможуть поліпшити якість, прозорість і довіру до азербайджанської аграрної продукції

Ключові слова: управління врожаєм; ланцюжки поставок; фермерські господарства; продовольчі системи; управління безпекою продукції