Implementing Blockchain for Organic Crop Production: Certification and Monitoring in Serbia and Romania

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ABSTRACT

Organic production undoubtedly faces numerous challenges and difficulties, such as a complex and expensive certification process, counterfeiting of products and loss of consumer trust. All this affects the reputation of the sector and its sustainable growth and development. Modern technology is increasingly enabling the solution of various problems and challenges. The aim of the research of this paper is to investigate the current and potential application of blockchain technologies in the certification and monitoring of organic plant production by means of a comparative analysis, on the example of Serbia and Romania. Data were collected from secondary sources and divided into three categories: legal regulatory framework, technical technological infrastructure and production and economic indicators. Data analysis was conducted qualitatively and quantitatively, and the results showed that Serbia and Romania are at different levels in terms of institutional readiness and technical and technological capacities for the implementation of blockchain technologies. Therefore, an individual approach is needed for each of the countries. The recommendations for the implementation of blockchain solutions for the certification and monitoring of organic plant production emphasize a strategic approach that will allow Serbia and Romania to use their advantages.

Keywords: blockchain, organic certification, traceability, agricultural digitalization, sustainable agriculture.

INTRODUCTION

Changes in social and environmental priorities over the last two decades have resulted in the continued growth of organic production both in Europe and on other continents. Organic production is increasingly recognized as a key segment of sustainable agriculture (Meena et al., 2020). The benefits are:

• reduce the use of synthetic pesticides and artificial fertilizers (Verma et al., 2019);

• preserve soil fertility and biodiversity (Mäder et al., 2002);

• reduce greenhouse gas emissions (Squalli and Adamkiewicz, 2018; Gerke, 2025);

• stimulate the local economy and healthier consumer habits (Yue and Tong, 2009; Lazaroiu, et al. 2019).

Since the intention is to expand existing organic production, it represents a strategic direction in the development of agriculture. This direction balances economic objectives through production that is in demand on the market, environmental objectives through the preservation of natural resources and biodiversity, and social objectives through the quality of life of rural communities and the encouragement of sustainable social practices.

However, organic production faces numerous challenges (Srivastava et al., 2022; Pantović, 2025) such as the high costs and complexity of certification (Soares et al., 2012), the risk of counterfeiting and greenwashing (Dahl, 2010), and the loss of consumer trust (Thorsøe, 2015). The certification process is complex and involves production in accordance with numerous standards and regulations, which requires constant monitoring. In addition to the complexity of the process and administrative requirements, the above are also accompanied by high production costs. Counterfeiting, which involves falsely labeling products as organic when they are not, undermines market integrity, disrupts healthy competition, and perhaps most importantly, endangers consumer health. As a result, consumer trust is lost.

As a solution to the above challenges, new technological solutions are being introduced.

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One technology that is increasingly being recognized as a potential tool for solving these problems is blockchain. Blockchain represents a technology that enables immutability, and integrity of data in which a record of transactions made in a system are maintained across several distributed nodes that are linked in a peer-to-peer network (Viriyasitavat, 2019; Paunovic and Milunovic Koprivica, 2026).

Once entered, data cannot be changed without the consensus of all participants in the network, which makes this technology highly resistant to fraud. In the context of overcoming challenges, blockchain technology as a solution provides:

- Immutability of data that allows all steps in production from sowing, fertilization, transport, etc. to be permanently recorded (van Hilten et al., 2020);
- Transparency that (farm to fork) allows regulatory bodies, but also consumers, to track the product through all stages of the supply chain (Tegeltija et al., 2022);
- Automation of the certification and control process through the application of smart contracts (Dos Santos et al., 2021);
- Documentation of all resources used in production, which is important for preserving the integrity of organic production.

Therefore, the introduction of blockchain technology protects the interests of consumers, producers, and the entire sector. In addition to the advantages, there are also challenges in the application of blockchain technology, such as implementation costs, system scalability, etc.

To analyze the potential for and challenges in the application of blockchain technologies in the organic production sector, two countries in Southeastern Europe that are in transition were selected, namely Serbia and Romania. The two countries were selected to enable a comparative analysis based on both their shared characteristics and their distinct contexts, thereby offering a nuanced perspective on the research problem. As for common characteristics, these are countries that are mainly located on the Balkan Peninsula and have a similar climate, have a significant share of small and medium-sized agricultural holdings, insufficient technical equipment and difficulties in penetrating foreign markets. A significant difference relates to the fact that Serbia is not a member of the European Union, while Romania is. Nevertheless, both countries have seen a growing trend in organic production over the past 10 years (Tracxn, 2025a; 2025b). However, the digitalization of the sector is at an early stage, and transparency and efficiency in the value chain remain key challenges. This is where blockchain technology finds its place.

The aim of the research is a comparative analysis of the application and possibilities of blockchain technology in certification and monitoring systems for organic crop production in Serbia and Romania.

The advanced chapter will discuss the methods and methodology used in the research, where the research framework is explained in detail. The research results are presented in a table and provide an overview of the application and possibilities of blockchain in the certification and monitoring systems of organic crop production in Serbia and Romania. The discussion comments on the obtained results, from which conclusions and directions for future research are finally drawn.

MATERIAL AND METHODS

Research design

This research was conducted as a comparative study of the application of blockchain technology in the certification and monitoring systems of organic crop production in two countries: Serbia and Romania. This is exploratory research because it deals with a new and insufficiently researched topic. Given the complexity of the topic, combined research was conducted, i.e. both comparative (quantitative and qualitative) and analytical, based on the analysis of secondary data sources.

Research type

Given the limited access to field data, a comparative review design with data analysis was applied. The research included a qualitative analysis of regulatory frameworks and strategies, a quantitative analysis of available statistical indicators by country, after which a comparative analysis was conducted according to different criteria for both countries.

Geographical and institutional setting

The research covers 2 countries of Southeastern Europe, Serbia and Romania. These are countries with different institutional capacities. Serbia is not a member of the European Union, but has the status of a candidate for membership. Accordingly, there are restrictions on access to funds. Romania is a member of the European Union, with access to Common Agricultural Policy instruments.

Data sources and collection methods

The data collection for this research is very complex. Multiple data sources were used. One of the most important data sources was scientific articles available in scientific databases and repositories, such as Google Scholar, Web of Science and Scopus. The search focused on blockchain technology, organic production, and agro-technological innovations. Special attention was paid to defining the keywords used for the search, which are "blockchain organic certification", "digital agriculture Southeastern Europe", "smart contracts agriculture", "organic farming digitalization" in combination with the terms Serbia and Romania. In addition, official government documents such as national strategies and programs, as well as EU, CAP, Horizon Europe and FAO reports, statistical data published by national statistical offices and Eurostat, industry reports such as case studies, project and platform descriptions were used.

Criteria for comparative analysis

In order for the comparative analysis to provide the most comprehensive results, it was performed according to several criteria. The defined criteria are grouped into three areas, namely institutional-regulatory framework, technical and technological infrastructure, economic and production indicators. The institutional-regulatory framework includes laws and strategies on organic production and digitization, as well as institutional cooperation through which regulation is implemented. Technical and technological infrastructure includes internet coverage, availability of information technologies, digital literacy and ICT start-ups. They provide information on technical capacities for digital transformation. Economic and production indicators refer to the state of organic production in terms of the number of producers, planting area, exports, but also financial support mechanisms, such as various funds. In addition to economic indicators, they also provide information on development potential.

Methods of processing and data analysis

Since the research includes the collection of qualitative and quantitative data, data analyzes were performed in accordance with the type of data. Qualitative methods of data analysis were used: comparative analysis, thematic analysis, categorical analysis and SWOT analysis. Quantitative methods of data analysis are descriptive statistics and correlation analysis.

Research limitations

There were limitations during the research, the most significant of which relate to data collection. Data availability differs significantly between the two countries. Romania is included in the statistical reports of the European Union, while data on Serbia are available in smaller numbers. In addition, in national surveys, data on Serbia are available without data on the part of the Serbian territory of AP Kosovo and Metohija. In European surveys, data for Serbia are also given without AP Kosovo and Metohija. Since they are not publicly available, the research is adapted to the available data. Also, there is a very small number of studies related to the mentioned countries, and that it refers to the application of blockchain technology in the certification and monitoring of crop production in general, and even less when it comes to organic crop production. These gaps point to the need for better reporting and more transparent data in the organic crop production sector.

Methodology for Presenting Results

The results are presented in comparative tables with data for each country. In this way, the results are presented thematically, as well as through statistical indicators, which enables a better approach to the discussion of the results and drawing conclusions.

RESULTS AND DISCUSSION

This chapter presents the results of the analysis of the application and possibilities of blockchain technology in the certification and monitoring systems of organic crop production in Serbia and Romania. The results are presented through a comparative matrix, in accordance with predefined criteria. In this way, a comprehensive analysis of the obtained results is enabled. The data analysis was also carried out using SWOT analysis. Based on the obtained results, recommendations were made for the implementation of blockchain solutions for the certification and monitoring of organic crop production for these two countries.

The institutional and regulatory framework

The institutional-regulatory framework includes laws and strategies on both organic production and digitization, as well as institutional cooperation through which regulation is implemented. Indicators from the field of institutional-regulatory framework, which refer to organic production and digitization in Serbia and Romania, are presented (Table 1).

Table 1. Regulatory and institutional framework for organic production and digitization

Indicator	Serbia	Romania
Legal framework for organic production	The Law on Organic Production no. 30/2010 and 17/2019[1] The draft of the new Law (2025) - under preparation[2]	EU Regulation (EU) 2018/848[3] + national regulation: Order No. 45/2022[4]
Compliance with EU regulations	Partial - alignment with Reg. (EU) 2018/848[3]	Full - as a member of the EU
Control and certification organizations	Private, accredited organizations (eg Control Union Serbia, Ecocert, TMS CEE); accreditation is carried out by ATS (Accreditation Body of Serbia)	Private, authorized control bodies (eg Bio Garantie, Ecocert RO); supervision and registration is managed by MADR; accreditation is carried out by RENAR (national accreditation body)
Competent institutions	Ministry of Agriculture, Forestry and Water Management ATS (for accreditation of control bodies)	Ministry of Agriculture and Rural Development RENAR (for accreditation of control bodies)
National strategies	The strategy for the development of agriculture and rural development of the RS 2014-2024[5], includes the segment of digitization of organic production; partial alignment with the EU Farm-to-Fork strategy[6]	National Strategic Plan for CAP 2023 2027 - development of platforms[7]; directly implements the EU Farm-to-Fork strategy[6]
Access to organic production funds	IPARD and national support measures	EU Common Agricultural Policy (CAP)
Legal framework for electronic data exchange/ e-signature/ e-document	Law on electronic document, electronic identification and trust services in electronic business (No 94/2017)[8] - fully valid; enables the legally valid exchange of digital documents and certificates.	Compliant with the EU eIDAS regulation (Reg. (EU) 910/2014)[9] - the electronic signature and seal have full legal force; wide application in state registers and agricultural systems.
National regulations on digital records in agriculture/digital registers	The eAgrar[10] system (from 2023) enables the digital registration of farms and the application of subsidies; currently in the integration phase with organic production control systems.	SIIAE[11] - national information system for organic production, connected to EU TRACES and control systems; mandatory digital records of all operators of organic production.

Sources: [1]Official Gazette of RS, 2010; [2]MAFWM, 2025; [3]Official Journal of the European Union, 2018; [4]MARD, 2022a; [5]MAEPRS, 2014; [6]European Commission, 2020; [7]MARD, 2022b; [8]Official Gazette of RS, 2017; [9]European Union, 2014; [10]Tomić et al., 2024; [11]MARD, 2022c.

The basis for blockchain implementation is the legislative framework, and since this concerns the certification of organic crop production, compliance with European Union regulations is important for interoperability. National strategies are key because they represent the starting point for the development of other strategic documents. Both countries have national regulations, with Serbia having a draft of a new Law on Organic Production, which is in preparation, which prescribes the introduction of a producer register, stricter control and mandatory reporting of activities.

The essential difference in the legal framework is that Serbia is not a member of the European Union, while Romania is, and that apart from the national regulations, Romania also has the regulatory framework of the European Union. However, as organic production relies heavily on exports, Serbia seeks to align its Law on Organic Production with the regulations of the European Union. On the other hand, Romania, as a member of the European Union, already applies all mandatory regulations. In addition, Serbia has indirect access to funds for organic production through IPARD and national support measures, while Romania has direct access through the Common Agricultural Policy of the European Union. Also, in Serbia there are specific initiatives and applications for digitization of the organic sector, e.g. eAgrarian; The SAFE platform, which is partially based on blockchain, but is not yet fully integrated with EU systems, while Romania uses SIIAE, which is fully compatible with EU platforms. Digital registries are the technical predecessors of blockchain. More about digitization follows through the analysis of technical and technological infrastructure.

Technical and technological infrastructure

The analysis of technical and technological infrastructure includes the coverage of the Internet in the mentioned countries, the degree of digitalization, as well as the percentage of digital literacy. It refers to the infrastructural predisposition for the implementation of blockchain technologies in organic certification in crop production, as well as the current level of application in the mentioned area (Table 2). As for the analysis of Serbia, data related to the Autonomous Province of Kosovo and Metohija are not presented, because the relevant data are not available in the sources.

Table 2. Technical infrastructure and level of digitization in the organic production process

Indicator	Serbia	Romania
Internet coverage (% of households)	88,85% (2024)[1]	94,57% (2024)[1]
Digital literacy	33,61% (2023)[2]	27,73% (2023)[2]
Digital registries and platforms	SAFE (digital certification)[3] eAgrar (land register and subsidies)[4]	SII-AE (Organic Production Information System)[5] FaST (Phytosanitary Certificate Platform)[6]
Blockchain solutions in organic production	Yes - SAFE platform. It uses blockchain for certification and data tracking[3]	No - Not implemented at the national level[7]
Level of acceptance of digital solutions among producers	Moderate[8]	Low to Moderate[6]
Challenges in the implementation of digitalization	Complex and unclear regulation[3] Administrative obstacles[3] Loss of licenses from certified bodies[3] Low motivation[3] Limited consumer confidence in control systems[3]	Weak digital literacy[6] Mistrust in data management[6] Infrastructural differences[6] Limited access to financial means for digitization[9] Legal framework[9] Resistance to new technologies[9] Difficult supervision and application of digital solutions[7]

Sources: [1]Eurostrat, 2025; [2]Eurostat, 2024; [3]Tegeltija et al., 2022; [4]Tomić et al., 2024; [5]MARD, 2022c; [6]Șerban et al., 2024; [7]Kovacevic et al., 2023; [8]Paraušić et al., 2025; [9]Badea et al., 2024.

The level of household internet coverage is at a high level in both countries, with a higher percentage in Romania. Paradoxically, when it comes to digital literacy, the data from 2023 show that Serbia has an advantage over Romania and is close to the lower limit of the medium level of digital literacy, while Romania is at a high level and is one of the countries with the lowest values in Europe. The reason for the lower level of digital literacy may be the insufficient integration of digital skills in education, the availability of the Internet and ICT in rural areas, or the aging of the population, since the elderly often do not have digital habits and it is difficult to develop them. A lower standard of living may be the reason why part of the population does not even have the opportunity to use ICT. On the other hand, since the digitization of public administration itself is progressing slowly, in these two countries, citizens are not obliged, and probably do not have the motivation to develop digital skills. Both countries have digital registers, although the functionality they provide is different. In the case of Serbia, it is eAgrar that enables digital registration of farms and application of subsidies, and is currently in the integration phase with organic production control systems. SAFE is a digital certification platform that uses blockchain for certification and data tracking. In the case of Romania, there is the Information System for Organic Production SIIAE which is integrated with EU systems, as well as the platform for phytosanitary certificates FaST. As for blockchain solutions in organic agriculture, no such solution has been implemented at the national level in Romania. It is certain that both countries are facing challenges in the application of digitization in agriculture, and therefore also in the organic crop production. The reasons for this are similar in both countries. The level of acceptance of digital solutions among producers in Serbia is moderate (Paraušić, et al., 2025). In Romania, the level of acceptance ranges from low to moderate, with digital solutions being adopted mainly by large producers, while smaller ones continue to face various barriers (Șerban et al., 2024).

Apart from the institutional and technical aspects of digitization, an important indicator of the development of digital infrastructure in agriculture is the AgriTech start-up ecosystem (Table 3).

Table 3. AgriTech start-up ecosystem in Serbia and Romania (2025)

Indicator	Serbia	Romania
AgriTech start-ups	49[1]	86[2]
Funded start-ups	8[1]	6[2]
Access to funding for startups	Limited[3]	Limited[4]
Series of financing (Series A+)	2 start-up (Series A+)[1]	NA
Average number of new companies per year (last 10 years)	2[1]	4[2]
Share of financed in the total number	About 16%[1]	About 7%[2]
General development trend	Smaller number of companies but higher level of investment activity[1]	Slow but stable growth[2]

Sources: [1]Tracxn, 2025a; [2]Tracxn, 2025b; [3]Tegeltija et al., 2022; **[4]**Szalavetz, 2023.

The indicators show that in both countries the number of AgriTech start-ups is increasing, with an average growth of about 2 for Serbia and 4 for Romania per year. Taking into account the share of funded startups in relation to the total number, Serbia is in the lead in the ratio of 16:7, although access to financing for AgriTech startups is limited in both countries. In Serbia, high certification costs represent a significant obstacle for producers (Tegeltija et at., 2022), while in Romania the availability of risk capital is low (Szalavetz, 2023), with the country still lagging behind the EU average in this segment. The presented data suggests that the development trend of AgriTech start-ups in Romania is slow but stable, while in Serbia the number of start-ups is lower, but the number of investment activities is higher.

Production and economic indicators

As the institutional and regulatory framework includes laws and strategies that provide a framework for both organic crop production and digitalization, the technical and technological infrastructure is the basis for the digital transformation of production. However, economic and production indicators (Table 4) show how much of the described potential is actually used in practice. The indicators that have been processed relate to the organic area, as well as the share of organic area in the total agricultural area, the number of producers, but also parameters on the topic of exports, sales and market barriers. These indicators provide information on the state of organic production in Serbia and Romania, as well as the wider market.

Table 4. Comparative presentation of production and economic indicators in organic production

Indicator	Serbia	Romania
Organic area [ha]	29002 (2023)[1]	693'998 (2023)[1]
Area fully converted [ha]	18086 (2023)[1]	344541 (2023)[1]
Area under conversion [ha]	10916 (2023)[1]	234177 (2023)[1]
Share of organic in total agricultural area (%)	0.8% (2023)[1]	5.1% (2023)[1]
Number of certified producers	525 (2023)[1]	12'598 (2023)[1]
Number of exporters	64 (2023)[1]	25 (2023)[1]
Export to EU and USA [MT]	17'077 (2023)[1]	25'691 (2023) USA only[1]
Export value of organic products (mil €)	€70 million (2022)[2]	€200 million (2022)[2]
Main sales channels	Mass retail (supermarkets), markets, online sales[2]	Supermarkets (2/3 of the market), online sales, small organic shops[2]
Main reasons for purchasing organic products	Health and food safety[2]	Health and environmental protection[2]
Main obstacles to the market	High price, low consumer awareness, weak local production[2]	High price, lack of information, imported goods[2]

Sources: [1]FiBL and IFOAM, 2025; [2]Agence BIO, 2024.

The results of the research show that the share of organic in the total agricultural area of both Serbia and Romania is below the European average. However, Serbia and Romania are among the 10 countries with the highest percentage growth of areas under organic production in 2022. In Serbia, the share of organic in the total agricultural area is less than 1%, for 2023, while in Romania it is around 5%. This may be the result of low demand for organic products on the market, which is caused by several factors, including lower consumer purchasing power, since the price of organic products is high compared to the price of other products. Therefore, agricultural producers do not have enough incentives to switch to organic production. Certification is complex and expensive, which particularly affects small producers. Although there are financial incentives, they are significantly lower than in some other EU countries. Considering the number of certified producers, Romania had almost 24 times more certified producers than Serbia in the same year. On the other hand, considering the number of producers in relation to the size of the organic area, Serbia and Romania are at the same level. The number of exporters in 2023 is more than 2.5 times higher in Serbia than in Romania. However, Romania is a member of the European Union, so the data on Romanian exports excludes the market in the European Union and only the US market is counted, while for Serbia both markets are recorded. Although the main sales channels for organic products are similar in both countries, there are also common obstacles on the market, such as the high price of the product. In Serbia, this is also low consumer awareness of organic products, as well as weak local production, while for Romania, the characteristic obstacles are the lack of information and the import of organic products.

In order to see the current position of Serbia and Romania in the application of blockchain technology in the certification and monitoring of organic crop production, a SWOT analysis was conducted based on the results obtained from the research (Table 5). SWOT analysis identified and detailed the strengths and weaknesses of both countries when it comes to the mentioned sector, thus providing an insight into the current situation. Identifying strengths and weaknesses plays a significant role in decision-making. Identification and analysis of opportunities and threats with strengths and weaknesses are the basis for further planning and strategy development.

Table 5. SWOT analysis of readiness for blockchain implementation in certification and monitoring of organic crop production

Aspect	Serbia	Romania
Strengths	- Existing SAFE platform (blockchain certification) - Existing eAgrar system (digital register) - More agile development of digital solutions - Flexibility outside the EU regulation - Higher rate of funding for startups	- Automatic recognition of certificates on the EU market - Existing digital infrastructure (SIIAE and greater Internet coverage) - Full compliance with EU regulations - Direct access to EU funds for digitization - Stable growth of the organic sector
Weaknesses	- Partial compliance with EU regulation (limits the interoperability of the blockchain system) - Limited access to funds technologies among manufacturers - Complex integration with EU systems - Low consumer awareness - Limited consumer confidence in the control system	- The bureaucracy of the EU system can slow down innovation - The need for coordination at the EU level - Higher implementation costs - There is no blockchain solution implemented at the national level - Lower digital literacy - Resistance to new technologies - Weak motivation of small producers - Lack of trust in data management
Opportunities	- New Law on Organic Production (2025) - Growing AgriTech sector - Bridge between EU and non-EU markets - Development of blockchain certification and digital markets - International cooperation - Access to IPARD funds - Improving digital literacy - Alignment with EU regulations	- EU funds for digitization - Large EU market (product placement) - Farm-to-Fork strategy as a framework for digital certification - Development of precision agriculture and digital solutions based on blockchain - Larger market for organic products
Threats	- Complicated integration with EU systems - Resistance of traditional producers - Low consumer awareness of digital certification - Administrative barriers - Limited access to financing	- Bureaucracy of the EU System - Import of cheaper organic products - Resistance to new technologies - Infrastructural differences between regions make digital standardization difficult - Regulatory changes and high costs of harmonizing digital systems - Slow digital education

SWOT analysis, as a strength of Serbia, shows existing platforms, registers and systems, of which SAFE is based on blockchain technology, which is significant for the future expansion and improvement of the system, and its acceptance and application. In the segment of legal regulation, Romania is fully aligned with the EU regulation and has direct access to the EU funds for digitization, which can facilitate future development in that direction. On the other hand, at the moment, when it comes to AgriTech startups, Serbia has a higher financing rate. Compared to Serbia, Romania has a higher internet coverage, but the percentage of digital literacy in Serbia is higher.

It was observed that in Serbia there is a national framework of legal regulations that is not fully harmonized with the regulations of the European Union, but that through the draft Law on Organic Production 2025, full compliance is seen as a chance. This is followed by the complex integration of solutions with EU systems. On the other hand, the bureaucracy of the EU system can slow down the development of innovation in Romania. As digital literacy in Romania is at a low level, the acceptance of digital solutions among producers is also low to moderate. Since Serbia is not a member of the European Union, access to funds is limited. Although Romania has direct access to funds, the number of funded AgroTech startups is at a very low level. The weakness of Romania is that it still does not have a digital system for agriculture that is based on blockchain technology, unlike Serbia (SAFE), which is why an additional effort should be made to spread awareness about the benefits of using blockchain technology in this sector. Interestingly, a lack of trust in the control system (Serbia) and data management (Romania) was observed, which can be attributed to a lower level of digital literacy or a limited number of digital solutions in agriculture.

The opportunities that Serbia can take advantage of are related to the excellent position of the country in the sense that it can be a bridge between the EU and non-EU markets, but only after the harmonization of legal regulations. The growing AgroTech sector, as well as a potential higher level of international cooperation, was also seen as a potential. Romania has a chance to have EU funds for digitization and the large market of the European Union. In addition, the Farm-to-Fork strategy as a framework for digital certification, as well as the development of precision agriculture and blockchain-based digital solutions, is also a chance.

Perceived threats refer to the complicated integration of national solutions with EU systems, on the example of Serbia, but also the complex bureaucracy of the EU System on the example of Romania, which can affect the slow implementation of solutions. Resistance among traditional producers in both Serbia and Romania may hinder the adoption of digital blockchain solutions for certification and monitoring of organic crop production in both countries.

In accordance with the identified strengths, weaknesses, opportunities and threats, a recommendation was made for the implementation of a blockchain solution for the certification and monitoring of organic crop production (Table 6).

Table 6. Recommendations for the implementation of blockchain solutions for the certification and monitoring of organic crop production

Rec.	Serbia	Romania
Short term (0-12)	1. Improve technical aspect of the SAFE platform and the integration of SAFE with the eAgrar system in order to pay for organic crop production in real time 2. Conduct training of control bodies and certification organizations to work on blockchain solutions (SAFE) in the certification of organic crop production 3. Develop pilot projects with the largest exporters of organic crop products to test blockchain certification	1. Development of the blockchain module of the SIIAE system for payment of organic crop production 2. Get involved in EU projects for digitalization of certification and monitoring of agricultural value chains 3. Conduct a feasibility and cost-effectiveness study of the application of blockchain technology in the organic sector of crop production
Mid-term (1-3)	1. Full integration with EU systems for the exchange of data on organic crop production 2. Extending the use of SAFE to all producers of organic crop production 3. Develop a mobile application for manufacturers and controllers for digital monitoring and verification of certificates	1. Implementation in the SIIAE system of the blockchain component for certification and monitoring of organic crop production 2. Training of all producers, controllers and certifiers on the use of blockchain technologies 3. Integration with other EU information systems for monitoring organic production
Long term (3+ years)	1. Develop a comprehensive blockchain ecosystem for certification, tracking and export of organic crop products 2. Introduce Smart contracts for the automation of certification and control procedures 3. To achieve complete digitization of the certification process through blockchain solutions	1. Position a national blockchain solution for certified organic crop production within the EU 2. Standardize the blockchain solution for monitoring organic crop production at the EU level 3. To achieve international interoperability of the Certification and Monitoring System

For the successful implementation of blockchain technologies in the certification and monitoring of organic crop production (Table 6), a strategic approach, adapted to the specifics of each country, is important. The specifics relate in particular to the technical-technological and regulatory context. Serbia, which has entered into the use of blockchain technologies for these purposes, has the task of improving the existing solution, expanding the integration of existing systems and enabling the complete digitization of the certification process and ensuring interoperability with European systems for monitoring organic production. Pilot projects would enable the testing of blockchain solutions in real conditions, which is a good introduction to the transition to the blockchain ecosystem. In addition, it is necessary to work on harmonizing legal regulations with EU regulations. Romania can take advantage of the regulatory advantages as a member of the European Union, so the recommendation is to be included in already existing European Union projects, but also to develop a national blockchain module within the existing information system and gradually position it within the framework of the European Union. Both countries should work on educating interested parties, both manufacturers, controllers and certifiers, so that the solutions are accepted and used in practice.

CONCLUSIONS

In accordance with the research objective of this paper, a comparative analysis of the application and possibilities of blockchain technology in the certification and monitoring systems of organic crop production in Serbia and Romania was carried out. The research results showed that the application of blockchain technology in the certification and monitoring of organic crop production represents a strategic opportunity for improving transparency, consumer trust and strengthening the competitiveness of the sector, both in Serbia and Romania. It was shown that the degree of institutional readiness and technical and technological capacities for the implementation of blockchain technologies are at different levels, but that the directions of future development are complementary. However, it is important to emphasize a different approach to future insight and shaping solutions, in accordance with the specificities of each of the mentioned countries.

Serbia's advantage is reflected in its technological edge, namely the existence of the SAFE platform for digital certification, which is partly based on blockchain technology, as well as a higher percentage of the population that is digitally literate compared to Romania, which can be reflected as a factor influencing the acceptance of blockchain solutions. The higher rate of financing of AgriTech start-ups indicates a dynamic, but smaller, sector that strives for innovation in order to break into the global market.

Romania has the advantage of having a significantly larger organic area and is among the countries with high growth in organic areas in recent years. In addition, the regulatory framework is aligned with EU regulations, which greatly facilitates the placement of products on the market of the European Union, of which Romania is a member, but on the other hand, it provides less flexibility.

In general, both in the case of Serbia and Romania, the share of organic in the total agricultural area is below the average in relation to the European Union countries. Since both countries are abundant in agricultural land, they need to be motivated towards organic crop production. A significant problem is also the level of digital literacy, resistance to change among producers and the lack of absolute trust in control systems (Serbia) and data management (Romania) because technological implementation is closely linked to the human factor. In addition, financial support can significantly slow down the development and digitalization of the organic crop production sector. Recommendations for the implementation of blockchain solutions for certification and monitoring of organic crop production emphasize a strategic approach that will allow Serbia and Romania to use their advantages. For Serbia, this would mean the improvement of the SAFE solution through additional technical and functional upgrades and integration with the existing eAgrar system, with further harmonization of regulations with EU regulations. For Romania, this would mean that it should take advantage of its membership in the European Union and access to digitization funds, and move towards the development of blockchain modules within the SIIAE System. For Serbia, blockchain could be a technology that offers a solution for building credibility on the market, since the regulatory framework is not yet harmonized with other countries, while for Romania it can be a solution for further affirmation within the EU market.

Therefore, the synergy between technological, regulatory, economic elements, as well as continuous education of all participants of the value chain can result in the successful digitization of branch crop production. This paper contributes to a better and clearer understanding of the current level of blockchain development and application in organic crop production, through a detailed approach to the aforementioned factors. It also provides an understanding of the upcoming path towards the application of blockchain technologies in the certification and monitoring of organic crop production, through a strategic approach, positioning blockchain not as a goal, but as a means to achieve a more sustainable, transparent and profitable sector of organic crop production.

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