DIGITAL MAPPING OF BUSINESS PERFORMANCE INDICATORS OF AGRICULTURAL HOLDINGS IN SERBIA

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ABSTRACT

The capacity of new technologies to boost agricultural yields, optimize resource utilization, enhance productivity, and improve financial outcomes has gained significant consideration among farmers, agricultural organizations, and policymakers. Across the globe, innovative digital solutions have emerged as key catalysts for transforming and advancing the agricultural sector. Hence, this study explores the adoption of digital tools by Serbian agricultural holdings to enhance business performance and sustainability. The employed mixed-methods approach highlights disparities in digital readiness and the barriers faced by small-scale farmers. Results reveal that while smartphones dominate technology use, broader adoption of digital platforms is hindered by low digital literacy, high costs, and limited infrastructure. The findings emphasize the potential of digital agro-economic maps to optimize resource allocation, reduce costs, and improve decision-making. Finally, the actions should be focused on improving digital literacy of rural population, expanding technological infrastructure, and designing policy incentives to encourage the adoption of smart agricultural practices.

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Introduction

During its long history, the modernization of agriculture has progressed gradually, mostly in correlation with the stages of intensive development of science and technology. "Smart farming", also known as Agriculture 4.0 marks a new era in agriculture, driven by the comprehensive integration of digital technologies (Geng et al., 2024). Although digital technologies for improving agriculture were recognized more than 50 years ago, digital agriculture emerged in the early 2000s. In the past few decades, digital agriculture has become a key driver of industrial integration and innovation. Digital agriculture represents a modern approach to agriculture that combines and integrates the principles of efficiency, high quality, environmental responsibility and sustainable development (Zhou et al., 2023).

Over the past two decades, the importance of information and communication technologies (ICTs) in the agricultural industry has grown rapidly, contributing to innovation and efficiency in the sector (Leng et al., 2022). ICTs in agriculture include digital platforms, sensors, IoT (Internet of Things), robotics and drones, big data, cloud computing, artificial intelligence (AI), blockchain, sixth-generation (6G) communication technology, machine learning, digital twin, etc. (Flamini & Naldi, 2022). As the agricultural industry faces the challenges of resource constraints, increasing demand and sustainability concerns, the use of new digital technologies is becoming crucial (Confo et al., 2023). New digital technologies and solutions may give a new impetus to the renewal of the agricultural ecosystem, improving the efficiency of resource distribution, reducing resource disparities and propelling advancements in agricultural practices quality (Bocean, 2024). A broad spectrum of technologies enables agricultural holdings to efficiently plan, monitor and manage both the operational and strategic aspects of their production systems, optimizing agricultural productivity and reducing ecological footprints (Karunathilake et al., 2023).

Identifying effective agricultural practices and solutions based on new digital technologies is essential for enhancing agricultural profitability and maintaining economic stability (Boecan, 2024). Digital agricultural practices can improve agricultural efficiency and sustainability while lowering resource waste and environmental impact. Increases in the efficiency of agribusiness are a connection between the improvement in productivity and the reduction of inputs through the use of technologies (Pérez-Pons et al., p. 48, 2020).

Furthermore, the advancements of agricultural digital tools have an important role in addressing food scarcity challenges and meeting the growing global demand for sustainable food production, offering strategic solutions for improving the efficiency and effectiveness of farm production. Efficient farm management relies on effectively utilizing production resources and maximizing profits based on limited financial and credit resources. Certain researchers (Bahn et al. 2021) have examined the role of digital technologies in improving business performance. They have discovered that the use of digital technologies can decrease production costs by monitoring agricultural inputs and labour.

Digital technologies have driven revolutionary changes in agriculture by enabling the development of smart systems that can monitor, control, and visualize different farm operations in real-time (Subeesh & Mehta, 2021). Real-time data and analysis in smart agriculture are prerequisites for sustainable development. Real-time analysis can help agricultural holdings better understand plant growth status, weather, and soil conditions. A key role in the automation of farming activities during pre-harvest and post-harvest operations is played by AI and IoT, developing smart farm machinery, greenhouse management, storage systems, etc. (Subeesh & Mehta, 2021).

Digital technology can reduce the cost of obtaining information and transaction costs for agricultural export enterprises, and improve their brand influence and competitiveness in the international market (Jia, 2024). Agricultural supply chain management could be optimized by using digital technologies. Some academics (Site & Salucci, 2006) concluded that the application of digital tools enables rural agricultural holdings to access both domestic and global markets. The new digital era and modern conditions highlight the significance of precision agriculture, based upon digital technologies for weather forecasting and the predictability of weather conditions. The information delivered by digital tools for weather prediction can be used by agricultural holdings to decide about planting and harvesting time (Fuentes-Peñailillo et al., 2024).

The potential of new technologies to increase yields, efficiency of resource use, productivity and financial gains in agriculture has been recognized by many farmers, agriculture organizations and policy-makers. Innovative digital solutions have been major drivers of agricultural transformation and enhancements across the world. Many countries and integrations, especially advanced economies, have been developing strategies for higher digitalization of the agricultural sector. The adoption of innovative tools in agricultural business that provide real-time data and relevant economic indicators significantly facilitates the decision-making process and contributes to the production process optimization, profitability growth and sustainability as well.

Digital agriculture is stated as one of the Program Priority Areas (PPAs) in the FAO Strategic Framework 2022-31 by the Food and Agricultural Organization of the United Nations (FAO), which could contribute to creating resilient and sustainable agri-food systems (FAO, 2021). Furthermore, the importance of technology, innovation and data in agriculture has been emphasized, identifying them as major accelerators of progress towards meeting the Sustainable Development Goals (SDGs) and FAO's vision, applied in all programmatic interventions.

Although the adoption and usage of digital technologies in agriculture have been widespread and accelerated in recent years, discrepancies among different areas and subjects remain significant. Disparities are particularly high between developed and developing countries and between international companies and local firms, especially family farms, mainly due to different levels of education, financial resources, access to infrastructure and technology, as well as the scale at which they operate (Trendov, Varas & Zeng, 2019). Besides that, the climate, demographic and ecosystem characteristics

of different areas vary considerably. Therefore, the need for a differentiated strategic approach at the regional and national levels is essential. Policymakers must identify appropriate instruments to target existing problems and constraints.

Despite differences among countries, some common factors of adoption and efficient utilization of digital technologies in agriculture have been identified. The practice of OECD countries indicates that policymakers should address issues related to infrastructure and connectivity, cost, relevance, user-friendliness and skills, and risk and trust-building to implement and facilitate the digitalisation of agriculture (McFadden et al., 2022). The lack of trust in new and often complex technologies has been identified as one of the major obstacles to greater adoption and usage of digital tools among farmers, including four issues: privacy, security and sharing of data; mistrust of technology providers, difficulty in learning and misunderstanding of new technologies; and lack of standards for assessment and certification of the functionality of digital tools (McFadden, Casalini & Antón, 2022).

Therefore, it is crucial that policies and programmes for agricultural digitalization provide an environment which would boost farmers' trust and encourage them to use digital technologies, giving them all the necessary knowledge and protection. The role of national governments in defining and carrying out an agricultural policy which would include innovative and technology-driven solutions is fundamental. Evidence suggests that digital technology increases the precision of policy instruments and enables their tailoring to specific agricultural problems, increasing the efficiency and effectiveness of agricultural policy (Ehlers, Huber & Finger, 2021).

Many estimates suggest that digital technologies will significantly change the agriculture and food sector over the next decade, but a significant gap between emerging and advanced economies still limits the achievement of the full potential of the agricultural revolution (Trendov, Varas & Zeng, 2019). The experience of the EU and other countries showed that successfully accomplishing the digital transition of agriculture and rural areas demands solutions which are able to respond to their specific requirements, needs, resources and issues, making it a "complex and context-specific process" (Barabanova & Krzysztofowicz, 2023, p.43). European Union has put a lot of effort into supporting the digitalisation of rural areas and integration of new technologies in the European agricultural value chains. Digital technologies are perceived not only as a tool for more efficient and sustainable production in the agricultural sector but also as one of the major "elements to improve quality of life, ensure geographically balanced development and economic prosperity" of rural areas (Barabanova & Krzysztofowicz, 2023, p.3).

Innovation and research activities for accelerating the digital transformation of the agricultural sector have been encouraged across the continent through many policy instruments, as well as the monitoring of its economic and social impact on rural areas. They are designed to support farmers, rural communities and related sectors through the use of digital technologies, innovation and data-driven practices. Certain regions, like Eastern Europe, still lag behind highly developed EU countries. Application of

information technologies in agriculture remains low due to mainly small family farms or agricultural businesses and the unfavourable educational and age structure of the rural population, which often does not have enough financial funds to invest in modern equipment and sustainable practices (Jurjević et al., 2019).

Serbia is a country where the agricultural sector is an important segment of the economy, with a share between 6.3% and 7.7% in GDP in the last five years, in overall employment around 13-16% and in exports up to 21.3% (SPP, 2024). However, the reduction of the rural population and in employment in agriculture has been evident. That trend is particularly present among the population with higher education. Such circumstances usually lead to the lower quality of the workforce in agriculture which is one of the factors that hinders the economic development of rural areas. According to the data from the current Strategy for Agriculture and Rural Development of the Republic of Serbia (2014-2024), 97% of the rural population did not attend additional training programs, and 54% did not have special knowledge and skills, while only 20% was computer literate, 14% was partially computer literate and approximately 66% was still computer illiterate (Official Gazette RS, 2014).

The diffusion of broadband internet connection was also significantly lower in rural areas. Although the internet infrastructure has been improved in recent years, as well as the availability of knowledge and technology, the digital gap between rural and urban areas is still noticeable. High costs of digital tools and technology devices, lack of knowledge about the benefits of their application and sceptical attitude towards innovations often cause farmers to opt for traditional means and avoid digital solutions (Jurjević et al., 2019; FAO, 2020; Kovljenić et al., 2023). In order to experience the most benefits from the digitalisation of agriculture and rural areas, developing countries would have to prioritize the improvement of technological infrastructure and digital literacy and skills of rural communities, as well as access to services and financial funds.

This article aims to point out the main benefits of agriculture digitalization, to emphasize its importance for sustainable development of rural areas and to address some of the main issues. It also highlights the major barriers to agricultural digitalization in Serbia, as well as prioritized areas for improving the competitiveness of the agricultural sector. The object of the research presented in this paper is to analyse the readiness of farmers and agricultural holdings for the adoption and use of digital tools and technological solutions in their business and to assess the current level of implementation. Furthermore, it gives insights into farmers' attitudes towards the application of information technologies and analytical tools which would help their agricultural holdings improve their business performance.

Materials and methods

In order to examine the use of digital technologies by agricultural holdings in Serbia and to explore the potential for the implementation of certain digital solutions at the individual holdings level, a survey was conducted. The research was a phase in the process of creating and validating an innovative solution, a digital agro-economic map, which

aims to help agricultural holdings improve their business performance. The structure and content of the research were created based on observed problems faced by agricultural holdings, especially in less developed regions of Serbia. Although Serbia is characterized by a favourable climate, vast expanses of arable land and a tradition of growing numerous crops, there is plenty of room for improving the competitiveness of domestic agricultural holdings. Problems are present at multiple levels, from the low level of mechanization and modernization, outdated machinery, and insufficient application of new technological solutions, to individual characteristics of farmers such as inadequate and outdated knowledge and skills (Statistical Office of the Republic of Serbia, 2019). These are just some of the obstacles that the agricultural sector in Serbia faces.

There are 508,365 registered agricultural holdings in Serbia (Statistical Office of the Republic of Serbia, 2024), and most of them, especially those operating in underdeveloped areas, are characterized by a low level of digital literacy. According to available data on the IT literacy of farmers, less than 2% of agricultural holdings use a computer, and low IT literacy is also a consequence of the very unfavourable age structure of farmers (Statistical Office of the Republic of Serbia, 2019). Also, according to recent research, significant digital support is needed for farmers to use modern agro-platforms and electronic registers (Research report *"The level of digital literacy and analysis of the required form of support with recommendations for improving the level of digital support for farmers"*). This is supported by the fact that the participation of farmers aged over 65 in the age structure of agricultural holdings represents a significant percentage (44.72%) (Statistical Office of the Republic of Serbia, 2024). At the same time, the use of business analytics in such areas can be an obstacle, but with adequate education and consulting assistance, the business performance of holdings can be improved and their profitability can be increased. It has been recognized that there is a need for farmers for incentive mechanisms to encourage them to actively participate in the process of digitalization of agriculture, and thus also increase the creation of added value and reduce business costs.

Available research also provides data that the largest number of decision-makers of agricultural holdings in Serbia (49%) gained their knowledge about agricultural business through practice, and therefore base their decision-making on previously acquired experience, which is not the path to creating an economically strong and sustainable farm (Statistical Office of the Republic of Serbia, 2019). Empirical determination of prices and operating costs by holdings without modern, software-based business analytics and long-term predictions does not lead to maximum product placement on the market and increased profitability, and reduces the ability of farmers to approach modern business flows and the digitalization of the agricultural sector.

In order to develop the proposed tool, a digital agro-economic map, it was necessary to research the market's readiness to accept and implement such a solution, since the application of digital agro-economic maps in agriculture is linked to farmers' awareness of the importance of business analytics and their willingness to accept new approaches to business. For this purpose, qualitative research was conducted. A semi-structured

questionnaire was created, including a set of questions needed to assess the digital literacy and readiness of farmers for digitization. GoogleForms was used to create the questionnaire, and it was sent by e-mail to farmers from the previously created contact database. The contact database was created based on the available databases of agricultural holdings in Serbia such as E-Agrar and Agricultural Advisory Agency of the Republic of Serbia. An example of the digital map for the agriculture holding producing blueberries is presented in Figure 1.

Figure 1. Digital agro-economic map

Source: Authors

The questions were formulated based on an earlier review of the existing literature and observed gaps in the operations of agricultural holdings. The questionnaire consists of several sets of questions. The first set of questions refers to the demographic characteristics of representatives of agricultural holdings and the area of operation of the agricultural holdings. The second set of questions was created to assess their knowledge and skills in the field of digitalization of agriculture, while the focus of the third set of questions is on the application of technology and digital tools for agricultural management, as shown in Table 1.

Table 1. Digital agricultural tools examination for analysed issues

Analysed agricultural digital issues	**Utilized digital agricultural assets**		
Type of technology for managing agricultural holdings	"Smart" phone	PC	Drone, GPS
Agricultural applications for managing agricultural holdings	E-mail Social media Cloud systems	Internet browsing options	Local government agricultural apps
Type of agricultural digital service for managing agricultural holdings	Digital agricultural platforms	Information-oriented apps for rural areas	Municipality agro-platforms
Type of agricultural activities which utilized agricultural digital toolbox	Weather forecast Market condition Efficient resource allocation	Process automatization Subsidies Supply chain management	Revenues/Expenses Import/Export Education of farmers through digital platforms

Source: Authors

The research sample consisted of 45 representatives of agricultural holdings. The target group consisted of agricultural holdings from the regions of Southern and Eastern Serbia and most of the participants in the research were from Nišava, Toplica, Jablanica, Pčinj, Pirot, Rasina and Zaječar areas. According to the Statistical Office of the Republic of Serbia (2024), the region of Southern and Eastern Serbia has a total of 145,744 agricultural holdings, of which there are 124,971 agricultural holdings in prominent areas.

As for the demographic characteristics of the representatives of the surveyed agricultural holdings (age, gender), the percentage of men is significantly higher, as much as 80%, as shown in Figure 2. The largest number of respondents were aged 40-55 (47%), while the number of respondents aged 25-40 and 55-70 was the same (27%). This age structure of the sample may be a consequence of the greater use of computers and the Internet by younger farmers, as the questionnaire was in an online form, sent by email.

Figure 2. Characteristics of the sample

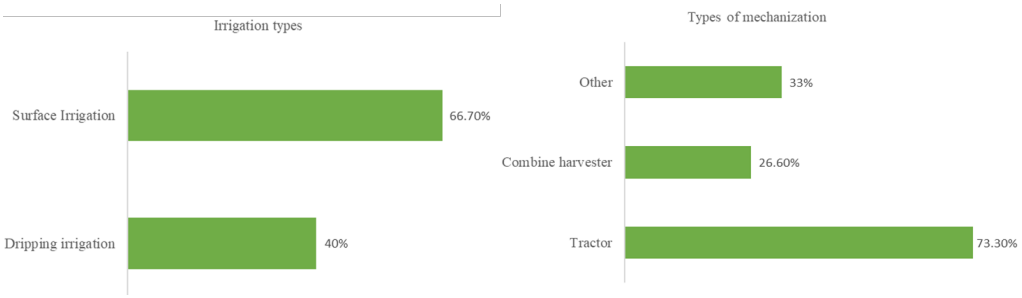
Source: Authors

When it comes to the type of agricultural holdings, the percentage of those registered as family agricultural holdings (93%) is significantly higher than those registered as enterprises (7%), which is also shown in Figure 2. The sample consisted of agricultural holdings of different structures that deal with agricultural and livestock production, fruit and vegetable processing, meat and dairy products processing and rural tourism, in the territory of the mentioned areas.

Results and Discussions

Based on the conducted research and on the examined sample of the previously mentioned, targeted group of farmers, the results were first obtained on the type of irrigation system that is most often used in agricultural holdings on the territory of the Republic of Serbia. Accordingly, it can be concluded that the most frequently used type of irrigation system is Surface irrigation with 66.70%, while the second in order is the Dripping irrigation system with 40% (Figure 3).

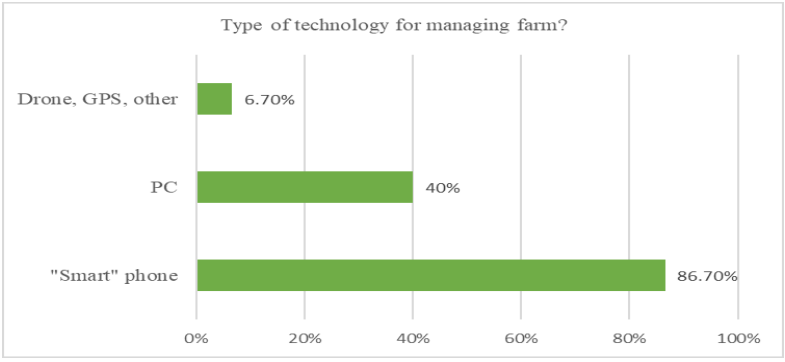
Figure 3. Irrigation type and type of mechanization for managing agricultural holdings – survey results



Source: Authors

On the other hand, the mechanization used in farms in the analysed regions of Serbia relates to tractors and attachment mechanisms in the amount of over 73%. The respondents estimated that the second most important type of mechanization is the combine harvester at 26.60%, which confirms the fact about the types of plant crops grown on the territory of the Republic of Serbia (Figure 3).

Figure 4. The most utilized types of technology in farm management in Serbia



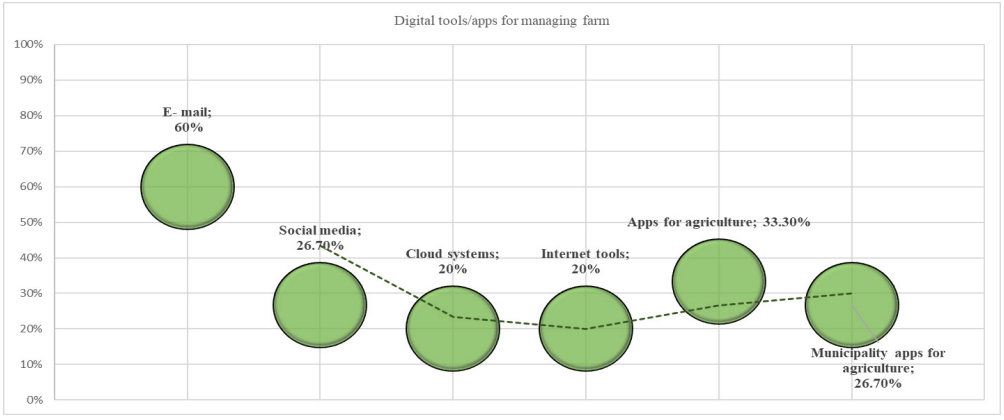
Source: Authors

Bearing in mind the digital readiness level of the analysed regions in which digital agricultural tools are used, based on the conducted research, the respondents evaluated the "Smart" phone as the device that is most used to valorise the ICT skill of the Serbian farmers. For mobile technology and its application support to experience full expansion, it is imperative that each country, or farm, shows a willingness to embrace digital innovations (Rađenović et al., 2020). In addition, high territorial coverage of the Internet and increased speed providers lead to the fact that the "Smart" phone represents the main device for managing digital tools of almost 87% of households (Figure 4).

One of the main goals of the mentioned research within the project of digitization of agriculture in Serbia and the formation of "smart" agricultural incubators, refers primarily to the evaluation of the application portfolio for the management of Serbian

agricultural holdings. In order to create a digitally sustainable and competitive environment, it is necessary to improve the digital skills of farmers, which will improve their productivity and eliminate unnecessary costs. Farmers' digital communication takes place via e-mail exchange of information in 60% of cases, while over 33% of farmers consider it useful to use applications as instruments for efficient management of daily farming activities. A significant percentage of the use of digital farming tools in the analysed regions of Serbia is made up of social networks (almost 27%), which represent a kind of medium both for the exchange of information and for the formation of digital "orbits" of farmers (Figure 5). Social networks are used to form various agro-communities where farmers join together to achieve greater competitive advantage and better price elasticity due to the easier availability of information on the market situation. In this way, better communication is achieved in the supply chain itself and the possibility of downtime due to inadequate flow of resources is reduced.

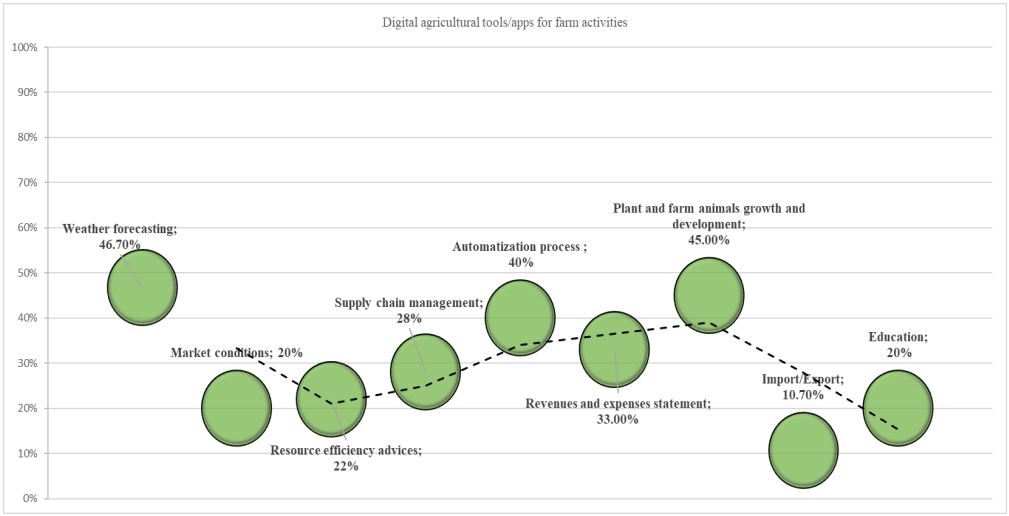
Figure 5. Digital agricultural application toolbox for farm managing in Serbia



Source: Authors

Digital instruments for managing activities on farms could be crucial to creating added value and long-term sustainability of a farm's operations. Therefore, in order to improve the business of the farm and increase its performance, digital tools are used for a large number of activities on farms that ultimately, and in the last resort increase the profitability and productivity of the farm. According to surveyed farmers, process automatization is one of the key activities where digital instruments are used the most (about 40%). Weather forecasting and Plant and farm animals' growth and development are directly related to farming activities, so the percentage of application use in this case is over 45%. Developing awareness of the importance of efficient resource allocation through the entire supply chain and among its stakeholders, implies the use of application solutions in these segments as well: Supply chain management (20%), Resource efficiency advices (22%), and Market conditions (20%). Observing the movement of financial indicators through a digital, applied economic barometer of the farm in the form of a single report is used by more than 33% of respondents (Figure 6).

Figure 6. Using digital agro-economic tools for farm activities among farmers in Serbian regions



Source: Authors

Conclusions

In recent decades, increasing attention has been paid to innovative approaches to improving the quality of agricultural products, which are largely based on the application of modern information technologies. The accelerated development of IT technologies and the digitalization of the agricultural sector provide space for the implementation of ideas based on the application of modern digital tools for data analysis, prediction, business simulation, budgeting and visualization of results, as well as the creation of digital agro-economic maps of farmers' businesses. For these reasons, it has been recognized that business analytics in agriculture can significantly increase the efficiency of this sector and improve the survival and progress of all stakeholders in the supply chain. Such a solution requires a large amount of information in order to increase the business performance of the farm in terms of greater productivity and profitability, as well as competitiveness in the market.

This research underscores the significant potential of digitalization to revolutionize agriculture in Serbia by enhancing efficiency, sustainability, and business performance. However, the findings highlight substantial barriers, including low digital literacy, inadequate infrastructure, and financial constraints. These challenges are particularly pronounced in less developed regions. Despite these obstacles, digital tools such as agro-economic maps show promise in optimizing resource use, reducing costs, and facilitating informed decision-making for farmers.

Therefore, the idea of creating a digital agro-economic map was born, in order to make decisions based on relevant indicators that would contribute to the optimization of the

farms' operations and the reduction of costs at all levels. The digital agro-economic map was designed with the aim of providing an economic prediction of business success, using existing business analytics tools. With the help of a digital agro-economic map, recommendations can be given to farmers on how to create efficient resource allocation and improve operations, instead of basing their business decisions solely on previous experience and acquired practices.

The position of all stakeholders in the supply chain can be improved by using adequate analytics. This scheme, based on timely analytics, also encourages improvements in product quality and sustainability. A digital agro-economic map has the potential to further contribute to answering questions such as: what resources help stakeholders achieve the best value for their products; what support they need to adopt newer methods and technologies; what market mechanisms should they provide; and how can these initiatives address gender and economic disparities? The proposed methodological framework classifies agribusiness analytics into several subcategories: supply chains; resources and markets; budgeting, pricing and financing; environmental and sustainability practices; government regulations and public policy; competitiveness; and import/export.

Based on the presented results to maximize the benefits of digital agriculture, key recommendations include: improving rural internet connectivity, increasing access to affordable digital tools, and implementing targeted education programs to enhance farmers' digital literacy. Policymakers should consider tailored strategies that address regional disparities and incentivize digital adoption. Collaboration between governments, technology providers, and agricultural stakeholders is essential for fostering a digitally inclusive and sustainable agricultural sector in Serbia.

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Conflict of interests

The authors declare no conflict of interest.

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