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Digital Transformation Processes in Vojvodina's Agricultural Systems

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A B S T R A C T

In recent years, the agricultural sector in Vojvodina has undergone significant digital development, which has contributed to an increase in the efficiency of the agricultural sector. Contemporary technologies, including precision agriculture instruments, GPS-based machine control systems, unmanned aerial vehicles (UAVs), sensors and smart devices, facilitate meticulous observation of the terrain and the implementation of targeted resource utilisation. Information technology and data analysis are playing an increasingly important role in farming, helping to optimise production processes, reduce costs and promote sustainability. By analysing data in real time, farmers can optimise the management of irrigation, nutrient replenishment and crop protection, thereby minimising the environmental impact. Furthermore, digital platforms and applications will facilitate the expeditious exchange of information and the monitoring of market trends among farmers. Digitalisation has been demonstrated to enhance the competitiveness of agricultural production in Vojvodina, whilst concomitantly contributing to the dissemination of environmentally sustainable farming practices.

1. Introduction

The sustainability and efficiency of agricultural production are increasingly contingent on the utilisation of digital technologies. In Vojvodina, where agriculture constitutes one of the primary pillars of the economy, it is imperative to scrutinise the processes of digitalisation. The present study sets out to explore the importance of digital agriculture, its advantages, and the obstacles to its introduction.

Vojvodina, Serbia's northernmost province, is located in the area bordered by the Danube, Tisza, and Sava rivers. The region's historical and cultural diversity, coupled with its fertile terrain, has historically afforded it a prominent role within the geographical confines of Central and Southeastern Europe. A substantial portion of the province is characterised by a flat terrain, which offers conducive conditions for agricultural activities. The region can be divided into three major regions: Bačka, Banat, and Srem (Božović et al., 2022). The region's fertile soil and temperate climate have led to Vojvodina being referred to as Serbia's "breadbasket", with agriculture being of paramount importance, particularly in the cultivation of wheat, corn, sunflower, and grape. Notwithstanding the region's considerable agricultural and cultural potential, Vojvodina is also beset by a number of challenges. The future of the province is influenced by a number of factors, including migration, the exodus of young people, and the pace of economic development. Concurrently, the consolidation of regional ties with the European Union, coupled with the proliferation of digital technologies, is giving rise to novel opportunities for the region. Agriculture has historically been one of the most significant economic sectors in Vojvodina. However, in recent years, it has faced considerable challenges in the process of modernisation. In the contemporary era, farmers are compelled to adopt novel technologies in response to three major challenges: climate change, labour shortages and market competition (Vukadinović et al., 2022). Digital agriculture, defined as the integration of precision and smart agricultural solutions, is gaining prominence in the region. Digital agriculture is predicated on the

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digitisation and automation of agricultural production. Examples of such innovations include the use of drones for soil and plant analysis, GPS-based precision sowing and spraying, and irrigation systems equipped with IoT (Internet of Things) sensors. Crop yield forecasting is another area of development, with models being built on the analysis of large data sets (Novković et al., 2023). Digital agriculture is defined as a set of technological solutions that are based on data collection, analysis, and automation. The following are included:

• Precision farming: The utilisation of GPS-based tractors and seeders facilitates the precise cultivation and employment of input materials.

• Unmanned aerial vehicles and satellite monitoring: A comprehensive evaluation of the plant and soil conditions is imperative to enable the implementation of targeted interventions. The utilisation of IoT-based sensors is of paramount importance in this context. Sensors, installed in the ground, perpetually monitor soil moisture, temperature, and other parameters.

• Automated irrigation systems: The optimisation of water usage is to be based on the analysis of relevant data.

The following discussion will focus on two major technological developments: Big Data and artificial intelligence. The processing of voluminous data sets is instrumental in predicting crop yields and in the optimisation of production processes. The implementation of these technologies has been demonstrated to engender enhanced productivity, diminished expenditure, and an improvement in sustainability (Kovljenić et al., 2023).

The geographical characteristics and developed agricultural traditions of Vojvodina offer ideal conditions for the introduction of modern agricultural technologies. In recent years, there has been an increasing trend of farmers adopting precision farming methods, particularly among larger farms.

2. The importance and development trends of digital agriculture

Digital technologies are assuming an increasingly significant role in the agricultural sector, particularly in the domains of precision farming, data analysis, sensors, and artificial intelligence. These novel solutions have the potential to engender substantial changes in production efficiency, cost reduction, and enhanced sustainability. In Vojvodina, the process of modernising the agricultural sector is progressing gradually. Local farmers are progressively adopting the following technologies:

- The implementation of precision sowing and fertilization techniques is imperative in order to optimise crop yields.
- The utilisation of unmanned aerial vehicles (UAVs) for the purpose of field analysis has emerged as a novel approach for the expeditious identification of nutrient deficiencies and diseases in agricultural contexts.
- The implementation of automated irrigation and soil moisture monitoring systems is of paramount importance.
- The utilisation of digital farm management systems has been demonstrated to enhance efficiency.

The utilisation of digital technologies confers numerous advantages:

- The efficiency has been enhanced. The implementation of more accurate production processes has been demonstrated to result in a reduction in costs.
- The issue of sustainability is of particular concern. The utilisation of chemicals, water, and energy has been reduced.
- The enhancement of competitiveness has been observed. A more rapid response to market fluctuations is indicated.

Nevertheless, there are also significant challenges to be addressed:

- It is evident that a considerable financial outlay is required at the outset.
- Farmers' digital literacy is suboptimal.
- Infrastructure development needs have been identified as a key priority (Kljajić et al., 2024).

As a major agricultural region, Vojvodina faces a number of challenges, including increasing productivity, labor shortages, and the need for efficient use of resources. The introduction of digital technologies has been identified as a potential solution to these issues (Ördögh 2017). The role of digital agriculture in Vojvodina is of particular pertinence due to technological developments,

sustainability challenges, and the effects of climate change. Contemporary technologies (e.g. drones, sensors, big data) have been shown to enhance agricultural efficiency, reduce expenditure, and facilitate environmental adaptation (Ördögh 2017). Digitalisation has been identified as a key factor in enhancing the competitiveness of agriculture in Vojvodina, facilitating data-driven decision-making processes and addressing pressing challenges such as labour shortages and food security issues. Government and EU subsidies have been demonstrated to encourage development, thus offering economic and regional benefits. Digital agriculture is becoming increasingly important in Vojvodina, particularly due to technological developments in agriculture and the challenges of sustainable farming (Petrović 2022). Digitalisation is fundamentally transforming traditional agricultural methods, thereby enabling more efficient, precise, and sustainable production. The utilisation of contemporary instruments such as drones, sensors, IoT (Internet of Things) systems, and big data analysis facilitates farmers' access to more precise data concerning soil conditions, meteorological phenomena, and the progression of crops. Consequently, this enhanced information enables the optimisation of production processes (Kamilaris et al., 2018). The impact of climate change on the development of agriculture in Vojvodina is a significant contributing factor. The repercussions of extreme weather conditions, drought, and soil erosion pose considerable challenges. In this context, digitalisation can assist producers in adapting to changing environmental conditions, thereby reducing risks and increasing productivity. The utilisation of data collection and predictive analytics empowers farmers to respond expeditiously to environmental fluctuations, for instance by modifying irrigation or fertilisation strategies. This approach has been demonstrated to enhance crop yields while concomitantly reducing chemical input and water consumption, which are pivotal in the pursuit of sustainability objectives (Trnka et al., 2014).

The introduction of digital technologies has been identified as a key factor in increasing competitiveness. For agricultural operators in Vojvodina, these innovations offer opportunities to produce more efficiently and with fewer resources, reduce costs, and make better use of resources. This is of particular importance in the context of global market competition, where efficiency and sustainability are increasingly determining the position of successful players. Digitalisation has been identified as a potential solution to the problem of labour shortages, which is becoming an increasingly pressing issue in rural areas. The utilisation of automated systems, such as robotic crop production or harvesting, has been demonstrated to reduce the necessity for labour while concomitantly enhancing production efficiency (Rose et al., 2018). Another salient factor pertains to the availability of subsidies from both the government and the European Union, which serve to encourage the digitalisation of agriculture in Vojvodina. It is evident that a number of EU agricultural development programmes and subsidies are specifically aimed at promoting the spread of digital solutions in agriculture. These programmes not only provide financial support for technological innovations, but also facilitate knowledge transfer and training for farmers, thereby ensuring optimal utilisation of the new tools. The Serbian government has also recognised the importance of digitisation and has launched several programmes with the aim of modernising rural economies and increasing their competitiveness. The advantages of digitalisation extend beyond the enhancement of economic efficiency (Petrović 2022). The advent of data-driven decision-making, facilitated by digital tools, has the potential to engender a paradigm shift within the agricultural sector. The utilisation of data collected by sensors, aerial images captured by drones, and weather forecasts empowers farmers to make more informed decisions at every stage of the production cycle. This type of data enables producers to monitor crop conditions in real time, optimise nutrient and water supply, and minimise environmental impact (Liakos et al., 2018). The economy of Vojvodina is heavily dependent on agriculture; as such, digitalisation is crucial not only for agricultural producers, but also for the economic development of the entire region. The introduction of new technologies has been demonstrated to have the capacity to contribute to the growth of the local economy, the creation of employment opportunities, and the enhancement of the attractiveness of agriculture to younger generations. It is imperative to attract young people to this sector, as digitalisation has the potential to enhance the appeal of agriculture, thereby contributing to the halting of rural depopulation and the safeguarding of the future of the agricultural sector (Olfert et al., 2010).

It is imperative for the agricultural sector to prioritise the maintenance and enhancement of its competitiveness in relation to that of EU member states, as this has become a matter of paramount

importance. Consequently, agricultural economies are compelled to confront novel challenges emanating from the accelerated pace of technological advancement and the increasingly globalised economic milieu. It has become imperative for such agricultural enterprises to adapt to the constant pressure to innovate while maintaining their competitiveness in both domestic and international markets. The analysis of the European Union is of particular importance, as Serbian agriculture can more easily adapt to Community standards and expectations by taking into account EU rules and requirements. It is also imperative to be acquainted with the EU support system and to adhere to the EU's strategy and aspirations in order to ensure that Serbian agricultural production maintains competitiveness with the Member States. In European terms, higher average yields can be observed. However, when agroecological factors are taken into account, it can be concluded that Serbian farms are struggling to remain competitive (Petrović 2022).

Serbia is on the threshold of digitalization, but the question arises as to whether family farms are ready for the digital transition. It is also worthy of further investigation to ascertain the attitude of farmers towards the utilisation of precision and digital tools. The objective of the present study is to provide a comprehensive overview of the current situation in Vojvodina. It is hypothesised that the concept of agricultural digitalisation is recognised among farmers in Vojvodina. Despite their preparation for the introduction of digital technologies, they perceive a shortage of resources. The sector is distinguished by an ageing population, which has been identified as a contributing factor to a decline in entrepreneurial spirit.

Based on the objectives, the following research questions were formulated:

- To what extent do farmers in Vojvodina use digital agricultural technologies?
- What are the main barriers to the adoption of digital solutions?
- Is there a relationship between farm size and the use of digital technologies?

2.1. The situation of arable crop production in Vojvodina

A total of 508,365 farms have been registered in the Republic of Serbia, of which 506,323 are family farms and 2,042 are legal entities. Of the farms in question, 111,884 are located in Vojvodina. Of these farms, 110,529 are family farms and 1,355 operate as legal entities (companies, limited liability companies, public companies, cooperatives, etc.). Consequently, family farms represent 99% of all productive farms. The average age of family farm managers is 60, while 11% of farm managers are under 40. This phenomenon signifies a substantial ageing of the population. A further analysis of the data reveals that 77.2% of farm managers are male, while 22.8% are female. (RZS/Republic Statistical Office, 2023).

Farmers under the age of 35 are responsible for the operation of 22% of farms with a size greater than 50 hectares. It is evident that a significant proportion of agricultural land, amounting to 66%, has been cultivated by farms with an average plot size that exceeds 30 hectares. The two primary crops in Vojvodina are wheat and maize. The precise data from the 2023 agricultural census are not yet available, but it is estimated that approximately 976,243 hectares were used for growing cereals. Of this, 330,293 hectares were used to grow wheat and 610,304 hectares were used to grow maize. As Ördögh (2017) demonstrate, industrial crops were cultivated on 346,943 hectares, with sunflowers occupying 167,173 hectares and soybeans covering 166,242 hectares.

The region's predominance of family farms, which frequently encounter substantial capital limitations and frequently lack the requisite expertise, severely restricts the adoption of precision farming practices. Conventional wisdom suggests that members of the older generation are less open to innovation and often lack the motivation or ability to change their previous production practices. Operators of small farms, typically encompassing a few hectares, frequently exhibit a paucity of contemporary market intelligence and possess only rudimentary farming skills. Consequently, they encounter difficulties in recognising changes in the market environment and are slow and hesitant to respond to new challenges and opportunities. (Ördögh 2017).

The majority of producers have been found to be utilising machinery that is no longer state-of-the-art, with only a very small proportion of producers employing the latest production technologies. A study by the Statistical Office of the Republic (2013) found that 90% of the almost 100,000 combine harvesters and tractors in use were over 10 years old, a situation that has arisen due to economic decline.

The utilisation of obsolete machinery invariably results in elevated production costs, owing to the increased fuel consumption and diminished efficiency of such equipment. The irrigation of arable land represents a significant challenge. According to the most recent agricultural census, 3.62% of the total arable land is irrigated. It is evident that farmers utilise surface water and water from wells. The Danube-Tisza-Danube canal is capable of irrigating only 30,000 hectares, a mere fraction of its total potential of 500,000 hectares. Furthermore, endeavours to privatise fertiliser factories have proved unsuccessful, with the consequence that 60% of fertilisers are now imported. The technological disparity is predominantly evidenced by the fact that the mean yield of our most significant agricultural product, grain, exhibits a lag in comparison to the mean yields of Germany and France. The average yield in Serbia of 4.2-4.8 t/ha is significantly lower than the French and German average of 7 t/ha (Strategija, 2014).

3.Materials and methods

In the course of my research, I examined family-run agricultural businesses in Vojvodina that are in some way connected to digital farming. In order to address this gap in knowledge, an online survey was developed with the aim of mapping the extent to which farmers use digital technologies and the challenges they face in this area. Despite the limitations of the survey, including its voluntary nature and the predominance of responses from digitally active farmers, the results offer valuable insights into the digital landscape of agriculture in the region. The data obtained, based on the number of items and the demographic composition of the respondents, provide a relevant picture of how open farmers in Vojvodina are to new technologies and what opportunities and obstacles they see in the introduction of digital solutions.

The survey was conducted over the period from 6 January to 6 February 2024. A total of 102 farmers completed the questionnaire, with the average age of respondents being 41.76 years. The results contribute to understanding how agricultural businesses in Vojvodina are digitising and what trends can be observed in the development of the region's agricultural sector.

The target group of the present research consisted of small and medium-sized agricultural enterprises operating in Vojvodina. During the course of the study, an online questionnaire was utilised, which was made available to farmers via Google Forms. In order to obtain responses from as wide a range of respondents as possible, the questionnaire was made available in both Hungarian and Serbian. The respondents were recruited in a targeted manner, primarily through agricultural associations and professional networks. This approach ensured that the questionnaire was disseminated to the relevant agricultural stakeholders.

In the course of the analyses, the Mann–Whitney test was utilised, which serves as the non-parametric equivalent of the two-sample t-test. The Mann–Whitney test is appropriate for the purpose of comparing the mean values of two independent samples in instances where the samples do not adhere to a normal distribution. The method requires that the samples examined be independent of each other and that the data be available in a rankable form (Ketskeméty et al. 2011). In the course of the statistical analysis, the present author compared data collected in 2021 and 2024, with a view to examining the effect of farm size on the prevalence of precision farming technologies.

In the course of the analysis, a distinction was made between two groups: farms with an area of less than 50 hectares and farms with an area of more than 50 hectares. The objective of this study was to ascertain whether the utilisation of precision farming technologies varies between the two groups under consideration, and thereby determine whether farm size exerts an influence on the adoption of innovative technologies. In the present study, farm size was treated as an independent variable, while the extent of precision farming tool use was defined as a dependent variable. The dependent variable indicated the extent to which digital technologies and precision tools are utilised on a given farm. The employment of the Mann-Whitney test was substantiated by the observation that the dependent variables do not conform to a normal distribution. Consequently, the non-parametric approach was deemed to be a more suitable option. The present study employed this method to examine whether the utilisation of precision farming tools exhibited significant disparities between farms of differing sizes.

The questionnaire consisted of several structured sections focusing on the adoption and perception of digital technologies in agriculture. The main topics included:

- demographic characteristics of respondents (age, gender, role in the farm),

- farm characteristics (farm size, type of production),
- use of digital and precision agriculture technologies (e.g. GPS, sensors, variable rate technologies),
- attitudes towards digitalisation,
- perceived barriers (financial, knowledge-related, infrastructural).

Most questions were closed-ended, using nominal and ordinal scales, allowing statistical comparison between groups.

The sample is not fully representative of the entire population of farmers living in Vojvodina, as the survey was conducted online and participation was voluntary. Therefore, the results primarily reflect the views of farmers who are more active in the digital sphere.

The statistical analysis was performed using IBM SPSS Statistics and Microsoft Excel. Prior to applying the Mann–Whitney test, the normality of the variables was tested using the Shapiro–Wilk test. The results indicated that the variables did not follow a normal distribution ($p < 0.05$), therefore non-parametric tests were applied.

We distributed the survey through agricultural organizations, social media groups, and professional networks. Due to the open distribution method, the exact response rate cannot be determined.

4.Results

The results of the questionnaire survey enabled the drawing of several important conclusions about the demographic characteristics of farmers in Vojvodina and the prevalence of precision farming technologies.

The mean age of the 102 respondents was 41.76 years, with the majority falling into the 36–50 age group. This is of particular interest when viewed in the context of Serbian statistical data, which indicates that the average age of farm owners is approximately 60 years, and that only one in eleven agricultural managers is under the age of 40 (RZS/Republic Statistical Office 2023). Consequently, the survey's primary demographic was younger farmers, suggesting that the utilisation of digital tools and online platforms is particularly appealing to this age group. The youngest participant in the study was only 17 years old, while the oldest was 74 years old (see Figure 1). An examination of the role of age in relation to the use of digital technologies yielded surprising results. It was hypothesised that farmers of a more mature generation would be less acquainted with and less inclined to utilise novel technological solutions. However, the data demonstrated that age is not a determining factor in individuals' openness to utilising digital agricultural tools (Figure 1). The size of the farm, the availability of resources, and the specific characteristics of the farm type play a much greater role in the introduction of precision technologies (Sinkovics 2024).

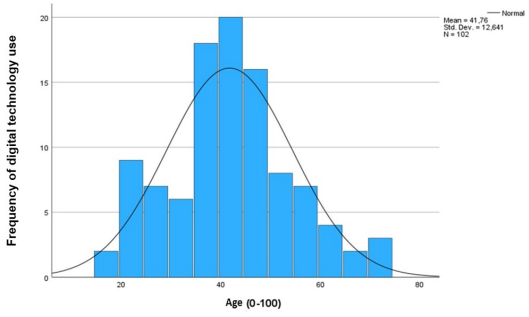

Figure 1. Relationship between age and technological competence (Own data, own compilation, 2024)

The gender distribution of respondents is outlined below: The demographic composition of the sample was as follows: 55% of the subjects were male, and 45% were female. An analysis of the ownership structure of farms indicated that the majority of respondents were also the proprietors of

their businesses. A higher proportion of male respondents than female respondents reported ownership, suggesting that women frequently assume a supportive role in the operation of family farms and often collaborate with their spouses in farm management. This phenomenon may also provide a rationale for the observed gender disparity in employee demographics, wherein the proportion of female employees exceeds that of their male counterparts (see Figure 2).

Owners: 82.4% (of which 87.5% are men and 76.09% are women)

Managers: 5.8% (of which 5.36% are men and 6.52% are women)

Employees: 11.8% (of which 7.14% are men and 17.39% are women)

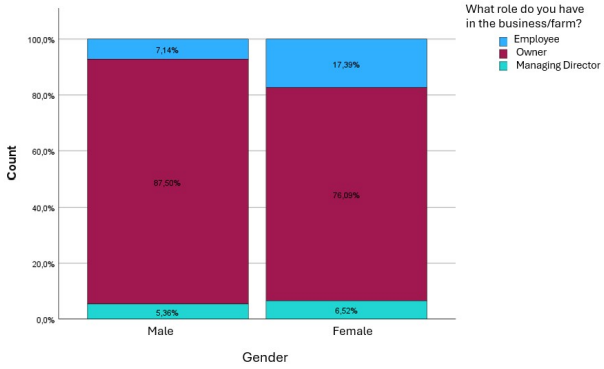

Figure 2. Roles and gender ratio (Own data, own compilation, 2024)

Geographical distribution indicates that the majority of respondents were from the Bačka region, specifically from North Bačka. With regard to the primary function of the farms, it was found that arable crop production was the most significant sector, evidently predominating the sample surveyed, with 80.4% of respondents designating it as their primary activity (Figure 3).

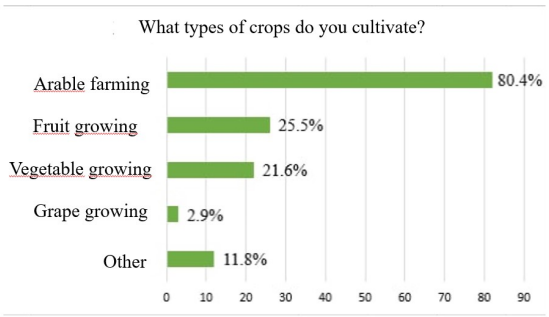

Figure 3. Crop cultivation (Based on own data, own compilation 2024)

The findings indicate that a proportion of farmers in Vojvodina have adopted a receptive stance towards digital agriculture; however, the dissemination of precision technologies remains incomplete. The introduction of innovative solutions is contingent on the size of the farm and the availability of financial resources. Conversely, age exerts a lesser influence on openness to digital technologies.

Upon rigorous examination of the relationship between agricultural output and the utilisation of digital agricultural technologies, it is evident that a clear trend can be identified. The data demonstrate a clear correlation between farm size and the adoption of digital technologies, with larger farms, defined as those exceeding 50 hectares, demonstrating a higher propensity for utilising such technologies. In contrast, the data indicate a lower prevalence of digital tools on smaller farms, suggesting a potential barrier to adoption in this segment. This finding indicates that the predominance

of digital solutions is predominantly influenced by farm size, rather than age or other demographic factors.

The data obtained during the research clearly show that the use of digital agricultural technologies is much lower on smaller farms. In the cohort of individuals already utilising digital solutions, the most prevalent tools encompass GPS-based navigation, autonomous vehicles, variable depth tillage, variable rate fertiliser application, variable rate seeding and variable rate pesticide application. Concurrently, 45.1% of respondents indicated that they have no plans to introduce precision farming technologies in the near future.

A detailed investigation of the data, with a focus on farm size, revealed that a significant proportion (approximately 64%) of managers of farms with a size greater than 50 hectares intend to adopt and enhance precision techniques within the next five years. The data indicates that 9% of the sample intend to make such investments in the current year, while a further 9% plan to do so in the following year. Conversely, 18% of respondents indicated that they have no intention of making such developments within the next five years. In contrast, farms with an area of less than 50 hectares exhibit a divergent pattern of adoption. Approximately 49% of these farms do not intend to adopt precision technology, while 40% express a desire to introduce such tools within the next five years.

Farmers intending to introduce precision technologies expressed a primary interest in autonomous vehicles, followed by variable rate fertiliser application and precision row cultivation. The challenges experienced by farmers are manifold, including but not limited to: poor mobile coverage, the complexity of establishing digital tools, and age-related concerns. It is evident that a divergence of opinion exists amongst respondents regarding the accessibility and relevance of digital technologies to their demographic. While a proportion of respondents express reservations regarding the applicability of such technologies to their age group, others have not encountered any impediments and are proactively utilising the opportunities presented by precision farming. A significant proportion of respondents expressed a willingness to utilise GPS-based systems and drones, contingent on more cost-effective alternatives (Sinkovics 2024).

The primary barriers to the dissemination of digital technologies encompass a paucity of financial resources and a dearth of pertinent expertise. In accordance with the responses obtained during the survey, the majority of farmers identified these factors as the most significant impediments to the broader adoption of digital technologies.

As illustrated in Figure 4, the responses pertaining to the utilisation of grant funds indicate that 47.1% of respondents intend to employ grant funds in the near future, while 14.7% do not anticipate utilising this opportunity. According to the data, 38.2% of respondents are considering applying for grant funding but have not yet made a final decision. This finding suggests that interest in grant opportunities is mixed, and that some farmers are still uncertain or awaiting further information on the availability and conditions of the funds. Furthermore, interest in grant funding is likely to increase if grant announcements are made easily accessible to farmers and if emphasis is placed on reducing bureaucratic burdens and introducing simplified procedures. The role of state and local institutions is therefore crucial in gaining the trust of farmers and thus promoting wider use of the funds.

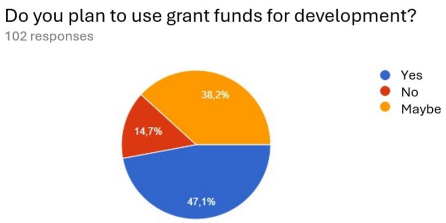

Figure 4. Use of grant funds (Own data, own compilation, 2024)

A comparison of the results by farm size further reinforces the observation that larger farms are more interested in new technologies and actively seek information about innovative solutions. It is a well-documented phenomenon that a technology which has been introduced to a larger farm will subsequently be adopted by other, smaller farms. A smaller proportion of farmers with more than 50 hectares of land believe that digital technologies are not cost-effective, while this attitude is more prevalent among farmers with less than 50 hectares.

It is evident that larger farms have the capacity to exert a substantial influence on the attitudes of smaller farmers. This influence can be exerted through the provision of a model for the application of new technologies and the maintenance of competitiveness. In the context of the competitive nature of the agricultural market, it is frequently observed that larger farms acquire or displace smaller farms, thereby increasingly adopting digitalisation strategies to fortify their own market position.

5. Conclusions and recommendations

It is evident from the findings of the research that agricultural producers in Vojvodina are cognisant of the potential of digital technologies; however, there are considerable disparities in their practical application. The region's favourable natural conditions and the structural characteristics of its land use create an environment conducive to the spread of digitalisation in agriculture. Nevertheless, in order to significantly increase competitiveness, it is essential to develop targeted state support systems and measures aimed at expanding expertise, with a particular focus on practical training and digital skills development.

From an international perspective, it can be observed that in several Member States of the European Union, particularly Germany, the Netherlands and France, digital agricultural technologies (e.g. precision farming, sensor-based monitoring systems, autonomous machines) are already part of everyday agricultural practice. Conversely, the integration of digital tools is progressing at a more gradual pace in the Western Balkan countries, including Serbia and Vojvodina. This is primarily attributable to deficiencies in infrastructure, inadequate capital resources and limited technological expertise. These disparities underscore the notion that the success of agricultural digitalisation is contingent not solely on technological factors, but also on the confluence of educational, economic, and institutional elements.

The study demonstrated that certain farmers evince a degree of caution with regard to the introduction of novel technologies. This is primarily attributable to elevated investment costs and the absence of certainty regarding returns. It is evident that smaller farms encounter significant disadvantages, primarily due to their limited capacity to implement developments using internal resources. Should the present support system remain unaltered, there is a strong probability of a gradual decline and eventual extinction of small and medium-sized farms over the long term. This is a cause for concern, given the evident demand for digitalisation among farmers. However, smaller farms are unable to meet the financial demands associated with technological advancements.

The size of the farm is a pivotal factor in the success of digitalisation, as contemporary technologies can be implemented more efficiently on farms with larger areas of land. This tendency indicates that it may be unwise for small farms to procure costly machinery and systems that exceed their requirements, as this can result in a futile expenditure of resources over time. A more sustainable solution would be cooperation and collaboration between farmers, which would allow for the joint purchase and use of machinery. The enhancement of accessibility to contemporary technologies, in conjunction with the reduction of expenses, would be a consequence of cooperation.

The research also highlighted that farmers' propensity to innovate is contingent not solely on age, but rather on farm size and financial resources. It has been observed that members of the older generation tend to exhibit a greater degree of caution with regard to the introduction of novel technologies. However, this reluctance can be mitigated through the provision of suitable professional demonstrations, training programmes and advisory services. Education and the sharing of practical experience have been demonstrated to play a key role in the spread of digitalisation (Kamilaris et al., 2018).

Indeed, practical examples and successful models have been shown to help farmers to adopt new technologies with greater confidence (Rose et al., 2018).

In order to ensure the long-term competitiveness of agriculture in Vojvodina, it is imperative to consider factors beyond the exploitation of natural resources. The employment of skilled labour and the integration of modern, digital and innovative solutions are also essential components of this strategy. In order to achieve sustainable farming, it is important to share knowledge between generations and to introduce digital agricultural technologies on a wider scale. State involvement and economic policy support are identified as pivotal factors in ensuring that smaller farms do not lag behind in the digitalisation process.

The digitalisation of Serbia's agricultural sector is still in its infancy, and the absence of state support and professional collaboration poses a significant challenge for smaller farms. It is evident that larger farms are better positioned to modernise promptly and efficiently due to their greater financial capacity to absorb the costs of digital tools, as well as their ability to expedite the return on investment. For smaller farms, the sharing of experiences and opportunities for cooperation may be one means of increasing competitiveness. However, with market competition intensifying and as a result of the EU accession process, it is predicted that smaller farms will become extinct unless targeted intervention is taken in the areas of support systems and professional assistance.

The findings of the research indicate that the implementation of targeted support programmes, cooperative forms and long-term strategic agricultural modernisation measures is imperative to foster digitalisation developments. The promotion of agricultural digitalisation is conducive not only to the individual development of farmers, but also to the enhancement of the region's agricultural sector as a whole. In addition to the involvement of state and EU funds, the wider dissemination of education and technological knowledge can also play a key role in the sustainable development of agriculture in Vojvodina.

The future outlook for digital agriculture in Vojvodina is positive. The introduction of agricultural technologies can be facilitated by EU subsidies and local government programmes. The agrarian sector is witnessing a paradigm shift, with young farmers and nascent enterprises offering digital solutions gaining significant market share. Digital agriculture is expected to contribute to increased production efficiency and the sustainable development of rural communities. The implementation of digital agriculture in Vojvodina signifies not merely a technological advancement, but also establishes the foundation for the future of agriculture.

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