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The state of agricultural digitalisation in Hungary

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Abstract: In recent years, the concept of digitalization has gained increasing attention in the field of agriculture. The adoption of digital technologies such as sensors, drones, and precision farming tools has the potential to revolutionize how agricultural production is carried out, leading to increased efficiency, productivity, and sustainability. This study examines the current state of digitisation and the use of digital tools in agriculture among Hungarian farmers. The uptake of digitalisation has been slow, and more comprehensive policies and strategies are needed to improve progress. The study shows that while there are positive developments, such as the increasing use of precision technologies, there is still a lack of digital infrastructure and skills, as well as limited access to finance and information. The study concludes by making recommendations for policy makers, stakeholders and farmers to enhance the digitalisation of agriculture in Hungary.

Keywords: digital divide; sustainability; precision agriculture; technology

Currently, one of the most important challenges to achieving food security is the intensification of global food production (FAO, IFAD, UNICEF, WFP, WHO 2021). Most surveys and research efforts in agriculture focus on crop production (Bodirsky et al. 2020). However, these analyses do not take into account the instability of yields over time or the variability and reliability of cereal production over several years. Yield stability is crucially affected by the negative impacts of climate change (Kang et al. 2009; Loboguerrero et al. 2019; Anderson et al. 2020). Besides climate change, rapid population increase also has a great effect on agricultural production (Popp et al. 2013; Brown et al. 2019). As the global population continues to grow (Knapp and van der Heijden 2018; UN 2019), agricultural production must also keep pace with it (FAO 2021). The size of urbanized areas is expected to increase threefold between 2000 and 2030 (UN 2019). In economically less developed regions, agriculture is of outstanding national economic importance, so there is growing pressure on agricultural production (Fróna et al. 2019; Kopittke et al. 2019; Giller et al. 2021). Production has to meet the demand of the growing population, but it has to be sustainable and not harmful to the environment (Popp et al. 2014; Basso and Antle 2020). Agrochemical use, animal production, the exploitation of water and soil, and other intensive agricultural practices have all been brought about by the rising food demand brought on by the unceasing growth of the world's population (Ray et al. 2013; Kopittke

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et al. 2019; Giller et al. 2021). There are some possible solutions to overcome these burning issues.

Precision agriculture and digitalization have the potential to play a crucial role in achieving sustainable food security in the face of a growing population (Hrustek 2020; Balasundram et al. 2023). The use of digital technologies, such as sensors, drones and precision farming tools, allows for more precise and efficient management of resources, such as water, fertilizer and pesticides (Srbinovska et al. 2015; Ezenne et al. 2019; Benyam et al. 2021). By providing real-time data and analysis, precision agriculture can increase crop yields while reducing inputs and environmental impact (Bongiovanni and Lowenberg-DeBoer 2004). Additionally, precision agriculture can also support sustainable land use and conservation practices by reducing tillage and soil erosion (Gebbers and Adamchuk 2010; Pozza and Field 2020). Furthermore, digitalization in agriculture can also provide a more efficient and sustainable supply chain by reducing food waste and reducing the use of fossil fuels (Munesue et al. 2015; Morone et al. 2019; Annosi et al. 2021).

The concept of digitalization in agriculture has gained significant attention over the past few decades, with the adoption of digital technologies such as sensors, drones, and precision farming tools having the potential to revolutionize the way agricultural production is carried out (Popp et al. 2018; Erdei et al. 2022; Neményi et al. 2022). These technologies can increase efficiency, productivity, and sustainability in the agricultural sector by providing farmers with precise information about their crops, soil and weather conditions (Kumhálová et al. 2011). Precision farming technologies, such as precision planting, variable rate application, and precision irrigation, can help farmers to reduce soil erosion (Kroulík et al. 2009). Thanks to technological enhancement, mapping and interpolating spatial patterns, and geographic information systems for overlaying and interpreting several soil, landscape and crop attributes, soil erosion can be mitigated (Mulla 2007; Maia et al. 2017). However, the adoption and integration of these technologies vary among different countries and regions (Barnes et al. 2019; Pathak et al. 2019; Michels et al. 2020). While some countries have made significant progress in the adoption of precision agriculture, others are still lagging behind (Zhang et al. 2002; Kendall et al. 2022).

In recent years, the adoption of digital technologies in agriculture has received significant attention in Hungary (Takácsné György et al. 2018; Gaál et al. 2021). In Hungary, precision farming is still in the early stages of adoption, and there are several barriers that farmers face when trying to implement these technologies (Kovács and Husti 2018; Balogh et al. 2021). One of the key drivers of agricultural digitalization in Hungary has been the adoption of precision farming techniques (Lencsés and Mészáros 2020; Bai et al. 2022). These techniques use advanced technologies such as GPS, sensors, and remote sensing to monitor and control various aspects of agricultural production, including soil moisture, nutrient levels, and pest infestations (Finger et al. 2019). By using precision farming tools, farmers can optimize their use of resources, such as water and fertilizers, leading to reduced input costs and increased crop yields (Zolkin et al. 2021). One of the main drivers of digitalization in Hungarian agriculture is the globally increasing demand for food production to meet the needs of the population. Digital technologies have the potential to increase efficiency and productivity in various aspects of the agricultural value chain, such as precision farming, supply chain management, and food processing (Cisternas et al. 2020).

This study aims to examine the state of agricultural digitalization in Hungary, including the trends, challenges and opportunities that have emerged in the country. The research will provide insights into the current status of the digitalization of agriculture in Hungary and will help in understanding the factors that are influencing its adoption. It examines solutions to overcome the barriers its adoption in Hungary, and also provides insights into how to create a more supportive institutional environment for agricultural digitization in Hungary. By providing an understanding of the current state of the field, this study contributes to the development of policies and strategies to promote the adoption of digital equipment in the country, ultimately leading to the increased efficiency, productivity, and sustainability of agricultural production and contributing to the economy of the country. The objectives of the study are to examine the extent to which digital technologies are being adopted by farmers and agribusinesses in Hungary, and to identify the most common digital tools and their application. The study also provides some viable recommendations to be considered for policymakers, stakeholders, and farmers to enhance the digitalization of agriculture in Hungary and to promote sustainable development.

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MATERIAL AND METHODS

The secondary data used during the writing of this research comes from the United Nations (UN), the Food and Agriculture Organization (FAO), and the United Nations International Children's Emergency Fund (UNICEF) databases. The relevant articles (both international and Hungarian) originate from the Google Scholar and Web of Science (WoS) databases. In terms of Hungarian specialised data, data was obtained from Hungarian Central Statistical Office (HCSO). Microsoft Excel (software veresion 2016) was used to visualize the data from the HCSO.

During the analysis of the literature related to the topic (digitisation and agriculture), mainly secondary data was analysed. International literature mostly contains studies presenting comprehensive analyses, and in the case of domestic sources, only a limited number of relevant research studies are currently available; however, the number of these shows an increasing trend.

During the literature review, the exploration and analysis of the theoretical background and the search for studies were essential. Accordingly, the focus of the analysis was the exploration of Hungarian-related data and their adaptation. The literature search was conducted primarily with the help of Google Scholar and WoS. In the case of Google Scholar, findings were sorted according to relevance, and the number of citations and their place of publication were also taken into account. As much as possible, the most relevant studies were referred to alongside the most recent ones. There is a large amount of international literature available, which shows the importance of the topic of the study. A network of connections was made based on the data retrieved from the WoS database. The visualisation of the connection network was made with VOS viewer (software version 1.16.18), which helped with the graphical display (Figure 1). During the filtering, the type of documents selected was exclusively articles; all publishers and all areas selected as search parameters were set using the WoS search engine, and the search was carried out in November 2022. During the searches, the following keywords/terms and their combinations were utilised: precision agriculture (data period 2002–2022; 10 034 results), smart agriculture (data period 2002–2022; 5 162 results), sustainable agriculture (data period 2002–2022; 30 937 results), climate-smart agriculture (data period 2002–2022; 1 087 results), agriculture 4.0 (data period 2016–2022; 1 248 results), digitalization and agriculture (data period 2000–2022; 565 results).

RESULTS AND DISCUSSION

In general terms, by 2025 Hungary could achieve an increase of up to EUR 9 billion in gross domestic product (GDP) from the potential economic and developmental benefits of digitization (Novák

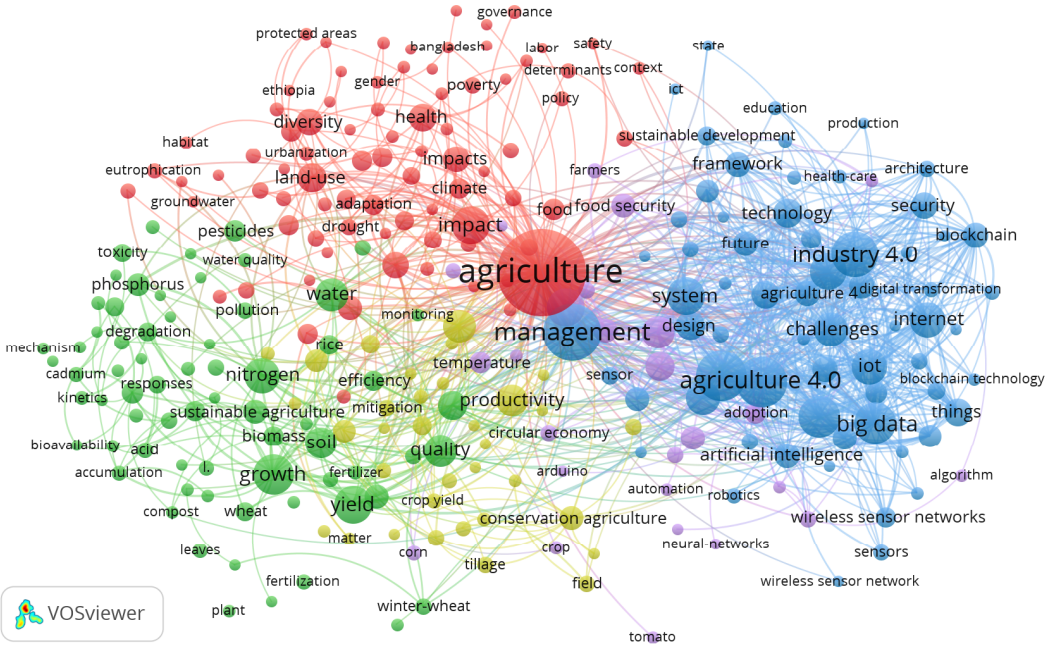

Figure 1. Network of connections displayed, based on keywords/terms

Source: author's own editing, based on data from Web of Science , made by VOS viewer

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et al. 2018). Hungary's 10 million citizens would enjoy greater prosperity and global competitiveness as a result, and the country would be able to join the most technologically sophisticated economies of Europe (Smit et al. 2022). Since the 1990s, Hungary's economy has grown significantly. Between 1996 and 2017, the gross domestic product (GDP) per capita increased by 74%. Traditional industries, dynamic exports, foreign investments, labour-cost advantages, and the inflow of EU funding were the key growth factors during this time. Similarly to the rest of the CEE, Hungary can use the digital economy as its next source of growth due to its lower level of digitalization (Novák et al. 2018).

Hungary has a considerable disparity when compared to Western EU nations, and it lags behind the CEE in the majority of industries. Utilities, manufacturing, and the financial and insurance industries all have significant shortcomings in digital terms (Smit et al. 2022). Furthermore, compared to other EU nations, Hungary's agriculture is significantly underdigitized (Vattai 2019). On the other hand, due to its position as a significant host of shared services centres in the region, Hungary has relatively high rates of digitisation in both professional and corporate services, as well as public sector services (Novák et al. 2018) (Figure 2).

The future engine of Hungary's sustainable prosperity may be digitization. Acceleration of digital transformation is necessary, particularly in the industries that are least competitive relative to their Digital Frontrunner benchmarks while also contributing significantly to the Hungarian economy. These include asset-intensive industries such as manufacturing and retailing, and decentralized ones such as agriculture. The second source of growth is the result of e-commerce and offline consumer expenditure on digital equipment expanding more quickly. The adoption of digital technology by all stakeholders is necessary to realize this promise.

Manufacturing, trade, and agriculture are three historically labour-intensive (Fróna and Kőmíves 2019) – and at the same time under-digitized – industries that show tremendous automation potential, with the potential to eliminate more than half of their existing workforce by 2030. On the other hand, industries with high vacancy rates now may gain in the short term by unclogging growth that has been constrained by a scarcity of available workers (Figure 3) (Novak et al. 2018).

The Hungarian Central Statistical Office (HCSO) carried out a full-scale agricultural census under the name "Agrárcenzus 2020", based on European Union (EU) and domestic legal authorization. According to the data, agriculture accounted for 4.1% of the gross added value of the national economy, 4.3% of investments, and 4.6% of employment in 2020 (HCSO 2022b). In Hungary, 216 000 agricultural firms farmed approximately 4.9 million ha in 2020. Grouping the farms based on the size of the agricultural area used, farmers with an area of fewer than 5 ha typically used their own land (HCSO 2022b). Consequently, agricultural areas in Hungary are characterized by a dual structure, since many farmers work on a small portion of the land. Small farmers are at a disadvantage compared to larger

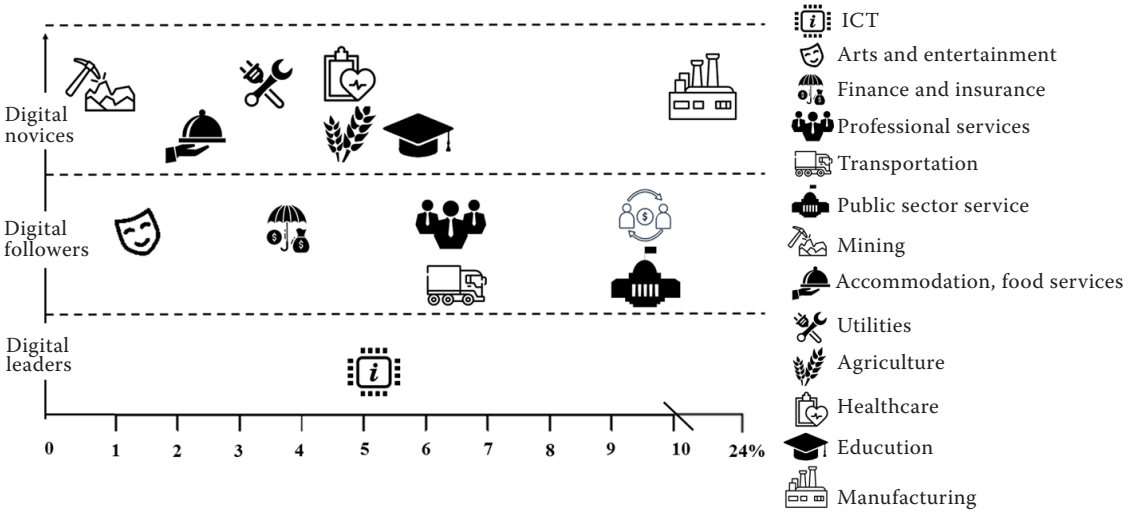

Figure 2. Sector-level digital leaders, followers, and novices in Hungary, proportion of gross domestic product (2018) (%)
Source: author's own editing, based on Novak et. al. (2018)

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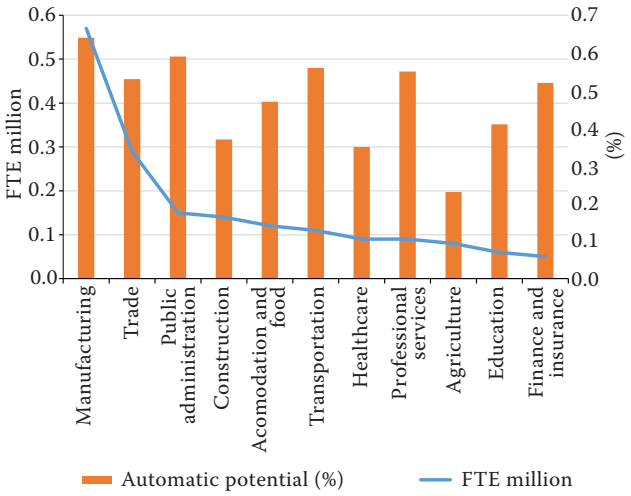

Figure 3. Total automation potential in an equivalent number of jobs in Hungary, 2018
Source: author's own editing, based on Novak et. al. (2018)

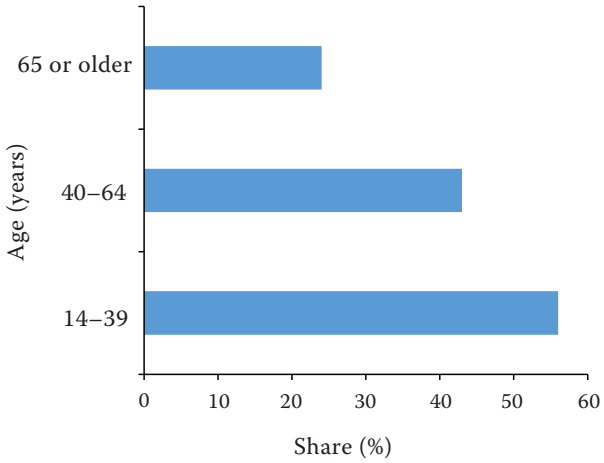

Figure 4. Proportion of use of digital devices, 2020
Source: author's own editing, based on HCSO data (2022a)

farms due to their small land use size and profitability, so digital technologies can help their efficiency and profitability, as has already happened in other Hungarian sectors.

In Hungarian farms, even simple digital technologies are not completely widespread. Only 38% of farms used some kind of digital tool in 2020, with farmers mostly handling matters related to banking and e-government electronically. Tools related to precision farming were used by 12%, within which the plant condition survey was the most widespread (5.6% of all farms). 15% of the farms used a specialist consultant, and producers were most often consulted on plant protection issues (HCSO 2022a). The rate of use of digital tools decreases with the age of farm managers but increases with the level of agricultural education (Figure 4). Despite this, this rate is only 75% even for those with higher agricultural education (HCSO 2022a). As in many EU member states, Hungary also suffers from aging in the agricultural sector.

However, as the size of the economy increases, the proportion of economies using digital tools increases dynamically. In the case of farms with a standard production value of EUR 100 000 or more, this is almost essential (Figure 5).

By type of farm, the use of digitization tools is most widespread in farms dealing with the keeping of mass feed-consuming animals, arable crop cultivation and mixed crop cultivation. However, the prevalence of the use of individual tools differs significantly, even within individual economic groups (HCSO 2022a).

Farmers most often carry out banking administration (between 16 and 42% of farmers), regardless of farm type, and 17% use general office software such as document management software (Figure 6). E-governance also plays a big role in farms, with an average of 20% of farmers using this. Electronic commerce (average of 7%) and administration software for farm management (average of 3%) is barely used among Hungarian farmers.

Precision farming increases the efficiency of agricultural production by supporting environmental protection and sustainability expectations, increasing yields, and reducing costs. In addition, it can promote sustainable agricultural production, thanks

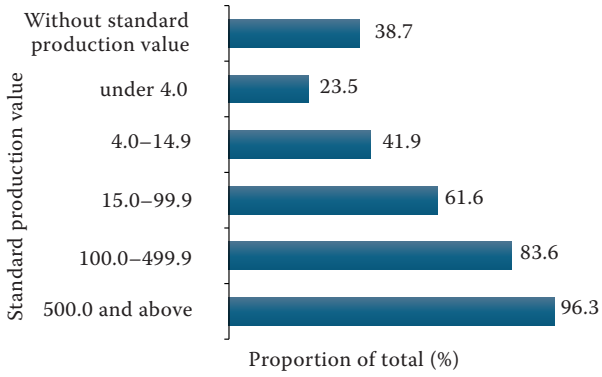

Figure 5. Proportion of use of digital devices by category of standard production value of the economy, 2020
Source: author's own editing, based on HCSO data (2022a)

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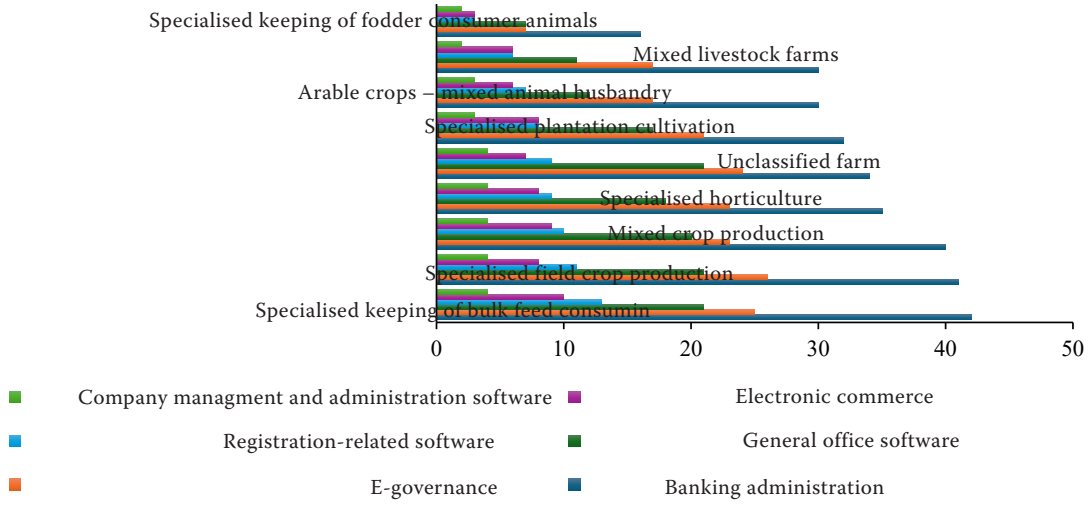

Figure 6. Proportion of farms using digital devices, by type of economy, 2020
Source: author's own editing, based on HCSO data (2022a)

to the more precise application of input materials and the more precise timing of different work processes. The labor shortage characteristic of agriculture can be mitigated by automatic systems of precision farming and robotics (Lencsés et al. 2014; Finger et al. 2019).

In Hungary, the prevalence of precision instruments is at a lower level than that of the previously listed digital instruments. 12% of farms use some kind of precision equipment. In Denmark, this rate was 23% in 2018, and precision instruments were already used in 57% of the total agricultural area. The plant condition survey is the most widespread, with 5.6% of all farms using it (Figure 7) (HCSO 2022a).

Among farm types, the most common practice among arable plant growers is the use of precision equipment with their own equipment or within the framework of a service. But overall, the use of these tools is the most common among those involved in crop cultivation. In farms dealing with arable crop production, in addition to plant condition assessment, the use of automatic/row-leading steering is also relatively widespread. The prevalence of precision feeding is a few percent in animal farm

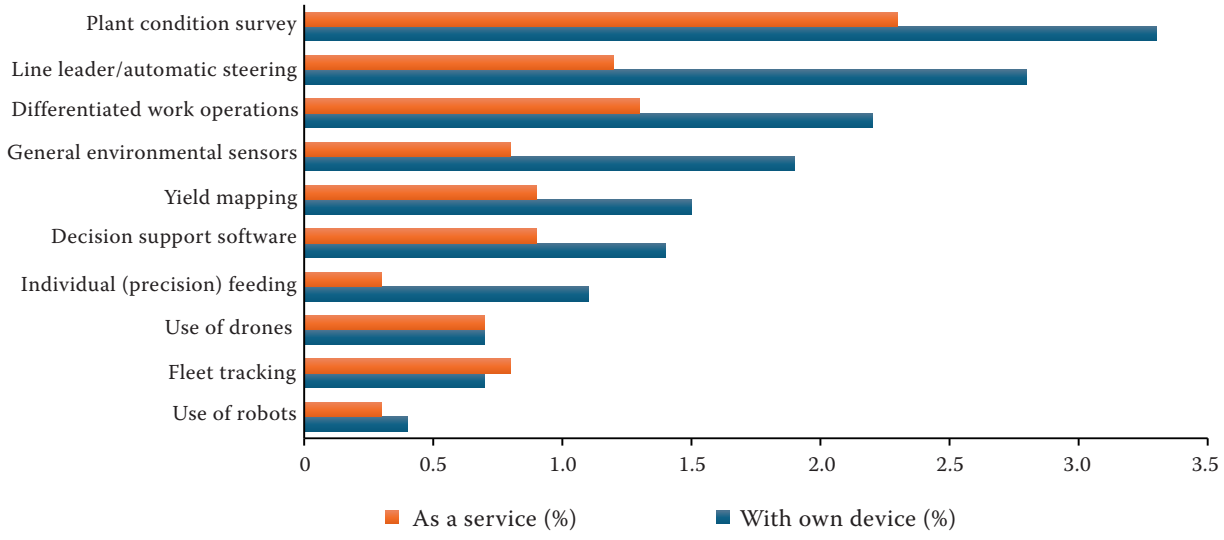

Figure 7. Proportion of farms using precision tools, 2020
Source: author's own editing, based on HCSO data (2022a)

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types, but only 16% in the case of farms with at least 100 livestock units (HCSO 2022a).

One of the key technologies in the digitalisation of Hungarian agriculture is the use of precision farming techniques. These techniques involve the use of sensors, GPS, and other digital tools to optimize crop production and reduce input costs (Popp et al. 2018). Another area where digital technologies have been adopted in Hungary's agriculture sector is the use of drones. Drones are becoming increasingly popular as a tool for collecting data on crops and livestock, as well as for performing tasks such as crop spraying and monitoring animal health. The use of drones in agriculture has the potential to reduce labor costs and improve efficiency, as well as provide more accurate and timely data for decision-making (Bai et al. 2022).

In addition to precision farming, digital technologies have also been used to improve supply chain management in Hungary. The use of digital tools, such as traceability systems and electronic marketplaces, has improved the efficiency and transparency of the supply chain in Hungary. The adoption of these technologies has had a positive impact on the competitiveness of small and medium-sized enterprises (SMEs) (Boros-Papp and Várallyai 2019).

Another area where digitalization has had an impact on Hungarian agriculture is food processing. The adoption of digital technologies in the food processing industry in Hungary has improved the efficiency and quality of products. The authors also found that the use of digital technologies has had a positive impact on the financial performance of food processing SMEs (Jeyakumar et al. 2021; Endrődi-Kovács and Stukovszky 2022).

Innovation can be influenced by a variety of factors that can be grouped into two categories: external and internal. External factors include the market environment, such as consumer demand and competition, as well as government policies and regulations. The social environment, such as consumer attitudes toward innovation and trust among economic actors, also plays a role (Balogh et al. 2021). Internal factors that can impact innovation include a lack of financial resources, skilled labor, and retention of high-skilled employees. Most studies on sustainable farming technologies evaluate their economic, environmental, and labor impacts, and their benefits have been documented (Balafoutis et al. 2020). Another study emphasizes the importance of indirect methods, such as providing information and demonstrations, in encouraging the adoption of precision agriculture technologies by land managers and policymakers (Barnes et al. 2019).

Despite the potential benefits of digitalisation in Hungarian agriculture, several challenges need to be addressed. One of the main challenges is the limited access to digital technologies for small and medium-sized farms. The adoption of digital technologies in Hungarian agriculture has mainly been concentrated among larger farms, while smaller farms have been less likely to adopt these technologies. The lack of knowledge about digital technologies has been a major barrier to the competitiveness of small and medium-sized farms in the sector. A study confirms this statement, reporting that, according to the majority of the participants in the study, it is necessary to increase human knowledge of and expertise in digitalization (Somosi Sarolta and Gabriella 2020).

The use of precision tools is much lower than the prevalence and existence of machines and tools on farms. On a national average, 28% of farms have their own power machinery, work machinery, or equipment used in animal husbandry. Despite this, only 8% use their own precision equipment. The reason for this is probably that farmers do not have sufficient knowledge of their use or do not feel they are needed for their farming (HCSO 2022a). One of the reasons for the relatively low prevalence of precision farming is that precision farming is a series of capital- and knowledge-intensive technologies. In addition, it involves a high investment cost (Somosi Sarolta and Gabriella 2020; Takácsné György 2020), which pays off in the long term and is only profitable above a certain farm size. Farmers do not always have the funding necessary for the additional expenditure required to introduce the technology. Another factor is the historical burden that Hungarian agriculture has been carrying since the regime change, and the lack of cooperation and information exchange among Hungarian farmers. Farmers with smaller farm sizes believe that cooperation and collaboration among farmers would accelerate the adoption of precision farming. They argue that by pooling resources and expertise through joint development projects, they would be able to mitigate the high costs of investment and achieve a faster return on investment. However, farmers in Hungary tend to be isolated and not open to collaboration or sharing information (Lencsés et al. 2014; Balogh et al. 2020; 2021).

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Small-scale farms are not as profitable as large farms. Due to their lesser economies of scale, and the lower value of collateral, which may limit their financial opportunities, etc., small-scale farmers generally do worse than large holdings. They often have fewer valuable assets that can be used as collateral for mortgages and produce less revenue. Even if they can afford PA technologies, their lower production makes them more vulnerable to higher additional fixed costs per unit of production. Their ability to compete on pricing is impacted (Mizik 2022).

Some other threats can include the lack of learning organizations (especially in higher education) that directly focus on precision agriculture and digitalisation in agriculture. Regarding the qualifications of farm managers, it can be said that the previously typical practical experience is increasingly being replaced by some level of agricultural education. Although in 2020, more than half of Hungarian farms (53%) were still managed by farmers based on practical experience, 11% of farmers have a basic agricultural education, 19% have a secondary education, and 9% have a higher education. It is worth highlighting that among the younger farm managers, already half have some kind of specialised training (HCSO 2021).

However, a further major challenge has been the lack of infrastructure and investment in digital technologies, particularly in rural areas, so the adoption of digital technologies in Hungary's agricultural sector has not been without its challenges (Vásáry and Biró 2020). Farmers in Hungary may have access to broadband internet, but they are barely – or even completely – unable to use digital tools and services (HCSO 2022a). In addition, the cost of purchasing and maintaining digital technologies can be a barrier for many farmers, particularly those with small-scale and medium-sized farms (Balogh et al. 2021). Another challenge that has been identified in the literature is the lack of knowledge and skills among farmers in using digital technologies. Many farmers in Hungary lack the necessary training and education to make effective use of digital tools, which can hinder their adoption of new technologies (Gaál et al. 2021). To overcome this challenge, governments, research institutions, and private sector organizations need to provide training and education programs for farmers, as well as support for the development of digital literacy skills (Kő et al. 2019).

Another challenge in the digitalisation of Hungary is the need to address data privacy and security concerns (Csányi et al. 2021). There were concerns among farmers in Hungary about the privacy and security of data collected through digital technologies (Beke et al. 2020). The lack of clarity about the ownership and use of data can be a barrier to the adoption of digital technologies in the whole economy (Raj et al. 2020), and in this sector as well.

A more supportive institutional background at both the national and EU level could encourage farmers to start investments. There is a need for centers that can provide testing and demonstration of precision farming systems under local conditions before farmers make a purchase. These centers would be able to provide useful information for farmers to make informed decisions about the systems (Balogh et al. 2021).

There are several potential solutions to the barriers facing the spread of precision agriculture in Hungary. Some possible approaches include:

Education and training: providing farmers (in every age group and skill level) with education and training on precision agriculture technologies and best practices which can help them better understand and utilize the systems.

Financial support: offering financial incentives or subsidies (from Hungary and the EU as well) can help make precision agriculture more accessible and affordable for farmers.

Centers of Excellence: setting up centers of excellence for precision agriculture, where farmers can test and demonstrate precision agriculture technologies under local conditions, can help farmers make more informed decisions about which systems to adopt.

Networking and collaboration: encouraging networking and collaboration among farmers can help build a community of farmers who can share knowledge and resources and jointly invest in precision agriculture technologies. Government support: government can play a vital role in providing support to farmers by providing financial and technical assistance, creating favorable regulations, and helping farmers to access markets for their products.

Industry partnerships: encouraging partnerships between farmers and industry can help farmers to access the latest technology and provide them with technical assistance.

Legal protection: providing legal protection against the deceptive practices of machine dealers can help farmers to make informed decisions and avoid negative experiences.

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To address these challenges, there is a need for policies and initiatives that support the adoption of digital technologies in Hungarian agriculture, particularly for small and medium-sized farms. One example of such an initiative is the Digital Agriculture Support Program, launched by the Hungarian government in 2018. The program provides financial and technical support to farmers to adopt digital technologies and improve the efficiency and competitiveness of their operations (Digitális Jólét Program 2019). In addition, the Digital Agricultural Strategy can also help the spread of precision farming in our country. In order to achieve the goal of Hungary's Digital Agricultural Strategy, it is necessary for precision farming to be applied as widely as possible.

At the end of December 2021, the Council of the European Union officially adopted the Common Agricultural Policy for the period 2023–2027. According to the new legislation, fairer, more environmentally friendly and performance-based regulation is needed, which aims to ensure a sustainable future for European agricultural producers and provide more targeted support to smaller farms. Another goal is to allow more flexibility for member states to adapt measures to local conditions. The ever-expanding comfort functions can also greatly contribute to the spread of digitalization, as high-level technological applications replace the heavy physical work, shorten the duration of the work to be performed, and make the working environment more comfortable for the workforce (European Commission 2022).

CONCLUSION

Digitalisation is becoming an increasingly important aspect of agriculture, with the adoption of digital technologies such as sensors, drones, and precision farming tools offering the potential for greater efficiency, productivity, and sustainability in agricultural production. This article has examined the current state of agricultural digitalisation in Hungary and highlighted the trends, challenges, and opportunities that have emerged in the country. The study has revealed that farmers with smaller farm sizes believe that cooperation and collaboration among farmers would accelerate the adoption of precision farming. They argue that by pooling resources and expertise through joint development projects, they would be able to mitigate the high costs of investment and achieve a faster return on investment. However, farmers in Hungary tend to be isolated and not open to collaboration. Furthermore, the study revealed that farmers in Hungary need more support from institutions and centers that can provide testing and demonstrations of precision farming systems under local conditions before they make a purchase. These centers would be able to provide useful information for farmers to make informed decisions about the systems. The farmers also highlighted the need for a more supportive institutional environment, which would protect them from the deceptive practices of machine dealers. There are several barriers to the adoption of precision agriculture in Hungary, such as lack of knowledge, high costs and lack of support, but with the right solutions these can be overcome. The implementation of solutions such as education and training, financial support, centers of excellence, networking and collaboration, government support, industry partnerships, and legal protection can help to overcome these barriers and promote the spread of precision agriculture in Hungary. This will result in the increased efficiency, productivity, and sustainability of agricultural production and will also contribute to the economy of the country. Decision-making in the agriculture and food industry should be data-based. For small-scale farmers, the high cost of access to the data might be a great obstacle. Encouragement of data collection, processing, and application in decision-making is crucial for advancing data-driven decision-making. Producers should also receive assistance in gathering farm-level data to achieve data-based decision making. Farmers can boost productivity, cut waste, and enhance their overall economic performance by utilising data and technology. The legal and economic environment for the collection, storage, processing and sharing of data needs to be addressed by future research.

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