Role of precision agriculture in food supply

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Abstract

Introduction. The aim of our research is to provide an overview of the role and challenges of precision agriculture, to examine the current situation, in particular its impact on sustainable food production.

Materials and methods. The study is descriptive and used scientific secondary data as the primary source. The authors also conducted a primary research of farmers in Hungary in 2022 what they think about the role of precision farming. The primary research method is a questionnaire survey.

Results and discussion. Precision farming is a management approach that focuses on (near real-time) observation, measurement, and responses to variability in crops, fields and animals. Precision farming means the practical appearance of digitized agriculture, the use of digital solutions in agriculture, where developments are directed to how to manage in a more competitive way, to increase efficiency, while also placing great emphasis on environmental sustainability. Precision farming is increasingly used in agriculture today. The demand for agricultural products will grow dynamically over the next few decades, and this can be met by more efficient production.

On the Internet, when we type the term of precision agriculture we will get 147 million search results.

In our research, according to 81% of respondents, precision farming is very important. In recent years, the development of precision agricultural technology, mechanization and agricultural informatics has undergone significant development. More than half of the farmers use some kind of precision support system. Nearly 70 percent of respondents think that precision technology systems are too expensive. 31 percent of farmers would like to have more knowledge about precision technologies, mainly concerning productivity (yield, quality, etc.), plantation condition (plant growth status, soil analysis, etc.) and the distribution of inputs (irrigation water, organic fertilisers, fertilisers, etc.). More than half of the farmers think that policy makers in the industry (financial support, legal environment, etc.) should take action to make precision farming more accepted in practice and they think that it would also be important to deal with it more intensively in education. Farmers are open to precision solutions, but there are challenges to effective spreading.

Conclusions. The competitive future of agriculture is influenced by digitalisation and the use of precision agriculture. Precision agriculture is becoming increasingly popular in practice, as it can make a major contribution to sustainable food production.

Introduction

Agriculture is the production of material goods, a major branch of the economy that produces food and industrial raw materials.

The development of agriculture is characterised by three eras. According to Jóri (2017), the first, the pre-industrial era of agriculture, lasted from pre-Christian times until the 1920s. Self-sufficient, small-scale, labour-intensive farms required approximately one hectare of land to produce one person's food. The second phase, the period of industrial agriculture, lasted from 1920 to 2010. Tractors, combine harvesters, fertilizers and hybrid seeds allowed the emergence of large-scale commercial farms. The productivity of these developments meant that as little as half a hectare was enough to feed five people. The third phase is taking place today, when a large amount of data for production is available through satellite systems and sensors on machines and plants. The large amount of data and the "Internet of Things" allow to analyse many sources of information through various intelligent software, thus helping farmers. If we look at the impact of agricultural development on mechanisation, the first period (from the early 1900s) is characterised by the advent of tractors, increased efficiency, the need for manual labour and low productivity. The second period is the so-called green revolution (from the 1950s), when new agrotechnical practices, use of fertilisers, pesticides, seeds of high quality and increased production have emerged. From the third era, with the advance of mechanisation (from the 1990s), precision agriculture was introduced, i.e. automated steering systems (optimised mechanisation, minimum overlap), crop mapping (objective base data), variable rate application (input optimisation), telemetry (machine monitoring) and data processing. Then the use of smart electronic tools became more widespread and digitalisation has now reached the agricultural sector. It has proven economic effect due to the steep implementation of digital decisions and tools in managerial processes (Remeikiene et al., 2021; Roshchyk et al., 2022). Thus, in the fourth era (from 2010), digital agriculture can be seen in practice, involving the use of real-time farm management systems, value-added services, automation capabilities, advanced processing and food value chains (data platforms) (Kireyeva et al., 2021; Vasa-Trendov, 2020). These advanced digital solutions in the agriculture sphere can significantly mitigate the problem of food security (Vasylieva and James, 2021) and social security respectively via the essential impact of the consumer food expenditures on the level and quality of life, especially low-income groups of the population (Mishchuk et al., 2018).

But what does precision agriculture mean and what are the characteristics of precision farming?

Precision agriculture and precision farming are generally regarded as the same thing. However, the term precision agriculture, often abbreviates PA, is more widely used.

Although more complex definitions exist, the simple description of the precision agriculture is a way to "apply the right treatment in the right place at the right time" (Gebbers and Adamchuk, 2010). It is a farming management concept based upon observing, measuring and responding to inter and intra-field variability in crops or in aspects of animal rearing. The first actual definition of PA came from the US House of Representatives (European Parliament, 2014), which defined PA as "an integrated information- and production-based farming system that is designed to increase long term, site-specific and whole farm production efficiency, productivity and profitability while minimizing unintended impacts on wildlife and the environment". Such a definition focused on "whole-farm" management strategies using information technology, highlighting the potential improvements on production while reducing environmental impacts. In addition, it already envisioned that PA was applicable not only to cropping systems, but to the entire agricultural production system (i.e. animal industries, fisheries, forestry) (Gál et al., 2013).

According to ISPA (2019) precision agriculture (PA) is a management strategy that collects, processes and analyses temporal, spatial and individual data and combines it with other information to support farmer decisions based on estimated variability to improve the resource use, productivity, quality, profitability and sustainability. In a 2016 report on how big data will revolutionize the global food chain, McKinsey & Company define precision agriculture as: "a technology-enabled approach to farming management that observes, measures, and analyzes the needs of individual fields and crops". According to McKinsey (Magnin, 2016), the development of precision agriculture is shaped by two trends: "big-data and advanced-analytics capabilities on the one hand, and robotics (aerial imagery, sensors, and sophisticated local weather forecasts) on the other".

There are many other definitions of precision agriculture in the literature. According to Husti (2018), "A modern agricultural management concept using digital techniques to monitor and optimise agricultural production processes. The aim is to reduce costs and environmental pressures and to produce more and better food raw materials. It will be achieved through a specific combination of new sensor technologies, satellite navigation and positioning, and the Internet of Things (IoT)." Husti (2018) thinks that the aim of precision farming is to produce good quality and safe food by using available resources (feed, water, energy, etc.) as efficiently as possible. Of course, this is no different from the objectives of conventional farming, but the difference is that the efficiency of information gathering is improved by the use of digital technologies. Precision farming makes farming more regulated and precise. Simply, it differs from the traditional approach in that it allows decisions to be made per square metre or even per plant/animal. This in turn has a positive influence both on the ecological consequences of the agriculture companies' activity and on their sustainable development (Piwowar, 2020; Przekota et al., 2020).

According to the European Parliament (2014), PA nowadays is seen as an "environment friendly system solution that optimizes product quality and quantity while minimizing cost, human intervention and the variation caused by unpredictable nature". PA allows seamless data interchange between farmers, suppliers, service providers, authorities, processors, and resellers of agricultural produce. This makes it possible to trace back food production to virtually each square meter of a farmer's field. The European Parliament's (2016) report on precision agriculture and the future of farming in Europe defines precision agriculture as "a modern farming management concept using digital techniques to monitor and optimize agricultural production processes". The key point here is optimization. Instead of applying an equal amount of fertilizers over an entire field, precision agriculture involves measuring the within-field soil variations and adapting the fertilizer strategy accordingly. This leads to optimized fertilizer usage, saving costs, and reducing environmental impact.

An accurate assessment of the situation of precision agriculture is difficutors, but the surveys the definition and categorisation of the elements of precision farming, which makes it difficult to comparing the resultsult because very few places collect data on it on a regular basis. The importance of the subject has led to an increasing number of questionnaire surveys and analyses based on data from input material and machinery distrib. According to 234 studies published between 1988 and 2005, the use of precision farming technologies was economically profitable in 68% of cases on average (Griffin and Lowenberg-DeBoer, 2005).

Gebbers and Adamchuk (2010) think that precision agriculture becomes a management practice of increasing interest because it links to key drivers directly related to worldwide issues such as sustainable agriculture and food security. Takácsné and Takács (2022) believes that if precision agriculture can spread faster worldwide, it can result in both individual and social utility coincidences that promote sustainability in a wider meaning. According to Nassar et al. (2022), Non-Governmental Organizations (NGOs), whether international (INGOs) or local (NGOs), are the primary engines of humanitarian assistance in almost all national economies. Food security and these organizations are inextricably linked. The main objective of the study of Nagy and co-authors (2017) is to identify key determinants that influence agricultural productivity to assure food security, as well as to analyze domestic and foreign trade in agricultural products.

Precision farming is a management approach that focuses on (near real-time) observation, measurement, and responses to variability in crops, fields and animals. It can help increase crop yields and animal performance, reduce costs, including labour costs, and optimise process inputs. All of these can help increase profitability. Precision farming contributes to the development of agricultural production and to the production of healthy food raw materials, while respecting environmental and ecological standards. It is based on the use of power equipment with positioning (GPS, RTK), machine-to-machine linkage and geo-information, remote sensing, data collection, data integration and data analysis. The technical prerequisites for precision farming are high-precision navigation and automatic steering of machinery. The advantage of automatic steering is that, when coordinated with other systems, they enable the machine to steer automatically. This further reduces human error, allows greater control over the driving and reduces overlap. One of the most accurate ways of doing this is through RTK, which enhances GPS-based tracking to give cm accuracy in determining the position of the machine. RTK is able to determine the position so accurately by coordinating satellite systems with the ground correction signal (Németh, 2014).

There are many ways to determine very precisely some of the parameters of agricultural field. Today, there are numerous possibilities to map fields with high precision to obtain detailed and site-specific information. Drones, planes and satellites use remote sensing to identify the features of the area. It is possible to work with yield maps, GPS-assisted soil surveys, "talking fields" maps or NDVI maps produced by nitrogen sensors. Real data such as soil nutrient levels, soil type, pH, pest emergence, etc. can be extracted. This fine data allows farmers to monitor changes in soil and crop conditions and react to events with lightning speed, after thorough and properly instrumented soil sampling (Kay et al., 2013).

Precision farming in the strict sense is when you work with site-specific information and apply materials site-specifically. Precision farming cannot be imagined without thorough data collection and processing, so software is as much a prerequisite as a GPS signal. At the same time, new technical and IT solutions are being developed every day. The competition for supply means that it is increasingly challenging for users on the practical side to keep up with technical developments and to create the conditions for their application. In Hungary, GPS guidance systems combined with automatic steering are the most widespread. With this solution, the tractor travels straight between two points, covering only the smallest area necessary, which saves fuel. If the farmer wants to sow at variable rates or apply fertiliser site-specifically, he needs information that gives a professional basis for the amount of material to be applied. Thus, the pillars of precision farming are agrotechnology, IT background and technical solutions.

Materials and methods

Materials

The study is descriptive and used secondary data as the primary international source. Our primary research method is a questionnaire survey. In September 2022, we asked 110 farmers in Hungary what they thought about precision farming. The questionnaire contained 18 questions.

Abbreviations

GPS (Global Positioning System). A satellite-based positioning system developed and operated by the US Department of Defense that operates independently of weather and time of day and provides three-dimensional positioning. In everyday usage, it generally refers to satellite positioning. The most advanced satellite system, GPS is the foundation of precision farming. It is mainly used for automated steering and landmarking in agriculture. GPS allows the machine to follow the same track several times with high accuracy. This minimises human error and makes work on the ground accurate and predictable.

- IoT (Internet of Things): A system of networked devices with unique identifiers.
- NDVI (Normalized Difference Vegetation Index): A normalized difference vegetation index, calculated from remote sensing images, used to characterize the state of vegetation.
- RFID (Radio Frequency IDentification): Radio Frequency Identification. A technology used for automatic identification and data communication based on the communication of a radio frequency transceiver unit with an RFID tag placed on the objects or products being monitored. An RFID tag (also known as a tag) is a small object that can be attached to or embedded in the object or product to be identified.
- RTK (Real Time Kinematics): Real time kinematic positioning with an accuracy of +/- 2 cm using correction signals.

Results and discussion

Precision agriculture in the word

Precision agriculture is present all over the world, but at very different rates. The concept has taken off in the United States and is now making its way into other parts of the world, including Europe (Table 1).

Table 1

Precision agriculture on Google

Expression	Match (pieces)		
	19. 11. 2018.	25. 06. 2019.	01. 12. 2022.
Precision Agriculture	79,500,000	94,700,000	147,000,000
Precision Agriculture Technology	16,800,000	26,300,000	55,000,000

Source: based on Jóri (2019) and supplemented by own research

According to Meister Media Worldwide (Sulecki, 2018), the US and Canada are the leaders, with Europe in second place and South America (Brazil and Argentina) in third in the use of the precision agriculture. China is prominent in research on drones and sensors, mainly due to the growing governmental interest in environmental protection. The Netherlands, Israel and Ireland are also at the forefront of technological developments.

According to Riports and Data (2020), the global precision agriculture market was valued at USD 6.33 billion in 2020 and is expected to reach USD 17.05 billion by the year 2028. It is gaining fabulous popularity among farmers due to the increasing need for ideal crop production with limited available resources.

According to a report by Grand View Research (2022), the global precision farming market size was valued at USD 6.96 billion in 2021 and is expected to expand at a compound annual growth rate of 12.8% from 2022 to 2030. The growth of precision agriculture is attributed to the burgeoning proliferation of the IoT along with the use of advanced analytics by farmers. Numerous government initiatives are being undertaken in developing countries such as India, Sri Lanka, and Nigeria to encourage the implementation of modern precision farming technologies, thereby maximizing productivity. China and Israel signed a trade agreement in September 2017 worth USD 300 million to facilitate the export of environment-friendly Israeli technology to China. Moreover, an effective administrative framework is also enabling farmers to gain adequate knowledge of the proper use and maintenance of precision farming equipment.

As one of the world's largest food producers, Brazil has significant potential in the digital agriculture market. According to Cherubin and co-authors (2022), the principles and tools of PA started to be adopted in the late 1990s in Brazil. It can bee seen in their reserch that research in precision agriculture has evolved substantially over the last 25 years in Brazil. Precision technologies have been mainly adopted in the production of large area crops such as soy, maize and cotton (Ferro and Oliveira, 2019). Automatic steering, yield mapping and differentiated nutrient allocation are used on 33 percent of agricultural land, but in the largest cereal-growing district, the use rate of automatic steering exceeds 60 percent. Even here, the use of drones is not widespread (6 percent).

In a 2018 survey of Kansas Farm Management Association (KFMA) members, 84 percent of 621 respondents said they use at least one precision technology (Griffin and Yeager, 2018). Automatic steering is the most widely used (68 percent), nearly half of farmers (47.8 percent) use staging, grid-based soil sampling and yield mapping is nearly 40 percent, and differential fertilization is used by a quarter of respondents (24.6 percent). Differential seeding is the least widespread (16.4 percent). Among U.S. corn, soybean, wheat, and cotton growers over 1,000 acres (about 405 hectares), the use of precision technologies is even higher (Thompson et al., 2018). 837 respondents have very high rates of yield measurement (93 percent) and automatic steering (91 per cent), followed by differential nutrient amendment (73 per cent) and precision soil sampling (60 per cent).

Statistically, China feeds 22 percent of the world's population with merely 7 percent of the arable land. China apply precision agriculture technologies since 2012. The technique is particularly important in Xinjiang, where more than 80 percent of the country's cotton is produced. High cost, lack of perceived benefits, and skills and capability required to adopt precision agriculture represente barriers to adoption (Kendall et al., 2017).

A questionnaire survey of farmers in western Canada (Steele, 2017) was able to assess 261 responses, representing nearly 1 million acres (approximately 405,000 hectares). 98 percent of respondents use GPS navigation and 79 percent use automatic steering. The use of automatic phase control is also widespread (73 percent), used mainly for spraying and to a lesser extent for nutrient replenishment and sowing. 60 percent of respondents said that they have a GPS-equipped combine, but only 48 percent produce a yield map. Differentiated application technology is mainly used for nutrient replenishment (48 percent) and seeding (24 percent). Remote sensing crop monitoring is also quite widespread, based on satellite imagery (28 percent) or drone imagery (19 percent). 48 percent of respondents use precision farming solutions overall farm, while 37 percent use it on only part of the farm. In Ontario, a survey of agricultural service providers was conducted (Mitchell et al., 2018). More than 96 percent of the service providers are engaged in precision agriculture-related activities, of which grid- or zone-based soil mapping, differential nutrient application, and nutrient application map production are prominent (81 percent and 74 percent, respectively). Differentiated seeding planning is carried out by 58 percent of respondents, while differentiated crop protection applications are even less common (32 percent). More than half of the providers offer yield mapping services and 41 percent also produce cost/benefit maps. Nowdays Canada is one of the five major countries, along with US, China, Germany, and Israel, in precision agriculture. In 2021, Canada's market was valued at USD 870 million, an annual growth of 11.5%. During 2017-21, the market grew at a compound annual growth rate of 11.8% (GlobalData, 2022).

Europe

A 2016 European Union study shows how and in what direction the use of precision farming can influence the direction of the European Union and its common agricultural policy (Table 2).

Precision solutions are advantageous if they can be extended over a large area, developed continuously and easily, applied in all units of the plant, independent of the sector, easy to operate for the machine user and applied in a sustainable and environmentally friendly way. The application of precision farming requires an appropriate economic scale. The cost/input ratio requires a certain minimum farm size. In Europe, smaller farms are still predominant, as 86% of farms are smaller than 20 hectares. In contrast, the spread of precision farming technologies (due to the turnover) is observed in farms larger than 100 ha, i.e. around 25% of farms in the European Union use this technology (Jóri, 2019).

There has been considerable research in farmers' adoption of precision agriculture technologies. According to a study by the Boston Consulting Group (Kurth et al., 2018), a quarter of European farmers use precision agriculture. However, available data suggest that there are significant differences between countries and that the technology used is often limited to vehicle navigation.

Denmark is one of the few countries where data on the uptake of precision agriculture is available from the Danish Statistical Office (DST, 2022). Precision technology agriculture cultivated 76 per cent of the Danish agricultural area in 2022 compared to 73 per cent in 2021. It is especially the large farms that have embraced the technology, as users had an average area of 179 hectares compared to 87 hectares among all farms in 2022. Farms with precision driving now cover 2/3 of the agricultural area. The spread of precision agriculture by area is increasing for all technologies. However, a majority of all farms, 63 per cent, still do not use precision farming. Among farmers who do not use precision technology, 48 percent cite excessive costs as a barrier.

Barnes and co-authors (2019) investigated the prevalence of machine guidance and differential N application in five European countries: Belgium, Germany, Greece, the Netherlands and the UK. 44 percent of the 971 respondents did not use these technologies, 34 percent used only vehicle navigation, while 22 percent also used differential N application. Belgium has the lowest take-up rate, while England (34 and 26 percent) and the Netherlands (48 and 24 percent) have the highest. In both cases, the use of technologies was significantly influenced by the age and education of the farmer, the size of the cultivated area, the income and if the farmer used some other precision technology (innovative attitude).

Table 2

How does precision agriculture influence policies?

Policy issue	Description	Effect on policy objective*
Competitiveness of EU farming	Farm holdings will apply PA technologies to produce ‘more with less’, increasing the competitiveness of farm holdings and agri-food chains. Large farms will benefit the most.	+
Farm holding size and number	Farm size will increase because of the required investments in PA technologies and know how. The number of farms will go down, which is the current trend already.	=
Jobs on farms in primary production	The number of jobs on farm holdings will decrease due to the implementation of PA technologies, especially on farms where still a lot of work is done by low skilled workforces.	-
Skilled workforces	PA requires more farmers skilled in (ICT) and a mature services industry.	+
Business development in agrifood chains	PA offers many opportunities for service industry (sensor industry, ICT, IoT, machine companies) and food companies (processors, logistics, retail) when the PA market grows.	++
Multi-functional agriculture	Farm holdings will focus more on farming when they invest in PA technologies and know how.	=/-
Demographic and rural development	PA may slow down or stop the trend of people leaving rural areas in the EU for better life in cities because it creates new business opportunities and work for highly skilled persons.	+
Food security	Sensor based monitoring systems and Decision Support Systems (DSS) will provide farmers and stakeholders with better information and early warning on the status of crops and animals and improve yield forecasts.	++
Food safety	Sensor based monitoring systems and DSS plus track and trace systems will provide farmers, processors and other stakeholders with better information and early warning on quality of food products.	++
Sustainable production	PA technologies allow the production of ‘more with less’. The use of natural resources, agrochemicals, anti-biotics and energy will be reduced to the benefit of both farmers and the environment, thus in turn society.	++
Climate change and action	See sustainable production and food security. Farmers and stakeholders can detect effects of climate change on agricultural production in an earlier stage and take action.	+

*++ and + are positive, = is neutral or unknown, - and -- are negative effects
Source: EPRS, 2016

According to Paustian and Theuvsen (2017), in Germany 30% of farms have adopted precision farming technologies.

In France, the Observatoire des Usages de L'Agriculture Numérique (Observatory of Digital Agriculture, 2017) collects data on precision agriculture. According to the information on the website, in 2017, nearly 1 million hectares of agricultural land were remotely sensed, of which about 85 percent was satellite imagery and 15 percent was drone or aircraft imagery. Thanks in large part to France's Naïo Technologies, more than 100 robots are used for weed control in arable vegetable production and more than ten in vineyards. About 4% of French field crop farmers use computer controlled variable rate input application, mostly for fertilizer. About 20% of farmland in France has professionally developed soil maps. Almost 1 million ha of farmland in France was managed with remotely sensed data in 2017. Roughly, 85% of the remote sensing is by satellite and 15% using drones or aircraft.

Precision agriculture technology is readily available in the Ukraine. According to Hrynevych and co-authors (2022), professionals working in the agro-sector need to gain an understanding of how this concept works and regularly update their knowledge of innovative technologies.

The majority of farms in Serbia are between 2 and 5 hectares, and only 16 percent of arable land is owned by larger farms and cooperatives. A further problem is that the average age of farmers on family farms is 59 years, which makes the adoption of precision farming technologies slow (Tagarakis et al., 2018). At the same time, Serbia is the only non-EU country that has access to satellite imagery from the EU's Earth observation programme (Copernicus). The practical application and promotion of precision farming is carried out in collaboration with the Krivaja Agricultural Society. Krivaja started precision farming on more than 2,000 hectares three years ago and officially became the first digital farm in Serbia in 2018.

When evaluating the uptake of precision farming in Europe, it should be noted that the average farm size in the EU is 17 hectares, which is one tenth of the average farm size in the US (175 hectares) and 47 times smaller than in Australia (800 hectares) (Dryancour, 2017).

Hungary

In the beginning, precision farming meant only information-based management applied to crop production. Advances in spatial information technology and rapid analytical techniques have laid the foundations for site-specific farming. The emergence of precision or site-specific agriculture in its present sense began in the 1990s in the world's developed agricultural countries (United States, England, Germany), but in Hungary it started to spread later, through satellite positioning. In the 2000s, the tools that still form the basis of precision farming were developed, based on the widespread use of GPS, the possibility of a high degree of automation of agricultural machinery and the emergence of advanced geographic information systems (GIS) (Jóri, 2017).

Today, the most intensive practical implementation of precision agriculture in Hungary is on arable land. Digital technologies are much better known and more frequently used in crop production and horticulture than in animal husbandry and livestock breeding. According to Halas (2017), „There is a very intensive growth in the number of dairy cattle farms practicing precision farming, with many countries now using digital technologies on large-scale farms. The first IT-enabled pig farms were established in Australia, followed by Western Europe and North America. Alongside Australia, Europe is still leading the way in research to develop the technology."

According to Hadászi (2018b), precision farming is (also) a widespread concept in Hungarian agriculture, however, each machinery manufacturer develops precision tools for their own brand, which are not compatible with each other. Thus, the data collected by the machines, which are highly valuable for precision technologies, are not compatible with each other. Hungarian farmers do not have a single brand of machinery, so this isolation poses a problem for the spread of precision solutions. Precision technologies will only really work well in Hungarian agriculture if these developments can be integrated into a system for compatibility. "Farmers use only 20 percent of the extremely valuable data from machines." Hadászi (2018a). It can be seen that the toolbox for precision agriculture is a mixed picture. It is not an easy task for farmers to find the optimal solution for them, as each farm has its own unique possibilities and conditions and there is currently no universal solution.

In 2018, the Institute for Agricultural Economics Research conducted a questionnaire survey to assess the IT skills of Hungarian farmers and company managers who are professionally involved in agricultural production towards the use of digital tools and information systems on their farms. The non-representative, voluntary survey yielded 760 valuable responses. 84 percent of respondents, 640 people, indicated the field crop sector as their field of activity (including grassland and field vegetable production). The farms typically cover less than 200 hectares (88 percent) and the online survey has shifted the age of respondents towards the younger age group. The presence of digital technologies and tools on farms is very low. The highest proportion (35 percent) of arable farmers use satellite positioning. 20 percent of the responding arable crop farmers indicated that they use a line guide or automatic steering. Differentiated application (e.g. sowing, fertilisation) is used by 11% of respondents, with even lower use of remote monitoring systems, crop sensors in the crop and yield mapping. The study of the Research Institute of Agricultural Economics provides an overview of the trends observed in the digitalisation of agriculture, and the domestic situation of precision arable crop production in Hungary. During the survey, they investigated how different information sources are used by farmers to obtain knowledge about PA; sought farmers' opinions on the barriers and drivers to the diffusion of these technologies; recorded their judgement on the contribution of PA to sustainability; and collected their experiences (if any) following the adoption of these technologies. Based on their questionnaire surveys, it is unfavourable that some farmers (1-5 per cent, depending on the technology examined) have tools suitable for PA but do not use them, and approximately 70 per cent of the non-adopters do not plan to use any of the examined tools and technologies. The planned digital investments are of low value (typically below HUF 500,000, which is enough to buy at most sensors or accessories), but it depends on the farm size. Respondents aged between 31 and 40 years have better digital competences and the greatest willingness to invest. In 2018, 54 of the 615 respondents claimed to be involved in PA to some extent (Gaál and Illés, 2020).

We also made a primary research of farmers in Hungary in 2022 what they think about the role of precision technology. The respondents farm are from all Hungarian counties. The 52.3% of respondents have a degree, only one farmer has a primary school education.

93 of the 110 respondents are exclusively involved in crop production. 75% of farms has between 1 and 10 employees. 33 farms are between 100 and 499 hectares and 15 farms are more than 1,000 hectares in size. 58 percent of farmers use precision support system. 81 percent of respondents consider that precision agriculture is important. Nearly 70 percent of respondents think that precision technology systems are too expensive. 31 percent of farmers said that they would like to have more knowledge about precision technologies, mainly concerning productivity (yield and quality, etc.), plantation condition (plant growth status, soil analysis) and the distribution of inputs (irrigation water, organic fertilisers, and

fertilisers). 52 percent of the farmers think that policy makers in the industry (financial support, legal environment) should take action to make precision farming more accepted in practice. More than half of the respondents think it would also be important task to deal with it more intensively in higher education.

Overall, precision farming is becoming increasingly popular in practice. With the possibilities offered by the system, work can be done more accurately and at the right time, saving pesticides, fertilisers, other inputs and fuel, making farming more profitable and protecting the environment. The weaknesses of precision farming are that it is unfortunately very expensive and time-consuming to set up a complete system and that it requires the right skills to use the tools. A further weakness is that once a precision system is purchased, the buyer does not receive the necessary training to put it into operation after the purchase. Another disadvantage is that not all machines, systems and applications are available in Hungarian. This can cause difficulties for everyday users in agriculture.

The system risk is that it could cause problems with incorrect data management. A potential risk is a satellite or internet connection failure, for example, when a workflow with automatic steering fails. Such problems are most likely to occur in border areas or in places where you have to work in the cover of tall trees or a mountainside.

The future

In the coming decades, technology will develop a lot further and many new tools will help farmers to farm. The more tools we use connected as part of a system, the more efficiently we can work the land. A digital networked system will result in higher yield averages and better quality crops, as well as less inputs to the land, less greenhouse gas emissions to the atmosphere and a more environmentally friendly farming system than today. This is also crucial because the amount of arable land is steadily decreasing due to urbanisation and the growth of industry, and we are building on land where production used to take place. Some estimates suggest that by the turn of the century the world's population could reach ten billion and agriculture will have to support it. The logical solution to the loss of land and population growth is to maximise production capacity, which can only be achieved by using a complete digital network. Soon, robots and unmanned heavy machinery will begin to proliferate and replace human resources in a given position to do the most precise work possible with the help of sensors and IT systems (Tamás, 2017).

Robotics technology and artificial intelligence, which have been applied in some countries in the world, will be the future direction of precision agriculture development, but they need to be adapted to fit local conditions in different areas. As precision farming grows, so do threats, including cyber threats, which are on the rise as hackers are able to exploit this technology.

According to Grispos and Doctor (2022) cyber attacks against agricultural targets are not some distant threat; they are already happening. In 2021, for example, a ransomware attack shut down one-fifth of US beef processing plants. Similarly, an Iowa grain storage cooperative was targeted by a group who claimed to have stolen data from the cooperative. While previous attacks have targeted larger corporations and cooperatives, individual farms may also be at risk. The incorporation of IT technologies into farm equipment, from GPS-guided tractors to artificial intelligence, potentially increases the ability of hackers to attack this equipment. Moreover, while farmers may not be ideal targets for ransomware attacks, farms can be tempting targets for hackers with other motives, such as terrorists. For example, an attacker could exploit vulnerabilities in fertiliser application technologies, which could result in a farmer unwittingly applying too much or too little nitrogen fertiliser to a particular crop. The farmer could then either end up with a smaller crop than expected or with over-fertilised land, leading to waste and long-term environmental consequences. Worst-case scenario could be a malicious actor taking full control of large machinery, particularly if it is carrying dangerous chemicals, in a highly populated area or along a busy road.

Conclusions

Precision farming is generally an information and technology-based farming system that identifies, analyses and manages spatial and temporal variability in fields for optimal productivity, profitability, sustainability and safety while rationalising production costs. The growing environmental awareness of the population requires changes in agricultural management practices to sustainably preserve the quality of natural resources (water, air, soil) while maintaining farm profitability. The practical areas of precision farming are not only crop, livestock and viticulture, but can also be applied to other sectors, such as horticulture, forestry, fish farming, biotechnology, etc.

In our opinion, precision farming is needed in Hungary to increase the output of agriculture in a meaningful way. Today, as a result of progress, various digital tools and the software that facilitates their use are available to almost all users in Hungary.

Precision agriculture typically involves the use of state-of-the-art machinery, and therefore the use and maintenance of the associated machinery and equipment requires appropriate expertise. The introduction of precision practices is an investment-intensive process, which is why their uptake by small and medium-sized farms is currently limited. Precision farming is a practical expression of digital farming, but it also raises the issue of farmers' inability to use agricultural information technology properly. Like all new technologies, the introduction of precision farming requires new skills from farmers.

In fact, precision agriculture can offer solutions to mitigate the adverse effects of climate change, to feed a growing population (food quality and crop safety), to protect the environment and to promote sustainability. Precision technologies can make a major contribution to sustainable food production, as efficient production also means a reduction in the emissions and ecological footprint of livestock production. At the same time, however, we must not overlook the need to look at the economical and economic context, in addition to creating new technical and technological development solutions.

The development of integrated systems, linking existing systems, is a key element for the future of agriculture. In our experiences, much progress has been made in the development of precision farming over the last decade, and precision farming has become accessible and good practice, but its full potential has not yet been exploited. In our opinion, Hungary is not lagging behind the world in the application of precision technologies, but a change of attitude is needed for all actors to spread them. To sum up, precision farming is becoming more popular and farmers are opening up to the opportunities offered by digitalisation, but the coutries must pay more attention to the new risks. These threats also pose a risk to the food supply.

References

Barnes A.P., Soto I., Eory V., Beck B., Balafoutis A., Sánchez B., Vangeyted J., Fountas A., van der Wal T., Gómez-Barbero M. (2019), Exploring the adoption of precision agricultural technologies: A cross regional s,tudy of EU farmers, *Land Use Policy,* 80, pp. 163–174, DOI:10.1016/j.landusepol.2018.10.004

Cherubin M.R., Damian J.M., Tavares T.R., Trevisan R.G., Colaço A.F., Eitelwein M.T., Martello M., Inamasu R.Y., Pias O.H.C., Molin J.P. (2022), Precision aiculture in Brazil: The trajectory of 25 years of scientific research, *Agriculture,* 1882, DOI: 10.3390/agriculture12111882

Hrynevych O., Canto M.B., García M.J. (2022), Tendencies of precision agriculture in Ukraine: Disruptive smart farming tools as cooperation drivers, *Agriculture*, 12(5), 698, DOI:10.3390/agriculture12050698

Dryancour G. (2017): *Smart agriculture for all farms. What needs to be done to help small farms access precision agriculture? How can the next CAP help?,* CEMA European Agricultural Machinery Industry Association, Brussels.

DST (2022), *Increase in area of precision farming*, Avialable at: https://www.dst.dk/da/Statistik/nyheder-analyser-publ/nyt/NytHtml?cid=42525

EPRS (2016), *Precision agriculture and the future of farming in Europe. Scientific Foresight Study, IP/G/STOA/FWC/2013-1/Lot 7/SC5, December 2016,* Avialable at: http://www.europarl.europa.eu/RegData/etudes/STUD/2016/581892/EPRS_STU(2016)581892_EN.pdf

European Parliament (2014), Directorate-general for internal policies, In: Zarco-Tejada P. J., Hubbard N., Loudjani P.: *Precision agriculture: an opportunity for eu farmers - potential support with the cap 2014-2020*, European Parliament, Avialable at: https://www.europarl.europa.eu/RegData/etudes/note/join/2014/529049/IPOL-AGRI_NT(2014)529049_EN.pdf

European Parliament (2016), Directorate-general for parliamentary research services, In: Daheim C., Poppe K., Schrijver R.: *Precision agriculture and the future of farming in Europe: scientific foresight study,* European Parliament, DOI: 10.2861/020809

Ferro A., Oliveira, E. (2019), *Digital farming: Potential market and adoption in Brazil. Céleres. Uberlandia – Minas Geraise,* Avialable at: https://www.gatewaytosouthamerica-newsblog.com/digital-farming-potential-market-and-adoption-in-brazil/

Furlan A. (2019), Information on the EU survey on Precision Farming Technologies*, 14th Meeting of the permanent Subgroup on Innovation for agricultural productivity and sustainability, 14 June 2019, Belgium,* Avialable at: https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/field_event_attachments/20190614_sgi14_andrea_furlan_eu_survey_pat.pdf

Gal T., Nagy L., David L., Vasa L., Balogh P. (2013), Technology planning system as a decision support tool for dairy farms in Hungary, *Acta Polytechnica Hungarica,* 10(8), pp. 231–244.

Gaál M., Illés I. (2020, *IK Research Institute of Agricultural Economics* (in Hungarian).

Gebbers R., Adamchuk V. (2010), Precision agriculture and food security, *Science*, pp. 828–831, DOI:10.1126/science.1183899

GlobalData (2022), *Market value of precision agriculture in Canada*, Avialable at: https://www.globaldata.com/data-insights/agriculture-amp-forestry/market-value-of-precision-agriculture-in-canada-2017-2021/

Grand View Research (2022), *Precision farming market size, share & trends analysis report by offering (hardware, software, services), by application (yield monitoring, weather tracking, field mapping, crop scouting), by region, and segment forecasts, 2022–2030. Report ID: GVR-1-68038-376-8,* Avialable at:
https://www.grandviewresearch.com/industry-analysis/precision-farming-market

Griffin T.W., Lowenberg-DeBoer J. (2005), Worldwide adoption and profitability of precision agriculture, *Revista de Politica Agricola,* 14(4), pp. 20–37.

Griffin T. W., Yeager E. A. (2018), Adoption of precision agriculture technology: A duration analysis, *Proceedings of the 14th International Conference on Precision Agriculture, International Society of Precision Agriculture*, Avialable at: https://www.researchgate.net/publication/334306511_How_quickly_do_farmers_adopt_technology_A_duration_analysis

Grispos G., Doctor A.C. (2022), *Rise of precision agriculture exposes food system to new threats,* Avialable at: https://theconversation.com/rise-of-precision-agriculture-exposes-food-system-to-new-threats-187589

Hadászi L. (2018a), *Agirultural digitalisation will not work without integration and standardisation,* Avialable at: https://www.agronaplo.hu/termekinformaciok/integracio-szabvanyositas-nelkul-az-agrardigitalizacio-sem-megy.

Hadászi L. (2018b), *No breakthrough without compatibility of precision techologies*, Avialable at: https://www.magro.hu/agrarhirek/a-precizios-eszkozok-kompatibilitasa-nelkul-elmarad-az-attores/ (in Hungarian)

Halas V. (2017), Precision technologies in animal production - more predictable, more efficient production, *Agroinform*, Avialable at: https://www.agroinform.hu/allattenyesztes/precizios-technologiak-az-allattenyesztesben-kiszamithatobb-hatekonyabb-termeles-31682-001

Husti I. (2018), Thoughts and opinions on precision farming, *Mezőgazdasági Technika*, 7, pp. 2–6.

ISPA (2019): *ISPA forms official definition of 'Precision Agriculture',* Avialable at: https://www.precisionag.com/market-watch/ispa-forms-official-definition-of-precision-agriculture

Jóri J.I. (2017), The future of agriculture - Smart agricultural machinery, Part 1, *Agrofórum*. pp. 68–74, Avialable at: https://agroforum.hu/lapszam-cikk/a-jovo-mezogazdasaga-intelligens-mezogazdasagi-gepek-1/ (in Hungarian)

Jóri J.I. (2019), *Mechanisation issues in precision farming*, Avialable at: https://mgi.naik.hu/system/files/uploads/2019-01/dr_jori_j_istvan_a_precizios_gazdalkodas_gepesitesi_kerdesei.pdf

Kay R.D., Edwards W.M., Duffy P.A. (2013), *Modern farm management*, Szaktudás Kiadó Ház.

Kendall H., Naughton P., Clark B., Taylor J., Li Z., Zhao C., Yang G., Chen J., Frewer L. J. (2017), Precision agriculture in China: Exploring awareness, understanding, attitudes and perceptions of agricultural experts and end-users in China, *Advances in Animal Biosciences,* DOI: 10.1017/S2040470017001066

Kireyeva A. A., Kredina A., Vasa L., Satpayeva Z. T. (2021), Impact of financial technologies on economic development: Theories, methods and analysis, *Journal of International Studies* 14(4), pp. 286–303.

Kurth T., Rubel H., Walker D., Meyer zum Felde A., Jerratsch J. F., Zielcke, S. (2018), *It's time to plant the seeds of sustainable growth in agriculture,* Boston Consulting Group, Avialable at: https://www.bcg.com/publications/2018/time-plant-seeds-sustainable-growth-agriculture

Magnin C. (2016), *Advanced analytics opens vast untapped potential for farmers, investors, and emerging economies to reduce the cost of goods sold*, Avialable at: https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/how-big-data-will-revolutionize-the-global-food-chain

Marquardt D. (2018), *Data collection on precision farming,* Background notes, EEA, Denmark, Avialable at: https://www.eea.europa.eu/themes/agriculture/background-note-data-collection-on

Mitchell S., Weersink A., Erickson, B. (2018), Adoption of precision agriculture technologies in Ontario crop production, *Canadian Journal of Plant Science*, 98(6): pp. 1384–1388, DOI: 10.1139/cjps-2017-0342

Mishchuk H., Yurchyk H., Bilan Y. (2018), Shadow incomes and real inequality within the framework of leadership and social change, In: *Leadership for the Future Sustainable Development of Business and Education* (pp. 89–101), Springer, Cham, DOI: 10.1007/978-3-319-74216-8_10

Nagy H., Káposzta J., Neszmélyi G.I., Obozuwa O.G. (2017), Effects of international trade agreements on the economy and society of Africa: Special focus on Nigeria, In: *Establishing Food Security and Alternatives to International Trade in Emerging Economies*, pp. 196–219.

Nassar S., Naárné Tóth Zs., Vasa L. (2022), The impact of leadership skills on food security intervention: a comparative study between males and females, *Journal of Asian Finance, Economics and Business,* 9(9), pp. 0131–0141, DOI: 10.13106/jafeb.2022.vol9.no9.0131

Németh T. (2014), *Precision crop production*, Part I, Avialable at: https://www.agronaplo.hu/szakfolyoirat/2013/03/szantofold/precizios-novenytermesztes-i-resz

Observatory of Digital Agriculture (2017), Avialable at: http://agrotic.org/observatoire

Paustian M., Theuvsen L. (2017). Adoption of precision agriculture technologies by German crop farmers, *Precision Agriculture*, 18(5), DOI: 10.1007/s11119-016-9482-5

Piwowar A. (2020). Challenges associated with environmental protection in rural areas of Poland: Empirical studies' results, *Economics and Sociology,* 13(1), pp. 217–229, DOI:10.14254/2071-789X.2020/13-1/14

Przekota G., Szczepańska-Przekota A., Mentel G., Mentel U., Snieška V. (2020), Causality of the relationship between wheat prices and economic conditions - an evidence for sustainable development, *Journal of International Studies,* 13(3), pp. 161–179, DOI:10.14254/2071-8330.2020/13-3/11.

Remeikiene R., Gaspareniene L., Fedajev A., Vebraite V. (2021), The role of ICT development in boosting economic growth in transition economies, *Journal of International Studies,* 14(4), pp. 9–22, DOI:10.14254/2071-8330.2022/14-4/1

Roshchyk I., Oliinyk O., Mishchuk H., Bilan Y. (2022), IT Products, E-Commerce, and Growth: Analysis of Links in Emerging Market, *Transformations in Business & Economics,* 21(1), pp. 209-227.

Steele D. (2017), *Analysis of precision agriculture adoption & barriers in western Canada: producer survey. Report prepared for Agriculture and Agri-Food Canada (AAFC), April 2017,* Avialable at: https://static.agcanada.com/wp-content/uploads/sites/3/2017/05/Final-Report-Analysis-of-Precision-Agriculture-Adoption-and-Barriers-in-western-Canada-April-2017.pdf

Sulecki J.C. (2018), *2019 outlook for global precision agriculture*, Meister Media Wordwide, Avialable at: https://www.meistermedia.com/wp-content/uploads/2018/12/2019-Outlook-for-Global-Precision-Agriculture.pdf

Riports and Data (2020), *Precision Farming/Agriculture Market Analysis*, *Report ID: RND_001291*, Avialable at: https://www.reportsanddata.com/report-detail/precision-farming-agriculture-market

Tagarakis A.C., van Evert F., Kempenaar C., Ljubicic N., Milic D., Crnojevic-Bengin V., Crnojevic V. (2018), Opportunities for precision agriculture in Serbia, *Proceedings of the 14th International Conference on Precision Agriculture, Canada.*

Takácsné Gy.K., Takács I. (2022), Towards climate smart agriculture: How does innovation meet sustainability?, *Ecocycles*, 8(1), pp. 61–72, DOI: 10.19040/ecocycles.v8i1.220

Tamás J. (2017), The drought, *Magyar Tudomány*, 178(10), pp. 1228–1237, DOI:10.1556/2065.178.2017.10.6

Thompson N.M., Bir C., Widmar D.A., Mintert J.R. (2018), Farmers perceptions of precision agriculture technology benefits, *Journal of Agricultural and Applied Economics,* 51(1), pp. 142–163, DOI:10.1017/aae.2018.27

Vasa L., Trendov N. (2020), Farmers' experience in adoption and usage of ICT solutions for agriculture in the Republic of Macedonia, *APSTRACT - Applied Studies in Agribusiness and Commerce,* 14(3-4), pp. 1–15.

Vasylieva, N., James, H. (2021). The effect of urbanization on food security and agricultural sustainability. *Economics and Sociology,* 14(1), pp. 76-88, DOI: 10.14254/2071-789X.2021/14-1/5