

## Application possibilities of artificial intelligence in grain trade

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### ABSTRACT

Grain trade plays a key role in global food security, but it faces several challenges, such as climate change, geopolitical conflicts and market fluctuations. As a result of these problems, increasing attention is being paid to the agricultural applications of artificial intelligence (AI). The application of AI technologies contributes to increasing efficiency, reducing losses and strengthening sustainability. The aim of this article is to examine the role of AI in grain trade and its future opportunities. In order to provide an overview and transparency of the topic, we conducted a questionnaire survey among Hungarian agricultural producers and employees of agribusinesses who are directly involved in grain trade processes.

## 1. Introduction

Grain trade is one of the most important sectors of the global agricultural economy, playing a key role in maintaining food security, developing international trade relations and stabilizing agricultural economic processes. Grains (most importantly wheat, corn, barley, rye and rice) are among the basic food sources of humanity, so their production and trade are of strategic importance.

The commercial market is affected by many challenges (the effects of climate change, geopolitical factors, supply and demand fluctuations and market volatility), one of the most important of which is the impact of extreme weather conditions on crop yields and supply chain stability. Geopolitical conflicts (such as the Ukrainian-Russian war) have caused significant disruptions in global grain trade, highlighting the vulnerability of the market. These challenges have brought many difficulties and changes to the grain trade, in response to which, in recent years, increasing attention has been paid to the agricultural application of artificial intelligence (hereinafter referred to as AI), which opens up new opportunities to increase the efficiency of grain trade, promote sustainability and optimize the global food chain. With the help of AI technologies, agricultural sector actors can make more accurate forecasts of crop yields, automate logistics processes and optimize their go-to-market strategies. Data-driven decision-making, predictive analytics (a data analysis methodology that predicts future events or behavior based on past data and patterns) and automated systems provide the opportunity for farmers and traders to respond faster and more effectively to market changes.

One of the most important areas of application of artificial intelligence is precision agriculture, weather and crop forecasting models, automated logistics systems, which enable process optimization, efficient use of resources, and reduction of losses.

The main goal of our article is to present in detail the relationship between grain trade and artificial intelligence, analyze the current and future applications of AI technologies in the agricultural sector, and evaluate their impact on market participants and sustainability aspects. The aim of the research is to explore the extent to which AI technologies contribute to increasing production efficiency, improving price stability, and the spread of sustainable agricultural practices. In order to better understand the topic, we also conducted a questionnaire survey among more than 300 agricultural

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professionals, where we received a more accurate insight into the relationship between the grain market and AI by filling out a professional questionnaire.

## 2. Literature review

### 2.1. Basics of Grain Trade

Grain trade (the trade of agricultural products on international or domestic markets) is one of the most important sectors of the agricultural economy, playing a key role in global food security and maintaining the stability of national economies (FAO, 2023). Cereals (including wheat, maize, barley, rye and rice) are among the basic food sources of humanity and their production and trade have a significant impact on global economic and social processes (OECD-FAO, 2023). The functioning of the grain market (the market environment where grains are bought and sold; International Grains Council [IGC], 2023) is greatly influenced by climate change, geopolitical events, supply and demand fluctuations and technological innovations, which together shape trends in global grain trade (USDA, 2023).

The most important players in the grain trade include the largest producing and exporting countries, such as the United States, Brazil, Russia, Ukraine and some member states of the European Union (USDA, 2023). In addition to exporting countries, importing countries also influence the development and trend of grain trade. The global grain market fluctuates due to the influence of countries and faces several challenges that are constantly shaped by fluctuations in demand and supply (e.g. extreme weather conditions caused by climate change) and geopolitical risks (FAO, 2023). At the same time, innovations and sustainable agricultural technologies (agricultural practices that conserve natural resources, maintain biodiversity and minimize adverse impacts on the environment in the long term, while ensuring food security; Pretty et al., 2018), especially AI-based decision support systems, precision agriculture, and automated logistics solutions, create significant opportunities to increase market efficiency (OECD-FAO, 2023). The application of AI in agriculture is a set of technological solutions that are capable of making automated decisions, analyzing data, and optimizing production processes in agricultural production. The application of AI enables precision farming, predicting and optimizing crop yields, accurately recognizing pests and diseases, and developing environmentally friendly and sustainable production methods (Magyar Mezőgazdaság, 2023).

### 2.2. The current grain market structure

Global grain trade is one of the most important areas of the agricultural economy (both in terms of volume and value), which plays a key role in maintaining global food security and in the stability of individual national economies. Its significance is fundamentally determined by the fact that cereals are the basic source of food for the population in many countries, which is why trade processes have a direct impact on social and economic stability (FAO, 2023). According to OECD 2023 data, the value of global grain trade has increased significantly in the past decade, and in 2023 it was estimated to have reached 250 billion US dollars, which accounted for a significant proportion of world agricultural trade (MNB, 2023; OECD, 2023). Behind the increase in global demand for cereals are demographic changes, urbanization, and the increase in per capita food consumption, which generate increasing import demand, especially in Asia and Africa (World Bank, 2023). The volume of grain trade, based on world trade turnover, exceeded 520 million tons by 2023 and continues to show continuous growth. This growth can be attributed to several factors:

- o the spread of intensive agricultural production,
- o agricultural technological innovation,
- o trade liberalization processes, etc. (USDA, 2023).

If we focus on the trade of the most significant grains based on FAO 2023 data, it can be stated that the vast majority of the volume of global grain trade is accounted for by wheat and maize. These two grains play a prominent role in the world agricultural market not only in terms of their commercial volume, but also in terms of their food, economic and social importance (FAO, 2023).

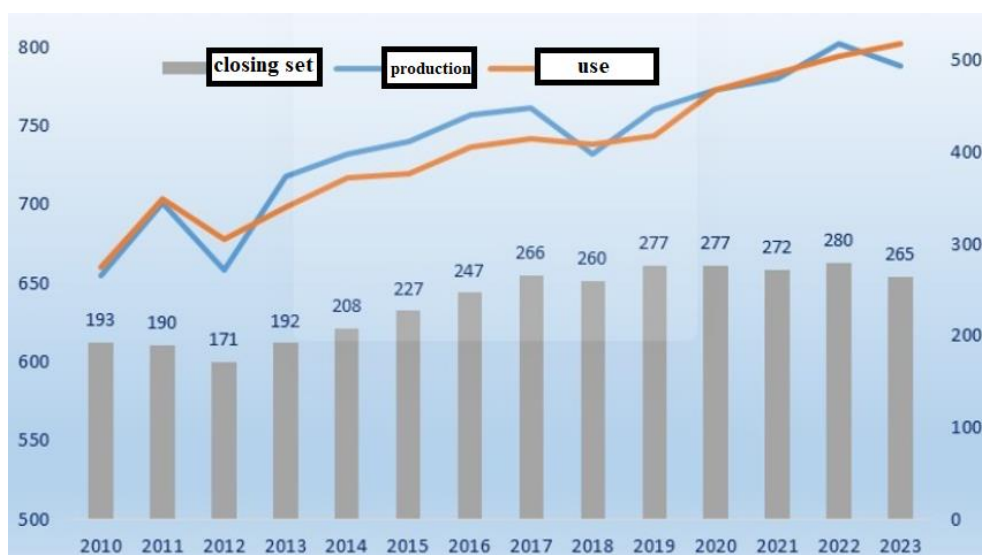
#### 2.2.1. Overview of trade in major cereals

The trade volume and importance of wheat are also outstanding in a global context, as this crop is one of the most widely grown cereals in the world. The global trade volume is about 200 million tons

per year, of which the largest exporters are Russia, the European Union, Canada, the USA and Ukraine. The demand for wheat is stable, as it is considered a staple food worldwide, especially in the Middle East, North Africa and Europe (USDA, 2023). Global wheat trade is significantly influenced by geopolitical events, which can cause serious price fluctuations (WTO, 2023).

Figure 1 shows the development of the global wheat balance between 2010 and 2023. It can be seen that wheat production and its consumption increased in parallel over the years, but in 2022 and 2023, consumption exceeded production, which led to a decrease in stocks. In 2010, global wheat stocks were 193 million tonnes, a figure that has been steadily increasing and has peaked at 280 million tonnes by 2020-2021. By 2023, this figure has fallen to 265 million tonnes, suggesting that demand is outstripping supply and that a decline in stocks could pose market challenges in the long term.

Global trade in maize has shown dynamic growth in recent decades. The volume of maize traded on international markets has reached 180 million tonnes per year, driven mainly by the growing demand for feed in the livestock sector (USDA, 2023). The boom in bioethanol production has also contributed to the growth in maize demand, particularly in the United States and Brazil (Clancy & Moschini, 2022). The main sources of corn exports are the United States, Brazil, and Argentina, while the largest importers are China, Mexico, Japan, and the European Union member states (USDA, 2023).

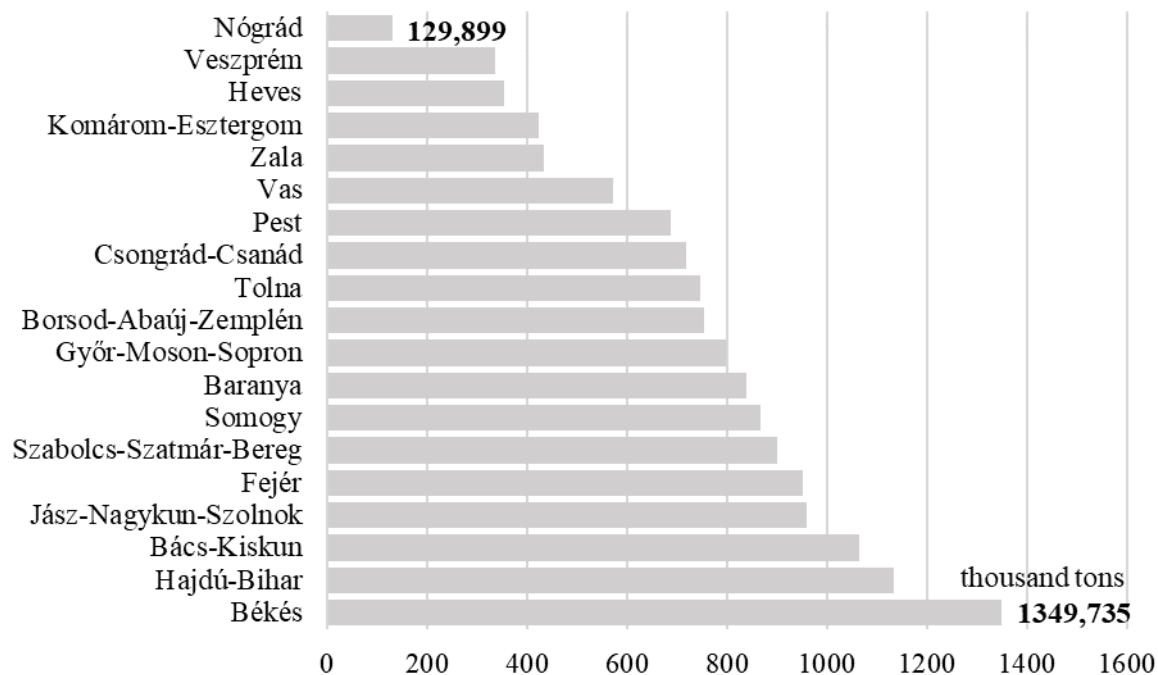


**Figure 1.** Global wheat balance 2010-2023 (tonnes)

Source: IGC (2023)

The third major cereal is rice, although its global trade volume is smaller than the other two cereals (approximately 55 million tonnes per year), its strategic importance is particularly high in Asia, where about 90% of it is produced and consumed (FAO, 2023). The most important exporters of world rice trade are India, Thailand, Vietnam, Pakistan and the United States, while the main importers include China, the Philippines, Nigeria and Bangladesh. The rice market is sensitive to changes in production volumes, which can be primarily attributed to weather factors and regional policies, thereby increasing market volatility (OECD-FAO, 2023; FAO, 2023). Figure 2 shows the shares of domestic cereal harvests by county in Hungary in 2021. It can be seen that the country's cereal production shows significant regional differences, which is an important factor in making domestic agricultural policy and economic decisions. It can be observed that the largest grain-producing regions in Hungary are linked to the Great Plain and certain parts of Transdanubia, where natural conditions and agricultural traditions favor large-scale production. Békés County leads the list with 1.35 million tons of harvested grain, followed by Hajdú-Bihar County with 1.13 million tons. Bács-Kiskun also contributes significantly to the country's grain supply with a production of more than 1 million tons. These values well reflect the excellent agricultural conditions of the Great Plain and the strong agricultural traditions of the region. The middle range includes Tolna, Somogy and Győr-Moson-Sopron counties,

where the production volume ranges between 700-900 thousand tons, while the lowest values can be observed in Nógrád county, where only 129 thousand tons of grain were harvested in 2021, which is due to less favorable natural conditions and smaller agricultural areas.



**Figure 2.** Share of domestic grain harvest by county in Hungary in 2021

Source: own editing based on data from the Central Statistical Office database (KSH, 2021)

### 2.2.2. Characteristics of the grain market

One of the most important characteristics of the grain market is seasonality, which results from the nature of the grain production cycle. According to Samuelson and Nordhaus, seasonality is linked to the harvest period of the crops, which typically occurs once or twice a year, depending on the region and grain variety. This significantly affects the annual fluctuation of supply and, accordingly, the development of market prices. During the harvest periods, supply increases, so prices can fall, while during the non-production period, prices usually increase in parallel with the decrease in stocks (Samuelson and Nordhaus, 2015). The grain market is also characterized by volatility, which is manifested in rapid, unpredictable and significant fluctuations in prices. According to FAO data for 2023, this volatility can be attributed to several factors, including the uncertainty of agricultural production caused by external conditions (e.g. drought, floods, heat waves, natural disasters, etc.) (FAO, 2023). Research by Hull (2015) points out that commodity exchanges have emerged to manage price fluctuations, providing producers and traders with the opportunity to manage market risks through futures and options transactions. Volatility in the grain market can also be increased by geopolitical events, which significantly affect the global supply-demand balance. Geopolitical conflicts and trade restrictions can directly interfere with the possibilities and prices of crop exports (Clark – Thompson 2021). A prominent example, according to WTO data from 2023, is the war between Ukraine and Russia in 2022, which caused significant disruptions in the global grain market, as both countries are among the world's most important grain exporters. The resulting export restrictions, maritime blockades and uncertainty in transport routes resulted in drastic price fluctuations, which increased food prices globally, threatening food security (WTO, 2023; Headey – Fan, 2008).

Based on literature research, it can be concluded that the role played in global grain trade depends to a large extent on the extent to which individual countries are able to sustainably increase grain production and their export capacity (Taylor, 2018). In this regard, the United States, Brazil, Russia and Ukraine play a prominent role, determining the dynamics of the grain market at a global level (FAO, 2023; USDA, 2023).

The United States has traditionally been one of the world's largest grain producers and exporters. It is particularly significant in terms of corn and wheat, whose annual exports have a significant impact on global grain prices. Thanks to its advanced agricultural technology and infrastructure, the USA is able to achieve consistently high yields, which is a stable supply factor on the world market. According to USDA data, in 2023 the USA accounted for about 30% of global corn exports and about 15% of wheat exports (USDA, 2023). The global role of Russia and Ukraine is particularly decisive in wheat exports. Together, they have provided nearly a third of the world's wheat exports in recent years, which entails significant geopolitical risks. The conflict in Ukraine (since 2022) has significantly disrupted supply chains (the process by which grain moves from producer to end user, including harvesting, storage, transportation and marketing, the efficient organization of which is critical for commercial success; Chopra & Meindl, 2019) and contributed to a significant increase in world market prices (OECD-FAO, 2023; WTO, 2023). Both countries' competitive advantages are largely due to their favorable natural conditions, the quality of their soil, and their lower production costs, combined with efficient logistics systems.

According to USDA data from 2023, Brazil has been playing an increasingly important role in global corn exports, especially since the 2000s. The country's corn exports are expected to reach 20% of the world market share in 2023 (USDA, 2023). According to the FAO 2023 report, Brazil's competitiveness is supported by its large production capacity, favorable climatic conditions, the use of modern agricultural technologies and an efficient logistics infrastructure. In addition, Canada, Argentina, Australia and the European Union are also significant players in the global grain market. Canada and Australia are large exporters of wheat, while the European Union is both an exporter and importer, playing a specific role in the world market. These countries are stable grain market players that contribute to maintaining the global supply-demand balance (FAO, 2023).

### 2.3. Current Applications of AI in the Agricultural Sector

The agricultural sector has undergone a significant technological transformation in recent decades, with artificial intelligence playing an increasingly important role (AIMojo.io, 2025). Among the agricultural applications of AI, data-driven decision-making based on precision farming, weather and crop estimation models, the use of automated machines and robots, and technologies used to recognize plant diseases and pests (Wolfert et al. 2017).

The essence of precision agriculture (Figure 4) is to optimize agricultural operations using data collected on crop fields, reducing inputs, improving yields, and minimizing adverse impacts on the environment.



**Figure 3.** Top grain importing countries according to 2021 OEC data  
Source: aimojo.io (2025)

By using GPS-based positioning, sensors, drones, and AI-based data analysis systems, farmers can more accurately determine the need for fertilization, irrigation, or pesticide use, thereby reducing waste and increasing production efficiency (Gebbers & Adamchuk, 2010).

The use of weather and crop prediction models allows farmers to more accurately predict expected crop yields and respond in a timely manner to potential adverse weather events (Vila et al, 2020). The AI-based algorithms of these models process large amounts of historical and real-time meteorological data, thus being able to more accurately predict droughts or frost damage (Chlingaryan et al., 2018).

One of the most visible areas of AI application in agriculture is the use of automated machines and robots. Self-driving tractors, drones, and automated harvesters can continuously collect data and perform analysis, thus reducing the need for human labor while increasing work accuracy and efficiency (Kassler, 2021).

In addition, AI-based detection and management of pests and plant diseases has brought a significant breakthrough in the agricultural economy. Intelligent image processing systems enable early, accurate detection of plant diseases and pests, allowing farmers to respond quickly, thereby reducing crop losses and the environmental burden of chemical use (Barbedo, 2020).

The listed technological solutions clearly demonstrate the increasing presence and indispensable role of AI in modern agriculture, contributing to the sustainability and competitiveness of farming.

### **2.3.1. Benefits of AI technologies in grain trade**

The application of artificial intelligence in grain trading brings significant economic, environmental and strategic benefits. These benefits are basically manifested in three main areas: increased efficiency and cost reduction, environmental benefits and strengthening competitiveness in the global market (magro, 2025).

The increased efficiency and cost reduction that can be achieved through artificial intelligence-based technologies primarily result from data-based decision-making. Precision farming makes plant protection, irrigation and nutrient supply more accurate, thereby minimizing unnecessary expenses and maximizing crop yields (Wolfert et al., 2017). The use of automated logistics systems and intelligent supply chain management can reduce transport and storage losses, which can result in significant savings for grain traders (Chopra & Meindl, 2019).

The application of AI also brings significant environmental benefits, contributing to the development of sustainable agriculture. Smart technologies reduce unnecessary use of chemicals and optimize energy and water use. This reduces the environmental impact and can improve soil quality and biodiversity in the long term (Pretty et al., 2018). Artificial intelligence and robotics applied in precision farming allow farmers to continue their production activities in a more sustainable way while preserving natural resources (Gebbers & Adamchuk, 2010). According to Wolfert et al., the use of artificial intelligence also provides a competitive advantage for grain traders, contributing to improving and stabilizing their market positions. With the help of AI, changes in demand and supply can be managed more effectively and market trends can be predicted, allowing traders to react more quickly to market changes (Wolfert et al., 2017). According to a 2019 study by Chopra and Meindl, automated logistics systems can further shorten delivery times, increasing the competitiveness and market value of the product.

### **2.3.2. Challenges and risks in the field of AI**

The application of artificial intelligence in grain trade not only brings benefits, but also many challenges and risks. Of particular importance are concerns about data protection and ethical issues, the problem of the digital divide resulting from inequalities in technological access, and the long-term effects of AI on the labor market (FAO, 2023; Rotz et al., 2019).

One of the most serious challenges of AI-based technologies is in the area of data protection and ethical issues. The large amounts of data collected in precision farming (e.g. information on crop yields, soil conditions, or even farmer habits) may contain sensitive business and personal information that must be adequately protected. It is vital for farmers and grain market participants that the collected data is stored, managed and secured in an appropriate manner, thus avoiding data breaches and abuses (Wolfert et al., 2017). Further ethical questions arise regarding the extent to which large companies can use this data to increase market advantages, potentially limiting market opportunities for smaller producers (Carolan, 2020).

Another significant issue is the technological accessibility and digital divide, which pose a significant barrier, especially for developing countries and smaller agricultural enterprises. Access to AI-based technologies is highly dependent on technological infrastructure, the necessary knowledge and financial resources, which are not equally available in all regions (Rotz et al., 2019). This digital divide can further deepen existing economic inequalities and make it more difficult for smaller farmers to compete with larger and more developed economies.

The application of artificial intelligence can also have a significant social and economic impact on the labor market. The widespread use of automated tools (self-driving tractors and robotic harvesters) could significantly reduce the need for agricultural labor, leading to short-term productivity gains but long-term employment losses. This poses serious social and economic challenges, especially in areas where agriculture is a major employment sector (FAO, 2023; Kassinis & Vafeas, 2021).

### 2.3.3. Future directions and opportunities in the field of AI

The further development of artificial intelligence offers promising opportunities for grain trade, especially in the areas of precision agriculture, sustainability and climate change management, as well as interdisciplinary cooperation. In the future, the integration of AI technologies could fundamentally transform grain markets, contributing to increased sustainability and competitiveness.

The future of AI and precision agriculture lies primarily in even more advanced data processing methods. More advanced machine learning algorithms can make more accurate predictions about future yield averages, weather events and field conditions possible, allowing for further reductions in production costs and optimization of production processes (Wolfert et al., 2017). The spread of these technologies could also become accessible to small and medium-sized farms, thus reducing the digital divide and strengthening the competitiveness of the agricultural sector.

AI technologies also have significant potential for sustainability and climate change management. AI is able to take into account the effects of climate change as accurately as possible and develop strategies for the development of grain varieties (Liakos et al., 2018). These intelligent systems can help the agricultural sector to use natural resources more sustainably, contributing to global food security.

A key element of the future will be an interdisciplinary approach, which, together with the application of AI technologies, can facilitate the integration of agricultural science, information technology, and economic and social sciences. This provides an opportunity to develop comprehensive, sustainable and economically viable solutions to the complex challenges arising in the grain trade (Carolan, 2020).

The integration of Internet of Things (IoT) technologies with AI is also a promising development direction. IoT-based sensors can enable continuous real-time data collection, allowing producers and traders to monitor grain growing conditions and market conditions in real time, providing them with the ability to respond quickly (Villa-Henriksen et al., 2020; Wilson, 2022).

## 3. Material and Methods

In order to address the topic, we reviewed studies, articles and materials containing the characteristics of the current international and domestic grain market. To establish the relationships, we used the databases of the United States Department of Agriculture (USDA), the Food and Agriculture Organization of the United Nations (FAO), the Organization for Economic Co-operation and Development (OECD), and the Central Statistical Office (KSH).

The objective of the study was to study the international spread and application of AI technologies in the grain trade sector. The increasing role of AI in the agricultural sector is becoming an increasingly decisive factor, with special emphasis on the spread of data-based, AI-based technologies, the forms of use of which are discussed in detail. When analyzing the role of AI in grain trade, we also present the opportunities and threats of AI-based technologies. With the emergence of AI technologies, we also examined measures to increase efficiency, reduce losses, and promote sustainability goals in the sector. We then explored the opportunities offered by AI, as well as the potential risks that may arise from the use of these technologies.

In order to assess the topic more precisely, we also conducted a questionnaire survey. The questionnaire was titled "The current and future role of artificial intelligence in grain trade". A total of 339 people filled out the questionnaire, of which 320 responses were included in the study after the data cleaning process (cleaning: inadequate or incomplete completion).

Hungarian agricultural producers and employees of agricultural companies who are directly involved in the grain trade processes participated in filling out the questionnaire. In my opinion, the sample thus reflects the opinions of those actors in the domestic agricultural sector who may be interested in the introduction or application of artificial intelligence. The data collection lasted for almost a month, which provided sufficient time to reach the respondents and complete the questionnaires in sufficient numbers. The questionnaire was prepared anonymously, so the personal data of the participants were not recorded, which increased the honesty and authenticity of the answers. The completion took place online, which allowed us to collect data from a wide geographical area. I asked the regionally competent village economists of five counties to cooperate in the data

collection. They agreed to forward the questionnaire to the farmers and agricultural companies in their own databases. In our opinion, this method ensured that the questionnaire reached real, active agricultural market players, and the intermediary role of the contacted village economists helped to achieve a high completion rate (the respondents received the invitation from a reliable source). The sampling is not random, but through professional connections and targeted outreach, it provides a representative picture of the relationship of the Hungarian grain trade to AI. The questionnaire contained 13 professional questions, which focused on the knowledge, application and future possibilities of artificial intelligence. The vast majority of the questions were multiple-choice, however, there were also 2 open-ended questions for the respondents to share their opinions with us without being influenced. The majority of the questions appeared in a closed, multiple-choice form, which facilitated the statistical processing of the data. The aim of the data collection was to explore the opinions of professionals active in the grain trade on the current role and future possibilities of AI.

## **4. Results and their evaluation**

### **4.1. The diffusion of AI technologies in grain trade**

The spread of AI technologies in grain trade is not uniform, but rather gradual. The spread is based on the different adaptation capabilities of different market players and the technological development of different regions. Innovation diffusion models help to understand how artificial intelligence is accepted by grain market players and what factors influence its spread. Based on the innovation diffusion theory developed by Everett Rogers, the adaptation of AI solutions in grain trade also occurs in stages. The first adopters (“innovators”) are mainly large agricultural companies and global trading companies that have significant capital to introduce advanced technologies. They are followed by “early adopters”, who are usually among the market-leading farmers and logistics service providers. In the next stage, when the benefits of using AI become clear, the “early majority” also starts to introduce these technologies. At this stage, medium-sized producers and regional grain trading companies are also joining the innovation, which can be significantly supported by state and international development programs. The “late majority” and “laggards” are smaller players who are late to the application of AI technologies, mainly due to the lack of infrastructure or financial resources. Analysis of innovation diffusion models shows that the main obstacles to the spread of AI in grain trading include the high initial investment cost, lack of technological knowledge and underdevelopment of digital infrastructure. At the same time, according to the models, the availability and application of AI technologies is spreading at an accelerating pace, especially in developed countries, where government subsidies and R&D investments act as incentives. The results of the innovation diffusion models show that AI in grain trading follows a typical technological development curve, where “early adopters” lead the market and gradually become more widely available to smaller producers and traders.

In our primary research, we also examined the practical applicability of AI in grain trading. Artificial intelligence can help farmers, producers, traders and consumers to mitigate and more effectively manage the challenges of grain trading (e.g. climate change, geopolitical conflicts and price volatility). AI-based systems offer the opportunity to minimize risks and stabilize the market, while increasing supply chain efficiency.

Artificial intelligence-based automated systems and digital decision support solutions (big data analytics) are playing an increasingly important role in grain trading and agricultural production. These technologies enable farmers, traders and logistics operators to manage price movements, supply chains and inventories more efficiently, while minimizing risks and reducing operating costs. As part of this, AI can help minimize financial and production risks. Automated systems can be applied at many points in the supply chain, including smart warehouse management, self-driving agricultural machinery and commodity market transactions. AI algorithms can optimize warehousing and transportation, reducing losses, which can lead to more efficient inventory management. Automated pouring systems offer the opportunity to increase water utilization, which can reduce water use by approximately 30-50% thanks to intelligent scheduling. Automated warehouse management systems enable real-time monitoring of grain stocks and optimization of logistics operations, which is especially important in the global grain trade, where fast transportation and proper storage are critical factors.

**Table 1.** The relationship between AI and grain trade

Tools		
Precision Forecasting	Digital Decision Support Solutions	Automated Irrigation Systems
Efficient Inventory Management	Smart Warehouse Management	Robotics
Automated Pricing	Self-Driving Agricultural Machinery	Risk Analysis
Automated Warehouse Management Systems		Precision Forecasting
Opportunities	Threats	Limitations
Predictive Analytics	Data security risks	Technology costs
Supply Chain Optimization	Technological dependence	Data dependency
Sustainability	Legal and ethical regulation	Market resistance
New Market Opportunities	Potential for market manipulation	
Increasing Competitiveness		

Source: own compilation (2025)

Robotics can reduce labor costs by automating tasks and achieve increased efficiency through automated processes. For example, self-driving tractors and combines can optimize sowing, irrigation, and harvesting processes using sensors and AI algorithms, reducing the need for human labor and increasing production efficiency.

AI-based models can predict weather effects and market trends with precision forecasts, helping grain traders make better decisions. This method can increase yields by up to 30%. AI provides real-time insights through crop monitoring systems, which can detect various diseases at an early stage and also visualize data. AI can improve soil quality by monitoring soil health and can improve soil health by up to 25%. Pest control solutions aim to reduce the use of chemicals to control insects, which can reduce losses caused by pests by 15%.

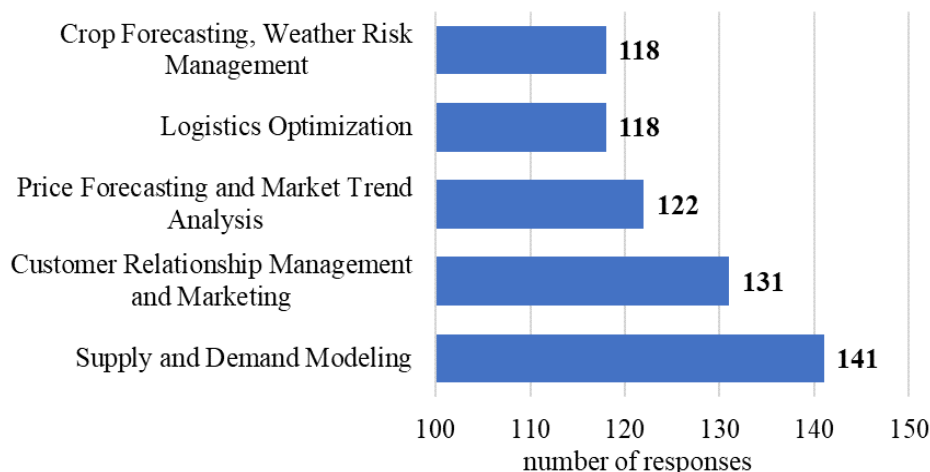
AI-based algorithms can analyze weather forecasts, market supply and demand conditions, and geopolitical events, helping farmers determine the best timing for sowing, harvesting, and marketing.

Implementing and maintaining AI systems requires significant investment, and in many cases, the effectiveness of the models is highly dependent on the availability of quality and sufficient data. Some traditional grain traders are still wary of AI-based decision-making, which is also a barrier to adoption on farms. The dangers of AI include data security risks and dependence on technology. Excessive technological dependence can also be a problem in the long term and it can be summarized that these tools and methods can in no way replace human work, which functions as a kind of strategic control in the case of the introduction of AI. Another danger is that the legal and ethical regulation of AI tools is not yet fully developed. Mastering AI algorithms provides an opportunity for market speculation and thus influencing the market, which the sector will have to deal with in the near future.

#### 4.2. Results of the questionnaire survey among farmers

The necessary calculations were made based on the responses received in the questionnaire survey. After performing the calculations, it can be stated that farmers see the greatest potential of artificial intelligence in the field of supply and demand modeling in grain trade. For market participants, AI can primarily provide a competitive advantage in the forecasting of market dynamics and price movements, according to the respondents. It was chosen 141 times that a more accurate estimate of demand and supply has a direct impact on pricing and profitability. In this context, the 122 responses to price forecasting also confirm that decision-makers interpret artificial intelligence as a tool for recognizing future market trends. The two areas (supply and demand modeling and price forecasting) are thus closely related to each other, since grain market prices are fundamentally determined by these factors.

The 131 responses from customer relationship management and marketing indicate that players see opportunities in AI not only on the technical side of the commodity market, but also in the areas of market communication and sales. Digital sales channels, automated offers and personalized market information enable new types of commercial strategies. Traders recognize that artificial intelligence in customer relations can not only save time, but also increase loyalty and market coverage.



**Figure 4.** The results of the questionnaire survey among respondents  
Source: Own data collection and calculation

The areas of logistics optimization and crop forecasting, as well as weather risk management, each received 118 responses. This balanced result shows that respondents consider operational efficiency and the reduction of production uncertainties to be key. In logistics optimization, AI can be used to reduce transportation costs, improve warehouse utilization and optimize the delivery route.

Based on the results obtained, it can be stated that the proportion of individual answers does not show extreme differences, as the difference between the highest and the lowest value is relatively small. This also supports the fact that AI is envisioned as a comprehensive, integrated tool in grain trade, which can create value in several processes at the same time. Since the 320 respondents could select multiple answer options for this question of the questionnaire, it can be stated based on the 630 answers that the majority of respondents considered several areas relevant, which shows openness to the topic and technological interest (grain trade actors are looking for ways to implement AI in practice).

Based on the answers given to the open question, it can be stated that the application of AI in the grain market enables data-driven decision-making, which can lead to market stability and efficiency in the long term. Artificial intelligence can have an impact on the entire grain trade value chain.

In the research, we separately examined the relationship between the questions “How realistic is the time frame for the widespread application of AI in grain trade?” and “How important is it for your company (or the sector) to develop its AI-based competencies?”. A moderate positive relationship can be observed between the two questions, i.e. the more important someone considers the development of AI-based competencies, the shorter the time frame they consider the widespread deployment of AI realistic (i.e. those who consider development less important tend to see the deployment of AI over a longer period). The values obtained do not represent a strong relationship, but they indicate a detectable, non-random relationship between the two questions (Table 2, the Creamer and Chuprov association coefficient took a value of 0.253-0.253, the contingency coefficient was 0.401).

**Table 2.** Examining the results of the questionnaire survey with a correlation analysis

Indicator name	Value
Cramer's association coefficient	0,252798
Cuprov's association coefficient	0,252798
Contingency coefficient	0,401095

Source: Own data collection and calculation

#### 4. CONCLUSION AND RECOMMENDATIONS

Our aim with the research was to summarize the role of AI technologies in the agricultural sector. AI technologies can help increase the sustainability and competitiveness of Hungarian and global grain trade. In our opinion, this analysis contributes to a deeper understanding of the functioning of the

grain market and agricultural technology trends and shows how AI can support global food security. AI can provide good solutions and alternatives in the future, but it is not worth relying entirely on artificial intelligence. AI can provide many advantages, but hybrid systems support appropriate decision-making to a much greater extent.

AI can contribute to the planning and optimization of the supply chain, as purchasing, warehousing, and inventory can be optimized by taking into account predicted price movements, which can further increase efficiency and reduce losses.

Future directions may include prioritizing sustainability efforts in the grain market, focusing on reducing the ecological footprint, which will help to make the grain supply environmentally friendly and sustainable in the long term by using precision farming, sustainable transportation solutions, minimizing food waste, and monitoring the carbon footprint.

The questionnaire survey we conducted also confirmed that it is worth sharing the knowledge of artificial intelligence among farmers and incorporating it into agricultural activities to the greatest extent possible. The survey results show that farmers will also consider artificial intelligence to be one of the most significant elements of future decision-making.

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