The use of artificial intelligence in agriculture

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Abstract

Nowadays, it is difficult to imagine the modern world without the involvement of technologies such as artificial intelligence (AI) – both in economic and social spheres. The concept was first formulated in 1956 at a conference in Dartmouth by J. McCarthy, an American computer scientist who is sometimes referred to in academic circles as the "father of artificial intelligence"[1]. At that time, in Dartmouth, New Hampshire, he put forward the thesis that every precisely described aspect of learning or any other form of intelligence could be simulated by machines[2]. The origins of the development of artificial intelligence – defined by the PWN encyclopaedia as a branch of science concerned with studying the mechanisms of human intelligence and with modelling and constructing systems capable of supporting or replacing intelligent human actions[3], therefore date back to the 1950s. This field of computer science, alongside the ongoing global technological advancement observed over recent decades, has aroused growing interest among scholars. The intensive development of artificial intelligence became particularly noticeable in the 21st century, when the use of AI software for professional purposes became widespread. This process significantly contributed to the optimisation of work tools, as well as the mechanisation and automation of many processes – not only in production. The development of machine learning and advanced technologies based on artificial intelligence has not only changed the nature of various industries but also influenced the transformation of the agricultural sector. Among the greatest advantages of this process are undoubtedly: effective resource management in agriculture, precise real-time monitoring of crops and livestock, and more efficient reduction of negative environmental impact. Through the computing power of artificial intelligence algorithms adapted for agricultural purposes, it is possible, among

1. K. Ciesielska, *Ewolucja sztucznej inteligencji – 67 lat rozwoju*, Magazyn Brandsit, https://www.magazyn.brandsit.pl/ewolucja-sztucznej-inteligencji-67-lat-rozwoju/, access 18.02.2025.
2. Ibidem.
3. PWN Encyclopedia; https://encyklopedia.pwn.pl/haslo/sztuczna-inteligencja;3983490.html, access 18.02.2025.

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other things, to predict yields with high accuracy, optimise the use of water and fertilisers, and detect plant diseases and pests at an early stage. Despite the clear benefits that artificial intelligence can bring to agriculture, its large-scale implementation in this sector will also be associated with certain challenges. It appears that the most significant of these are the costs of implementation and maintenance, as well as the potential risk of software failures, which could lead to serious production delays and slowdowns. Nevertheless, the development of AI in agriculture is inevitable.

The aim of the study is to present the prospects for the use of artificial intelligence in agricultural activity.

Hypothesis: Artificial intelligence is being used more and more comprehensively and increasingly in agricultural, crop and livestock production.

Keywords: KRUS, agriculture, crop production, animal production, artificial intelligence (AI).

Introduction

Modern agriculture must now face numerous challenges – from climate change and the growing demand for food to the necessity of sustainable management of natural resources. Increasingly, modern technologies, including artificial intelligence (AI), are proving effective in addressing these issues. With each passing year, AI is undoubtedly gaining importance in the transformation of the agricultural sector. Thanks to AI, farmers can make more optimal decisions, manage their farms more effectively, and reduce their negative impact on the environment. The following text explores what artificial intelligence actually is and how it is practically applied in agriculture.

What is artificial intelligence and how does it work?

According to a definition developed by the European Council, an institution of the European Union, artificial intelligence is "the use of digital technology to create systems that can perform tasks usually requiring human intervention"[4]. Artificial intelligence is therefore intended to imitate or replicate the thinking of the human mind. Its operational system performs the following four steps[5]:

4. European Council, https://www.consilium.europa.eu/pl/policies/ai-explained/, access 19.20.2025.
5. Ibidem.

1) analyses large amounts of data inputs,
2) detects patterns through algorithms,
3) performs task,
4) learns and improves performance.

Thus, the more examples and data artificial intelligence is presented with, the more precise its suggested outcomes or solutions become. AI encompasses areas such as evolutionary algorithms, heuristics, genetic algorithms, expert systems, artificial neural networks, and fuzzy logic[6]. Moreover, according to the classification proposed by the European Council, artificial intelligence is used to serve sectors such as:

1) manufacturing,
2) security,
3) education,
4) healthcare,
5) energy,
6) transport[7].

Its application therefore also extends, indirectly, to the agricultural sector – specifically crop and livestock production, crop security, and the supply chain.

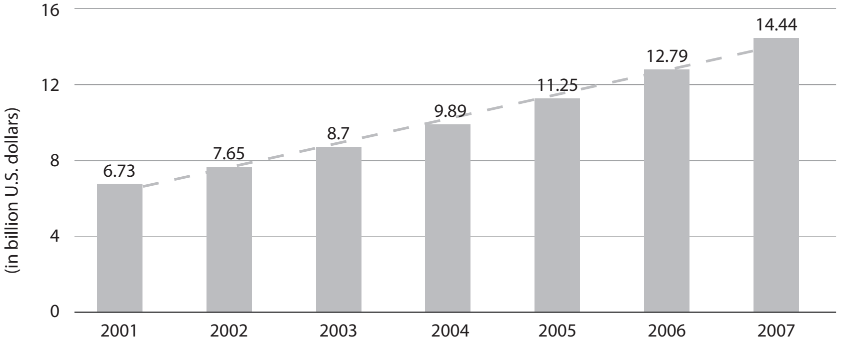
Precision agriculture

Considerations regarding the use of technology in agriculture should begin with an explanation of the concept of precision agriculture. This term refers to a comprehensive farm management system that enables precise control of production through a set of appropriate technological systems. Precision agriculture involves identifying yield variations in a cultivated field and their causes, introducing possible solutions based on economic rationale, and implementing new technologies[8]. Its application serves to optimise costs and revenues, as well as to improve environmental conditions. Precision agriculture is particularly important in the context of climate change and the growing global population, as it helps reduce resource consumption and achieve the maximum yield potential[9]. It is therefore no surprise that this innovative model of agricultural production is becoming increasingly popular on a global

6. K. Różanowski, *Sztuczna inteligencja: rozwój, szanse i zagrożenia*, "Zeszyty Naukowe: Warszawska Wyższa Szkoła Informatyki" 2007, No. 2, p. 115.
7. European Council, https://www.consilium.europa.eu/pl/policies/ai-explained/, access 19.20.2025.
8. Y. Huang, Y. Qian, H. Wei et al, *A survey of deep learning-based object detection methods in crop counting*, "Computers and Electronics in Agriculture" 2023, Vol. 215, 108425.
9. M. Sanyaolu, A. Sadowski, *The Role of Precision Agriculture Technologies in Enhancing Sustainable Agriculture*, "Sustainability" 2024, Vol. 16(15).

scale. Below is a forecast of the value of the global precision agriculture market for the years 2021–2027, prepared by the German company Statista, which specialises in developing reports based on previously conducted market research. A clear upward trend can be easily observed in Figure 1 – indicating the growing value of precision agriculture worldwide.

Figure 1. Forecast market value of precision agriculture worldwide from 2021 to 2027



Source: Statista, https://www.statista.com/statistics/721921/forecasted-market-value-of-precision-farming-worldwide/, access 12.03.2025.

A 2021 study conducted by the Association of Equipment Producers, an American association operating in the agricultural and construction sectors, reveals tangible benefits resulting from the application of precision agriculture. According to the data, farmers within the surveyed group achieved specific, measurable results:

- 4% increase in crop production,
- 7% increase in fertilizer placement efficiency,
- 9% reduction in herbicide and pesticide use,
- 6% reduction in fossil fuel use,
- 4% reduction in water use[10].

The development of precision agriculture would not be possible without the use of tools and systems that employ artificial intelligence. Through these, data is analysed, evaluated and verified – all of which contribute to the overall optimisation of agricultural cultivation. Devices such as specialist drones, sensors, and machines with integrated GPS systems are continuously transforming agriculture. Thanks to these technologies, farmers, for example, can map fields, analyse real-time data on crop

10. Association of Equipment Producers, https://www.aem.org/news/the-environmental-benefits-of-precision-agriculture-quantified, access 19.02.2025.

conditions, and automate agricultural tasks. AI systems, in turn, make it possible to forecast optimal cultivation measures based on machine learning models. All of these activities also contribute to the optimisation of resource use, which translates into more effective planning of fertilisation, irrigation, and the application of plant protection products.

Intelligent resource management

In order to optimise costs and revenues, as well as to increase crop yields, it is essential to manage the resources required for cultivation as efficiently as possible. Irrigation and soil fertilisation systems using artificial intelligence allow for more efficient distribution of resources than traditional methods, thanks to real-time measurements. The use of artificial intelligence is particularly crucial in regions which, due to their geographical conditions, lack abundant water resources because of low rainfall and the absence of reservoirs or watercourses. Moreover, agriculture is one of the sectors with the highest demand for water consumption, which is why it plays a vital role in shaping approaches to water conservation[11]. In such circumstances, the application of intelligent resource management also contributes to reducing negative environmental impacts.

The specialist sensors that underpin intelligent systems for managing agricultural resources utilise innovative technologies and are continuously evolving. They provide access to data concerning soil, weather, and the crops themselves, based on which schedules for distributing resources such as water, fertilisers, or lighting (in greenhouse conditions) are established. For example, the amount of water needed by specific plants is assessed in relation to their growth stage, the climate, type of crop, soil moisture, and weather conditions. AI systems use dedicated algorithms that allow them to calculate changes in soil moisture for agricultural crops depending on the aforementioned factors. The entire production process thereby becomes an automated operation based on real-time data, enabling it to adapt continuously to changing conditions.

11. V. Lattore, L.C. Zingali, C. Bragalli et al, *Smart Water Management in Agriculture: a Proposal for an Optimal Scheduling Formulation of a Gravity Water Distribution System* [in:] *IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor)*, Institute of Electrical and Electronics Engineers, November 2020.

Intelligent crop monitoring

One of the major advantages of using artificial intelligence in agriculture is the ability to remotely monitor and control crops. Through specialist systems, farmers are able to read real-time data such as temperature, humidity, light levels, and even carbon dioxide emissions. This makes it possible to detect deficiencies, identify essential nutrients, and spot the early development of plant diseases, weeds, or pests. Under such conditions, the use of chemical agents in cultivation – such as pesticides – can be effectively reduced, which in turn improves plant health and decreases environmental pollution. Properly programmed AI models therefore contribute overall to increased agricultural efficiency, as well as reduced water usage and environmental impact. Modern crop monitoring tools include:

1. Sensors: Placed directly in the field, sensors provide continuous real-time access to fundamental parameters such as soil moisture and temperature. They offer detailed insights that enable precise adjustment of irrigation, fertilisation, and other resource management practices[12].
2. Drones: Equipped with high-quality cameras and sensors, drones allow for precise monitoring of crop conditions. They make it easy to assess plant growth, identify potential pest infestations, and detect nutrient deficiencies at a detailed level[13].
3. Satellite imagery: Offers a broad perspective of crops and environmental conditions across large areas. Satellite images are particularly useful for tracking long-term changes in cultivation, such as soil degradation or the impact of weather conditions on fields[14]. In the case of Poland, satellite imagery – thanks to its precision – can replace the traditional commissions appointed by voivodes for estimating crop losses. These images may also be used in agricultural insurance as a tool for accurately determining the extent of damage.

Moreover, by analysing weather patterns, soil conditions, and historical data, AI models can predict yields with high accuracy. Artificial intelligence forecasts based on predictive models help farmers to plan production, manage resources efficiently, and ultimately reduce food waste in agricultural production.

12. Alteia, https://alteia.com/resources/blog/crop-monitoring/, access 3.03.2025.
13. Ibidem.
14. Ibidem.

Livestock farming and the use of AI

In addition to contributing to crop optimisation, artificial intelligence also supports another vital branch of agriculture: livestock farming. Thanks to modern technologies, farmers can primarily automate the processes of feeding and watering animals, as well as production processes, such as automatic egg collection or milking cows. AI-based systems in livestock farming, just like in crop cultivation, enhance overall resource use efficiency. Equally important, farmers can manage the care of livestock far more effectively. With the help of biometric identification technology adapted for agricultural purposes – originally developed for human facial recognition – farmers can continuously monitor the condition of their livestock[15]. This solution enables precise observation of individual animals' health, nutrition, and behaviour. It is worth noting that the identification system is now so advanced that it can distinguish between individual animals of the same species in detail. In the case of cattle, for instance, footage from cameras integrated with a specialised system based on AI algorithms makes it possible to recognise specific animals based on their unique physical features[16]. In this way, artificial intelligence algorithms continuously collect and store data, and then manage it – enabling accurate health monitoring of each cow.

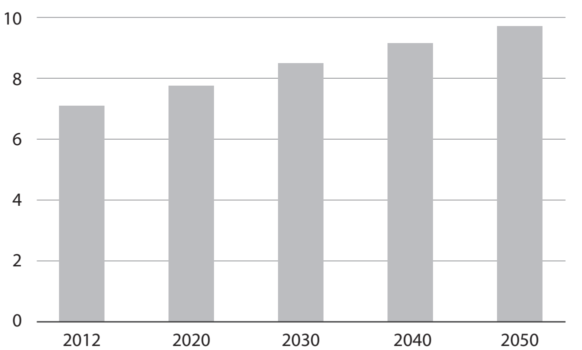
In addition to the use of cameras in livestock farming, advanced technological sensors are also widely employed to collect a range of key information. These sensors can be placed directly on the animals' skin or within the facilities where the animals are kept. An example of the first application is the precise monitoring of animals' birthing times. The second involves real-time monitoring of conditions in the livestock environment, which allows, among other things, for the early detection of potential disease outbreaks. By using machine learning and predictive models, farmers can identify anomalies at an early stage, thereby reducing risks and improving the overall welfare of their livestock[17].

15. S. Mahato, S. Neethirajan, *Integrating Artificial Intelligence in dairy farm management – biometric facial recognition for cows*, Information Processing in Agriculture, 2024.
16. Ibidem.
17. J. Pawar, R. Sonavale, Prajkta S. Sarkale, *Transforming Cattle Farming with Artificial Intelligence: Innovations, Applications, and Implications for Precision Livestock Management and Sustainable Agriculture Practices*, "Revista Electrónica de Veterinaria" 2024, Vol. 25, No. 1, p. 525.

The future of artificial intelligence in agriculture

Over time, further development of artificial intelligence in agriculture can be expected – both in terms of technological advancement and its increasingly widespread practical application. Progress in robotics, automation, biotechnology, machine learning, and data analysis will be particularly conducive to this trend. Given forecasts predicting continuous global population growth in the coming decades, a corresponding increase in overall food demand is only natural. An inevitable phenomenon, strongly correlated with global population expansion, is therefore the rise in agricultural production. Figure 2 below presents a forecast of global population growth, while Figure 3 shows the projected increase in global crop production on arable land, as prepared by the Food and Agriculture Organization of the United Nations (FAO).

Figure 2. World population projections to 2050

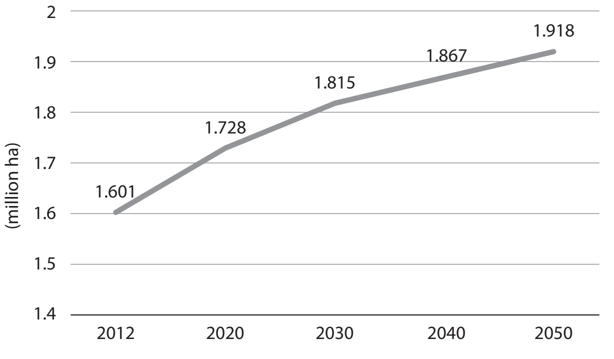


	2012	2020	2030	2040	2050
Global population (mln)	7.1	7.76	8.5	9.16	9.72

* Rounded values

Source: Food and Agriculture Organisation of the United Nations (FAO), https://www.fao.org/global-perspectives-studies/food-agriculture-projections-to-2050/en/, access 23.03.2025.

Figure 3. Forecast of global agricultural production on arable land to 2050



* Rounded values

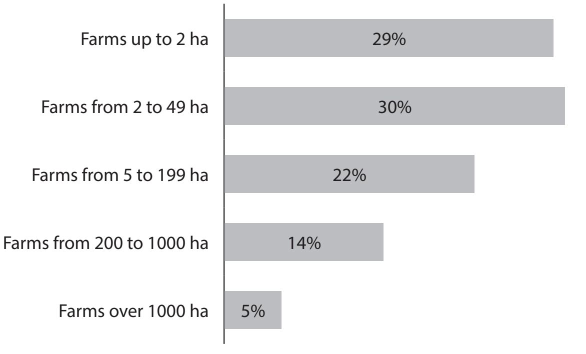
Source: Food and Agriculture Organisation of the United Nations (FAO), https://www.fao.org/global-perspectives-studies/food-agriculture-projections-to-2050/en/, access 23.03.2025.

In such circumstances, the future of agriculture will inevitably require the optimisation of agricultural production efficiency, the effective minimisation of food waste, and the best possible resource management. The development of artificial intelligence in agriculture thus appears to be imperative. With each passing year, it becomes less of a futuristic vision and more of a necessity for the advancement of this sector of the economy. It is also worth noting that data analysis over the years, and the insights it provides, will enable better decision-making regarding the structure and composition of crops, as well as livestock production. The ongoing digital transformation of agriculture will therefore be key to optimising agricultural output and, consequently, ensuring food security for the entire global population.

Challenges of artificial intelligence in agriculture

A key challenge associated with the use of artificial intelligence in agriculture is its large-scale implementation. One of the main obstacles is the high investment cost, which can pose a barrier to both the adoption and maintenance of such solutions for farmers operating small-scale farms. Depending on the country, the definition of a "small farm" may vary. However, it is commonly accepted that small farms are those with less than 1 ha, 2 ha, or 5 ha of agricultural land[18]. According to statistics from 2018, as many as 84% of the world's 570 million farms had an area of less than 2 hectares[19]. These farms were responsible for as much as 29% of global crop production intended for food, animal feed, and fuel[20].

Figure 4. Share of global crop production for food, animal feed and fuel by farm size in 2018



Source: Statista based on data from Our World Data, https://www.statista.com/chart/25902/share-of-global-crop-production-by-farm-size/, accessed 23.03.2025.

In such circumstances, it would be worth considering the development of financial or technological support models for small farms, for instance through grants, subsidies, or technology-sharing programmes. Without such measures, it is highly likely that the productivity gap between small farms (up to 2 ha) and larger agricultural holdings will continue to widen. Another significant challenge is digital exclusion, which affects many farmers – particularly in regions where access to the internet or the devices required to implement modern agricultural technologies is limited or non-existent. The digital divide between farmers may thus contribute further to the inequality between small and large farms. The lack of digital competence therefore represents a major obstacle to the effective use of AI-based technologies.

One of the risks associated with the use of AI systems in agriculture is the potential for serious operational downtime in the event of software failure. While automated agricultural solutions can naturally increase productivity, each failure can

18. Dudzińska M., Kocur-Bera K., *Definicja Małego Gospodarstwa Rolnego*, "Infrastruktura i Ekologia Terenów Wiejskich" 2013, No. 1/IV, p. 22.
19. World Economic Forum, https://www.weforum.org/stories/2021/10/fuel-food-work-world-farms-agriculture/, access 23.03.2025.
20. Statista, https://www.statista.com/chart/25902/share-of-global-crop-production-by-farm-size/, access 23.03.2025.

lead to significant interruptions in production. It seems essential, therefore, to provide training for farmers on the use of artificial intelligence in agricultural production.

Conclusion

Artificial intelligence has undoubtedly already become one of the key elements of modern agriculture – enabling not only increased production efficiency but also improved crop quality, animal welfare, and optimal resource management. The technological potential in agriculture is immense; however, to fully harness it, appropriate investments are essential – both in tools and infrastructure, as well as in farmer education in this area. There is no doubt that in the coming years we can expect further development of technologies that support agriculture. Accordingly, it will be important to implement these solutions responsibly, so that, wherever possible, farms of all sizes and every farmer can benefit from them. By supporting farmers' key decisions and automating processes, artificial intelligence can genuinely contribute to making agriculture around the world more sustainable. It is therefore beyond doubt that artificial intelligence is finding increasingly frequent and widespread application in both crop and livestock production.

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