ARTIFICIAL INTELLIGENCE IN AGRICULTURE, THE BASIS OF SUSTAINABLE MANAGEMENT

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Abstract: *This paper is an analysis of the potential that AI must revolutionize the way farmers operate and manage their farms. Artificial intelligence (AI) has become a key factor in transforming modern industries, and Romanian agriculture is no exception. In Romania, a country where agriculture accounts for 4.5% of the gross domestic product (GDP), agriculture is transforming dramatically thanks to advanced technologies. In the context of climate change, population growth, resource scarcity and declining soil fertility, innovations brought by artificial intelligence in agriculture are essential to solving many of the challenges. AI has a broad spectrum, from optimizing production processes and reducing waste, to crops monitoring and management and improving yields. However, the adoption of these technologies depends on investments in infrastructure, farmer education and support from authorities. If implemented correctly, AI can ensure a sustainable and prosperous future for Romanian agriculture. This research shows that AI will continue to play an increasingly significant role in agriculture in the future, contributing to the development of sustainable solutions that will support farmers in the current challenges, but also can help farmers to obtain and market agricultural products, by adding value in a competitive market. More than that, the wider integration of AI will enable more efficient land and resource management, reduce negative environmental impacts, and ensure a more sustainable global food system. However, research shows that the real risk farmers face is losing control over their own data and knowledge, thus becoming dependent on AI, for which they must pay dearly.*

Key words*: precision, farm efficiency, work optimization, resources.*

INTRODUCTION

Agriculture makes extensive use of artificial intelligence, which is defined as systems that can carry out tasks that normally need human intelligence. As a result, incorporating AI into agricultural operations is a revolutionary step toward utilizing the newest technology that may offer farmers priceless assistance in addition to cutting-edge hybrids and creative crop protection solutions for Romania's cutting-edge agriculture. Decision-making procedures that are faster, more accurate, more analytical, and multitasking than human capacities are made possible by technology.

Particularly, artificial intelligence is a field of inquiry within computer science that focuses on the creation of systems capable of performing tasks conventionally associated with human intellect. This includes, but is not limited to, cognitive functions such as learning, reasoning, problem-solving, perception, and the comprehension of natural language [1,10]. A foundational principle distinguishing AI from traditional computing is its capacity to learn and adapt through exposure to extensive datasets, thereby identifying patterns and relationships that would elude human analysis. From a definitional standpoint, AI is classified into three categories based on its intellectual capacity. Narrow AI, or weak AI, is the only type of AI that has been realized to date. It is engineered to execute a single, highly specific task. Examples of this include virtual assistants, facial recognition software, and recommendation engines [14]. The other two categories remain theoretical. General AI, or strong AI, is a hypothetical form of AI that would possess cognitive abilities akin to

a human, capable of learning and applying its intelligence to solve any problem. The most advanced, and speculative, form is Super AI, a conceptual intelligence that would surpass human intellect across all domains, including creative and problem-solving capacities. The applications of AI are increasingly pervasive, influencing a wide range of industries [9]. The modern meaning of artificial intelligence extends far beyond its initial conceptualization as a field of study. Today, AI is an encompassing term for a set of technologies that enable computers and systems to perform tasks that were once exclusively the domain of human intellect. This includes the ability to reason, learn, make decisions, and create under unpredictable circumstances and without continuous human supervision. The current state of AI is defined by its rapid integration into nearly every aspect of business and daily life, driven by significant advancements in subfields such as machine learning [13].

AI and agriculture have a basic relationship that offers revolutionary ways to solve problems, boost productivity, and advance precision farming. AI-guided automation, for instance, optimizes processes like harvesting, applying biological or crop protection agents, and precision sowing [8]. The development of artificial intelligence in agriculture has evolved from simple data processing to sophisticated, real-time decision-making systems that are transforming every aspect of farming. This evolution has been driven by advancements in computing power, sensor technology, and the availability of large datasets [5,6]. The initial applications of AI in agriculture were based on expert systems. These were early computer programs that used a set of predefined rules and knowledge bases to mimic the decision-making of human agricultural experts. For example, a system could analyze soil type, rainfall, and historical yields to recommend specific crop varieties or fertilizer applications. While these systems were a significant step forward, they were limited by their rigid, rule-based nature and could not adapt to unforeseen variables [12]. Predictive analytics capabilities of AI also help with productivity forecasting and weather forecasting. AI in agriculture will be important in the future since it will support resilient and sustainable methods. AI is increasing productivity, cutting waste, and fostering innovation in agricultural methods as the world's population rises and climate change presents difficulties [7]. The agriculture industry is under tremendous pressure to boost output and optimize yields due to the world's population expansion, which is predicted to reach 10 billion people by 2050. In this context, there are two potential strategies to prevent a food crisis: increasing land use and implementing large-scale agriculture, or utilizing creative methods and utilizing technology to boost output on already-existing farms.

AI can monitor weather, provide information on soil quality, and suggest specific herbicides and fertilizers. Decision-making in the agricultural sector is based on visual evaluation. Farmers of all ages, education levels, and experience levels carry out thousands of jobs and make judgments at every point of the food value chain, mostly based on visual inspection [4]. These decisions and acts can vary widely in quality and accuracy and have actual economic repercussions. In response, industry innovators adopt a strategy, utilizing drones or satellite imaging, adding more sensors, increasing automation, and adding more field data. As a result, farmers now have access to more agronomic data than they did in the past [11]. It is crucial for farmers to be receptive to adopting new technologies, learning how to use data, and utilizing data to inform their decision-making process because it is not always simple to utilize the available data and interpret it accurately. Although AI has significantly changed agriculture, it is important to note the following: AI is meant to support farmers, not to replace them. If the farmer correctly analyzes the results, artificial intelligence can improve decision-making, but it cannot fully replace human expertise [15]. Today, the development of AI in agriculture is focused on robotics,

automation, and the seamless integration of various technologies. Autonomous farming equipment, such as self-driving tractors and robotic harvesters, are becoming more common. These machines use AI to navigate fields, plant seeds with precision, and even identify and remove weeds, significantly reducing manual labor and increasing efficiency. Furthermore, AI is being integrated into the entire agricultural supply chain, from seed selection to distribution. AI platforms can help farmers choose the most suitable crops for their specific land and climate, optimize logistics to ensure fresh produce reaches markets on time, and analyze consumer demand to guide production. The future of AI in agriculture is also moving towards the democratization of technology, with mobile apps and user-friendly platforms making advanced AI tools accessible even to small-scale farmers in developing regions [3].

Real issues in agriculture cannot be solved with a prefabricated kit; instead, they require rigorous analysis with adequate quantities of high-quality data, augmented by human skill. Understanding the scope and nature of the issues that need to be resolved, whether they be financial or technical, requires going out into the field to gather input from farmers. Experience in the industry has shown that a strong emphasis on artificial intelligence is the way to go, both for acquiring and selling agricultural products and for generating value in a cutthroat market [2].

MATERIALS AND METHODS

As part of this research, data provided by the European Commission and the Ministry of Agriculture of Romania were analyzed and processed. This study employs a comprehensive research methodology to analyze the application of artificial intelligence in Romanian agriculture, focusing on its potential for sustainable management. The research is conducted within the specific context of Romanian agribusiness, where agriculture contributes significantly to the national GDP. The methodology accounts for the unique challenges and opportunities in Romania, including the digital divide, fragmented land ownership, and varied levels of technological adoption among farms.

RESEARCH RESULTS

To monitor the entire supply chain, understand soil quality, manage agricultural processes, and gather crucial production statistics, organizations in the agricultural sector require data. Farmers can handle data more quickly by utilizing artificial intelligence in agriculture. In addition, AI can forecast prices, analyze market demand, performing predictive analytics, and figuring out the best times to plant and harvest. Another advantage of applying AI to agriculture is cost savings. Precision farming, when paired with artificial intelligence, can help farmers produce more crops with less. AI maximizes crop yields while cutting costs by combining the most effective data management techniques with the greatest soil management techniques. AI applications in agriculture give farmers access to real-time data about the condition of their crops, enabling them to pinpoint areas in need of pesticide treatment, fertilization, or irrigation. Vertical farming is one example of an innovative agricultural technique that can boost food output while using less resources. Labor shortages are nothing new because farming is a labor-intensive industry. However, automation is a solution that eliminates the need for more staffing. A few examples of automated agricultural equipment include driverless tractors, smart irrigation, fertilization systems, agricultural drones, smart spraying, software for vertical farming, and greenhouse harvesting robots. AI-based tools are more accurate and efficient than a human worker. Regarding the application of artificial intelligence in agriculture that may be mentioned is optimizing automated irrigation systems. Autonomous crop

management is made possible by AI systems. The algorithms can determine how much water to give crops in real time when paired with sensors that track weather and soil moisture levels. Regarding the detection of leaks or damage to irrigation systems, patterns and irregularities that point to possible leaks can be found using AI algorithms. It is possible to utilize machine learning models that have been trained to identify leak signatures, like variations in water pressure and flow.

Real-time data on evapotranspiration and relative humidity can be gathered thanks to modern technology, which also makes it possible to create precise predictions of future weather patterns and put warning systems in place. By concentrating primarily on the crops and plots that require water, farmers can maximize their use of it. Artificial intelligence algorithms, on the one hand, find hybrids and varieties that are more resilient to pests, illnesses, and drought as well as extreme temperatures. Early detection is made possible by real-time monitoring and analysis, which helps to avoid water waste and possible crop damage. To pinpoint regions with excessive water use, AI also integrates weather data and agricultural water requirements. AI technology helps farms save resources by improving water use efficiency through automated leak identification and notifications. Crop health and growth can be significantly impacted by an improper nutrient mix in the soil. However, AI can recognize these nutrients and ascertain how they affect crop productivity, making it simple for farmers to make the required modifications. The accuracy of human observation is restricted, but computerized monitoring models can collect precise data by tracking the soil.

In agriculture, artificial intelligence can be used to identify illnesses or pests. AI specifically uses picture scanning to find insects, rot, mold, and other pests. Farmers can take prompt action to eradicate pests or isolate crops to stop the spread of illnesses by integrating alert and intelligent systems. Insects like flies, bees, and moths can also be identified by AI with comparable precision. In the past, scientists gathered pictures of different insect species and utilized them to train clever programs to identify them.

Remote animal health monitoring is also possible with artificial intelligence. The system recognizes events like calving, the effects of feed and environmental factors on the animals, and abnormal animal behavior. With all this knowledge, farmers can enhance the health of their cattle and boost milk production.

Drones with artificial intelligence employ computer vision to calculate how much insecticide should be sprayed in each location. Yield mapping analyzes massive data sets in real time using algorithms. This facilitates improved planning by assisting farmers in comprehending the trends and traits of their crops. To help farmers determine where and when to plant seeds as well as where to deploy resources for the highest return on investment, techniques like 3D mapping and data from sensors and drones provide forecasts about future yields for certain crops.

In agriculture, invasive plant species and weeds can be identified with artificial intelligence. Computer vision uses the size, shape, and color of leaves in conjunction with machine learning to differentiate crops from weeds.

AI systems can also be used to sort crops according to their size, color, and shape, so farmers can swiftly classify their goods and offer it to various clients at varying costs because to this. Sorting by hand, on the other hand, can be very time-consuming.

Despite the advantages, there are still difficulties, concerning the lack of knowledge and resources: It is possible that many farmers are unaware of the possible advantages of digitalization and lack the knowledge and resources necessary to employ new technology; digital divides- one of the main causes of the "digital divide" among farmers is the fact that many rural areas still lack access to dependable and reasonably priced internet, which makes it difficult for them to adopt digital technology; lack of cost-effectiveness- some

digital technologies may be more expensive to use than they could be advantageous, particularly for small farms; need for trust in data sharing is another difficulty, it concerns about data privacy and ownership among farmers may hinder data sharing between different actors in the agricultural sector; interoperability deficiencies: lack of interoperability between different systems, as many digital applications or machines from different brands may not be compatible, making data exchange and data integration difficult. The percentage of Romanian agricultural businesses with more than ten workers that have implemented at least one AI technology is only 1.5%, which is much lower than the EU average. Many agricultural businesses believe AI is quite costly, with license and support fees accounting for a portion of the total cost. This idea deters investment, particularly from farmers, who may not always have the funds to support such projects. Adoption efforts are further complicated by the dearth of skilled experts with artificial intelligence skills, as businesses struggle to hire or train staff members with the requisite knowledge.

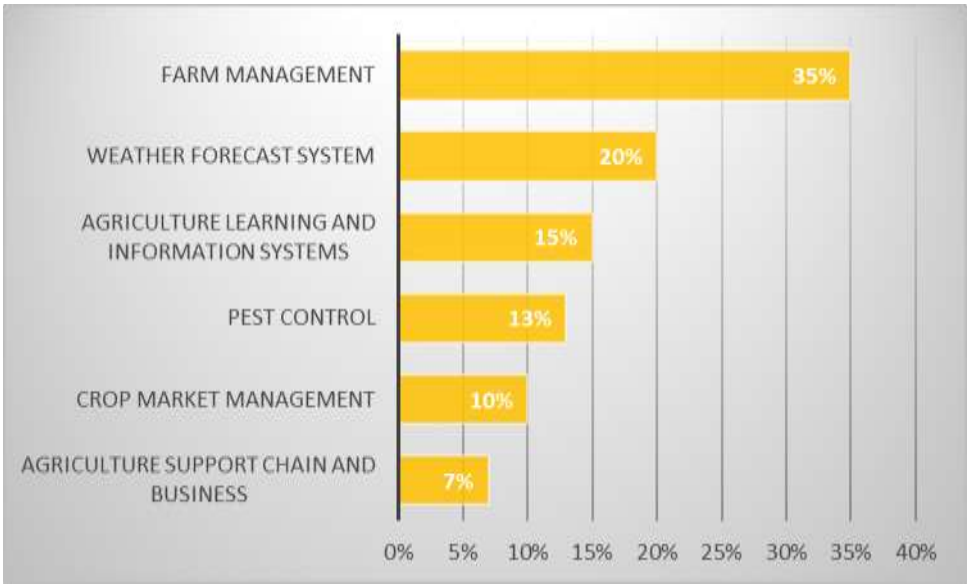

Figure 1. Use of AI in Precision Agriculture in Romania

One noteworthy feature of these technological revolutions is IA's ability to maximize agricultural productivity through the analysis of geographical data. Advanced sensors and satellite imagery enable farmers to identify crop conditions and forecast harvests, thereby minimizing their environmental impact. Furthermore, financial institutions are increasingly using investment risk analysis as a key instrument to evaluate the risks of lending to farmers using prediction models.

However, there are significant concerns over farmers' control over their own data due to the volume of publicly available data and the dependence on AI systems. Although technology promises more efficient and sustainable farming, farmers must be careful when navigating this environment to avoid becoming passive recipients of advice based on their own knowledge and instead continue to actively influence agriculture's future. Another major obstacle is organizational culture resistance to change. Because they are afraid of the unknown or worry about losing their jobs, agricultural workers may be hesitant to embrace new technologies.

CONCLUSIONS

There are hazards and difficulties associated with integrating AI into agriculture. Agriculture could benefit greatly from artificial intelligence, but there are also serious concerns. We need cooperation and sensible legislation that guarantees AI's advantages and guards against its drawbacks if we are to use it sensibly and morally. To comprehend and adjust to the effects of AI on our lives and society, we also require awareness and continual education. The quality of crop productivity, animal health, and—most importantly - farmers' quality of life will all be enhanced by artificial intelligence. Nevertheless, the industry faces numerous difficulties because of the lack of funding. To increase their capacity to produce things more effectively, Romanian farmers need training in artificial intelligence techniques in addition to funding for the acquisition of machinery and other equipment. While the public can freely utilize some AI apps (at least basic versions), developing robotics, software, and AI applications takes a significant amount of time and money. For AI algorithms to remain current, function at their best, and satisfy all requirements, they must be able to run on the newest hardware and software systems. Therefore, for an agricultural organization interested in implementing AI, an application can be highly costly.

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