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Agriculture and Artificial Intelligence: Unlocking a Sustainable Future

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Farming methods are being revolutionised by the application of artificial intelligence (AI), which provides creative answers to urgent problems like resource optimisation, food security, and climate resilience. AI technologies maximise crop yields, reduce environmental effects, and support sustainable farming practices, all of which increase efficiency and productivity. Despite obstacles including high upfront costs and technological hurdles, AI has the potential to revolutionise the food system by promoting climate-smart practices, enhancing decision-making, and promoting a more sustainable food system. This review covers the current state, future possibilities, and consequences of AI in agriculture, highlighting its role in building a sustainable future for global food supply.

Introduction

Artificial Intelligence (AI) is revolutionising agriculture by changing how we grow, care for, and maintain our crops. The need for sustainable and effective food production is greater than ever as the world's population continues to rise. AI increases productivity, decreases waste, and encourages eco-friendly behaviour, it presents a possible option. The word artificial intelligence was first used by John McCarthy at the Dartmouth Conference, but numerous experiments and research had already been conducted in the subject before the term was created. Many fields had seen a great deal of upheaval since the day they discovered it (McCarthy, 2006).

Several studies have been conducted in this area right now to determine how artificial intelligence might be used to enhance agriculture. A pilot study using AI to forecast weather and test soil moisture in Maharashtra, Madhya Pradesh, and Gujarat is being conducted by the Government of India in partnership with IBM. The government of several other countries has also offered assistance to farmers in implementing AI in farming (Mohamed et al., 2021). Many nations have used artificial intelligence in agriculture for a variety of purposes, with the best results from their implementations. Artificial intelligence makes it easier to forecast the weather, monitor the soil, lessen bug infestation, use fewer pesticides in the field, and more (Talaviya et al., 2020). The technologies found in

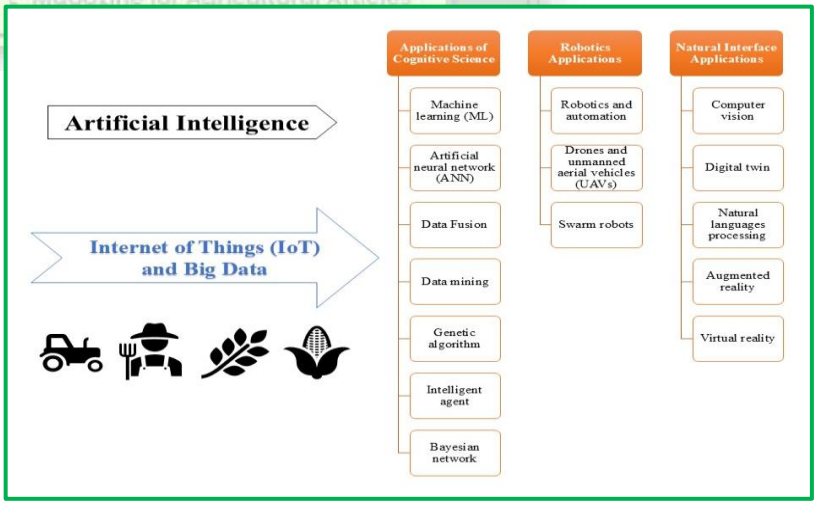

Figure 1: Descriptive analysis identified AI technologies

the previous researches under analysis are depicted in Figure 1. IoT, big data, and cloud computing technologies help apply particular AI approaches such computer vision, robotics, machine learning, augmented reality, and virtual reality.

Key Applications of AI in Agriculture

- **Crop and Soil Management:** AI systems track crop health, identify early disease symptoms, and forecast yields using data from drones, cameras, and satellite photography. This makes it possible to allocate resources optimally and to intervene promptly. In order to predict yields accurately and make well-informed decisions on planting, watering, and harvesting, machine learning algorithms examine past data, weather trends, and present crop conditions. By using AI algorithms to evaluate soil samples, nutrient inadequacies can be found, allowing for more efficient fertiliser application and less waste. In order to ensure effective water utilisation, AI-driven systems analyse crop demands, climate, and soil moisture levels to optimise irrigation. Using IoT sensors, AI determines the moisture content and nutrient composition of the soil, allowing for accurate fertiliser delivery and irrigation scheduling. Crop yields are predicted by predictive models that include historical trends, satellite photography, and weather data.
- **Disease and Pest Control:** Early detection of pests and diseases by AI-powered picture recognition technology enables preventative actions to stop crop damage and yield loss. Targeted fertiliser and pesticide application is made possible by AI-driven systems, which lowers chemical consumption and its negative effects on the environment. By using drone-captured imagery to identify crop illnesses and pests, deep learning algorithms (such as YOLOv8 and Mask R-CNN) have been shown to reduce pesticide use by 25% in experiments. Convolutional neural networks (CNNs) are used in AI-driven "smart spraying" to target weeds and reduce chemical runoff.
- **Precision Irrigation and Resource Optimization:** Automated devices, such as soil moisture sensors based on Arduino, maximise water use, reducing it by 20% to 30% while preserving harvests. IoT networks with AI enhancements continuously monitor microclimates and dynamically modify irrigation. By combining AI with robotics and drones, processes like harvesting, pruning, and weeding may be automated, saving labour costs and increasing productivity. Artificial intelligence (AI) evaluates enormous volumes of data to offer insights on the best practices for fertilisation, irrigation, and planting, reducing waste and increasing output.
- **Harvesting and Supply Chain Efficiency:** Computer vision-enabled AI-powered robots can recognise ripe crops, automate harvesting, and save human costs. Robots have been created by companies like as Blue River Technology to do duties like weeding and thinning. AI-powered solutions can cut harvesting times by up to 80%, lowering the dangers associated with physical labour and enhancing safety. AI uses robotic devices to automate picking and forecast the best times for harvest. By optimising logistics, machine learning lowers overproduction and post-harvest losses.

Benefits of AI in Agriculture

AI technologies improve farming efficiency across the board and assist the public and private sectors in addressing problems. In the agricultural sector, it aids in the establishment of crops, their monitoring and administration, field weed control, plant watering, and figuring out the composition of the soil for efficient planting. Now, farmers can ensure greater yields with less investment thanks to AI-based technologies. These technologies analyse the market to ensure farmers receive the best price for their produce. Over the next few years, farmers will use 75 million connected agricultural devices. By 2050, millions more people will profit. There are numerous ways in which agricultural artificial intelligence could enhance agriculture (Talaviya et al., 2020).

- **Increased Efficiency and Productivity:** By automating monotonous processes like crop monitoring and predictive analytics, artificial intelligence frees up farmers to concentrate

on making strategic decisions. Higher yields and greater crop quality are the results of precision farming techniques, which maximise the use of resources like water, fertiliser, and pesticides.

- **Predictive Analytics and Decision Making:** AI algorithms forecast crop yields and possible problems like pest outbreaks or market swings by analysing historical data, weather trends, and soil conditions. This makes it possible for farmers to allocate resources, plant, and harvest with knowledge.
- **Sustainability and Environmental Impact:** AI-powered systems minimise environmental harm by using fewer chemicals and performing targeted remedies. Water conservation and soil health are enhanced by efficient resource management and precision irrigation.
- **Cost Reduction and Economic Viability:** Automation increases operational efficiency and lowers labour costs, increasing the economic viability of agriculture. Predictive analytics powered by AI assists farmers in improving supply chain management and minimising possible losses.

Challenges and Limitations

AI has a lot to offer the agricultural industry, but adoption is hampered by a number of obstacles and restrictions. To successfully overcome these obstacles and guarantee the proper integration of AI in agricultural practices, it is imperative to comprehend these problems. For small-scale farmers or those with limited finances, the significant upfront investments in hardware, software, and infrastructure required to implement AI technology may be prohibitive (Mohan *et al*., 2023). Since AI systems produce important, often sensitive data, it is imperative that problems pertaining to data ownership and use be addressed through clear agreements. Many farmers lack technical knowledge in data science and machine learning, which is necessary for using AI. The shift from conventional procedures to AI-powered techniques can be difficult and calls for patient assistance and education. It can take a lot of time and careful planning to implement AI because it calls for changes to workflows, data management, and decision-making procedures. Although AI can improve resource use and lessen its influence on the environment, there are worries about possible over-reliance on chemical inputs and adverse ecosystem repercussions (Purushotham *et al*., 2024).

Conclusion

Precision farming will be further improved by cutting-edge sensors, drones, and satellite photography, which will offer unmatched insights into crop conditions and soil health. Through reducing human expenses and streamlining processes, AI-driven autonomous farming systems promise more output and a less environmental effect. Via anticipating climate-related issues and optimising water use, artificial intelligence will be essential to climate change adaptation. In order to ensure food security and sustainability, generative AI will speed up crop breeding procedures, optimise farm designs, and model the effects of the environment on crop yields.

Furthermore, in order to satisfy the demands of food production in the future while maintaining sustainability, the use of AI in agriculture is not merely a trend but a requirement. Artificial intelligence (AI) will become more and more important in determining the direction of agriculture in the future by providing effective and ecologically friendly solutions.

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