Applications of Artificial Intelligence (AI) in the field of agriculture: A Review

Abstract

Artificial Intelligence (AI) has emerged as a crucial instrument in the agriculture industry, with the opportunity to transform conventional farming methods and tackle issues such as climate change and population increase. Artificial intelligence (AI) technologies are used throughout the entire agricultural industry, starting with planning which crops to grow to the last stages of harvesting and distributing the produce. Machine learning algorithms process extensive agricultural data, empowering farmers to make decisions based on data and optimise the allocation of resources. The implementation of artificial intelligence (AI) in robotics and automation has significantly transformed operations that need a lot of manual labour, resulting in lower operational expenses and increased efficiency. Artificial intelligence (AI) powered predictive analytics technologies empower farmers to forecast market trends, enhance supply chain management, and manage risks related to price volatility and demand changes. Nevertheless, it is crucial to give considerable thought to challenges such as data privacy, interoperability, and algorithmic bias. The disparity in access to digital resources between rural and urban communities also creates obstacles to the adoption of technology, underscoring the importance of focused investment in infrastructure and skill development. AI technology can transform agriculture by promoting sustainable practices, improving productivity, and guaranteeing food security for future generations.

Keywords: AI, agriculture, challenges and limitations

1. Introduction

In the current era of digital technology, humans have advanced their thinking to unprecedented levels to create several forms of artificial intelligence, which will significantly boost any system's operational efficiency(Das et al. 2024). Artificial intelligence (AI), a rapidly evolving technology, is poised to revolutionize sectors like healthcare and finance by imitating human cognitive processes like learning and reasoning (Shmelova, et al., 2023). AI enhances

efficiency and precision in processes by automating tasks traditionally requiring human intelligence, with its applications and societal influence expected to rapidly grow (Eugene et al., 2022). In everyday life, AI has started to play a major role, expanding our perceptions and ability to alter the world around us(Naresh et al. 2020; Adamu, 2024). AI is increasingly being used in agriculture to enhance productivity, and plant health, and mechanize activities like irrigation and harvesting. This not only improves efficiency but also promotes sustainable farming by minimizing waste and environmental harm. The integration of AI in agriculture can address food security issues and provide a more reliable and robust food supply chain for the future (Abid et al., 2023). AI's continuous advancement in technology has vast potential applications in agriculture, as it can gather and analyze vast amounts of data, revolutionizing decision-making and operational management of farms (Tawseef et al., 2022). AI's continuous advancement in technology has vast potential applications in agriculture, as it can gather and analyze vast amounts of data, revolutionizing decision-making and operational management of farms (Misra et al., 2020).

2. Current Applications of AI in Agriculture

AI is being utilized in agriculture for precision farming, crop monitoring, and automated harvesting, enhancing fertilization practices and improving resource utilization, leading to increased crop yields (Tawseef et al., 2022). AI-enabled drones are used in agriculture for field surveillance, intervention identification, and pesticide reduction, demonstrating significant potential in enhancing sustainability and productivity, thereby reducing pesticide usage (Alexander et al., 2024). The implementation of automated machinery and robots in agriculture has resulted in enhanced efficiency and decreased labour expenses, empowering farmers to make well-informed choices in crop management. The progress of artificial intelligence (AI) in agriculture is anticipated to improve sustainability and production significantly, hence facilitating future innovations in the industry (Gretchen et al., 2008). Drones and satellite photography are crucial tools for farmers, providing real-time data on crop health and enabling precise actions to maximize production.

These technologies help detect pest invasions and nutrient deficiencies, resulting in more accurate resource allocation. This technology is fundamentally transforming farming methods and paving the way for a more environmentally friendly and efficient future in the industry

(Sérgio & Pedro, 2021). Predictive analytics is a crucial aspect of agricultural technology that enhances crop yields and optimizes resource management. It allows farmers to make informed decisions about planting, harvesting, and fertilizer application, thereby optimizing productivity and preventing environmental damage (Lan et al., 2017). Predictive analytics aids farmers in optimizing resource management, including water usage, ensuring sustainable utilization, thereby improving economic well-being and promoting the overall sustainability of agriculture (Sachin et al., 2020).

POTENTIAL OF AI IN AGRICULTURE

The Indian agricultural industry is set to undergo a significant transformation with the implementation of IoT technology. Artificial intelligence can help farmers monitor crop health, optimize irrigation systems, and enhance output. This technology can also aid in informed decision-making, leading to increased crop yields and sustainable farming practices. This could revolutionize traditional farming practices and help India become a global leader in agriculture (Showkat & Nen-Fu, 2021). IoT is transforming agriculture by providing farmers with real-time insights through images. Drones and satellite imaging enable farmers to monitor crop health and pest presence, enabling them to implement preemptive strategies (Figure 1). This technology also helps identify areas for improvement and streamlines farming processes, thereby enhancing Indian farmers' production and profitability in a sustainable manner (Ali et al., 2021). Computer Vision is a vital tool in agriculture, enabling farmers to quickly identify crop health issues, track growth patterns, and detect irregularities. This technology aids in making informed decisions and optimizing crop management practices for optimal production and sustainability. By incorporating computer vision technology, Indian farmers can proactively address challenges and foster innovation in their agricultural practices, ultimately enhancing their productivity and sustainability (Dhanya et al., 2022).

Indian farmers can use computer vision technology to identify the best agricultural inputs for their crops, considering factors like soil composition, meteorological conditions, and crop variety. This data-driven strategy can optimize resources, enhance input efficiency, and increase agricultural yields and profitability. By analyzing agronomic products, farmers can make informed decisions, leading to sustainable and prosperous farming methods (Arpit et al., 2020). Crop health monitoring systems can significantly benefit Indian farmers by providing real-time

information on moisture levels, nutrition levels, and pest infestations. These systems, using sensors and satellite imaging, enable farmers to identify and address issues affecting their crops, leading to stronger plants and increased yields. By integrating this data with their understanding of agronomic goods, farmers can improve their crop management plans, ultimately achieving greater success in sustainable and profitable agriculture (Kumar et al., 2022).

Figure: 1 Artificial intelligence (AI) applications in the agricultural sector

Smart irrigation systems use sensors and meteorological data to regulate water consumption for farmers. They prevent excessive irrigation, water waste, and soil erosion, and ensure adequate moisture for crops. This not only conserves water and reduces costs but also encourages environmentally friendly farming methods. When combined with other monitoring systems, smart irrigation can significantly improve the success and profitability of Indian farmers (Felix & Geophrey 2022). Smart irrigation systems help farmers manage and reduce risks from weather patterns and climate change by providing up-to-date information on soil moisture levels and meteorological conditions. This proactive approach can lead to increased crop production and improved economic security for Indian farmers. The use of smart irrigation technology is

crucial for ensuring the durability and sustainability of the agricultural industry in response to environmental challenges (Dongwei et al., 2023).

3. Challenges and Limitations of AI in Agriculture

AI in agriculture offers numerous benefits, but farmers must also consider its limitations, particularly the high initial investment required, which may be too costly for many farms to fully utilize it (Showkat & Nen-Fu, 2021). Farmers unfamiliar with advanced technology may face a learning curve, hindering its widespread adoption. Additionally, data privacy and security concerns arise, as confidential information about crop yields and farming methods may be compromised (Emma et al., 2019). AI has the potential to revolutionize agriculture, but it still faces challenges that need to be addressed for widespread adoption by the farming community (Alesandros et al., 2021). The successful adoption of AI in agriculture necessitates careful management of data privacy and security concerns, which pose a significant challenge. Farmers need assurance that their data is protected against cyber attacks. Collaboration with cyber security specialists and strong privacy protections are crucial to ensure farmers' trust and fully utilize AI technology for enhanced production and sustainability (Williamson 2021).

AI technologies can be costly for farmers, but they may be more willing to invest if they offer long-term cost savings and improved operational efficiency. Government subsidies and grants can help reduce initial costs and facilitate AI adoption in agricultural operations. By addressing financial and cyber security issues, AI can transform operations and contribute to a more environmentally friendly future in the agriculture industry (Tittonell 2012). The lack of technical proficiency among farmers can hinder the use of AI technology. To overcome this, training and assistance in understanding AI solutions can be provided. Collaborations with technology firms and research institutions can provide the necessary knowledge and resources for farmers to effectively incorporate AI into their activities. This approach promotes the widespread implementation of AI in agriculture, benefiting both farmers and the environment (Abid et al., 2022).

Limitations of AI in Agriculture

1. The impact of AI limitations on crop yield and quality in agriculture

AI limitations in agriculture can significantly affect crop yield and quality. Inadequate training or calibration can lead to inaccurate pest detection, resulting in reduced yields. AI also struggles to adapt to changing environmental conditions and new threats, affecting crop quality. Therefore, it's crucial for farmers and researchers to continuously monitor and improve AI systems to ensure their effectiveness in supporting agricultural practices (Murilo et al., 2021)

2. Challenges faced by farmers when relying on AI technology for decision-making in farming practices.

Farmers encounter several problems when depending on AI technology for decision-making in farming techniques, including the upfront expenses of deploying and sustaining the technology, as well as the requirement for specific training to proficiently employ it. Furthermore, there can be apprehensions regarding data privacy and security, given that AI systems depend on substantial quantities of sensitive information for their correct functioning. Farmers may encounter difficulties in incorporating AI technology into their current farming methods and processes, necessitating a significant investment of time and effort to ensure a smooth transition. Notwithstanding these obstacles, the advantages of employing AI in agriculture, such as heightened efficiency and output, justify the expenditure for numerous farmers (Sachin et al., 2020).

3. Potential risks associated with the use of AI in agricultural operations, such as data privacy concerns or cyber threats

Nevertheless, with the ongoing progress of technology, farmers must remain watchful in safeguarding their data and fortifying their systems against possible dangers. Through the implementation of robust cyber security measures and maintaining awareness of industry best practices, farmers can effectively reduce the dangers associated with utilizing AI in their operations. In the end, the benefits of enhanced efficiency and productivity provided by AI can surpass the difficulties, rendering it a significant asset for contemporary agriculture (Michele & Vidya Sagar 2023).

4. How advancements in AI technology could potentially address current limitations in the agriculture industry

The progress in AI technology can overcome existing constraints in the agriculture sector by equipping farmers with up-to-the-minute data and valuable insights to enhance their decision-making process. This can assist farmers in optimizing the allocation of resources, enhancing crop yields, and minimizing waste. In addition, AI-driven solutions can assist farmers in accurately forecasting and handling weather patterns, pests, and illnesses, ultimately resulting in more sustainable and lucrative farming methods. In summary, adopting AI technology in agriculture has the potential to completely transform the methods employed by farmers and result in a more productive and adaptable business (Kumar et al., 2022).

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5. Strategies for integrating human expertise with AI tools to maximize productivity and sustainability in farming practices

An effective approach to combining human experience with AI tools is offering training and education to farmers on the optimal utilization of these technologies. By integrating the expertise and practical know-how of farmers with the data-driven insights facilitated by AI, farmers may enhance their decision-making process and amplify their productivity. Engaging in collaboration with AI professionals and researchers may assist farmers in remaining informed about the latest technological breakthroughs and guaranteeing the utilization of the most efficient instruments tailored to their individual agricultural requirements. Through collaborative efforts, humans and AI can establish a symbiotic alliance that optimizes efficiency and long-term viability in agricultural operations (Subeesh et al., 2021).

4. Future Trends in AI Agriculture

Future trends in AI agriculture involve the advancement of increasingly sophisticated AI algorithms capable of analyzing data with greater efficiency and accuracy. Additionally, AI will be integrated with other technologies like drones and sensors to further improve precision farming methods (Saqib et al., 2022). With the ongoing advancement and enhancement of AI, there is significant potential for it to completely transform the methods of farming, resulting in higher levels of productivity, sustainability, and profitability for farmers globally. To remain up-to-date and adjust to these developing patterns, farmers may proactively anticipate and optimize the advantages of AI technology in agriculture (Gretchen et al., 2008). The future of farming will

be significantly influenced by the integration of Artificial Intelligence (AI) with Internet of Things (IoT) devices. Through the integration of artificial intelligence (AI) systems with Internet of Things (IoT) devices such as weather sensors, soil monitors, and crop health trackers, farmers can collect up-to-date data and enhance their decision-making process regarding their agricultural activities (Tanzila et al., 2022). This seamless connectivity will not only optimize farming processes but also enable farmers to proactively recognize possible issues before they worsen, ultimately resulting in increased crop yields and reduced expenses. The potential for utilizing AI and IoT in agriculture is limitless, and those who adopt these technologies early on will surely experience long-term advantages (Mohammad & Abul, 2023).

Further advancement of machine learning algorithms for crop analysis will boost the precision and effectiveness of these technologies, enabling farmers to identify precise areas of concern in their crops. Through the application of artificial intelligence (AI) and the Internet of Things (IoT) in agriculture, farmers may efficiently manage their resources and reduce inefficiencies, resulting in a more environmentally friendly and financially viable farming enterprise. With the continuous advancement of technology, the agriculture sector holds immense innovation potential. Those who are open to adapting and evolving with the changing landscape will prosper in the future (Eli-Chukwu, 2019). The implementation of AI-driven precision agriculture methods will fundamentally transform how farmers oversee their crops, resulting in higher crop yields and diminished environmental consequences. By harnessing the capability to collect up-to-the-minute information on soil quality, meteorological trends, and crop development, farmers can make well-informed choices that will positively impact their financial performance and the environment. The future of agriculture rests with people who adopt and utilize this advanced technology to establish a sustainable food system for future generations (Francisco 2020).

5. Case Studies of Successful AI Implementation in Agriculture

By utilizing AI technologies, farmers have successfully enhanced irrigation schedules, minimized the usage of detrimental pesticides, and proactively anticipated crop illnesses before they emerged as potential hazards. An exemplary instance involves a farm in California that had a significant 30% augmentation in grape yields by employing artificial intelligence to monitor soil moisture levels and adapt irrigation practices accordingly (Dhara et al., 2020). A farm in

Iowa achieved success by employing AI algorithms to scan satellite photos and detect regions with nutrient deficiencies, leading to a substantial decrease in fertilizer consumption. These examples showcase the immense capacity of AI in agriculture and provide inspiration for those seeking to enhance their farming methods (Redhu et al., 2022). A farm in Iowa achieved success by employing AI algorithms to scan satellite photos and detect regions with nutrient deficiencies, leading to a substantial decrease in fertilizer consumption. These examples showcase the immense capacity of AI in agriculture and provide inspiration for those seeking to enhance their farming methods (Showkat & Nen-Fu, 2021).

John Deere's utilization of artificial intelligence (AI) in autonomous tractors exemplifies the transformative impact of technology on the agriculture industry. These self-governing tractors possess the capability to accurately and effectively carry out tasks such as planting, fertilizing, and harvesting crops, hence decreasing the need for a human workforce and minimizing mistakes. This not only conserves farmers' time and finances but also enhances overall efficiency and crop output. These discoveries demonstrate that AI can fundamentally transform our approach to farming and food production in the future (Duckett 2018). Microsoft's Farm Beats project, which focuses on data-driven farming, is a significant advancement in the agricultural industry. Farm Beats utilizes artificial intelligence (AI) and Internet of Things (IoT) technology to enable farmers to make informed decisions based on data, leading to increased crop yields and decreased resource inefficiencies. This novel methodology enables farmers to continuously monitor soil conditions, crop vitality, and meteorological trends in real time, resulting in the adoption of more sustainable and effective agricultural techniques. The collaboration between John Deere's autonomous tractors and Microsoft's Farm Beats initiative clearly indicates that the agricultural industry is progressively moving toward automation and technological advancement (Tufail 2023)

Conclusion

Ultimately, the incorporation of artificial intelligence (AI) and Internet of Things (IoT) technologies in agriculture holds the capacity to transform the industry by enhancing efficiency, diminishing expenses, and mitigating environmental consequences. By furnishing farmers with up-to-the-minute observations and practical information, these technologies enable them to make well-informed choices that can result in increased crop production and improved utilization of

resources. With the ongoing progress in automation and digitalization, AI will certainly have a vital impact on the future of agriculture, leading to improvements. Suggested strategies for addressing obstacles in the implementation of AI encompass allocating resources to training initiatives aimed at enhancing farmers' comprehension and proficient utilization of AI tools, establishing robust data privacy and security protocols to safeguard sensitive information, and fostering partnerships with specialists in the domains of agriculture and technology to devise tailored solutions for individual farming practices. To fully leverage the potential of AI for driving innovation and sustainability, the agriculture business must directly confront these difficulties. Artificial intelligence (AI) can completely transform the way farmers handle crop management, monitor livestock, and improve overall farm productivity. By implementing effective ways to tackle obstacles like data security and training, artificial intelligence (AI) has the potential to assist farmers in making well-informed choices, optimizing resources, and enhancing crop yields. The agricultural business is poised for a promising future as artificial intelligence takes the lead in driving sustainability and productivity.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

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3.

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