A Review on AI Enhanced IoT Technologies in Transforming Modern Agriculture

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Abstract
Recent widespread use of Artificial Intelligence (AI) in fields of farm work. Agriculture is using AI technology to breed healthier crops, manage pests and fertilise grow condition; monitor soil and other management activities in the food chain for farmers to analyse data on one side of supply chain. With the help of AI algorithms and IoT-compatible devices, farmers can gain invaluable insights regarding weather, soil health, plant growth, and resource consumption and make well-substantiated data-based decisions for boosting agricultural efficiency. The present paper discusses some AI methods, including machine learning, computer vision, and natural language processing, and their integration with IoT sensors, drones, and other smart devices in agriculture. Further, the paper highlights the limitation of AI-based IoT deployment, e.g., confidentiality of data, security, and infrastructure limitations, and discusses the ways to overcome them. Lastly, the paper mentions future directions, e.g., deployment of AI to facilitate predictive analytics, autonomous agriculture, and precision agriculture, and their revolutionary worth in redefining the face of efficient and sustainable agriculture.

Keywords:
Internet of Things; Smart Agriculture; Artificial Intelligence; Crop Monitoring; Data Driven Farming

1. Introduction

AI, precision agriculture along with new technologies such as IoT helps farmers to practice 'farmer-yield' which enables them to minutely track their crops and soil status, enable targeted interventions, automate truely repetitive tasks making them efficient, and sustainable. Precision farming holds significant promise for increasing farmer incomes, enhancing both the extrinsic and intrinsic quality of agricultural products, and reducing the adverse environmental effects of farming [1]. The majority of manual labour tasks in agriculture have been largely replaced by machines and technology over time, enhancing overall value, effectiveness, and enticing more individuals to rely on farming for their living [2]. Farming methods based on human effort and nature cannot fulfill the needs of an expanding world. AI and IoT technologies have opened new fronts of intelligent agriculture with new solutions for meeting the challenge of food security, scarcity of resources, and climatic change. AI-IOT is a combination of AI algorithms and techniques with agricultural IOT devices and networks, which is to gather, process and analyze the form data to automate data-operated decision making and automatic form operations. AI-operated algorithms such as computer visions, machine learning, and natural language processing farmers provide real-time monitoring of forecast analysis, automation, and crops, livestock and agricultural machinery. IoT sensors, drones, and intelligent machines provide the data infrastructure to extract useful information from the fields to build a smart agricultural ecosystem. Smart agriculture is an evolving field that leverages technological innovations to transform traditional farming practices. The integration of digital technologies into agriculture has opened up new opportunities and possibilities, revolutionizing the way farmers manage their crops, resources, and operations [3].

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This research paper attempts to provide a comprehensive report on AI-based IoT in agriculture, including its applications, benefits, drawbacks, and the future ahead. Based on the recent research, case studies, and industry reports, this paper attempts to place the revolutionary power of AI and IoT in reshaping agriculture today and making the world a sustainable and food-secure place.

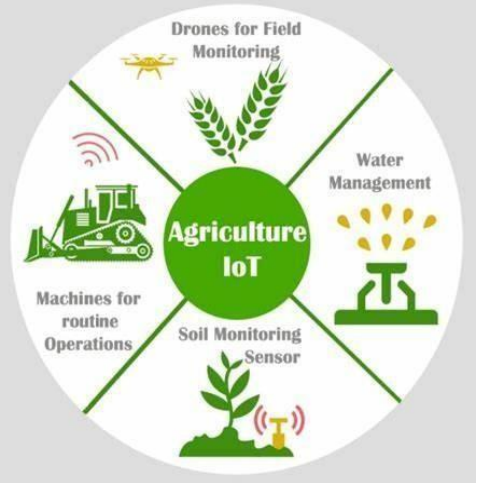

FIGURE 1.
Applications of IoT in agriculture

2. Implementations of AI IoT Technologies in Agriculture

1) **Smart decision support systems (SDSS):** The implementation of Smart Decision Support Systems (SDSS) in the agriculture sector aims to support farmers and those interested in agricultural investment for making proper decision making The decision support systems in agricultural management are numerous such as irrigation management, fertilization, and others for service operations, as the system includes spatial location data and crop characteristics in terms of crop growth stages, planting date and water requirements, precipitation, temperature, as well as soil characteristics and water holding capacity [4].

2) **Artificial Intelligence (AI):** AI technology can help farmers increase yields by assisting them in choosing suitable crop types, adopting improved soil and nutrient management practices, managing pests and diseases, estimating crop production, and forecast commodity prices [5]. IoT systems leverage farm machinery to increase its effectiveness, including automation and predictive maintenance. Autonomous tractors and UAVs (drones) with AI-powered fulfil crop monitoring of fields, farm operation optimization as well as harvesting.

3) **Targeted Irrigation and Controlling Water:** AI in IoT smart irrigation system makes it understand soil moisture levels, weather conditions allow the targeted application of water. Method would help save the water and provide irrigation required to the crop, with best possible efficiency in the available water resource.

4) **Automated Pest and Disease Control:** Early pest infestations/Plant Diseases: AI, Image processing & Deep Learning models can provide early detection of pest infections and plants diseases allowing for targeted pesticide sprays. IoT-smart traps and sensor-based monitoring can generate instant alarms, facilitating the use of useful measures for pest control.

5) **Crop Health Surveillance:** A machine learning model uses multispectral and hyperspectral images captured from drones or satellites to determine plant health. IoT capable sensors that measure environmental parameters (temperature, actual water level etc.) work behind the scene for early disease detection and yield prediction are continuously updated with the data, so help farmers take right decisions in crop management.

6) **Smart Livestock:** As IoT Devices are connected, and the wearable clothes for animals as well as AI-Driven analytics continuously monitor health, nutrition and behaviour of the livestock to make livestock more productive, animal welfare enhanced. Provides this tech helps farmers to know health of every individual animal, feeding strategy

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optimizations and early detection of health issues.

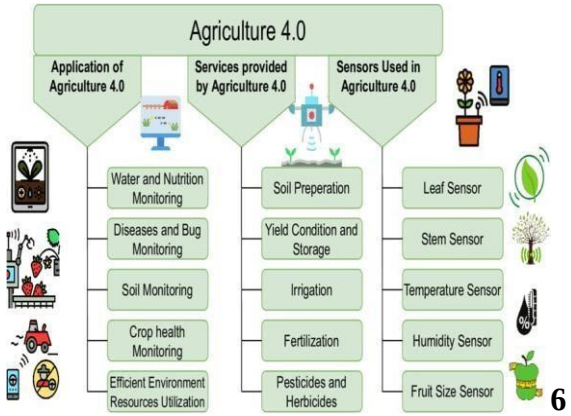

FIGURE 2.
Various applications, services and sensors used in Agriculture 4.0

3. Benefits of AI-based IOT in agriculture: There are many benefits in the combination of IoT and AI in agriculture, which change the traditional methods of agriculture and encourage stability. Some of the major benefits are:

3.1) Increased Productivity and Yields
Informed intelligence and best practices based on artificial intelligence lead to higher livestock production and output, ensuring food security for the growing population.

3.2) Resource Optimization
AI-powered IoT enables optimal utilization of water, pesticides, and fertilizers without wastage and least damage to the environment.

3.3) Decreasing Cost
The farming operations are mechanized and the resources are utilized to the maximum, and therefore there is minimum labor cost, input cost, and operational inefficiencies.

3.4) Enhanced Sustainability
Smart technologies optimize water usage, reduce waste, and enhance sustainability in farming operations. AI-driven predictive models can help prevent overuse of fertilizers and pesticides, leading to eco-friendly farming practices [6].

3.5) Take better decisions
Artificial intelligence algorithm provides data-powered insight and future analytics to farmers, and they enable farmers to decide and improve farming practices.

4. Some Obstacles of AI-IoT Adoption in Agriculture
Although there is immense possibility via implementation of AI-IoT in agriculture, many obstacles drive its adoption for wide indoor use-cases:

4.1) High Up Front Costs: The expense of IoT units, AI program and infrastructure is essentially a big roadblock for smallholder farmers as they do not have means towards these kinds of technologies.

4.2) Data Privacy and Security: The large amount of data tracked by AI-IoT systems results in a barrage of concern over data privacy and security.

4.3) Cybersecurity: Urgently needs to have strong firewall in order not allow outsider and security protection for sensitive information.

4.4) Connectivity: Rural areas may not have reliable high-speed internet connectivity which could also slow the real time transmission of IoT data and impede results derived from AI-powered analytics.

4.5) No need of Farmers: Remote location cannot rely on good technical and training expertise of Farmers that are necessary to use AI grounded IoT instruments in effective manner as well interpret data produced by these systems.

4.6) Lack of Financial Resources: Financial supporters could provide adequate loans to farmers if farmers did not get the anticipated yield, perhaps because unexpected calamities like drought, flood, pests, and diseases impacted the crops [7].

4.7) Climate impact: The operation of drones is affected by climatic conditions. The wind speed and rains affect the drone

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performance, so the weather must be considered before work [8].

4.8) Variability in the Environment: AI models need to be trained on different agricultural specifics and variable climate patterns for accurate results and dependable behaviour.

4.9) Lack of Technical Knowledge and Expertise: Despite the fact that technology can revolutionize the agriculture sector, a lack of technical knowledge among farmers to use the technology-led machinery is a major challenge in the ecosystem. The best way to tackle this is to keep the farmers in mind while developing the systems. The designers need to focus on the user interface in the case of digital products and providing solutions in local languages are the possible ways to overcome the challenge [9].

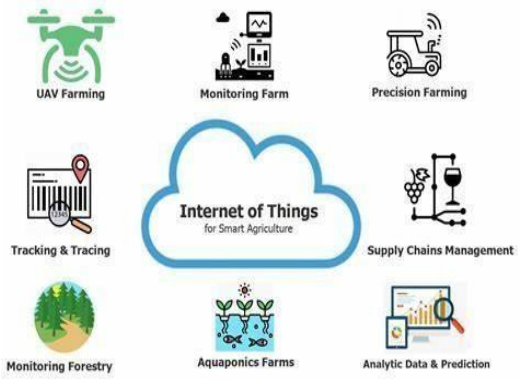

FIGURE 3.
An illustration of IoT applications for smart agriculture.

5. Insights and Trends for Future

AI enabled IoT for agriculture is going to be really big with some new trends and innovations coming up in the future:

5.1) 5G/6G connectivity: As 5G unfolds and eventually followed on by 6G, we will this boosts faster and available data transfer for real-time farming monitoring along with tighter AI enhancements. The IoT in agriculture field has experienced a burst of creativity, activity, venture capital firms and exciting entrepreneurs. The space becomes visible as an active group of large firms and new startups that are willing to become the part of what may be a giant market and technologies [10].

5.2) Using AI insights for Sustainable Agriculture Practices: This could drive ag-tech to use more regenerative agriculture practices which we have known can have an environmental benefit whilst providing resource conservation. Slowly the agriculture sector is moving towards precision farming in which management will we done on the basis of individual plant. Deep learning and other extend methods are used to detect the plant or flower type, this will help farmers to provide favourable environment to the plant for sustainable growth [11].

5.3) Digital twins enabled by AI: Farmers will use digital twins (virtual replicas of farms) to simulate different crop management scenarios before applying them in real life. AI-driven simulations will provide insights into how different farming practices impact crop yields. Digital twins will help in optimizing farm productivity while minimizing resource usage [12].

5.4) Blockchain Integration: Blockchain technology can improve transparency and traceability of agri-supply chains, product authenticity, lower fraud, and build trust among stakeholders.

5.5) Edge Computing: Edge computing will enable near-source processing and analysis, reduce latency, and enable real-time decision-making even in low-connectivity scenarios.

6. Conclusion

AI-Operated IOT technologies are changing today's agriculture with increased productivity, efficiency and record levels of stability. Taking advantage of farmers, AI algorithms and IOT sensors, can get real-time actionable insights on the use of crop health, soil conditions, climate and resources, resulting in data-powered decisions and best-in-class farming practices may be used. AI-Enhanced IOT technologies are changing modern agriculture by enabling smart farming, accurate irrigation

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and automatic crop and livestock management. These innovations have the ability to significantly improve efficiency, stability and food security. However, addressing the challenges such as infrastructure costs, connectivity issues and data security is important to fully feel the benefits of A-IIT integration in agriculture. Constant progress in connectivity, AI-powered analytics, and smart automation will further enhance the change of agriculture, which will lead to more durable and productive future for agriculture.

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