Impact of Internet of Things (IoT) in Smart Agriculture: Trends and Challenges in 2025

Author(s): Rahul Dhumal, Aniket Kolekar, Shrikant Deshmukh

Abstract : Agriculture is undergoing a rapid digital transformation to address the global challenges of food security, climate change, and resource scarcity. By 2025, smart agriculture has become a central pillar of sustainable development, integrating the Internet of Things (IoT) with artificial intelligence (AI), blockchain, edge computing, and 5G/6G networks. IoT-based systems enable real-time monitoring of soil, crops, livestock, and weather conditions, supporting data-driven decisions that improve yield, reduce costs, and conserve resources. Emerging technologies such as drones, autonomous tractors, and digital twins of farms are revolutionizing precision farming. However, IoT in agriculture also faces critical challenges, including data privacy, cybersecurity, interoperability, and infrastructure limitations. This paper reviews the role of IoT in agriculture, its applications, benefits, security issues, and future scope, providing an updated perspective for 2025.

Index Terms: Internet of Things, Smart Agriculture, Precision Farming, AIoT, Blockchain, 5G, Food Security, Sustainability

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I. INTRODUCTION

Agriculture remains the backbone of global economic development, feeding nearly eight billion people today and expected to feed 9.7 billion by 2050. Traditional farming methods are increasingly inadequate due to climate change, declining soil fertility, and water scarcity. To meet these challenges, agriculture is embracing the concept of Smart Farming, enabled by IoT and related technologies. In 2025, IoT devices—ranging from soil sensors and drones to autonomous machinery—are embedded across the agricultural value chain. These devices connect with cloud platforms, edge processors, and AI models to deliver predictive analytics, automation, and real-time monitoring. Unlike 2021, when IoT adoption in agriculture was emerging, by 2025 it has matured into an ecosystem integrated with AI-driven decision-making, blockchain-based traceability, and 5G/6G-powered connectivity.

II. INTERNET OF THINGS (IoT) OVERVIEW

The Internet of Things is a system of interconnected sensors, devices, and software that exchange data autonomously. In agriculture, IoT enables seamless data collection from farms, transmitting it to cloud or edge servers for analysis. By 2025, IoT has expanded with:

- 5G and satellite IoT for low-latency rural connectivity.
- AIoT (AI + IoT) for automated decision-making.
- LoRaWAN and NB-IoT for energy-efficient, wide-area farming applications.
- Blockchain integration for secure data sharing and food traceability.

These advancements have transformed farming from intuition-based practices to data-driven digital agriculture.

III. RESEARCH ELABORATIONS

3.1 Smart Agriculture Using IoT

IoT-based smart farming integrates sensing, automation, and analytics into agricultural processes. The major benefits include:

- **Efficiency:** IoT enables precision irrigation, fertilization, and pest control. Farmers can remotely monitor soil moisture and crop health, reducing waste and increasing yield.
- **Expansion into Urban Farming:** With urbanization, IoT-powered greenhouses, hydroponics, and vertical farms are increasingly feeding urban populations. Smart farms in rooftops, shipping containers, and supermarkets bring food closer to consumers.
- **Resource Optimization:** IoT ensures minimal usage of water, energy, and chemicals. Precision farming provides exactly what each plant or animal requires, improving sustainability.
- **Hygienic & Organic Production:** Reduced pesticide and fertilizer use ensures healthier and more organic produce, meeting consumer demand for safe food.
- **Agility:** Farmers receive real-time alerts on weather, pests, and soil conditions, allowing them to respond quickly to environmental changes.
- **Quality Improvement:** Drone surveillance, crop mapping, and AI-powered analytics help replicate optimal growing conditions, improving nutritional value and quality of produce.

4. Major Applications of IoT in Agriculture (2025)

- **Climate Monitoring:** Smart weather stations and IoT sensors predict climate changes, reducing risks of crop loss.
- **Precision Farming 2.0:** Automated irrigation, robotics, and AI models maximize productivity.
- **Smart Greenhouses:** IoT sensors powered by renewable energy self-regulate humidity, light, and temperature.
- **Data Analytics & AI:** Big data and predictive modeling improve yield forecasting and pest management.
- **Drone & Satellite Imaging:** Hyperspectral imaging detects crop diseases early.
- **Livestock Monitoring:** Wearables track health, reproduction, and feeding patterns of animals.
- **Food Supply Chain:** Blockchain combined with IoT ensures traceability, reduces food fraud, and tracks carbon footprints.

V. RESULTS OR FINDINGS

5.1 Security Challenges in IoT Agriculture Despite its benefits, IoT in agriculture introduces significant security risks:

- **Authentication:** Ensuring only authorized users and devices access farm data.
- **Encryption:** Protecting sensitive data (e.g., soil, livestock, production statistics) from cyberattacks.
- **Access Control:** Preventing unauthorized control of IoT devices.
- **Data Privacy:** Farmers' personal and financial data are vulnerable to leaks.
- **Cyber Threats:** IoT devices may be hacked, leading to crop loss or supply chain disruptions.
- **Standardization Issues:** Lack of uniform communication protocols creates interoperability problems.

Solutions: Blockchain for secure transactions, AI-based intrusion detection, post-quantum cryptography, and stronger international standards.

6. Implications of Implementation

- **Government Support:** Subsidies, training, and rural IoT infrastructure are essential for adoption.
- **Sustainability:** IoT contributes to water conservation, reduced carbon emissions, and eco-friendly farming.
- **Economic Impact:** While IoT reduces long-term costs, high upfront investment is a barrier.
- **Social Aspects:** IoT reduces labor needs but creates a digital divide between tech-enabled and traditional farmers.
- **Infrastructure Needs:** Reliable 5G/6G, cloud/edge platforms, and secure applications are critical.

7. Future Scope Beyond 2025

- 6G-powered Smart Farming with real-time holographic farm simulations.
- Self-sustaining farms integrating renewable energy with IoT.
- Autonomous Farming Robots performing sowing, weeding, and harvesting.
- Digital Twins of Farms to simulate environmental conditions before real-world implementation.
- Global Agriculture Data Sharing Networks enabling real-time international cooperation.

VI. CONCLUSION

By 2025, IoT has become the cornerstone of smart agriculture, integrating with AI, blockchain, and advanced connectivity to transform farming into a sustainable, efficient, and secure practice. While challenges remain in security, standardization, and affordability, the benefits of IoT far outweigh the risks. The future of global food security depends on scalable adoption of IoT-enabled smart agriculture to ensure resilience against climate change, growing populations, and resource scarcity.

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AUTHORS

First Author: Rahul Dhumal, MSc Computer Application , Aabasaheb Garware College,Pune

Second Author: Aniket Kolekar, MSc Computer Application , Aabasaheb Garware College,Pune

Third Author: Shrikant Deshmukh, MSc Computer Application , Aabasaheb Garware College,Pune