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ESTABLISHING INFRASTRUCTURE FOR IOT-DRIVEN SMART AGRICULTURAL SYSTEMS

Email

snandal15@yahoo.com

¹Sunil Kumar*, ¹Raghavendra Singh, ¹Bipin Kumar and ¹Kamlesh

¹ICAR- Indian Institute of Farming Systems Research, Modipuram, Meerut 250110 (Uttar Pradesh), India

The Internet of Things (IoT) refers to the rapidly expanding network of connected devices that collect and exchange data in real time using embedded sensors. This technology allows for the access and control of everyday devices and equipment via the Internet. The term "Things" in IoT encompasses any object in daily life that is connected through the internet. IoT integrates advanced automation and analytics systems with artificial intelligence, sensors, networking, electronics, and cloud messaging to deliver comprehensive solutions for products and services. The Internet of Things (IoT), a new wave of innovation has emerged that promises increased productivity, sustainability, and efficiency. With a network of interconnected devices and sensors that collect and exchange data, IoT in Agriculture will enhance the management of livestock rearing and crop cultivation, fostering predictability and optimizing efficiency. By harnessing IoT in the agriculture industry, farmers & agribusinesses can make data-driven decisions, maximize resource utilization, monitor crop health, and automate various processes (Li and Yang, 2018). IoT provides a network of interconnected devices and sensors for the industry that collects and share data. They can be embedded in soil, crops, machinery, and livestock to monitor temperature, humidity, soil moisture, nutrient levels, and animal behaviour.

By 2050, the global population is expected to reach approximately 10 billion. To sustain such a large population, agriculture must integrate technology to maximize efficiency and productivity. IoT plays a crucial role in crop and soil monitoring, offering precise solutions for farming needs. Smart farming, driven by IoT, enables farmers to reduce waste and boost productivity by monitoring fields with sensors, thus allowing real-time management of agricultural activities (Chen et al., 2011).

Smart Agriculture System Using IoT

Smart agriculture refers to the application of IoT solutions in farming. IoT in agriculture aims to enhance traditional farming practices to meet increasing demands and reduce production losses. It employs robots, drones, remote sensors, and computer imaging, combined with advanced machine learning and analytical tools, to monitor crops, survey and map fields, and provide data-driven insights for efficient farm management. The adoption of IoT in agriculture is accelerating, particularly due to disruptions caused by events like COVID-19, which highlighted the need for innovative solutions in the supply chain and workforce shortages. As a result, the smart farming market is projected to grow significantly, with market value expected to reach \$6.2 billion by 2021 and \$15.3 billion by 2025 (Farooq et al., 2019).

Infrastructure Requirements for Adopting a Smart Agriculture System Using IoT

- **High Initial Investments:** Setting up sensors, drones, and robots requires significant initial investment.
- **Skilled Field Staff:** Hiring well-trained personnel to operate and manage IoT devices is essential.
- **Power Connectivity:** Reliable power sources are necessary to charge and operate drones and robots.
- **Hardware Maintenance Costs:** Ongoing maintenance of IoT hardware is required.
- **Internet Connectivity:** Continuous internet connectivity is crucial for real-time data transmission and device operation.

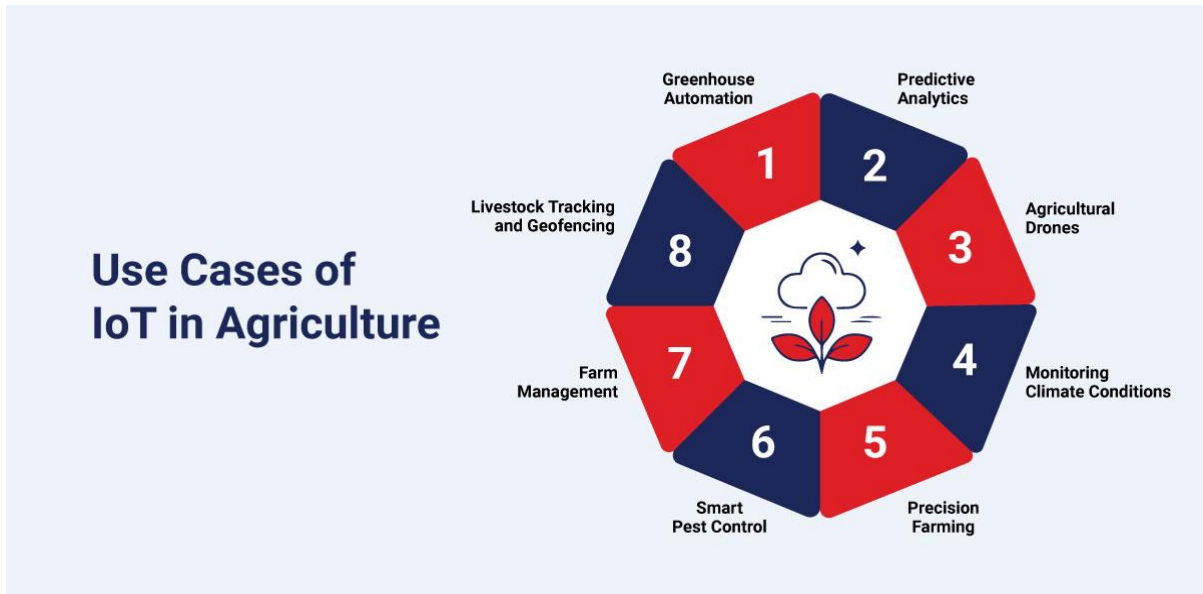
IoT Use Cases in Agriculture

There are various types of IoT sensors and applications in agriculture:

- **Monitoring Climate Conditions:** Weather stations equipped with smart sensors collect environmental data from the field and send it to the cloud. This data helps in making informed decisions about farming practices.
- **Greenhouse Automation:** IoT sensors provide real-time information on greenhouse conditions such as lighting, temperature, soil condition, and humidity. They can also automatically adjust these conditions to match predefined parameters.
- **Crop Management:** Similar to weather stations, IoT sensors placed in fields collect data specific to crop farming, including temperature, precipitation, leaf water

potential, and overall crop health. This helps in monitoring crop growth and identifying any anomalies to prevent diseases or infestations.

- **Cattle Monitoring and Management:** IoT sensors attached to farm animals monitor their health and performance. These sensors collect data on livestock health, well-being, and location. For example, they can identify sick animals so that farmers can isolate them to prevent the spread of disease.



Source : <https://www.linkedin.com/pulse/iot-agriculture-senthil-kumar-wfrtc/>

□ **Precision Farming:** Precision farming, also known as precision agriculture, focuses on enhancing efficiency and making accurate, data-driven decisions. It is one of the most effective and widespread applications of IoT in agriculture. IoT sensors enable farmers to gather extensive data on various aspects of the field's microclimate and ecosystem, including lighting, temperature, soil condition, humidity, CO2 levels, and pest infestations. This information helps farmers determine the optimal amounts of water, fertilizers, and pesticides needed for their crops, ultimately reducing costs and producing healthier, higher-quality crops.

□ **Agricultural Drones:** One of the most promising advancements in agricultural technology is the use of agricultural drones, also known as unmanned aerial vehicles (UAVs), in smart farming. Drones are more capable than airplanes and satellites in collecting agricultural data, providing detailed and precise information that can significantly benefit farming practices.



Source: <https://www.javatpoint.com/iot-in-agriculture>

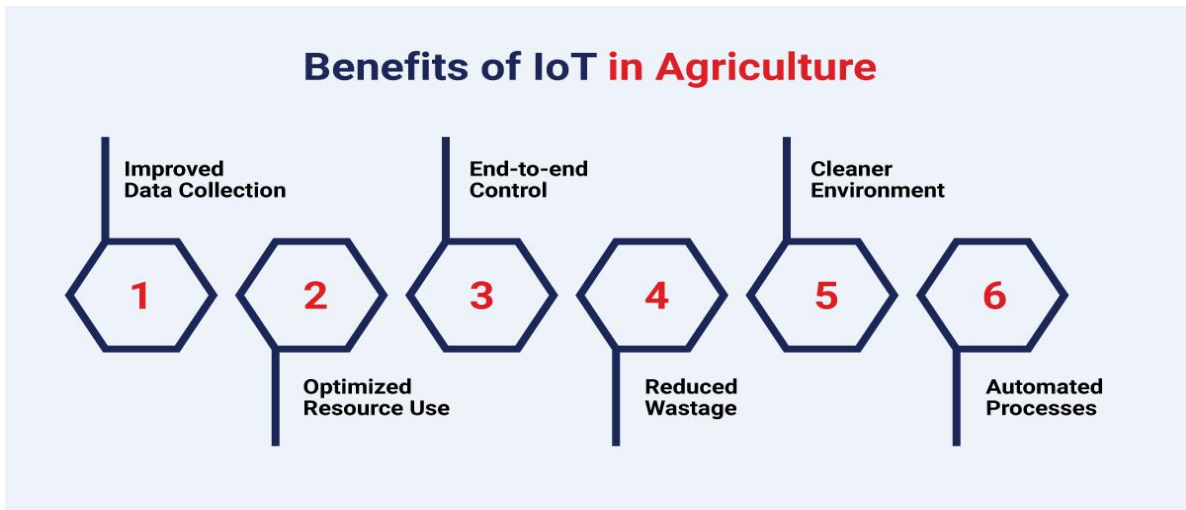
1. **Predictive Analytics for Smart Farming:** Precision agriculture is greatly enhanced by predictive data analytics. While IoT and smart sensor technology provide valuable real-time data, data analytics helps farmers interpret this information and make crucial predictions regarding crop harvesting times, risks of diseases and infestations, yield volumes, and more. These tools help make farming, which is highly dependent on weather conditions, more manageable and predictable.
2. **End-to-End Farm Management Systems:** A comprehensive approach to IoT in agriculture is represented by farm productivity management systems. These systems typically include multiple IoT devices and sensors installed throughout the farm, along with a powerful dashboard featuring analytical capabilities and integrated accounting/reporting functions. This setup enables remote farm monitoring and helps streamline various business operations. Additionally, IoT in agriculture offers opportunities for vehicle tracking, automation, storage management, logistics, and more.

Advantages of IoT in Agriculture

IoT technology brings numerous benefits to agriculture, from improving efficiency and reducing waste to enabling precision farming and enhancing product quality. It helps farmers address the challenges of feeding a growing population while ensuring a more sustainable future for agriculture. Here are the key benefits of IoT in agriculture:

- Increased efficiency in farming operations

- Reduction of waste
- Enhanced precision in farming techniques
- Improved product quality
- Better resource management
- Sustainable farming practices
- Data-driven decision making
- Enhanced monitoring and control of agricultural processes



Source: <https://www.rishabhsoft.com/blog/iot-in-agriculture-industry>

Improved Data Collection for Enhanced Farming Efficiency: As farmers face the challenge of maximizing yields on shrinking land while dealing with unpredictable weather and deteriorating soil, IoT-enabled agricultural solutions offer significant advantages. These technologies allow real-time monitoring of crops and environmental conditions, providing farmers with valuable insights. By collecting crucial data on weather, soil conditions, livestock, and crop health, farmers can make informed decisions and address potential issues proactively, thus enhancing overall farming efficiency.

(<https://www.verifiedmarketresearch.com>).

Optimized Resource Use for Sustainable Agriculture: Precision farming powered by IoT technology enables farmers to gather real-time data from sensors placed across their farms. This information helps farmers make precise decisions regarding resource allocation, ensuring that crops receive the appropriate amounts of water, fertilizers, and other necessary inputs.

End-to-End Control of the Production Process: IoT systems offer farmers the ability to respond quickly to changes in weather, air quality, and humidity through predictive and real-time monitoring. This capability helps prevent potential damages and supports a more successful crop production cycle.

Reduced Waste and Efficient Cost Management: IoT solutions in agriculture play a key role in minimizing risks and reducing waste by identifying anomalies and inconsistencies in crop production. This allows farmers to take immediate action to cut down on waste and manage costs more effectively.

A Cleaner Environment with a Greener Approach: Through precision farming techniques enabled by IoT, farmers can reduce the use of fertilizers and pesticides, leading to more organic crop production. This eco-friendly approach helps decrease the overall carbon footprint of agricultural practices while ensuring high-quality yields.

Enhanced Efficiency with Process Automation: IoT technology has automated various farming processes, including demand-based fertilizing, irrigation, and robotic harvesting. By streamlining these tasks, farmers can optimize operations, save time, and improve overall productivity.

Impact of the Industrial Internet of Things on Agriculture

The Industrial Internet of Things (IIoT) has had a transformative effect on agriculture, ushering in a new era of smart farming. Key impacts of IIoT in agriculture include (He et al., 2013):

- **Increased Efficiency and Productivity:** Remote monitoring of soil conditions, weather patterns, crop health, and equipment performance enhances operational efficiency.
- **Improved Resource Management:** Intelligent irrigation systems adjust watering schedules based on real-time data, ensuring crops receive the optimal amount of water.
- **Enhanced Crop Monitoring and Disease Detection:** Continuous crop monitoring allows for early detection of diseases, nutrient deficiencies, and pest infestations.
- **Livestock Monitoring and Management:** IIoT technologies track livestock health, behavior, and environmental conditions, monitoring parameters like body temperature and feeding patterns.

- **Data-Driven Decision-Making:** Insights from IIoT enable farmers to optimize production processes, fine-tune resource allocation, and mitigate risks.
- **Supply Chain Optimization:** End-to-end visibility and traceability from field to market ensure transparency, quality control, and food safety.

Turn Your Farm into a Smart Ecosystem

Explore the potential of IoT development services for your farm. IoT in agriculture, often referred to as smart farming, involves leveraging technology to optimize and automate various farming practices. Key areas where IoT is making a significant impact include:

1. Precision Farming:

- **Soil Sensors:** Measure moisture, temperature, and nutrient levels to guide irrigation and fertilization decisions.
- **Weather Stations:** Provide real-time data on weather conditions to optimize planting and harvesting schedules.

2. Livestock Monitoring:

- **Wearable Devices:** Track the health, location, and activity of livestock, improving herd management and reducing losses.
- **Automated Feeding Systems:** Ensure animals receive appropriate feed based on their health and growth needs.

3. Smart Irrigation Systems:

- **Automated Sprinklers:** Adjust watering schedules based on soil moisture data to reduce water waste and ensure adequate hydration.
- **Drip Irrigation Systems:** Use sensors to deliver water directly to plant roots, enhancing water use efficiency.

4. Crop Monitoring:

- **Drones and Satellite Imagery:** Offer aerial views to monitor crop health, detect diseases, and assess damage from pests or weather events.
- **Remote Sensing Technologies:** Analyze plant health and growth patterns to improve yield predictions and management practices.

5. Supply Chain Optimization:

- **Traceability Systems:** Track products from farm to market, ensuring food safety and reducing waste.

- **Smart Packaging:** Monitor the condition of perishable goods during transportation and storage to maintain quality and freshness.

6. Automated Equipment:

- **Robotics:** Perform tasks such as planting, weeding, and harvesting with precision, reducing labor costs and increasing efficiency.
- **Autonomous Tractors and Machinery:** Operate with minimal human intervention, optimizing field operations and reducing the risk of human error.



Source : <https://www.cdix.io/#>, <https://pyno-media.s3.amazonaws.com/1616071603489>

Conclusion

The outlook for IoT in agriculture is highly optimistic. This technology significantly enhances agricultural practices by optimizing resource use, facilitating data-driven decision-making, and boosting productivity. Addressing current challenges and leveraging emerging trends will unlock the full potential of IoT, leading to a more sustainable and efficient agricultural system.

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<https://www.verifiedmarketresearch.com/product/iot-in-agriculture-market>.