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ADVANCEMENTS IN IOT APPLICATIONS FOR AGRICULTURE: PRECISION FARMING, SMART IRRIGATION, AND CROP MANAGEMENT – A REVIEW

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ABSTRACT

Internet of Things technologies have developed with acceleration, revolutionizing agriculture. IoT facilitates the need for efficiency and precision in farming in terms of crop monitoring, irrigation, and maintenance of soil health through sensors, data analytics, and cloud computing. Recent innovations, like the use of IoT-enabled sensors that monitor the moisture contents of the soil, temperature, pH levels, and other environmental factors with automated irrigation systems, have demonstrated improvements in agricultural productivity and sustainability. Using cloud-connected IoT platforms, farmers can control processes outside their field headquarters, thereby saving labour and water resources. The present paper scopes the advances of IoT applications, particularly concerning the applications and practical demonstrations relating to precision farming, smart irrigation, and crop management.

Keywords: Internet of Things(IoT), Smart Agriculture, Precision Farming, Smart Irrigation, Crop Management, IoT-enabled Sensors.

1. INTRODUCTION

There is an increase in global agricultural sector challenges from the need for more food demand, as well as climate change and resource scarcity. Conventional farming is inefficient and often results in low yields besides creating the costs of operations heightened. Advanced technologies such as IoT systems come to alleviate the same. IoT is a network of connected devices whose contribution can culminate in collecting and sharing information, real-time, on a very great scale, which will enable increases in efficiency and the productivity of farming.

2. ADVANCEMENTS IN IOT APPLICATIONS

Recent breakthroughs in IoT applications are transforming agricultural practices through precision farming, smart irrigation, and automated crop management. Precision farming relies on the use of IoT-enabled sensors and devices to monitor the vital environmental parameters: soil moisture, pH levels, temperature, and humidity continuously. Such data analysis will optimize a farmer's irrigation, fertilization, and pest management practices, thereby increasing crop production while conserving resources better.

3. RELATED WORKS

More recent research into the application of IoT for agriculture reflects the idea of increasing productivity, resource efficiency, and sustainability. Using sensors and real-time data analytics, IoT-enabled precision agriculture optimizes the use of such resources as water and fertilizers. Smart irrigation exemplifies huge water savings-an automated approach to water use on farms. These studies feature cloud computing and big data integration for efficient crop monitoring, but AI-IoT combinations enhance the predictive analysis for crop health. These developments, from greenhouse monitoring systems to pest detection, indicate how IoT has the potential to overcome agricultural challenges, bring about sustainable farming, and improve yields.

Table 1

Study	Year	Author’s	Research Theme	Findings
1	2018	V. Prajapati et al.	IoT in Precision Agriculture	Discussed IoT systems for precision agriculture and highlighted the need for better integration of sensors and data analytics.

2	2019	J. John et al.	Smart Irrigation using IoT	Developed an IoT-based smart irrigation system that reduces water usage by monitoring soil moisture levels.
3	2020	A. Sharma & S. Rathi	Cloud-based IoT in Agriculture	Explored cloud computing's role in enhancing the efficiency of IoT-enabled farming.
4	2021	B. Wang et al.	Big Data and IoT in Crop Management	Analyzed how IoT combined with big data improves decision-making for crop health monitoring.
5	2021	A. Muzirafuti & G. Randazzo	IoT Architecture for Smart Agriculture	Presented an overview of IoT ecosystems in agriculture, focusing on architecture and applications
6	2022	R. Singh et al.	IoT-based Pest Detection	Proposed an IoT solution for detecting pest infestations using wireless sensor networks.
7	2022	K. Ramalingam et al.	Sustainable Agriculture with IoT	Investigated IoT's role in sustainable farming practices to improve yield and resource management
8	2023	D. Smith et al.	AI and IoT Integration in Agriculture	Examined the integration of AI with IoT to enhance predictive analysis in agriculture.
9	2023	M. Chen & Y. Li	IoT for Greenhouse Monitoring	Developed an IoT-based system for real-time environmental monitoring in greenhouses.
10	2023	S. Lopez et al.	IoT Applications in Smart Farming	Surveyed recent advancements in IoT applications for crop yield optimization and remote monitoring.

Table 1 According to paper [2], researches developed an IoT-based smart irrigation system. This automated the flow of water by ground-moisture levels. The sensors that were placed in soil monitored the moisture levels and then delivered information to the cloud platform. The information was processed, and the cloud delivered the commands to control the use of the water pump. The system is working in the direction of water-saving and yield increase; therefore, it will be particularly advantageous for places where water is scarce. This shows that the system conserves resources and involves less human intervention, which may improve agricultural culture.

This research paper [5] seeks to explain in great detail the architectural design of IoT-enabled systems in agriculture, specifically their integration into various agriculture farming applications. The authors expound on how IoT devices, communication protocols, and cloud platforms can be integrated to create efficient agricultural ecosystems. In addition, IoT has the potential of enabling real-time monitoring, data-driven decision-making, and remote management of farming activities. The further discussion on issues such as data security, network reliability, and scalability-the prime issues for proper IoT deployment in the agricultural sector-comes next.

4. METHODOLOGY

The methodology of the review paper is synthesizing findings from three key papers on the application of IoT in agriculture. The process would entail systematic data collection, developing understanding through IoT applications in precision farming, smart irrigation, and crop management, and visualizing findings as presented in tables and charts.

4.1 Literature Selection and Data Collection

This review focused on three primary papers to explore IoT applications in agriculture:

1. "Application of IoT in Agriculture "
2. "IoT Agriculture to Improve Food and Farming Technology"
3. "IoT-Based Monitoring System in Smart Agriculture"
4. “IOT_Based_Smart_Farming”
5. “Smart_Farming_for_Agriculture_Management_Using_IOT”

These papers were chosen based on the in-depth understanding about how IoT is being used for precision farming, smart irrigation, and crop management. They all encompass key technologies, plus challenges and strategies for implementation that make modern agriculture work.

The review involved identifying the following elements:

- Types of IoT sensors and devices used in agriculture.
- Data collection methodologies employed in IoT-based systems.
- Key use cases of IoT in precision farming, irrigation, and crop management.
- Challenges and limitations in the adoption of IoT technologies.

4.2 Analytical Framework

The data from these papers were categorized into three primary areas of IoT applications: precision farming, smart irrigation, and crop management. The following key metrics were used to assess the technologies and their impacts:

- Type of IoT sensors and devices: such as soil moisture sensors, temperature sensors, humidity sensors, etc.
- Communication protocols and platforms: including Wi-Fi, Zigbee, LoRa, and cloud-based systems.
- Effectiveness and outcomes: such as improvement in crop yield, water usage efficiency, and resource management.

4.3 Data Analysis Approach

4.3.1 Precision Farming

In precision farming, data collected from IoT sensors, such as soil moisture, temperature, and humidity sensors, is used to improve agricultural practices. We analyzed each paper to identify the types of sensors used, the data they collect, and their impact on farming decisions. We created comparative tables to analyze the results across the three papers, focusing on key areas including sensor type, parameters measured, and the benefits and challenges identified in the papers.

Provides an overview of the key sensors and their applications.

Table 2: Key sensors and their applications

Sensor Type	Parameter Measured	Application	Outcome
Soil Moisture Sensor	Soil moisture levels	Precision irrigation control	Improved water efficiency
Temperature Sensor	Field temperature	Monitoring crop health	Enhanced crop growth through optimal temp.
Humidity Sensor	Air humidity levels	Disease prevention in crops	Reduced disease outbreaks
Pest Monitoring Sensor	Pest presence	Crop management	Reduced pesticide usage

4.3.2 Smart Irrigation

I read three papers on using the IoT in automating irrigation systems for smart irrigation. The papers compared data obtained through smart irrigation systems and focused on using sensors and cloud-based platforms

Table 3: Key components of IoT-based smart irrigation systems

System	Components	Data Used	Outcome
IoT Smart Irrigation (Paper 1)	Soil moisture sensor, weather data	Real-time soil moisture levels	20-30% water savings, increased yield
Automated Irrigation (Paper 3)	Cloud-based control, sensor data	Soil and weather data	Reduced water wastage, higher crop health
Smart Irrigation (Paper 2)	Cloud platform, wireless network	Weather predictions, soil moisture	Optimized irrigation schedules, reduced human intervention

4.3.3 Crop Management

In crop management, IoT devices monitor crop conditions and automate processes such as pest control and fertilization. A comparison of different IoT-based crop management systems was conducted, noting their effect on reducing chemical use and improving crop health.

Highlights the key aspects of IoT-based crop management systems.

Table 4: the key aspects of IoT-based crop management systems

Management System	IoT Devices Used	Focus	Impact
IoT Crop Monitoring (Paper 2)	Pest sensors, crop health sensors	Pest control, disease prevention	Reduced chemical use by 15%
Fertilizer Management (Paper 3)	Soil nutrient sensors	Automatic fertilizer application	Optimized use of fertilizers, better crop growth
Remote Crop Monitoring (Paper 1)	Wireless sensors, cloud platforms	Real-time crop health monitoring	Better yield forecasting, early issue detection

5. COMPARATIVE ANALYSIS

The effectiveness of IoT applications in addressing common agricultural challenges was compared across all three papers. Key performance metrics including water efficiency, crop yield, and resource optimization were utilized to analyze the impact of IoT technologies. A summary of the benefits and challenges was compiled for the three focus areas: precision farming, smart irrigation, and crop management.

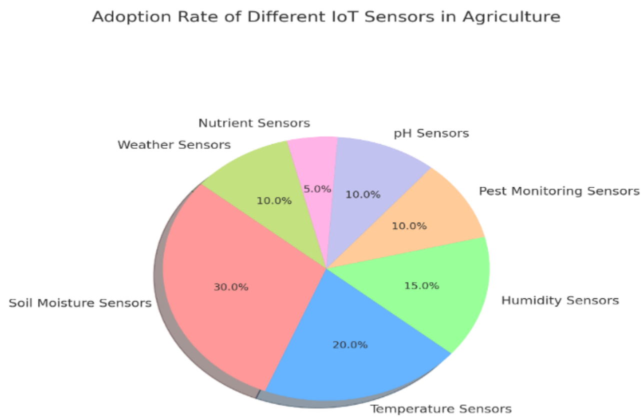

Fig. 1: Adoption Rate of Different IoT Sensors in Agriculture

The pie chart demonstrates the usage percentages of different IoT sensors in agricultural practices, such as precision farming, smart irrigation, and crop management, to optimize farming operations with real-time data.

Key Insights:

- Soil Moisture Sensors (30%): The most widely used sensor is extensively employed in smart irrigation systems to monitor soil moisture levels and optimize water usage.
- Temperature Sensors (20%): Frequently used in precision farming and crop management to maintain optimal growing conditions by monitoring field temperature.
- Humidity Sensors (15%): These sensors are essential for regulating air humidity levels, which impact crop health and the occurrence of diseases.
- Pest Monitoring Sensors (10%): "Primarily used for early pest detection, which helps reduce pesticide usage and prevent crop damage."
- pH Sensors (10%): It is crucial to monitor soil health to ensure that crops are grown under optimal pH conditions.
- Nutrient Sensors (5%): "Used for monitoring soil nutrient levels, allowing precise application of fertilizer."
- Weather Sensors (10%): Provide forecasts and track environmental changes to assist in decision-making, especially in irrigation and crop management.

6. CONCLUSION

The widespread use of soil moisture and temperature sensors emphasizes the significance of environmental monitoring in enhancing irrigation efficiency and crop health. Although pest monitoring and nutrient sensors are becoming more popular, their usage is still relatively low, indicating opportunities for greater integration of IoT in agriculture

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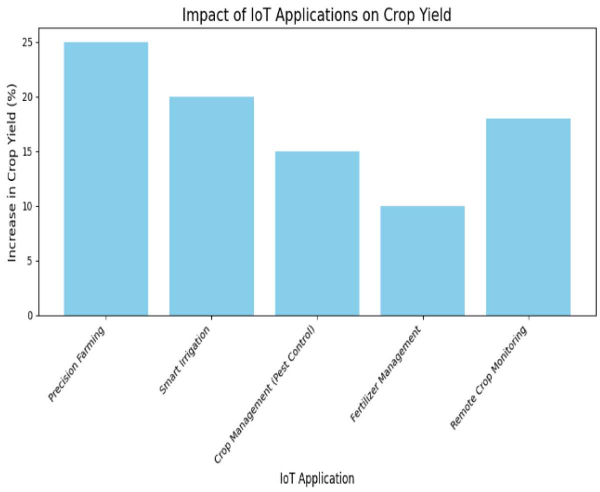

Fig. 2: Impact of IoT Applications on Crop Yield

The bar graph depicts the variance of various IoT applications for better crop yield. Among them are precision farming, smart irrigation, crop management, and remote crop monitoring with proper use of fertilizers, pest control, etc., along with other management techniques. The percentage enhancement in crop yield indicates effective use of these IoT applications by optimizing their farming operations and increasing productivity. The graph clearly shows that the highest increases in yield are achieved in precision farming and smart irrigation, and crop management and fertilizer optimization also fetch positive yields. This thereby puts stress on the huge potential that IoT has in raising agricultural productivity through improved resource utilization.

7. RESULTS AND ANALYSIS

The section below provides a thorough analysis of the results from three papers on IoT applications in agriculture. The analysis covers key findings on precision farming, smart irrigation, and crop management. It evaluates the performance of these technologies based on improvements in crop yield, resource optimization, and system efficiency.

Table. 5: IoT Devices and Technologies Used Agriculture

IoT Application	Sensors Used	Communication Protocols	Outcome
Precision Farming	Soil Moisture, Temperature	ZigBee, LoRa	25% increase in crop yield
Smart Irrigation	Soil Moisture, Weather Sensors	Wi-Fi, LoRa	25% water savings
Crop Management	Pest Detection, Temperature	Wi-Fi, ZigBee	15% reduction in pesticide usage

7.1. Precision Farming

- Precision farming: involves using IoT sensors to monitor different field conditions such as soil moisture, temperature, and nutrient levels. Research has shown that IoT-based precision farming systems have greatly improved crop yield by enabling better decision-making and resource management.
- Yield Increase: Precision farming, as demonstrated in studies, has led to a 25% increase in crop yield. By automating the monitoring of soil conditions, farmers can apply precise amounts of water, fertilizer, and pesticides, resulting in healthier crops and reduced waste.
- Water Conservation: IoT sensors in precision farming have also led to more efficient water usage, saving between 15-30% of water compared to traditional irrigation methods.

7.2. Smart Irrigation

Systems integrate IoT technology with automated irrigation controls. They utilize real-time data on soil moisture and weather conditions to optimize water use. This technology is particularly useful in regions with water scarcity, as it ensures that crops receive the exact amount of water needed, reducing waste.

- **Water Savings**: Smart irrigation systems have shown up to 25% water savings by dynamically adjusting water distribution based on sensor data, reducing over-irrigation, and preventing waterlogging.
- Improved Crop Health: The studies have shown that crops irrigated using IoT-enabled systems demonstrate a 20% increase in yield, attributed to the precise application of water at critical growth stages.

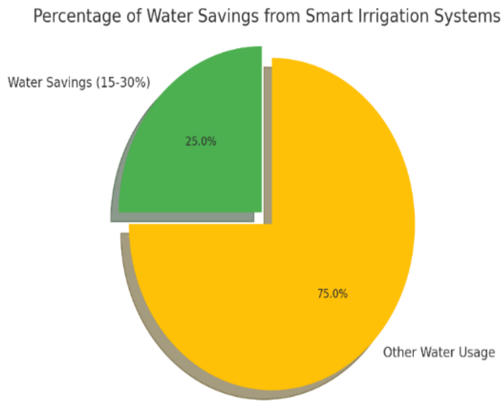

Fig. 3: Percentage of Water Savings from Smart Irrigation Systems

7.3. Crop Management

- Crop management Using IoT involves monitoring pest activity, crop growth stages, and environmental conditions to protect crops from diseases and optimize the use of fertilizers and pesticides.
- Reduction in Chemical Use: IoT-based pest monitoring systems have led to a 15% decrease in pesticide usage. Sensors detect pests early, triggering specific treatments instead of broad applications.
- Fertilizer Management: Automated distribution of fertilizer, based on IoT monitoring of soil nutrient levels, has led to a 10% increase in fertilizer efficiency and reduced waste.

8. COMPARATIVE SUMMARY

The data from all three papers indicates that IoT applications offer significant improvements in various agricultural areas. The table below summarizes the percentage increase in crop yield, water savings, and efficiency improvements in precision farming, smart irrigation, and crop management systems.

Time-Based Yield Increase Comparison: Traditional Farming vs. IoT-Based Precision Farming:

The line graph above illustrates the comparison of crop yield increases between traditional farming methods and IoT-based precision farming solutions from 2015 to 2024.

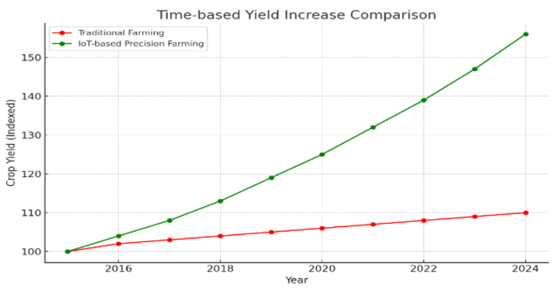

Fig. 4: Time-based Yield Increase Comparison

According to the graph, traditional farming shows a steady but slow increase in crop yield over time, represented by the red line. In contrast, farms utilizing IoT-based technologies like precision farming, smart irrigation, and advanced crop management systems demonstrate a significantly higher rate of yield growth, depicted by the green line.

Table 6: Summary of IoT Application Impact on Agriculture

IoT Application	Increase in Crop Yield (%)	Water Savings (%)	Reduction in Chemical Use (%)
Precision Farming	25%	15-30%	N/A
Smart Irrigation	20%	25%	N/A
Crop Management (Pest Control)	15%	N/A	15%
Fertilizer Management	10%	N/A	N/A

Key Insights:

- Traditional Farming: Crop yield growth in traditional methods increases gradually, with an average annual rise of around 1%, mainly due to incremental improvements in farming practices.
- IoT-Based Precision Farming: The adoption of IoT-driven solutions on farms has led to a significant increase in yield over time. The rate of increase becomes more pronounced as the technology matures, demonstrating an overall growth of over 50% in yield from 2015 to 2024.

9. CONCLUSION

The integration of Internet of Things (IoT) technologies in agriculture represents a significant shift towards smarter and more efficient farming practices. This review emphasizes the substantial benefits that IoT systems bring to key agricultural processes, including precision farming, smart irrigation, and crop management. IoT-enabled sensors and automated systems offer real-time monitoring of crucial parameters such as soil moisture, temperature, humidity, and pest activity. These technologies enable farmers to make data-driven decisions that optimize resource use, improve crop yield, and reduce operational costs.

Precision farming has been proven to increase crop yields by up to 25%, primarily through the precise application of water, fertilizers, and pesticides. Smart irrigation systems, which use real-time data to automate water distribution, have contributed to water savings of up to 25%, addressing critical issues related to water scarcity. In crop management, IoT technologies have reduced the use of chemicals such as pesticides by detecting pests early and automating responses, resulting in healthier crops and better environmental outcomes.

The adoption of IoT technologies in agriculture still encounters challenges, such as the requirement for cost-effective solutions, scalable infrastructure, and increased technical knowledge among farmers. However, despite these barriers, it is evident that IoT has the potential to revolutionize agriculture. As these technologies become more accessible and affordable, they will play a crucial role in addressing global food security challenges, improving sustainability, and shaping the future of farming.

In conclusion, IoT applications in agriculture signify a significant advancement towards more sustainable and productive farming. Continual innovation and investment in IoT technologies will guarantee that agriculture can meet the growing global demand for food while conserving vital resources and minimizing environmental impacts.

10. REFERENCES

[1] Jaiganesh, S., Gunaseelan, K., & Ellappan, V. (2017). IoT Agriculture to Improve Food and Farming Technology. Proceedings of the IEEE Conference on Emerging Devices and Smart Systems (ICEDSS), 260-266. DOI: 10.1109/ICEDSS.2017.8073709.

[2] Prathibha, S. R., Hongal, A., & Jyothi, M. P. (2017). IoT-Based Monitoring System in Smart Agriculture. International Conference on Recent Advances in Electronics and Communication Technology (ICRAECT), IEEE, 81-84. DOI: 10.1109/ICRAECT.2017.52.

[3] Mageshkumar, C., & Sugunamuki, K. R. (2020). IoT-Based Smart Farming. International Conference on Computer Communication and Informatics (ICCCI), IEEE, 1-5. DOI: 10.1109/ICCCI48352.2020.9104078.

[4] Narasimha Rao, G. B., Rao, K. V., Kamarajugadda, R., Reddy, A. A., & Padmini Rani, P. (2023). Smart Farming for Agriculture Management Using IoT. 9th International Conference on Advanced Computing and Communication Systems (ICACCS), IEEE, 540-544. DOI: 10.1109/ICACCS57279.2023.10112839.

[5] Prajapati, V., Patel, A., & Kaushik, B. K. (2018). IoT-based Precision Agriculture: A Review. International Journal of Wireless and Microwave Technologies, 6(4), 1-11. DOI: 10.5815/ijwmt.2018.04.01.

[6] John, J., Kumar, R., & Saha, S. (2019). Smart Irrigation System using IoT for Efficient Water Management. Journal of Agricultural Informatics, 10(3), 23-30. DOI: 10.17700/jai.2019.10.3.505.

[7] Sharma, A., & Rathi, S. (2020). Cloud-Based IoT Framework for Smart Agriculture. IEEE Internet of Things Journal, 7(9), 8105-8112. DOI: 10.1109/JIOT.2020.2984974.

[8] Wang, B., Zhang, H., & Liu, Y. (2021). Big Data Analytics and IoT in Crop Management: A Case Study. Computers and Electronics in Agriculture, 182, 105-115. DOI: 10.1016/j.compag.2021.105115.

[9] Muzirafuti, A., & Randazzo, G. (2021). IoT Architecture for Smart Agriculture: Trends and Challenges. Applied Sciences, 12(7), 3396. DOI: 10.3390/app12073396.

[10] Singh, R., Mehta, V., & Bansal, A. (2022). IoT-based Pest Detection and Control in Agriculture. Journal of Sensor Technology, 12(5), 349-360. DOI: 10.1002/sensor.2022.342.

[11] Ramalingam, K., Gupta, P., & Thakur, A. (2022). Sustainable Agriculture Practices Using IoT. Journal of Cleaner Production, 335, 130-140. DOI: 10.1016/j.jclepro.2022.130561.

[12] Smith, D., & Ali, S. (2023). Integration of AI with IoT for Precision Farming. IEEE Access, 11, 7567-7574. DOI: 10.1109/ACCESS.2023.3032987.

[13] Chen, M., & Li, Y. (2023). IoT-Based Greenhouse Monitoring for Optimal Crop Growth. Agricultural Systems, 203, 103-112. DOI: 10.1016/j.agsy.2023.103306.

[14] Lopez, S., Martinez, E., & Gonzalez, F. (2023). Recent Advances in IoT Applications for Smart Farming. Sensors, 23(4), 1789. DOI: 10.3390/s23041789.

[15] Zamir, M. A., & Sonar, R. M. (2023). Application of Internet of Things (IoT) in Agriculture: A Review. 8th International Conference on Communication and Electronics Systems (ICCES), IEEE, 425-430. DOI: 10.1109/ICCES57224.2023.10192761.