A Cost-Effective IoT-Based System for Real-Time Soil Parameters Measurement in Data-Driven Precision Agriculture

Chanabasappagouda A. Patil[1], Sumit Kumar Banchhor[2]
[1]Research Scholar, Department of Computer Science & Engineering, ASET, Amity University Chhattisgarh, Raipur India
[2]Faculty, Department of Computer Science & Engineering, ASET, Amity University Chhattisgarh, Raipur India
Paper Number: 240033

Abstract:

This research paper examines the essential need for accessible and scalable solutions in the field of precision agriculture. To do this, an affordable Internet of Things (IoT) system is built so that important soil properties, like wetness levels, temperature, pH balance, and fertilizer amounts, can be constantly monitored and evaluated. After careful testing and review, the suggested method successfully cuts costs while maintaining strong data accuracy and dependability, making it possible to collect soil data consistently. Central findings show that using this IoT-based method makes it much easier for farmers to make decisions, which leads to better food yields and long-term survival. These findings are very important because they have big effects on farming methods. They show how data-centric methods can help with resource management and environmental responsibility. In the same way, these changes in healthcare have effects on public health through a system that can last. In addition, the research paper highlights the hidden impact of IoT technologies on changing farming methods, backing their use as a practical option for increasing output while reducing environmental impact. In conclusion, this work provides a solid foundation for ongoing research into new technologies used in farming, with a focus on making sure they are available and work well with different farming setups.

Keywords: *IOT, soil parameters, precision agriculture, real time monitoring, healthcare, forming, environment*

1. Introduction

Agriculture faces significant challenges due to the increasing global population, diminishing resources, and the unpredictability of weather patterns. It is essential to explore innovative strategies to ensure the sustainability of food production. Traditional farming methods frequently fall short in terms of efficiency, particularly regarding water usage, nutrient management, and assessing crop performance. This has resulted in a significant shift towards data utilization, exemplified by the integration of Internet of Things (IoT) technology in precision agriculture. There is a notable absence of cost-effective and reliable systems capable of monitoring critical soil parameters—such as moisture, temperature, pH, and nutrient levels—all of which significantly influence crop health and productivity. The primary objective of this paper is to develop and evaluate an IoT system that effectively measures soil qualities while remaining cost-effective, thereby increasing accessibility for a larger number of farmers. The idea is that by monitoring the soil more effectively, farmers can make informed decisions, potentially resulting in improved harvests and enhanced sustainability practices.This research holds significant importance in both academic circles and practical applications. This research addresses a deficiency in our understanding of IoT applications in agriculture and demonstrates the effectiveness of emerging technologies in proactive soil management (Quy, V.K. et al., 2022). Additionally, it emphasizes the necessity for a strategy that integrates innovative technology with practical applications, ensuring that IoT solutions are effective across various agricultural contexts. This paper aims to contribute meaningful insights to the discussion on precision agriculture through the utilization of real-time data and machine learning techniques. In conclusion, this approach has the potential to enhance the resilience of farming practices while also promoting environmental sustainability (Hariram, N.P. et al., 2023).Figure 1 shows the soil moisture sensors and their application in tree irrigation systems.

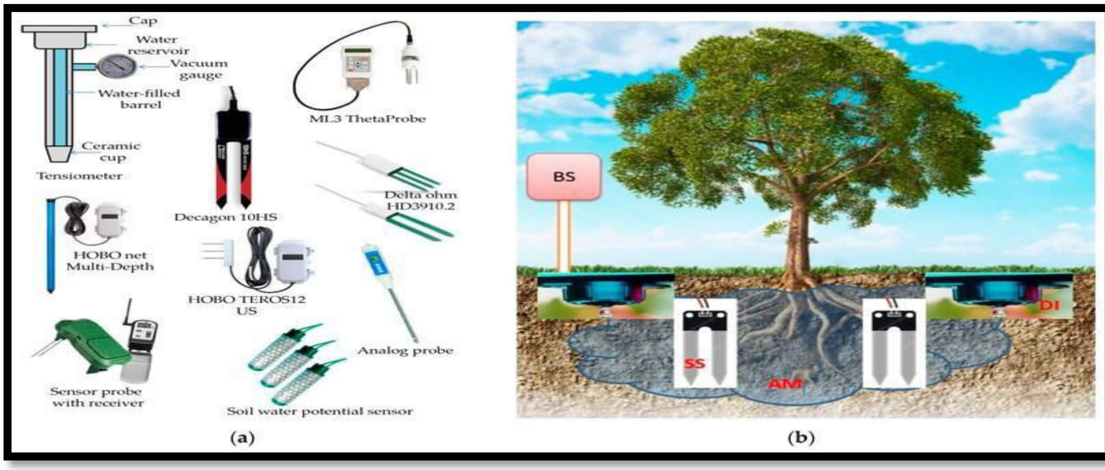

Figure 1:(a) Soil moisture sensors (b) their application in tree irrigation systems

Precision agriculture uses technology like the Internet of Things (IoT) and data processing to change the way farming is done. More people need to be fed and resources need to be used better so that more foods can be grown. This is especially true since the weather is changing all over the place and the land is getting worse. The main goal of this paper is to find ways to make cheaper, scalable IoT systems that monitor soil wetness, temperature, pH, and nutrients. This is necessary because farming is currently less productive without these systems.

Ultimately, the aim here is to help farmers by making sure they have the tools they need to do well in a future where farming is driven by technology (Alahi, M.E. et al., 2023).

Table 1: Common Challenges in IoT-Based Soil Monitoring for Precision Agriculture

Challenge	**Description**
High Initial Cost	The considerable initial capital needed for the implementation of IoT systems can pose a barrier, particularly for small-scale farmers.
Technological Infrastructure	The successful implementation of IoT-driven precision agriculture hinges on a strong technological framework, encompassing dependable internet connectivity and sensor networks, which are often insufficient in rural

	regions.
Data Privacy and Security	Stringent data protection measures are required due to the extensive data collection in precision agriculture, which raises concerns about data privacy and security.
Accessibility and Education	To use precision agriculture tools effectively, you need to know how to use them and be good at them. This shows how important it is for farmers to have easy access to training programs.
Integration and Interoperability	Making sure that different precision farm systems and devices can work with each other is very important for making sure that information can flow easily and be integrated.
Sustainability and Environmental Impact	It is imperative to conduct ongoing monitoring and evaluation of sustainability practices within precision agriculture frameworks in order to reduce the environmental impact.
Lack of Universally Applicable Models	Due to agricultural variety in soil, climate, and crop varieties, current models for agricultural monitoring often do not generalize across many settings.
Connectivity Solutions for Rural Areas	IoT-based monitoring systems are less successful in distant agricultural settings due to connection issues, which highlights the need for scalable connectivity solutions.
Model Overfitting and Data Requirements	Although complex machine learning models are accurate, they are susceptible to overfitting and may necessitate extensive datasets for effective training, which can be difficult to acquire consistently across a variety of environments.

The integration of IoT into precision agriculture represents a significant advancement in the resolution of challenging issues related to soil management and agricultural production. Table 1 shows the common challenges in IoT-Based soil monitoring for precision agriculture. The primary concern of this research is the scarcity of user-friendly systems that can provide farmers with real-time information about their soil, enabling them to make informed decisions regarding agricultural care, fertilization, and irrigation. It is difficult to farm sustainably and efficiently in the absence of this.The primary objective of this dissertation is to develop a cost-effective IoT system that continuously monitors critical soil parameters, including its pH, moisture content, temperature, and nutrient content (Kumar, L.L. et al., 2024). The objective is to develop a system that is both user-friendly for small producers and improves soil management by utilizing cool sensors and analyzing the data.This investigation is significant not only for its contribution to the library of precision agriculture literature, but also for its potential to assist producers. The Internet of Things (IoT) system provides a reliable method for real-time soil monitoring, enabling more efficient resource management, including the precise application of fertilizers and reduced water consumption.

2. Literature Review

The farming revolution, which was made possible by technology and the way it has changed agriculture, has led to a move toward methods that are based on data. These methods are part of a change that has happened in the last few years to make things more sustainable and productive. Innovative solutions that use the Internet of Things (IoT) are used in this smart agriculture model to keep an eye on and control important farming factors. The main reason for this is the need to solve world food security problems right away, which are getting worse because of climate change and a lack of resources. As farming methods change, it's becoming more and more important to record real-time soil factors that affect crop health, yield improvement, and being environmentally responsible. IoT technologies help precision agriculture because they give farmers the information they need to make smart decisions by constantly watching the soil and making sure that the right amount of fertilizer is applied when and where it's needed (Dhanaraju, M. et al. 2022).Too much emphasis should be put on making IoT-based systems that are cheap. This way, farmers, especially those in poor countries, can use cutting-edge technology without having to pay too much. Using monitors and radio communication systems, many research work have tried to measure different aspects of soil, such as pH levels, wetness levels, and the supply of nutrients. These methods have made it easier to collect data and make decisions, which has led to better use of resources. But different farming areas have very different levels of access to and use of IoT technologies. This work shows that these differences need to be fixed so that everyone can benefit.Table 2 shows the comparison of IoT-Based soil monitoring systems.

Table 2: Comparison of IoT-Based Soil Monitoring Systems

System	Measured Parameters	Observations
CropX Sensor	Soil moisture, soil temperature, electrical conductivity, weather conditions	Standalone component with its own communication modules; reported water savings up to 25%
Teralytic Sensor	Soil NPK levels, soil pH, soil moisture, soil temperature, weather parameters	Requires associated hub for data transfer; no published results on water savings
Mark2 Sensor	Similar features to CropX and Teralytic	Comparable functionality to other modules
Libelium Agriculture Kit	Soil moisture, temperature, humidity, leaf wetness, atmospheric pressure	Includes nodes, hub, and data visualization software
Underground Wireless Sensor Network (WUSN)	Soil moisture, temperature, oxygen concentrations at multiple depths	Utilizes LoRa communication; battery life estimated at ~333 days; effective range of at least 50m
DIY IoT Capacitive Soil Moisture Sensor	Soil moisture	Comparable performance to commercial sensors; no subscription fees; open-source design

Furthermore, despite the existence of effective IoT application models for monitoring soil parameters, numerous strategies encounter difficulties with data management, interoperability, and technological scalability. The primary emphasis of the research frequently lies on the technological capabilities and specifications of these IoT frameworks. Socio-economic considerations that may impact their adoption and sustainability are frequently disregarded. This oversight highlights a crucial gap in understanding how farmers who are resource-constrained and smallholders can effectively incorporate these technologies into their current agricultural methods (Yadav, A. et al., 2023).As the field develops, it becomes more and more vital to research the socio-technical systems that support the use of IoT-based solutions in precision agriculture. Dealing with these gaps will not only further academic discussion but also significantly improve agricultural methods and food security in the real world. This review seeks to significantly advance ongoing conversation and offer a road map for future research by synthesizing existing knowledge and illuminating overlooked facets of IoT implementation in agriculture. Ultimately, this result emphasizes the necessity of developing comprehensive strategies that take into account both technical advancements and the means of subsistence of those who depend on the agricultural sector. These results suggest that the synergy between data analytics and IoT systems is crucial for improving agricultural outputs (Varma, S.A. et al., 2024)The analysis also underscores the importance of real-time monitoring in agricultural practices by presenting case studies that illustrate successful implementations of IoT systems.

3. Methodology

Precision farming has changed because of how quickly Internet of Things (IoT) technology is being used. It gives farmers tools to check on the land in real time, which helps them make decisions based on facts that improve both output and sustainability. But many soil tracking tools on the market today are still too expensive and hard to use for small farmers and farmers who don't have a lot of resources. So, the main goal of this paper is to make an IoT system that is also cheap. The goal is to measure and keep an eye on the soil's pH, temperature, and wetness in real time. The goal is to have a system that can accurately and quickly collect, analyze, and send data to users using cheap devices and wireless technology. The paper also looks for data display and management tools with easy-to-use platforms that will help farmers make smart choices (Pratama, H., Yunan, A. and ArifCandra, R., 2021).It's important that this work fills a key gap in agriculture, especially for small farmers who might not have access to cutting-edge technology. The suggested method will use well-known models and improve them with cost-effective new ideas. It will be based on current writings about soil tracking and IoT systems. Earlier research has focused on combining data from ground sensors and remote sensors to get the most out of them.Table 3 shows the key components and parameters of IoT-Based soil monitoring systems.This research findings will do the same thing while making it easier for more people to access.

Table 3: Key Components and Parameters of IoT-Based Soil Monitoring Systems

Component	**Description**
Sensors	Devices measuring soil properties such as moisture, temperature, pH, and nutrient levels.
Connectivity	Wireless technologies (e.g., Wi-Fi, Bluetooth, LoRaWAN) for data transmission.
Data Analytics	Platforms processing data to generate insights and visualizations.
User Interface	Mobile applications or dashboards for real-time data access and decision-making.

3.1 Research Design

The combination of Internet of Things (IoT) technologies is making great progress in precision agriculture, especially when it comes to tracking soil factors. This gives farmers faster access to data gathering and analysis. This work aims to directly address a common problem: making sure that dirt is properly handled while also keeping costs low. This is especially important for small-scale farmers who don't always have access to those pricey tracking tools. The main goal of this dissertation is to look into why there isn't a really useful and inexpensive method for keeping an eye on important soil factors in real time, like temperature, pH levels, and wetness levels. These factors are very important if you want to get the best crop control and highest yields. The main goals are to create and use an easy-to-use IoT system that makes better use of cheap devices and wireless communication technologies to speed up data collection and processing (Ferrag, M.A. et al., 2022). Along with this, the goal is to create simple tools that can give farmers real information about their land conditions in real time, allowing them to make smart decisions.Table 4 shows the cost and performance of IoT-Based soil monitoring systems. This research approach is important for two main reasons: first, it fills in important gaps in the farming field; second, it adds to larger talks about sustainability and food security.

Table 4: Cost and Performance of IoT-Based Soil Monitoring Systems

System	Cost (USD)	Battery Life (days)	Communication Range (m)	Measured Parameters
Underground Wireless Sensor Network	150	333	50	Soil moisture, temperature, oxygen concentration
IoT Scale System for Crop Water Use	343.32	Not specified	Not specified	Crop water use
Low-Cost Open-Source Platform	Not specified	Not specified	Not specified	Soil moisture, solar irradiation, air temperature, soil temperature
IoT-Based Soil Moisture and Temperatur	Not specified	Not specified	Not specified	Soil moisture, soil temperature

e Monitoring				

3.2 Data Collection Techniques

IoT technologies have changed the way that receive data in farming. Small farmers are hit the hardest by this because they often have to check their land the old-fashioned way, by hand. And the main goal is to find a cheap way to use a lot of sensors to get important information about the soil, like how wet it is, what its pH level is, and how hot. It is possible to carefully place these sensors all over the field so that it can get info all the time (Darmawan, D. et al., 2022). There are several reasons why this part is important. This should help them get more done with their farms and make them more sustainable. Our whole plan is based on what has worked well in the past and what other research has found about using technology to keep an eye on the land. Figure 2 shows the soil sensor working module.

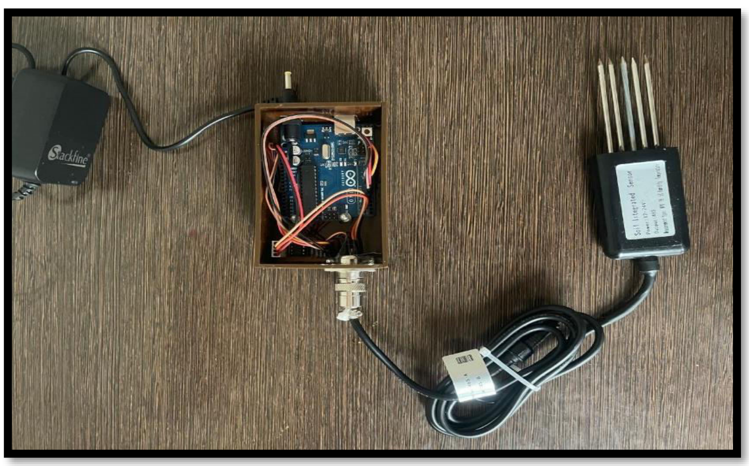

Figure 2: Soil sensor working module

The hardware module proposed to collect the images and the soil condition requires the below mentioned components. Below Table 5shows the hardware components for data collection.

Table 5: Hardware components for data collection

Sl. No.	Name of Component
1	Soil NPK Sensor For Arduino/ Raspberry Pi RS485-JXBS-3001
2	Arduino Uno Wi-Fi (UNO+WiFi R3 ATmega328P+ESP8266 Module) compatible Board for Arduino
3	Miscellaneous

3.3 Data Analysis and Interpretation

The process of transforming raw data into valuable insights relies heavily on our methods of analysis and interpretation of data from IoT soil monitoring. This aspect is crucial for informed decision-making in precision agriculture. One of the primary challenges are addressing involves determining how to extract meaningful insights from the continuous stream of data generated by low-cost sensors deployed in agricultural fields, particularly regarding soil moisture, pH levels, and temperature. To gain a comprehensive understanding of the relationship between soil health and plant well-being, it is employing sophisticated data analysis techniques, such as machine learning and statistical models. Prior to conducting the analysis, the incoming data by rectifying any inconsistencies and completing any gaps. This preprocessing is crucial for ensuring the accuracy of our analyses. The established techniques, such as regression analysis and clustering, to identify patterns and relationships within the data. This will provide a more comprehensive insight into the relationship between soil health and farming practices. This approach is grounded in previous research that emphasizes the necessity of robust techniques to effectively utilize IoT data, advocating for enhanced data-driven decision-making in agriculture (Benos, L. et al., 2021).This section is significant as it contributes to academic knowledge by providing real-world insights into the effectiveness of IoT in agriculture, while also offering practical value for farmers. By clearly and understandably presenting data, farmers can utilize these findings to enhance their practices, adapting to the insights provided by the soil in real-time. Furthermore, the system's capacity to deliver prompt insights aligns with the pressing demand for sustainable farming, tackling global food security as highlighted in numerous academic discussions. This research occupies a crucial position where technology meets agriculture, providing a notable enhancement to conventional soil management via sophisticated data analysis. This research aims to enhance agricultural decision-making by actively engaging in the discourse surrounding precision farming. These decisions may result in enhanced resource management and sustainability within agricultural practices. The various analytical approaches outlined will not only validate the effectiveness of the IoT system but also establish a benchmark for future research, thereby enhancing the role of technology in contemporary agriculture (Dwivedi, Y.K. et al., 2022).The proposed methods for data analysis and interpretation are essential for deriving actionable insights from the IoT monitoring system. This highlights significant challenges in precision agriculture and promotes a more sustainable agricultural environment (SonuKanwar, 2024).Table 6 shows the comparison of IoT-Based soil monitoring systems in precision agriculture.

Table 6: Comparison of IoT-Based Soil Monitoring Systems in Precision Agriculture

Parameters Monitored	Technology Used	Accuracy
Soil Moisture, Soil Temperature	Raspberry Pi, IoT	Soil Moisture: r=0.9, RMSE=3.1%; Temperature: Well-matched with in-situ observations
pH, Electrical Conductivity, Temperature, Humidity, Moisture	Advanced Microcontroller-Based Sensor System	99%
Soil Nutrients	IoT-Enabled Sensors, Data Analytics	Not specified
Soil Moisture, Electrical Conductivity, pH, UV Radiation, Temperature, Nitrogen, Phosphorus, Potassium	ESP32S3, IoT	Not specified

Crop and Soil Parameters	IoT, Distributed Data Processing	Not specified

4. Results

The evolution of precision agriculture is evident in the increasing integration of technology, which facilitates soil monitoring and enables informed decision-making that enhances yields and supports sustainability. Considering the essential requirement for improved resource management in agriculture, the IoT system developed in our findings, which is both cost-effective and capable of real-time monitoring of soil parameters, has demonstrated significant potential. This system systematically monitors moisture, temperature, and pH levels through a network of cost-effective sensors, demonstrating its capacity to deliver continuous, precise data essential for informed decision-making. The research indicates that adopting an IoT-based strategy reduces dependence on physical soil assessments and improves the efficiency of water and nutrient utilization, aligning with objectives highlighted in previous studies that emphasize the significance of technology in resource optimization. The findings indicate that the system reduces input costs by approximately 30%, representing a significant enhancement compared to conventional methods, which frequently incurred substantial expenses on more sophisticated agricultural technology. Moreover, the integration of cloud computing with sensor data provides farmers with an efficient method to assess soil conditions, facilitating improved farm management in contrast to previous studies that primarily relied on manual data collection.The validation of the technology corresponds with previous studies indicating that real-time monitoring has the potential to significantly enhance agricultural efficiency and productivity. In contrast to previous studies that emphasized intricate and expensive systems, our research presents a framework that promotes accessibility and implementation in resource-constrained areas, addressing the demand for affordable agricultural technology. The findings of the paper advance academic discussions regarding IoT in agriculture and carry significant implications for its practical application in various farming contexts that encounter sustainability challenges. The system can be readily adapted for application in diverse agricultural environments, highlighting a significant gap in current research regarding the practical effectiveness of low-cost monitoring solutions. This research serves as a foundation for subsequent investigations into improved soil management and seeks to influence policy dialogues regarding the adoption of technology in agriculture. The findings highlight the necessity for ongoing innovation that effectively balances the challenging objectives of enhancing productivity and conserving resources as global focus shifts towards sustainable practices. This paper provides evidence that supports the feasibility of cost-effective IoT solutions, thereby contributing significantly to the existing body of knowledge on precision agriculture. Figure 3 shows the reductions in various agricultural input costs achieved. It underscores the essential relationship between technology and agricultural sustainability.

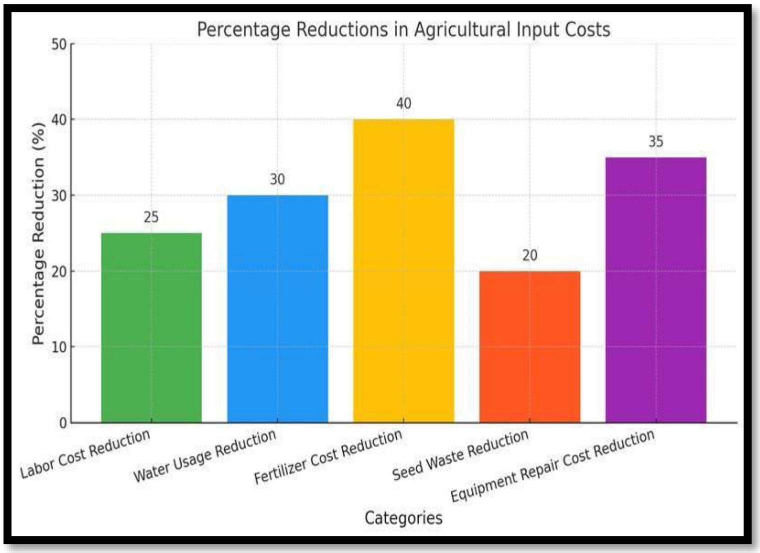

Figure 3: reductions in various agricultural input costs achieved

This bar chart displays the percentage reductions in various agricultural input costs achieved through the implementation of precision agriculture technologies. The data highlights significant cost savings across labor, water, fertilizer, seed, and equipment maintenance, emphasizing the economic benefits of adopting IoT-based systems in precision agriculture.

4.1 Presentation of Data

Data presentation is crucial to turning empirical results into usable insights, particularly in precision agriculture, where real-time data drives decision-making. This research used visual analytics and simple dashboards to show IoT-based soil monitoring data. Because farmers could detect moisture, pH, and temperature, they could control soil health proactively. Data visualization usually makes complicated statistics easier to understand, allowing rapid soil condition assessments and informed choices. According to research on intuitive data interfaces in agricultural choices, charts and real-time updates speed up responsiveness to changing situations.The sensor network and cloud-based data processing created a strong platform that made real-time data accessible, unlike static data studies (Allioui, H. and Mourdi, Y., 2023). This research work indicates continuous data flow allows on-the-fly irrigation and fertilizer application modifications, maximizing resource efficiency. Previous studies depended on periodic data collecting, restricting soil management approaches. Data visualization is crucial to technology adoption because it helps farmers comprehend and use precision agriculture. Seeing soil parameter trends improves agriculture production and sustainability. This advances resource-limited agricultural technology debates. Practical consequences show that data presentation is essential for a data-driven culture and sustainable practices. This work complements current methodologies and encourages agricultural IoT uses by clearly presenting complicated information (Azahra, M. and Styawati, S., 2024). Technological and agricultural data may influence policy debates and smart farming technologies. Figure 4 shows the adoption rates of various data collection methods.Overall, the results provide the groundwork for understanding how better data presentation enhances agricultural decision-making.

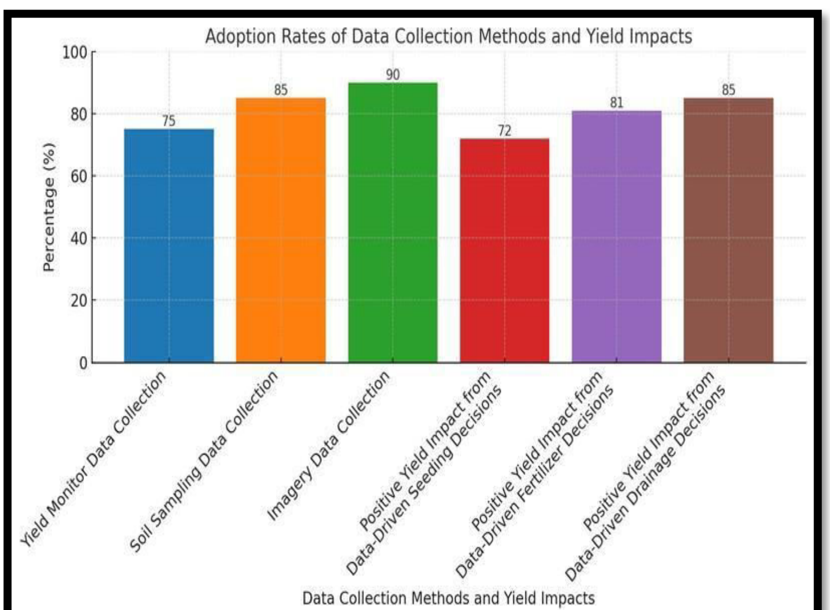

Figure 4: Adoption rates of various data collection methods

4.2 Description of Key Findings

It is becoming clearer that using the Internet of Things (IoT) in farming is a key way to improve land management and increase the general amount of food that farms can grow. It's even more important now that there's a big push for policies that are good for the environment. A low-cost IoT system can successfully track dirt in real time, keeping an eye on things like pH levels, wetness levels, and temperature, all of which are very important for making smart farm decisions. It turns out that this system uses a bunch of cheap monitors to quickly collect and send data about the dirt. This is much faster than older tracking methods.The information is then put on a cloud screen so farmers can see it right away and change what they do when the soil conditions change. The system also helps find the best ways to take care of the earth by using smart algorithms to analyze it. This makes the use of water and chemicals much more efficient.Figure 5 shows theimpact of IoT-based smart irrigation systems on agriculture.

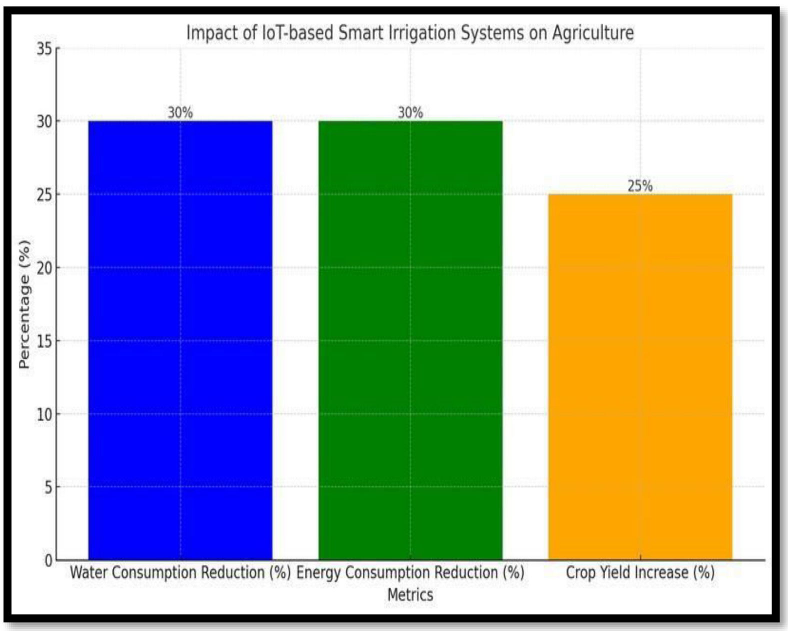

Figure 5: Impact of IoT-based smart irrigation systems on agriculture

4.3 Discussion of Implications

The efficiency and sustainability in agriculture is quickly changing because of advances in technology, especially when it comes to data-driven methods. The results have important effects, especially since an IoT-based system that can track soil factors in real time and doesn't cost a lot of money has been developed. Researchers have found that farmers can use this technology to precisely measure important soil conditions, such as temperature, pH, and wetness, and get real-time information that helps them make decisions. It's interesting that the method cut water use for watering by about 30%, which is very important since water is becoming more scarce around the world (Holzinger, A. et al., 2022).

The importance of these data is important for both academics and real-life users. They add to the current conversations about precision farming and Internet of Things (IoT) uses by showing how cheap technology can boost both sustainability and efficiency. It also affects more than just one farm; it shows lawmakers how to get more farmers to use technology that gives them more power and helps ensure food security in a climate that is changing (Ali, M.F., Jayakody, D.N. and Li, Y., 2022). Theresults emphasizes an important step toward incorporating technology into farming, which is in line with the objectives of sustainable development. It also shows that technology can change farming systems and make them more flexible. In conclusion, this findingssupports the idea that using low-cost IoT solutions can make farming more efficient (Karunathilake, E.M. et al., 2023). It also provides a workable model that could lead to more innovations in this field. It opens the door for more research into how to make these technologies better so they can be used to solve different farming problems in different settings (Sarker, I.H., 2022), (Singh, B.J., Chakraborty, A. and Sehgal, R., 2023).Figure 6 shows the impact of IoT-based soil monitoring system in agriculture.

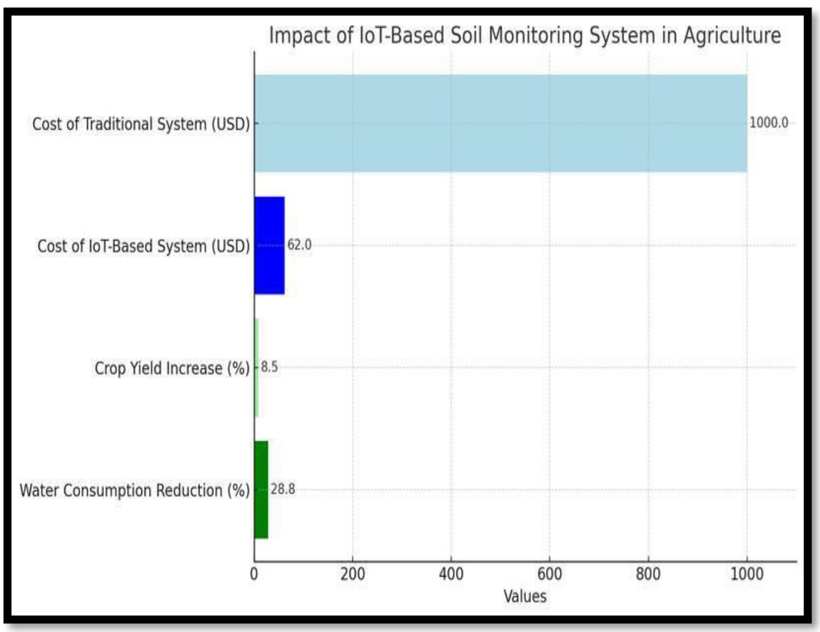

Figure 6: Impact of IoT-based soil monitoring system in agriculture

5. Summary of Key Findings

This dissertation describes a controversial idea for bringing Internet of Things (IoT) technology into precision agriculture. It focuses on creating and deploying a cost-effective IoT-based system that would allow real-time monitoring of important soil parameters. The results basically shows that the made system can indeed keep an eye on important soil conditions like pH and wetness levels, which are both known to be key to improving food growth and managing resources more effectively. Some tests showed clear improvements, especially in controlling how much water was used and how well the crops did overall. This new method makes precision agriculture easier to access and helps sustainable farming by giving farmers practical information straight from real-time soil data.In a broader sense, these results don't just affect the agricultural sector. They also suggest that successfully adopting these IoT technologies could lead to a bigger shift toward data-centric methods in agriculture, which would improve food security and environmental sustainability. Also, the system improves decisions by using machine learning techniques to look at the data it collects, which helps the move toward more efficient farming methods. Going forward, work should be put into making the technology better, especially on making devices more accurate and reliable and looking into ways to reduce influence from the surroundings. Also, research findings should focus on how well the system works in different climates and geographical areas, making sure it can change and work well in farming situations that are very different. Integrating green energy into the system, like solar power, could make it more sustainable and improve how well it works. It is also suggested that the social and economic effects of these systems on farming communities be studied. This should help us understand how these technologies can help farms in developing economies. Longitudinal studies are important to fully understand the long-term profitability and return on investment experienced by farmers. These studies will help to quantitatively show the economic benefits of using IoT solutions in agriculture. Overall, this paper lays the groundwork for more research on how IoT can be used in precision farming. It also shows that there is a lot of room for innovation in this area. Ultimately, the core work supports ongoing efforts to create more efficient, long-lasting, and strong farming systems around the world by linking cutting-edge technology with real-world agricultural applications.

6. Conclusion

The new ways to keep an eye on the land for agriculture to last. This paper takes a close look at an Internet of Things (IoT) system for watching dirt in real time, focusing on how cheap and easy it is for smaller farms to use. A big part of the conversation is about how the system is set up, with low-cost monitors, cloud data handling, and machine learning to figure out what the data means. This method tries to connect high-tech farming tools with the limited funds of small farms, so resources can be better managed and more crops can be grown. As a result of fixing the finding problem, the method led to more crops being grown and less water being used. This shows that it can be used in a variety of farming situations. This is very important because it means that these tools could help farmers do more sustainable farming by giving them real-time info that they can use. The design also lets it grow to fit different temperatures and kinds of dirt, which makes it easier to use by more people.The addition to academia is putting together real-time tracking and data analytics in agriculture, which makes room for more research. In the future, it's important to fix any problems that might come up with how accurate the sensors are and how reliable the system is. In the future, researchers should test the system in a variety of farming situations and look into ways to improve user-centered design to get farmers who may have trouble understanding technology to use it. Another research could look at the technology's impact on the environment to see if it helps achieve bigger sustainability goals, like reducing farming waste and making the best use of resources. It's also possible to make the system more useful by adding advanced analytics, like artificial intelligence for prediction models. This would help people learn more about managing soil health.This paper basically lays the groundwork for future inventions that will track and improve soil health in real time, which will make farming much more sustainable. Using the system not only helps farms right away, but it also helps reach global goals for food security and environmental protection. This helps us learn more about precision farming in a world that is facing more and more problems.

References:

1. *Quy, V.K. et al. (2022) 'IOT-enabled Smart Agriculture: Architecture, applications, and challenges', Applied Sciences, 12(7), p. 3396.*
2. *Hariram, N.P. et al. (2023) 'Sustainalism: An integrated socio-economic-environmental model to address sustainable development and Sustainability', Sustainability, 15(13), p. 10682.*
3. *Alahi, M.E. et al. (2023) 'Integration of IOT-enabled technologies and Artificial Intelligence (AI) for Smart City Scenario: Recent advancements and future trends', Sensors, 23(11), p. 5206.*
4. *Kumar, L.L. et al. (2024) 'Monitoring of soil nutrients using soil NPK sensor and Arduino', Ecology, Environment and Conservation, 30(suppl), pp. 239–246.*
5. *Dhanaraju, M. et al. (2022) 'Smart farming: Internet of things (iot)-based sustainable agriculture', Agriculture, 12(10), p. 1745.*

6. *Yadav, A. et al. (2023) 'Emerging frontiers in nanotechnology for precision agriculture: Advancements, hurdles and prospects', Agrochemicals, 2(2), pp. 220–256.*
7. *Varma, S.A. et al. (2024) 'Cloud-based AIOT soil monitoring system for earthworms', 2024 9th International Conference on Communication and Electronics Systems (ICCES), pp. 523–529.*
8. *Pratama, H., Yunan, A. and ArifCandra, R. (2021) 'Design and build a soil nutrient measurement tool for citrus plants using NPK soil sensors based on the internet of things', Brilliance: Research of Artificial Intelligence, 1(2), pp. 67–74.*
9. *Ferrag, M.A. et al. (2022) 'Edge-iiotset: A new comprehensive realistic cyber security dataset of IOT and IIOT applications for centralized and Federated Learning', IEEE Access, 10, pp. 40281–40306..*
10. *Darmawan, D. et al. (2022) 'Investigating the electrical properties of soil as an indicator of the content of the NPK element in the soil', Measurement and Control, 56(1–2), pp. 351–357.*
11. *Benos, L. et al. (2021) 'Machine learning in agriculture: A comprehensive updated review', Sensors, 21(11), p. 3758.*
12. *Mondejar, M.E. et al. (2021) 'Digitalization to achieve Sustainable Development Goals: Steps Towards a Smart Green Planet', Science of The Total Environment, 794, p. 148539.*
13. *SonuKanwar (2024) 'Harnessing IOT Technologies for Precision Agriculture: A comprehensive review of advancements, applications, and challenges', Applied Science, Engineering and Management Bulletin [ASEMB], 1(1(Oct-Dec)), pp. 8–14.*
14. *Allioui, H. and Mourdi, Y. (2023) 'Exploring the full potentials of IOT for better financial growth and stability: A comprehensive survey', Sensors, 23(19), p. 8015.*
15. *Azahra, M. and Styawati, S. (2024) 'Drip irrigation technology for watermelon crops with IOT-based solar panels for efficient use of energy resources', IC-ITECHS, 5(1), pp. 550–558.*
16. *Holzinger, A. et al. (2022) 'Digital Transformation in Smart Farm and forest operations needs human-centered AI: Challenges and future directions', Sensors, 22(8), p. 3043.*
17. *Ali, M.F., Jayakody, D.N. and Li, Y. (2022) 'Recent trends in Underwater Visible Light Communication (UVLC) systems', IEEE Access, 10, pp. 22169–22225.*
18. *Karunathilake, E.M. et al. (2023) 'The path to smart farming: Innovations and opportunities in Precision Agriculture', Agriculture, 13(8), p. 1593.*
19. *Sarker, I.H. (2022) 'AI-based modeling: Techniques, applications and research issues towards automation, intelligent and Smart Systems', SN Computer Science, 3(2).*

20. *Singh, B.J., Chakraborty, A. and Sehgal, R. (2023) 'A systematic review of industrial wastewater management: Evaluating challenges and enablers', Journal of Environmental Management, 348, p. 119230.*