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IoT Based Soil Nutrients Monitoring Decision System

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Abstract: Conventional methods for monitoring soil nutrients are often labor-intensive and inefficient, relying on manual sampling and laboratory analysis, which delays necessary interventions and results in resource inefficiencies in agriculture. This study introduces an IoT-driven system for real-time soil nutrient monitoring and analysis, addressing these limitations. The system employs advanced sensors to measure essential soil parameters such as nitrogen, phosphorus, potassium (NPK), moisture, and pH levels. Sensor data is transmitted wirelessly to a cloud-based platform for continuous processing and analysis, offering immediate insights into soil conditions. The novelty of this approach lies in the integration of IoT technology, cloud computing, and data analytics to enable accurate and timely decisions for effective soil management. Unlike traditional or existing systems that lack real-time functionality or require substantial investments, this solution is cost-effective, scalable, and efficient. By delivering actionable insights, the system helps optimize fertilizer usage, improve crop productivity, and promote sustainable agricultural practices, ultimately contributing to enhanced resource management and increased yields.

➢ ***General Terms***

Conventional methods, soil nutrient monitoring, manual sampling, laboratory analysis, resource inefficiencies, IoT-driven system, real-time monitoring, soil parameters, sensor data, cloud- based platform, data processing and analysis, decision-making, effective soil management, traditional systems, cost-effective solutions, scalable systems, sustainable agricultural practices.

Keywords: *IoT (Internet of Things), Soil Nutrients, Nitrogen (N), Phosphorus (P), Potassium (K) (NPK), Moisture Levels, pH Levels, Cloud Computing, Data Analytics, Fertilizer Optimization, Crop Productivity, Smart Farming, Precision Agriculture, Agricultural Technology, Yield Enhancement, Real-Time Insights, Sensor Integration.*

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I. INTRODUCTION

The global agricultural sector is under increasing pressure to address challenges such as food security, climate change, and the sustainable use of natural resources. Among these, maintaining soil health plays a critical role in achieving optimal crop productivity. However, traditional methods of soil nutrient assessment are often inefficient and time-intensive, providing only limited, periodic information about soil conditions. With the rising demand for enhanced food production, there is a growing need for precise, real-time soil monitoring solutions that can improve resource management and boost agricultural yields. The advent of the Internet of Things (IoT) has opened up new opportunities for revolutionizing agricultural practices by enabling continuous data collection and real-time monitoring of soil health. IoT-based systems can measure essential parameters such as soil nutrients, moisture, and pH, providing valuable insights for optimizing crop management. Despite the advancements in smart farming, existing IoT applications in soil nutrient management often lack comprehensive integration with data analytics platforms capable of delivering actionable insights to farmers.

Recent developments in IoT technology, particularly in communication infrastructure, have significantly benefitted the agricultural sector, enabling more efficient monitoring and management of crops. Farmers, who traditionally face challenges in monitoring soil conditions across large fields, can now leverage IoT sensors to detect unfavorable conditions and nutrient deficiencies with greater accuracy. These sensors continuously track key soil properties, such as temperature, moisture, pH, and nutrient levels like nitrogen, phosphorus, and potassium, and store this data in the cloud for easy access via mobile or computer devices.

The integration of IoT and smart agriculture supports precise spatial management, reducing the overuse of

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fertilizers and promoting sustainable farming practices. By adopting these technologies, farmers can enhance crop yields, conserve natural resources, and contribute to reducing greenhouse gas emissions— ultimately fostering a more sustainable and resilient agricultural-ecosystem.

II. METHODOLOGY

The proposed system employs Internet of Things (IoT) technology to create a real-time soil nutrient monitoring and analysis framework. Key components of this system include the Arduino Uno Rev3, ESP32S microcontroller, and the ThingsBoard cloud platform, which collectively enable seamless data collection, processing, and visualization. The Arduino Uno functions as the primary unit for receiving input from various sensors, such as NPK sensors for nitrogen, phosphorus, and potassium levels, soil temperature sensors, soil moisture sensors, and pH sensors. These sensors measure critical soil parameters, and the Arduino processes this data before transmitting it to the ESP32S. The ESP32S, equipped with a Wi- Fi module, acts as a bridge between the Arduino and the cloud platform. It receives data from the Arduino and uploads it to the ThingsBoard cloud, where the information is stored and made accessible for further analysis. Farmers can easily access this cloud-stored data using mobile devices or computers. The data is continuously updated and analyzed using predefined crop-specific nutrient values coded into the Arduino. This allows for real- time feedback on soil conditions, helping farmers make informed decisions on irrigation scheduling, fertilizer application, pH adjustments, and other agronomic practices. Additionally, the system enhances on-site monitoring by providing immediate visual feedback through an LED indicator strip, which helps farmers quickly evaluate soil health and take necessary actions. This integrated system not only improves crop management practices but also promotes sustainable agriculture by reducing resource wastage and optimizing inputs for better yields.

III. PROPOSED METHOD

The integration of Internet of Things (IoT) technology in agriculture has revolutionized traditional farming practices by enabling real-time monitoring and precise data analysis. IoT systems offer continuous soil condition monitoring, facilitating data collection on critical parameters such as nutrient levels, moisture, temperature, and pH. This information empowers farmers to make informed decisions, optimizing farming techniques to improve crop yields and promote sustainability.

An IoT-based soil monitoring system relies on interconnected components that work seamlessly to capture, process, and transmit soil data for immediate analysis. By employing a combination of sensors and microcontrollers, such as NPK sensors, temperature sensors, and soil moisture sensors, the system ensures accurate measurement of soil parameters essential for crop health. These sensors feed data into platforms like Arduino and ESP32, which process and transmit the information wirelessly to cloud platforms such as ThingsBoard.

The processed data is then made accessible through user-friendly dashboards on mobile devices or computers, enabling farmers to remotely monitor soil conditions and make well-informed adjustments to irrigation, fertilization, and other agricultural practices. By leveraging IoT platforms, the system not only simplifies soil monitoring but also encourages sustainable land management and resource efficiency. Moreover, advancements in sensor technology, the incorporation of predictive analytics, and the adoption of renewable energy sources, such as solar power, enhance the system's capabilities and reliability. This IoT-driven approach to precision agriculture addresses critical factors such as scalability, cost-effectiveness, energy efficiency, and accuracy, contributing to a future of more sustainable and productive farming.

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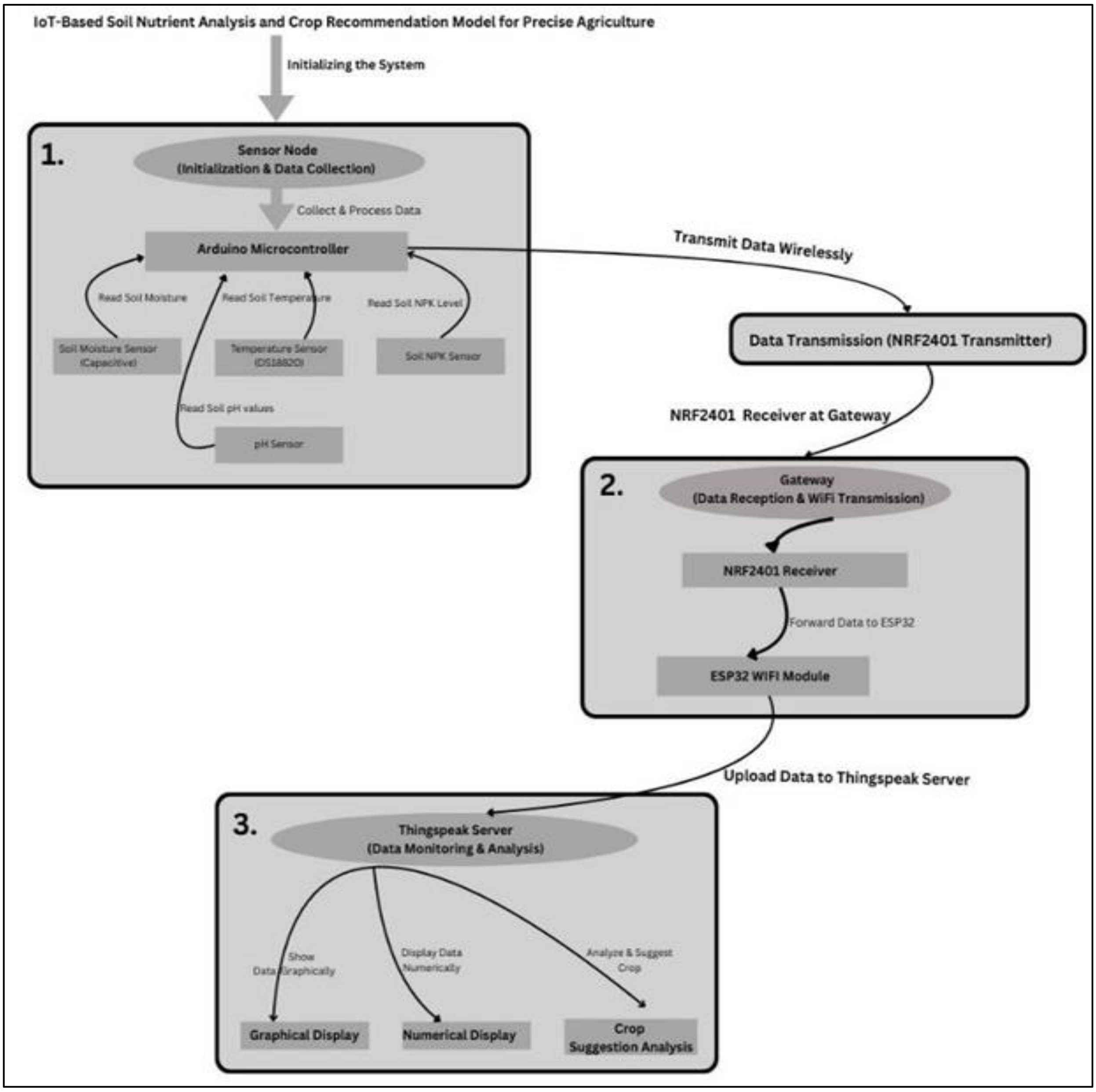

Fig 1 IoT-Driven Approach

IV. LITRATURE REVIEW

Advancements in agriculture have led researchers to explore various strategies, structures, and technologies tailored to different crops and field conditions for efficient monitoring and communication of crop information during growth stages. IoT technology has emerged as a key enabler in this domain, facilitating enhanced agricultural productivity through real-time data collection and analysis.

Raneesha Madhushanki, A.A., highlights the role of IoT in agriculture, emphasizing its ability to gather and analyze sensor data to boost productivity while reducing manual labor. Among the applications of IoT, water management has been identified as the most significant subdomain, followed by crop management, smart farming, animal monitoring, and irrigation. Key parameters like environmental temperature, humidity, soil moisture, and pH levels were found to have the most influence on sensor data, With Wi-Fi being the most widely used communication technology in agriculture [1].

N. Misra, in the study *"Internet of Things (IoT) in Agriculture: Applications, Challenges, and Future Directions,"* provides a comprehensive review of IoT applications, such as precision farming, crop monitoring, and smart irrigation, while also addressing implementation challenges and future research needs [2]. Similarly, S. Mukherjee et al., in their work on recent advances in IoT technologies for precision farming, highlight the roles of wireless sensor networks (WSNs), cloud computing, and data analytics in enhancing agricultural productivity and sustainability [3].

Precision agriculture, as reviewed by R. Kaur et al., emphasizes technologies like GPS, GIS, remote sensing, and IoT for improving resource efficiency, crop yield, and environmental sustainability [4]. S. Singh et al., in their

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paper on WSNs in agriculture, discuss case studies showcasing the use of sensor networks for monitoring soil conditions, crop growth, and environmental factors while addressing challenges and opportunities [5]. M.K. Patel et al., in their study *"IoT-Based Smart Agriculture: Toward Making the Fields Talk,"* provide an overview of IoT-based systems, focusing on sensor technologies, communication protocols, and data analytics, accompanied by case studies illustrating their applications [6].

Traditional soil testing methods, while informative, are often labor-intensive, costly, and limited by spatial and temporal inconsistencies in soil properties. This leads to challenges in maintaining optimal soil health, directly impacting crop productivity and environmental sustainability. Addressing these limitations, researchers are focusing on IoT-based solutions that enable real- time monitoring and analysis of critical soil nutrients such as nitrogen, phosphorus, and potassium.

By leveraging IoT sensors, cloud computing, and data analytics, these systems aim to optimize fertilizer usage, enhance crop yield predictions, and support sustainable farming practices. This research aims to design and implement a low-cost, scalable IoT solution for real-time soil health monitoring, providing farmers with actionable insights through a data-driven decision-support system. Through such innovations, IoT-driven approaches are expected to revolutionize agriculture by reducing input costs, minimizing environmental impact, and promoting resource-efficient and sustainable farming practices.

V. CONCLUSION

This study introduces an integrated soil monitoring system that marks a substantial leap forward in precision agriculture. The system provides farmers with a robust tool for real-time observation and management of soil health. Utilizing Arduino and ESP32 platforms, combined with a variety of sensors such as NPK, temperature, soil moisture, and pH sensors, it enables accurate detection and evaluation of essential soil parameters critical for crop development and yield. By offering detailed and actionable insights, this system equips farmers to adopt data-driven approaches, enhancing efficiency, productivity, and sustainability in agricultural practices. Through continuous monitoring and analysis of soil properties, any nutrient imbalances—whether surplus or deficiency—can be detected. This paves the way for automating the precise delivery of nutrients, reducing the dependency on manual intervention.

REFERENCES

[1]. A.A. Raneesha Madhushanki, "IoT in Agriculture: Applications and Advancements," *Proceedings of the IEEE International Conference on IoT-Based Control Networks and Intelligent Systems*, 2024.
[2]. N. Misra, "Internet of Things (IoT) in Agriculture: Applications, Challenges, and Future Directions," *IEEE Access*, vol. 8, 2020.
[3]. S. Mukherjee, et al., "Recent Advances in IoT Technologies for Precision Farming," *Journal of Precision Agriculture Research*, vol. 9, no. 3, pp. 145-160, 2021.
[4]. R. Kaur, et al., "Precision Agriculture: Leveraging IoT and GIS for Sustainable Crop Management," *Environmental Systems Research*, vol. 10, no. 2, 2022.
[5]. S. Singh, et al., "Wireless Sensor Networks in Agriculture: Opportunities and Challenges," *International Journal of Agricultural Technology*, vol. 15, no. 4, 2023.
[6]. M.K. Patel, et al., "IoT-Based Smart Agriculture: Toward Making the Fields Talk," *Springer Smart Agriculture Series*, pp. 210-225, 2021.
[7]. P. Ponniah, Data Warehousing Fundamentals for it Professionals: Second Edition. 2010.
[8]. P. Rajalakshmi and S. Devi Mahalakshmi, “IOT based crop-field monitoring and irrigation automation,” in Proceedings of the 10th International Conference on Intelligent Systems and Control, ISCO 2016, 2016.
[9]. I. Mat, M. R. Mohd Kassim, A. N. Harun, and I. Mat Yusoff, “IoT in Precision Agriculture applications using Wireless Moisture Sensor Network,” in ICOS 2016 - 2016 IEEE Conference on Open Systems, 2017.
[10]. X. Zhang, J. Zhang, L. Li, Y. Zhang, and G. Yang, “Monitoring citrus soil moisture and nutrients using an IoT based system,” Sensors (Switzerland), 2017.
[11]. Recent Advances in Internet of Things (IoT) Technologies for Agriculture and Precision Farming by S. Mukherjee et al. (2020).
[12]. Precision Agriculture Techniques and Practices: A Review by R. Kaur et al. (2018).
[13]. Wireless Sensor Networks for Agriculture: A Review by S. Singh et al. (2017).