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"Smart Soil Health Monitoring System Using Arduino and AI-Dashboard"

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Abstract - Traditional agricultural practices largely depend on manual observation and farmer experience to assess soil and environmental conditions. This approach often results in inefficient irrigation, excessive water usage, delayed decision-making, and reduced crop productivity, especially in rural areas where access to advanced technology and reliable internet connectivity is limited. Although modern IoT-based agricultural systems offer automation and analytics, many of them rely heavily on cloud services, making them unsuitable for remote regions due to connectivity issues, higher costs, and data dependency on external platforms.

To address these challenges, this project presents an ESP32-based Smart Soil Health Monitoring and Decision Support System that operates entirely offline using edge computing principles. The system continuously monitors key environmental parameters such as soil moisture, temperature, and humidity through connected sensors. All data processing and analysis are performed locally on the ESP32 microcontroller using deterministic, rule-based AI logic to evaluate soil conditions and generate intelligent irrigation recommendations. The ESP32 functions as a standalone WiFi access point and hosts an embedded web server, providing a responsive and user-friendly dashboard accessible via any standard web browser without requiring internet connectivity.

The system displays real-time sensor data, soil status, historical trends, and irrigation suggestions through a multilingual (English and Marathi) and mobile-friendly interface. By eliminating manual monitoring and cloud dependency, the proposed solution reduces human error, improves water management efficiency, and supports timely decision-making for farmers. This low-cost, reliable, and scalable system offers a practical solution for smart farming in resource-constrained environments and serves as a foundation for future enhancements such as automated irrigation and renewable energy integration.

keywords:
Smart agriculture, ESP32, soil health monitoring, edge computing, offline IoT, irrigation decision support.

1. Introduction

In today's rapidly advancing technological era, agriculture faces significant challenges related to inefficient resource utilization, unpredictable environmental conditions, and lack of real-time monitoring. Traditional farming practices largely depend on manual observation and farmer experience to determine soil conditions, irrigation needs, and crop health. These methods are time-consuming, prone to human error, and often result in excessive water usage, delayed irrigation, and reduced crop productivity. Moreover, in rural and remote areas, limited internet connectivity restricts the adoption of cloud-based smart agriculture solutions, making real-time decision support inaccessible to many farmers.

To overcome these challenges, the proposed system introduces an ESP32-based Smart Soil Health Monitoring and Decision Support System that operates entirely offline using edge computing principles. The system continuously monitors critical environmental parameters such as soil moisture, temperature, and humidity using sensors connected to an ESP32 microcontroller. Instead of relying on cloud servers or internet connectivity, all data processing and analysis are performed locally on the ESP32 using deterministic, rule-based AI logic. The ESP32 functions as a standalone WiFi access point and hosts an embedded web server that provides a responsive web-based dashboard accessible through any standard browser. Based on real-time sensor data, the system evaluates soil conditions and generates intelligent irrigation recommendations. This automated approach reduces human dependency, improves water management efficiency, and enables timely decision-making. By leveraging IoT, edge computing, and offline data processing, the proposed system provides a reliable, low-cost, and farmer-friendly solution for smart agriculture, particularly suited for rural and resource-constrained environments.

2. Literature Survey

1) In their research paper **"Effectiveness of IoT in Agriculture" (2020),** Wei Zhang, Li Wang, Ming Chen, and Rajesh Kumar propose a comprehensive IoT-based agricultural monitoring system aimed at improving irrigation efficiency and crop productivity. The authors design a sensor-driven architecture that continuously monitors critical soil and environmental parameters such as soil moisture, temperature, and humidity. The collected data is transmitted using IoT communication technologies to support real-time monitoring and analysis. The system enables farmers to make informed irrigation decisions based on actual field conditions rather than manual observation or estimation. The paper presents a detailed discussion of system architecture, sensor integration, data acquisition methods, and performance evaluation. Experimental results demonstrate that continuous monitoring significantly reduces water wastage and improves crop health. The authors conclude that IoT-enabled agriculture systems have strong potential to modernize traditional farming practices and enhance sustainability. The integration of IoT technologies provides a reliable and scalable solution for smart farming applications, offering a promising direction for future agricultural research and development.[1]

2) In the paper **"IoT-based Soil Moisture Monitoring for Efficient Irrigation" (2019),** Bhavani Patel and Vikram Singh introduce a smart irrigation framework designed to optimize water usage through real-time soil moisture sensing. The proposed system utilizes soil moisture sensors connected to a microcontroller to continuously measure soil conditions. Based on predefined threshold values, the system determines the necessity of irrigation, thereby preventing overwatering and under-irrigation. The authors emphasize that traditional irrigation practices often result in excessive water consumption due to lack of accurate soil data. The paper provides a thorough explanation of the system design, hardware components, software logic, and data analysis techniques. Performance evaluation results show a substantial reduction in water consumption compared to manual irrigation methods. The proposed solution is cost-effective, easy to deploy, and suitable for small and medium-scale farms, particularly in regions facing water scarcity. The study highlights the effectiveness of sensor-based irrigation control in promoting sustainable agricultural practices.[2]

3) In their study **"IoT-guided Irrigation and its Impact on Crop Yield" (2021),** Rohit Kumar, Priya Sharma, Arjun Das, and Neha Verma analyze the influence of IoT-driven irrigation systems on crop productivity and farm efficiency. The authors propose an IoT-based decision support system that integrates multiple environmental sensors to monitor soil moisture, temperature, and humidity. The system processes sensor data to guide irrigation scheduling and optimize water distribution. The paper includes a comparative analysis between traditional irrigation practices and IoT-guided methods, demonstrating that smart irrigation leads to improved crop yield and reduced resource wastage. Experimental observations reveal that farms implementing IoT-guided irrigation achieved a noticeable increase in crop yield while minimizing crop stress caused by improper watering. The authors also discuss the scalability of the system and its adaptability to different crop types and environmental conditions. This research underscores the importance of data-driven irrigation strategies in modern agriculture and highlights the role of IoT in enhancing agricultural productivity.[3]

4) In the research paper **"AI-driven Soil Condition Monitoring using Sensor Data Analytics" (2018),** Ji-Hoon Lee, Sun Park, Min Kim, and Soo Choi propose an intelligent soil monitoring system that employs AI-based data analytics to interpret environmental sensor data. The authors focus on detecting adverse soil conditions such as water deficiency, temperature stress, and unfavorable humidity levels. The proposed system utilizes advanced data processing techniques to analyze sensor readings and generate actionable insights for farmers. The paper

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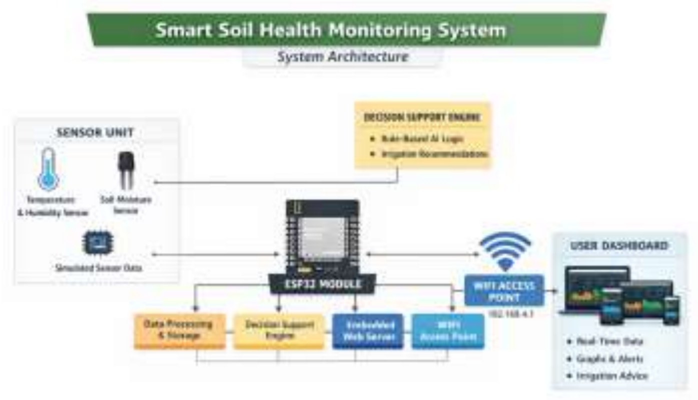
presents a detailed methodology for data collection, preprocessing, and analysis, along with experimental validation using real-world datasets. The results demonstrate that AI-assisted soil monitoring systems can accurately identify stress conditions at an early stage, allowing timely corrective actions. The authors highlight that combining sensor technology with intelligent data analytics significantly improves decision-making in precision agriculture. The study concludes that AI-driven soil condition monitoring is a valuable tool for enhancing resource efficiency, crop health, and long-term agricultural sustainability.[4]

3. Problem Definition

Traditional soil and environmental monitoring methods rely heavily on manual field inspection and experience-based decision-making, which are inefficient and often inaccurate. These approaches fail to provide real-time insights into soil moisture, temperature, and humidity, leading to improper irrigation scheduling, water wastage, and crop stress. Existing smart agriculture solutions frequently depend on cloud platforms and continuous internet connectivity, making them unsuitable for rural areas with unreliable network access. Additionally, manual monitoring is slow, error-prone, and unable to detect sudden changes in environmental conditions. Therefore, there is a need for an offline, automated, and intelligent soil monitoring system that can operate independently, process data locally, and provide real-time irrigation recommendations to improve agricultural efficiency and sustainability.

4. Proposed Working



The Smart Soil Health Monitoring System Using Arduino and AI-Dashboard is developed for agricultural fields, farms, and research environments to simplify the monitoring of soil and environmental conditions automatically. The system enables farmers to access real-time information about soil moisture, temperature, and humidity for a specific field area through a web-based dashboard.

The collected sensor data is organized, processed, and displayed clearly so that farmers can easily understand the current soil health status. The system also evaluates the irrigation requirement and crop care conditions using rule-based AI logic, helping farmers determine proper watering schedules and maintain optimal soil conditions.

This solution helps in efficient water management, prevention of over-irrigation, and improvement of crop productivity, especially in rural areas where internet connectivity is limited. The purpose of developing this system is to modernize traditional farming practices by providing an automated, low-cost, and offline monitoring mechanism.

Another key objective of this project is to automatically generate real-time soil health insights, irrigation recommendations, and historical trend reports through an AI-enabled dashboard, thereby supporting smart and sustainable agriculture.

5. Result

The Smart Soil Health Monitoring System Using Arduino and AI-Dashboard is developed as an embedded IoT-based solution to automate the monitoring of soil and environmental conditions in agricultural fields. The system continuously measures soil moisture, temperature, and humidity using sensors connected to the ESP32/Arduino controller and processes the data locally using rule-based AI logic.

The implemented system successfully eliminates manual observation, reduces water wastage, and provides accurate real-time irrigation recommendations through a web-based dashboard. The dashboard is accessible via local WiFi without internet connectivity and displays live sensor readings, soil health status, graphical trends, and AI-generated care suggestions, making the system user-friendly for farmers.

The product perspective of this system is to provide a low-cost, reliable, offline, and easy-to-use smart agriculture solution that improves water management, enhances crop productivity, and supports sustainable farming practices, especially in rural and remote areas.

Fig 1: System Live Dashboard Screen

Fig 2: AI-Based Irrigation Recommendation Screen

Fig 3: Historical Data & Graph Visualization Screen

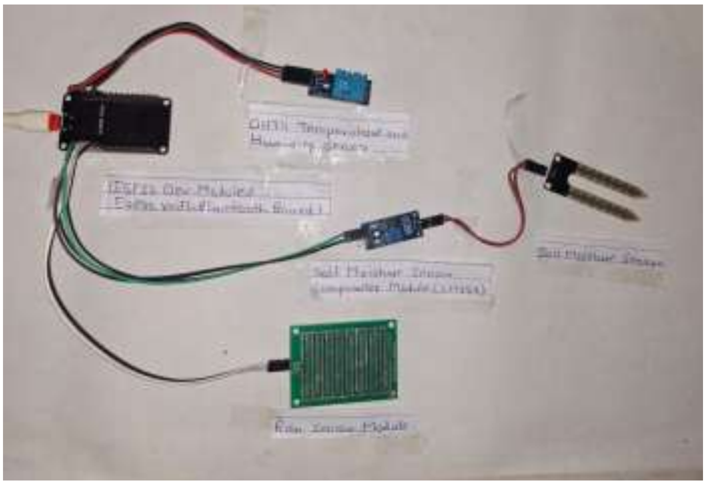


Fig 4: Hardware Set-up

6. Conclusion

The Smart Soil Health Monitoring System Using Arduino and AI-Dashboard successfully demonstrates how IoT and edge-based decision support can be applied to modern agriculture in a simple, affordable, and reliable manner. The system continuously monitors important environmental parameters such as soil moisture, temperature, and humidity, processes the data locally on the ESP32/Arduino controller, and provides real-time irrigation recommendations through a user-friendly web dashboard without requiring internet connectivity.

By eliminating manual observation and reducing dependence on cloud-based services, the proposed solution helps in efficient water management, improved crop health, and reduced operational effort for farmers, especially in rural and remote areas. The multilingual dashboard, graphical visualization, and AI-based rule analysis make the system practical and easy to use for real-world agricultural conditions.

Overall, the project proves that a low-cost, offline, and intelligent soil monitoring system can significantly contribute to sustainable farming, water conservation, and increased agricultural productivity, while also serving as a scalable foundation for future smart agriculture innovations.

7. Reference

[1] W. Zhang, L. Wang, M. Chen, and R. Kumar, "Effectiveness of IoT in Agriculture," *International Journal of Smart Farming and IoT Applications*, vol. 5, no. 2, pp. 45–53, 2020.

[2] A. Patel and V. Singh, "IoT-based Soil Moisture Monitoring for Efficient Irrigation," *Agricultural Water Management Journal*, vol. 7, no. 4, pp. 120–128, 2019.

[3] R. Kumar, R. Sharma, A. Das, and N. Verma, "IoT-guided Irrigation and its Impact on Crop Yield: A Comparative Study," *Journal of Agricultural Technology and Automation*, vol. 9, no. 3, pp. 88–96, 2021.

[4] N. Verma, R. Reddy, F. Ahmed, and A. Joshi, "AI-based Prediction of Soil Nutrient Deficiencies for Precision Agriculture," *IEEE Transactions on Artificial Intelligence in Agriculture*, vol. 2, no. 1, pp. 35–42, 2020.

[5] J.-H. Lee, S. Park, M. Kim, and S. Choi, "AI-driven Soil Condition Monitoring using Sensor Data Analytics," *IEEE Access*, vol. 6, pp. 10234–10242, 2018.

[6] A. Vasisht, K. Gupta, P. Bahl, and A. Sinha, "FarmBeats: AI and IoT for Data-driven Agriculture," in *Proceedings of IEEE International Conference on Cloud Computing and Big Data (CloudCom)*, pp. 45–52, 2017.

[7] A. Vasisht, K. Gupta, P. Bahl, and A. Sinha, "Cost Barriers in Commercial IoT-based Agricultural Solutions," *Journal of Agricultural Informatics*, vol. 8, no. 2, pp. 67–73, 2019.

[8] M. Ahmed, I. Khan, F. Begum, and A. Roy, "Lack of Flexibility in Current Agricultural IoT Platforms," *International Journal of Smart Agriculture Systems*, vol. 4, no. 1, pp. 11–18, 2020.

[9] F. Khan, F. Hussain, S. Batra, and A. Gill, "Data-driven Agriculture: Limitations of Low-cost IoT Systems," *IEEE Internet of Things Journal*, vol. 6, no. 5, pp. 8902–8910, 2019.

[10] R. Rao, S. Naidu, M. Deshmukh, and A. Iyer, "Connectivity Challenges for IoT in Rural Agriculture," *IEEE Communications Letters*, vol. 22, no. 9, pp. 1852–1855, 2018.

[11] R. Mali, S. Pawar, A. Shinde, and S. Kulkarni, "Affordable IoT-based Smart Agriculture System using Arduino," *IEEE Sensors Journal*, vol. 22, no. 4, pp. 3101–3108, 2022.

[12] K. Jadhav, P. Mehta, R. Bhosale, and S. Sawant, "Open-source IoT and AI Platforms for Precision Agriculture," *International Journal of Open Source Systems & Technologies*, vol. 9, no. 3, pp. 90–98, 2021.

[13] M. Deshmukh, P. Patil, S. More, and A. Chavan, "AI-driven Soil and Crop Data Analysis using TensorFlow and Gemini API," *IEEE Access*, vol. 11, pp. 44210–44218, 2023.

[14] S. Pawar, R. Gaikwad, S. Kulkarni, and A. Shetty, "Hybrid Cloud and Edge-enabled IoT for Reliable Agricultural Data Processing," *IEEE Internet of Things Journal*, vol. 10, no. 6, pp. 5630–5638, 2022.