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SOIL-MAS - IoT-Based Soil Nutrient Monitoring System

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1. Product Description

SOIL-MAS (Soil Nutrient Monitoring & Analysis System) is an IoT-based smart farming solution designed to help farmers monitor soil nutrients and environmental conditions in real time. The system utilizes sensors to measure critical parameters, including nitrogen, phosphorus, potassium (NPK), soil moisture, pH level, EC, temperature, and humidity. These readings are then transmitted to cloud dashboards using platforms such as Node-RED and Grafana. Farmers can view this data through user-friendly dashboards and even receive alerts through a Telegram bot. By providing timely insights, SOIL-MAS empowers farmers to make better decisions about crop management, reduce unnecessary fertilizer use, and improve yields in a sustainable way. The prototype was tested on chili crops, but it can be applied to other agricultural settings, making it a versatile tool for precision farming.

2. Innovation Objectives

The main objectives of SOIL-MAS are to bring the power of IoT and data analytics into the hands of local farmers. This project aims to develop IoT devices that can accurately detect soil nutrients and environmental factors that influence crop health. It also wanted to collect and analyze data in real time, which could provide farmers with actionable insights for decision-making. The system is designed to reduce the overuse of fertilizers and water, ensuring cost savings and environmental protection. It is believed that by achieving these objectives, it will increase crop yield and sustainability by encouraging data-driven farming practices. Through these goals, SOIL-MAS contributes to food security, farmer empowerment, and modern agricultural innovation.

3. Problem Statement

Traditional farming practices often rely on guesswork and manual record-keeping, which are time-consuming and prone to errors. Farmers face recurring challenges, including pest infestations, unpredictable soil nutrient conditions, and crop failures. Many do not maintain proper records of planting history, soil conditions, or fertilizer use, leading to inefficiency. Overuse of fertilizers not only wastes money but also damages soil health and the environment. At the same time, adoption of IoT technology in agriculture remains low due to cost, lack of awareness, and perceived complexity. SOIL-MAS addresses these issues by offering a simple, affordable, and effective IoT-based solution tailored for smallholder farmers.

4. Authenticity / Novelty

SOIL-MAS is unique because it integrates multiple features into a single IoT system, allowing users to monitor soil data such as pH level, water temperature, soil moisture, and fertilizer content (NPK), along with weather conditions like humidity and temperature. It is also able to collect data for EC sensors, which are commonly used to measure the nutrient and salt concentration in soil or water. Unlike many existing projects, it not only collects raw data but also analyzes it and provides actionable insights through dashboards and alerts. The use of platforms such as Node-RED, Grafana, and Telegram improves the system's usability and accessibility. Farmers receive real-time data on their dashboards and instant notifications on their devices. This combination of features makes SOIL-MAS a comprehensive and practical solution, especially for farmers in developing countries like Malaysia. By using SOIL-MAS, farmers can save money by reducing their reliance on manual soil testing and by applying only the necessary number of inputs.

5. Implementation Level

a) Analysis Phase of the Problem

The first step in the implementation of SOIL-MAS was identifying the real issues faced by farmers in managing soil nutrients and crop health. Through interviews and surveys, it became clear that many farmers lacked proper tools to monitor soil conditions such as pH, moisture, and fertilizer content. They relied heavily on manual soil testing and guesswork, which often led to over-fertilization, wasted resources, and reduced yields. By analyzing these challenges, the project defined the essential requirements for an IoT system that could provide real-time monitoring and actionable insights.

b) Develop Sensor Data and Dashboard Content

In this phase, the focus was on developing reliable data content by integrating IoT sensors

for soil monitoring. Sensors such as NPK, moisture, pH, temperature, and humidity modules were deployed to gather accurate readings (Figure 1). These data streams were then processed and structured for visualization. Dashboards were designed to translate raw sensor data into meaningful insights that farmers could easily understand. Charts, graphs, and alert notifications were prepared to show readings of soil and environmental conditions.

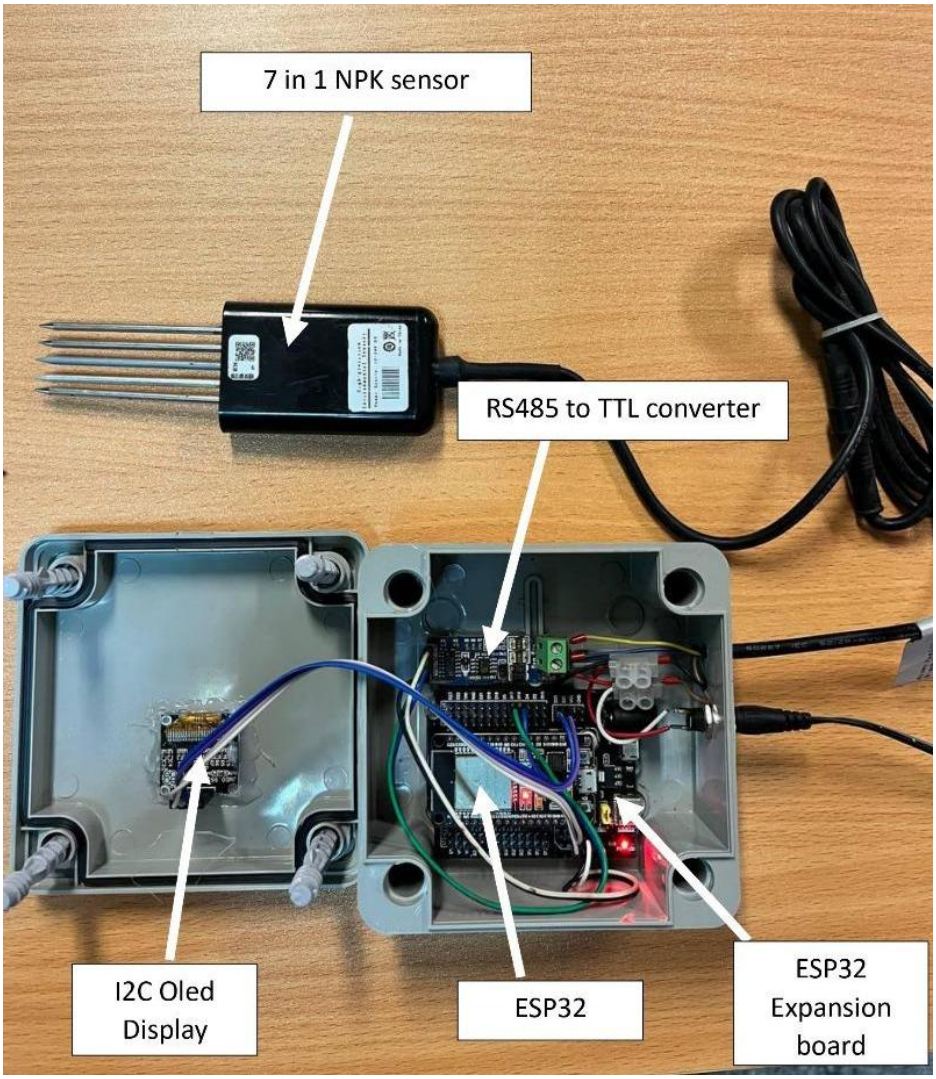

Figure 1: IoT sensor Design for SOIL-MAS

c) Develop an Interactive Application Interface

The next stage was building a user-friendly interface for farmers to access the collected data. Platforms such as Node-RED and Grafana were used to create interactive dashboards. These interfaces displayed soil conditions in real time, with visual indicators that made the information easy to interpret. Additionally, a Telegram bot was

developed to send direct notifications and alerts to users (Figure 2). This ensured farmers could access information anytime and anywhere, even on their mobile phones, making the system more practical for everyday use.

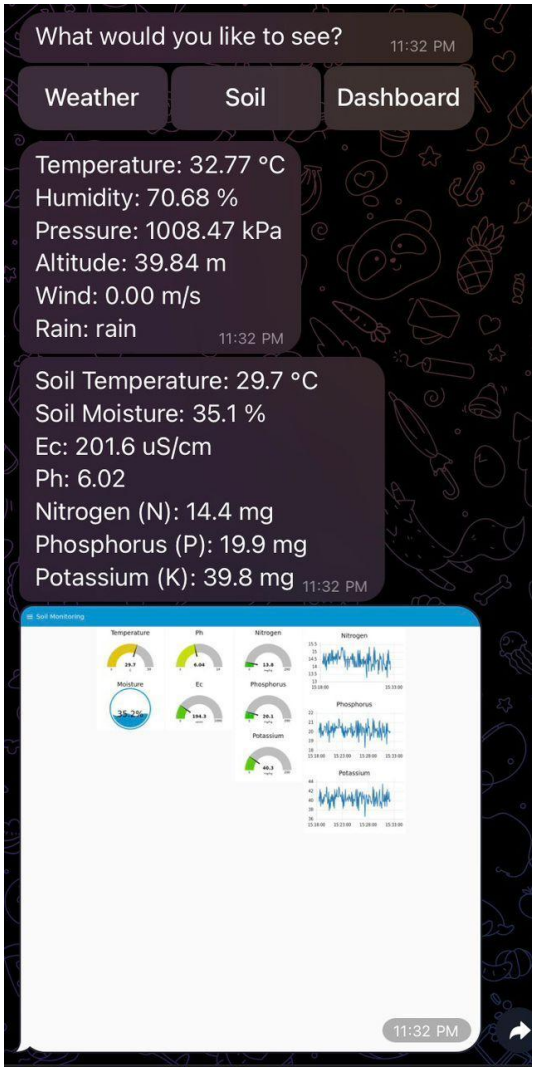

Figure 2: Telegram Bot for SOIL -MAS

d) Testing the Effectiveness of the System with Users

Finally, the system was tested through unit testing and user acceptance testing (UAT). Each module, such as soil sensors, dashboards, and alert systems, was individually tested to ensure accuracy and reliability. Farmers were then invited to use the system and provide feedback. Results showed that farmers were able to interpret soil and weather conditions more effectively, leading to better crop management decisions. The system was found to be easy to use, informative, and reliable, though some challenges, such as sensor calibration and hardware costs, were noted. Overall, the testing confirmed that SOIL-MAS is a practical and impactful solution for modern farming.

6. Uses and Applications

SOIL-MAS can be applied in many areas of agriculture. For smallholder farmers, it offers an affordable and practical way to start using IOT devices on their farm. Agencies related to farming or agriculture could encourage farmers and raise awareness on the uses of the system to gather reliable data that supports better policy decisions. In universities, colleges, and schools, SOIL-MAS serves as an excellent teaching and research tool to introduce students to smart farming technologies. NGOs and community organizations can also implement it to uplift rural farming communities by giving them access to modern agricultural practices. Beyond chili, the system is flexible enough to be used for various crops, making it suitable for different farming environments.

A project such as SOIL-MAS shows support for the TVET agenda by bridging technology and agriculture. It provides hands-on learning opportunities for students in agricultural and technical programs, equipping them with real-world skills in IoT, data analysis, and sustainable farming. This not only helps develop a skilled workforce but also prepares future farmers and technicians to contribute to food security and smart agriculture initiatives.

7. Innovation Product/Project Impact

The impact of SOIL-MAS can be seen in several dimensions. For farmers, it improves crop yields, reduces waste of fertilizer and water, and lowers overall costs. For the community, it promotes awareness of smart farming and sustainability. At the national level, it supports Malaysia's food security goals and aligns with the country's efforts to modernize agriculture. Globally, SOIL-MAS represents a scalable model of how IoT can be used to promote sustainable farming practices.

It encourages the efficient use of water and fertilizers, reducing environmental pollution and conserving natural resources. This supports the community by promoting cleaner, safer, and more sustainable farming, which benefits not only farmers but also consumers and the surrounding ecosystem. The system can contribute to agricultural data collection that local governments, researchers, or cooperatives can use for long-term planning, improving food security, and addressing climate-related challenges in farming communities. By bridging the gap between technology and agriculture, SOIL-MAS contributes in building more resilient and efficient food systems.

8. Achievements

SOIL-MAS was successfully developed and tested as a Final Year Project at Universiti Selangor. It demonstrated real-world feasibility by providing farmers with accurate, real-time soil and weather data. It received an Innovation Grant from TIER 1 2022 by UTHM with an amount of RM20,000.