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Low-Cost Embedence Meter for Soil Water Content Measurement using IoT

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***Abstract*—The goal of this project is to develop a sophisticated and intelligent system that tracks soil moisture levels and detects human and animal movement when it approaches crops and PIR motion sensors. Please notify us of any changes so that we can address them, identify them, and set up crop protection strategies to stop insect-related losses. Temperature sensors can also be used to track humidity and temperature. It aids in comprehending how plants behave under various weather circumstances. The humidity and temperature will be shown so that the fasrmer can take appropriate action if the weather is excessively hot and the soil's moisture content percentage is low. In advance. shields your house from flooding and extreme heat. In In order to enable IOT devices, such as sensors, to take actions depending on predetermined conditions and to store and display real-time data on the microcontroller, we will utilise the ESP8266 microcontroller Wi-Fi module in this project. Users may see the sensor readings displayed on both the Android app and the I2C LCD display, enabling convenient access to data from the device.**

***Index Terms*— Android application, iot (internet of things), humidity, microcontroller.**

I. Introduction

In this article, we will look at how to provide an inexpensive in-line soil moisture meter using online tools and devices that will be used in this project to protect crops exposed to different weather conditions and reduce the burden on farmers. With the conditions and greenhouse effect, and with the help of these IOT devices, it will be very easy. [1] For the people to monitoring the problems to the crop and It also help us in the increasing the production of the crop by observing the alter messages that was received from the sensor and the microcontroller and by taking the immediate precautions for the negative outcomes that was get from the ESP8266 microcontroller and other iot devices named as [2]Temperature sensor, PIR motion sensor, soil NPK senor, Soil moisture sensor, and all of this devices are connected to the one microcontroller ESP8266 to perform the tasks according to conditions that which are mentioned in the code and this code was integrated to the ESP8266 after the all connections were connected properly and check connections once again before you integrate the code into the microcontroller to the project. [3] by using the temperature detector By learning about the plant's temperature and humidity, the user can avoid potential health problems for the plant. Since this project is too costly for all of

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the formers to purchase and use, we are creating it at a very low cost so that every former may purchase and utilise it frequently. [4] We have already talked about the benefits of this initiative and know that we will soon learn how it operates. and how to monitor the data in the Android application as well as how to retrieve real-time data from IoT devices.

The ESP8266 microcontroller is connected to all of the devices, and when the motion The Blynk App, which was installed and linked to the wifi to receive real-time data from all devices, will receive the altered messages when there is an unwanted movement or changes in the sensor readings. When the sensor detects any motion, the led will blink. [5] When the sensors begin gathering data, the microcontroller transfers the information to the Blynk app, where it is shown virtually as readings for the benefit of farmers and other individuals who may comprehend and utilise the information to safeguard plants and crops. We're going to utilise the to find the motion. [5] When the sensors begin gathering data, the microcontroller transfers the information to the Blynk app, where it is shown virtually as readings for the benefit of farmers and other individuals who may comprehend and utilise the information to safeguard plants and crops. The PIR motion sensor will be used to detect motion, the DHT-11 temperature sensor will be used to measure temperature, and the NPK Soil Sensor will be used to measure soil moisture and measure the levels of nitrogen, phosphorus, and potassium—all of which are crucial for plant growth—to determine the nutrients present. must be linked to the ESP8266 microcontroller in the manner described below: This is depicted in the image below.

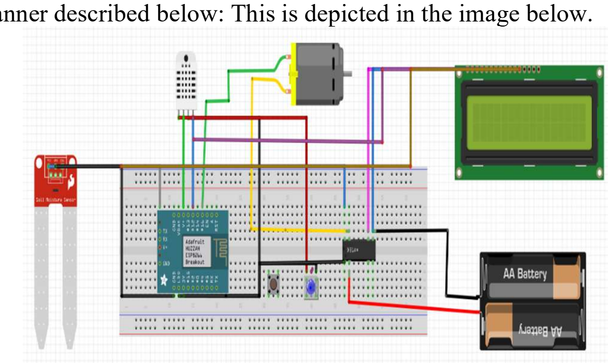


Fig 1. Circuit diagram of our proposal system

It uses temperature sensors and soil NPK sensors to check nutrient levels, nitrogen, phosphorus and potassium levels in the soil, which are very important for plant growth, and finally moisture levels in the soil. We are using soil moisture sensors and all these devices need to be connected to ESP8266 microcontroller as shown below.

By arranging the circuit diagram once again check the connections were properly connected or not before you implement the code into the microcontroller and be sure about the pin numbers it may help you at the time of adding the devices in the android application you should been asked to arrange the proper pin numbers to receive the data from the iot sensors. Now we are going to looking into briefly about each devices individually to know more about the devices.

ESP8266 NODEMCU

ESP8266 is a development board based on the ESP8266 Wi-Fi module. The ESP8266 is a highly integrated chip designed for Internet of Things (IoT) requirements. applications, with built-in Wi-Fi connectivity and a powerful processing core. The NODEMCU board is specifically designed to make it easy to prototype IoT projects by providing a convenient USB-to-serial interface for programming and debugging, as well as onboard voltage regulation and other useful features. [6] The NODEMCU board typically features General purpose input/output (GPIO) pins that can be used to interface with various sensors, actuators, and other electronic components. It also includes a micro USB port for power and communication, as well as a built-in voltage regulator to provide stable power to the ESP8266 module. One of the key advantages of the NODEMCU board is its compatibility with the Arduino IDE, which allows developers to program it using the Arduino programming language and libraries. [7] This makes it accessible to a wide range of developers with experience in Arduino programming, while still providing the flexibility and power of the ESP8266 module for IoT applications.

PIR motion sensor

A passive infrared (PIR) motion sensor is an electrical sensor that detects motion by varying the amount of infrared light emitted by objects in its range of view. PIR sensors are widely used in motion-detecting applications, including security systems and lighting control. [8] PIR sensors are considered "passive" as they

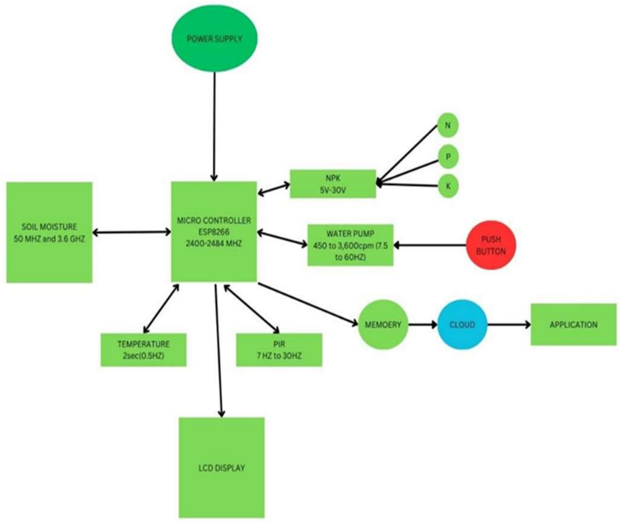
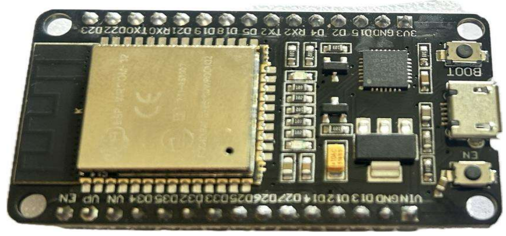


Fig. 2 Block diagram

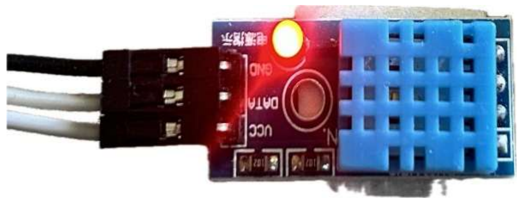


ESP8266 NODEMCU

PIR motion sensor

don't release any infrared radiation. It simply detects infrared radiation emitted by nearby objects. The sensor then provides an output signaling the detection of motion. PIR detectors are often used in conjunction with microcontrollers or other electronic devices to create motion-activated systems. A PIR sensor, for instance, can be used to switch on lights when someone enters a room or activate a security alarm when an intruder is detected. In general, PIR motion sensors are simple and effective motion detection devices that Due to its reliability and low cost, it is widely used in a variety of applications.

DHT11 Sensor



The DHT11 is a low-cost digital temperature and humidity sensor commonly used in DIY electronic projects. It consists of a capacitive humidity sensor and a thermistor that measure the humidity and temperature of the surrounding air, respectively. This sensor generates a digital signal that can be easily read by a microcontroller, making it ideal for interfacing with platforms such as the ESP8266. [9] The DHT11 sensor has four pins: VCC (power), GND (ground), DATA (data signal), and NC (not connected). It operates from 3.3V to 5V and communicates using a simple serial protocol. To read data from a sensor, the microcontroller sends a trigger signal and a data request. The sensor then responds with a 40-bit data stream containing the humidity and temperature readings. [10] While the DHT11 sensor is affordable and easy to use, it has some limitations compared to more advanced sensors. It has a relatively low accuracy and resolution, especially for humidity measurements, and it is not suitable for high-speed or high-precision applications. However, for many hobbyist projects and basic environmental monitoring applications, the DHT11 sensor provides a cost- effective solution.

Soil moisture sensor

A soil moisture sensor is a device used to measure the moisture content of soil. Commonly used in agriculture, horticulture, and environmental monitoring. when to water plants or to collect data for research purposes. There are several types of ssoil moisture sensors, but one of the most common is the capacitive soil moisture sensor. This type of sensor measures the dielectric constant of the soil, which is directly related to the moisture content of the soil.[11] One electrode is supplied with alternating current and the other electrode measures the capacitance between the electrodes, converting this into a soil moisture measurement. Capacitive soil moisture sensors are widely used because they are relatively inexpensive, easy to use, and provide accurate measurements. You can connect it to a microcontroller or other device to record data or control your irrigation system based on soil moisture levels. Other types of soil moisture sensors include resistive sensors, which determine moisture content by measuring soil resistance, and time-domain reflectometry (TDR) sensors, which measure soil moisture by sending an electromagnetic pulse into the soil and measuring the time it takes for the pulse to reflect. there is. Back to the sensors. Overall, soil moisture sensors are useful tools for effectively managing water resources and promoting healthy plant growth.

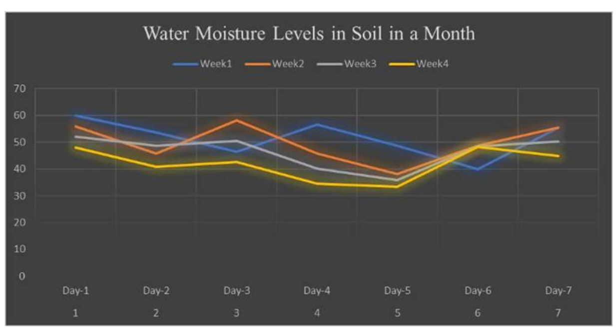


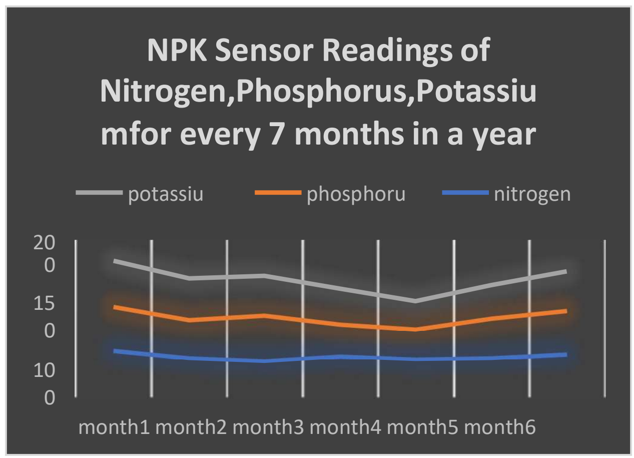
Fig.3 graphical representation of soil moisture level of a plant

Soil NPK sensor

A soil NPK sensor is a device used to measure the levels of nitrogen (N), phosphorus (P), and potassium (K) in the soil, which are three major nutrients important for plant growth. These sensors can provide valuable information to farmers and gardeners, helping them to optimize fertilizer application and improve crop yields.

[13] There are several types of soil NPK sensors, but they generally work by extracting a sample of soil and analyzing it using various techniques to determine the nutrient levels. Some sensors use chemical reagents to extract and measure the nutrients, while others use spectroscopy or other methods to analyze the soil composition. Soil NPK sensors can be used in conjunction with other soil sensors, such as pH and moisture sensors, to provide a comprehensive picture of soil health and fertility. By monitoring soil nutrient levels regularly, farmers and gardeners can make informed decisions about fertilization and soil management practices, leading to more sustainable and productive agriculture.

Fig.3. a. graphical representation of nitrogen, phosphorus, potassium level of a plant, b. soil NPK sensor



16x2 I2C display

The I2C 16x2 display is a two-line liquid crystal display (LCD) that can display 16 characters per line and communicates using the I2C protocol. These displays are popular in projects that require displaying information from a microcontroller, such as an Arduino or ESP8266, using a limited number of GPIO pins. [16] The I2C interface requires only two wires for communication, making it a convenient choice for connecting to microcontrollers. To use a 16x2 I2C display with an ESP8266 NODEMCU, you typically need to install a library that supports the display and provides easy-to-use functions for displaying text and controlling the display settings. [17] Once the library is installed, you can connect the display to the NODEMCU using four wires: VCC (power), GND (ground), SDA (data), and SCL (clock). With the display connected, you can then use the library functions to initialize the display, set cursor positions, and display text. For example, you can use the LiquidCrystal_I2C library in Arduino to control a 16x2 I2C display with an ESP8266 NODEMCU.

II. Literature Survey

2019: The most important challenge to achieve this goal is how to obtain affordable sensors and make them as flexible as possible to make farmers' jobs easier. In this sense, it is important that the sensor operates independently of the soil type and can adapt to the different conditions and measuring equipment used. The following describes the sensor's specific electronic design and SDI-12 software code, as well as the implemented soil-specific calibration protocol.

2020: There are many studies in the literature on the development of soil moisture sensors for precision agriculture, most of which are based on traditional technological approaches using rigid substrates. The design and construction of materials must fundamentally minimize the potential risk of environmental contamination by unwanted substances. Therefore, sensor units must be designed so that their components can be reused and key parts must be easily replaceable if damaged. Our research focuses on fully printed capacitive sensing elements to replace existing copper-based sensors. The main goal was to develop a completely add-on sensor for measuring soil moisture without the need to install other components, leading to low-cost, material- and energy-efficient production.

2021: Proper watering is achieved by monitoring soil moisture and accurately determining soil moisture content. Therefore, it is useful to study and understand the dynamic changes and spatial distribution of soil moisture and the different soil moisture requirements of different crops during the same period. Monitoring real-time and spatiotemporal variability of soil moisture has become a hotspot in the field of soil research. Accordingly, large-scale production and application of soil moisture sensors that can quickly and conveniently measure soil moisture are underway. Along with the history of soil sensor development, research and review have been conducted to analyze principles, methods, and applications from various perspectives.

2022: Among hydrological variables, soil moisture influences many hydrological, meteorological, and vegetation growth processes. Between precipitation events, soil moisture reserves are the primary source of water for plants and affect crop yields, and soil moisture levels influence water management decisions on farms, such as planting timing, pesticide, herbicide, fertilizer application, and irrigation schedules. Surface soil moisture (SSM) is an important hydrological cycle variable that affects runoff, evapotranspiration, and vegetation growth. The depth of the root layer, which is the part where plants can receive water, is a major factor in controlling soil moisture. Adequate rhizosphere depth is assessed based on the amount of water applied to the soil, precipitation, and drainage of the soil.

2023: Modern methods include sensors mainly classified as electrochemical, electrical and electromagnetic (EM), optical and radiometric. The most commonly used sensors in PA are electrical and electromagnetic sensors. This is because not only can it easily interface with WSN and IoT systems, but it is also less expensive to develop and more reliable than other SWC sensors. SWC is one of the key soil physical properties that must be managed in agriculture and is influenced by factors such as soil infiltration and fertilization [18]. SWC sensors are typically installed in the soil at various depths and use wireless sensor networks (WSNs) to transmit real-time soil properties to a central station during measurements. As part of the Internet of Things (IoT) precision agriculture (PA) technology, it must also provide low-cost measurements and additional environmental parameters such as temperature and soil conductivity.

2024: In this project, we plan to create a smart and intelligent system that monitors the moisture content of the soil and indicates the movement of people or animals when they are near the crops and PIR motion sensors. Send us a message about the changes so we can make changes, identify them and prepare crop protection measures to prevent losses due to insects. We can also monitor temperature and humidity levels using temperature sensors. It helps in understanding the condition of plants in different weather conditions. If the weather is too hot and the moisture content percentage in the soil is low, the humidity and temperature will be displayed so the former can take action. Advance. Protects your home from high temperatures and flooding. In this project, we will use the ESP8266 microcontroller Wi-Fi module so that IOT devices such as sensors can perform actions based on given conditions, so that real-time data can be stored and displayed on the microcontroller. Displayed on both the Android app and the I2C LCD display, allowing users to view readings obtained from the sensor on both the Android app and the I2C LCD display.

III. DATA COLLECTION & PREPROCESSING

A. Field testing and verification

A research technique used for field testing of soil moisture sensors under realistic conditions. Evaluate methods to calibrate sensors and verify measurement accuracy against reference methods or established standards. Consider factors such as soil type, climate, and vegetation cover that may affect sensor performance.

B. User interface and data visualization

Previous work on developing user-friendly interfaces for soil moisture monitoring systems is reviewed. Discover techniques to visualize real-time soil moisture data and provide actionable information to users. When designing the interface, consider the needs and preferences of end users, such as farmers or researchers.

C. Scalability and Deployment

Explore strategies for expanding your soil moisture monitoring network using low-cost inline meters. Consider deployment scenarios in a variety of agricultural environments, including large farms, small properties, and research sites. Consider integrating embedded meters into your existing agricultural infrastructure or IoT network.

By combining insights from previous research and related work, we can develop a robust methodology for the design and implementation of low-cost embedded meters for measuring soil moisture content using the Internet of Things. Additionally, consider partnering with experts in soil science, agricultural engineering, and Internet of Things technologies to leverage their interdisciplinary knowledge and expertise.

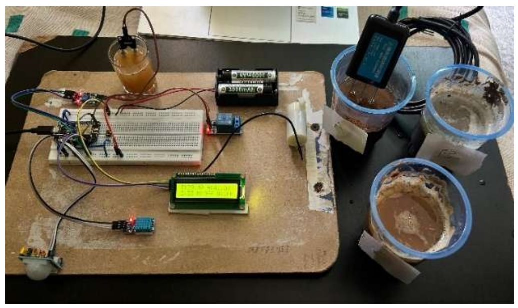


Fig.4 the Manual representation of circuit diagram

IV. PRINCIPLES AND METHODS

When evaluating the performance of a low-cost embedence meter for soil water content measurement using IoT, several metrics can be considered. These metrics help assess the accuracy, efficiency, and reliability of the system. Here are some performance metrics along with their corresponding formulas:

Accuracy (Root Mean Square Error – RMSE): RMSE measures the average deviation between the measured values and the actual values.

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(y_i - y_i)}{n}}$$

yi is the actual soil moisture content.

yi1 is the measured soil moisture content. n is the total number of observations.

Precision (Standard Deviation):

Standard deviation indicates the variability of the measured values around the mean.

$$\sigma = \sqrt{\frac{\Sigma_{i=1}^{n}(xi - xi')}{n-1}}$$

where:

xi is each parameter. Ëx is the average of all measurements.

n are all measurements.

s.no	Name of the tool	Range
1	ESP8266 NODEMCU	2400-2484 MHZ
2	PIR Motion sensor	7 – 30HZ
3	Soil moisture sensor	50 MHZ-3.6 GHZ
4	Soil NPK sensor	5-30V
5	DHT11 Temperature sensor	2SEC(0.5HZ)
6	Water Pump	450-3,600CPM (7.5-60HZ)

V. Results and Discussion

The photodiode sensor module responds to LED light and selects separate light paths. Figure 5 below compares each of these responses. Specifies the distance along the path in millimeters (1.0x4.0). In what way does this appear in the picture? 5. At least 1 cm. The photodiode is exposed to a specific quantity of UV radiation. When the length is increased by 2-4 cm, the voltage value will be shown. There is a significant decrease in measurable voltage. Thus, based on the analysis's findings, the ideal optical path length for different optical route lengths is as follows: The size of 1 cm was selected due to its highest level of brightness. Table III displays the NPK soil thresholds at three different voltages. level: medium, low, and high. The importance of x stands for: Takes up each nutrient's tension.

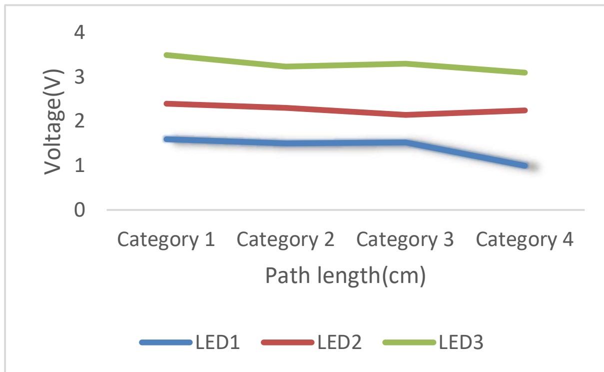


Fig 5 Determination of visual field length

Thresholds of low, medium and high nutrient values in soil samples

Nutrient	Low(V)	Medium(V)	High(V)
Nitrogen	3.5<x<3.8	3.8<x<4.1	x>4.2
Phosphorous	2.45<x<2.8	2.9<x<3.3	x>3.4
Potassium	1.6<x<2.2	2.3<x<2.8	x>2.9

The histogram in Figure 6 is Photodiodes Due to light the formula includes: Nitrogen (N). It contains the most nitrogen. This is because for The value of sample 1 exceeds the threshold voltage 4.51. V. Samples 2, 3, 4, 5 and 6 have too little nitrogen. Model 2While the phosphorus content is high, the average for sample 3 is As shown in the picture, they are 3.65V and 3.5V respectively. 7. The high potassium threshold for Model 3 has a value of 3.83. V (Fig. 8). Table 4 describes the food items of the samples. Based on the thresholds in Table 3, they are 1, 2, 3, 4, 5, and 6. Therefore, you can easily check the NPK content in the soil of each sample. Determined solely by specific nutrients and should be distributed to the sample.

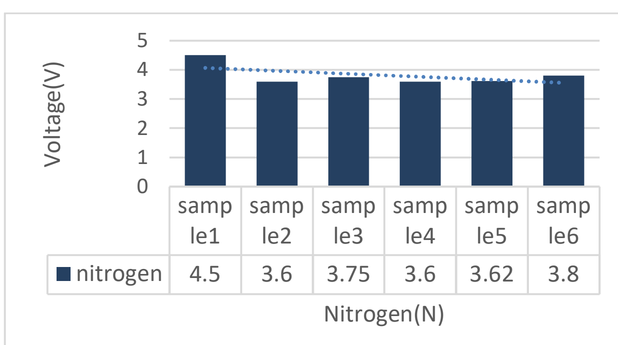


Fig. 6 Voltage response of different soil samples containing nitrogen

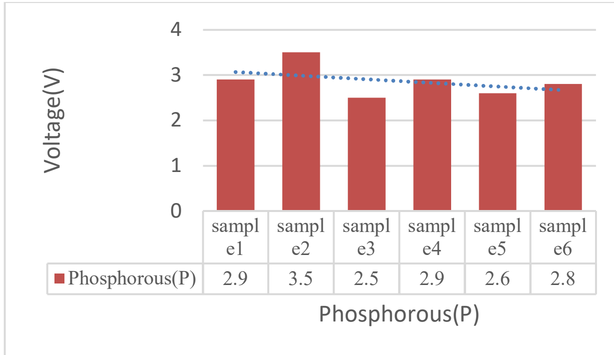


Fig. 7 Voltage response of soil samples with different phosphorus content

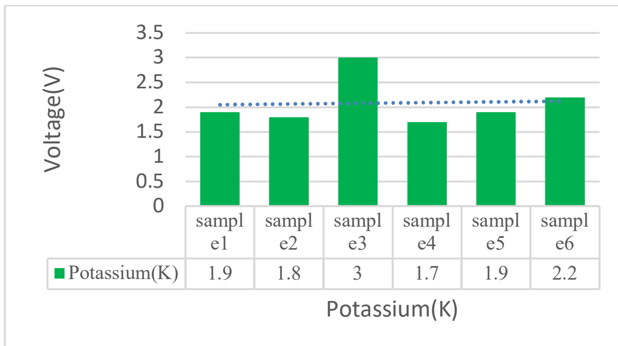
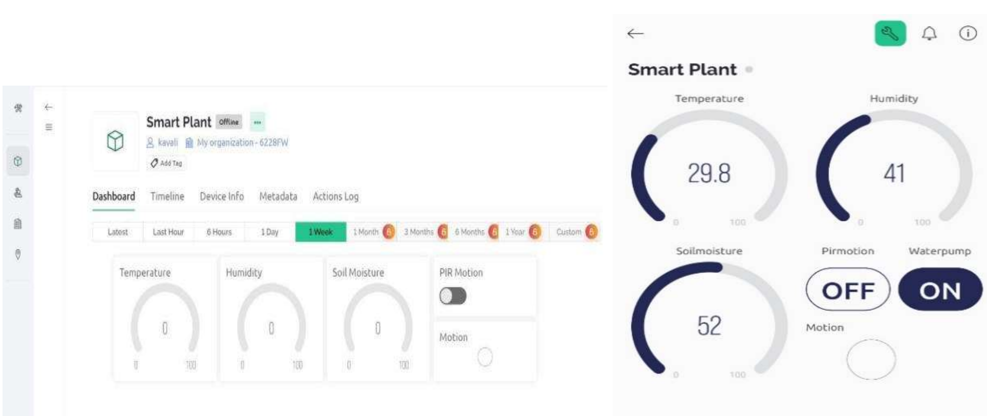


Fig.8 Voltage responses for different soil samples containing Potassium

TABLE. THE NUTRIENT CONTENT LEVEL IN ALL SAMPLES

Sample	Nitrogen(N)	Phosphorous(P)	Potassium(K)
1	High	Medium	Low
2	Low	High	Low
3	Low	Low	High
4	Low	Low	Low
5	Low	Low	Low
6	Low	Low	Low

VI. OUTPUT VALUES



Range of the Proposed System

VII. CONCLUSION

In summary, significant progress has been made in agricultural and environmental monitoring through the development of low-cost impedance meters to estimate soil moisture content using IoT technology. Combining low-cost hardware and Internet of Things connectivity, this system provides an inexpensive way to accurately measure soil moisture under a variety of agricultural and environmental conditions. It also integrates IoT capabilities to enable real-time data collection and monitoring, giving customers immediate access to critical information about soil moisture status. This improves decision-making processes and facilitates the implementation of timely interventions, such as the development of irrigation schemes and drought mitigation measures, to increase crop yields and maximize resource use. The versatility and scalability of this system allows it to be implemented in a variety of environments, from large farms and research stations to small agricultural fields. Modular design allows for application diversity and flexibility, allowing you to expand and customize to fit your unique needs. Considering all of the above, creating a low-cost impedance meter for measuring soil moisture content using IoT technology is a positive step towards solving problems related to modern agriculture and environmental management. This technology has the potential to transform the way we monitor and manage soil moisture through innovation, teamwork and continuous improvement, ultimately leading to more resilient and sustainable ecosystems.

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