

Internet of Things (IoT) Based Integrated Multi-Measuring Device for Agriculture

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Abstract: The rise of Internet of Things (IoT)-driven smart agriculture has transformed conventional farming methods and provided answers to modern problems like resource scarcity, environmental degradation, and climate change. The integration of IoT technologies with agricultural sensing systems enables continuous collection and transmission of field-level data, thereby supporting data-driven and timely agricultural decision-making. This is why the creation of an Internet of Things (IoT)-based Multi-measuring Device for Agriculture is a remarkable advancement meant to improve crop management and monitoring. The IoT-based Multi-measuring Device, which combines a variety of sensors and IoT capabilities to deliver real-time data on crucial environmental factors, is the subject of this research article, which also discusses its design, implementation, and results. The gadget helps farmers make informed decisions about irrigation, fertilization, and pest control to maximize crop yields while limiting resource use. It does this by measuring temperature, humidity, soil moisture, and pH levels. With its low cost, high effectiveness, and adaptability, the gadget can be used in a variety of agricultural situations and allows farmers the flexibility to customize its monitoring features to meet their own requirements. The study also emphasizes optimization techniques for encouraging sustainable farming methods, minimizing the impact on the environment, and enhancing the adaptability of agricultural systems. In summary, the Internet of Things-based Multi-measuring Device is a promising technological development for precision farming that could help tackle the challenges of contemporary agriculture. Farmers can handle the difficulties of a changing climate while maintaining the long-term sustainability and productivity of agricultural methods by embracing innovation and utilizing IoT technology.

Keywords: Internet of Things (IoT), Crop Monitoring, Sustainable Agriculture, Precision Farming, Sensors.

1. Introduction

Every day, smart agriculture emerges to address issues including low agricultural output, overuse of pesticides, climate change, and water resource waste. Historically, agriculture has been associated with sustainability because of its efforts to lessen the negative effects of its activities on the environment. The Internet of Things (IoT) presents itself as a potential remedy for these problems. Additionally, as IoT becomes widely used, gadgets become a more affordable solution for monitoring environmental factors. The integration of IoT with agricultural sensing technologies enables continuous monitoring of field conditions and provides farmers with timely information for improving crop management. Such technologies can support precision agriculture by reducing dependence on manual measurements and enabling more efficient utilization of agricultural resources. The fig. 1 illustrates major IoT-enabled agricultural applications, including environmental, soil, crop, pest, and production monitoring.

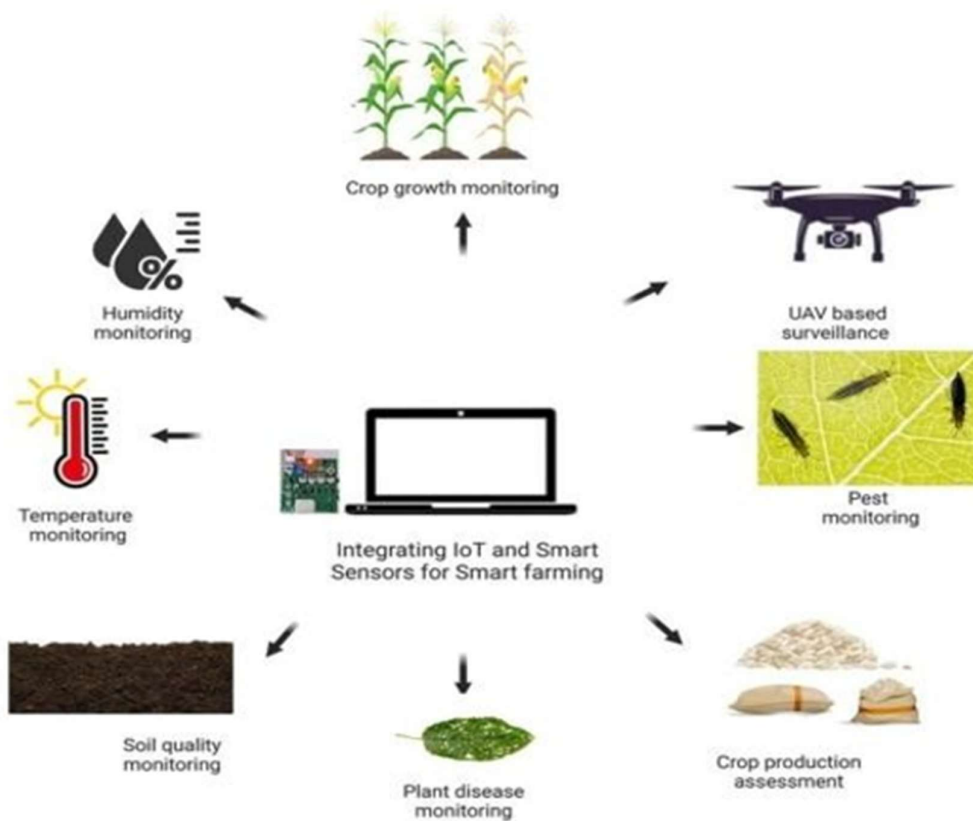


Fig. 1. Applications of IoT in agriculture

IoT-based technologies are used in precision farming to track many agricultural parameters. For improved environmental protection and ongoing agricultural production sustainability, IoT offers crucial real-time data on crop, soil, water, and air conditions. In order to improve yield, sensor-based continuous monitoring of temperature, humidity, pH, water level, and soil moisture is used. The availability of these measurements in real time allows variations in agricultural conditions to be identified at an early stage and supports timely intervention.

These automated sensors support decision-making for the implementation of more appropriate safeguards against harm to agriculture. IOT integrates several types of linked devices in an attempt to build a vast network. Temperature, humidity, soil moisture, and the quality of the water are believed to be IoT-dependent surveillance methods. Several environmental factors, including temperature, humidity, soil moisture, and water pH level, are monitored via sensors. However, using separate instruments for monitoring different parameters can increase equipment requirements, measurement time, and operational complexity. Therefore, integrating multiple sensing capabilities into a single IoT-enabled device can provide a more convenient and cost-effective approach for agricultural monitoring.

This paper presents an IoT-based solution to collect weather and soil parameters essential for the proper development of crops. This solution is cost-effective and is capable of measuring several different things with a single instrument. The goal is to develop an innovative Integrated Multi-measuring Device that improves efficiency by combining several measuring features into one affordable device. The proposed device integrates multiple sensors to measure key environmental and soil parameters through a unified monitoring system, reducing the need for farmers to use multiple independent measuring instruments. This device will save time and eliminate the need for additional instruments, offering an efficient and complete solution for a range of measuring requirements.

2. Literature Review

The Internet of Things (IoT) is a concept in which commonplace items and gadgets are linked to the internet and are capable of exchanging data to offer clever solutions. A developing approach in agriculture that mostly relies on Internet of Things technology is called smart farming [5][8][11]. Smart farming integrates IoT devices, sensors, communication technologies, and data-processing platforms to improve the monitoring and management of agricultural activities. IoT devices can be used, for instance, to track agricultural vehicles, keep an eye on animals, storage conditions, and crop and plant health [4][6][9].

Farmers may access real-time data and insights using IoT technology, which can assist them in making more informed decisions about their farming methods [1][11][14]. IoT technology is being adopted increasingly across many industries, including farming and agriculture. Approximately 43% of businesses globally, according to the report, have used IoT apps in some way [11]. It shows that Internet of Things technology is becoming more than just a catchphrase; rather, it is an essential tool for a wide range of industries, including agriculture [8][10]. This implies that IoT-based farming solutions have a bright future and that farmers will likely benefit from these innovative solutions. IoT applications can also be extended to smart irrigation and agricultural supply-chain systems to improve monitoring, safety, and operational efficiency [3][20]. It is expected that more and more farmers will use IoT-based solutions throughout their agricultural endeavors in the future due to the technology's quick acceptance. The integration of IoT with agricultural practices can therefore contribute to continuous field monitoring, efficient resource utilization, and timely intervention when abnormal conditions are detected.

In many developing countries, the agriculture sector contributes significantly to the economy and creates a sizable number of jobs. In reality, 64% of the people living in these countries depend on agriculture for their food and means of livelihood. Agriculture strives to produce more robust and productive plants and crops by improving the soil and supplying water [13][18]. This demonstrates the importance of agriculture in countries like India, where the vast majority of people live off farming and where the majority of the nation's income comes from it. Agriculture needs to be modernized and adopt more scientific practices to increase agricultural output and the sector's overall performance. In order to increase crop productivity and efficiency, there is a necessity to modernize agriculture and implement more scientific techniques. In this context, IoT-based agricultural systems provide an opportunity to combine traditional farming practices with data-driven approaches for more efficient crop and resource management.

Utilizing Internet of Things (IoT) technology and remote sensors to monitor plant conditions and collect data on many environmental factors that impact agricultural conditions, such as climate, humidity, temperature, pH level, and soil moisture, is possible [1][4][6][7]. These sensors can continuously capture field-level information and transmit the collected measurements to processing or monitoring platforms for further analysis. This data is gathered and analyzed using Internet of Things (IoT) technology, which makes it possible to efficiently collect and process data from several sources [9][11][15]. An IoT-based study can find wild plants, water levels, exact location, field interruption, field development, horticulture, and other important factors that affect crop growth and development. By obtaining this information, farmers may make more informed decisions that will improve crop management and boost output [2][12][14]. Farmers may now connect to their fields from anywhere thanks to Internet of Things technology, which also makes it easier to remotely manage and keep an eye on their crops. This gives farmers more adaptability and makes it possible for them to react swiftly to shifting weather patterns or other elements affecting their crops. Real-time monitoring also enables early identification of unfavorable field conditions, allowing farmers to take corrective actions before these conditions significantly affect crop growth. In general, the application of IoT technology and remote sensors in agriculture has the potential to greatly increase crop yields and enhance farming's sustainability and efficiency. Farmers may make better judgments and take proactive measures to fix issues before they worsen by collecting and evaluating data in real-time.

3. Design Methodology

The proposed system is designed as an IoT-based agricultural monitoring device that integrates multiple sensors with an ESP32 microcontroller to measure important soil and environmental parameters. The collected measurements are processed by the microcontroller and presented to the user through an LCD interface. The circuit diagram in fig. 2 illustrates the connections between the ESP32 microcontroller, environmental sensors, soil sensors, and I2C LCD.

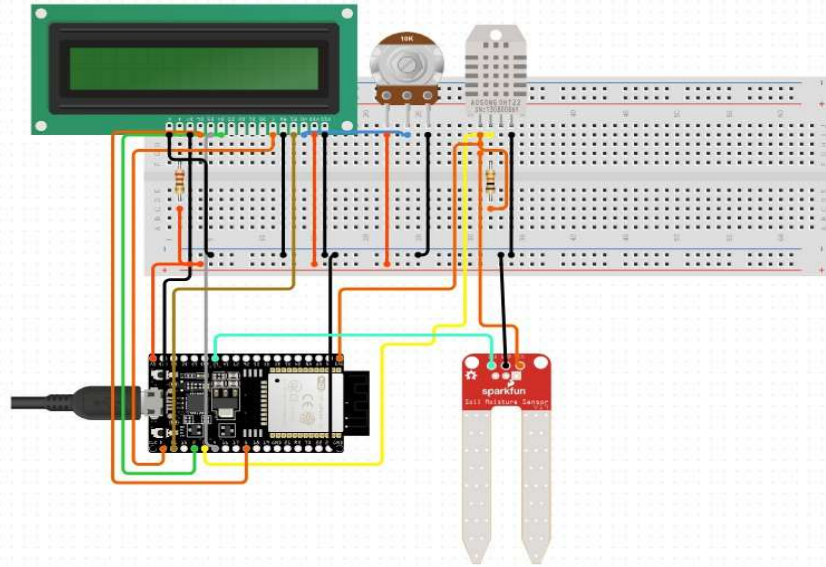


Fig. 2. Circuit Diagram of the proposed IoT-based agricultural monitoring system.

3.1 Sensors Used

- Espressif 32 (ESP32), Microcontroller:** The ESP32 is an affordable, 32-bit microcontroller. As Bluetooth and Wi-Fi are integrated inside, it can be used for Internet of Things applications. Having 48 general-purpose input-output (GPIO) pins, it can support many sensors and devices. Additionally, information can be sent from the microcontroller to a cloud system, which can then pass it to a website or application. We are able to obtain data from many locations as a result of this. This microcontroller is connected to every other sensor. Therefore, the ESP32 acts as the central processing and communication unit of the proposed system, receiving measurements from the connected sensors and controlling the display output.
- DHT 11 to measure air temperature and humidity:** This sensor connects to a high-performance 32-bit microcontroller (ESP 32) that offers great quality, rapid response, anti-interference ability, and cost-effectiveness. It also features resistive-type temperature and humidity measurement components. Additionally, it is easy to use and implement. The accuracy of this sensor is superior to that of an infrared thermometer. Additionally, it has the accuracy to measure temperature up to 20 meters away from the sensor. The measured temperature and humidity values provide information about the surrounding environmental conditions that may influence plant growth.
- Soil Moisture Sensor, to measure moisture percentage in the soil:** A fork-shaped probe that has two exposed conductors is part of the sensor, which is placed in the soil where the moisture content needs to be determined. The sensor also has a module that links the Arduino to the probe. In accordance with the resistance generated by the probe, which is accessible at an Analog Output pin(AO), the module produces an output voltage. A LM393 Highly Precise Comparator receives the same signal, digitizes it, and outputs the result to a Digital Output pin(DO). Two LEDs are also included in the module. Whenever the module is turned on, the Power LED glows. The soil moisture measurement is used to determine whether the soil requires additional water and consequently supports irrigation-related decisions.
- pH Sensor, To measure the pH of the soil:** A pH sensor detects a solution's acidity and alkalinity, which is linked to an Arduino-based microcontroller for processing the data. An Arduino microcontroller can be utilized as a data processor when used with the water PH sensor. The PH electrode of the water PH sensor is submerged in the sample solution, which allows it to detect the generator sample and alter the PH electrode signal. Arduino then converts the sensor's output into digital data. A range of solutions, such as vinegar, milk, and soapy water, are assessed using PH meters. In the proposed agricultural application, the pH measurement provides an indication of soil acidity or alkalinity and can be used to identify conditions that may require corrective action.
- 12C LCD, LCD screen to display readings:** An HD44780-based character LCD plus an I2C

LCD adaptor make up a standard I2C LCD. It can show two rows of 32 ASCII characters. If you look closely, every word or number on the screen has tiny rectangles that you can see in addition to the individual pixels that make up each character. These rectangles are all 5 by 8 pixel grids. The 8-bit I/O expander chip, PCF8574, is the brain behind the adaptor. This chip transforms the parallel data needed for an LCD from the I2C information received from an Arduino. Additionally, the board has a tiny trimpot that allows you to precisely control the contrast of the display. The backlight is powered by a jumper that is located on the board. The LCD provides a local interface through which the measured parameters can be viewed without requiring a separate monitoring device.

3.2 Implementing and Working of Sensor

- The device requires a power input to function. This power can be provided by means of rechargeable batteries or a power bank.
- The LCD screen displays two readings at a time and keeps switching to show all four readings.
- Temperature and humidity are displayed first, followed by Moisture and pH value.
- To measure the moisture, the fork-shaped probe should be inserted at least 3 cm inside the soil and wait till the readings become stable.
- The probe should be cleaned after every use to ensure a longer life and precise readings.

The LCD in Fig. 3 displays the measured ambient temperature and humidity values.

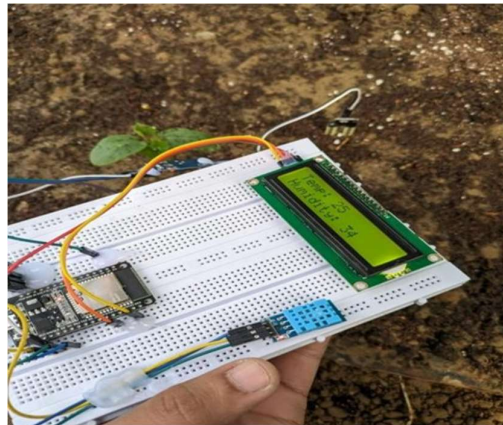


Fig. 3. Temperature and humidity reading

The LCD in fig. 4 displays the measured percentage of moisture present in the soil.



Fig. 4. Soil moisture percentage reading

The block diagram in fig. 5 shows the flow of sensor data acquisition, processing, and display.

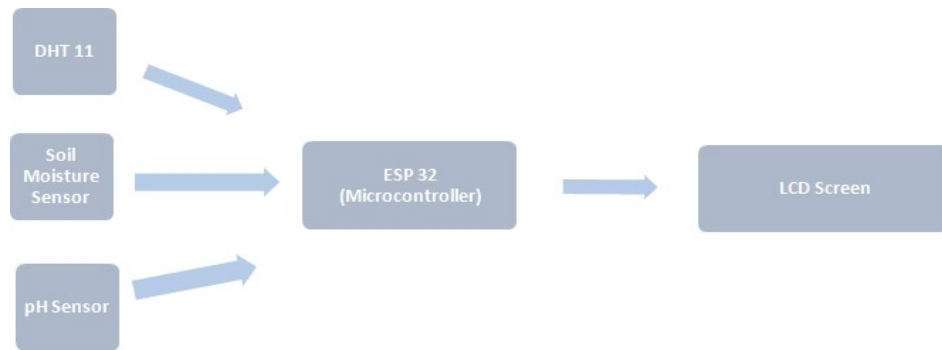


Fig. 5. Block diagram of the firmware

3.3 Optimization

- **Low Moisture:** Supply water at regular intervals. Applying compost or manure to the soil reduces evapotranspiration and enriches the soil with essential nutrients as it decomposes. Mulching is the application of an organic or inorganic material layer over a plant's root zone. Materials for mulch can include peat, wood chips, and straw. Plastic sheeting is another sort of inorganic mulch that is utilized.
- **High Temperature:** On days when high temperatures are predicted, give plants plenty of water in the morning to help them withstand the heat. A withering, wilting plant can frequently be brought back to life with more water if it is found early during a heat wave. To shield plants from direct sunlight and to lower the surrounding air temperature, cover exposed plants with shade cloth [17].
- **Low Temperature:** Keeping your plants well-nourished also aids in preventing cold damage to them. Plants must be properly nourished. When a plant has the right nourishment, it can withstand low temperatures, bounce back from cold damage, and tolerate abrupt reductions in temperature. This is in contrast to plants that lack sufficient nutrients. Temporary covers or other windbreaks can help shield plants from the damaging effects of cold. The most effective way to lessen damage from chilly winds and advective freezes is via windbreaks. Do not forget to mulch the ground. Mulching minimizes temperature swings by shielding plant roots and assisting in the reduction of heat loss [16].
- **High pH:** The best ways to lower the pH of soil are by adding sulfuric acid, aluminum sulfate, or elemental sulfur. Which substance to use will depend on the size and type of plant facing the deficiency as well as how quickly you expect the pH to change. Although sulfuric acid, which is often sold as battery acid, works quickly, it is not advised for home gardeners to use it due to its high level of danger. However, experts in the green business sometimes employ sulfuric acid to lower the pH of the soil surrounding huge, well-established specimen trees. Homeowners can safely utilize elemental sulfur and aluminum sulfate. Because aluminum sulfate is very soluble, it acts more quickly than elemental sulfur. Reducing the pH levels in the soil before planting is generally better than trying to do it after plants have taken root [19].
- **Low pH:** The standard recommendations are to apply ground limestone if a soil test results in a pH of less than 6.5. Limestone contains calcium in addition to having the capacity to increase pH. Since dolomitic limestone includes both calcium and magnesium, some people prefer it. However, soils with high magnesium content, such as serpentine, don't require additional magnesium.

4. Result

This research article presents an IoT-based Multi-measuring Device for Agriculture that provides a comprehensive approach for monitoring critical environmental parameters required for optimal crop development. By combining multiple sensors with an affordable microcontroller, the device can measure temperature, humidity, soil moisture, and pH levels in real time. The developed prototype was evaluated based on its ability to acquire and display the selected environmental and soil parameters through a single integrated monitoring device. The obtained measurements demonstrate the practical operation of the proposed system for agricultural monitoring. The principal discoveries and results of this investigation are as follows:

- 1) **Efficiency and Affordability:** The developed device combines multiple measuring features into a single, cost-effective instrument. This is an effective approach for agricultural

monitoring because it saves time and eliminates the need for various instruments.

- 2) **Real-time Data Collection:** The gadget uses Internet of Things (IoT) technology to enable continuous environmental factor monitoring, giving farmers access to real-time data on crop, soil, water, and air conditions. This makes it possible to make timely decisions and put suitable agricultural methods into action.
- 3) **Improved Crop Management:** Farmers can gain extensive information on plant conditions and environmental factors influencing crop growth by utilizing IoT technology and remote sensors. Better crop management techniques are made possible as a result, increasing output and efficiency.
- 4) **Customizable Solutions:** Due to the device's flexibility in sensor selection and design, farmers can customize its monitoring capabilities to meet their unique agricultural requirements. This flexibility improves the device's use in various farming situations.
- 5) **Optimization Strategies:** In order to mitigate environmental problems, including low moisture, high or low temperatures, and pH imbalances, the study offers workable optimization solutions. These tactics provide feasible recommendations for enhancing crop resilience and health.
- 6) **Sustainable Agriculture:** The IoT-based Multi-measuring Device supports effective resource management and precision farming methods, which both enhance the sustainability of agricultural activities. It helps farmers to increase crop yields while minimizing resource waste and lessening their impact on the environment.

Overall, the Multi-measuring Device serves as an excellent example of how IoT-based technologies can be implemented in agriculture to meet contemporary agricultural difficulties. Farmers may increase production, sustainability, and resistance to changing environmental circumstances by utilizing data-driven insights and intelligent monitoring technologies.

5. Conclusion

In conclusion, a major development in precision farming technology has been made with the creation and application of the Internet of Things-based Multi-measuring Device for Agriculture. Through the integration of many sensors and Internet of Things capabilities, this gadget provides farmers with an economical and effective means of keeping track of key environmental parameters that are crucial for crop development. The developed prototype integrates an ESP32 microcontroller with sensors for temperature, humidity, soil moisture, and pH measurement, providing a unified platform for monitoring multiple agricultural parameters.

Farmers can maximize crop yields while minimizing resource waste by using real-time data gathering and analysis to improve their decisions about irrigation, fertilization, and pest management. Due to its adaptability and versatility, the gadget may be used in a variety of agricultural conditions and provide farmers customized solutions based on their specific needs.

The study also emphasizes the importance of IoT technology in modernizing agriculture and tackling issues that the farming sector faces, such as soil degradation, water scarcity, and climate change. The Internet of Things-based Multi-measuring Device enhances resource efficiency and supports sustainable farming practices, which in turn supports the long-term resilience and viability of agricultural systems. As IoT-based agricultural technologies continue to be researched and developed, their capabilities will be further enhanced, enabling farmers to fulfill the increasing demand for food production while protecting the environment. A more productive and sustainable future for agriculture is possible if it embraces innovation and makes use of data-driven decision-making.

The Internet of Things-based Multi-measuring Device, in short, is a major step toward the accomplishment of smart agriculture's goal of using technology as a useful instrument to improve farming operations' resilience, sustainability, and production. The incorporation of IoT solutions holds the potential to mitigate the obstacles that lie ahead and guarantee the well-being of farmers and the agricultural industry at large, particularly as we go through the intricacies of contemporary agriculture.

Compliance With Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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