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ESP32-Based Real Time Soil Weather Monitoringand Smart Irrigation System in Urban Farming

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Abstract:

The Urban farming is increasingly gaining importance as cities seek sustainable solutions for food production. However, challenges such as inefficient irrigation, excessive water consumption, and poor soil condition monitoring hinder optimal crop growth and resource management. This project proposes an Arduino-based real-time soil and weather monitoring system integrated with smart irrigation technology to address these issues.

The system utilizes an Arduino microcontroller interfaced with various sensors to monitor soil moisture, temperature, humidity, and nutrient levels in real time. These sensor readings are continuously transmitted to an IoT-enabled mobile application, providing farmers with actionable insights to make informed decisions. Additionally, an automated irrigation mechanism ensures that water is dispensed only when necessary, based on predefined thresholds, thereby optimizing water usage and enhancing crop health.

By integrating real-time data processing, wireless communication, and cloud-based monitoring, this smart irrigation system reduces water wastage, improves soil fertility management, and enhances agricultural productivity in urban environments. The proposed solution not only supports sustainable farming practices but also offers a scalable and cost-effective approach to modern urban agriculture.

Keywords: Real-time soil weather monitoring, Smart IoT Device, ESP-32 microcontroller, soil moisture sensor, DTH11 sensor, Pump.

1.INTRODUCTION

Technology is advancing quickly today and has taken over humankind's way of life entirely. Even though technology plays a significant role in our daily lives, some people have totally different lifestyles from those associated with the term. Therefore, it is our duty to create a few trustworthy systems that farmers can employ effectively. The farmer who labours and works hard to produce the crop ultimately endures great suffering. Unexpected rains that fall during the drying process before selling the crop can completely ruin the yield or reduce it to second-rate quality. Automatic rain-protected drying shelters must be built to prevent this situation. In this project, we suggest a system that automatically detects rain and wraps a shield around the rooftop sensor using an intelligent microprocessor and a DC motor. The crop is protected from rain and getting wet by the drying shed's rain sensor. A rain sensor monitors the rain and transmits information to the microcontroller to automate this job. The data is processed by the microcontroller, which also turns on the DC motor control circuit and wraps a protective cover around the roof.

Crops are not protected in the current system from natural calamities like floods, rain, or excessive solar heat. which in turn slows plant growth, which in turn lowers production. After their crops were ruined by natural weather disasters, the formers committed themselves. Through the media, only weather updates or alerts are provided to the public. However, there is no precise timing notice or system in place to safeguard previous crops.

Unexpected and out-of-season rains are still occurring today, harming crops. If a hurricane or flood strikes, crops will be lost, as will obligations to the government in the form of relief contributions. We lost 20 chores of land for just one cyclone because HudHUd destroyed 9 chores of agricultural land and the government spent 11 chores of money as a relief fund. Unexpected showers are frequent in India. By putting in place an automated system that can cover agricultural land and collect rainfall for use in farming, we may overcome this loss. The primary functions of this system are to measure the amount of rainfall and the percentage of moisture in the field. The system should be turned on to safeguard the crops if there is more water than is necessary. If the water storage capacity is exceeded, the water should flow to the drainage system without affecting other regions. We will build a roofing structure that can allow the water to flow in a predesigned way.

Crops are not protected in the current system from natural calamities like floods, rain, or excessive solar heat. which in turn slows plant growth, which in turn lowers production. In this study, we suggest a method that guards against crop spoilage brought on by prolonged periods of rain. The design of embedded systems makes this possible. The main idea behind this project is to automatically cover the field in order to protect the crops from severe rain and to also conserve the water that is gathered.

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2. LITERATURE SURVEY

The agricultural issues that farmers currently confront in society are explained in this chapter. This project offers autonomous watering equipment that operates using a temperature and humidity sensor. Rain sensors are used to gather information on rainfall so that crops can be covered, depending on whether it is wanted or not. Weather conditions can change from place to place, crops require different amounts of water, and crops can be damaged by drought or heavy rain. Drip lines can be installed to ensure that water reaches roots directly and increase the system's effectiveness. According to a programme created in the Python environment, this design will sense when motion is detected, and the controller will command the camera to snap a photo and communicate the image to the farmer. The process of sensing changes in relation to objects and the surrounding environment is included in motion detection systems. When animals or people enter an agricultural area, the video-based surveillance system is generally beneficial for identifying them and sounding an alarm. To identify and analyse the duration of motion as detected from both a static camera and a moving camera, a new approach is applied. Motion detection reduces the need for and expense of monitoring. The objects will be periodically detected and classified by a real-time gadget. Frequency analyses can be used to find the regular motion. We can also take pictures and categorise them using algorithms for image processing.

We have reviewed earlier studies on projects of this nature. The Indian economy is based on agriculture, which can be compared in several ways. Because agriculture produces our primary source of food, life would be impossible without it. However, it is uncommon to find labour available nowadays to carry out agricultural tasks. Industrial expansion is a result of automation in many types of industries. Agriculture is automated at this place. A single person is sufficient to check if everything is operating normally in the proposed system, where all equipment operates on its own with the aid of inputs from sensors that continuously monitor agricultural land. A programmable logic controller regulates and keeps an eye on the entire process [1]. Seeding, irrigation, planting, fertilizing, weeding, and harvesting are all part of the agricultural process. Three processes can be used in this situation. The primary goal is to show that anyone, including professionals, can work in agriculture. Due to this methodology, the cost of manual cultivation for one acre of land is reduced to roughly Rs. 9000 to 10,000, and the yield is higher than it would be with a typical method [2].

A substantial amount of water can be conserved by using the RainGun Irrigation System, which was proposed by Sanjay Kumawat, Ashwini Kapadnis, and others [1]. This system uses an automatic microcontroller and only irrigates when there is a serious need for water. The administration of field resources can be improved because of this system's creation of the Android software stack, which is used for mobile devices and includes an operating system, middleware, and important applications. The Java programming language is supported by the Android SDK, which offers the tools and APIs required to start creating applications for the Android platform. Mobile phones play a crucial role in meeting people's many demands. The solution for the irrigation control system is to employ the GPRS feature on a mobile device. These methods weren't economically feasible and only covered lower-quality agricultural land. When there is a significant amount of water on the land, the GSM is used to relay messages. An Android app is used to prevent soil contents that affect nutrient availability from being washed away. The Microcontroller extends the life of the system and reduces power consumption. This system only supports automatic irrigation and lacks other unique features. The advantages include time savings, careful water use, and earlier knowledge of the crops that may be produced in a field thanks to the autonomous irrigation system installation and PH value determination. The drawback is that this technology only functions in locations with intermittent electrical supplies. Proteus software has been suggested for use in system design and simulation by Naveen K.B., Sagar G.H., et al. [2]. The soil moisture sensor and the rain sensor are the two sensors. The moisture sensor measures the moisture content, while the rain sensor calculates the amount of precipitation, both of which are displayed on the LCD. The car roof is employed. The automatic system for conserving rainwater and crops shields crops from heavy downpours and reduces water waste. Utilising an auto roof minimises human work while saving electricity and increasing production in both sunny and wet weather. Since the advent of agriculture, irrigation has been the foundation of human civilization. In the current situation, it is important to save water and protect the earth's natural resources. We can manage the water flow and reduce wastage by regularly monitoring the condition of the soil and employing soil moisture sensors. Low power usage and simplicity of installation are advantages. From the field to the farmer's house, remote monitoring is feasible. We can save power by automating DC motor control. Water waste can be minimized. Temperature and high humidity levels can be sensed and managed. controlling soil moisture. The expense of applying the demerit is high. According to A. Pederi and H.S. Cheporniuk et al. [3], this work combines innovative agricultural techniques and technologies. On the basis of the "Aerodrone" spraying drone project, the perspectives and advantages of using unmanned aerial vehicles in various aspects of agriculture are taken into consideration. Unmanned Systems Reduce Human Effort is the merit. Implementation costs are the flaw. The term "precision agriculture" has been used frequently in the UAV business for a few years. This can be explained by the fact that more farmers globally are basing their judgements on the information gathered by drones. Different kinds of plant protection chemicals can be sprayed by UAVs. Products for plant protection are widely available nowadays. Insecticides, fungicides, and herbicides are the main pesticides used in precision agriculture. The Ukrainian start-up "Aero Drone" creates an original project with no counterparts anywhere else in the world. This project is the first functioning fixed-wing spraying UAV prototype known. Compared to conventional crop protection strategies, it offers a number of benefits. The "AeroDrone" PAM-20 features an autopilot, modems, measuring tools, sensors, and other electronics suspended from a portable control unit. Other UAVs may have such a control unit installed, but it will require the operator to input a different settings file before the flight. Up to 1000 GPS points can be supported for mission routing using the autopilot, which offers fully autonomous missions. This paper introduces a modified device based on a wireless network and radio communication, as suggested by Shital Mahadik, Monika Paygude, Supriya Randive, and others [4]. The system consists of three layers. The controller and action unit (sensors and detectors) for surveillance are an Android control platform or an Android smartphone. Orders can be delivered to the controller via an Android control platform or a mobile, and the controller can send information such as soil moisture, salinity content, and water level to an Android platform or a mobile through a GSM modem. Reduced manpower, a dependable system, and an affordable system are the benefits. Water use and a slow development rate are the drawbacks. This soil moisture sensor was suggested by Wen-Yaw Chung, Jocelyn F. Villaverde, Janine Tan, et al. [5] and measures volumetric water content. The ratio of the volume of water to the entire sample volume of dry soil is known as the volumetric water content. The soil sample from Dai-Yun Organic Farm can be used to determine the calibration curve of the EC-5 sensor. The voltage input of the analog-to-digital converter is provided by the analogue data derived from the characteristic curve. Using the KEIL uVision4 IDE, the MPC82G516A microcontroller is programmed. To transmit the data to the receiver node, the MPC82G516A microcontroller is coupled with the wireless transceiver nRF24L01. To display transferred data on a computer monitor and store it in a database, the Tera Term terminal emulator is employed. The green house's irrigation schedule will be created using the saved settings. These numbers define the soil's volumetric water content. The four soil types that are taken into account while scheduling irrigation are dry soil, slightly damp soil, moist soil, and wet soil. Easy installation and replacement on the farm are the benefits. The drawback is that it is exceedingly challenging to meet the rising food demand. This agricultural automation system's installation, according to Vidadala et al. [6], will be carried out via web and GSM technologies. The goal of the embedded project is to create a low-cost, embedded platform-based system for agricultural automation. The fundamental goal of this system is to use water as efficiently as possible. In this project, soil moisture sensors, temperature sensors, and water level sensors are used to measure the amount of water present in agriculture and the level of a tank, respectively. We use Web and GSM technology in this system to keep an eye on the health of the sensors. Here, a web page with a microcontroller may be used to monitor temperature, soil moisture, and water level, and information will be sent by SMS. GPRS technology will be used to enable remote viewing of the sensor's status information. The benefit is creating a low-cost system that ensures optimal water utilisation. Due to the sensor being activated for an extended period of time, this article has some drawbacks. This was suggested by Kirankumar et al. [7] The device will successfully aid in plant growth and can be used as a prototype on a half-acre plot of land. The benefit is that the plant grows naturally without any human intervention. The drawbacks of this paper device can be reduced in overall cost if it is applied on a wide scale, as shown by the use of the quality simulator. Saleemmaleekh et al. [8] have claimed that as technology advances, the environment around us is becoming increasingly automated in all facets of our lives. These automated technologies are taking the place of manual processes because they are more labour- and energy-efficient. This essay makes a case for the use of wireless sensor networks in the Indian agricultural sector, outlining how they can help farmers in rural areas replace some of their outdated practices. The system developed in this work has the advantage of overcoming the drawbacks of conventional agricultural methods by making efficient use of water resources and cutting labour costs. International Journal of Engineering Science and Computing, February 2019 (http://ijesc.org/) It is challenging to uphold this paper's shortcomings. This prototype has been suggested by Jaichandran et al. [9] for the automatic control and remote access of irrigation motors. Sensor nodes, controller nodes, and smartphones are all part of the prototype. In an irrigation field, a sensor node is placed to measure the amount of soil moisture, and the controller node receives the received information. A mobile phone is used to transmit SMS requests for the irrigation field's soil moisture value and directions to turn on and off the irrigation motor. Three pots filled with soil with various levels of wetness are abstracted as irrigation fields to test the prototype. The results of the experiments demonstrate that the prototype can operate the irrigation motor automatically and remotely based on information from a soil moisture sensor. This paper's benefit is that farmers may monitor and manage irrigation activity from a distance. The flaw in this paper is that farmers have to incur significant financial losses as a result of inaccurate weather predictions and poor crop irrigation techniques. This system includes certain sensors, an LCD display, a GSM modem, and an ARM processor, according to Priyanka et al. [10]. As soon as necessary, the user will take the appropriate action. Here, we are monitoring the field conditions with a total of seven sensors. These include sensors for temperature, humidity, soil moisture, leaves, PH, levels, and phases. GSM is used by all of these devices connected to the ARM CPU for communication, and AT (attention) commands are used to interact with the components. We use motors for applications such as level monitoring and soil modules. Water is kept in one motor, and then it is released into the soil in another. The paper's strengths are economic expansion, income equality, and food security. Lack of data is one of this paper's flaws.

3. PROPOSED METHODOLOGY

The proposed Arduino-Based Real-Time Soil-Weather Monitoring and Smart Irrigation System is designed to enhance urban farming efficiency by integrating IoT-enabled soil monitoring and automated irrigation. The system utilizes an Arduino Uno microcontroller along with multiple sensors to continuously monitor key environmental parameters and optimize water usage.

The proposed Arduino-Based Real-Time Soil-Weather Monitoring and Smart Irrigation System is designed to enhance urban farming efficiency by integrating IoT-enabled soil monitoring and automated irrigation. The system utilizes an Arduino Uno microcontroller along with multiple sensors to continuously monitor key environmental parameters and optimize water usage.

If the moisture level falls below a predefined threshold, the water pump is automatically activated, ensuring precise water delivery. Once the optimal soil moisture level is reached, the pump is turned off, preventing excessive water usage.

A DHT11 sensor is integrated to continuously measure temperature and humidity in the farming environment. This real-time weather data is transmitted to an IoT cloud platform, allowing farmers to remotely monitor field conditions. The system can adjust irrigation schedules based on environmental conditions, preventing unnecessary water usage during rainy or humid conditions.

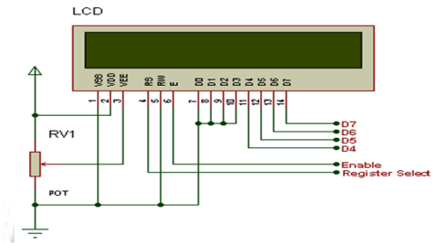
All sensor readings are sent to an IoT-enabled mobile application or web dashboard, providing real-time insights into soil and weather conditions. Farmers can manually control the irrigation system via the IoT application, overriding the automatic function if necessary. Alerts and notifications are sent to the user in case of critical conditions, such as extreme dryness or sudden temperature fluctuations.

The Arduino-based system automatically decides when to irrigate based on soil moisture levels, temperature, and humidity data. This approach ensures efficient water usage, reducing waste and improving crop yields in urban farming settings. The system can be programmed to adapt to different crop types, making it a versatile solution for diverse urban agricultural applications.

Applications:

The ESP32-Based Real-Time Soil Weather Monitoring and Smart Irrigation System can be applied in various innovative waysElderly soil weather monitoring for continuous tracking of vital signs.

- Urban Farming Soil and Weather Monitoring for Continuous Crop Health Tracking
- Fall Detection for Gardeners and Irrigation System Failures.



- Remote Farm Monitoring for Real-Time Environmental Data Access
- Emergency Alerts for Extreme Weather or Irrigation Issues
- Fitness and Growth Tracking for Plants and Crops.

Advantages:

- Optimized Water Usage: Prevents over-irrigation and under-irrigation.
- Remote Monitoring & Control: IoT integration allows farmers to manage irrigation from anywhere.
- Improved Crop Health: Continuous monitoring of soil and environmental conditions.
- Sustainability: Reduces water wastage, promotes eco-friendly farming, and enhances soil fertility.
- Scalability: Suitable for small-scale urban farms and larger agricultural settings.

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4. EXPERIMENTAL ANALYSIS

The ESP32-Based Real-Time Soil Weather Monitoring and Smart Irrigation System for urban farming aims to assess the effectiveness of a system that uses sensors and an ESP32 microcontroller to monitor soil moisture, weather conditions, and automate irrigation processes. The experimental analysis is focused on evaluating the system's performance in accurately measuring environmental variables and optimizing water usage.

The experimental procedure starts with calibrating the sensors to ensure accurate readings, especially for soil moisture. The system then continuously measures environmental data, including soil moisture levels, temperature, humidity, and rainfall. Using this data, the smart irrigation system is programmed to trigger irrigation based on moisture levels. For instance, irrigation is activated when the moisture falls below a certain threshold, and the system adjusts irrigation based on weather conditions, such as skipping watering during rainfall or increasing it during extreme heat.

The performance of the system is evaluated by testing its responsiveness to environmental changes. Key metrics such as water usage and the system’s ability to conserve water are measured and compared to traditional irrigation methods. The results are analyzed to determine the system’s efficiency, including how well it reduces water consumption while maintaining optimal soil conditions for plant growth. The system’s reliability is also tested over time, ensuring that it operates without frequent interruptions.

Figure 1: LCD Display

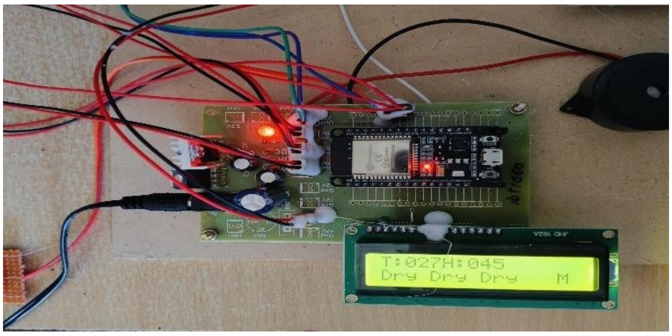

Figure 2: Output Analysis

Figure 1: The LCD display in the image is showing real-time sensor data from what appears to be a soil moisture and environmental monitoring system. The reading likely represents a temperature of 27°C, while may indicate a humidity level of 44%. The word ON suggests that the system has activated a component, possibly a water pump. The terms Dry Wet indicate that the system is monitoring soil moisture conditions, switching between dry and wet states. The phrase Dry A could mean that the soil in a specific area has been detected as dry, triggering the irrigation system. This setup seems to be part of a smart irrigation or automated farming project, ensuring optimal water management based on real-time environmental conditions.

Figure 2: The image displays an electronic circuit setup featuring an ESP32 microcontroller mounted on a custom PCB, connected to various components such as an LCD display, a buzzer, and multiple wires. The LCD screen shows real-time sensor data, where likely indicates a temperature of 27°C and a humidity level of 45%. The repeated Dry readings suggest that the soil moisture sensors have detected dry conditions across multiple zones.

Pump_ON Pump_OFF

S.No	Temperature	Humidity	Mos1	Mos2	Mos3	Pump_Status	Date
1	27.50	30.00	Dry		Dry		2025-01-22 13:35:06
2	27.40	31.00	Dry		Wet		2025-01-22 13:32:49

The above image represents the state of Pump along with temperature, humidity, and sensors at particular date and time.

5. CONCLUSION

The Arduino-Based Real-Time Soil-Weather Monitoring and Smart Irrigation System provides an efficient, automated, and sustainable solution for urban farming. By integrating IoT technology with real-time monitoring of soil moisture, temperature, humidity, and nutrient levels, the system ensures optimal water usage and enhances crop health. The automated irrigation mechanism, controlled by an Arduino Uno microcontroller, minimizes water wastage, reduces manual labour, and promotes precision agriculture.

With three soil moisture sensors, a DHT11 weather sensor, a pH sensor, and IoT-based remote access, farmers can make data-driven decisions to optimize irrigation schedules and soil conditions. The IoT-enabled mobile application provides real-time insights and allows remote monitoring and control, ensuring a user-friendly and scalable approach to modern farming.

This system contributes to sustainable agriculture by reducing resource wastage, increasing efficiency, and improving crop productivity in urban farming environments. The proposed solution can be expanded and customized for different crop types, making it a versatile, cost-effective, and environmentally friendly approach to modern agriculture. By integrating technology with farming, this system paves the way for smarter, more sustainable urban agriculture, ensuring food security and conservation of essential resources.

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