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IoT Based Smart Agriculture Monitoring System

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Abstract: *Internet of Things This work introduces design and implementation of IoT-Based Smart Agricultural Monitoring System, which is entirely offline, to provide real-time environmental monitoring and automated irrigation in environments with no internet coverage. The system incorporates soil moisture, flame, and light-dependent sensors with a microcontroller to monitor vital field parameters and independently activate actuators like water pumps and DC motors. Power is provided by a solar panel and regulated with a buck converter and rechargeable battery, providing sustainable, continuous functionality. In contrast to traditional IoT systems that rely on cloud infrastructure, this approach prioritizes local decision-making, cost-effectiveness, and ease of installation, making it perfect for rural and remote applications. With modular design, scalability and customization are possible, providing an affordable, low-cost alternative to sophisticated commercial smart farming systems. Experimental results confirm the system's ability to maximize water efficiency, field safety, and environmental sustainability. The study shows the value of embedded, autonomous systems in solving critical issues in agriculture i.e., water scarcity, lack of labor, and crop susceptibility without needing costly infrastructure. The strategy encourages inclusive agricultural growth, especially in the neglected areas, and allows for future upgrades like mobile application integration, GSM-based SMS notifications, or predictive analysis via onboard storage.*

Keywords: Soil moisture sensor, Flame Sensor ,LDR sensor Concept of smart agriculture, IoT

I. INTRODUCTION

Agriculture Agriculture is still a core component of world food security and the economy, particularly in the developing world where most people rely on agriculture to survive. Despite being a critical industry, traditional farming methods are generally linked with resource inefficiency, mainly water usage and energy consumption. The beginning of climate variability, dramatic climate conditions, and low-water availability has never required technology-based interventions in agriculture more than it does now.

Integration of Internet of Things (IoT) in agriculture, also referred to as smart agriculture, has revolutionized the operation of monitoring and managing agricultural activities. IoT solutions typically enable farmers to capture data in real-time from environmental sensors, which can again be used to automate critical activities such as irrigation, crop monitoring, and risk detection. The biggest hurdle to the implementation of such systems in rural or underdeveloped regions is the requirement for internet connectivity and cloud infrastructure. These demands render most commercial IoT solutions inefficient for communities with poor or no network connectivity.

To bridge this gap, this study proposes an offline, standalone IoT-Based Smart Agriculture Monitoring System that addresses the most serious issues of small and marginal farmers. The system has been developed in a way that it can operate as an independent system without the support of Wi-Fi or the cloud, hence being highly suitable for rural farm locations. It uses real-time inputs from soil moisture sensors, LDR (Light Dependent Resistor) sensors, and flame sensors to offer automation in irrigation and enhance safety features. Utilizing microcontroller-based local processing and hardware-level logic, the system offers real-time response to changing environmental conditions without any external instruction.

II. RELATED WORK

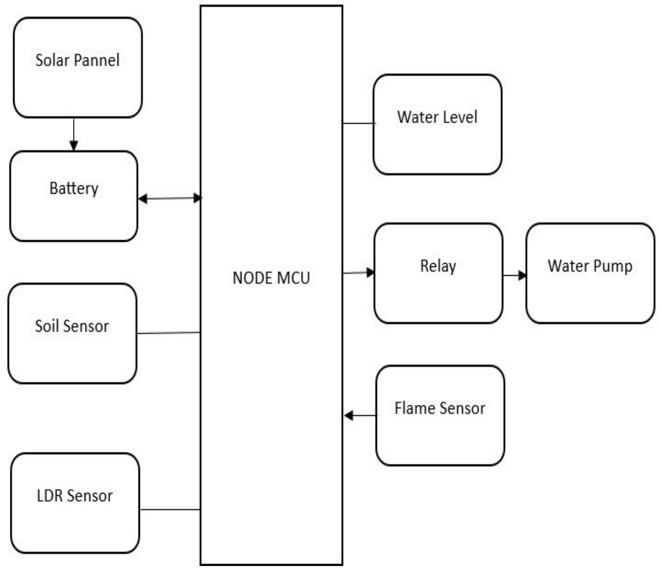
A number of researchers have in recent years studied the use of IoT technologies in agriculture to improve productivity, efficiency, and sustainability. The systems are likely to utilize sensor networks and microcontrollers to track environmental parameters

- Patel and Singh (2019) employed an Arduino-based low-cost smart irrigation system and soil moisture sensors to achieve maximum water use efficiency. Their system was suitable for small-scale farms but lacked mature features such as multi-sensor fusion (e.g., flame and light sensors) and offline capability. Our system improves on this solution with flame detection and ambient light sensing for better field safety and irrigation timing adjustment and better for farming.
- Chakraborty et al. (2018) proposed a low-cost sunlight and dry soil-sensitive sensor-based irrigation system. They prioritized ease of operation and easy deployment but did not leave much scope for system scalability, degree of automation, and energy autonomy. Our system overcomes these limitations through the application of solar-based energy balancing, hardware modularity,and the employment of relays to fully automate the field devices.water only, when necessary, based on real-time data.
- Swaraj and Sowmyashree (2020) have developed a soil moisture sensing-based solar-powered irrigation system. Their system also included wireless modules for transmitting data to websites. Our system eliminates this by being entirely offline, which is especially fitting for resource-constrained agricultural environments.

III. PROBLEM STATEMENT

Agriculture continues to be the main livelihood for the majority of the people in rural and developing areas. Yet, farmers in these communities experience several challenges in irrigation management, crop protection, and access to energy. Conventional irrigation practices are highly dependent on human labor and rigid schedules, causing water to be wasted through inefficiencies, over-irrigation, or under-irrigation damage to crops. In addition, the escalating volatility of climatic conditions and the rising incidence of field threats like fire make farming operations even more challenging. Although several IoT-enabled smart farming solutions have been presented to overcome them, the majority rely on permanent internet connection, cloud platforms, or cellular networks for data processing as well as control. These conditions render such systems unfeasible and unreliable in rural and far-flung areas where digital infrastructure is in short supply. Additionally, most current solutions are either costly, difficult to establish, or depend considerably on outsourced power sources, which further exacerbate the strain on small and marginal farmers. In response to such limitations, there exists an urgent need for a cost-effective, entirely offline, and energy-efficient smart agriculture system that can function independently. Such a system should be able to monitor environmental conditions such as soil wetness, sunlight, and fire risk in real time, automate irrigation and safety reactions, and operate sustainably under solar power. The system should also perform reliably without the need for Wi-Fi, mobile applications, or cloud infrastructures. Making this solution will enable farmers in poor areas to enhance productivity, save water, and promote safer farming with little technical sophistication. It must run on renewable power, employ low-cost technologies, and accommodate modular expansion as necessary. By precluding reliance on the internet, mobile networks, and sophisticated user interfaces, such a system would facilitate inclusive and accessible smart farming, allowing even the remotest agricultural communities to share in the benefits of technological progress. The work reported in this project strives to bridge this important gap by creating an entirely offline, solar-powered smart agriculture monitoring system that is both scalable and feasible for real-world deployment.

IV. BLOCK DIAGRAM



Power supply from Solar Panel and Battery

The device is driven by a solar panel, which is utilized to charge a battery. The battery stores energy and delivers controlled power to the whole circuit, enabling free and environmentally friendly operation, particularly in off-grid systems

Soil Moisture Sensor Input: NodeMCU is interfaced with the soil moisture sensor that provides live measurements of the water in the ground. The system waters automatically when the water level falls below a predefined threshold.

LDR Sensor for Light Detection: The LDR sensor senses the level of ambient light. This information can be utilized for day/night status determination or for scheduling irrigation based on sunlight availability.

Fire Detection Flame Sensor: The flame sensor tracks the field for flame hazards. In case of a flame detection, the system may initiate alarms or cut power to avoid damage, adding security to crops.

Data Water Level Monitoring: A water level sensor monitors water in the reservoir or the storage tank. It prevents the water pump from getting dry and makes the system water only when water is present.

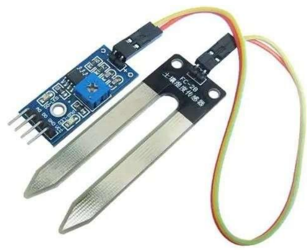
NodeMCU : NodeMCU is the decision-making controller that receives sensor inputs and decides based on pre-programmed rules. It controls all the outputs (e.g., pump through relay) and manages power input/output.

Relay module: It is a switch controlled by the NodeMCU. The relay is turned on by the NodeMCU when the soil is low in moisture and other conditions. The relay turns on the water pump to irrigate the field.

V. HARDWARE COMPONENTS

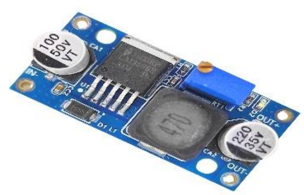
Soil Moisture sensor

The device designed to detect moisture levels in soil is known as a soil moisture sensor, also depicted in the figure. When the sensor identifies a lack of water in the field, the output from the module will be high; otherwise, it remains low. This sensor serves as a reminder for users to irrigate their plants and tracks the moisture levels in the soil. It is commonly applied in agriculture, irrigation practices, and gardening.



Buck Converter

A buck converter is a power DC-DC converter that reduces a higher input voltage to a lower output voltage with higher efficiency. A buck converter employs a switching device (e.g., a transistor) configuration, an inductor, and a diode to control the voltage. Buck converters are required in IoT-based systems for delivering stable, low-voltage power to sensitive electronic devices. Buck converters are most appropriate in solar- or battery-powered systems as they have high efficiency..

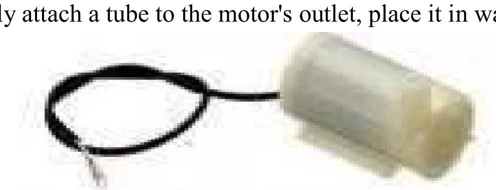


Relay

A relay functions as an electrically operated switch, as illustrated in the figure. It features a group of input terminals designed for either single or multiple control signals and a set of operating contact terminals. The switch can include various contacts in different configurations that either make or break connections. In agriculture, a relay is utilized to activate a water pump, helping to regulate the moisture levels of crops.

Water pump

The DC 3-6V Mini Micro Submersible Water Pump illustrated in the figure is a compact submersible pump motor. It operates on a power supply ranging from 2.5 to 6V and can move up to 120 liters per hour while consuming a minimal current of 220mA. To use it, simply attach a tube to the motor's outlet, place it in water, and turn it on.



NODEMCU ESP8266

NodeMCU is an open-source firmware and development board intended for creating Internet of Things (IoT) applications. It is built on the ESP8266 Wi-Fi module, integrating a robust microcontroller with built-in Wi-Fi functionalities. NodeMCU simplifies the process for developers, hobbyists, and engineers to fabricate connected devices, thanks to its affordability, versatility, and solid community backing.

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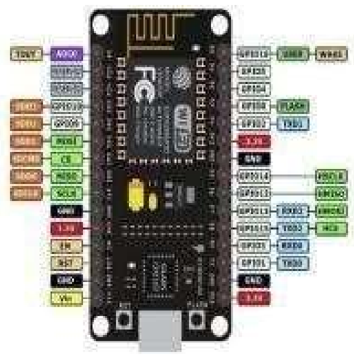
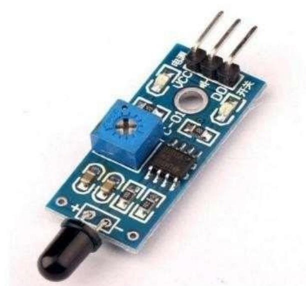


Flame Sensor

A flame sensor into the IoT-enabled Smart Agriculture System allows for the swift detection of fires in the fields. Once a fire is identified, the system can automatically initiate irrigation or fire suppression measures, protecting crops and equipment. This functionality enables farmers to react quicker, minimizing risks and damage from fires.



LDR Sensor

A Light Dependent Resistor (LDR) is a sensor that changes resistance based on light intensity. Its resistance decreases in bright light and increases in darkness, making it useful in automatic lighting, light meters, and alarms. LDRs are cost-effective, simple, and widely used in light-sensing and automation applications.

Solar Panel

Solar panels provide a dependable, off-grid power source for agricultural activities. They supply energy to sensors, controllers, communication devices, and automated systems like irrigation and pumps, particularly in isolated regions. By utilizing renewable energy, solar panels lower electricity expenses, ensure the continuous operation of systems, and promote sustainable farming practices, even in areas lacking conventional power access.

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VI. METHODOLOGY

- Sensor Deployment: Soil moisture level, LDR (Light Dependent Resistor), and fire sensors are installed in the farm to provide real-time measurement of environmental parameters such as soil moisture level, intensity of sunlight, and fire danger.
- Microcontroller programming: A NodeMCU or Arduino microcontroller is programmed with threshold-based logic to receive sensor values and independently choose to power irrigation and safety systems.
- Relay-Based Actuation: Relay modules are used to switch on high-power devices like the DC motor and water pump so that the microcontroller can automate irrigation and safety features based on sensor inputs.
- Solar Power Management: A solar panel feeds the system, with the stored energy in a rechargeable battery. A buck converter regulates the voltage, delivering stable power to all components for efficient, smooth operation.
- Offline Autonomous Operation: The system is completely offline-capable and does not use Wi-Fi or cloud-based systems, and is therefore most appropriate for implementation in rural and distant locations where internet connectivity is weak. 6. Scalability and Manual Override There is an integrated manual switch for emergency shutdown or maintenance. The modular nature of the system allows for the addition of future sensors or features like GSM modules or data logging.

VII. LITERATURE SURVEY

1. Kumar et al. (2020) developed a soil moisture and temperature sensor-based smart irrigation system with partial dependence on internet platforms for control and visualization. While efficient in reducing manual intervention, these systems cannot be used in offline mode and hence are unsuitable for connectivity-limited locations.
2. Patel and Singh (2019) also utilized a low-cost, soil-moisture–based irrigation system that they developed based on Arduino. Although their model was easy to automate, it lacked the most critical features of this project, including multi-sensor integration (e.g., light and flame sensors), renewable energy, and offline capability.
3. Chakraborty et al. (2018) proposed an LDR and soil sensor-based irrigation system with a focus on light-based irrigation scheduling. The proposed system was efficient and easy but did not have fire safety measures and renewable energy components, thus being less scalable and dependable for remote areas.
4. Raza et al. (2021) proposed a cloud-based smart agriculture system with sensors for environmental monitoring in real-time. However, its dependence on an uninterrupted internet connection for cloud logging and remote user interfaces renders it incapable of being used in remote fields where there is no steady network connectivity.
5. Swaraj and Sowmyashree (2020) had developed a solar-powered intelligent irrigation system based on IoT devices and wireless modules for cloud updation. Although this ensured sustainability from the energy usage point of view, reliance on Wi-Fi and cloud services was still a concern in offline scenarios.
6. Pawar and Mehta (2020) developed real-time agricultural monitoring and control system using IoT technologies. Their setup employs various environmental sensors along with a central controller that adjusts irrigation and other

parameters accordingly. The key contribution lies in their dynamic feedback system, which ensures precise agricultural intervention..

VII. CONCLUSION

The current paper suggests a low-cost and effective solution for automating farming activities through the assistance of a fully offline, IoT-based smart agriculture monitoring system. Utilizing the application of soil moisture, flame, and LDR sensors together with a microcontroller and relay-based control, the system facilitates autonomous irrigation and environmental monitoring through the lack of internet connectivity and cloud infrastructure. The use of solar power and a buck converter facilitates constant energy-efficient operation, and the system is well suited for use in remote or underdeveloped areas. The design is centered on affordability, scalability, and usability to meet the urgent requirements of marginal and small farmers. Test results validate the system's water-saving potential, increased field safety, and precision agriculture. The project, overall, addresses the increasing demand for inclusive, sustainable, and resilient agro-technology that will be capable of operating by itself even in low-resource settings. Future additions such as GSM modules or data logging are possible to make it even more versatile while still maintaining its fundamental offline nature. resources.In conclusion, highly functional agriculture innovation is not necessarily costly or complicated Rather, with the incorporation of sensible planning with simple sensors, power-saving hardware, and offline automation, it is possible to develop highly functional smart farming systems at an affordable cost. This project provides a template that can be used in future research and development to enhance rural agricultural productivity using sustainable technology. The current design lays the groundwork for future integration of features such as GSM modules for SMS alerts, Bluetooth connectivity for mobile interfacing, or machine learning for intelligent irrigation. These enhancements can be added modularly, extending the system’s capabilities without redesigning the core hardware.

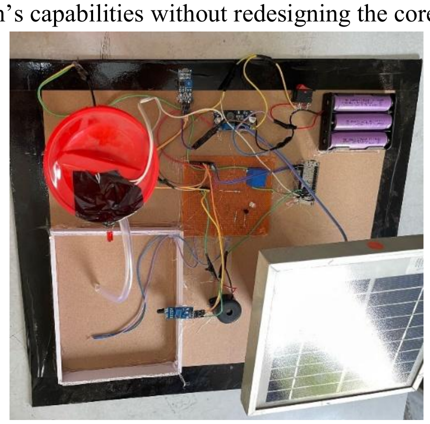

FIG-HARDWARE SETUP

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