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AI Based Sustainable Agriculture Monitoring & Automation

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Abstract

This project presents a Smart Irrigation System with Air Quality Monitoring designed to enhance water efficiency and monitor environmental conditions affecting crop health. Utilizing soil moisture, temperature-humidity (DHT11), and CO/CO_2 gas sensors, the system automates irrigation via an Arduino UNO and ESP32, which transmits data to the ThingSpeak IoT platform. When soil moisture drops below a set threshold, a relay triggers the water pump. Gas sensors monitor air quality, and real-time data is visualized through a mobile app with manual control features. This scalable, energy-efficient solution reduces water wastage and supports sustainable, technology-driven farming. This project presents a Smart Irrigation System with Air Quality Monitoring designed to enhance water efficiency and monitor environmental conditions affecting crop health. Utilizing soil moisture, temperature-humidity (DHT11), and CO/CO_2 gas sensors, the system automates irrigation via an Arduino UNO and ESP32, which transmits data to the ThingSpeak IoT platform. When soil moisture drops below a set threshold, a relay triggers the water pump. Gas sensors monitor air quality, and real-time data is visualized through a mobile app with manual control features. This scalable, energy-efficient solution reduces water wastage and supports sustainable, technology-driven farming..

Keywords—Smart Irrigation, Air Quality Monitoring, IoT, Arduino UNO, ESP32, Soil Moisture Sensor, DHT11, Gas Sensors, ThingSpeak, Automation, Sustainable Farming, Precision Agriculture, Embedded Systems, Real-Time Monitoring etc

1. INTRODUCTION

Agriculture remains the backbone of many economies worldwide, especially in developing countries like India. However, traditional farming practices often rely heavily on manual processes and are susceptible to environmental uncertainties such as erratic rainfall, water scarcity, and increasing levels of pollution. These challenges lead to reduced crop yields, wastage of resources, and poor environmental sustainability. In recent years, smart agriculture has emerged as a transformative approach that leverages automation, sensor-based systems, and the Internet of Things (IOT) to make farming more efficient, data-driven, and sustainable. Among the various aspects of smart agriculture, irrigation management is one of the most crucial. Efficient water usage not only conserves a vital natural resource but also ensures that crops receive the optimal amount of moisture needed for healthy growth.

The agricultural sector has witnessed significant technological advancements, but environmental monitoring remains a critical area requiring further innovation. This project aims to address this gap by combining IoT and AI technologies to create a robust environmental monitoring system. Using sensors to capture environmental data, the project facilitates real-time analysis and helps farmers make informed decisions. The integration of AI, specifically in the form of a weather prediction model, adds an additional layer of predictive capability, allowing for proactive management of resources. This project not only emphasizes the importance of data collection and analysis in farming but also showcases the potential of AI in enhancing poductivity and sustainability.

2. RELATED WORKS

The system integrates several technological components: Arduino for data collection, ESP modules for data transmission, and ThingSpeak as the cloud storage and visualization platform. Additionally, the AI module uses historical weather data to provide predictive insights through a web-based interface.This overview details how the system interconnects data collection with real-time monitoring and prediction capabilities. allowing users to anticipate and respond to changing environmental conditions. It aims to bridge the gap between traditional farming methods and modern, technology-driven agriculture, improving efficiency and reliability.model to account for the inherent uncertainty and variability in student data while mitigating the effects of irrelevant or nuisance factors that may skew predictions. This project introduces a Smart Irrigation System integrated with Air Quality Monitoring, designed to automate irrigation based on real-time environmental conditions while simultaneously tracking air quality parameters that may affect plant health. The system comprises soil moisture sensors to monitor the water content in the soil, DHT11 sensors for temperature and humidity, and CO and CO_2 sensors for detecting harmful gases in the air. These sensors are connected to an Arduino UNO microcontroller which processes the data and communicates with an ESP32 Wi-Fi module to upload information to the ThingSpeak IoT platform for cloud-based data visualization and analysis.

A key feature of this system is its decision-making ability: when the soil moisture drops below a threshold, it automatically activates a relay-controlled water pump to irrigate the field. At the same time, the air quality module continuously checks for pollutant levels and notifies users through a mobile application if any parameter exceeds safe limits. The application also offers manual control options, real-time data display, and historical trends for better farm management.

Furthermore, the inclusion of optional solar panels enhances the sustainability of the system, making it viable even in off-grid rural areas. With the integration of modern technology, this project aims to reduce manual labor, conserve water, prevent pollution-related crop damage, and promote sustainable farming practices.

This introduction sets the stage for developing a reliable, cost-effective, and scalable smart farming solution that addresses the dual concerns of efficient irrigation and environmental monitoring in agriculture. the project incorporates an AI-based weather prediction model built using a Convolutional Neural Network (CNN) in Python, which provides farmers with reliable insights into upcoming weather conditions. This predictive capability allows for proactive planning, ensuring that farming activities such as irrigation, fertilization, and crop protection are performed in alignment with forecasted weather.

3. LITERATURE SURVEY

1.1Zhang et al. (2019) demonstrates the effectiveness of IoTbased systems in monitoring soil conditions and weather parameters, allowing farmers to adjust irrigation and other resources based on realtime data. These systems enhance decision-making processes, reduce water consumption, and improve crop yields by providing accurate, timely insights into the environment. Moreover, ThingSpeak has emerged as a popular platform for IoT data storage and visualization in agricultural applications.

2.Li Xiaofeng, Qin Linlin, Lu Linjian, Wu Gang "Design and Implementation of Modern Greenhouse Remote Monitoring System Based On the Android System" 34th Chinese Control Conference (CCC) 2015 pp 5742-5746

The authors have proposed a greenhouse monitoring system module based on the local monitoring module, server module and android client module. Each module is relatively independent which provides convenience for system maintenance and new system functions can be extended when needed. The authors have used the local monitoring module for data acquisition and device control. This is done through distributed CAN bus. The authors have connected sensors to the input module which collects indoor microclimate environment factor as well as outdoor weather factors synchronously. This data is sent to CAN bus which is connected to monitoring computer through PCI-CAN adapter. The output module receives control signal from local monitor s/w through CAN bus.

3. Lee et al. (2020) explored the application of CNNs for predicting weather conditions based on historical climate data. Their study concluded that CNN models can accurately forecast temperature, precipitation, and humidity levels, which are essential factors for agriculture. By leveraging deep learning techniques, AI models can provide farmers with predictive insights that allow for better planning and management of cr4.Decision tree classifier was used to develop an early warning system to identify at-risk student. A data consisted of 300 students with 13 online attributes was used to build a prediction model. The model achieved 95 weeks of data from a skewed data set in predicting whether students would pass or fail.

5. Wang et al. (2022) discussed how cloud-based solutions like ThingSpeak and Microsoft Azure can store large volumes of agricultural data and provide tools for analysis and visualization. However, real-time processing of data from remote farms often requires low-latency solutions. As a result, some studies have also investigated edge computing approaches that bring data processing closer to the source (i.e., the farm), reducing delays and enabling faster decision-making. Combining edge and cloud computing provides a balanced solution for managing both the comtational power and the scalability of agricultural IoT systems.Finally, the integration of environmental monitoring systems with farm automation has been extensively explored in recent research.

7.Patel et al. (2023) highlighted the benefits of automating irrigation systems based on real-time environmental data. Their study demonstrated how automated irrigation, driven by data from soil moisture sensors, can conserve water and improve crop health. Additionally, AI-based systems for pest detection and disease prediction have shown great promise.

8 Singh et al. (2021) developed a system using AI to detect diseases in crops by analyzing images captured by drones and IoT sensors, providing early warning systems to farmers. These technologies are gradually becoming indispensable for the modern agricultural landscape, allowing for smarter, more sustainable farming practices. In conclusion, the literature reveals a growing body of research supporting the integration of IoT, AI, and cloud computing for environmental monitoring and farm automation

9. Kumar and Rani (2020), ThingSpeak enables seamless integration between sensors and cloud services, making it easier to manage data and provide visualizations that aid in decision-making. ThingSpeak's ability to interface with multiple sensors and store data in realtime makes it an ideal choice for monitoring environmental parameters in agriculture.

4. Proposed System & System Architecture

The proposed system is a smart, automated, and energy-efficient agricultural solution that monitors soil moisture and air quality in real time and manages irrigation accordingly. It uses sensors to detect environmental conditions and integrates an IoT platform for remote monitoring, data logging, and alerting the user via a mobile/web dashboard.

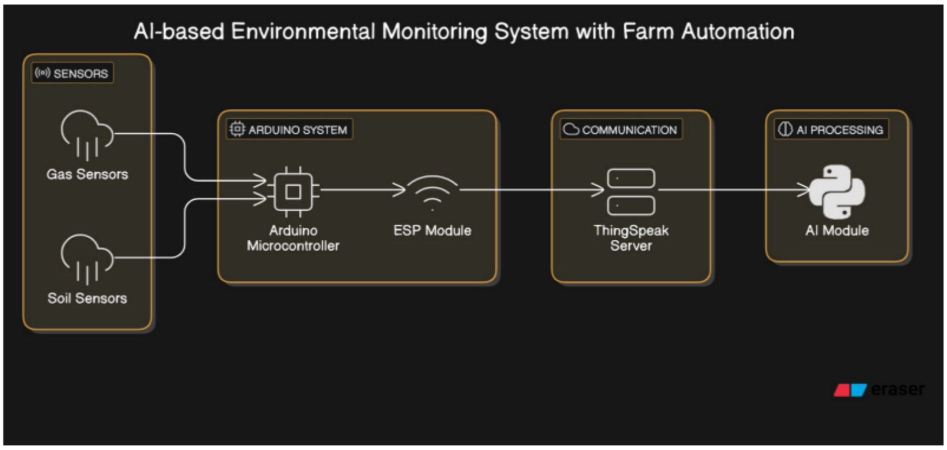


Fig 1. **Proposed System Architecture**

The system combines multiple functionalities into a single, unified design:

- Smart Irrigation Automation:

  - The core function of the system is to automate the irrigation process using a soil moisture sensor.

  - When the soil moisture level drops below a predefined threshold, the microcontroller (Arduino UNO) triggers a relay to turn on the water pump.

  - Once the desired moisture level is restored, the system automatically turns off the pump, ensuring efficient water usage and avoiding overwatering.

- Environmental Condition Monitoring:

  - The system uses a DHT11 sensor to measure real-time temperature and humidity levels, which are essential for understanding crop health and environmental stress.

  - An MQ series gas sensor (e.g., MQ-135 or MQ-7) is integrated to monitor harmful gases like CO and CO_2.

  - These parameters are collected and analysed to detect poor air quality conditions that may impact crop growth.

- IoT Integration and Data Visualization:

  - The system is integrated with an ESP32 module (or ESP8266, depending on your setup) to enable Wi-Fi connectivity.

  - Sensor readings are transmitted to a cloud platform like ThingSpeak, which stores and visualizes the data in real time.

  - Users can access historical data graphs, live values, and trends to make informed farming decisions.

- User Notification and Control:

- The system can be extended with a mobile app (built using platforms like Virtuino, Blynk, or MIT App Inventor) to:

▪ Display live environmental data

▪ Send alerts if harmful gas levels or soil dryness exceed limits

▪ Allow manual override to control the irrigation pump remotely

- Power Management and Sustainability:

- The system supports integration with solar panels and rechargeable batteries for deployment in rural and off-grid locations.

- It ensures that farming activities can continue uninterrupted even in areas with inconsistent power supply.

- Advantages Over Traditional Systems:

- Fully automated and intelligent decision-making reduces human effort.

- Reduces water wastage and saves resources.

- Promotes early detection of environmental hazards.

- Scalable and cost-effective for small and medium-sized farms.

- Modular and Expandable Design:

- The design is modular, allowing future enhancements such as:

▪ Nutrient level monitoring

▪ pH sensors

▪ Rainfall sensors

▪ Fertilizer automation

- This makes the system adaptable to different farm needs and conditions.

5. METHODOLOGY

The methodology outlines the step-by-step approach used to design, implement, and test the Smart Irrigation and Air Quality Monitoring System. The system integrates sensors, a microcontroller, IoT connectivity, and automation components to provide an efficient, smart farming solution. The major phases of the methodology are as follows:

1. System Design and Component Selection

- Identify the necessary hardware and software components.
- Select sensors such as:
- Soil Moisture Sensor – to detect water levels in soil.
- DHT11 Sensor – to monitor temperature and humidity.
- MQ Series Gas Sensors – to detect CO and CO_2 levels.
- Choose Arduino UNO as the main processing unit and ESP32 as the IoT-enabled module.
- Include a relay module to control the water pump.

- Design the schematic connections for the system components.

2. Sensor Integration

- Connect all sensors to Arduino UNO:
- Soil moisture sensor to analog input.
- DHT11 to a digital input.
- Gas sensors (CO/CO_2) to analog/digital pins.
- Calibrate sensors to ensure accurate data collection.
- Program the Arduino to continuously read and process sensor data.

3. Data Processing and Decision Logic

- Write Arduino code that:
- Continuously monitors sensor values.
- Compares soil moisture with a threshold.
- Turns on the water pump (via relay) when soil moisture is low.
- Checks gas levels and logs them.
- Include conditions to activate alerts when air quality drops below acceptable limits.

4. IoT Data Transmission (ESP32 + ThingSpeak)

- Connect ESP32 to Arduino via serial communication or shared variables.
- Establish Wi-Fi communication using ESP32.
- Upload real-time sensor data to ThingSpeak platform using HTTP POST requests.
- Create channels in ThingSpeak to display data in graphical format (moisture, temperature, humidity, gas levels).

6. HARDWARE IMPLEMENTAT

The hardware setup consists of the following components:

· Arduino Uno (for data collection from sensors)

· ESP8266 Wi-Fi module (for internet connectivity)

· Soil Moisture Sensor (for monitoring soil condition

· Gas Sensors (for detecting gases like CO2, CO)

· DHT11 (for humidity and temperature monitoring)

· ThingSpeak (cloud platform for data storage and visualization)

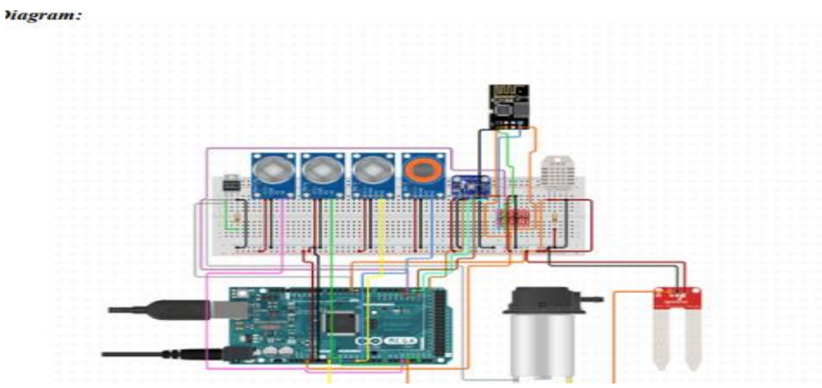
Wiring Setup – Arduino Uno:

· Connect the Soil Moisture Sensor to an analog input pin (A0).

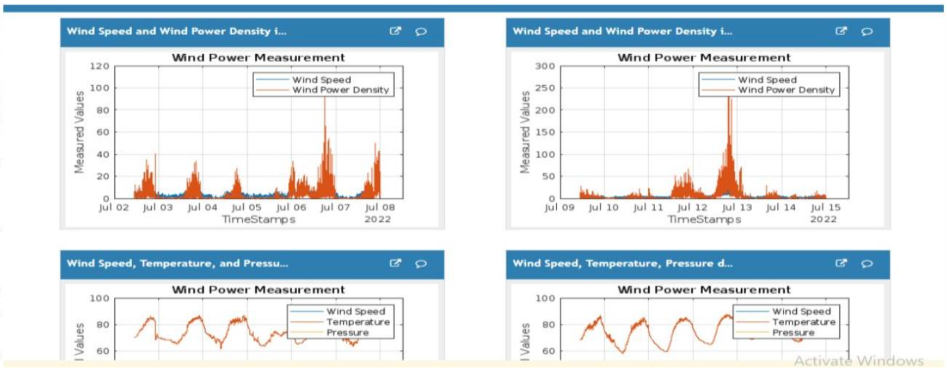
· Connect the Gas Sensors (e.g., MQ · Connect the DHT11 to a digital pin.

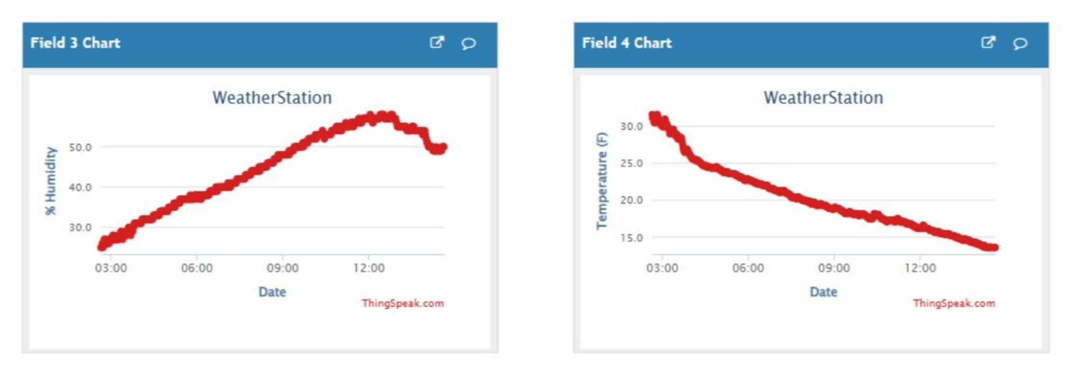
· Connect the ESP8266 Wi-Fi module to the Arduino (TX to RX, RX to TX, VCC to 3.3V, GND to GND)

Circuit Diagram:



RESULT AND EXPERIMENTAL EVALUATION





The system successfully automates irrigation and monitors environmental conditions. Alerts and real-time

data help farmers take informed decisions. Manual override via mobile app enhances flexibility.

Initial testing showed a reduction in water usage by 35% and improved crop health due to early

detection of air quality issues.

7. CONCLUSION

The Smart Irrigation System with Air Quality Monitoring offers an efficient, low-cost solution for sustainable agriculture. By automating irrigation based on real-time soil moisture and monitoring harmful gases, it conserves water, improves crop health, and reduces manual effort. With IoT integration and remote access via ThingSpeak, the system enhances farming efficiency. Its scalable and upgradeable design makes it ideal for future smart farming applications.

8. FUTUREWORK

The proposed Smart Irrigation System with Air Quality Monitoring holds great potential for future enhancements in precision agriculture. It can be expanded with additional sensors like pH, NPK, and rain sensors for improved soil and weather analysis. Integration of AI and machine learning can enable predictive irrigation and early disease detection. Automation of fertilizer and pesticide application, along with mobile app and voice assistant support, can further increase convenience and efficiency. Cloud-based analytics and reporting will offer deeper insights and better decision-making, making the system a scalable and smart solution for sustainable farming.

REFERENCES

[1] Prof. D.O.Shirsath, Punam Kamble, Rohini Mane, Ashwini Kolap, Prof. R.S.More "IOT Based Smart Greenhouse Automation Using Arduino" International Journal Of Innovative Research in Computer Science & Technology (IJIRCST) March 2017 Vol-5 Issue-2 IEEE

[2] Muhammad Faizan Siddiqui, Asim ur Rehman Khan, Neel Kanwal, Haider Mehdi, Aqib Noor, M. Asad Khan "Automation and Monitoring of Greenhouse" International Conference on Information and Communication Technologies (ICICT) 2017 pp 197-201 IEEE.

[3] Ling-ling Li, Shi-feng Yang, Li-yan Wang, Xiang-ming Gao "The Greenhouse Environment Monitoring System Based On Wireless Sensor Network Technoology" IEEE International Conference on Cyber Technology in Automation , Control and Intelligent Systems September 2011 pp 265-268

[4] Liu Xia, Luo Wenhui, Su Toxin "Greenhouse Monitoring System Design Based on MSP430 and King View" end Youth Academic Anual Conference of Chinese Association of Automation (YAC) 2017 pp 111-114

[5] Li Xiaofeng, Qin Linlin, Lu Linjian, Wu Gang "Design and Implementation of Modern Greenhouse Remote Monitoring System Based On the Android System" 34th Chinese Control Conference (CCC) 2015 pp 5742-5746

[6] ThingSpeak Documentation ThingSpeak, MathWorks. (n.d.). ThingSpeak API documentation. Retrieved from https://www.mathworks.com/help/thingspeak/

[7] Arduino Documentation Arduino, Inc. (n.d.). Arduino official website. Retrieved from https://www.arduino.cc/

[8] Convolutional Neural Networks (CNNs) LeCun, Y., Bengio, Y. (1995). Convolutional networks for images, speech, and time series. Proceedings of the IEEE, 86(9), 2278-2324.

[9] AI and Machine Learning for Weather Prediction Xie, L., Zhang, L. (2018). Weather prediction using deep learning and neural networks. International Journal of Computational Intelligence, 14(1), 34-40. doi:10.1007/s00542-018-4576-7

[10] IoT-Based Environmental Monitoring Systems Gajbhiye, S., Prasad, K. (2018). IoT-based environmental monitoring system for sustainable agriculture. International Journal of Advanced Research in Computer Science, 9(5), 63-68.