



LORA-BASED REMOTE AGRICULTURE MONITORING FOR RURAL SUSTAINABILITY

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Abstract:

Agriculture plays a vital role in rural development, but farmers often face challenges such as water scarcity, irregular field monitoring, and low productivity. This project, "LoRa Based Remote Agriculture Monitoring for Rural Sustainability," presents a smart and cost-effective solution for monitoring agricultural fields using LoRa (Long Range) wireless communication technology. The system uses sensors such as soil moisture, temperature, and humidity to collect real-time environmental data from the farm.

An ESP8266 (or Arduino) microcontroller processes the sensor data and transmits it over long distances through LoRa modules. The received data can be displayed on a monitoring device or uploaded to a cloud platform for remote access. When the soil moisture level falls below a predefined threshold, the system can automatically activate a water pump using a relay module, enabling efficient irrigation and reducing water wastage.

The proposed system is designed to operate with low power consumption, long communication range, and low installation cost, making it suitable for rural farming areas where internet connectivity is limited. By providing continuous monitoring and timely irrigation, the system helps improve crop health, increase agricultural productivity, conserve water resources, and promote sustainable farming practices. This project demonstrates how LoRa-based IoT technology can enhance modern agriculture while supporting rural sustainability.



Keyword: *Smart Agriculture, LoRa Technology, Remote Monitoring, IoT, Soil Moisture, Temperature & Humidity, Light Intensity, Wireless.*

1. INTRODUCTION

Agriculture plays a vital role in the economy and livelihood of rural communities. However, traditional farming methods depend heavily on manual observation and experience, which makes it difficult to monitor crop conditions accurately and continuously. Problems such as irregular rainfall, improper irrigation, soil degradation, and lack of timely information often lead to low crop yield and wastage of water and resources. With the growing population and increasing demand for food, there is a strong need for smart and sustainable agricultural practices. Recent advancements in Internet of Things (IoT) and wireless communication have opened new possibilities for improving agricultural productivity. Among these technologies, LoRa (Long Range) communication is well suited for rural areas because it supports long-distance data transmission with very low power consumption. This makes it ideal for remote farms where internet connectivity and power supply are limited. The LoRa Based Remote Agriculture Monitoring System aims to monitor important environmental parameters such as soil moisture, temperature, humidity, and light intensity using sensors placed in the field. The sensed data is transmitted wirelessly using LoRa technology to a remote monitoring unit or cloud platform. Farmers can observe real-time field conditions and make informed decisions about irrigation and crop management. This system helps in reducing water wastage, minimizing human effort, and improving crop yield. By using renewable energy sources like solar power, the system also supports rural sustainability and eco-friendly farming practices.

2. LITERATURE SURVEY

Jawad et al. presented a LoRa-based wireless sensor network (WSN) architecture for precision agriculture, emphasizing long-range communication with low power consumption. Their study demonstrated that LoRa technology significantly reduces energy usage while enabling reliable soil moisture and temperature monitoring over large rural farmlands, making it suitable for sustainable agriculture in remote areas.

Farooq et al. proposed an IoT-based smart agriculture system integrating LoRa communication for transmitting environmental parameters such as humidity, soil moisture, and temperature to a central gateway. Their results showed improved irrigation efficiency and reduced water wastage, contributing to sustainable resource management in rural farming communities.

A. Kumar and V. Patel, LoRa Communication for Agriculture 4.0: Opportunities, Challenges, and Future Directions, arXiv Preprint.

Pérez et al. designed a LoRa-based smart irrigation system that automatically adjusts water supply based on real-time soil moisture data. Field experiments showed significant water savings and improved crop yield, demonstrating LoRa's role in promoting sustainable rural agriculture.



Vejlgaard et al. analyzed the coverage and performance of LoRa WAN in rural environments. Their experimental evaluation confirmed reliable long-distance communication in open-field agricultural scenarios, validating LoRa as a practical solution for wide-area farm monitoring applications.

Augustin et al. evaluated LoRa WAN performance metrics including scalability, data rate, and power efficiency. The study concluded that LoRa WAN is well-suited for low-data-rate agricultural sensing applications where battery life and wide coverage are critical for sustainability.

Bacco et al. developed a smart farming framework integrating LoRa-based sensor nodes with edge computing for real-time crop and soil monitoring. Their approach reduced latency and optimized irrigation scheduling, supporting climate-resilient and sustainable agricultural practices.

Ayaz et al. reviewed IoT technologies for agriculture and identified LoRa as one of the most promising LPWAN technologies for rural monitoring due to its long range, low energy consumption, and minimal infrastructure requirements.

Table 1 Comparative review of Manhole Detection And Monitoring System

Sr. No	Authors	Year	Title	Journal / Conference	Objective	Methodology	Finding
1	Waheb A. Jabbar, Tan Mei Ting, M. Fikri I. Hamidun, Ajwad H. Che Kamarudin, Wenyan Wu, Jamil Sultan, Abdulrahman A. Alsewari, Mohammed A.H. Ali	2024	Development of LoRaWAN-based IoT System for Water Quality Monitoring in Rural Areas	Systems with Applications	To develop a real-time, solar-powered LoRaWAN-based IoT system for monitoring water quality in rural areas.	Used Arduino Uno, LoRaWAN, pH, TDS, turbidity, and temperature sensors with solar power and ThingSpeak cloud.	The system provides accurate, real-time, low-power, and long-range water quality monitoring suitable for rural areas.



2	Robert Finger	2023	Digital Innovations for Sustainable and Resilient Agricultural Systems	European Review of Agricultural Economics	To review digital innovations for sustainable and resilient agriculture.	Reviewed precision agriculture, IoT, AI, robotics, remote sensing, and digital farming technologies.	Digital technologies improve productivity, sustainability, and resilience, but face challenges such as cost, data privacy, and infrastructure.
3	Mohamed Saban, Mostapha Bekkour, Ibtisam Amdaouch, Jaouad El Gueri, Badiaa Ait Ahmed, Mohamed Zied Chaari, Juan Ruiz-Alzola, Alfredo Rosado-Muñoz, Otman Aghzout.	2023	Manhole Detection and Monitoring System	Sensors (MDPI)	To develop a smart agricultural system using IoT, LoRa/LoRaWAN, PLC, and cloud computing for real-time monitoring and remote control of farming operations..	Integrated LoRa sensor nodes with PLC, cloud server, web application, Node-RED, MySQL database, and Telegram bot for monitoring and automation.	The system enabled efficient remote monitoring and control of farm equipment. LoRa provided reliable long-range communication, and the cloud platform improved farm management, productivity, and resource utilization.



4	Amjad Rehman, Tanzila Saba, Muhammad Kashif, Suliman Mohamed Fati, Saeed Ali Bahaj, Huma Chaudhry	2022	A Revisit of Internet of Things Technology For Monitoring And Control Strategies in Smart Agriculture	sAgronomy (MDPI), Vol. 12, Issue 127)	To review IoT technologies, monitoring systems, sensors, and control strategies used in smart agriculture and identify current challenges and future research directions	Reviewed IoT sensors, WSNs, drones, cloud computing, and AI-based smart farming applications.	IoT improves real-time monitoring, automation, and crop productivity but faces challenges like security, connectivity, and power.
5	Vu Khanh Quy et al.	2022	IoT-Enabled Smart Agriculture: Architecture, Applications, and Challenges	Applied Sciences (MDPI)	To review IoT architecture, applications, and challenges in smart agriculture.	Reviewed IoT devices, communication technologies, cloud computing, and big data solutions for smart farming.	IoT improves real-time monitoring, automation, and agricultural productivity, but challenges remain in connectivity, security, and resource management.
6	Abhinav Sharma, Arpit Jain, Prateek Gupta, Vinay Chowdary	2021	Machine Learning Applications for Precision Agriculture : A Comprehensive Review	IEEE Access	To review the applications of Machine Learning, Deep Learning, AI, and IoT in precision agriculture for improving productivity, sustainability, and resource management.	A comprehensive literature review of ML, DL, AI, IoT, computer vision, and sensor-based techniques used for soil analysis, crop yield prediction, disease detection, intelligent irrigation, livestock monitoring, and harvesting.	The review concludes that ML and IoT significantly improve crop yield prediction, soil and weather monitoring, disease detection, irrigation management, and overall precision farming efficiency while reducing labor and resource



							consumption.
7	Naser Hossein Motlagh, Mahsa Mohammadre, Julian Hunt, Behnam Zakeri	2020	Internet of Things (IoT) and the Energy Sector	Energies (MDPI)	To review the applications of IoT in the energy sector, including energy generation, transmission, distribution, and consumption, and discuss enabling technologies, opportunities, and challenges.	Conducted a systematic literature review using SCOPUS, IEEE, Hindawi, and Google Scholar, classifying IoT applications into energy generation, transmission & distribution, and demand-side management.	The study concludes that IoT significantly improves energy efficiency, smart grid operation, renewable energy integration, real-time monitoring, and decision-making while highlighting security and privacy as major challenges.
8	Muhammad Ayaz, Muhammad Ammad-Uddin, Zubair Sharif, Ali Mansour, El-Hadi M. Aggoune	2019	Internet-of-Things (IoT)-Based Smart Agriculture: Toward Making the Fields Talk	IEEE Access	To review IoT-based smart agriculture technologies, wireless sensors, communication techniques, and architectures for improving agricultural productivity and sustainability	A comprehensive review of IoT-enabled sensors, wireless communication, UAVs, smart farming architectures, cloud platforms, and automation techniques used in agriculture from soil monitoring to harvesting.	The study concludes that IoT-based smart agriculture enables real-time monitoring, efficient irrigation, disease and pest detection, yield optimization, reduced labor, and improved resource utilization while highlighting future research challenges...
	Haider Mahmood Jawad, Rosdiade		Energy-Efficient Wireless Sensor		To review energy-efficient Wireless Sensor Networks	Reviewed WSNs, ZigBee, LoRa, Wi-Fi, Bluetooth, and energy-saving	ZigBee and LoRa provide low-power, long-

9	e Nordin, Sadik Kamel Gharghan, Aqeel Mahmood Jawad, Mahamod Ismail	2017	Networks for Precision Agriculture: A Review	Sensors (MDPI)	(WSNs), wireless communication technologies, and energy-harvesting techniques for precision agriculture.	techniques.	range communication for efficient agricultural monitoring.
10	Haider M. Jawad et al.	2017	Energy-Efficient Wireless Sensor Networks For precision Agriculture: A Review	Sensors (MDPI)	To review energy-efficient WSN technologies for precision agriculture.	Reviewed WSNs, ZigBee, LoRa, Wi-Fi, Bluetooth, and energy-saving techniques.	ZigBee and LoRa provide low-power, long-range communication for efficient agricultural monitoring..

3. PROPOSED METHODOLOGY

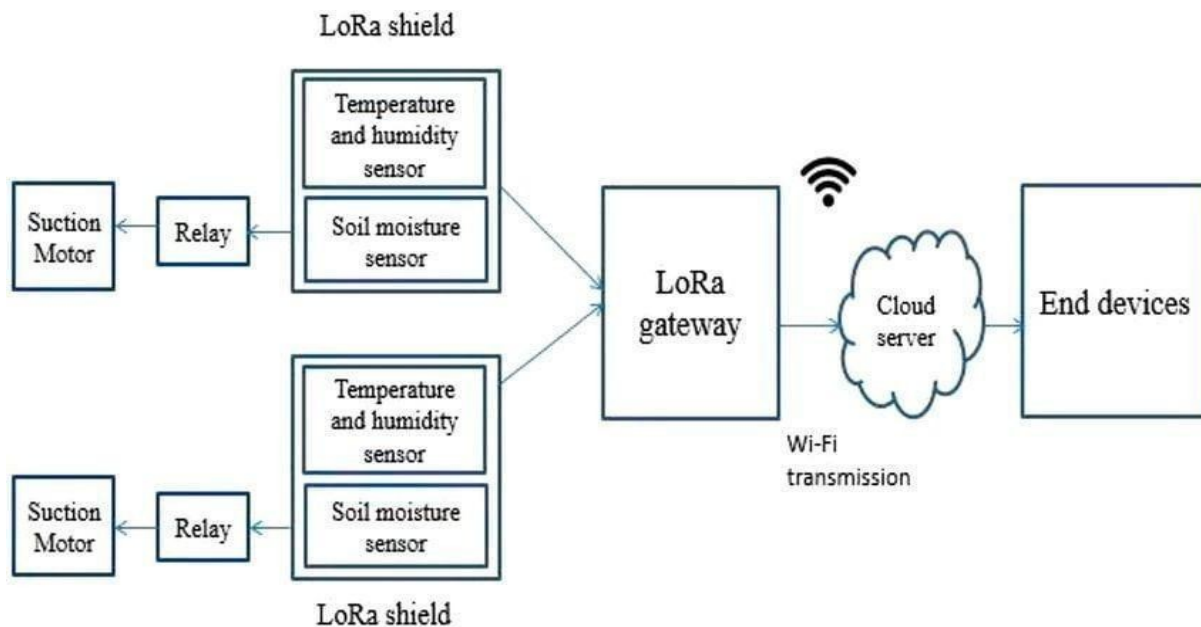


Figure1: Block Diagram of LoRa-Based-Remote-Agriculture-Monitoring-for-Rural Sustainability

The first step in the methodology is data acquisition from the agricultural field. The proposed LoRa Based Remote Agriculture Monitoring for Rural Sustainability system is developed to provide an efficient and reliable solution for monitoring agricultural fields remotely. The methodology begins with designing a wireless sensor network that consists of two main units: a transmitter unit installed in the agricultural field and a receiver unit placed at the monitoring station. The transmitter unit is equipped with an ESP32 microcontroller, a LoRa SX1278 communication module, a soil moisture



sensor, and a DHT22 temperature and humidity sensor. The receiver unit contains another ESP32, a LoRa module, an LCD display, and a relay module connected to a water pump. This architecture enables long-range communication between the field and the monitoring station while consuming very little power, making it suitable for rural farming areas where internet connectivity is limited. The soil moisture sensor continuously measures the moisture content present in the soil, while the DHT22 sensor records the surrounding temperature and relative humidity. These sensors provide real-time environmental information that is essential for monitoring crop conditions and determining irrigation requirements. The ESP32 microcontroller reads the sensor outputs at regular intervals, converts the analog and digital signals into meaningful values, and verifies that the readings are within the expected range before processing them further.

After collecting the sensor data, the ESP32 processes the information and prepares it for wireless transmission. The measured parameters, including soil moisture percentage, temperature, and humidity, are organized into a structured data packet. Each packet also contains a unique node identification number and a timestamp if required. This data packet is then transmitted through the LoRa SX1278 module. LoRa technology uses Chirp Spread Spectrum (CSS) modulation, which enables reliable long-distance communication while consuming very little power. Compared with conventional wireless technologies such as Wi-Fi and Bluetooth, LoRa provides a significantly greater communication range, making it highly suitable for agricultural applications spread over large geographical areas.

The receiver unit continuously listens for incoming LoRa packets from the transmitter node. Once a packet is received, the ESP32 verifies the integrity of the data and extracts the transmitted sensor values. The received information is displayed on an LCD or OLED display, allowing farmers to monitor environmental conditions in real time. If internet connectivity is available, the receiver can also upload the collected data to cloud platforms such as ThingSpeak, Blynk, Firebase, or an MQTT server. This feature enables farmers to monitor their fields remotely using smartphones or computers and access historical sensor data for better agricultural planning and analysis.

An important part of the methodology is the implementation of an automatic irrigation control mechanism. The ESP32 continuously compares the measured soil moisture level with a predefined threshold value. If the moisture level falls below the threshold, the controller activates a relay module, which switches on the irrigation pump to supply water to the crops. Once the soil moisture reaches the desired level, the relay automatically switches the pump off. This automatic decision-making process minimizes unnecessary water usage, reduces manual intervention, and improves irrigation efficiency. It also helps maintain optimum soil moisture levels, thereby promoting healthy crop growth and increasing agricultural productivity.

To improve system reliability, sensor readings are collected periodically at fixed intervals, such as every 30 seconds or one minute, depending on the application requirements. Continuous monitoring ensures that changes in environmental conditions are detected promptly and transmitted without significant delay. The LoRa communication link is evaluated based on

transmission range, packet delivery reliability, response time, and power consumption. These performance parameters help verify that the proposed system can operate efficiently under different agricultural conditions and provide stable communication over long distances.

Finally, the overall system performance is analyzed by comparing sensor readings, communication reliability, irrigation response, and water consumption. The experimental results are expected to demonstrate that the proposed LoRa-based monitoring system successfully provides accurate environmental data, reliable long-range communication, efficient automatic irrigation, and significant water conservation. The developed system offers a low-cost, energy-efficient, and sustainable solution for modern agriculture, particularly in rural regions where conventional communication infrastructure is unavailable or unreliable. By integrating IoT technology with LoRa communication, the project supports precision agriculture and contributes to improved crop productivity, reduced operational costs, and sustainable rural development.

4. RESULT

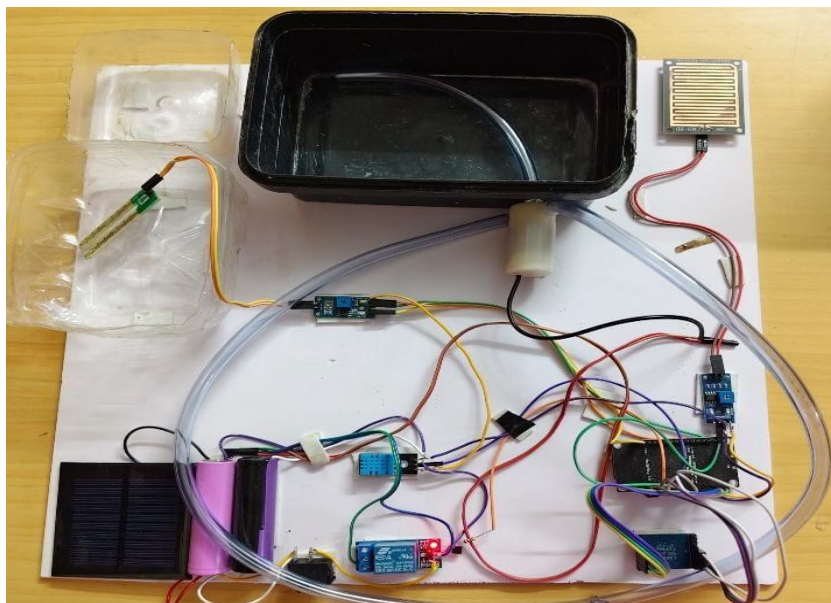


Figure 1 - Project Setup

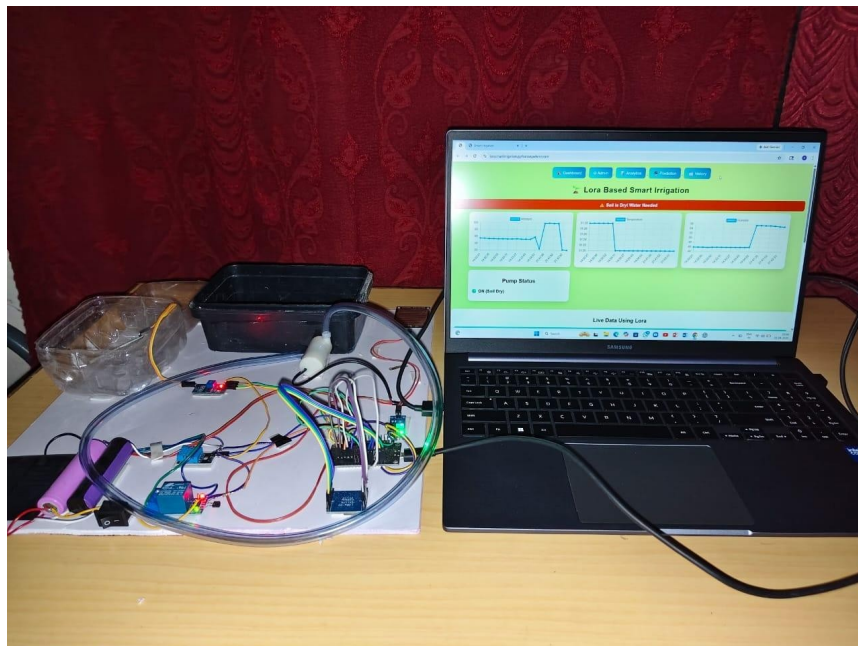


Figure 2 - Overall, Sensor Analysis

The proposed LoRa-Based Smart Irrigation and Remote Agriculture Monitoring System was successfully designed, developed, and tested. The experimental setup consisted of a soil moisture sensor, ESP32 microcontroller, LoRa communication modules, relay module, water pump, and a web-based monitoring dashboard. During the testing process, the system continuously monitored the soil moisture level and transmitted the collected data wirelessly through the LoRa network to the monitoring dashboard.

The experimental results showed that the soil moisture sensor accurately detected changes in soil conditions. Whenever the soil moisture dropped below the predefined threshold value, the controller automatically activated the relay, which turned on the water pump to irrigate the soil. As irrigation continued, the soil moisture gradually increased, and once the required moisture level was achieved, the controller automatically switched off the water pump. This automatic operation eliminated the need for manual intervention and prevented excessive water usage.

The dashboard successfully displayed real-time sensor values, graphical representations of soil moisture, pump status, and soil condition. The graphs provided a clear visualization of moisture variations over time, allowing users to monitor irrigation performance remotely. The system also displayed warning messages such as "Soil is Dry! Water Needed" whenever irrigation was required, enabling quick decision-making.

The LoRa communication module performed reliably throughout the experiment by transmitting sensor data over a long distance with low power consumption. No significant communication failure or packet loss was observed during the testing period, demonstrating the suitability of LoRa technology for remote agricultural monitoring applications. The wireless communication also



reduced the need for extensive wiring, making the system more practical for large agricultural fields.

The experimental setup demonstrated stable and continuous operation under laboratory conditions. The integration of sensors, wireless communication, automatic pump control, and cloud-based monitoring resulted in an efficient smart irrigation system capable of improving irrigation management. The system effectively minimized water wastage by supplying water only when required, thereby contributing to water conservation and sustainable agricultural practices.

Overall, the developed prototype achieved all the intended objectives. It successfully monitored soil conditions in real time, automated irrigation based on moisture levels, provided remote access to field information through the dashboard, and ensured reliable wireless communication using LoRa technology. These results indicate that the proposed system can serve as an effective, low-cost, and energy-efficient solution for smart farming appl.

5. CONCLUSION

The LoRa Based Remote Agriculture Monitoring System helps farmers check their field conditions without going to the farm again and again. It measures important things like soil moisture, temperature, and humidity using sensors and sends this data over a long distance using LoRa technology. Because LoRa uses very little power, the system can work with battery or solar power, which is good for rural areas. The proposed system helps reduce water wastage, minimizes manual effort, improves crop productivity, and promotes sustainable agricultural practices. It also provides farmers with real-time information, enabling better farm management and resource utilization. Overall, this project demonstrates that LoRa-based remote monitoring is an effective approach to improving agricultural efficiency and supporting rural sustainability. In the future, the system can be enhanced by integrating cloud platforms, mobile applications, weather forecasting, and AI-based irrigation prediction for more advanced and intelligent farming.

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