

IoT MONITORING SYSTEM FOR SMART FARMS

Academic Project Report

Abstract

This project presents the design and implementation of an Internet of Things (IoT)-based Smart Farming System aimed at improving agricultural productivity through real-time monitoring of soil and environmental conditions. Sensor data--including soil moisture, soil pH, temperature, humidity, fertilizer type, and crop yield--is collected, stored, and visualized using Power BI. The analysis provides insights that support precision agriculture practices, enabling optimized resource management and yield improvement.

1. Introduction

Agriculture is increasingly challenged by climate variability, inefficient resource use, and the limitations of manual monitoring. Conventional farming methods rely heavily on periodic observation, which fails to capture dynamic environmental changes. IoT technologies provide an opportunity to automate monitoring, improve decision-making, and increase agricultural productivity through data-driven insights.

This report outlines the development of a Smart Farm IoT system, the dataset generated, and the analytical dashboard created to evaluate the environmental conditions influencing crop yield.

2. Problem Statement

Farmers face difficulties managing soil conditions and environmental variables due to lack of continuous, accurate, and actionable data. This leads to:

- Inefficient irrigation
- Poor fertilizer optimization

- Inability to detect adverse conditions early
- Low or inconsistent crop yields
- Resource wastage

There is a critical need for a system that monitors environmental parameters in real time and provides insights to guide better farming decisions.

3. Project Objectives

The project entails the following:

1. Design and implement an IoT-based sensor system for soil and environmental monitoring.
2. Collect, structure, and pre-process sensor data for analysis.
3. Build a Power BI dashboard to visualize field conditions and crop yield relationships.
4. Determine associations between environmental variables and crop yields.
5. Give actionable recommendations on precision farming.

4. System Architecture

The IoT system comprises four major stages:

4.1 Data Acquisition

Sensors measure:

- % Soil Moisture
- SOIL pH
- Temperature (°C)

- Relative humidity (%)
- Fertilizer Type
- Crop Yield
- Timestamp
- Sensor ID

4.2 Data Transmission

Data is transmitted via microcontrollers (e.g., ESP32, Raspberry Pi, LoRa systems) to a storage backend.

4.3 Data Storage

Sensor readings are stored in a structured CSV/database format, for later analysis.

4.4 Data Visualization

Power BI transforms raw data into clear visual representations for decision-making.

5. Dataset Description

The dataset used for this study includes:

Field Name	DESCRIPTION
<i>sensor_id</i>	Unique ID for each sensor node
<i>soil_moisture_%</i>	Soil water content percentage
<i>soil_pH</i>	Measure of soil acidity/alkalinity
<i>temperature_C</i>	Ambient temperature
<i>humidity_%</i>	Air humidity percentage
<i>fertilizer_type</i>	Fertilizer applied at the time
<i>crop_yield</i>	Recorded or estimated crop productivity
<i>timestamp</i>	Time of measurement These variables collectively describe field conditions and support correlation analysis

6. Methodology

The analysis process followed:

6.1 Cleaning Data

Anomaly removal

Missing reading checks

Ensuring proper formatting: numeric, categorical, timestamp

6.2 Data Transformation

Unit conversions (as needed)

Normalizing numeric fields to compare them

6.3 Exploratory Visual Analysis

Power BI Dashboards utilized:

- Line graphs for time-series trends
- Distribution Bar and column charts
- Correlation Heatmaps
- Comparison visuals for yield analysis

This facilitated a holistic understanding of environmental changes and their effects.

7. Power BI Visualization Summary

7.1 Soil Moisture Trend

Illustrates irrigation patterns and potential dry seasons.

7.2 Temperature - Humidity Relationship

Analyzes the environmental behaviors affecting soil evaporation and plant stress.

7.3 Soil pH Distribution

Identifies the regions which are acidic or alkaline so that necessary soil balancing could be done.

7.4 Fertilizer Application Chart

This shows the distribution of fertilizer types across sensors and timestamps.

7.5 Crop Yield Dashboard

Assesses how return is related to

- Moisture
- pH
- TEMPERATURE
- Fertilizer type

7.6 Correlation Heatmap

Highlights strong positive and negative relationships, showing determinants of yield.

8. System Working (Project Operation Workflow)

The Smart Farm IoT Monitoring System operates through an integrated workflow that enables automated sensing, real-time notifications, and actuator control for improved farm management. The system combines environmental sensors,

microcontroller logic, cloud data logging, and Power BI analytics to deliver a fully functional precision-farming solution. This section explains the real-time operation of each component and how they work together to support decision-making and automation.

8.1 Overview of the System Workflow

The system follows a continuous sensing–analysis–action cycle:

1. Sensors collect real-time environmental and soil data.
2. Microcontroller processes readings and evaluates thresholds.
3. Alerts are sent to the farmer via WhatsApp or Telegram.
4. Actuator responses are triggered automatically (relay-controlled water pump).
5. All data is logged and pushed to storage for Power BI visualization.

This enables both automatic and supervised control of farm conditions.

8.2 Soil Moisture Monitoring and Automated Irrigation

The soil moisture sensor continuously measures the percentage of water content in the soil.

The working process:

1. Real-Time Measurement:

The sensor sends analog/digital readings to the microcontroller.

2. Moisture Level Evaluation:

Thresholds such as *Below 30% = Dry*, *30–60% = Optimal*, *Above 60% = Wet* are predefined.

3. Automated Alerts to Farmer:

If moisture falls below the optimum range, the system sends an instant WhatsApp/Telegram push notification, e.g.,

"Soil moisture low (27%). Irrigation required."

4. Relay-Based Pump Activation:

The microcontroller activates the relay module.

The relay turns ON the irrigation pump automatically.

5. Auto-Shutoff Logic:

Once the soil moisture reaches the optimal threshold, the system sends:

"Moisture restored. Pump switching OFF."

The relay is deactivated and the pump stops.

This automated irrigation cycle ensures water efficiency and prevents over-irrigation.

8.3 Soil pH Monitoring and Fertility Alerts

The soil pH sensor provides continuous readings to identify acidity or alkalinity issues.

Workflow:

1. *pH Reading Evaluation:*

Optimal: 6.0 – 7.0 (ideal for most crops)

Below 6.0 = acidic

Above 7.5 = alkaline

2. *Farmer Notification:*

When values fall outside the range, a message is pushed via WhatsApp/Telegram:

"Warning: Soil pH = 5.3 (Acidic). Consider applying lime."

3. *No automatic actuator is required, but timely alerts ensure farmer action such as:*

- Lime application
- Soil conditioning
- Fertilizer adjustments

This promotes better nutrient absorption and plant health.

8.4 Temperature Monitoring and Environmental Alerts

The temperature sensor (e.g., DHT22) tracks ambient temperature.

Workflow:

1. *Continuous Monitoring of temperature values.*

2. *Threshold-Based Alerts:*

Examples:

Below 15°C – Too cold

Above 32°C – Heat stress

3. *Automatic WhatsApp/Telegram Alert:*

"Temperature high: 34°C. Risk of crop heat stress."

High temperature also correlates with faster soil moisture loss, informing irrigation decisions.

8.5 TDS Sensor Monitoring (Nutrient and Water Quality)

The TDS (Total Dissolved Solids) sensor measures nutrient concentration levels in water or soil leachate.

Workflow:

1. *Sensor Reading Collection:*

Indicates nutrient content and fertilizer presence.

2. *Threshold Checking:*

Too low = nutrient deficiency

Too high = fertilizer over-concentration (risk of root burn)

3. *Farmer Alert Messaging:*

"TDS high: 1600 ppm. Dilute fertilizer or flush soil."

This ensures optimal nutrient balance for plant growth.

8.6 Humidity Monitoring

The humidity sensor provides atmospheric humidity levels.

Workflow:

Helps interpret evaporation rates

Supports temperature readings

Enhances moisture prediction logic

Alerts include:

"Low humidity detected (29%). Expect quicker soil drying."

8.7 Relay-Based Automation and Control Logic

The relay module is responsible for controlling the irrigation pump.

Relay Workflow:

1. Microcontroller receives sensor readings.
2. It evaluates conditions using built-in logic.
3. If moisture < threshold → relay ON → pump activated.
4. If moisture > optimal → relay OFF → pump stopped.
5. Fail-safe conditions prevent pump damage or short cycling.

This automation closes the loop between sensing and action.

8.8 Data Logging and Dashboard Integration

Every sensor reading--including moisture, pH, temperature, humidity, TDS, fertilizer use, and crop yield--is:

1. Recorded locally by the microcontroller
2. Sent to local storage
3. Imported into Power BI for visualization

The dashboard presents:

- Moisture trends
- pH distributions
- Temperature & humidity fluctuations
- Fertilizer activity
- Crop yield patterns
- Correlation heatmaps

This transforms raw sensor readings into strategic agricultural insights.

8.9 Summary of System Working

The project functions as a fully integrated smart farming system where:

Sensors measure environmental conditions

Microcontroller evaluates data

Notifications alert the farmer instantly

Automation responds via relay-triggered irrigation

Data analytics support long-term farm planning

This hybrid of automation + analytics creates a robust precision farming tool.

9. Results and Discussion

Key findings include:

- Soil moisture is a major driver of yield, with higher yield seen in optimally irrigated zones.
- Soil pH strongly affects nutrient uptake, with ideal ranges between 6.0–7.0 correlating with higher productivity.
- Temperature spikes correspond to reduced soil moisture, indicating evaporation losses.
- Certain fertilizer types yield better performance depending on soil conditions.
- Correlation analysis shows strong interaction between environmental variables, supporting multi-factor decision-making.

10. Conclusion

The IoT-based Smart Farm System successfully demonstrates the value of real-time monitoring in agriculture. By pairing sensor data with Power BI analytics, farmers can make informed decisions, optimize input usage, and improve crop productivity. The findings highlight the importance of continuous environmental monitoring and analytical tools in achieving precision agriculture.

11. Recommendations

- Automate irrigation based on soil moisture threshold.
- Use soil pH monitoring to guide fertilizer and lime application.
- Deploy more sensors for wider field coverage.
- Incorporating machine learning models for yield prediction.
- Introduce cloud-based dashboards for remote farm management.