

Original Article

AI-Driven Smart Farming and Weather Prediction System

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Abstract

Agriculture is highly dependent on weather conditions, and sudden heavy rainfall can cause crop damage, waterlogging, soil erosion, and significant financial losses for farmers. Timely weather alerts can help farmers take preventive actions and reduce potential losses. This work presents an AI-Driven Smart Farming and Weather Prediction System that combines Internet of Things (IoT) technology, online weather forecast data, and machine learning techniques for intelligent rainfall prediction and early warning generation. The system collects environmental parameters from field sensors and combines them with online weather forecast information to analyze changing weather conditions. A machine learning model is used to predict rainfall risk levels based on the collected data. According to the prediction results, automated Telegram alerts are generated and sent to users for timely precautionary measures. The proposed system offers a low-cost, scalable, and intelligent approach for smart agriculture applications and demonstrates the potential of AI-enabled weather monitoring systems in supporting better farming decisions.

Keywords: Smart Farming, Internet of Things (IoT), Rainfall Prediction, Machine Learning, Random Forest Algorithm

Objective

To develop a low-cost AI-enabled smart farming system for rainfall risk prediction using local sensor data and online weather forecast information.

Introduction

Agriculture is highly vulnerable to changing weather conditions, especially heavy and unseasonal rainfall, which can cause severe crop damage, waterlogging, soil erosion, and major financial losses for farmers. Recent reports have shown that excessive rainfall has significantly affected Kharif crops in several regions of India, highlighting the need for timely weather monitoring and early warning systems. Traditional forecasting methods often provide generalized regional information and may not accurately reflect local farm conditions. Recent advancements in Artificial Intelligence (AI), Machine Learning (ML), and Internet of Things (IoT) technologies have created new opportunities for intelligent weather prediction and smart agriculture applications. According to the various meteorological organizations, AI-based forecasting systems are transforming weather prediction by improving forecasting speed, accuracy, and decision-making capabilities. The proposed AI-Driven Smart Farming and Weather Prediction System combines local environmental sensing with online weather forecast data to generate intelligent rainfall alerts. Environmental parameters such as temperature, humidity, atmospheric pressure, and rainfall status are collected using IoT sensors connected to a NodeMCU microcontroller. The collected data is processed using a Random Forest machine learning model to predict rainfall risk levels, and alert notifications are automatically sent to users through Telegram.

Data Collection

The proposed system collects data from both local environmental sensors and online weather forecasting services. Local field data is acquired using sensors connected to a NodeMCU (ESP8266) microcontroller. The DHT11 sensor measures temperature and humidity, the BMP180 sensor measures atmospheric pressure, and the raindrop sensor detects rainfall presence on the field surface.

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These sensors continuously monitor environmental conditions and provide real-time data to the NodeMCU. The NodeMCU transmits the collected sensor readings to a computer server through Wi-Fi using HTTP requests. In parallel, the server retrieves online weather forecast information from the OpenWeather API. The online forecast data includes rain probability percentage, forecast rainfall amount, humidity forecast, and pressure trend forecast. The combination of local sensor measurements and large-scale forecast data improves the reliability and accuracy of rainfall prediction.

The collected data is organized into a structured dataset before being processed by the machine learning model. Each dataset entry includes sensor readings and forecast parameters corresponding to a particular time interval. This fused dataset forms the input for the AI prediction stage.

Experimental Methodology

The experimental setup of the AI-Driven Smart Farming and Weather Prediction System consists of sensing, communication, AI processing, and alert generation stages (fig 1).

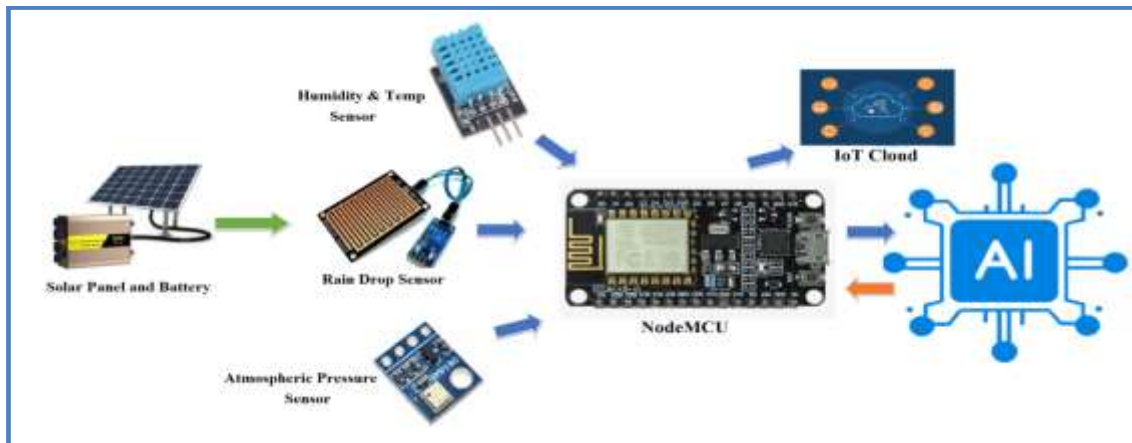


Fig 1: Dataflow Diagram of AI-Driven Smart Farming and Weather Prediction System

The DHT11 sensor module shown in fig. 2 is a low-cost digital temperature and humidity sensor used for environmental monitoring applications. It contains a thermistor for temperature measurement and a capacitive humidity sensing element for relative humidity detection, along with an internal 8-bit microcontroller for signal processing and calibration. The sensor operates with a supply voltage of 3.3 V to 5 V and communicates using a single-wire digital communication protocol, which simplifies interfacing with microcontrollers such as NodeMCU. The DHT11 measures temperature in the range of 0 °C to 50 °C with an accuracy of approximately ± 2 °C and relative humidity in the range of 20% to 80% RH with an accuracy of $\pm 5\%$ RH [1]. The sensor has low power consumption and a sampling rate of approximately 1 Hz, making it suitable for continuous environmental sensing in IoT-based smart farming systems. In the proposed project, the DHT11 continuously measures ambient temperature and humidity values that are used as important input parameters for AI-based rainfall prediction.

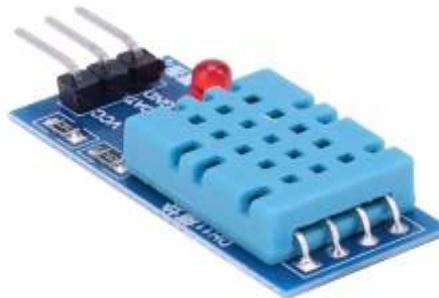


Fig 2: DHT11 Sensor Module

The BMP180 shown in fig. 3 is a digital barometric pressure sensor developed for weather monitoring and altitude estimation applications. The sensor operates at a voltage range of 1.8 V to 3.6 V and communicates using the I²C protocol through SDA and SCL lines, enabling efficient integration with NodeMCU. It can measure atmospheric pressure in the range of approximately 300 hPa to 1100 hPa with high resolution and low noise performance. The BMP180 also contains an integrated temperature sensor that is internally used for pressure compensation and calibration [2]. Due to its low power consumption, compact size, and accurate pressure measurement capability, the sensor is widely used in portable weather stations and IoT monitoring systems. In the proposed system, the BMP180 continuously monitors atmospheric pressure variations, which are highly significant for detecting weather changes and rainfall probability. Pressure trends obtained from the sensor are combined with forecast data and analyzed by the machine learning model for rainfall risk prediction.

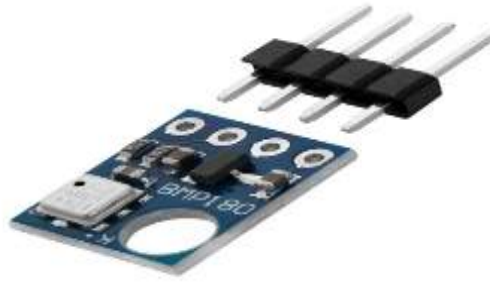


Fig 3: BMP180 Pressure Sensor Module

The raindrop sensor module shown in fig 4 is used for detecting rainfall presence and surface wetness conditions in the environment. The module consists of a rain-sensitive conductive detection plate and an LM393 comparator-based interface circuit [3]. When water droplets fall on the conductive surface, the resistance between conductive tracks changes, producing corresponding analog and digital output signals. The sensor operates at 3.3 V or 5 V DC and provides both analog output for rainfall intensity estimation and digital output for threshold-based rain detection. The sensitivity level can be adjusted using the onboard potentiometer integrated into the comparator module [4]. The raindrop sensor is simple, low-cost, and suitable for real-time weather monitoring applications. In this project, the sensor acts as a local rainfall indicator and helps validate environmental conditions measured by other sensors. The rain detection information improves the contextual understanding of weather conditions during AI-based rainfall prediction.

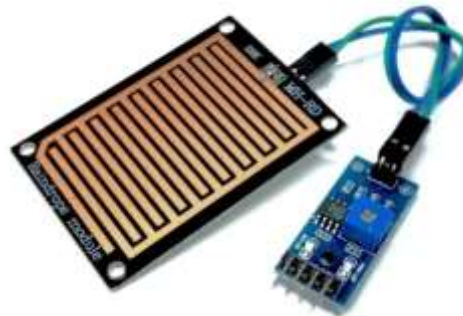


Fig 4: Raindrop Sensor

The NodeMCU is an open-source IoT development platform based on the ESP8266 Wi-Fi microcontroller. It integrates a Tensilica L106 32-bit microprocessor operating at 80 MHz or 160 MHz, built-in Wi-Fi capability, flash memory, GPIO pins, UART, SPI, I²C communication support, and a USB-to-serial converter on a compact board. The board operates at 3.3 V logic levels and is powered either through a USB interface or an external regulated supply. NodeMCU provides one analog input pin and multiple digital GPIO pins for sensor interfacing and peripheral communication. It supports programming using Arduino IDE with C/C++ language, making firmware development easier for embedded applications [5-7].

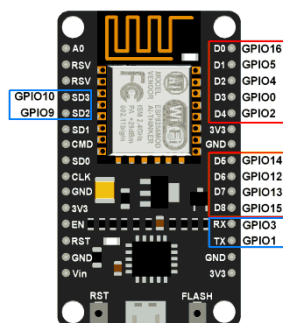


Fig. 5: NodeMCU

In the proposed smart farming system, the NodeMCU serves as the central sensing and communication unit. It continuously acquires environmental data from DHT11, BMP180, and raindrop sensors, formats the readings into structured packets, and transmits the data wirelessly to the computer server through Wi-Fi using HTTP protocol. Its low cost, compact design, and wireless capability make it highly suitable for smart agriculture and remote monitoring applications.

The communication layer of the proposed system is implemented using the built-in IEEE 802.11 b/g/n Wi-Fi capability of the ESP8266-based NodeMCU. Sensor readings collected from the field are transmitted wirelessly to a computer server using HTTP POST requests over a local wireless network. The data is organized in JSON format to ensure structured and lightweight

communication between the NodeMCU and the server application [8]. Wireless communication eliminates the need for long wired connections in agricultural environments and enables real-time remote monitoring. The HTTP-based communication approach provides compatibility with cloud platforms, web APIs, and machine learning servers. This stage ensures reliable transfer of environmental data for AI analysis and alert generation.

The OpenWeather API is integrated into the system to obtain online weather forecast information that complements the local environmental sensor data. The API provides forecast parameters such as rain probability percentage, forecast rainfall amount, humidity forecast, temperature forecast, and atmospheric pressure trends. These parameters are retrieved by the server through internet-based REST API requests in JSON format. The online forecast data represents macro-level atmospheric conditions, while the local sensors provide micro-level environmental observations [9]. The integration of both datasets improves the reliability and prediction capability of the AI model. API-based weather integration also enables continuous access to real-time forecast information without requiring additional external weather hardware infrastructure.

The AI prediction stage uses a Random Forest classifier, which is a supervised ensemble machine learning algorithm based on multiple decision trees. The model processes combined environmental and forecast parameters including temperature, humidity, atmospheric pressure, rainfall status, rain probability, and forecast rainfall intensity. Random Forest performs classification by generating predictions from multiple decision trees and selecting the majority voting outcome [10]. The algorithm is selected because of its robustness, low computational complexity, resistance to overfitting, and suitability for environmental prediction tasks involving multiple parameters. The trained model classifies weather conditions into rainfall risk categories such as Normal, Moderate Risk, and High Risk. The AI model operates on the computer server and provides fast prediction output suitable for real-time alert systems.

The Telegram alert system is implemented using Telegram Bot API for instant notification delivery. After AI prediction is completed, the server automatically generates structured alert messages containing sensor values, rainfall risk level, date, time, and location information. These messages are transmitted through secure HTTPS requests to the Telegram cloud server and are delivered directly to the user's mobile application. Telegram-based notification systems provide advantages such as low cost, real-time communication, rich text formatting, multilingual support, and high reliability compared to conventional SMS-based systems. In the proposed project, Telegram alerts act as the final decision-support interface between the AI prediction system and the end user.

The programming of the proposed AI-Driven Smart Farming and Weather Prediction System is divided into NodeMCU firmware and Python-based AI server programming. The NodeMCU is programmed using Arduino IDE with Embedded C/C++ and libraries such as ESP8266WiFi, DHT, Adafruit_BMP085, and ArduinoJson for sensor interfacing, Wi-Fi communication, and JSON data transfer. The controller continuously reads temperature, humidity, atmospheric pressure, and rainfall status from the connected sensors and transmits the data to the server through HTTP requests over Wi-Fi. The server-side application is developed in Python using Flask, requests, pandas, and joblib libraries. It receives sensor data, retrieves online weather forecast information from the OpenWeather API, and processes the combined dataset using a Random Forest machine learning model for rainfall risk prediction. Based on the AI prediction result, Telegram Bot API is used to automatically send rainfall alert messages to the user's mobile device in real time.

Results and Discussion

The developed system shown in fig 6 was successfully implemented and tested under practical field conditions. The NodeMCU-based sensing unit reliably measured temperature, humidity, atmospheric pressure, and rainfall presence. Sensor data transmission through Wi-Fi remained stable during testing and data packets were successfully received by the server without significant delay.

The integration of online weather forecast data with local sensor measurements improved the contextual understanding of weather conditions. The Random Forest machine learning model effectively analyzed the combined dataset and classified rainfall risk levels into normal, moderate, and high-risk categories. Telegram alerts were generated automatically and delivered instantly to the user's mobile application whenever rainfall risk conditions were detected.

Experimental observations showed that pressure drop and humidity rise combined with forecast rain probability were strong indicators of rainfall events. The bilingual Telegram notifications (fig 8) improved readability and user accessibility. The proposed system demonstrated that AI-based fusion of local sensing and online forecast data can provide practical early warning support for smart farming applications.



Fig 6: Designed system Photos



Fig 7: On field Placement

Telegram Messages:



Fig 8: Telegram bilingual messages

Conclusion

The AI-Driven Smart Farming and Weather Prediction System successfully demonstrated the integration of IoT sensing, online weather forecast services, and artificial intelligence for rainfall risk prediction. By combining local environmental measurements with machine learning analysis, the system provides intelligent early warning alerts through Telegram notifications. The proposed approach offers a low-cost, scalable, and user-friendly solution for smart agriculture applications. Experimental testing confirms reliable sensing, wireless communication, and real-time alert generation. Although the system is intended primarily as an early warning support tool, it shows strong potential for future enhancement through additional sensors, cloud connectivity, and advanced AI models for improved agricultural decision support.

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Nil.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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