

## REVIEW PAPER ON IOT BASED AI ML SMART IRRIGATION SYSTEM

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### ABSTRACT

*The rapid progress in internet of things IOT and machine learning ml technologies has significantly influenced modern agricultural practices one of the key applications one of the most prominent applications of these technologies is smart irrigation which emphasizes efficient and sustainable water management smart irrigation systems regulate water supply by utilizing real-time soil moisture data weather-related parameters and remote monitoring mechanisms such an approach significantly reduces excessive water consumption while simultaneously supporting optimal crop growth and agricultural sustainability improved crop health and productivity the objective of this study is to analyse the present condition of irrigation systems by incorporating soil moisture data and*

*weather-related information the paper presents a detailed review of the hardware components commonly used in smart irrigation systems such as sensors controllers and actuators it also discusses various communication technologies that support reliable and efficient data transmission between system components furthermore the study explores different machine learning techniques applied for irrigation decision-making and water requirement prediction cloud-based platforms and database systems used for storing processing and managing irrigation data are also examined overall this paper offers a comprehensive understanding of smart irrigation systems and highlights future research directions for enhancing agricultural efficiency through IOT-based solution.*

**Keywords:** *IOT, Smart Irrigation, Artificial Intelligence, Machine Learning, Precision Agriculture, Soil Moisture Sensors, Predictive Water Management*

### INTRODUCTION

The integration of Internet of Things (IOT) technologies with Artificial Intelligence (AI) and Machine Learning (ML) has significantly transformed irrigation management systems by enabling data-driven and automated decision making. Goldstein *et al.* [1] proposed a recommendation-oriented irrigation management framework that combines agronomic domain knowledge with machine learning techniques. Their study demonstrated that advanced tree-based models, namely Gradient Boosted

Regression Trees for regression tasks and Boosted Tree Classifiers for classification tasks, achieved higher prediction accuracy compared to traditional linear regression models. The models were trained using multiple feature subsets, allowing agronomists to make more informed irrigation decisions.

To enhance irrigation optimization using advanced sensing modalities, Al Zu'bi *et al.* [2] introduced the concept of the Internet of Multimedia Things (IOMT). Their approach incorporates multimedia sensors and digital image processing techniques to monitor crop and soil

conditions. Images captured from agricultural fields are analysed to estimate soil crack density, which serves as an indicator for irrigation requirements. This vision-based methodology supports autonomous and unmanned irrigation management systems.

In another study, Ghadge *et al.* [3] employed data mining techniques using both supervised and unsupervised machine learning algorithms to analyse soil characteristics, crop type, land suitability, and nutrient content. The proposed system assists farmers in selecting appropriate crops based on soil quality and provides timely recommendations related to nutrient management, thereby improving crop yield and sustainability. Accurate soil moisture estimation is a critical component of smart irrigation systems. To address this, a system has been proposed. Environmental parameters such as soil moisture, air and soil temperature, humidity, and solar radiation are collected from the field and used to train the SVR model. The results are further enhanced using the K-means clustering method for reducing estimation errors. The results are used to apply the predictions on the irrigation control system such as the water pump controller to aid in crop yield management efficiently. In the past, prediction methods usually encountered a problem due to high variance since they were unable to produce consistent results with different data sets.

As an alternative way of solving the mentioned problems, ensemble learning techniques have been widely researched by scholars. As discussed by Zhao *et al.* [4], Catolino and Ferrucci [5], Joshi and Srivastava [6], and Ren *et al.* [7], using more than one learning model in prediction can be a promising approach that may significantly enhance

prediction outcomes. Out of the different ensemble methods, bagging technique was found effective as it could deal with overfitting and underfitting issues. By implementing bootstrap aggregation approach, the prediction result produced by regression trees will have low prediction error. This was proved by Gonzalez *et al.* [8] who compared it with random forest models. The designed system ensures automatic and effective irrigation by consistently monitoring the moisture content of the soil in the crop root zone. A soil moisture sensor installed close to the roots of the plants detects the moisture content of the soil and generates analog signals to the ESP32 microcontroller. The microcontroller then analyses the signals in relation to preset threshold values to determine the need for irrigation.

In case the moisture level of the soil drops below the threshold value, the ESP32 activates the relay module to switch ON the water pump to provide water. The water supply continues until a certain threshold is met. Once the required threshold is achieved, the ESP32 turns off the relay and automatically stops the pump. The ON-OFF operation enables prevention of over irrigation and wastage of water.

In order to monitor and control the system, the ESP32 relays the real-time soil moisture and the pump status to the cloud-based IoT application via the Wi-Fi connection. The farmers can remotely monitor this, hybrid models combining Support Vector Regression (SVR) and K-means clustering have access the soil conditions, irrigation activities, and general performance of the system via the mobile application. Moreover, the system might have an emergency override feature that gives the user control over the irrigation process.

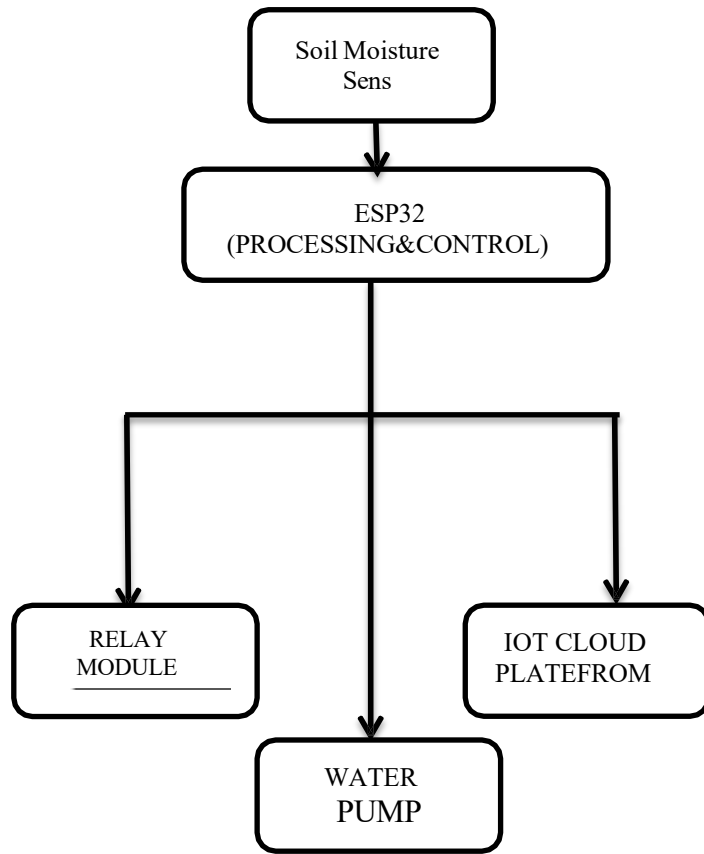


Figure 1: Flowchart of System Architecture of

References (Year)	Architecture	Technology	AI/ML Algorithms
2026	Edge-First IoT with TinyML	ESP32 microcontroller + Raspberry Pi	Gradient boosting, Random Forest
2025	IoT with advanced ML Model	IoT sensors (soil moisture, temp, pH), cloud/edge connectivity	Decision Tree Classifier, Random Forest Classifier
2025	IoT+ML data- driven irrigation system	IoT sensor array (moisture, temperature, humidity, weather)	Machine Learning algorithms for irrigation scheduling

2024	IoT enabled intelligent irrigation monitoring	IoT node platform with sensors (for effective rice irrigation)	ML algorithms for monitoring and irrigation decision support
2024	Integrated IoT+ML irrigation optimization	IoT multi-sensor system with cloud/analytics	Supervised learning models for irrigation optimization
2025	Review: IoT Irrigation+ML Architectures	Multi-tech integration overview	N/A

**Table 1:** Comparison table of various IoT enabled irrigation systems based on AI/ML

## METHODOLOGY

### Proposed Solution

As illustrated in Fig. 1, the suggested IoT-based smart irrigation system employs artificial intelligence (AI) and machine learning (ML) algorithms to support intelligent irrigation based on the IoT concept. Specifically, soil moisture and soil temperature data can be obtained via the IoT-based system's sensors, which are linked to the NodeMCU microcontroller unit equipped with Wi-Fi capabilities.

However, because the microcontroller unit works at low voltages, it is incapable of driving the water pump directly. Hence, a relay module is employed as an intermediary to facilitate communication between the controller unit and the water pump. The relay is supplied with power from an external source, i.e., battery.

### Hardware Architecture

The hardware architecture of the proposed IOT-based AI-ML smart irrigation system consists of sensing, processing, communication, and actuation units. These components collectively enable real-time data acquisition, wireless transmission, and automated irrigation control. The components are listed below:

- Soil Moisture Sensor: Detects soil water level
- Temperature & Humidity Sensor: Measures ambient environment
- ESP8266: Main control of the system
- Relay Module: Power Switching
- Water Pump: Water Supply
- Power Supply: Provides working voltage
- Jumper Wires & Breadboard: Circuit connection

### Software Architecture

The software architecture manages data acquisition, cloud communication, data analysis, and intelligent decision-making using AI and ML techniques. Below are the software components required for system development.

- Embedded Firmware: Arduino IDE
- IoT Cloud Platform: ThingSpeak
- Programming Language: Python
- APIs: ThingSpeak Read/Write API
- ML Models: NB, DT, SVM, ANN, RF
- Ensemble Techniques: Voting Classifier
- Dataset Source (Format): Kaggle (JSON)

## RESULTS AND DISCUSSION:

The in-depth analysis of already developed IoT-based AI/ML irrigation systems, that were reported in recent published papers show a definite improvement in water management efficiency

compared to conventional irrigation practices. Many of the studies used real-time sensing techniques to monitor soil moisture, also supporting various environmental parameters like temperature & humidity, which are then further processed by intelligent decision-making models. Many research works have reported a reduction in water consumption that ranges from 25% to 45%, while also improving and maintaining crop output. Going further, more comparisons across different studies show that soil moisture is the most important and influential parameter in irrigation decision-making, which serves as the main input for control algorithms. Certain environmental factors like temperature and humidity are complementary by refining predictions of irrigation and improving system reliability under different climatic conditions. ML and other related approaches improve the accuracy further by getting rid of uncertainty and variance. The proposed IoT-based AI/ML smart irrigation framework is put forward to address these constraints by simplifying, modulating and scaling architecture. By preferring soil moisture as the main decision variable and using lightweight AI/ML models, the proposed solution targets to get efficient control over irrigation process with lesser computational load.

## CONCLUSION AND FUTURE SCOPE

Frequent crop reports like the moisture humidity and temperature are vital in the data accuracy of the farming climate forecasting technology has improved in a fantastic way because of the advancement of technology the weather forecasting data can now be used to predict the amount of rainfall that will fall upon a given location the task performed by the suggested technique is to create one model that trains a large number of models and classifies the output based on the collective majority of the votes of each output class predicted rainfall possibilities are much better in terms of accuracy and error rate a single system prototype may also be used in providing the forecasts this is the task .

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