International Scientific Journal of Engineering and Management (ISJEM) ISSN: 2583-6129
Volume: 05 Issue: 02 | Feb – 2026 DOI:10.55041/ISJEM05453
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

Intelligent IOT Framework for Precision Agriculture using Cloud and AI-Based Smart Irrigation

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Abstract

AI and IoT are turning traditional agriculture into data-driven systems that enhance production and sustainability. This research introduces AI-powered IoT. Precision farming's smart irrigation and fertilizer management maximizes resource use and crop yield in real time. A dense IoT sensor network monitors soil water, nutrient levels, humidity, temperature, and crop phenology in real time in the proposed system. AI approaches like Random Forest, LSTM networks, and Reinforcement Learning models analyze these streams for predictive and adaptive decision-making. The Random Forest algorithm identifies soil conditions and determines nutrient deficiencies, while LSTM models predict irrigation needs by studying soil moisture and weather patterns. Reinforcement Learning optimises irrigation and fertiliser application using real-time soil sensor and vegetation response indicator data to maximise water and nutrient supply with minimal waste. Farmers and agricultural stakeholders can use a single dashboard for real-time data processing, remote monitoring, and autonomous control with edge analytics and cloud computing.Field tests show the technique saves 30% water and fertilizer (International Journal Advanced Research, www.ijarp.com). ISSN 2456-9992 Page: 01-25 Research Article Volume: 01 Issue: 03 Received: 14 November 2025, Revised: 04 December 2025, Published: 24 December 2025 Chandigarh College of Engineering, Chandigarh Group of Colleges, Jhanjeri, Mohali, Punjab, India – 140307, Department of Computer Science and Engineering Associate Professor R Naveenkumar is the corresponding author. International Journal Advanced Research Publications www.ijarp.com 2 Improves yield consistency and soil fertility above traditional methods. The modular and extendable design suits small and large farms and adjusts to different crop varieties and weather. This study shows that AI-IoT convergence in precision agriculture can address global food security, resource scarcity, and environmental sustainability. The AI-driven IoT framework automates and optimizes farm choices from soil to harvest, promoting sustainable smart farming.

Keywords: Precision Agriculture, IoT, Artificial Intelligence, Smart Irrigation, Fertilizer Management, Machine Learning, Sustainability.

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1. Introduction

There has never been a time in the twenty-first century when agricultural methods and the digital revolution are coming together in a way that has never been witnessed before. Although it is anticipated that the worldwide population will continue its upward trend and reach more than 9.7

billion by the year 2050, the demand for food, water, and land is rising at a rapid rate all over the world. This is despite the fact that the global population is predicted to continue its upward trend.

not been previously seen in the history of humanity. Despite this, agriculture is confronted with a number of issues, some of which include the depletion of natural resources, the unpredictability of climatic patterns, and the requirement to implement methodological approaches to food production that are responsible to the environment. It is becoming increasingly difficult for traditional farming, which is primarily centered on the use of manual observation and empirical decision-making, to satisfy the objectives that have been established for environmental sustainability and food security. By utilizing data analysis, sensing technologies, and automation, precision agriculture (PA) is a technology-based paradigm that aims to maximize agricultural production. This is accomplished through the utilization of these technologies. In order to maximize the usage of resources and the productivity of agricultural activities, it was developed as a result of the necessity to do so.

2. Literature review

The convergence of Artificial Intelligence (AI) and the Internet of Things (IoT) has emerged as a foundational component in the process of transforming traditional farming into a platform that is data-driven and intelligent. There have been a number of research papers that have investigated solutions that are based on AI and IoT in order to improve the effectiveness of irrigation, the monitoring of crops, and the application of fertilizer. The majority of the systems that are currently in use are focusing on functions that are not connected to one another rather than an integrated real-time platform that includes irrigation and fertilizer management. Within the realm of precision agriculture, this section provides an in-depth analysis of recent developments in research, including the algorithms, methodology, and deficiencies of the works that are now being produced.

Recent research in precision agriculture demonstrates that IoT-enabled irrigation systems integrated with AI techniques significantly improve water-use efficiency through real-time sensing and predictive control. Neural networks, LSTM, and ensemble learning models have been widely applied for irrigation scheduling and weather- aware decision-making, achieving notable resource savings; however, most systems remain cloud-dependent and focus primarily on irrigation without considering nutrient dynamics. Similarly, AI-based fertilizer recommendation models using machine learning, fuzzy logic, and reinforcement learning have enhanced nutrient-use efficiency and crop yield, but often suffer from delayed responsiveness, scalability limitations, and high computational demands. Although integrated AI–IoT frameworks combining irrigation and fertilization have been proposed, many lack continuous learning, real-time adaptability, or cost-effective deployment in rural environments. These limitations highlight the need for a unified, adaptive, and scalable AI–IoT framework that jointly optimizes water and fertilizer management with reduced cloud reliance.

3. Related Work

Several studies have explored IoT-enabled irrigation systems to enhance water efficiency. Machine learning techniques such as Artificial Neural Networks, Random Forests, and Long Short-Term Memory (LSTM) networks have been applied to predict soil moisture and irrigation requirements. Weather-aware irrigation models using cloud-based forecasting have further improved scheduling accuracy. Despite these advancements, most existing solutions focus solely on irrigation and depend heavily on cloud infrastructure, which may not be suitable for rural or resource-constrained environments. Integrated and adaptive frameworks with real-time intelligence are still limited.

4. A Framework for the Intelligent Internet of Things

There are four primary layers that make up the framework that has been proposed: sensing, communication, intelligence, and application applications.

Sensing Layer, Option A

In order to monitor the soil moisture, temperature, humidity, and light intensity, this layer is comprised of Internet of Things sensors that are dispersed around the agricultural area. In a continual manner, these sensors gather data in real time and send it to the processing layer.

(B) The Layer of Communication

The transmission of sensor data to the cloud or edge devices is accomplished through the utilization of wireless communication technologies such as Wi-Fi, LoRa, or GSM protocols. Data transfer that is both dependable and scalable is ensured by this layer.

(C) Cloud computing and edge computing are both incorporated into the intelligence layer along with AI algorithms. To forecast the amount of water that will be needed for irrigation, machine learning models examine sensor data. The use of weather forecast data obtained from cloud services helps to increase the precision of decision making. When it comes to irrigation, the duration and timing are both dynamically determined by AI-based control logic.

(D) Application Layer, Farmers and agricultural managers have access to a user interface that is provided by the application layer. In order to facilitate informed decision-making, it displays the current field conditions, the status of the irrigation system, and specific recommendations.

4. The methodology

Supervised machine learning models that have been trained on historical sensor and meteorological data are utilized in the system that has been proposed. Containing elements such as soil moisture, temperature, humidity, and the likelihood of precipitation are included. After being trained, the model makes predictions about the appropriate irrigation levels, which are subsequently carried out by means of automated mechanism. The performance of the model is continuously improved through the utilization of feedback from sensors, which enables adaptive learning.

Intelligence Layer.

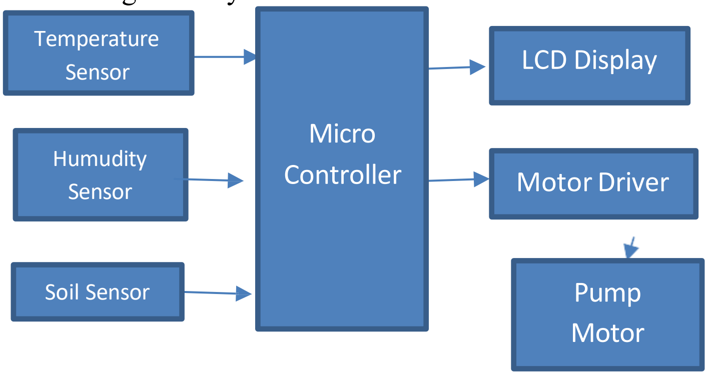
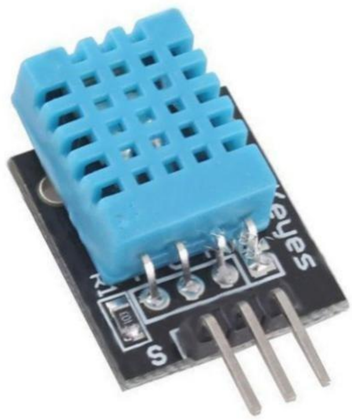


Figure 1: Block Diagram

5. BLock diagram description:

DC Water Pump

Water pumps can be classified from many dimensions. DC water pump refers to the pump which is classified based on the type of power supply and uses a DC power source. The DC power source could be a constant voltage supply, a battery, or a solar panel.

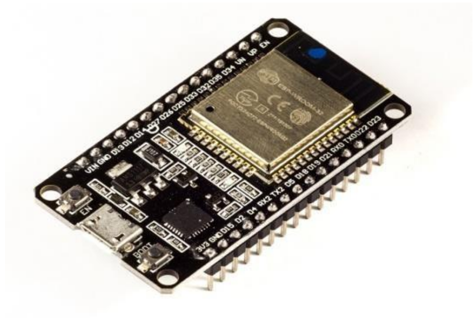


DHT11–Temperature and Humidity Sensor

The DHT11 is a commonly used Temperature and humidity sensor that comes with a dedicated NTC to measure temperature and an 8-bit microcontroller to output the values of temperature and humidity as serial data.

ESP-32

ESP32 is the SoC (System on Chip) microcontroller which has gained massive popularity recently. Whether the popularity of ESP32 grew because of the growth of IoT or whether IoT grew because of the introduction of ESP32 is debatable. If you know 10 people who have been part of the firmware development for any IoT device, chances are that 7–8 of them would have worked on ESP32 at some point. So what is the hype all about? Why has ESP32 become so popular so quickly? Let's find out.

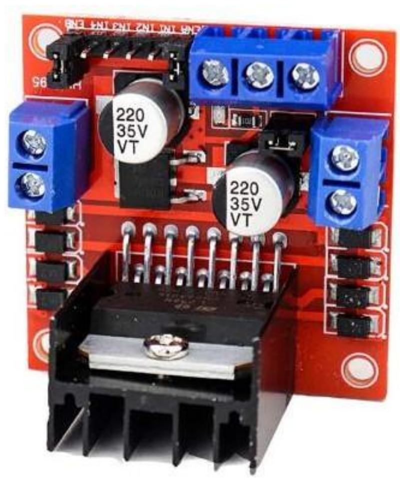


L298N Motor Driver IC

There are multiple kinds of motion we face in our daily life some are linear some are rotatory motion. Both motions have their importance in machines and our life. In the 19th century, the scientist started discovering/inventing some ways of producing current and motions when British physicist John Ambrose Fleming invented the right-hand rule.

L298N IC is known as a motor driver. It is a low voltage operating device like other ICs. The other ICs could have the same functions like L298N but they cannot provide the high voltage to the motor. L298N provides the continuous bidirectional Direct Current to the Motor. The Polarity of current can change at any time without affectin g the whole IC or any other device in the circuit. L298N has an internal H- bridge installed for two motors.

H-Bridge is an electrical circuit that enables the load in a bidirectional way. L298N Bridge is controlled by external low voltage signals. It may be small in size, but its power output capacity is higher than our expectation. It could control any DC motor speed and direction with a voltage range of 4.5 – 36 Volts. Its diodes also save the controlling device and IC from back EMF. To control the max 600mA amount of current an internal “Darlington transistor sink” installed in it, which could be used to control a large amount of current by providing a small amount of current. It has also internal “pseudo-Darlington source” which amplifies the input signal to control the high voltage DC motor without any interception.



LCD

LCD is a flat display technology, stands for "Liquid Crystal Display," which is generally used in computer monitors, instrument panels, cell phones, digital cameras, TVs, laptops, tablets, and calculators. It is a thin display device that offers support for large resolutions and better picture quality. The older CRT display technology has replaced by LCDs, and new display technologies like OLEDs have started to replace LCDs. An LCD display is most commonly found with Dell laptop computers and is available as an active-matrix, passive-matrix, or dual-scan display. The picture is an example of an LCD computer monitor.

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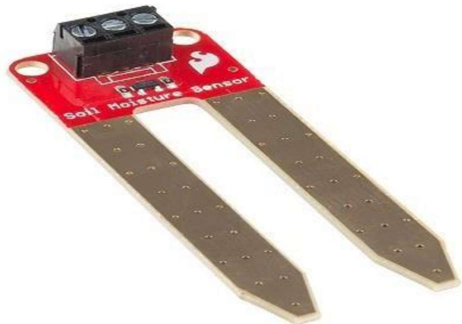
The Liquid Crystal library allows you to control LCD displays that are compatible with the Hitachi HD44780 driver. There are many of them out there, and you can usually tell them by the 16-pin interface.

Soil Moisture Sensor

The soil moisture sensor is one kind of sensor used to gauge the volumetric content of water within the soil. As the straight gravimetric dimension of soil moisture needs eliminating, drying, as well as sample weighting. These sensors measure the volumetric water content not directly with the help of some other rules of soil like dielectric constant, electrical resistance, otherwise interaction with neutrons, and replacement of the moisture content.

The relation among the calculated property as well as moisture of soil should be adjusted & may change based on ecological factors like temperature, type of soil, otherwise electric conductivity. The microwave emission which is reflected can be influenced by the moisture of soil as well as mainly used in agriculture and remote sensing within hydrology.



Temperature sensors

A temperature sensor is a device, typically, a thermocouple or resistance temperature detector, that provides temperature measurement in a readable form through an electrical signal.A thermometer is the most basic form of a temperature meter that is used to measure the degree of hotness and coolness.

Temperature meters are used in the geotechnical field to monitor concrete, structures, soil, water, bridges, etc. for structural changes in due to seasonal variations. A thermocouple (T/C) is made from two dissimilar metals that generate an electrical voltage in direct proportion to the change in temperature. An RTD (Resistance Temperature Detector) is a variable resistor that changes its electrical resistance in direct proportion to the change in the temperature in a precise, repeatable, and nearly linear manner.

6. Results and Discussion

The experimental evaluation of the proposed AI-powered IoT framework for Smart Irrigation

and Fertilizer Management was conducted on a 1000 m² experimental field to validate its

performance, accuracy, and operational efficiency.
The system integrates a multi-layer

architecture consisting of a Sensing Layer, Communication Layer, AI Processing Layer, and

Actuation Layer, which collectively enable autonomous, real-time irrigation and nutrient management.

7. Conclusion and Future Work

This paper presented an intelligent IoT framework for precision agriculture using cloud and AI-based smart irrigation. By integrating real-time sensing, AI-driven analytics, and automated control, the system enhances water-use efficiency and sustainability. Future work will focus on integrating fertilizer management, expanding reinforcement learning techniques, and deploying the system at large-scale agricultural sites.

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