BODHIVRUKSHA JOURNAL OF DIVERSE DISCIPLINE
E-ISSN : 3139-1486
An Open Access, Peer-Reviewed, Multidisciplinary Scholarly Journal
Bi-monthly | Multilingual (English, Hindi, Marathi) | Academic Research
@ Volume 2, Issue 5 (September-October 2026) (Special Issue 1) ISSN: 3139-1486 (Online)

AI-Powered Smart Agriculture System

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Abstract

This paper presents the design and prototype evidence for an Internet of Things (IoT)-based smart agriculture system described in the project presentation. The proposed system monitors soil moisture, temperature, humidity, water level, rainfall, and light; an ESP32-S3 is listed as the edge controller. The design connects sensor acquisition and local display with Wi-Fi communication, cloud-based monitoring, proposed AI-assisted decision support, and relay-controlled pump operation. The paper follows the project presentation's system workflow and hardware inventory, explains the intended data path and control functions, and includes the supplied block diagram, circuit drawing, simulation view, and prototype photograph. The listed prototype components have an approximate total cost of INR 2,680. The presentation does not specify a trained model, cloud service, control thresholds, sensor calibration, test protocol, or measured water-use and accuracy results. Therefore, AI, cloud, and irrigation-efficiency functions are treated as design objectives rather than validated performance. The paper makes no quantitative claim of water savings and identifies the implementation details and experiments needed for reproducible evaluation.

Index Terms: Internet of Things, smart agriculture, precision irrigation, ESP32-S3, soil-moisture sensing, automated irrigation.

I. INTRODUCTION

Irrigation decisions depend on soil moisture, water availability, weather, and crop requirements. A schedule based only on time may not reflect current field conditions, while manual observation requires a person to repeatedly inspect the farm and operate the pump. The project presentation addresses these issues with a sensor-based system intended to monitor field conditions, automate pump switching, and make readings available remotely. It identifies soil moisture, temperature, humidity, tank level, rainfall, and light as relevant inputs, and proposes a local ESP-based controller with cloud connectivity and a web or mobile dashboard.

The project objectives are to acquire and process agricultural sensor readings, control irrigation according to soil and water conditions, display and transmit system status, and support more informed water use. The presentation also proposes the use of weather information and AI/ML decision-making. It does not, however, provide an algorithm, model parameters, training data, or measured irrigation outcomes. In this paper, these functions are therefore described as intended capabilities. The distinction is important: a diagram of an AI-assisted workflow is not evidence that a trained model or cloud service has been implemented.

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Prior IoT irrigation studies provide relevant design comparisons. Benyezza et al. examined wireless sensing and fuzzy-logic control for zoned irrigation [1]. Pereira et al. presented an ESP32-based smart drip-irrigation prototype with sensing and remote monitoring [2]. Tzerakis et al. developed an open-source IoT platform for irrigation scheduling and decision support in olive-grove parcels [3]. These studies show that sensing, communication, decision logic, and actuation can be integrated in different ways; their results are not measurements of the system reported here.

The remainder of this paper is organized as follows. Section II reviews related work. Section III describes the project methodology, architecture, hardware, and intended operation. Section IV discusses the prototype evidence, cost, limitations, and evaluation needs. Section V concludes and identifies future work.

II. LITERATURE SURVEY

IoT-based irrigation research commonly combines field sensors with embedded processing and a communication layer, while differing in how irrigation decisions are made. Benyezza et al. reported a wireless-sensor and fuzzy-control approach organized around irrigation zones [1]. Its relevance is the explicit separation of field measurements from control decisions. The project described in this paper also proposes sensor-based pump control, but does not specify zones or a fuzzy rule base.

Pereira et al. described an ESP32-based drip-irrigation system that integrates sensing with remote monitoring [2]. This work is a useful embedded-platform comparison; the project inventory here instead lists an ESP32-S3, a single relay module, and no flow sensor. Tzerakis et al. presented an open-source monitoring and decision-support platform with implementation at olive-grove parcels [3]. It illustrates the role of data collection and scheduling support, but does not establish performance for this project's hardware or proposed AI component.

Together, these studies motivate a modular architecture with sensing, edge processing, communications, decision support, and actuation. Direct comparison of irrigation performance would require equivalent crops, soil, sensor calibration, test duration, and water-volume measurements. The project presentation supplies none of those comparative measurements; consequently, this paper uses the literature to frame the design and does not transfer published accuracy or water-saving results to the present prototype.

III. METHODOLOGY

A. Development Methodology

The system is organized as a sensing-to-actuation workflow. First, field sensors observe soil and environmental conditions. Second, the ESP32-family controller collects readings and is intended to filter or format them. Third, the design sends processed measurements over Wi-Fi to a cloud service for storage and monitoring. Fourth, a decision stage is intended to consider sensor values together with weather and crop requirements. Finally, a relay switches the irrigation pump, while an LCD and remote dashboard are intended to present readings, pump state, and alerts. Fig. 1 summarizes this layered arrangement as shown in the project presentation.

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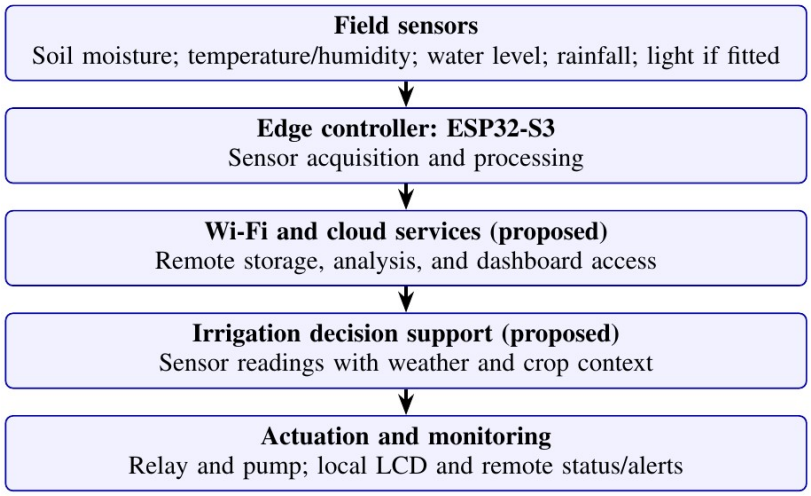


Fig. 1. Vector redraw of the project block diagram. Cloud and AI-assisted functions are proposed elements, not verified deployments.

B. System Inputs and Processing

The listed sensing channels are soil moisture, temperature, humidity, water level, and rainfall. Light is also shown in the architecture and prototype imagery, but is absent from the priced component list; its final inclusion should be confirmed. The presentation does not identify the exact models of the soil-moisture, water-level, and rain sensors, nor does it provide pin assignments, units, sampling frequency, calibration curves, or sensor accuracy. The DHT11 is the only specifically named environmental sensor.

For repeatable operation, sensor readings should be associated with a timestamp and a device or plot identifier, with the pump state recorded alongside the measurements. Raw readings and calibrated values should be distinguished so that later analysis can trace sensor conversion and decision behavior. These are recommended data-recording practices; the presentation does not specify a data schema or storage format. Likewise, filtering and conversion are described at a high level, but the project files do not state the filters, validation checks, or handling of missing and implausible readings.

C. Circuit and Power Design

The project circuit drawing is reproduced in Fig. 2. It shows sensor connections to a generic ESP-labelled controller, a separate ESP-01 Wi-Fi module, relay switching, and a pump output. In contrast, the bill of materials specifies an ESP32-S3 development board, which already differs from the controller and separate Wi-Fi-module representation in the drawing. The presentation also depicts an AC mains input and a rectifier/regulator power stage. These inconsistencies mean the image should be treated as a conceptual project schematic, not as verified construction instructions. The mains-related portion requires review by a qualified person and appropriate electrical isolation and enclosure design before any physical implementation.

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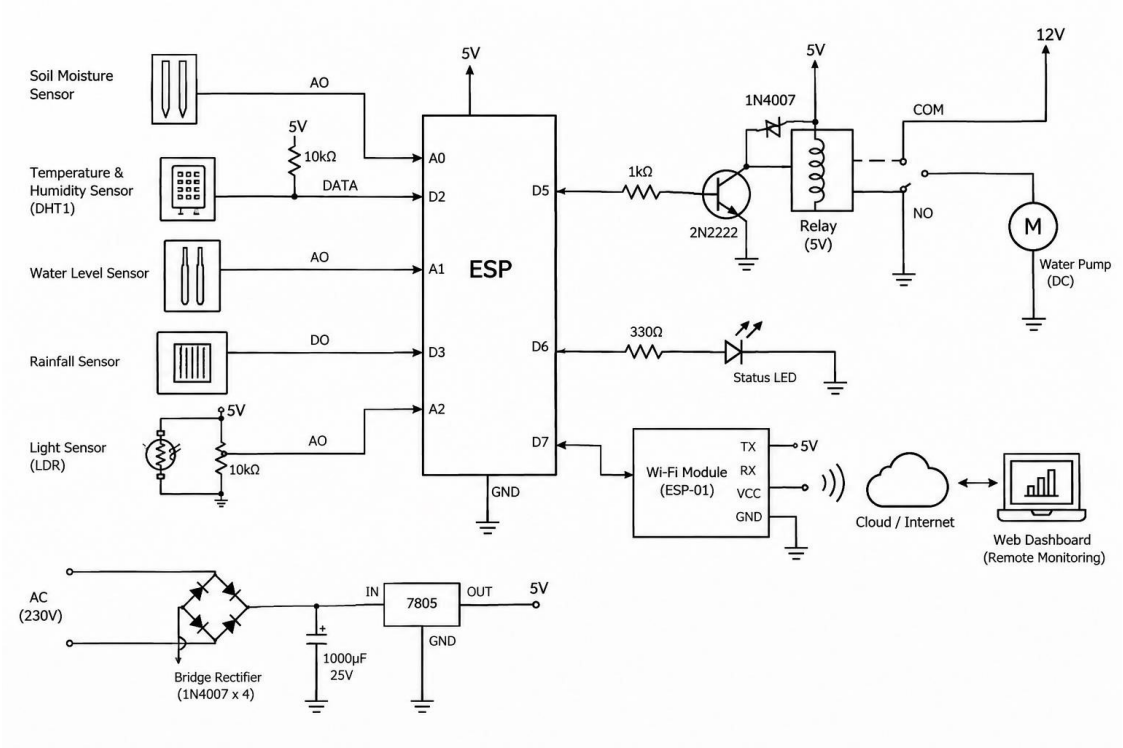


Fig. 2. Circuit drawing supplied in the presentation. Controller, Wi-Fi, and power-stage details require verification; this figure is not a wiring or mains-safety guide.

D. Components Used

Table I summarizes the hardware named in the presentation and its intended role. The project also identifies a 16×2 LCD, breadboard, and jumper wires. The pump appears in the system diagrams, but it is not a priced line item in the component-cost slide. The light sensor is visible in project imagery but likewise is not included in that cost list.

TABLE I. HARDWARE COMPONENTS AND THEIR INTENDED ROLES

Component	Role stated or implied in the project
ESP32-S3 N16R8 board	Edge controller for sensor acquisition and processing.
DHT11 sensor	Measurement of ambient temperature and humidity.
Soil-moisture sensor	Observation of soil water condition for irrigation decisions.
Water-level sensor	Monitoring of water availability in the source or tank.
Rain sensor module	Detection of rainfall conditions for decision support.
1-channel 5-V relay	Switching interface between controller and pump.
16×2 LCD	Local display of system readings or status.
Breadboard and jumper wires	Prototype assembly and component connections.

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Component	Role stated or implied in the project
Light sensor	Shown in diagrams and project photograph; not itemized in the component list.

Table II separates the software and communication functions in the concept from details actually specified. No source code, cloud provider, dashboard framework, communication protocol, or AI model is identified in the supplied materials.

TABLE II. SOFTWARE AND COMMUNICATION FUNCTIONS IN THE PROPOSED DESIGN

Function	Intended role	Specified detail
Controller firmware	Read, filter, and format sensor values.	ESP32-S3 listed; code absent.
Wi-Fi uplink	Send readings to remote storage.	Wi-Fi shown; protocol absent.
Cloud/dashboard	Display current values, history, and alerts.	Service and application unnamed.
AI/decision support	Combine sensor, weather, and crop context.	Model and data absent.
Pump control	Use relay to switch irrigation.	Threshold and safety logic absent.

E. System Working

Fig. 3 reproduces the workflow presented by the project team. At a functional level, the proposed operation is:

1) Sensors acquire soil-moisture, temperature, humidity, water-level, rainfall, and (if fitted) light readings.

2) The ESP-family controller receives the sensor signals and is intended to check, filter, and format them.

3) Processed values are transmitted over Wi-Fi to a cloud service, where the proposed design stores data for monitoring and later analysis.

4) The decision stage is intended to assess irrigation need from soil and environmental readings, optional weather information, and crop requirements.

5) If irrigation is requested, the controller energizes the relay to switch the pump; the presentation describes stopping at a target moisture condition.

6) The LCD and web/mobile dashboard are intended to display sensor values and pump status, with alerts for dry soil, low water, or abnormal conditions.

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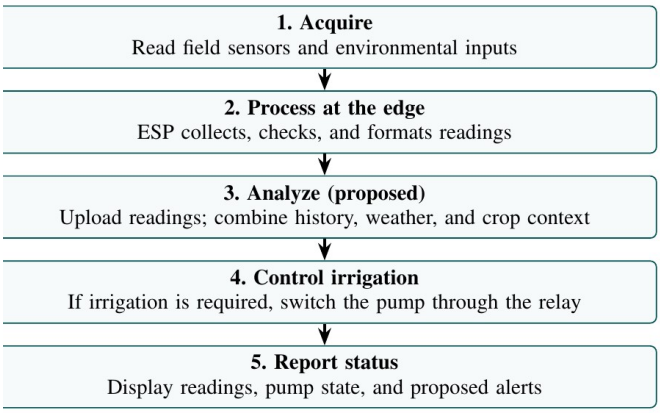


Fig. 3. Vector redraw of the project workflow. The decision algorithm, thresholds, and alert rules are not specified in the supplied materials.

The specific decision rule, moisture threshold, water-level interlock, pump timeout, and manual override are not documented. A practical implementation should calibrate thresholds for the soil and crop, use appropriate hysteresis to reduce rapid relay switching, and define safe behavior for sensor faults or network loss. These are engineering requirements for completion, not functions verified by the supplied presentation.

F. Simulation and Prototype Evidence

The presentation includes a simulation image and a photograph of a physical project assembly. The simulation screenshot in Fig. 4 visibly labels a generic ESP32 and DHT22, while the component list specifies ESP32-S3 and DHT11. It therefore illustrates a related circuit arrangement, but does not confirm that the simulated and listed configurations are identical. Fig. 5 shows the assembled demonstration setup. A photograph establishes that a prototype arrangement is presented; it does not by itself establish sensor accuracy, reliable pump operation, field readiness, or water savings.

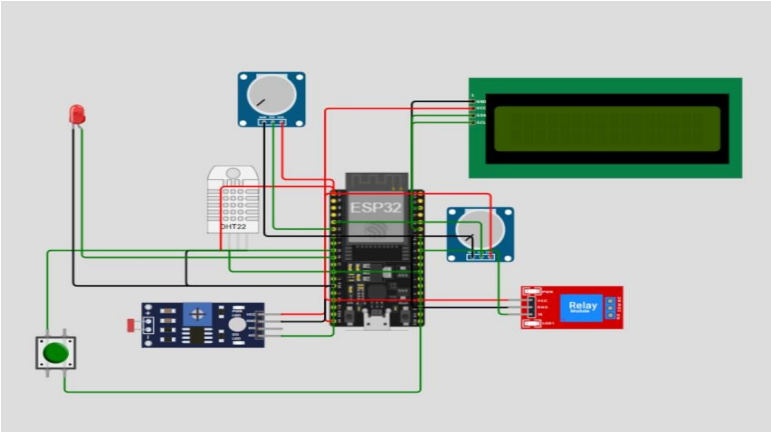


Fig. 4. Simulation view supplied with the project. Visible controller and sensor labels differ from the priced component list.

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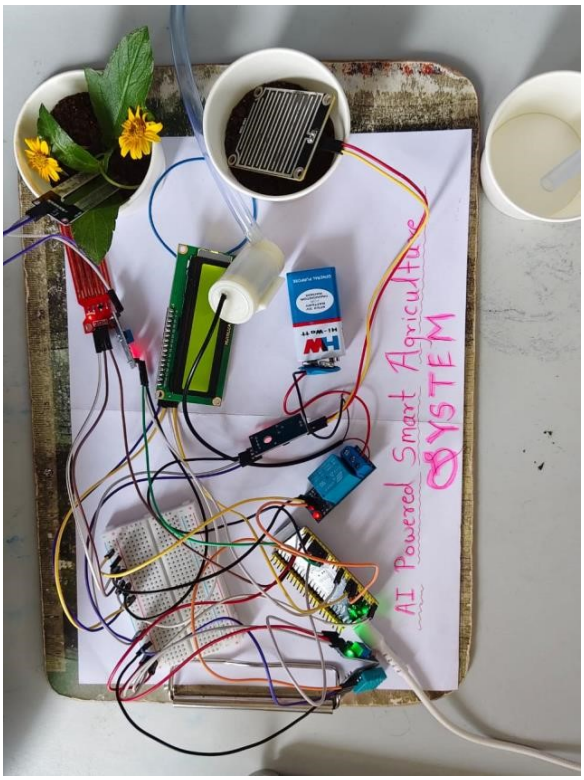


Fig. 5. Project photograph from the presentation. The visible assembly is illustrative and is not a measurement of operating performance.

IV. RESULTS AND DISCUSSION

The project files provide a component inventory, system and workflow diagrams, a simulation screenshot, and a prototype photograph. They do not provide timestamped sensor logs, calibration results, a defined test duration, a crop/soil description, a comparison baseline, measured pump response, or water-volume readings. No numeric accuracy, response-time, yield, or water-saving result can therefore be reported. In particular, the AI/ML component remains a proposed decision-support function because no model, dataset, training procedure, or evaluation is documented.

Table III transcribes the approximate component costs from the presentation. The listed amounts sum to INR 2,680. This total is a project estimate, not a verified purchase record, and it excludes unpriced items such as the pump, the unlisted light sensor, cloud or connectivity charges, and any enclosure or field-protection hardware.

TABLE III. APPROXIMATE PROTOTYPE COMPONENT COST REPORTED IN THE PRESENTATION

Component	Cost (INR)
ESP32-S3 N16R8 development board	1400

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Component	Cost (INR)
DHT11 temperature and humidity sensor	150
Soil-moisture sensor	150
Water-level sensor	130
Rain sensor module	170
1-channel 5-V relay module	160
16×2 LCD display	200
Breadboard	120
Male-to-male jumper wires	100
Male-to-female jumper wires	100
Approximate listed total	2680

A suitable validation study should first calibrate each sensor against a reference instrument and report error over the intended operating range. It should then test normal and fault conditions, including dry and adequately moist soil, low tank level, disconnected sensors, and network interruption, recording pump commands and actual actuation. Water use should be measured with a defined baseline and equivalent crop, soil, and test conditions. If AI/ML is implemented, the model, dataset source, input features, data split, target variable, and held-out metrics should be documented. Table IV summarizes the evidence required before performance claims can be made.

TABLE IV. EVALUATION EVIDENCE NEEDED FOR QUANTITATIVE CLAIMS

Evaluation area	Measurement required; not present in supplied files
Sensor quality	Calibration method, reference readings, measurement error, and drift.
Control reliability	Trigger/stop behavior, low-water response, fault handling, and pump actuation logs.
Connectivity	Update interval, data loss, and end-to-end latency over a stated test duration.
Water efficiency	Pumped volume compared with a defined baseline under equivalent conditions.
AI performance	Named model, dataset, train/test protocol, target, and held-out performance metrics.

The current documentation also leaves several design choices unresolved. The component list, circuit drawing, and simulation use different controller or sensor labels; the light sensor appears in diagrams and the photograph but is not costed; and the pump is shown but absent from the cost table. The cloud service, dashboard, network protocol, control location, sensor pins, and power design likewise need confirmation. These inconsistencies do not invalidate the concept, but they limit reproducibility and prevent the diagrams from serving as final build documentation.

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V. CONCLUSION AND FUTURE SCOPE

This paper organizes the project presentation into an IEEE-style description of an IoT smart-agriculture system. The proposed design combines environmental and soil sensing, ESP32-family edge processing, Wi-Fi/cloud monitoring, AI-assisted irrigation decision support, and relay-based pump control. The presentation also supplies a hardware list, diagrams, a simulation view, a project photograph, and an approximate component cost of INR 2,680. The available evidence supports a design and prototype description, but not a quantitative claim about prediction accuracy or water savings.

Future work should reconcile the final controller and sensor models across the bill of materials, circuit, and simulation; document wiring and a safe power architecture; identify the cloud and dashboard implementation; and specify calibration, sampling, thresholds, interlocks, and fault handling. The team should then collect reproducible sensor, pump, and water-volume data under stated crop and soil conditions. If AI/ML is retained, its model and dataset should be described and evaluated on held-out data. Multi-zone irrigation and detailed water-use analytics may be explored later, but the current bill of materials lists only a single relay and does not document a multi-zone implementation.

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