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# Smart Agriculture Monitoring System Using IoT

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***Abstract:*** ***This paper presents an Internet of Things (IoT)-based smart agriculture monitoring prototype built around an ESP32 microcontroller.***
***The system integrates soil-moisture sensing, ambient temperature and relative-humidity measurement, and irrigation-water monitoring through total dissolved solids (TDS) and turbidity sensors. A relay interface controls a water pump, and an OLED provides local status information.***
***Selected values and pump state are shared through Firebase Realtime Database for a web dashboard, while a Telegram bot supports status requests and remote mode and pump commands. The supplied firmware implements threshold-based automatic control with soil-moisture hysteresis and multi-sample confirmation. This manuscript documents the implemented architecture and interface evidence.***
***It does not claim calibrated sensor accuracy, water savings, crop-yield improvement, or field-scale reliability; these require controlled validation.***
***Keywords: Internet of Things, smart agriculture, ESP32, irrigation control, Firebase, Telegram.***

## I. INTRODUCTION

Irrigation decisions based only on a fixed schedule or visual inspection may not reflect changing soil and environmental conditions. IoT-based monitoring systems can collect relevant measurements and make their status accessible locally and remotely. Prior work demonstrates the use of connected sensors and controllers for agricultural monitoring and irrigation support [1], [2].
The present student project integrates soil moisture, temperature, humidity, TDS, and turbidity sensing with a relay-controlled pump, OLED display, Firebase dashboard, and Telegram interface. Its contribution is the integration of these functions in one working prototype, rather than a new sensing principle or a quantitatively validated irrigation method.

## II. RELATED WORK AND OBJECTIVES

Suma et al. [1] and Rajakumar et al. [2] describe IoT-oriented agricultural monitoring systems that combine sensor inputs with remote access.
These works motivate the present architecture. They do not validate the specific sensor mappings, thresholds, or hardware implementation used in this prototype. The objectives are to monitor soil and ambient conditions together with selected irrigation-water indicators; perform threshold-based pump control; provide local and cloud-based status visibility; and allow a user to query status or select operating modes remotely. The ESP32 is the central controller for acquisition, decision logic, Wi-Fi communication, display updates, and relay control.

## III. SYSTEM ARCHITECTURE AND COMPONENTS

### *A. Architecture*

The system consists of an ESP32 development board, soil-moisture sensor, DHT11 sensor, TDS sensor, turbidity sensor, SSD1306 OLED display, relay module, DC pump, battery supply, and buck-converter stage. The ESP32 reads the sensors, processes their values, updates the OLED, exchanges selected state with Firebase, and controls the relay. The dashboard and Telegram bot provide remote interaction through the cloud data layer.

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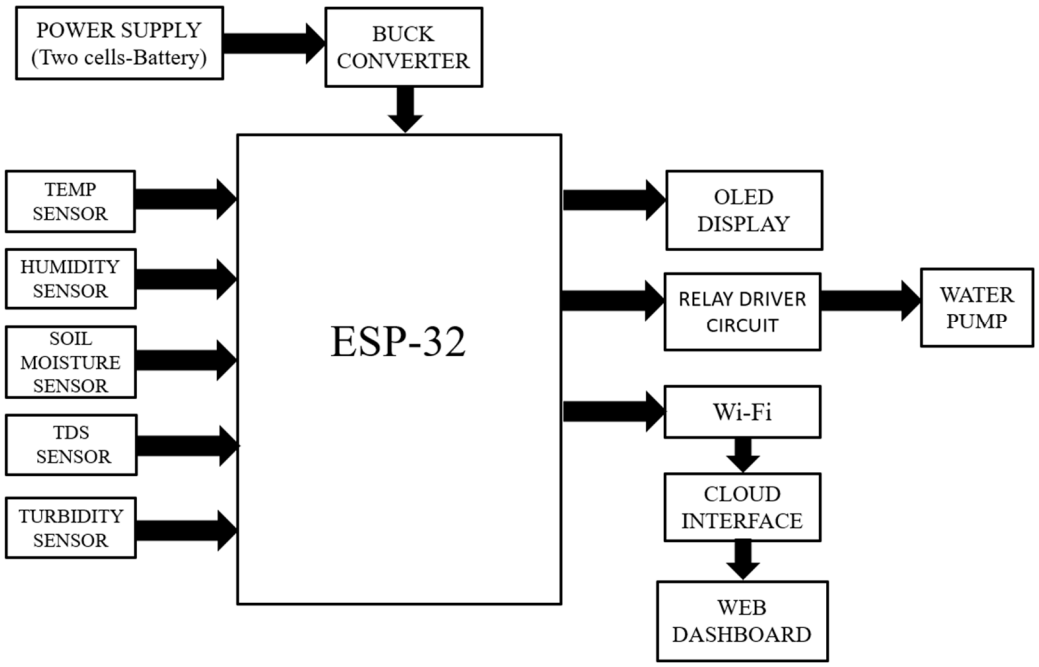



Fig. 1 Block diagram of the Smart Agriculture Monitoring System.

The supplied interconnection diagram is reproduced as an architecture aid in Fig. 2. Exact component variants, supply voltages, and wiring should be checked against the assembled prototype before this document is used as a final circuit schematic.

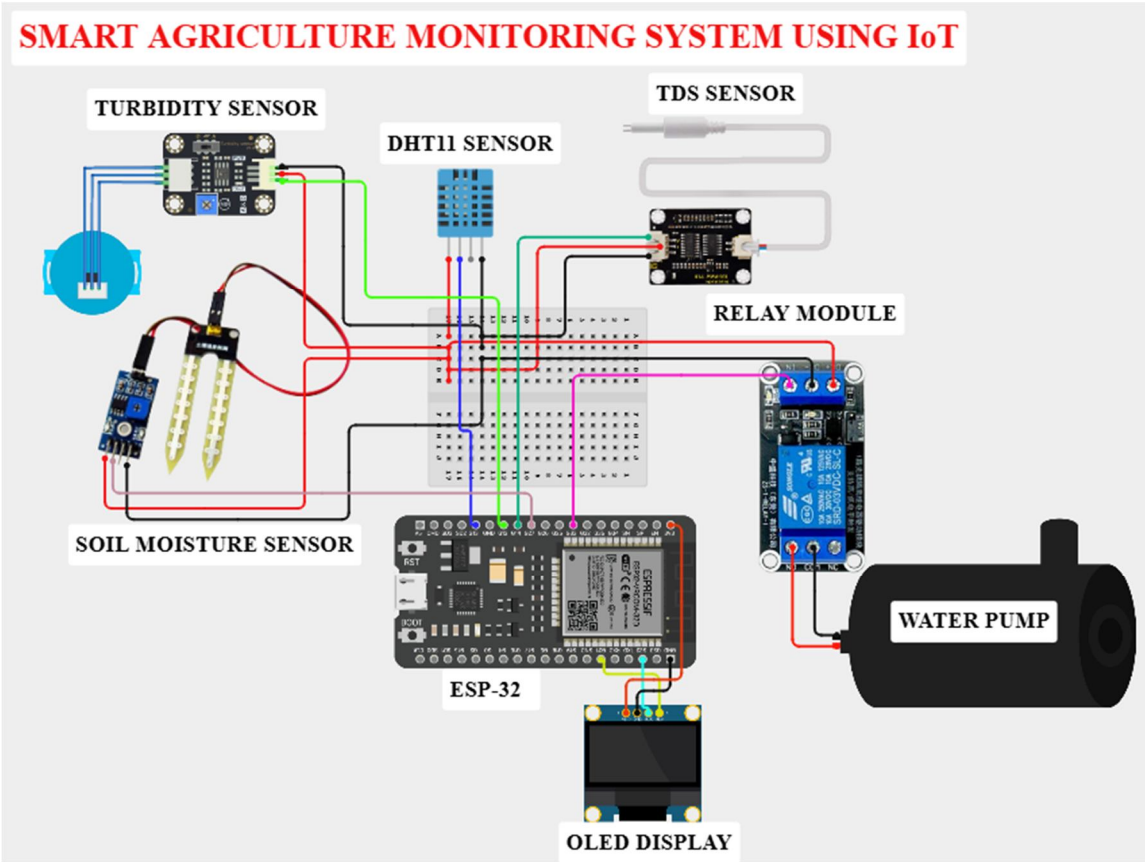



Fig. 2 Project hardware-interconnection diagram.

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### *B. Components*

The soil-moisture sensor supplies the irrigation-condition input; the DHT11 supplies temperature and relative-humidity values; the TDS and turbidity sensors supply water-condition inputs; and the OLED provides local readout. The relay is active-low in the supplied firmware and switches the pump. Firebase stores current state for the dashboard, while Telegram provides commands and status interaction. The ESP32 family and Firebase and Telegram interfaces are documented by their providers [3]–[5].

## IV. IMPLEMENTATION AND CONTROL METHOD

### *A. Data Acquisition and Processing*

The supplied code assigns GPIO 35 to soil moisture, GPIO 33 to TDS, GPIO 34 to turbidity, GPIO 4 to DHT11 data, GPIO 25 to relay control, and GPIO 21 and GPIO 22 to OLED I2C SDA and SCL, respectively. It initializes the sensor interfaces, OLED, Wi-Fi, Firebase, and Telegram functions before repeatedly acquiring inputs, updating the local display, evaluating control conditions, and publishing selected state.

The soil analog input is constrained to 1800–4095 and mapped inversely to a 0–100 display scale. The turbidity input is constrained to 900–2200 and mapped to a relative 0–100 scale. Therefore, the values shown here are firmware display values, not calibrated volumetric soil moisture or verified turbidity in NTU. The TDS path uses a GravityTDS library with smoothing and added scaling. Reference calibration is required before measurement accuracy can be stated. The DHT library interface is described in [6].

### *B. Pump Control*

The supplied firmware defines SOIL_ON = 40, SOIL_OFF = 60, TDS_LIMIT = 500 ppm, TURB_LIMIT = 25, and CONFIRM_COUNT = 3. In AUTO mode, pump activation requires soil moisture below 40%, TDS below 500 ppm, and mapped turbidity below 25 for three consecutive checks. Pump deactivation occurs when soil moisture exceeds 60% or either water-quality threshold is reached, also after the confirmation count. The 40% and 60% settings provide hysteresis. In MANUAL mode, the pump follows the requested command. These are prototype code settings, not crop-independent recommendations.

### *C. Cloud and Telegram Interaction*

The firmware publishes soil, TDS, turbidity, temperature, humidity, and pump state through Firebase Realtime Database. The dashboard presents current cards and short trends. The Telegram interface supports /status, /auto, /manual, /on, and /off commands. The available screenshot documents command and status interaction; it is not a controlled measurement of response latency or pumping performance.

## V. PROTOTYPE EVIDENCE AND DISCUSSION

Figures 3–6 show the assembled prototype and the corrected interface screenshots supplied for this revision. They establish that the prototype has hardware and user-interface implementations. They do not independently establish calibration, accuracy, field reliability, water savings, or crop-yield improvement.

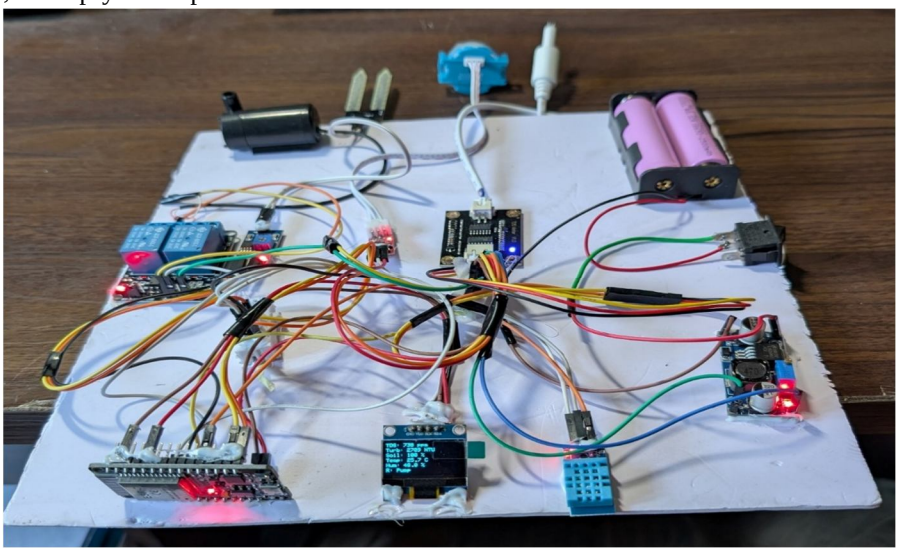


Fig. 3 Assembled Smart Agriculture Monitoring System prototype.




Fig. 4 Corrected dashboard screenshot during prototype operation. Displayed values are not presented as calibrated measurements.

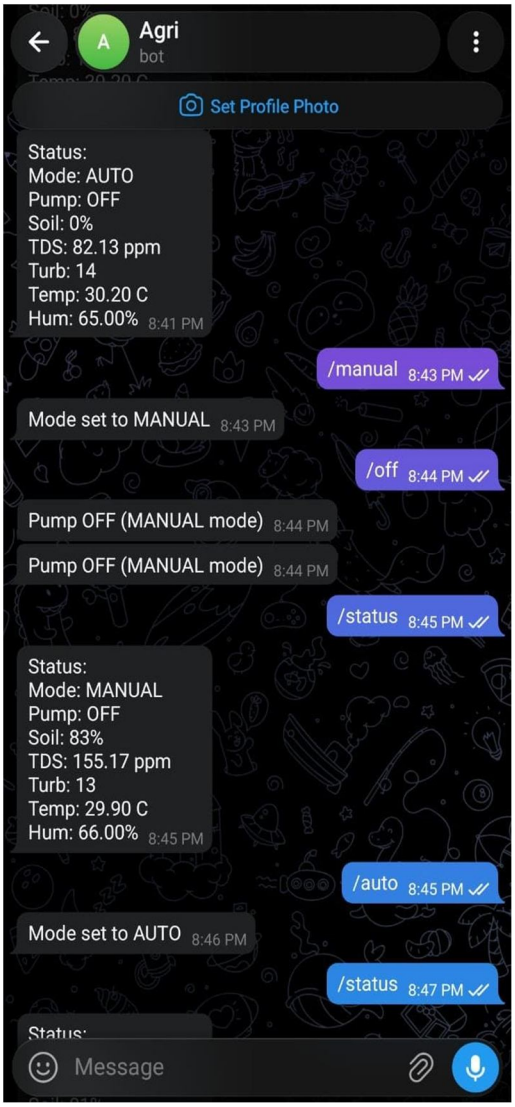



Fig. 5 Telegram status and mode-command interaction. This message record is not a controlled pump-response test.

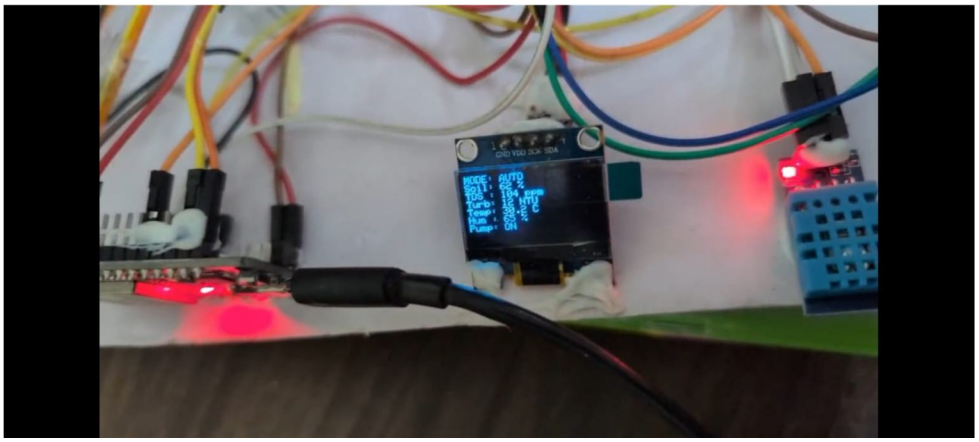


Fig. 6 Local OLED status display during prototype operation.

The dashboard presents temperature, humidity, soil, turbidity, TDS, and pump-control cards with short time-series charts. The Telegram image records switching from AUTO to MANUAL, an OFF command, a status request, and a later return to AUTO. The OLED photograph shows local status presentation. These are visual implementation records only; calibration and repeatable testing remain required.

## VI. LIMITATIONS AND FUTURE WORK

The system depends on Wi-Fi for cloud synchronization and remote access. Analog mappings, TDS scaling, and water-condition thresholds require calibration and validation against appropriate references. The available screenshots are status snapshots rather than repeated, time-stamped experimental trials. Future work should log raw and processed readings, document calibration procedures, verify actual pump actuation against commands, measure delivered water volume under comparable baseline and automated conditions, and perform repeated tests under recorded soil and environmental conditions.

## VII. CONCLUSION

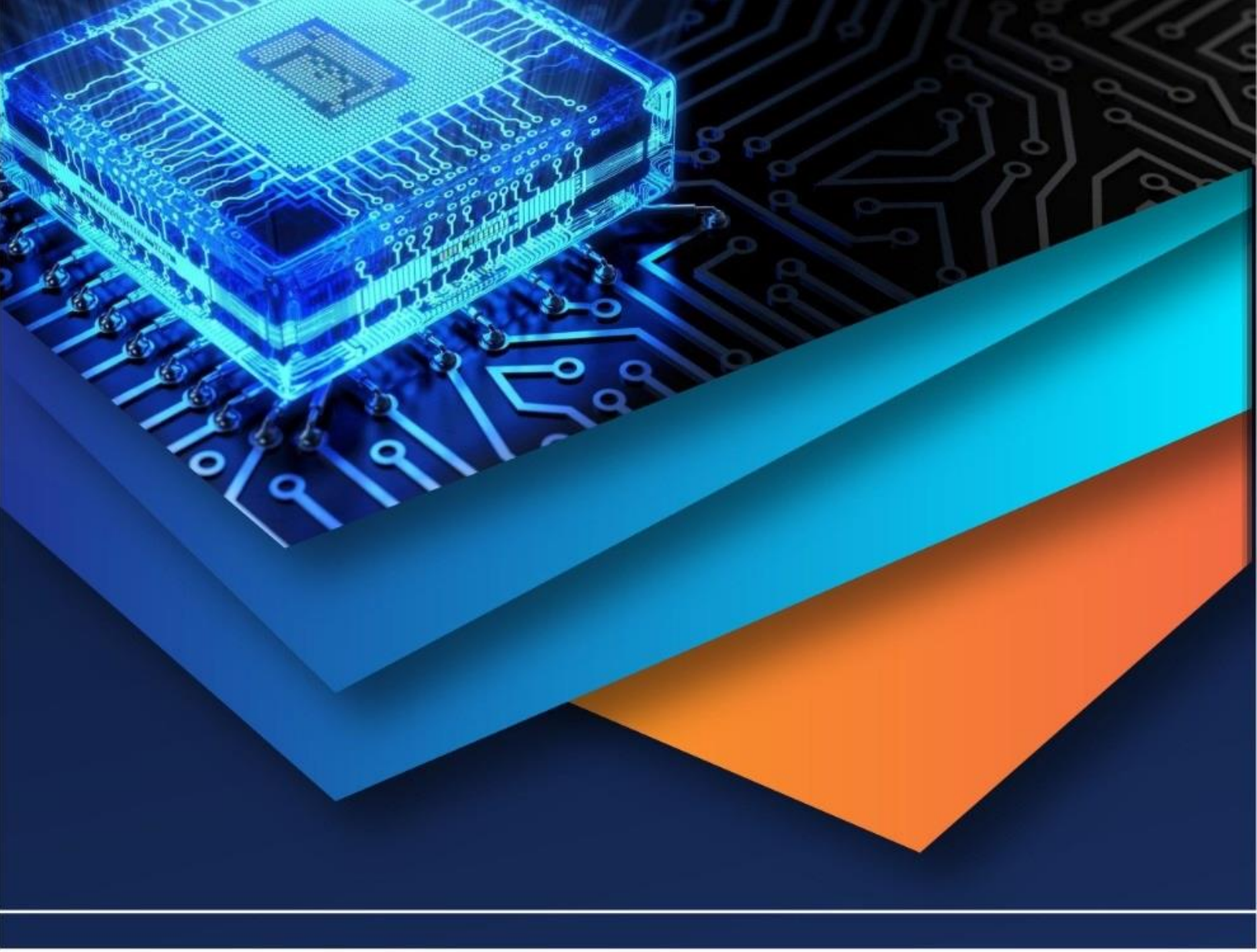
An ESP32-based smart agriculture monitoring prototype has been implemented by integrating soil, ambient, and irrigation-water sensing with local OLED output, relay-controlled pumping, Firebase dashboard monitoring, and Telegram commands. The provided firmware implements threshold-based automatic operation with soil-moisture hysteresis and multi-sample confirmation. The present evidence supports an implementation-focused preliminary report. Calibration and controlled trials are still necessary before quantitative performance claims are made.

## VIII. ACKNOWLEDGMENT

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