# IoT-Based Smart Agriculture System for Real-Time Soil Monitoring and Automatic Irrigation

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**Abstract** - *Agriculture still depends heavily on manual observation and fixed irrigation routines, which waste water and leave crops exposed to sudden changes in weather. This paper presents a low-cost Smart Agriculture System based on the Internet of Things (IoT) that continuously monitors soil moisture, air temperature, humidity and the water level of the supply tank. An ESP8266 Node MCU reads the sensors, connects to the internet through Wi-Fi and publishes the readings to the Blynk cloud, so that the farmer can follow the condition of the field on a smartphone from anywhere. Two submersible pumps, switched through a relay module, refill the tank and irrigate the field automatically when preset thresholds are crossed, and the same pumps can also be operated manually from the mobile application. Because the prototype uses only inexpensive and easily available modules, it is affordable for small farmers and is especially useful in regions where water is limited.*

**Key Words: IoT, Smart Agriculture, Soil Moisture, ESP8266 Node MCU, DHT11, Ultrasonic Sensor, Automatic Irrigation, Blynk.**

## 1. INTRODUCTION

Agriculture is the backbone of the Indian economy and the main source of livelihood for a large part of the population. Yet erratic rainfall, falling groundwater levels and rising labour costs make farming harder every year. On many farms irrigation is still decided by habit or by guesswork: the farmer walks to the field, judges the dryness of the soil by sight or touch, and switches the pump on or off by hand. This wastes water and time, and it can easily over-water or under-water a crop, which directly reduces the yield.

The Internet of Things (IoT) offers a practical way out. Small sensors can measure the condition of the soil and the surrounding air, a microcontroller with built-in Wi-Fi can send those measurements to a cloud service, and the farmer can read them on a phone and decide – or let the system decide – when water is really needed. Since the hardware is cheap and the software tools are free, the technology is within reach even of small and marginal farms.

The objectives of this work are: (i) to monitor soil moisture, temperature and humidity of the field in real time; (ii) to monitor the water level of the supply tank; (iii) to automate irrigation using threshold values while allowing manual control from a smartphone; and (iv) to keep the overall cost of the system low.

## 2. LITERATURE SURVEY

Many researchers have applied sensor networks and IoT to farming. Nandurkar et al. [2] and Dholu and Ghodinde [3] studied precision agriculture with wireless sensor networks and IoT, where field parameters are sensed and used to support better farming decisions. Gayatri et al. [1] proposed smart agricultural solutions that give farmers information for improved yield, and Vidya Devi and Meena Kumari [5] described a real-time automation and monitoring system for modernised agriculture.

Gutiérrez et al. [4] built an automated irrigation system in which soil-moisture and temperature thresholds are programmed into a microcontroller-based gateway; the system is powered by a photovoltaic panel and uses a cellular (GPRS) link so that irrigation can be scheduled through a web page. Dagar et al. [6] and Pendyala et al. [8] discuss smart-farming and IoT-based agriculture monitoring systems, while Vijay Bhaskar et al. [7] use predictive analytics for crop prediction.

From this survey it is clear that sensing, wireless communication and automatic control are the three building blocks of a smart farm. The present work combines them in a compact prototype that also watches the water level of the supply tank, so the pump is never run dry, using only low-cost Wi-Fi hardware and a free mobile application.

## 3. PROPOSED SYSTEM

### 3.1 SYSTEM OVERVIEW

The proposed Smart Agriculture System has four parts, shown in Fig-1: (a) a sensing unit with a soil moisture sensor, a DHT11 temperature-humidity sensor and an HC-SR04 ultrasonic sensor; (b) a control unit built around the ESP8266 Node MCU; (c) an actuation unit with a two-channel relay module that drives two small water pumps; and (d) a cloud and user interface formed by the Blynk server and the Blynk smartphone application.

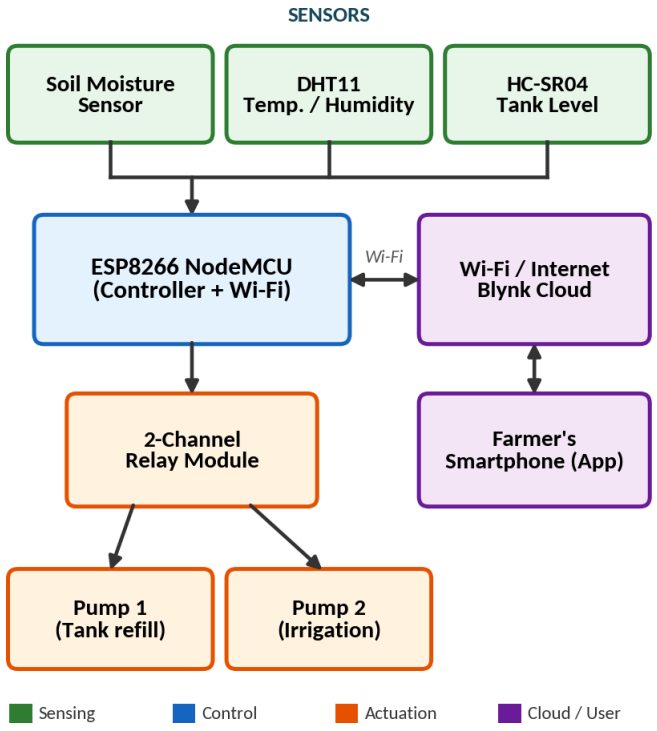



**Fig-1**: Block diagram of the IoT based Smart Agriculture System

The sensors send their readings to the Node MCU, which uploads them to the Blynk cloud over Wi-Fi. The same connection works in the opposite direction: commands given in the app reach the Node MCU and are passed on to the relays. Pump 1 fills the supply tank from a reservoir such as a well, river or water-supply line, and Pump 2 distributes water from the tank to the field.

### 3.2 Hardware Components

Table-I lists the modules used and their main specifications, and Fig-2 shows the actual modules.

**TABLE-I**: Components and specifications

| Component | Key specification |
|---|---|
| ESP8266 Node MCU | 32-bit Tensilica L106 CPU, 80/160 MHz, built-in 802.11 b/g/n Wi-Fi, 3.3 V logic, one 10-bit analog input (A0) |
| Soil moisture sensor | Two-probe resistive type with comparator board; analog and digital outputs; 3.3–5 V supply |
| DHT11 | Temperature 0–50 °C (±2 °C); humidity 20–90 % RH (±5 % RH); 1 sample per second |
| HC-SR04 | Ultrasonic ranging 2–400 cm at 40 kHz; 5 V supply; Trigger and Echo pins |
| 2-channel relay | 5 V relay board; one NO/NC contact set per channel; isolates pump supply from the controller |
| Mini submersible pump (x2) | DC 3–6 V, low current, up to about 120 L/h |

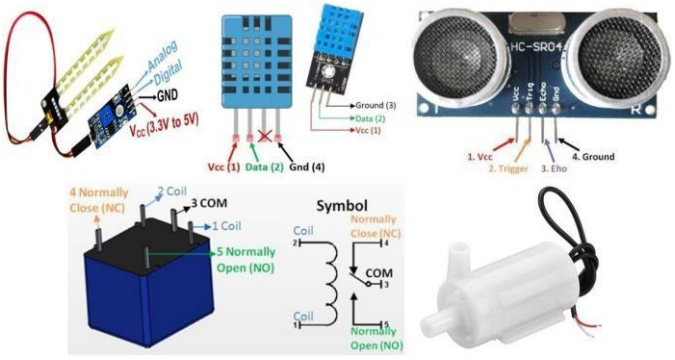



Fig-2: Main hardware modules – soil moisture sensor, DHT11, HC-SR04, relay module and mini submersible pump

Soil moisture sensor. Two metal probes are pushed into the soil. Wet soil conducts better than dry soil, so the resistance between the probes falls as moisture rises. The analog output is read on pin A0 and converted into a percentage after the dry-air and fully-wet readings are measured once for calibration:

$$Moisture\,(\%) = (R_{dry} - R) / (R_{dry} - R_{wet}) \times 100 \quad (1)$$

**DHT11.** The sensor combines a negative-temperature-coefficient thermistor with a capacitive humidity element. An internal chip converts both into a digital signal that the Node MCU reads on a single data pin. It is cheap and adequate for field-level trends, although it is less accurate than DHT22-class sensors.

**HC-SR04.** The sensor is fixed at the top of the supply tank facing the water. A 10 µs pulse on the Trigger pin makes the module send eight bursts of 40 kHz sound; the Echo pin stays high until the reflection returns. With the speed of sound taken as 343 m/s, the distance to the water surface and the tank level are:

$$Level\,(\%) = (D_{empty} - d) / (D_{empty} - D_{full}) \times 100 \quad (3)$$

where t is the echo time in microseconds, and Dempty and Dfull are the distances measured when the tank is empty and full.

### 3.3 Circuit Connections

The Node MCU board and its pin functions are shown in Fig-3. Table-II gives the connections used in the prototype. The Echo pin of the HC-SR04 outputs 5 V, so it is connected to the Node MCU through a two-resistor voltage divider to protect the 3.3 V input. The pumps are supplied from a separate 5 V source through the relay contacts, with a common ground, so that pump current does not disturb the controller.

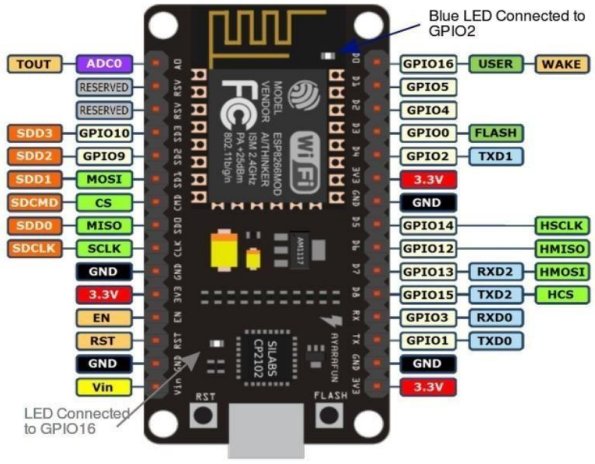



**Fig-3**: ESP8266 NodeMCU pin configuration

**TABLE-II**: Pin connections (*through voltage divider)

| Module | Module pin | NodeMCU pin |
|---|---|---|
| Soil moisture | AO / VCC / GND | A0 / 3V3 / GND |
| DHT11 | DATA / VCC / GND | D4 (GPIO2) / 3V3 / GND |
| HC-SR04 | Trig / Echo | D5 (GPIO14) / D6 (GPIO12)* |
| HC-SR04 | VCC / GND | VIN (5 V) / GND |
| Relay board | IN1 (Pump 1) / IN2 (Pump 2) | D1 (GPIO5) / D2 (GPIO4) |
| Relay board | VCC / GND | VIN (5 V) / GND |

### 3.4 Working principle

After power up the node MCU connects to the Wi-Fi network and to the Blynk cloud. In every it reads the three sensors calculate soil moisture and tank level, and sends the four value of the

$$d\,(cm) = 0.0343 \times t / 2 \qquad (2)$$

dashboard. It then compares them with the threshold values of Table-III. The complete logic is shown in the flowchart of Fig-4.

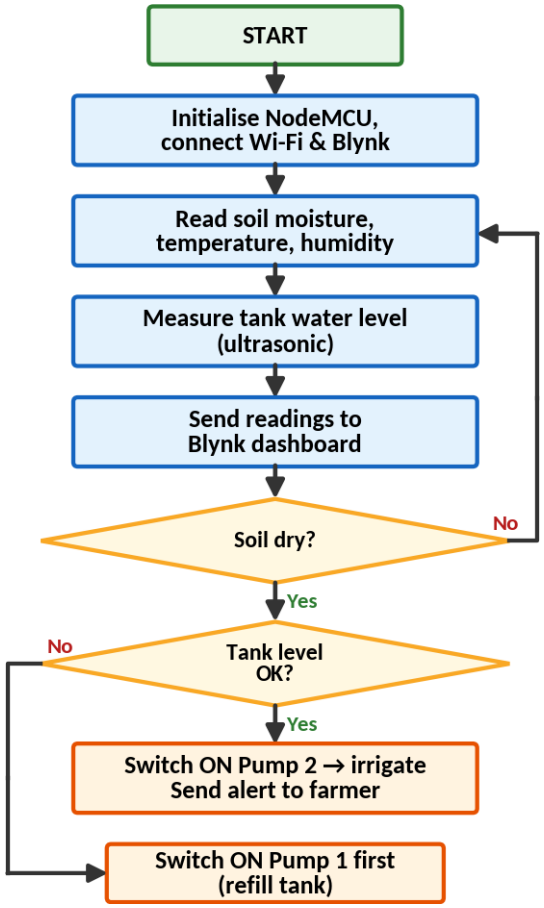



Fig-4: Flowchart of the monitoring and automatic irrigation process

TABLE-III: Control logic of the prototype.

| Condition | Action |
|---|---|
| Soil moisture below lower limit (soil dry) and tank level adequate | Pump 2 ON; irrigate the field and notify the farmer |
| Soil moisture reaches upper limit | Pump 2 OFF |
| Tank level below minimum | Pump 1 ON; refill tank from reservoir |
| Tank level reaches maximum | Pump 1 OFF (prevents overflow) |
| Farmer presses a switch in the app | Corresponding pump is switched manually (override) |

The numerical limits are set in the program and can be tuned for the crop and soil type. Using a lower and an upper limit (hysteresis) prevents the pump from switching on and off rapidly around a single value. If the tank is low when the soil is dry, Pump 1 refills the tank first so that Pump 2 never runs dry.

### 3.5 Software and Mobile Application

The program is written in the open-source Arduino IDE using the ESP8266 board package together with the Blynk and DHT libraries. The Blynk platform has three parts: the smartphone app, in which gauges and switches are placed to build the dashboard; the Blynk cloud server, which links the phone and the hardware; and the Blynk library on the Node MCU, which handles all incoming and outgoing data. Each value is mapped to a virtual pin – soil moisture, temperature, humidity and tank level as gauges, and the two pumps as switches – as in the dashboard layout of Fig-5.

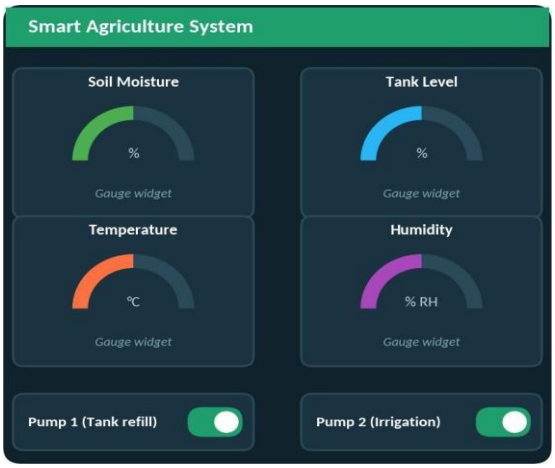



Fig-5: Proposed Blynk dashboard layout (gauges for sensor values, switches for pumps)

## 4.RESULTS AND DISCUSSION

The prototype hardware kit is shown in Fig-6. The sensors, NodeMCU and relay board are wired on a small board, the moisture probes are placed in the soil, and two containers act as the supply tank and the reservoir. Once powered, the system reports the soil condition, air temperature, humidity and tank level on the phone, so any change in the field can be noticed early without visiting the field.



Fig-6: Prototype hardware setup of the Smart Agriculture System

Compared with manual irrigation, the proposed system gives several practical benefits (Table-IV): water is used only when the soil needs it, the farmer can monitor and control the pumps remotely, and the pump is protected from running dry.

TABLE-IV: Traditional irrigation vs. proposed system

| Aspect | Traditional method | Proposed system |
|---|---|---|
| Irrigation decision | Guesswork / fixed timing | Based on soil-moisture data |
| Monitoring | Physical visit to field | Remote, on smartphone |
| Pump control | Manual at the site | Automatic + remote override |
| Tank safety | Not monitored | Level sensed; dry run avoided |
| Cost | Low (labour-heavy) | Low hardware cost |

**Limitations.** The DHT11 has modest accuracy, resistive soil probes corrode over time and should be replaced or coated, and the system needs Wi-Fi coverage in the field. These points can be improved with better sensors and communication modules, as discussed in Section 6.

## 5. CONCLUSION

This paper presented a low-cost IoT based Smart Agriculture System that monitors soil moisture, temperature, humidity and tank water level and controls two pumps automatically or manually through a smartphone. By irrigating only when the soil is dry and by protecting the pump from running dry, the system saves water, time and labour and helps in taking timely decisions. The design uses simple, easily available modules and free software, which makes it suitable for small farmers.

## 6. FUTURE SCOPE

The system can be extended in several ways:

- A rain sensor can stop irrigation when rainfall is detected, and a motion (PIR) sensor can warn about animal intrusion in the farm.
- A capacitive soil moisture sensor and a DHT22 can replace the low-cost sensors for better accuracy and a longer life.
- A solar panel with a battery can make the system independent of grid power.
- Voice alerts and notifications in regional languages such as Marathi and Hindi can make the application easier for farmers.
- GPS, a camera and machine-learning based crop and fertiliser recommendation can be added for

complete precision farming.

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