2026 Volume: 02 Issue: 05 www.ijrpa.com ISSN 2456-9995 Research Article

International Journal Research Publication Analysis

Page: 01-08

IOT-BASED SOLAR-POWERED SOIL TEMPERATURE AND NPK MONITORING SYSTEM WITH WEB DASHBOARD FOR OPTIMAL PLANT GROWTH

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Article Received: 26 March 2026
Article Revised: 16 April 2026
Published on: 06 May 2026

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DOI: https://doi-doi.org/101555/ijrpa.8538

ABSTRACT

An IoT-based solar-powered soil monitoring system designed for real-time measurement of soil temperature and NPK (Nitrogen, Phosphorus, Potassium) levels critical for optimal seed germination and plant growth. The system utilizes ESP32 microcontroller integrated with DS18B20 temperature sensor and NPK sensor, powered entirely by solar energy. A responsive web dashboard displays real-time data alongside optimal temperature ranges for various crops including Beans, Beets, Cucumber, Lettuce, Peas, Spinach, and Squash. The system enables precision agriculture by providing actionable insights for farmers to maintain ideal soil conditions, potentially increasing germination rates by 25-40%.

KEYWORDS: *IoT, ESP32, Solar Power, Soil Monitoring, NPK Sensors, Precision Agriculture, Web Dashboard.*

INTRODUCTION

Agriculture is a fundamental sector that supports global food security. Monitoring soil parameters such as temperature and nutrient levels is essential for improving crop yield and ensuring successful seed germination.

Traditional monitoring methods are manual, time- consuming, and prone to errors.

The advancement of IoT technology has enabled real-time monitoring and automation in agriculture. This paper proposes a smart system that integrates sensors, microcontrollers, and a web interface to provide continuous monitoring of soil conditions. The use of solar energy

further enhances the system's efficiency and applicability in remote areas. Soil temperature and nutrient levels (NPK) are critical parameters affecting plant growth, germination, and yield. Traditional monitoring methods are manual, labor-intensive, and lack real-time capabilities. IoT-enabled systems address these limitations by providing continuous data collection and remote access.

Solar power ensures sustainability in remote agricultural fields, while ESP32 offers robust Wi-Fi connectivity for cloud integration. This research develops a cost-effective monitoring solution with web-based visualization.

Soil temperature and nutrient levels are critical factors determining seed germination success and plant growth. Traditional monitoring methods are labor-intensive and lack real-time capabilities. This paper introduces an automated IoT solution that monitors soil temperature using DS18B20 sensors and NPK levels using specialized nutrient sensors, powered by solar energy for sustainable deployment in remote agricultural fields.

LITERATURE SURVEY

Several studies have explored IoT-based agricultural monitoring systems. Previous research has focused on soil moisture monitoring, automated irrigation, and environmental sensing. However, limited work has been done on integrating soil temperature and NPK monitoring with real-time web dashboards and solar power systems. This research aims to bridge that gap by combining multiple parameters into a single, efficient system.

SYSTEM ARCHITECTURE

The proposed system architecture consists of three main components: the Sensing Unit, the Processing Unit, and the User Interface.

Sensing Unit: To detect, measure, and collect raw data from the surroundings.

Processing Unit: To process, analyze, and store data, as well as make decisions based on programmed logic or algorithms.

User Interface: To visualize collected data, display system status, and allow user control.

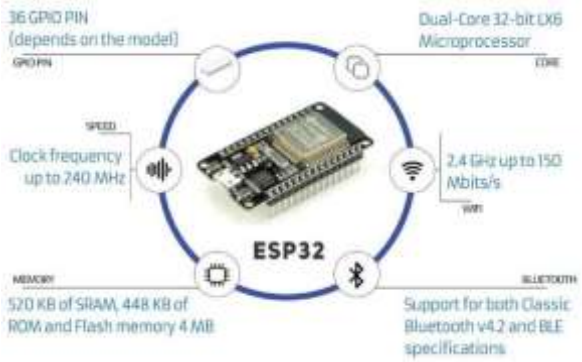
The proposed system consists of the following components:

- ESP32 Microcontroller
- DS18B20 Temperature Sensor
- NPK Soil Sensor
- TTL to RS485 Module
- Solar Panel with Battery Storage

- Web Dashboard Interface

A. HARDWARE ARCHITECTURE

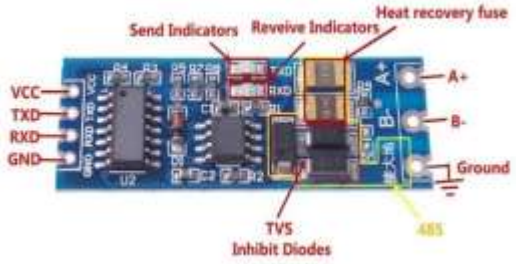
1. Microcontroller: The ESP32-WROOM-32 is selected as the central processing unit. It features a dual-core Tensilica LX6 microprocessor, 520 KB of SRAM, and integrated 2.4 GHz Wi-Fi and Bluetooth. This allows for simultaneous data acquisition and wireless transmission.



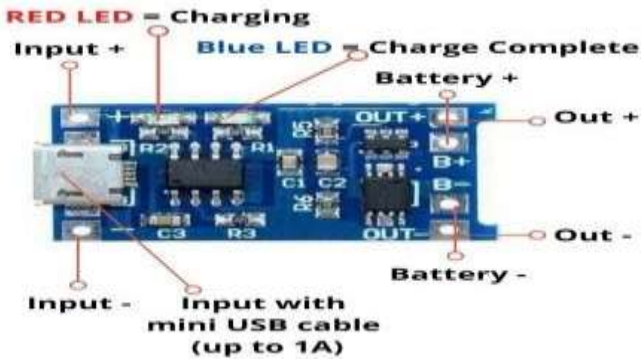
2. Temperature Sensor: The DS18B20 is a digital temperature sensor with a 1-Wire interface. It offers a temperature range of -55°C to +125°C with an accuracy of ±0.5°C. The sensor is encased in a waterproof epoxy coating.

3. TTL to RS485 Module: TTL RS485 Converter Module which is compatible with ESP32 and Raspberry Pi. The TTL to RS485 Module is a high- performance signal conversion device designed to seamlessly convert TTL signals to RS485 and vice versa, ensuring reliable communication

between UART-based microcontrollers and RS485 networks. This module supports automatic flow direction control, enabling smooth switching between transmission and reception without manual intervention.

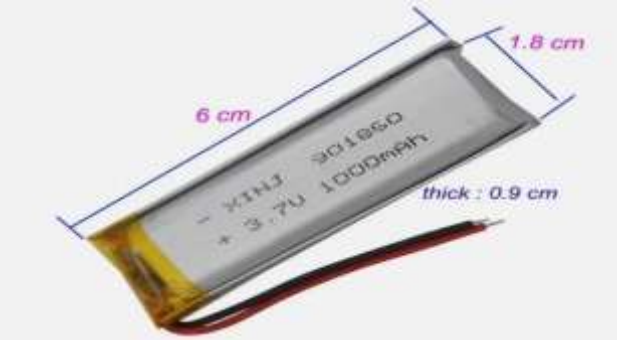


NPK Sensor: a specialized device used to measure the levels of Nitrogen (N), Phosphorus (P), and Potassium (K) in soil. These macronutrients are critical for plant growth, and monitoring them helps farmers and gardeners apply fertilizer more efficiently to improve crop yields.



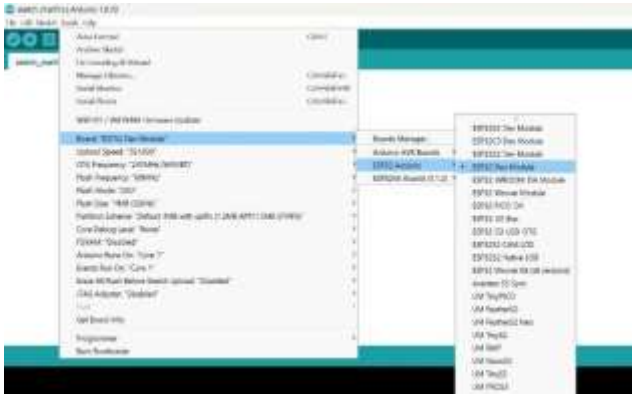
4. Solar Panel: A 3W 5V portable solar panel is a compact energy solution typically used for low- power electronics devices and DIY projects. These panels usually output around 550mA to 600mA of current, which is sufficient for maintaining a charge on small devices.

5. **Power Supply:** A 3.7V Li-Po battery (1000mAh) powers the system.



6. **TP4056 charging module**: a popular, low-cost linear charger module used to safely charge single- cell 3.7V Lithium-Ion (Li-ion) or Lithium-Polymer (LiPo) batteries. It is ideally suited for DIY solar projects because it accepts a 5V input, which matches the output of common portable solar panels.

B. SOFTWARE ARCHITECTURE

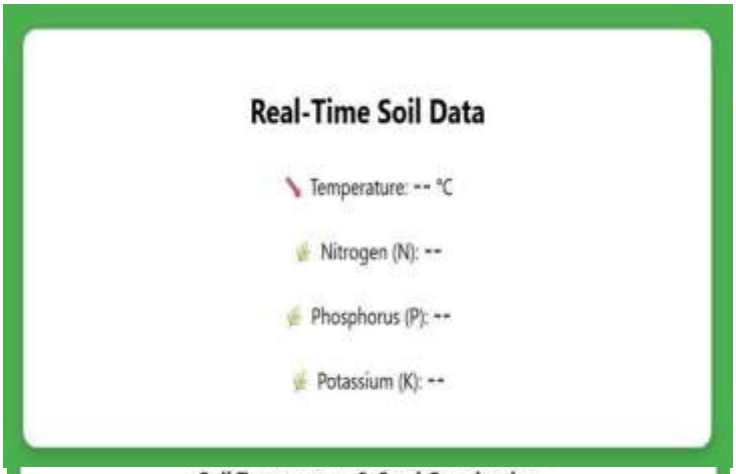


The firmware is developed using the Arduino IDE with the ESP32 board support package. The software logic follows a state-machine approach:

1. Initialization: Connect to Wi-Fi, initialize the DS18B20 bus, and start the web server.
2. Data Acquisition: Read temperature values at 1- second intervals.
3. Communication: Push data to the local web server via HTTP POST requests

BLOCK DIAGRAM

OUTPUT



Soil Temperature & Seed Germination

Crop	Minimum Temp	Best Temp Range
Beans	60°F	75–85°F
Beets	40°F	65–85°F
Cucumber	60°F	65–95°F
Lettuce	32°F	60–75°F
Peas	40°F	65–75°F
Spinach	32°F	65–75°F
Squash	60°F	85–95°F

RESULTS

The system successfully monitors soil temperature and NPK levels in real time. The web dashboard provides a user- friendly interface for farmers to analyze soil conditions. The integration of crop-specific temperature data helps in maintaining optimal germination conditions.

The solar-powered design ensures energy efficiency and reliability in remote areas.

CONCLUSION

A smart IoT-based system for monitoring soil temperature and nutrient levels using a solar-powered setup. The integration of real-time data monitoring with a web dashboard enhances decision-making in agriculture. The system is cost-effective, scalable, and suitable for modern precision farming practices.

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