E-BOOK OF EXTENDED ABSTRACT

THE 14TH INTERNATIONAL INVENTION, INNOVATION & DESIGN COMPETITION 2025

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IoT-DRIVEN SMART HYDROPONICS SYSTEM FOR PRECISION AGRICULTURE

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ABSTRACT

Agriculture faces significant challenges from climate change, urbanisation, and resource depletion, prompting the need for innovative solutions like hydroponics. However, traditional hydroponic systems are often labor-intensive and prone to human error due to the need for constant manual supervision. This paper presents an IoT-driven smart hydroponics system built around the ESP32 microcontroller and integrated with sensors, including a light-dependent resistor (LDR), ultrasonic sensors, a TDS meter, and a temperature sensor. The system continuously monitors key parameters such as light levels, water levels, nutrient concentration, and temperature, sending real-time data to a cloud-based platform. Based on predefined thresholds, the system automatically adjusts water and nutrient levels by controlling pumps, reducing manual intervention and ensuring consistent growing conditions. The prototype was successfully developed and implemented, demonstrating reliable automation of environmental monitoring and control. The results indicate that the system significantly reduces manual effort, improves accuracy in nutrient dosing, and enhances resource efficiency. Moreover, the system is modular and adaptable, making it suitable for integration into any conventional Nutrient Film Technique (NFT) hydroponic system. Future enhancements will include machine learning for adaptive management, expanded remote monitoring capabilities, and the use of renewable energy sources to further improve sustainability and automation.

Keywords: smart hydroponics, IoT, ESP32, automation, sustainability

1. INTRODUCTION

Agriculture plays a crucial role in sustaining human life by providing food security and nutrition. However, the increasing global population and rapid urbanisation have intensified demands on traditional agriculture, necessitating sustainable methods that maximise productivity with minimal resource usage (Ramakrishnan et al., 2023). Hydroponic systems, which cultivate plants in nutrient-enriched water without soil, can reduce water consumption by up to 90% compared to conventional farming while enabling year-round production in limited spaces (Rahman et al., 2024). However, existing implementations often rely on manual adjustment of critical parameters, leading to inefficiencies and potential crop stress (Panigrahi et al., 2021). Recent advances on the Internet of Things (IoT) offer real-time data acquisition and automated control of environmental factors such as water level, nutrient concentration, and temperature (Muhasin et al., 2024). Therefore, this research introduces an innovative IoT-driven smart hydroponics solution tailored specifically for precision agriculture. Utilising advanced ESP32 microcontrollers integrated with sophisticated sensors, the system continuously tracks and precisely manages essential growth parameters such as water level, nutrient concentration, and temperature. This smart technology not only optimises plant growth conditions but also significantly reduces resource wastage and manual labor, making it particularly ideal for urban agriculture settings where space and resource efficiency are crucial.

2. METHODOLOGY

2.1 System Development

The core of smart hydroponics system is the ESP32 microcontroller, which orchestrates all sensing, actuation, and IoT connectivity using Blynk in Figure 1. System development is divided into two key parts: sensor integration and actuator control are shown at Table 1.

Table 1 Input and output of the system.

INPUT		OUTPUT	
Sensor	Integration	Actuator	Control
Digital Light Dependent Resistor (LDR) Sensor	Detects ambient light levels to distinguish between day and night.	**Water Pump A**	Fills the mixing tank when its ultrasonic sensor detects low water.
Ultrasonic Sensor at Mixing Tank	Measures water level in the mixing tank.	**Water Pump B**	Refills the hydroponic tank based on its water-level sensor.
Ultrasonic Sensor at Hydroponic Tank	Measures water level in the hydroponic (growth) tank	**Water Pump C**	Circulates nutrient solution to NFT system
TDS Meter	Reads electrical conductivity to assess nutrient concentration.	**Nutrient Pump A &B**	Dose fertiliser to mix water with A/B Nutrient.
Temperature Sensor	Reads the temperature of the water		

2.2 System Implementation

Implementation follows the sequence in the flowchart system in Figure 1. On power-up, the ESP32 first loads its firmware, connects to Wi-Fi and initialises all sensors (LDR, two ultrasonics, TDS and temperature). It then enters a tight loop in which each sensor is read, its value sent live to the Blynk dashboard and immediately compared against the thresholds in Table 2.

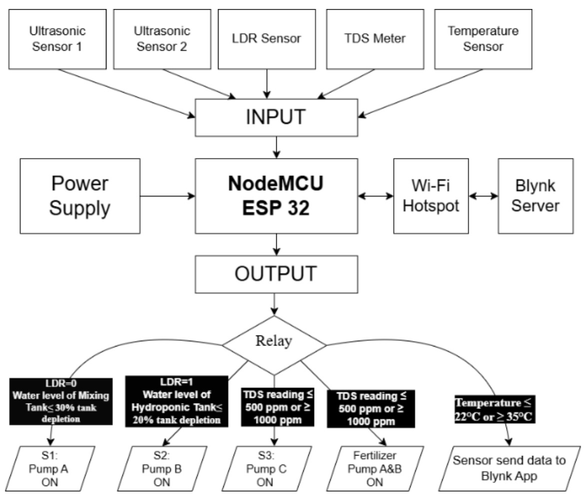
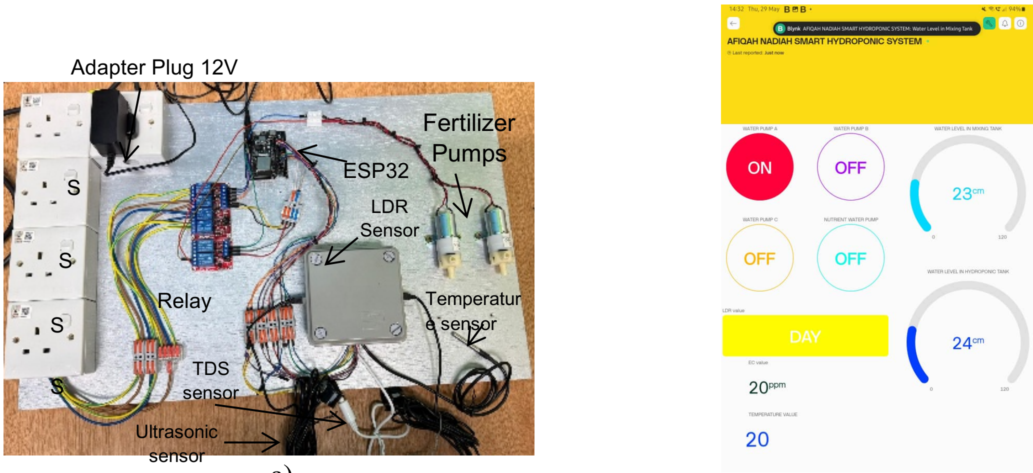


Figure 1 Block Diagram of the system

3. FINDINGS

The system was successfully designed to optimise the growing conditions of hydroponic plants through continuous monitoring and automatic adjustments using Blynk as shown at Figure 2 (a) and (b). Key findings from the integration of sensors and actuators in the system include the effectiveness of real-time data collection, automated responses to environmental changes, and the ease of remote monitoring through the Blynk platform. The system integrates various sensors and actuators to monitor and control the environmental conditions in both the fertiliser mixing and hydroponic tanks, this ensuring optimal growth conditions for the plants. The LDR sensor detects light levels, triggering NFT pumps to turn ON during daytime and to turn OFF at night when light is low. The ultrasonic sensors in the mixing and hydroponic tanks monitor water levels, activating pumps to refill the tanks when the water level drops below 30% and 20%, respectively. The TDS meter measures nutrient concentration, adjusting the nutrient levels by activating A/B fertiliser pumps when the TDS reading is low until optimal levels being achieved. Additionally, the temperature sensor monitors water temperature, sending alerts if it falls below 22°C or exceeds 35°C. All sensor data is monitored and controlled remotely via the Blynk platform, ensuring the plants receive the necessary care and conditions for growth.



a) b)

Figure 2 a) Prototype of the system. b) Blynk Interface.

4. CONCLUSION

The developed IoT-driven smart hydroponics system demonstrates reliable automation of water-level management, nutrient dosing, and temperature monitoring, thereby reducing manual intervention and enhancing resource efficiency. Real-time connectivity via a mobile dashboard enables proactive system oversight, translating sensor data into actionable controls that maintain stable growing conditions. The modular architecture permits scalability across various soilless cultivation methods, positioning this solution as a promising model for sustainable urban agriculture. Future work will explore predictive analytics and renewable energy integration to further reduce environmental impact and support autonomous operation.

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