



Automated Fertigation System For Organic Farming

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Abstract: Organic farming is all about working with nature not against it. But even the most sustainable practices need a little help from technology. This paper explores how automated fertigation systems can make organic farming smarter and more efficient. By combining ESP32 microcontrollers with soil moisture and climate sensors, we've built a system that delivers water and nutrients exactly when crops need them. Real-time feedback is provided through an OLED display and a Blynk dashboard, making it easy for farmers to monitor conditions and control irrigation remotely. Drawing from ten research papers, we highlight how IoT-based fertigation improves water use, reduces manual labour, and supports sustainable agriculture. We also dive into the challenges like affordability, calibration, and power supply and suggest ways to make these systems more accessible to small-scale organic farmers.

Index Terms - Organic farming, Blynk Template, Telegram Bot, automated fertigation, ESP32, soil moisture sensors, IoT irrigation, climate control

1. INTRODUCTION

Organic farming is increasingly recognized as a sustainable agricultural alternative focusing on soil health, biodiversity, and the use of natural inputs while avoiding synthetic chemicals. Despite its benefits, organic farming faces challenges in efficient water and nutrient management, often relying on labour intensive and imprecise manual methods. Automation through embedded systems and IoT technologies offers a promising solution to these challenges by enabling precise fertigation the combined application of irrigation and fertilization tailored to real-time soil and climate conditions. This paper presents a low-cost, practical fertigation system based on the ESP32 microcontroller, integrating soil moisture and environmental sensors with remote monitoring via an OLED display and a mobile app dashboard. By reviewing existing technologies and identifying gaps, the proposed system aims to enhance resource efficiency, labour savings, and sustainability tailored specifically to the needs of organic farms.

2. LITERATURE REVIEW

A growing corpus of research has tackled automated irrigation and fertigation, with escalating sophistication in system design, sensor integration, and analytic decision support:

2.1 Advances in Wireless Drip Irrigation

[1] Meri et al. engineered a wireless sensor network for drip irrigation, instrumenting fields with distributed nodes to monitor soil moisture, flow rate, and line pressure. Automated valve actuation based on sensor thresholds produced responsive, closed-loop irrigation cycles. While water use efficiency leapt upward, practical challenges in calibration, signal interference, and field environment variability (soil texture, topography, sensor fouling) were noted as constraints on real-world deployment.

2.2 IoT-based Sensor Scheduling

[2] Abdelmoneim et al. compared soil-moisture-driven IoT scheduling with traditional weather-based models in commercial crops. Results were striking: IoT systems provided up to 28.8% water savings and 52.5% productivity gains. However, sensitivity of low-cost sensors to salinity, connectivity interruptions, and battery reliability remain limiting factors. The authors advocate for hybrid models, combining direct soil feedback with weather forecasts and redundancy.

2.3 Economic and Social Integration

[3] Shroff & Miglani in Indian micro irrigation programs underscored the importance of government subsidy, technical training, and ongoing support in enabling low-resource farmers to adopt smart solutions. While technological efficacy is established, social and financial inclusion remain essential.

2.4 Precision, Adaptive, and Multi-Sensor Approaches

Works by [4] Li and [5] Tornese et al. focus on nutrient management, multi-sensor integration, and AI-based analytics, emphasizing the need for flexible, crop-stage-specific scheduling. Challenges identified include data interpretation complexity, sensor drift, and field ruggedization. Their proposals validate the platform's approach of combining robust logic with modular sensor hardware and updatable firmware.

2.5 Climate Change and Data Gaps

Adaptation to climate variability is another driver for smart fertigation systems. [6] Kandula & Umamahesh and [7] Singh et al. demonstrate that crop models and ML-enhanced sensing are needed for climate-resilient scheduling, yet these introduce requirements for more intensive local calibration, retraining, and data management protocols.

2.6 Practical System Deployments

[8] Sivakumar et al. and [9] Abdelzaher et al. reveal in-field limitations corrosion, electronic failures, environmental exposure, and failed network links pointing to the need for simple, protective system designs, as well as multilingual, accessible dashboards and maintenance documentation.

2.7 Organic Fertilizer and Crop-Stage Optimization

Recent studies on micronutrient application in organic cotton have shown that targeted, dosed application timed to growth phases significantly improves yield and fiber quality, while overuse can damage long-term soil biology. Proper scheduling, system logging, and feedback integration are essential for compliance and operational optimization

3. SYSTEM DESIGN AND IMPLEMENTATION

The Automated Fertigation System designed for organic farming uses the ESP32 microcontroller as the central control unit due to its powerful processing capabilities, built-in Wi-Fi, and flexible GPIO pins. The design integrates several key components to monitor environmental conditions and automate nutrient and water delivery.

3.1. Block Diagram :

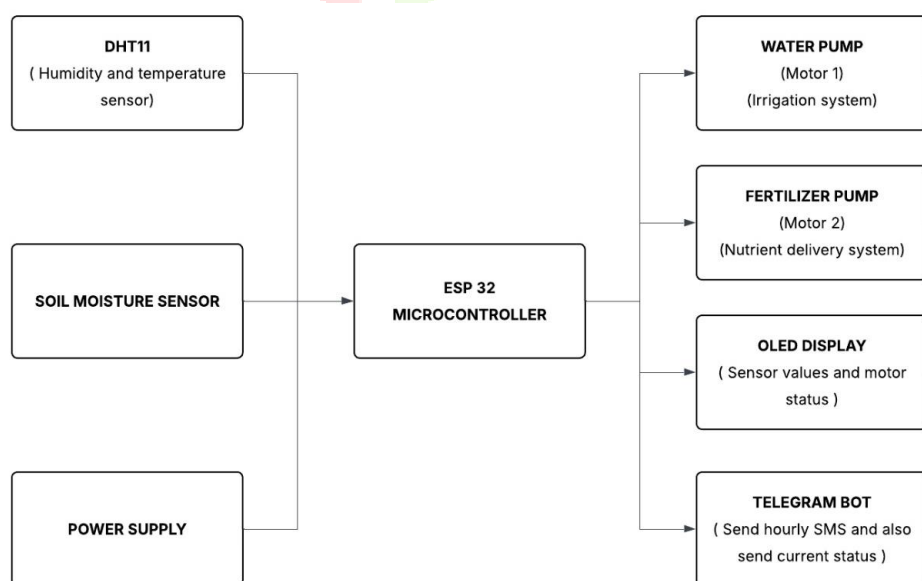


Figure 1 . Block Diagram of automated fertigation system .

3.2. Hardware Components:

1. The ESP32 microcontroller interfaces with soil moisture and climate sensors to gather real-time data.
2. A soil moisture sensor is connected to analog input GPIO pins on the ESP32 to continuously monitor soil water content.
3. A DHT11 sensor measures ambient temperature and humidity, offering climate condition inputs.
4. Two channel relays are connected to ESP32 GPIO pins to control water pumps and nutrient dosing pumps (motors).
5. Power is supplied via a 9V battery connected through relay contacts to pumps, ensuring controlled activation.
6. An OLED display is included to show live sensor readings and motor status locally.

3.3. Connections:

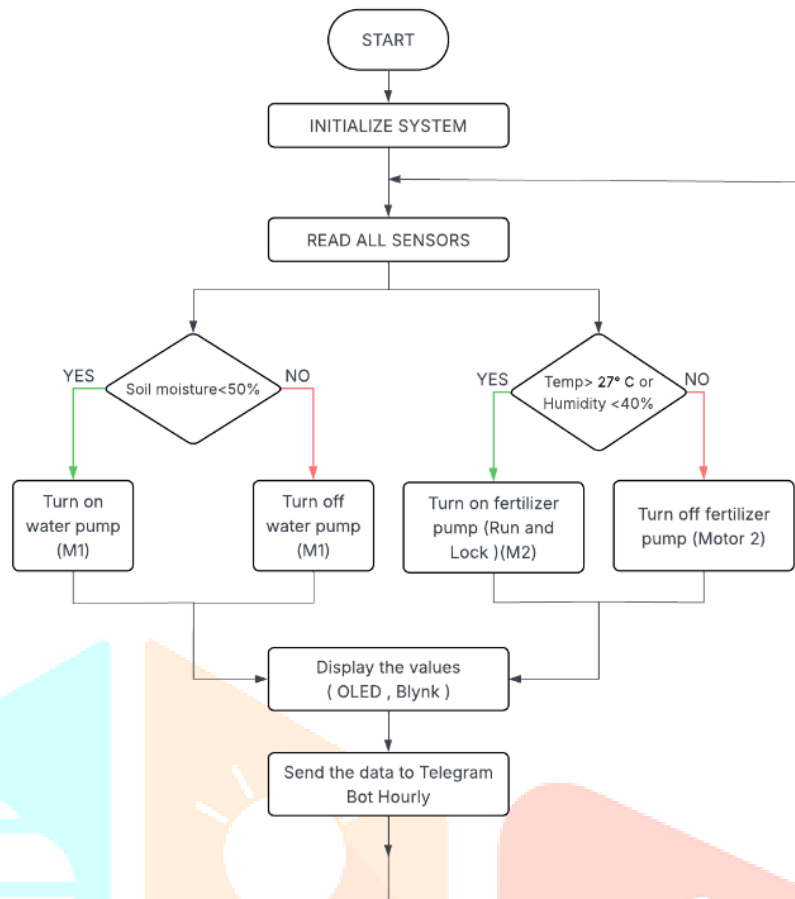
1. Soil moisture sensor VCC and GND are connected to ESP32 Vin and GND pins; analog output is connected to GPIO34.
2. DHT11 sensor data pin connects to GPIO5.
3. Relay module VCC and GND connect to ESP32 3.3V and GND; relay inputs are connected to GPIO pins controlling two pumps.

3.4. Software Components:

1. The ESP32 is programmed using the Arduino IDE, employing libraries for sensor reading, relay control, and Wi-Fi communication.
2. The system uses threshold-based logic: if soil moisture falls below a set limit, the water pump activates; if temperature or humidity cross thresholds, nutrient pump activates.
3. Real-time data and control interfaces are provided via the Blynk mobile app, allowing remote monitoring and operation.
4. A Telegram bot is integrated to send hourly updates and receive user commands for system control.

3.5. Operational Flow:

1. Sensors continuously provide environmental data to ESP32.
2. The microcontroller processes data and compares readings against predefined thresholds.
3. Upon threshold breaches, corresponding relays activate pumps to supply water or nutrients as needed.



4. Local OLED display provides instant feedback; remote platforms offer convenient access.

Figure 2. Operational flow chart for automated fertigation system

3.6. Power and Reliability:

1. The system is designed to consume low power for off-grid and rural applications.
2. Battery monitoring and power optimization techniques ensure reliability.
3. Future improvements include solar power integration for energy autonomy.

3.6. Modularity and Scalability:

1. The design supports easy addition of components like nutrient dosing modules and extra environmental sensors.
2. Suitable for small to medium farms and adaptable to multi-zone setups.

This integrated hardware-software design achieves precise, efficient automated fertigation tailored to organic farming needs, maximizing resource use while reducing labor and manual intervention. The inclusion of IoT capabilities and user-friendly interfaces enhances accessibility and remote management for farmers.

4. RESULTS

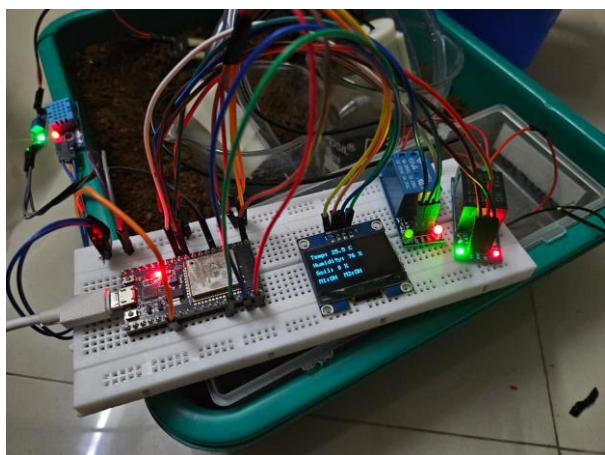


Figure 3 . Motor 1 and 2 turned ON based on the sensor values (Temp: 25.4 C , Humidity : 76% ,Soil moisture :0%)

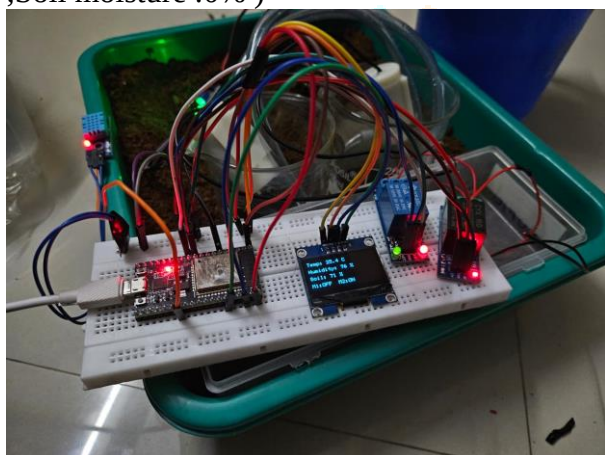


Figure 4 . Motor 1 turned OFF and Motor 2 turned ON based on the sensor values

The automated fertigation system using the ESP32 microcontroller with soil moisture and climate sensors demonstrated effective real-time control of irrigation and nutrient delivery in organic farming. The system maintained optimal soil moisture levels by activating water pumps based on sensor thresholds, leading to significant water conservation. Remote monitoring through an OLED display, Blynk app, and Telegram bot provided farmers with timely data and control, improving operational convenience and decision making. The system reduced manual labour efforts and minimized resource wastage by precisely applying water and nutrients only as needed. Testing under varied environmental conditions confirmed system reliability and adaptability for small-to-medium scale organic farms. The modular design supports future feature expansions like automated nutrient dosing and solar power integration.

5. CONCLUSION AND FUTURE SCOPE

Automated fertigation systems hold immense potential to transform organic farming. By integrating ESP32 microcontrollers, environmental sensors, and real-time dashboards, farmers can manage irrigation and nutrient delivery with precision. This not only saves time, water, and effort but also ensures that crops receive exactly what they need for healthy growth.

However, several challenges remain before such systems can be widely adopted. Cost is a major barrier, as many existing solutions are too expensive for small and marginal farms. Compliance is another concern, since automation must align with organic farming standards to maintain certification and trust. Power availability also poses difficulties, particularly for off-grid farms that require reliable battery or solar-based options. Finally, usability is critical interfaces must be simple, multilingual, and farmer-friendly to ensure accessibility for diverse users.

Looking ahead, there are several promising directions for development. Building crop-specific logic with the help of AI can make fertigation more adaptive and efficient. Incorporating solar modules will provide



Figure 5. Real-time farm status updates received via Telegram bot.

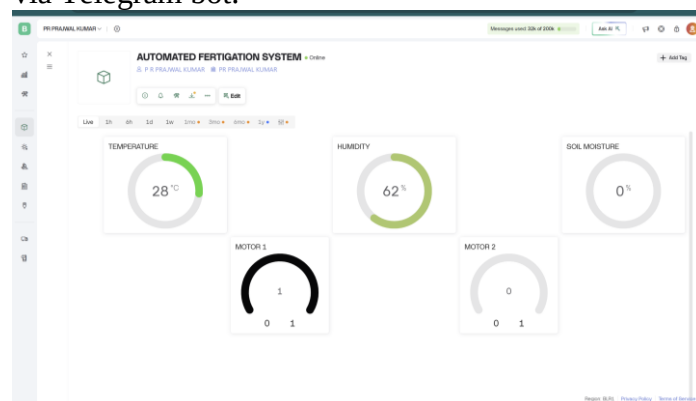


Figure 6 . Real-time irrigation system monitoring on the Blynk dashboard.

energy independence, especially for remote farms. Designing plug-and-play kits can simplify setup and maintenance, making the technology approachable even for farmers with limited technical expertise. Collaborations with universities and NGOs can further support training and knowledge transfer, ensuring that farmers are equipped to use these systems effectively. Expanding dashboards with historical data and smart alerts will also empower farmers to make informed, data-driven decisions.

With the right tools, partnerships, and support, smart farming technologies can be made accessible to every farmer especially those committed to organic cultivation. This vision of affordable, sustainable, and farmer-friendly automation has the power to reshape agriculture for the better.

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