Performance and Resource Efficiency Evaluation of an Automated Solar-Powered IoT-Based Irrigation and Nutrient Management System for Small-Scale Vertical Urban Farming

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Urbanization reduces agricultural land, increasing food demand and creating a need for practical approaches to urban agriculture. One promising approach is vertical farming, which allows crops to be grown in limited space, but small-scale systems still require careful management. Frequent monitoring and manual intervention can also make system operation demanding. It is creating a need for approaches to urban agriculture. Vertical farming offers a way to grow crops in limited spaces, although systems still require management. Monitoring and manual intervention can make the operation demanding.

To address these concerns, a prototype integrates Arduino-based sensors, irrigation and nutrient regulation, Internet of Things (IoT) monitoring, solar energy, and rainwater harvesting into a vertical farming system. This study evaluates its performance, resource efficiency, monitoring capability, and sustainability under urban farming conditions.

The system uses soil moisture, temperature, humidity, and nutrient sensors connected to an Arduino-based control system and IoT platform. Pumps and solenoid valves regulate water and nutrient delivery based on predefined sensor thresholds, while a solar-powered subsystem provides energy. Rainwater harvesting serves as an alternative water source. Results indicate that soil moisture was maintained within 30%–45%, while nutrient concentration remained within approximately 800–1,200 ppm. Water consumption ranged from 2.5 to 3.5 liters, allowing the 25-liter tank to support an estimated 7–10 days of operation.

The IoT platform enabled monitoring, while the solar subsystem demonstrated a charging time of 150–240 minutes and a discharge duration of 300–330 minutes. The findings highlight the system’s potential and opportunities for improvement.

Keywords: Vertical Urban Farming, Rainwater Harvesting, Automated Irrigation, Nutrient Regulation, Sustainable Agriculture