AUTOMATED HYDROPONIC FARMING SYSTEM USING NUTRIENT FILM TECHNIQUE

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ABSTRACT

This study addresses the challenge of designing an automated hydroponic system utilizing the Nutrient Film Technique (NFT) to optimize lettuce growth. Conducted during the academic year 2022-2023 in Barangay Lower Katingawan, the research involved fifteen participants, including hydroponic farmers, local farmers, government employees, and future developers from various barangays in Midsayap.

The Automated Hydroponic Farming System integrates automation and IoT technologies to reduce manual workload by regulating critical environmental factors. Key features include temperature monitoring (mean: 3.89), humidity control (mean: 3.77), pH management (mean: 3.80), TDS monitoring (mean: 3.85), automatic water pump timer (mean: 3.91), light indicators and alarms (mean: 3.92), and real-time SMS updates (mean: 3.95). These features ensure precise control over the growing environment, enhancing plant health and productivity.

Results demonstrate the system's efficiency, reliability, and sustainability. The project reduces farmer workload, supports sustainable crop production, and promotes water savings and year-round yields. Specifically, the system's temperature, humidity, and pH monitoring capabilities received high approval ratings, indicating their effectiveness in maintaining optimal growing conditions. Automating the water pump and integrating light indicators and SMS updates further enhance operational efficiency and user convenience.

The novelty of the proposed work lies in the comprehensive integration of environmental and nutrient monitoring features with real-time data transmission and remote alerts, offering a significant advancement in hydroponic farming practices. This innovative approach not only addresses existing challenges but also provides a scalable solution that can be adopted by current and future hydroponic farmers, with potential support from the government to enhance food security amid population growth and climate change.

KEYWORDS

Automated Hydroponic System, Nutrient Film Technique, IoT, Sustainable Agriculture, DHT1 sensor

1. INTRODUCTION

1.1. Background of the Study

Global food shortages are becoming increasingly critical due to rapid population growth, climate change, resource depletion, and land fragmentation. With the world's population projected to reach nearly 10 billion by 2050 [1], food production systems face immense pressure. Climate change exacerbates these challenges by altering weather patterns and reducing crop yields.

Additionally, land fragmentation—where agricultural land is divided into smaller, less productive plots—complicates efficient food production and resource management. Whereas, traditional farming practices further contribute to environmental degradation and resource exhaustion, underscoring the urgent need for sustainable food production methods [2].

In the Philippines, agrarian reform has significantly altered land ownership and distribution, leading to unintended consequences such as declining local food production. As farmlands become fragmented, individual farmers are left with small parcels of land, negatively impacting economies of scale, efficiency, and agricultural productivity [3].

Hydroponic farming presents a promising solution to these challenges. This innovative method, which grows plants without soil using water-based nutrient solutions, optimizes resource use and minimizes environmental impact. Hydroponics allows for year-round crop production regardless of external climate conditions and can mitigate issues related to extreme weather, water scarcity, and temperature fluctuations [4].

In Midsayap, hydroponic farming is still uncommon, with residents primarily engaging in it as a hobby rather than a mainstream practice. Those who have adopted hydroponics face challenges in monitoring plant growth, including maintaining optimal temperature, humidity, and nutrient levels. To address these issues, the project proposes the development of a Hydroponic Farming System Using Nutrient Film Technique. This system includes SMS updates, timers, water pumps, temperature and humidity sensors, pH level sensors, TDS meters, and light indicators.

The study aims to simplify plant growth monitoring, enhance productivity, and reduce manual labor, ultimately contributing to the region's improved food security and sustainable agricultural development.

1.2. Objectives

The project proponents aimed to design an “Automated Hydroponic Farming System using Nutrient Film Technique”. The primary objectives of the research are:

1. **Design and Implementation**: To design and implement a hydroponic farming system utilizing the Nutrient Film Technique (NFT) that integrates automated features for efficient plant growth management.
2. **Environmental Monitoring**: To monitor environmental conditions, including humidity and temperature, using a DHT11 sensor, ensuring optimal growth conditions for the plants.
3. **Water Quality Monitoring**: To assess and maintain water quality by measuring the pH level (alkalinity or acidity) using a pH sensor and monitoring the total dissolved solids (TDS) in the water using a TDS meter.
4. **Automation**: To automate the water pump operation with a timer, facilitating efficient and consistent water delivery to the plants.
5. **User Alerts**: To provide real-time alerts to users through a light indicator and alarm system in case of deviations from optimal conditions.
6. **Remote Updates**: To enable remote updates and notifications via Short Message Service (SMS), allowing users to receive important information and alerts regarding system performance and plant health.

1.3. Conceptual Framework

Figure 1 presents the independent, intervening, and dependent variables considered in the study. The Independent Variables in this project considered the problems encountered by hydroponic and traditional farmers regarding excessive human labor. The Intervening Variable is the solution to the stated Independent Variables. The Dependent Variables are the results of the system designed to solve the problem. This figure emphasizes the relationship between the variables used in the study.

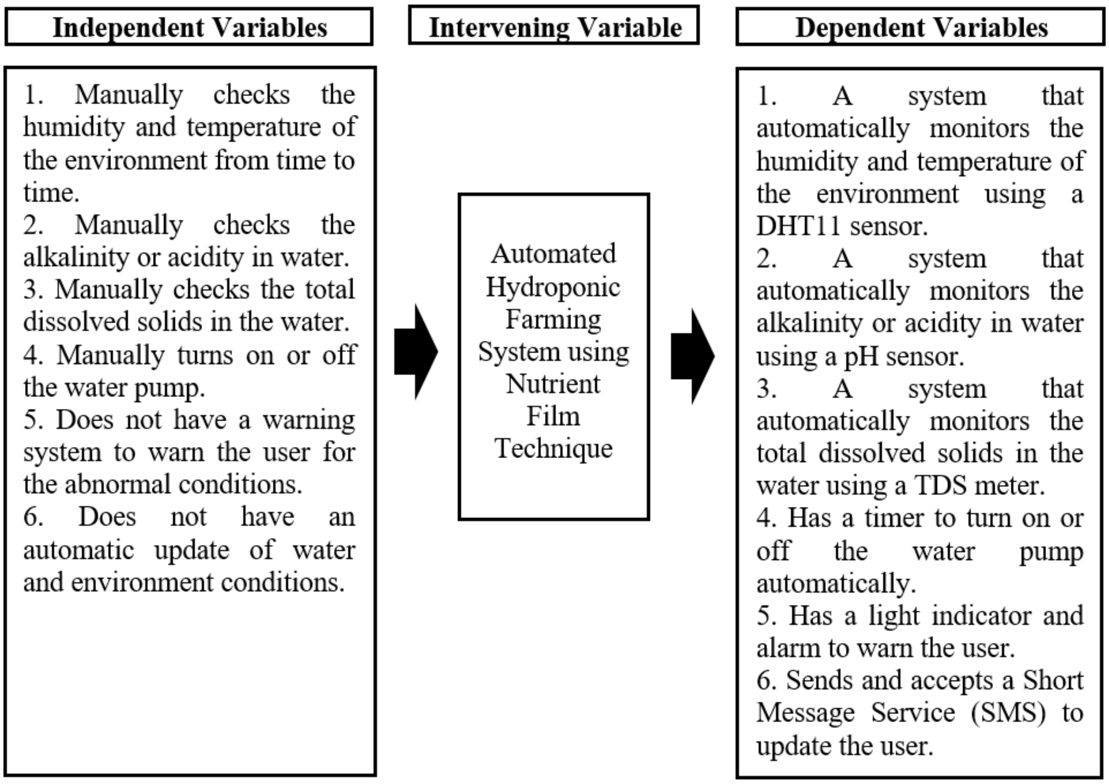

Figure 1. Conceptual Framework of the Study

2. RELATED WORKS

2.1. Environmental Control

Recent studies emphasize the critical role of environmental control in hydroponic systems. Specifically, precise temperature and humidity monitoring using sensors like the DHT11 is crucial for maintaining optimal plant growth conditions. For example, high humidity can lead to diseases and stunted growth, whereas low humidity can negatively impact plant transpiration and overall growth [5]. In addition, accurate pH measurement is vital as it affects nutrient availability; different crops have specific pH requirements, with lettuce thriving at pH 6.0 to 7.0 and tomatoes preferring pH 6.0 to 6.5 [6]. Moreover, Total Dissolved Solids (TDS) measurements are equally important because they indicate the concentration of essential nutrients in the water, directly impacting plant health and growth [7].

2.2. Automated Hydroponic Systems

Automation represents a significant advancement in hydroponics, improving efficiency and resource management. In particular, automated systems can reduce water usage by up to 90% compared to traditional soil-based methods, thereby highlighting their potential for sustainable agriculture [8]. Furthermore, automation enhances efficiency and simplifies the management of hydroponic systems, making them more accessible and effective. For example, research by Savvas and Passam (2003) demonstrates that automation in hydroponics significantly lowers water consumption while improving nutrient delivery [9]. Similarly, the study by Zhang et al. (2020) reveals that automated hydroponic systems enhance operational efficiency and resource use, thus supporting their role in sustainable farming practices [10]. Moreover, research by Giuffrida et al. (2021) underscores that automation helps streamline system management, leading to increased productivity and reduced manual labor [11].

2.3. Nutrient Film Technique (NFT)

The Nutrient Film Technique (NFT) is favored for its efficiency in nutrient delivery and simplicity. Specifically, NFT systems provide a continuous flow of nutrient solution, ensuring that plants receive essential nutrients while allowing their roots to access oxygen from the air. As a result, this method is particularly effective for growing leafy greens and herbs, offering rapid growth rates and high yields [12]. Research by Jones (2005) confirms that NFT systems are highly efficient for these crops due to their optimal nutrient delivery and oxygenation [13]. Similarly, a study by Resh (2012) supports the effectiveness of NFT in producing high-quality, high-yield crops with minimal resource use [14]. Nevertheless, NFT requires precise control of nutrient concentrations and flow rates, which makes automation a crucial component in preventing nutrient imbalances [15]. Further, Savvas et al. (2013) highlight that automation in NFT systems helps maintain the stability of nutrient levels, ensure consistent plant growth, and avoid deficiencies or excesses [16].

2.4. Nutrient Management

Effective nutrient management is essential for hydroponic success. In particular, integrated with pH and electrical conductivity (EC) sensors, automated nutrient dosing systems help maintain optimal nutrient levels and improve plant growth. Consequently, these systems ensure that nutrient solutions are adjusted in real time to meet plant needs, enhancing nutrient uptake and overall productivity [17]. Moreover, research by Savvas and Mitrakos (2012) demonstrates that precise nutrient management through automation can significantly boost crop yields and quality [18]. Additionally, the study by Heuvelink (2005) emphasizes that automation in nutrient dosing improves nutrient use efficiency and reduces waste [19].

2.5. Technological Integration

The integration of advanced technologies has notably transformed hydroponic farming. In particular, solutions such as the Internet of Things (IoT) and microcontrollers like the ESP32 have significantly enhanced the field. These technologies facilitate remote monitoring and control, thus providing real-time data and enabling informed decision-making. For instance, research has demonstrated the benefits of IoT-based systems in improving the efficiency and effectiveness of hydroponic operations [20]. Moreover, the study by Pantelidis et al. (2019) highlights how IoT solutions contribute to better resource management and optimized growing conditions in hydroponics [21]. Similarly, Zhao et al. (2021) confirm that integrating microcontrollers with IoT allows for precise control and monitoring, enhancing overall system performance and plant growth [22]. Furthermore, Wang et al. (2020) emphasize that such technological advancements not only improve operational efficiency but also provide valuable insights for managing hydroponic systems more effectively [23].

2.6. Addressing Gaps and Contributions

While the literature underscores these critical aspects, some key points were previously overlooked. This study addresses these gaps by incorporating comprehensive environmental and nutrient monitoring features into the hydroponic system, including real-time data integration and remote alerts. By leveraging automation and advanced technologies, this research contributes to improved hydroponic practices, addressing challenges related to nutrient management and environmental control, and promoting sustainable agricultural development. This enhanced focus on automation and technological integration represents a significant advancement in hydroponic farming, offering valuable insights and solutions to existing challenges.

3. RESEARCH DESIGN

In this study, the proponents employ an applied research approach to address the practical challenge of designing an automated hydroponic system. The experimental site extends both the respondents' existing greenhouses and the proponents' own greenhouse in Barangay Lower Katingawan during the academic year 2022-2023. The proponents strategically sampled fifteen (15) participants, including hydroponic farmers, local farmers, local government employees, and future developers from various barangays in Midsayap.

The heart of the project lies in the development process. The proponents meticulously crafted the Automated Hydroponic Farming System by integrating automation and IoT technologies. Along the way, the proponents encountered milestones and overcame challenges to optimize lettuce plant growth.

Data collection involved a questionnaire with a Likert scale, capturing feedback on system features and functionalities. Participants received an overview and witnessed a brief demonstration. Their responses, collected via survey forms, form the basis for analysis.

Descriptive statistics, including mean and frequency distribution, guide the interpretation. The Likert scale allows the proponents to gauge responses from "Strongly Agree" to "Strongly Disagree." The consistency of participants' evaluations was assessed by calculating the standard deviation.

In summary, the research design combines theory and practical implementation, paving the way for an innovative hydroponic solution.

4. PROJECT DEVELOPMENT

4.1. Block Diagram

Figure 2 shows the flow of the developed project. The design project has a solar panel and solar battery that power the microcontroller in panels A and B. The microcontroller then sends signals to all the components used in the system, including sensors, displays, motors, and other devices. In panel A, the alarm and LED indicators are activated, and an SMS update is sent via the GSM module if the pH sensor, TDS sensor, humidity and temperature sensor, and water temperature sensor send an output signal to the ESP32 microcontroller that falls short or exceeds the threshold. The button is used to enter a command, and the RTC sends real-time monitoring to the ESP32 microcontroller, which is displayed on the LCD. The real-time clock in panel B sends a signal to the microcontroller for real-time monitoring. The button is used to customize the panel's operation. When the time comes to turn on and off the water pump, the microcontroller sends a signal to the water pump relay, which controls the water flow.

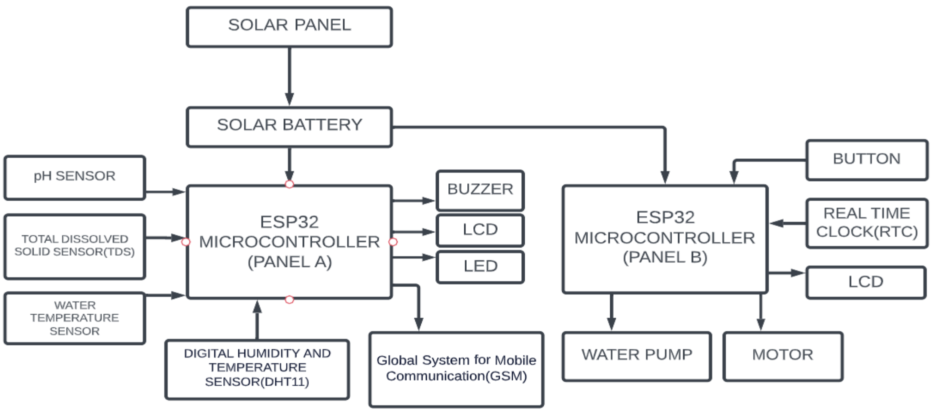

Figure 2. Block Diagram

4.2. Schematic Diagram

Figure 3 shows the schematic diagram of Control Panel A of the Automated Hydroponic Farming System using Nutrient Film Technique. It shows all of the system's components and how they are linked. The system's brain is the ESP32 microcontroller. The microcontroller is connected to the DHT11 sensors, which monitor the ambient temperature and humidity. The pH sensor monitors the pH level of the water. The TDS meter monitors the total dissolved solids in water. The water temperature monitors the temperature of the water. The LCD displays the readings of the sensors and other components, the LED lights and buzzer, which alarms the person in the area, the GSM module, which sends SMS, and the ultrasonic module, which monitors the water level.

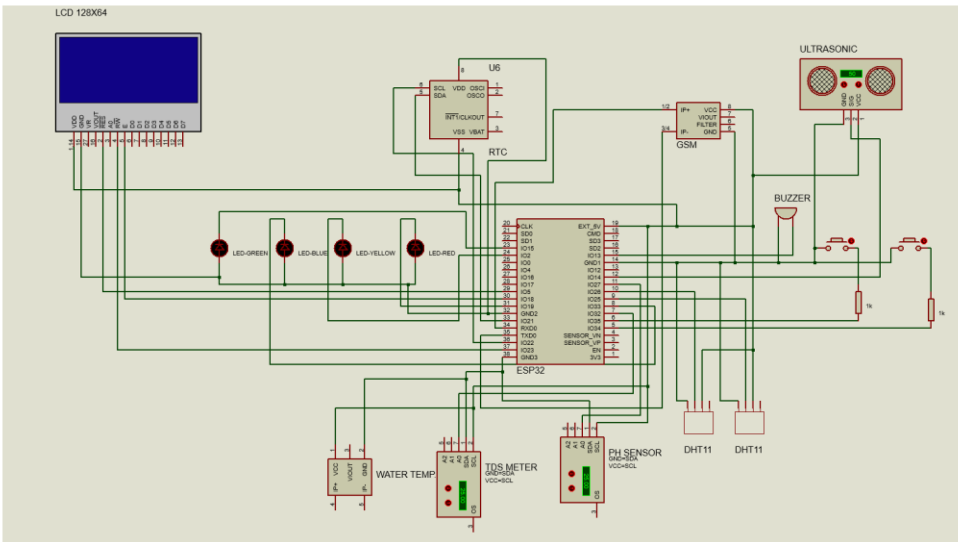

Figure 3. Schematic Diagram of Control Panel A

Figure 4 shows the schematic diagram of Control Panel B of the Automated Hydroponic Farming System using Nutrient Film Technique. It shows that all components are connected to the ESP32 microcontroller, including the LCD display, RTC module to keep track of the current time, button switch for the forward and reverse of the wiper motor, relays, wiper motor for the opening and closing of net shade, water pump, and push button switches.

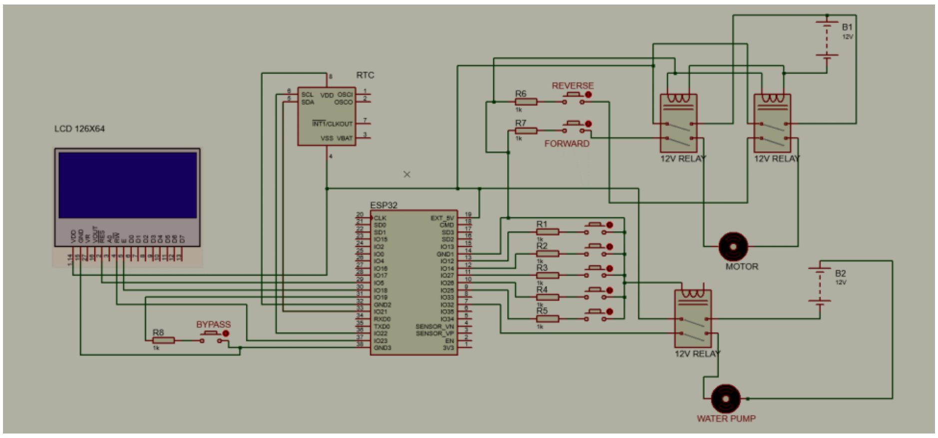

Figure 4. Schematic Diagram of Control Panel B

4.3. Wiring Diagram

Figure 5 shows the wiring diagram of Control Panel A of the Automated Hydroponic Farming System using Nutrient Film Technique. It shows all components, including an LCD, buzzer, ultrasonic module, RTC module, pH sensor, TDS meter, DHT11 sensors, water temperature sensor, LED lights, GSM module, push buttons, and their interconnections. It also demonstrates that the ESP32 microcontroller is the system's brain, where all components are connected and programmed to perform their respective functions.

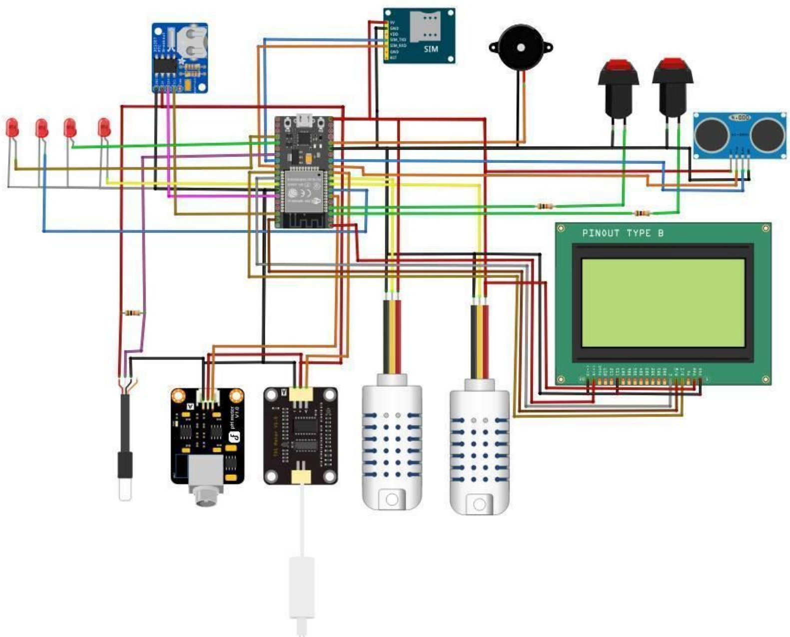

Figure 5 Wiring Diagram of Control Panel A

Figure 6 shows the wiring diagram of Control Panel B of the Automated Hydroponic Farming System using Nutrient Film Technique. The components that make up the system include a servo motor, LCD, RTC module, relays, push buttons, water pump, wiper motor, and power supplies. All of these components are connected using wiring connections. The ESP32 microcontroller is used as the system's brain, controlling all of the components in the system. The ESP32 microcontroller is programmed to control the various components according to their functions.

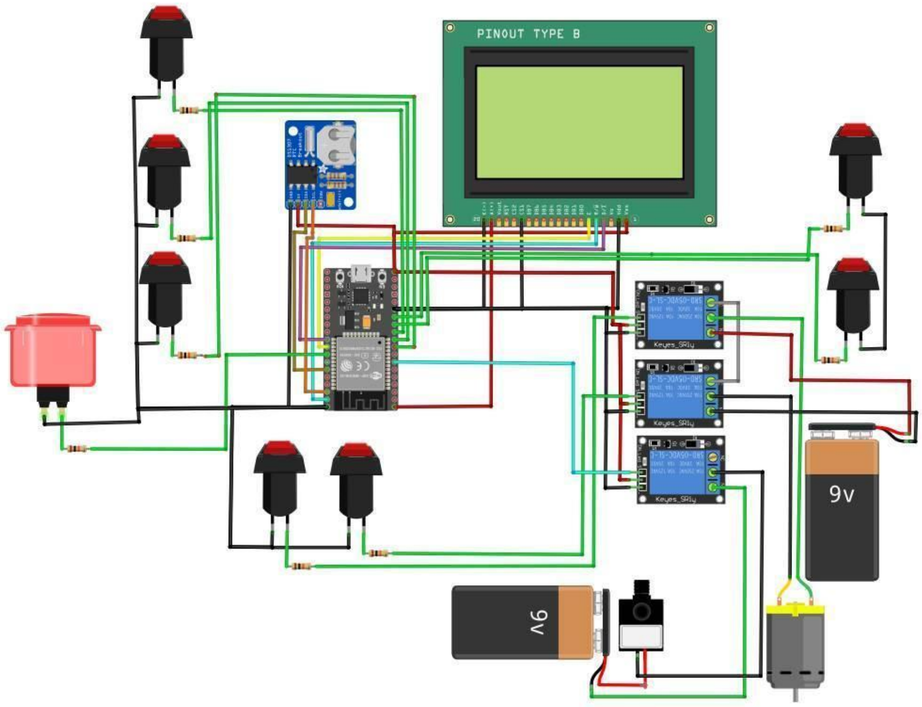

Figure 6. Wiring Diagram of Control Panel B

4.4. Main Materials Used

DHT11 Sensor. In this study, the DHT11 sensor measures the environment's temperature and humidity, ensuring the plants remain within their safe humidity and temperature range. The DHT11 is a popular temperature and humidity sensor featuring a dedicated NTC thermistor to measure temperature and an 8-bit microcontroller to output temperature and humidity values as serial data.

ESP32 Microcontroller. The ESP32 microcontroller serves as the brain for this system due to its low power consumption, support for multiple programming languages, and compatibility with a wide range of development boards. The ESP32 is an embedded module that supports both Wi-Fi and Bluetooth (dual-mode) connectivity, making it ideal for cloud-based IoT projects.

GSM Module SIM800L. This system utilizes the GSM Module SIM800L for communication between the system and the receiver. The SIM800L is a miniature cellular GSM modem from Simcom that easily interfaces with any microcontroller, providing GSM functionality and GPRS transmission.

PH Sensor. In this study, the pH sensor measures the acidity of different nutrient solutions for plants and tests water quality. A pH sensor detects the concentration of hydrogen ions in a solution and converts it into a usable output signal.

Real-Time Clock (RTC) Module. The RTC module tracks the current time and date, allowing the water pump to turn on or off at predetermined intervals. The RTC module is an integrated circuit clock commonly found in modern computers, servers, and embedded systems.

Submersible Water Pump. This hydroponic system employs a submersible water pump to distribute the nutrient solution throughout the entire setup. A submersible water pump operates completely submerged in water, pushing the water to the surface rather than pulling it.

TDS (Total Dissolved Solids) Meter. The TDS module with a probe monitors the total dissolved solids in the nutrient solution. The TDS meter measures water's electrical conductivity (EC) in parts per million (ppm).

Ultrasonic Sensor. An ultrasonic sensor module checks the water level inside the plastic container. An ultrasonic sensor uses ultrasonic waves to measure distance.

5. Limitations

The study has several limitations. The scope was limited to a small geographical area and a single crop type, which may affect the generalizability of the findings. Additionally, the system's reliance on stable internet connectivity for real-time updates could be a constraint in areas with poor network infrastructure. The initial cost of setting up the automated system might also be a barrier for small-scale farmers.

Future research should focus on expanding the system to support multiple crop types and testing it in diverse geographical locations to validate its broader applicability. Investigating alternative communication technologies, such as low-power wide-area networks (LPWAN), could enhance system reliability in areas with limited connectivity. Additionally, exploring cost-reduction strategies and assessing long-term economic benefits will be crucial in making the technology more accessible to small-scale farmers.

6. Results and Discussion

This chapter presents the survey results conducted to evaluate the effectiveness of the system being developed. It also discusses the highest and lowest mean and its implications. Four (4) point Likert Scale was used in evaluating the design project. The Scale is presented below:

Scale	Range	Description
4	3.26 – 4.00	Strongly Agree
3	2.51 – 3.25	Agree
2	1.76 – 2.50	Disagree
1	1.00 – 1.75	Strongly Disagree

Temperature Monitoring: The system's temperature monitoring using a DHT11 sensor was highly effective, receiving a strong agreement (mean: 3.89). This ensures precise environmental control within the hydroponic setup, optimizing plant growth and overall system performance.

Humidity Monitoring: The humidity monitoring feature also received strong agreement (mean: 3.77). Reliable humidity monitoring ensures optimal growing conditions for hydroponic crops, promoting healthy plant growth through consistent humidity levels.

pH Monitoring: The pH sensor's effectiveness in monitoring water acidity/alkalinity was strongly agreed upon (mean: 3.80), ensuring precise control over nutrient availability. The system's ability to accurately display pH level readings was slightly lower (mean: 3.60), but still rated as strongly agreeable.

Total Dissolved Solids (TDS) Monitoring: The TDS meter's monitoring effectiveness was strongly agreed upon (mean: 3.85), ensuring water quality control in hydroponics. This allows users to manage nutrient concentrations confidently, preventing imbalances and optimizing plant growth.

Automatic Water Pump Timer: The automatic timer for the water pump received strong agreement (mean: 3.91), enhancing efficiency and reliability in hydroponic farming. Users can rely on precise timing for nutrient delivery and irrigation.

Light Indicator and Alarm: The system's light indicator and alarm features received strong agreement (mean: 3.92), playing a crucial role in user awareness and system maintenance. This allows users to respond promptly to alerts, preventing potential issues.

SMS Updates: The SMS functionality for real-time updates received the highest mean (3.95), ensuring seamless communication with users. This empowers users to monitor the hydroponic system remotely and take timely actions.

7. CONCLUSIONS

The Automated Hydroponic Farming System using Nutrient Film Technique (NFT) provides a valuable and reliable solution to the challenges faced by farmers due to manual monitoring of environmental factors. The system effectively reduces the workload by automatically regulating critical environmental factors, making it ideal for NFT and adaptable to other hydroponic methods. The study highlights significant implications for hydroponic agriculture, emphasizing the practical benefits, reduced workload, and contributions to sustainable crop production. The system's adoption is recommended for existing and future hydroponic farmers, emphasizing water savings, chemical-free cultivation, and year-round yields. Government support could enhance food security amid population growth and climate change .

8. RECOMMENDATIONS

To the future designers who wish to improve the existing design project, the following suggestions must be considered for further development of the system:

1. *Automated Nutrient Mixing and pH Adjustment:* Consider allowing automatic mixing of nutrient solutions and implement an automated pH adjustment system using pH up and down solutions. This streamlines nutrient management and ensures optimal plant health.
2. *Automated Net Shade Installation:* Install an automated net shade within the hydroponic system. Efficiently adjust shading for plants based on changing weather conditions. This further reduces manual labor and enhances crop protection.
3. *Water Pump Condition Monitoring:* Implement water pump condition monitoring to ensure proper functioning and prevent potential failures that could harm the plants. This further protects plant health and system reliability.
4. *Waterproof Control Panels:* Design control panels with waterproof features to enhance durability and prevent damage due to exposure to water or moisture.

5. *Real-Time Remote Monitoring:* Enable real-time monitoring using Android software applications. This allows remote system control and adjustments for more efficient management.

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