International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 11s, 2025
https://theaspd.com/index.php/ijes

Automation Of Potable Hydroponics For Smart Cities

Sheetal Mital[1], Jyoti Srivastava[2], Aditi Agarwal[3], K.P. Mishra[4], Ajeet Pratap Singh[5], Ruchika Singh[6], Deepti Seth[7]

[1,7] Department of Applied Sciences and Humanities, KIET Groups of Institutions, Ghaziabad-201206, U.P., India.
[3]Novartis India Ltd., Hyderabad, A.P., India
[2,6]Department of Electrical and Electronics Engineering., KIET Groups of Institutions, Ghaziabad-201206, U.P., India.
[4,5]Department of Electronics and Communication Engineering., KIET Groups of Institutions, Ghaziabad-201206, U.P., India
*Corresponding author: Sheetal Mital, Department of Applied Sciences and Humanities, KIET Group of Institutions, Ghaziabad; E-mail: sheetal.mital@kiet.edu
ORCHID ID https://orchid.org/0000-0002-8994-9620

Abstract

Hydroponics is a soilless cultivation approach wherein plants are grown in water-based systems, including saline solutions, with essential nutrients directly supplied to the root. This process can be conducted in either a static or circulating solution environment, typically within greenhouses or glasshouses. Conventional hydroponic systems often require continuous human supervision to adjust and regulate key factors such as water temperature, pH levels, electrical conductivity, light intensity and humidity. Managing these parameters manually can be challenging and may hinder optimal plant growth. To address this, the present study proposes a portable, fully automated system that integrates Internet of Things (IoT) technology. This system collects real-time data and transfers it to cloud storage while a mobile application provides users with live updates and control capabilities through their smartphones, ensuring all growth conditions remain within ideal ranges.

The main objective of this work is to develop an affordable and fully automated system for hydroponic solution that minimizes the need for human intervention once the germinated plant is placed into the system. Additionally, the system is designed to be compact, user- friendly, and accessible to everyday consumers.

Keywords: Hydroponics, Deep Flow Technique, IoT, Automation

1. INTRODUCTION

With the rapid population growth globally, it is expected that the global population will reach to 9.7 billion by the year 2050 [1], creating an urgent need for advanced and efficient agricultural technologies that can ensure food security while supporting sustainable economic development. Modern agricultural approaches such as precision farming and the extensive application of agrochemicals like fertilizers and pesticides are becoming common strategies to boost crop production [9]. However, despite their benefits in enhancing yield, the overuse of agrochemicals can lead to harmful accumulation in crops, deteriorating their quality, affecting beneficial soil organisms, and posing potential health risks to consumers.

Growing plants and vegetables in harsh environmental conditions, such as deserts, polar regions, and areas with inconsistent rainfall, presents additional challenges. Only a limited variety of plants can survive under these extreme conditions, and these are often not viable as food sources. Additionally, urbanization has reduced available farmland, and issues such as soil preparation and excessive pesticide use further complicate traditional farming, threatening long-term food security [8][11].

In response to these challenges, hydroponic farming methods are gaining popularity in India as an effective solution to produce nutritious crops. This approach is particularly essential for a population of over 1.6 billion, facing both urban expansion and climate-related threats. Hydroponic techniques also contribute to improving the export quality of fruits and vegetables, resulting in better financial outcomes. Compared to conventional agriculture, hydroponics offers superior space management, higher crop yields, and increased profitability [17].

In large-scale hydroponic operations, manual supervision is still widely practiced, which is critical for plant survival. However, maintaining optimal conditions such as temperature, humidity, sunlight exposure, and soil pH is difficult through manual methods alone.

Controlled environments help plants grow more rapidly and healthily than they would under natural conditions [2][4].

Hydroponics, a concept that dates back to Gericke in 1937, stands out as a promising alternative to conventional farming, addressing many of its limitations [7]. This paper introduces a smart, IoT-based automated hydroponic system that incorporates Deep Neural Networks for the first time in this context. The proposed system intelligently analyzes various input parameters and automatically adjusts the environment for optimal plant growth, offering a faster and more cost-effective solution compared to manual management. Unlike traditional soil farming, this automated system requires minimal human intervention, reducing the need for tasks like watering, weeding, pest control, and fertilizer application.

The primary focus of this work is twofold: to automate greenhouse cultivation and to enable remote monitoring. Using IoT, the system transmits real-time environmental data to cloud storage, and a mobile application provides users with instant updates, simplifying monitoring and maintenance. Through this technology, authorized users can track plant growth remotely, ensuring efficient management. Ultimately, this project aims to fully automate the process of growing plants in a compact system designed for home use.

2. HYDROPONICS SYSTEM DESIGN AND IMPLEMENTATION

To efficiently grow vegetables and fruits, the Deep Flow Hydroponics Technique is employed. For the purpose of developing an automated hydroponic cultivation system suited for urban household [6][14], an IoT-based architecture has been designed. This system integrates suitable sensors to automate watering and crop monitoring. Additionally, a mobile application has been developed to monitor and control key parameters such as Total Dissolved Nutrient levels, water temperature, pH levels, humidity, and grow light conditions.

2.1 Design and Implementation Overview

Based on research and current practices, there is a clear need for a cost-effective and capable vertical hydroponic system to replace traditional farming methods. The target users for this system are urban households and small-scale farmers, so affordability and ease of use are key considerations [5][18]. The system has been divided into three main components: automation, monitoring, and Internet of Things (IoT) integration.

To achieve an economical and functional solution, a NodeMCU controller is used to connect and manage various sensors, including pH, water temperature, and humidity sensors, along with the hardware essential for constructing an IoT-based hydroponic framework [19].

2.1.1 Tools for Managing Hydroponic Solutions

- **pH Sensor:** Different plants require specific pH levels for optimal growth. Some thrive in acidic environments, while others prefer neutral or slightly alkaline conditions. Generally, acceptable pH levels range from 5 to 6.5, though some plants may tolerate levels above 7.5. pH monitoring can be both complex and costly, as pH probes typically output signals of 59 mV per pH unit. The NodeMCU requires signal amplification for accurate digital conversion due to the high impedance (approximately 101310^{13}1013 Ω) of pH probes.

- **Water Temperature Sensor:** Maintaining water temperatures between 25°C and 30°C is essential for healthy plant growth in hydroponic systems. The temperature sensor transmits readings to the processor, which adjusts system conditions to keep the temperature within the desired range based on the specific plant types.
- **Environmental Temperature and Humidity Sensor:** Environmental factors significantly influence plant health. Low temperatures can lead to frost damage, while high temperatures may cause moisture loss or heat stress. The DHT11 sensor is employed to monitor both temperature and humidity, offering quick response times and high measurement accuracy. Humidity can be measured across a full range from 0% to 100%.
- **LED Grow Lights:** Supplementary lighting is often required in hydroponics. LEDs are energy-efficient and emit specific light wavelengths beneficial for plant development. Red light supports flowering, stem elongation, and fruit production, while blue light enhances vegetative growth.

2.1.2 Hardware Components

- **Arduino MEGA:** This microcontroller serves as the foundation for a low-cost sensor monitoring system in hydroponics. It measures critical parameters like pH, electrical conductivity, environmental temperature, and humidity.
- **NodeMCU:** As the central processing unit of the system, the NodeMCU is an open- source IoT platform [3]. It operates at 3.3V with transmission and reception currents of 170mA and 56mA, respectively. The processor runs at 80 MHz but can be configured to operate between 40 MHz and 160 MHz. The NodeMCU was selected for its ability to effectively interface with all required sensors and for its data transfer speed of maximum 11 Mbps.
- **4-Channel 5V Relay Module:** This module is used to control three essential devices in the system: the submersible water pump, the water heating element, and the LED grow light panel.

2.2 System Implementation

The proposed hydroponic system design utilizes a connected pipe network, as illustrated in Figure 1, to create a controlled growing environment. Key factors such as sunlight exposure, LED light usage, humidity, and water pH will be regulated. Adjustments to these factors will be based on data collected from the sensors [13]. The system processes this data into two distinct flows: one dedicated to climate control and the other to managing the nutrient solutions provided to the plants [15].

Fig. 1: Hydroponic Plantation System

Manipulation has been done using an algorithm which identifies whether it is needed to open or close some of the gates as illustrated in Figures 2-4 below:

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 11s, 2025
https://theaspd.com/index.php/ijes

Fig. 2: pH Sensor Response

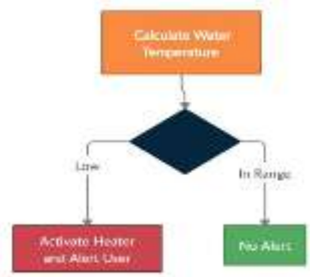

Fig 3: Water-Temperature Response

Fig 4: Temperature-Humidity Sensor

The overall system structure, as depicted in Figures 2 to 4, outlines the below key stages involved in the system's development:

(a) Monitoring

Plants are highly responsive to even minor environmental changes, making continuous monitoring essential. Critical factors such as temperature, humidity, and pH levels must be consistently tracked to ensure healthy plant growth [12].

(b) Automation

Manually managing plant growth in a hydroponic setup is a complex and time-consuming process. Therefore, incorporating a significant level of automation is highly beneficial. During daylight hours, plants perform both photosynthesis and respiration, whereas at night, only respiration occurs. With this understanding, it is possible to control the timing of LED grow lights to simulate natural sunlight exposure. Additionally, parameters like pH levels, water levels, temperature, and humidity can be automatically regulated to maintain optimal conditions.

(c) IoT Integration

Once the system is automated, a platform is needed for remote control and real-time monitoring [16]. The Blynk application serves as an effective interface, allowing users to easily manage and monitor the system from a distance.

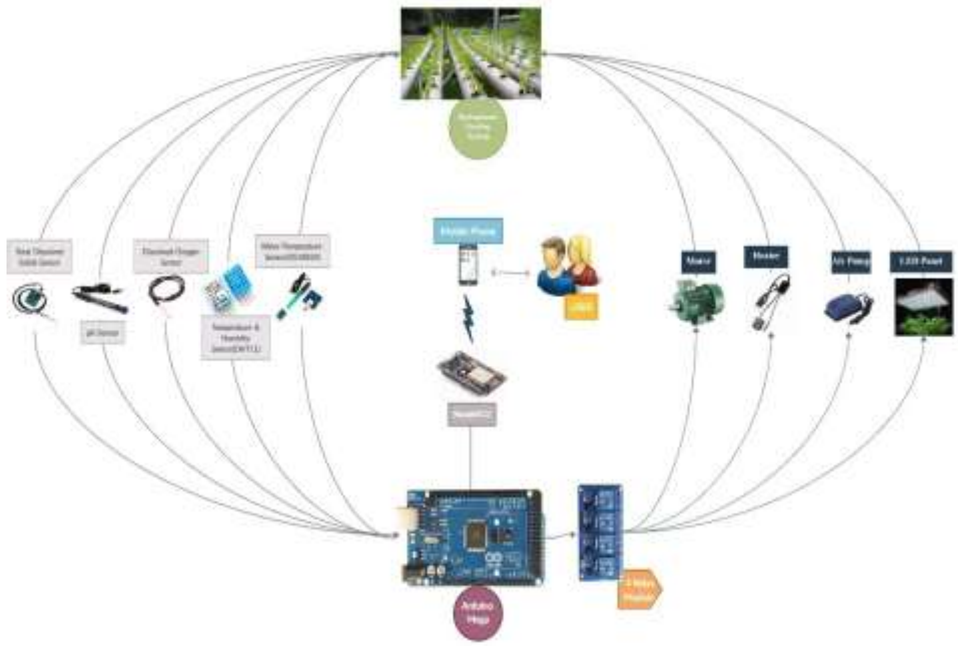

Fig. 5: Proposed System

The proposed system flow chart can be presented as shown below:

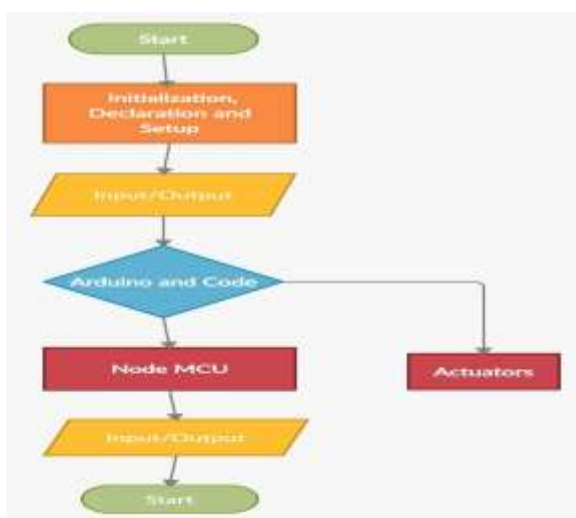

Fig. 6: Final Flowchart

The final design of the system demonstrates the feasibility of developing a fully automated hydroponic farming setup by controlling a select number of key parameters. The approach simplifies hydroponic agriculture by leveraging the power of computer systems and precision sensors. Thanks to the high processing capabilities and the dependable accuracy of modern sensors, this system can make rapid and precise adjustments. As a result, plants receive optimal care almost instantly, promoting healthier growth and ultimately leading to higher yields and increased profitability.

For effective installation of an automated hydroponic management system, conductivity and pH sensors must be positioned in the water reservoir that supplies the nutrient solution to the plants. Sensor readings serve as the basis for activating pH regulators and control devices that manage the opening and closing of valves or the operation of pumps.

For instance, if the nutrient concentration in the tank becomes too high, raising the solution's conductivity, the system can automatically activate a freshwater pump to dilute the solution and restore balance. Similarly, if the concentration drops too low, the conductivity controller can start the feed pumps to increase nutrient levels. In the same way, if the pH rises beyond the acceptable range, the system can automatically open a solenoid valve to adjust the pH accordingly.

3. CONCLUSION AND FUTURE SCOPE

The prototype model using Arduino MEGA is built and Fig. 7 gives the pictorial representation of this working model.

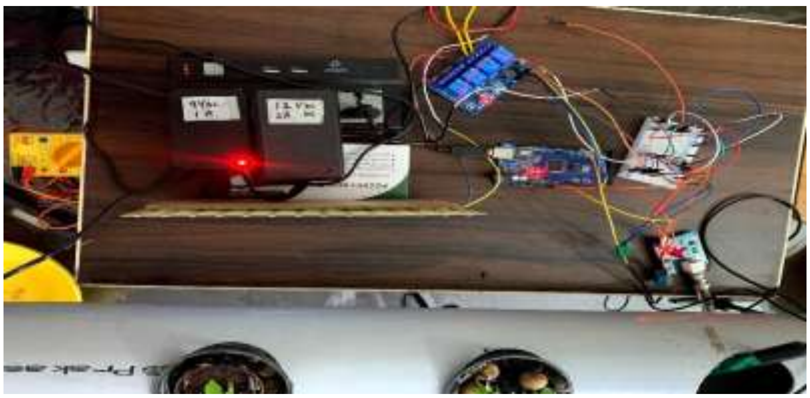

Fig 7: Working model

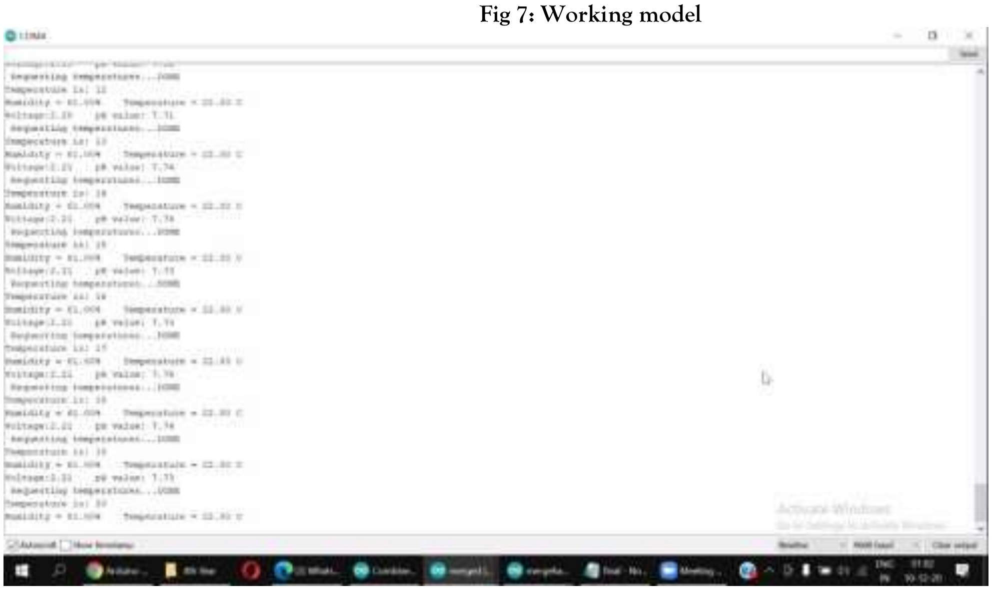

Fig 8: Values obtained

Hydroponic systems offer significant advantages such as higher crop yields, greater efficiency, and the ability to produce fresh, high-quality crops throughout the year, regardless of seasonal or climatic variations. These systems can support a wide variety of plants, catering to diverse markets which include farms, institutional buyers, restaurants and supermarkets. Hydroponic setups can vary from very small-scale units to large farms covering multiple hectares.
Based on this study, several key conclusions have been reached:

1. Both agricultural professionals and everyday individuals can successfully manage hydroponic farming by using IoT-based automated systems.

2. These systems can be customized to suit specific user needs.
3. Modern sensors have advanced significantly, offering high reliability and accuracy, which simplifies the data collection required for system adjustments.
4. IoT technology effectively automates tasks that previously required manual effort. For example, managing nutrient solutions is typically a complex process, but with this system, adjustments can be made almost instantly. Sensors quickly gather precise measurements and transmit the data wirelessly to the central computer, enabling rapid analysis and immediate corrective action. This level of automation makes hydroponic farming nearly self-sufficient, with minimal human involvement.

For future improvements, it is recommended to introduce additional parameters for system monitoring and control. One promising enhancement is the integration of cameras and image processing to assess plant health in real-time. This technology can enable early detection of plant stress or disease, allowing for timely interventions. Additionally, image processing could assist in accurately determining harvest readiness, particularly for fruit-bearing plants.

REFERENCES

1. N. Bakhtar, V. Chhabria, I. Chougle, H. Vidhrani, and R. Hande, “IoT based hydroponic farm,” Proc. Int. Conf. Smart Syst. Inven. Technol. ICSSIT 2018, no. Icssit, pp. 205–209, 2018, doi: 10.1109/ICSSIT.2018.8748447.
2. R. Vidhya, K. Valarmathi, “Survey on Automatic Monitoring of Hydroponics Farms Using IoT”, in Proc. of IEEE the Int. Conf. on Commun. Electron. Syst. (ICCES 2018), Coimbatore, India, Oct 15-16, 2018, ISBN:978- 1-5386-4765-3.
3. S. Pawar, S. Tembe, R. Acharekar, S. Khan, S. Yadav, “Design of an IoT enabled Automated Hydroponics system using Node MCU and Blynk”, 5th Int. Conf. for Converg. in Tech. (I2CT), Mumbai, India, Mar.29-31, 2019, doi:10.1109/12CT45611.2019.9033544.
4. M. S. Gour, V. Reddy, V. M., S. N., Vishuvardhan and V. T. Ram, " IoT based Farming Techniques in Indoor Environment: A Brief Survey," 5th International Conference on Communication and Electronics Systems (ICCES), 2020, pp. 790-795, DOI: 10.1109/ICCES48766.2020.9137950.
5. R. Perwiratama, Y. Setiadi, Suyoto,” Smart hydroponic farming with IoT-based climate and nutrient manipulation system”, Int. Conf. of Artif. Intell. Inform. Tech. (ICAIIT), 2019, pp. 129-132, DOI: 10.1109/ICAIIT.2019.8834533.
6. T. Namgyel, S. Siyang, C. Khunarak, T. Pobkrut, J. Norbu, T. Chaiyasit and T. Kerdcharoen,” IoT based hydroponic system with supplementary LED light for smart home farming of lettuce”, 15th Int. Conf. on Elect. Eng./Electron. Comput. Telecommun. Inf Tech., 2018, pp. 221-224, DOI: 10.1109/ECTICon.2018.8619983.
7. W. F. Gericke, “Hydroponics- Crop production in liquid culture media”. Science, vol. 85, no. 2198, pp. 177- 178, 1937.
8. C. Stanghellini, “Horticultural production in greenhouses: efficient use of water,” Acta Hortic., vol. 1034, no. 1034, pp. 25–32, May 2014, doi: 10.17660/ActaHortic.2014.1034.1.
9. A. Hussain, K. Iqbal, S. Aziem, P. Mahato, and A. K. Negi, “A Review On The Science Of Growing Crops Without Soil (Soilless Culture) - A Novel Alternative For Growing Crops,” Int. J. Agric. Crop Sci., vol. 7, no. 11, pp. 833–842, 2014.
10. M. D. S., “a Review on Plant Without Soil-Hydroponics,” Int. J. Res. Eng. Technol., vol. 02, no. 03, pp. 299–304, 2013, doi: 10.15623/iiret.2013.0203013.
11. I. A. Lakhiar, J. Gao, T. N. Syed, F. A. Chandio, and N. A. Buttar, “Modern plant cultivation technologies in agriculture under controlled environment: a review on aeroponics,” J. Plant Interact.,

vol. 13, no. 1, pp. 338– 352, Jan. 2018, doi: 10.1080/17429145.2018.1472308.

12. G. Kantor, "Demo Abstract: Integrated Wireless Sensor / Actuator Networks in an Agricultural Application," p. 317, 2004.
13. M. I. Sani, S. Siregar, A. P. Kumiawan, R. Jauhari, and C. N. Mandalahi, "Web-based monitoring and control system for aeroponics growing chamber," ICCEREC 2016 - Int. Conf. Control. Electron. Renew. Energy, Commun. 2016, Conf. Proc., pp. 162–168, 2017, doi: 10.1109/ICCEREC.2016.7814977.
14. M. Mehra, S. Saxena, S. Sankaranarayanan, R. J. Tom, and M. Veeramanikandan, "IoT based hydroponics system using Deep Neural Networks," Comput. Electron. Agric., vol. 155, no. November, pp. 473–486, 2018, doi: 10.1016/i.compag.2018.10.015.
15. D. Sivaganesan, "DESIGN AND DEVELOPMENT AI-ENABLED EDGE COMPUTING FOR INTELLIGENT-IOT APPLICATIONS." vol. 01, no. 02, pp. 84–94. 2019.
16. S. C. Kerns and J.-L. Lee, "Automated Aeroponics System Using IoT for Smart Farming," Eur. Sci. J, no. September, pp. 7–8, 2017, doi: 10.19044/esi.2017.clp10.
17. R. Nalwade and T. Mote, "Hydroponics farming," Proc. - Int. Conf. Trends Electron. Informatics, ICEI 2017, vol. 2018 -Janua, pp. 645–650, 2018, doi: 10.1109/ICOE1.2017.8300782.
18. M. Jagadesh, M. Karthik, A. Manikandan, S. Nivetha, and R. Prasanth Kumar 5, "IoT Based Aeroponics Agriculture Monitoring System Using Raspberry Pi," vol. 6, no. 1, p. 601, 2018, [Online]. Available: www.ijcrt.org.
19. C.J. G. Aliac and E. Maravillas, "IOT hydroponics management system," 2018 IEEE 10th Int. Conf. Humanoid, Nanotechnology, Inf. Technol. Commun. Control. Environ. Manag. HNICEM 2018, pp. 1–5, 2019, doi: 10.1109/HNICEM.2018.8666372.