INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND ANALYSIS

ISSN(print): 2643-9840, ISSN(online): 2643-9875

Volume 08 Issue 06 June 2025

DOI: 10.47191/ijmra/v8-i06-75, Impact Factor: 8.266

Page No. 3666-3672

Development and Evaluation of the Agrifresh Cloud-Based IoT Monitoring System for Optimized Hydroponics Management

Janerose G. Culanibang[1], Kimberlyn V. Narte[2], Melanie R. Albarracin[3], Lorenz A. Landero[4]

[1,2]State University of Northern Negros Graduate School

[3,4]Cebu Technological University Argao Campus

ABSTRACT: This study presents the development and evaluation of the AgriFresh Cloud-based Monitoring System, designed to address inefficiencies in the current hydroponics system. The current system struggled to maintain stable environmental parameters, leading to disrupted plant growth and health issues. The current system had difficulty maintaining stable environmental parameters, such as temperature, humidity, pH levels, and water conductivity. This instability led to disrupted plant growth, reduced efficiency, and health issues for the plants. Furthermore, the reliance on manual data logging and monitoring led to delays and human errors, hindering timely decision-making, and the lack of real-time alerts was a critical drawback. To overcome these challenges, the AgriFresh Cloud-based Monitoring System integrates IoT technology for real-time environmental monitoring, automation, and enhanced sensor capabilities, enabling more accurate control of the hydroponic system (Kang et al., 2024). The system was evaluated through user feedback and ISO/IEC 21823-4:2022 standards, receiving high marks for perceived ease of use and functional effectiveness. While slight improvements are needed in areas such as system flexibility and environmental impact, the findings suggest that AgriFresh provides a reliable, efficient, and user-friendly solution for modern agricultural management. With continuous refinement, the system holds strong potential for broader implementation and long-term success in advancing sustainable, technology-driven farming practices.

KEYWORDS: Agricultural Technology, Cloud-based Monitoring System, Greenhouse, Hydroponics, IoT, Sensor Networks

I. INTRODUCTION

Greenhouse manufacturing is a rapidly growing sector that involves cultivating plants in enclosed structures made of transparent materials (Mehdi et al., 2018). Among the innovative approaches to greenhouse cultivation, hydroponics has gained popularity due to its efficient use of resources and potential for higher yields (Oliveira et al., 2006). However, despite its advantages, hydroponics presents several operational challenges, particularly in ensuring continuous monitoring and maintenance to achieve optimal crop growth and productivity.

To address these limitations, the growing integration of Internet of Things (IoT) technology in agriculture has emerged as a transformative solution (Safarov et al.,2024). The Internet of Things (IoT) enables real-time monitoring of environmental conditions and plant health using interconnected smart sensors, devices, data analytics, and intelligent decision-making systems (Khalid et al., 2025). These technologies enable automated monitoring and control within greenhouse environments, allowing for data storage and access through cloud platforms, which in turn enhances decision-making for farmers. Intelligent sensor networks have proven effective in collecting accurate and timely data on critical parameters such as temperature, humidity, and nutrient levels (Md Anisur et al., 2024).

At Cebu Technological University's Argao Campus, the AgriFresh hydroponic greenhouse faced persistent challenges in monitoring nutrient solutions and maintaining ideal air and water temperatures. The existing system relied on manual testing and data entry, which proved time-consuming and inefficient. In response to these issues, researchers developed a cloud-based IoT monitoring system designed to automate the tracking of water temperature, acidity, and pH levels of the nutrient solution through sensors connected to a microcontroller and integrated with a web-based platform.

Given the potential benefits of such technologies, this study aimed to develop and evaluate the IoT-based hydroponics monitoring system to address the operational gaps and inefficiencies observed in AgriFresh (Rahimi et al., 2022). Specifically, the research examined the impact of the system on the effective management of environmental parameters—namely, air temperature and humidity, pH regulation, water temperature control, and water conductivity adjustment. The system quality is assessed based on ISO/IEC 21823-4:2022 standards through expert evaluation by IT professionals.

II. OBJECTIVES OF THE STUDY

This study aimed to develop an IoT-based hydroponics monitoring system to address operational gaps and technological challenges faced by AgriFresh, a hydroponic greenhouse project. Specifically, the research focused on evaluating the impact of the existing monitoring setup on the efficiency and effectiveness of managing key environmental variables, including air temperature and humidity, pH regulation, water temperature control, and water conductivity adjustment to ensure optimal crop productivity. Additionally, the study investigated recurring issues related to manual monitoring and data reporting, which often hindered accurate decision-making and timely interventions. To ensure compliance with global standards, the system was evaluated by IT professionals using the ISO/IEC 21823-4:2022 framework, which highlights the quality attributes of IoT systems. Lastly, the research assessed user perceptions regarding the system's overall usability, specifically examining perceived ease of use and perceived usefulness to determine its practical viability in real-world agricultural applications.

II. MATERIALS AND METHODS

The study employed the Rapid Application Development (RAD) model to guide the integration and evaluation of the AgriFresh IoT-based hydroponics monitoring system. A descriptive survey design was utilized to assess the system's software quality, perceived ease of use, and overall usefulness. A purposive sampling technique was applied to select 42 respondents, comprising agriculture students, instructors, and IT professionals with relevant expertise. The data gathered through this method offered meaningful insights into user perceptions and the effectiveness of the survey instruments used in the evaluation process.

Table 1. Rapid Application Development Model

Respondents	n	Percentage
Agriculture Student	25	59.52%
Agriculture Instructors	5	11.90%
AgriFresh Community	5	11.90%
IT experts	7	16.67%
Total	42	99.99

A. Rapid Application Development Model

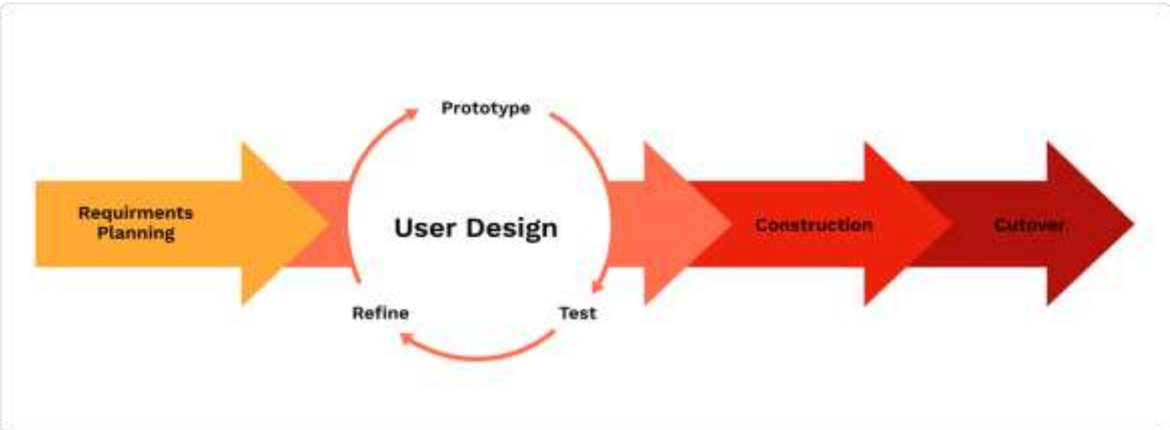


Figure 1. Rapid Application Model

The concept map follows the Rapid Application Development (RAD) model, starting with Frame 1, which focuses on requirement elicitation—identifying stakeholder needs and core system functionalities such as real-time sensor reading, data logging, SMS alerts, and analytics. Frame 2 breaks the system into modules, beginning with hardware reading and display (Stage 1), progressing through data logging (Stage 2), analytics (Stage 3), SMS notifications (Stage 4), and sensor management (Stage 5). Each stage involves iterative testing, debugging, and integration of sensor data using Arduino and web interfaces.

Finally, Frame 3 consolidates all modules in the transmission phase, where integration, testing, and deployment complete the system development. This structured flow ensures modular, fast-paced, and feedback-driven progress in building the AgriFresh IoT monitoring system.

B. Treatment of Data

The procedural flow of this study began with an initial assessment of the existing hydroponics monitoring system at Cebu Technological University's Argao Campus.

It includes evaluating critical parameters such as water temperature, air temperature and humidity, water conductivity, pH level, and acidity. The researchers identified key issues and inefficiencies associated with the current manual monitoring process, which became the basis for developing an improved system. The data collection phase involved distributing structured questionnaires to purposively selected respondents, including agricultural students, faculty members, and IT experts. The gathered data were systematically analyzed and interpreted in alignment with the study's objectives, leading to valuable insights for system enhancement.

The study was conducted within the university's hydroponic greenhouse facilities on the Argao Campus, where students enrolled in the Bachelor of Science in Agriculture program actively engage in hands-on farming practices. The campus provided a suitable research environment supported by both modern infrastructure and technical expertise. Building on the identified gaps, the researchers designed and implemented an IoT-based monitoring system tailored to AgriFresh's specific needs. The results of this research offer promising implications for advancing hydroponic agriculture by introducing a more efficient, sustainable, and technologically driven farming approach.

C. **Model Perspective of the Hardware System**

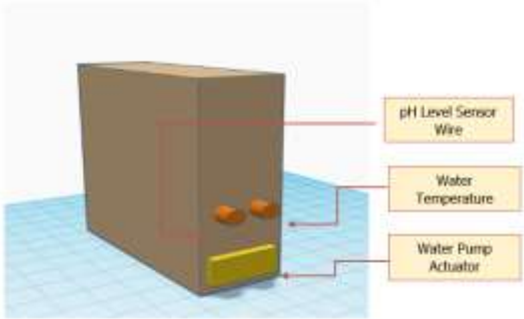


Figure 2. Front View of Hardware System

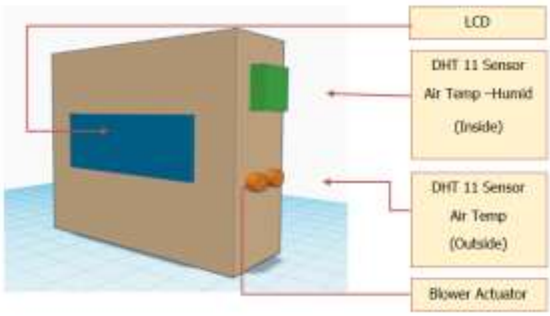


Figure 3 . Back View of the Hardware System

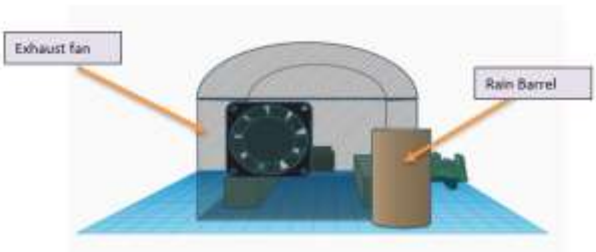


Figure 4. Front View of the Hardware System

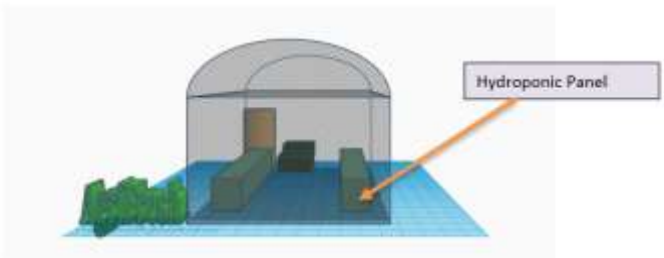


Figure 5. Back View of the Hardware System

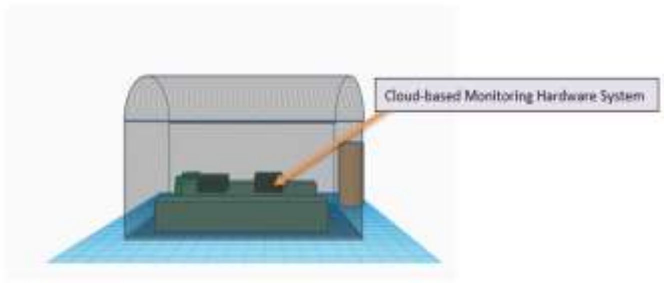


Figure 6. Side View of the Perspective Design for the AgriFresh Greenhouse

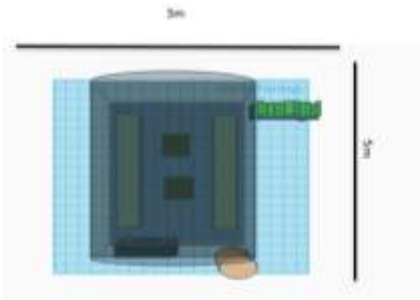
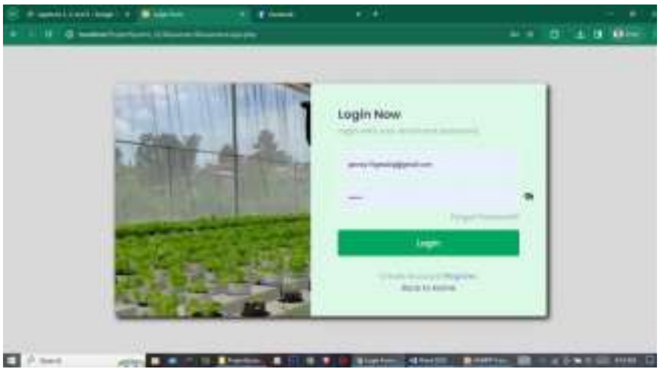


Figure 7. Top View of the Perspective Design for the AgriFresh Greenhouse



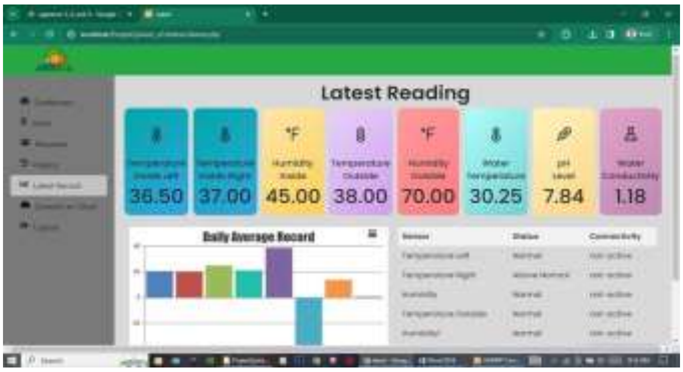


Figure 8. WebApp Reading of Sensors

Figure 9. WebApp Login

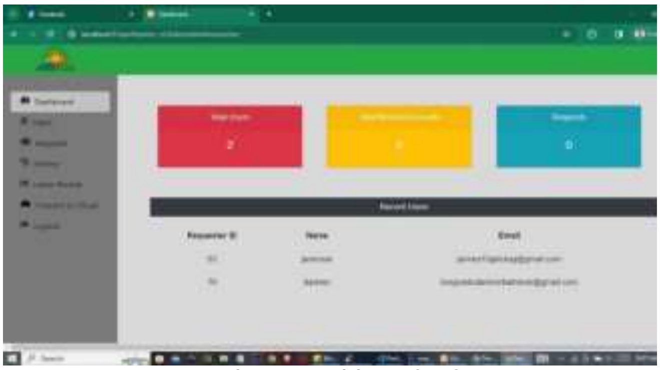


Figure 10. WebApp Dashboard-Admin

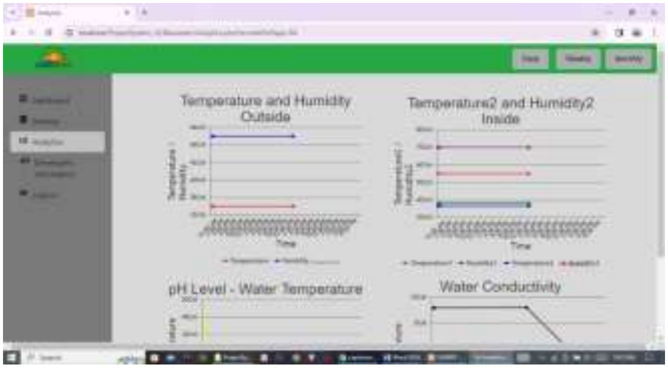


Figure 11. WebApp Analytic Reading of Sensors

III. RESULTS AND DISCUSSION

The system was evaluated using a Likert-scale questionnaire adapted from standardized usability surveys to measure users' perceptions of ease of use, usefulness, flexibility, and environmental impact. In parallel, IT professionals assessed the system based on ISO/IEC 21823-4:2022 standards to determine its compliance with essential IoT system quality attributes, including interoperability, scalability, and modularity. To evaluate the effectiveness of the existing hydroponics monitoring setup, key environmental factors—such as humidity, air and water temperature, pH levels, and electrical conductivity—were closely monitored. The collected data revealed persistent challenges in maintaining optimal environmental conditions, which adversely affected plant growth and overall system performance. Frequent fluctuations in these parameters resulted in efficiency losses, increased manual intervention, and recurring plant health issues, underscoring the need for a more reliable and automated monitoring system.

Table 2. Key Monitoring Issues in the Current Hydroponic System

Monitoring Aspect	Issues Identified	Impact	Frequency/Observation
Temperature & Humidity	Fluctuations in air/water temperature and humidity	Inconsistent plant growth, reduced efficiency, and health issues	Often to Always Observed

pH Level Regulation	Unstable pH levels, manual adjustments required	Disrupted nutrient uptake, poor root development, and plant stress	Always Observed
Water Conductivity	Irregular nutrient concentration	Nutrient imbalance, growth issues, and yield reduction	Often to Always Observed
Manual Monitoring Process	Manual data logging, no alarms, delayed responses	Increased human error, time-consuming, and slow decision-making	Most Frequently Reported Problem
System Limitations	Inadequate sensors, transmission failures, and no automated database	Inaccurate/incomplete data, unreliable performance tracking	Frequently Reported (Top Issues)

The evaluation of the AgriFresh hydroponics monitoring system revealed significant limitations in both technical performance and operational efficiency. Key environmental factors—such as temperature, humidity, pH level, and water conductivity—were inconsistently regulated, leading to frequent plant health issues, efficiency losses, and increased manual intervention. Users and IT professionals assessed the system using standardized surveys and ISO/IEC 21823-4:2022 guidelines, identifying issues with usability, limited flexibility, and a lack of essential IoT quality attributes, such as scalability and interoperability.

The data highlighted that unstable air and water temperatures, improper pH regulation, and fluctuating nutrient concentrations had a severe impact on plant growth and system reliability. Manual monitoring further compounded these issues, with the top problems being time-consuming processes, lack of real-time alerts, and error-prone data handling. These findings underscore the need for automation, accurate sensor-based monitoring, and a real-time alert system to enhance environmental control, optimize productivity, and improve decision-making in hydroponics setups.

Table 3. Evaluation of AgriFresh Cloud-Based Monitoring System

Dimension	Indicators (Highlights)	Weighted Mean Range	Overall Rating
Ease of Use	Easy to learn, skill development, system interaction clarity	3.57 – 3.71	Very Easy to Use
Usefulness	Productivity improvement, user capability, environmental benefit, and monitoring support	3.57 – 4.00	Very Helpful / Beneficial
Functionality & Reliability	Delivers features and performs consistently	3.14	Very Functional/Dependable
Usability	User-friendly, intuitive operation	3.57	Very Easy to Use
Efficiency	Responsive system, optimized performance	3.71	Very Efficient
Maintainability	Easy to update and adapt for long-term sustainability	3.64	Very Repairable
Portability	Transferable across different platforms with minimal adjustments	3.39	Very Portable

The evaluation of the AgriFresh Cloud-based Monitoring System shows intense user satisfaction in terms of ease of use (3.66), usefulness (3.85), and software quality. Users found the system easy to learn, operate, and master while also recognizing its benefits in monitoring, productivity, and user capability. Although environmental impact and certain software aspects, such as functionality (3.14) and portability (3.39), received slightly lower scores, overall feedback remains highly positive. The system is user-friendly, efficient, and practical, making it a valuable tool for agricultural monitoring and management.

IV. CONCLUSIONS

This study successfully developed and evaluated an IoT-based hydroponics monitoring system for AgriFresh aimed at addressing critical gaps in environmental control, data reporting, and system usability. The integration of sensors and cloud connectivity has significantly reduced manual monitoring time and improved the consistency of key parameters, including air and water temperature, humidity, pH levels, and electrical conductivity. These improvements led to more stable growing conditions, enhanced plant health, and increased operational efficiency.

The system was positively evaluated by users through a Likert-scale usability survey, indicating high levels of perceived ease of use, usefulness, flexibility, and environmental impact. Furthermore, IT professionals assessed the system's architecture by ISO/IEC 21823-4:2022 standards, confirming its compliance with essential IoT quality attributes. Overall, the results demonstrate that the developed system not only meets its intended objectives but also offers a scalable and sustainable solution for modern hydroponic farming, paving the way for more innovative, data-driven agricultural practices.

ACKNOWLEDGMENT

We would like to express our sincere gratitude to our family and friends for their unwavering support and encouragement throughout this research journey. Sincere thanks to Mrs. Christine Joy A. Tomol and Mrs. Melanie R. Albarracin, my co-instructors, for their valuable assistance in creating and deploying this study and to Mr. Ryan Teo, my research adviser, for his guidance and insights. We also extend our appreciation to the entire BSIT community for their inspiration and to the AI tools that helped enhance the quality of this paper. Above all, We thank the Lord God for His wisdom and strength that made this work possible.

REFERENCES

1) Severson, K. (2021, July 6). *No soil. There are no growing seasons. Just add water and technology*. The New York Times. Retrieved from https://www.nytimes.com/2021/07/06/dining/hydroponic-farming.html
2) MarketsandMarkets. (2023, April 15). *Hydroponics Market by Type (Aggregate Systems, Liquid Systems), Crop Type (Vegetables, Fruits, Flowers), Equipment (HVAC, LED Grow Light, Irrigation Systems, Material Handling, Control Systems), Input, and Region - Global Forecast to 2025*. Retrieved from https://www.marketsandmarkets.com/Market-Reports/hydroponic-vegetable-market-574.html
3) Rayhana, R., Xiao, G., & Liu, Z. (2020). Internet of Things empowered smart greenhouse farming. *IEEE Journal of Radio Frequency Identification*, 4(3), 195–211. https://doi.org/10.1109/JRFID.2020.2984391(joarps.org)
4) Enderling, H. (2019, May 28). Towards a quantitative personalized oncology. *Research Outreach*, (107), 130–133. https://doi.org/10.32907/ro-107-130133
5) Muruganandam, M. (2019, July 3). How fisheries biotechnology could benefit watershed-based rural aquaculture? *Acta Scientific Agriculture*, 3(8), 09–12. https://doi.org/10.31080/asag.2019.03.0555
6) Republic Act No. 8435, Agriculture and Fisheries Modernization Act (AFMA) of 1997. Retrieved from https://newsinfo.inquirer.net/1650550/solon-files-bill-to-promote-urban-agriculture-vertical-farming
7) Hutabri, E. (2019, October 14). Penerapan metode Rapid Application Development (RAD) dalam perancangan media pembelajaran. *James Martin's Approach to (RAD) Rapid Application Development*. Retrieved from https://jurnal.unsil.ac.id/index.php/innovatics/article/view/932
8) Krikser, T., Zasada, I., & Piorr, A. (2019). Socio-economic viability of urban agriculture—a comparative analysis of success factors in Germany. *Sustainability*, 11(7), 1999. https://doi.org/10.3390/su11071999
9) Smart Garden Guide. (n.d.). *15 common problems with hydroponics (and how to fix them)*. Retrieved from https://smartgardenguide.com/problems-with-hydroponics/
10) BusinessMirror. (2022, January 30). IoT innovative greenhouse hydroponics turns lettuce into a farm enterprise. Retrieved from https://businessmirror.com.ph/2022/01/30/iot-smart-greenhouse-hydroponics-turns-lettuce-as-farm-enterprise/
11) Todd, R. J. (2021, March 26). From net surfers to net seekers: The WWW, critical literacies and learning outcomes. *IASL Annual Conference Proceedings*, 231–242. https://doi.org/10.29173/iasl8173
12) iGrow Pre-Owned. (2021, July 8). *No soil. There are no growing seasons. Just add water and technology*. Retrieved from https://www.igrowpreowned.com/igrownews/no-soil-no-growing-seasons-just-add-water-and-technology
13) Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2020). Survey on Smart Greenhouse Monitoring Based on the Internet of Things. *IEEE Access*, 8, 194269–194288. https://doi.org/10.1109/ACCESS.2020.3037754
14) Hernández-Santana, V., Moreno-Moreno, A. J., & Dorta-González, P. (2018). IoT in agriculture: A review. *Computers and Electronics in Agriculture*, 153, 255–271. https://doi.org/10.1016/j.compag.2018.08.029
15) Phettong, W., Yimyam, N., & Chaiyarat, R. (2019). Hydroponics cultivation and its advantages over soil-based systems. *Agriculture and Natural Resources*, 53(5), 403–408. https://doi.org/10.1016/j.anres.2019.09.004
16) Ramsari, N., & Hidayat, T. (2022). Monitoring system and hydroponic plant automation using microcontroller Internet of Things (IoT). *Compiler*, 11(2). https://doi.org/10.28989/compiler.v11i2.1365

17) Vasantha Lakshmi, C. H., Koppad, A. G., Vijayalakshmi, M., & Hegde, L. (2020). Evaluation of hydroponic lettuce cultivation with an integrated nutrient management approach using organic and inorganic sources. *Journal of Plant Nutrition*, 43(4), 542–552. Retrieved from https://www.researchgate.net/publication/356664868_IoT_based_Indoor_Hydroponics_System
18) Thakur, P., & Malhotra, M. (2023). Role of IoT in automated hydroponic systems: A review. In Dutta, P., Chakrabarti, S., Bhattacharya, A., Dutta, S., & Piuri, V. (Eds.), *Emerging Technologies in Data Mining and Information Security* (Lecture Notes in Networks and Systems, 491). Springer, Singapore. https://doi.org/10.1007/978-981-19-4193-1_33
19) Lazarev, A. A. (2009). Algorithms for exceptional cases of making a point-of-the-mach-notal-tardiness problem or application to the eighth-odd partition problem. Retrieved from http://istina.msu.ru/media/publications/articles/1fb/e54/4492875/1-s2.0-S0895717709000089-main.pdf
20) Kryzen. (n.d.). *Hydroponic Growing Techniques for Tropical and Exotic Fruits*Retrieved from https://kryzen.com/hydroponic-growing-techniques-for-tropical-and-exotic-fruits-2/
21) Oliveira, A., Almeida, E., Silva, F., & Filho, V. (2006). Elemental contents in exotic Brazilian tropical fruits evaluated by energy dispersive x-ray fluorescence. *Scientia Agricola*, 63(1), 82–84. https://doi.org/10.1590/s0103-901620060001000134
22) Grow Depot 757. (2023, August). *Are hydroponic vegetables as healthy as soil-grown plants? Hydroponic supplements in Virginia Beach*. Retrieved from https://growdepot757.com/2023/08/are-hydroponic-vegetables-as-healthy-as-soil-grown-plants-hydroponic-supplements-in-virginia-beach/
23) Kenya University Library. (n.d.). *Assessment of Home Grown School Feeding Programme (HGSFP) Theory in Kinango Sub-County, Kwale County, Kenya*. Retrieved from https://ir-library.ku.ac.ke/handle/123456789/23764
24) Othman, Y., Alananbeh, K., Tahat, M., & Tahat, M. (2024). Can arbuscular mycorrhizal fungi enhance crop productivity and quality in hydroponics? A meta-analysis. *Sustainability*, 16(9), 3662.
25) Khang, A., Ya'akub, A., Gani, J., Teh, A., Kovtun, V., Pusppanathan, J., … & Alsayaydeh, J. (2024). Greening of an automated hydroponic system based on IoT and enhanced solar energy with an electricity-saving box. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, 62(1), 142–150. https://doi.org/10.37934/araset.62.1.142150
26) Safarov, R., Shomanova, Z., Nossenko, Y., Mussayev, Z., & Shomanova, A. (2024). Digital visualization of environmental risk indicators in the territory of the urban industrial zone. *Sustainability*, 16(12), 5190.
27) The Home Tasker. (n.d.). *Steel Roots – The preferred partner of Athena Nutrients, the #1 in hydroponics*. Retrieved from https://thehometasker.com/steel-roots-the-preferred-partner-of-athena-nutrients-the-1-in-hydroponics/
28) FileCR. (2025). *Arduino IDE for MacOS Download (Latest, 2025)*. Retrieved from https://filecr.com/macos/arduino-ide/
29) Niswar, M. (2024). Design and implementation of an automated indoor hydroponic farming system based on the Internet of Things. *International Journal of Computing and Digital Systems*, 15(1)