

Chapter 8

Urban Agriculture and Food Security

Wisdom Leaf Press

Pages number, 45–50

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<https://journals.icapsr.com/index.php/wlp>

DOI: 10.55938/wlp.v1i2.110



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Abstract

This article discusses hydroponics, a vertical farming technique that offers a thorough approach for setting up a hydroponic system. Hydroponics requires very little space, uses 90% less water, and supports year-round growing of practically organic produce. The cyclical and robustness of vertical farming systems are increased when Plant Growth-Promoting Rhizobacteria (PGPRs) are added to plant growth medium, thus enhancing microbial diversity. This method minimizes the demand for synthetic crop protection products and fertilizers. This paper investigates how vertical and hydroponic farming methods employ plant growth-promoting microorganisms (PGPMs). It advocates a coordinated strategy for treating post-germination PM10, which includes giving seeds or seedlings a microbial solution, particularly in aquaponic and aeroponic systems, and applying a biostimulant extraction to the hydroponic medium. The impact of vertical hydroponic farming on the environment in urban environments is explored in this article. It was demonstrated that the factors affecting the system's ecological impact were the growing media, pots, electricity use, and transportation. As per the study, there is a significant potential to reduce greenhouse gas emissions and the decline of abiotic resources by employing the fiber as the growing medium and substituting paper over plastic containers. In order to analyze data, this research study leverages big data analytics to showcase the design and implementation of automated vertical hydroponic farming techniques coupled with Internet of Things (IoT) platforms.

Keywords

Vertical Farming, Vertical Hydroponic Farming, Climate-Resilient Produce, PGPMs, PGPR

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I. Introduction

Vertical farming systems are gaining popularity as a sustainable alternative to traditional urban food production methods due to the growing population and global food market dynamics. However, their long-term effectiveness research remains insufficient [1]. VF, using advanced technologies like hydroponics, aeroponics, and aquaponics, is gaining popularity worldwide for producing high-quality food and sustainable resource management, particularly in urban areas with limited resources [2]. PGPMs enhance plant growth, resilience to stress, and phytoremediation effectiveness, making hydroponics and soil-free systems popular in agriculture due to efficient space utilization, minimal water consumption, pesticide-free behaviors, precise nutrient input control, and user-friendly technology [3]. VF, an emerging technique utilizing LED lighting and hydroponic automation, is promoting sustainable food production by enhancing plant performance and resilience through studies on microbial ecosystems, water quality, and Plant Growth-Promoting Rhizobacteria [4]. VF, a sustainable alternative to conventional food production, uses hydroponic cultivation techniques and customized growth environments to grow indoor plants, controlling nutrient levels using electrical conductivity to prevent loss and inadequacies [5]. VF is an indoor crop-growing technology that reduces the gap between producers and consumers, improving resource utilization efficiency, but it consumes excessive energy due to its use of electric lighting [6]. Controlled environment agriculture (CEA) technologies like hydroponics and VF are revolutionizing conventional farming by optimizing crop growth, reducing transportation costs and carbon emissions, and cultivating crops without soil [7]. The shortage of cultivable land is a critical issue forced on by the exponential increase in the global population. Considering there is less arable ground available for agriculture as a result of urbanization and the migration of rural inhabitants to urban areas, vertical farming and hydroponics have been growing increasingly popular [8]. VF promotes crop productivity in constrained space by indoor plant production that is regulated by temperatures, light, gasses, and humidity. It fulfills customer demand for fresh, nutritious produce in densely populated areas, produces pesticide- and fertilizer-free, climate-resilient produce, while consuming less land and water [9]. Figure 1 shows the technologies in vertical farming.

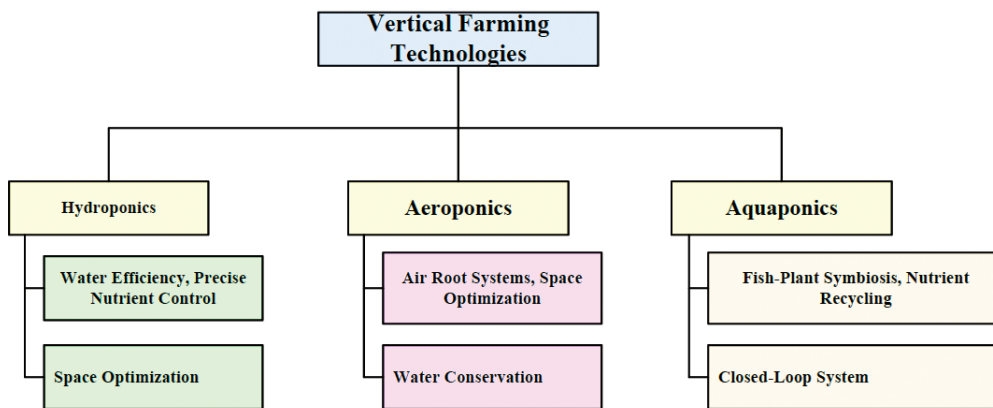


Figure 1. Vertical Farming Technologies

2. Innovative Hydroponics and Vertical Farming

Hydroponic, aquaponic, and aeroponic soil amendment techniques represent examples of controlled environment farming approaches that maximize plant growth. An aspect of this strategy called "vertical farming" is attracting interest from entrepreneurs all over the world. It entails growing crops in well-regulated indoor spaces with precision control over temperature, lighting, and fertilizers ^[10]. The concept of a VF has been completely transformed by innovations in greenhouse technologies including hydroponics, aeroponics, and aquaponics, that offer practical city farming techniques with less maintenance and greater yields. VF might become a reality owing to these technological advancements ^[11]. Both vertical farming and film farming, which use soilless crop cultivation and stacked shelves and beds to optimize growth environments while minimizing water consumption, can improve food safety and water-saving efficiency. However, their success centers on increased yield and plant quality, which could boost the volume of sales and costs ^[12]. Utilizing a microcontroller and an open internet of things (IoT) platform for remote control, an indoor automated vertical hydroponic system was created for home crop production. IoT platform assessments validate the system's ability to sustain healthy plant development with minimal input from human beings ^[13]. As an ecologically friendly and more productive alternative to traditional farming methods which involve an extensive amount of time and labor commitment, hydroponic farming makes utilization of IoT sensors to monitor crop health and restore nutrients and water in time frame ^[14]. Table 1 below shows the technological innovations in vertical and hydroponic system.

Table 1. Technological innovations in vertical and hydroponic system

| | Innovations | Details |
|---|--------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 | Innovations in Vertical Farming (VF) | Technologies like hydroponics, aeroponics, and aquaponics enable practical city farming with reduced maintenance and higher yields ^[11] . |
| 2 | Vertical and Film Farming | Utilize soilless cultivation and stacked shelves to optimize growth environments, minimize water consumption, and enhance food safety and yield ^[12] . |
| 3 | Automated Vertical Hydroponic System | Uses a microcontroller and IoT platform for remote control; sustains healthy plant growth with minimal human intervention, suitable for home production ^[13] . |
| 4 | IoT in Hydroponic Farming | IoT sensors monitor crop health and ensure timely restoration of nutrients and water, offering a sustainable and efficient alternative to traditional farming ^[14] . |
| 5 | AI and IoT in Vertical Agriculture | Employs AI, machine learning, deep learning, and IoT to address urban land and water constraints, facilitating precision agriculture in vertical farming ^[15] . |
| 6 | Smart Hydroponics with AI and IoT | |
| 7 | Hydroponic DFT and IoT | Vertical farming systems leverage IoT technology, sensors, and an automatic pH and TDS balancing system with the hydroponic Deep Flow Technique (DFT) ^[17] . |



Figure 2. IoT enabled vertical farming technique

Artificial intelligence, machine learning, deep learning, and IoT are all employed within vertical agriculture—a solution to the constraint of land and water in urban areas—to facilitate precision agriculture, especially in the framework of vertical farming [15]. By integrating real-time sensors, a deep learning convolutional neural network, and an Android-based application for farmers to monitor sensor data and plant disease status, the artificial intelligence (AI) application—integrated with an IoT framework—aims to revolutionize smart hydroponics [16]. Leveraging IoT technology, vertical farming—a cutting-edge agricultural technique for governed plant growth—is growing. In addition to sensors and an automatic pH and Total Dissolved Solids (TDS) balancing system, the system makes utilization of hydroponic Deep Flow Technique (DFT) [17]. An IoT-enabled hydroponic farming system regulates fertilizer delivery and monitor environmental conditions for crops. It has a Raspberry Pi, a microcontroller unit, actuators, and sensors. In addition to managing water pumps and serving as an intermediary for message queuing telemetry transport, the system records temperature, humidity, pH, and TDS [18]. With real-time environmental monitoring, energy savings, adaptability, versatility, and ecologically sound agriculture, IoT platform empowers operators to control soil moisture and supply plants with UV light [19]. A sustainable way to grow plants, veggies, and fruits without land is to use hydroponic techniques, especially those utilizing Rockwool. Substantial yields and shorter growing seasons can be achieved with this technique, particularly in places with polluted water. Smart IoT sensors monitor nutrient levels and productivity parameters [20]. Employing IoT sensors, the Hydroponic Farming Ecosystem (HFE) maintains an accurate watch on hydroponic conditions in real-time, delivering information on humidity, temperature, light intensity, and additional variables. This method is designed for novice urban farmers, people with limited expertise in farming, and anyone enthusiastic in urban vertical farming [21]. Figure 2 below shows a picture of IoT enabled vertical farming approach for crop cultivation.

3. Recommendations

After thorough review of the past and current literature available on the technology assisted Hydroponics and Vertical Farming practices adopted by urban population across the globe, we propose following recommendations for further enhancing and promoting vertical farming techniques.


- With the world's population growing and cultivable land becoming limited, the fast-expanding field of hydroponics agriculture has the potential to revolutionize food production. Innovations in hydroponics and vertical farming provide progressive producers with reduced cost disparities.
- In hydroponics, plants can be grown in any location, regardless of the season, as a result of continuous water circulation in tanks that replaces traditional insecticides and watering approaches and eliminates harmful residues.
- Crops grown indoors in vertical farms reduce the demand for heavy agricultural equipment and the burning of fossil fuels. Since crops are delivered closer to the production purposes, the implementation of such farms has the potential to significantly reduce air pollution and CO₂ emissions.
- In addition to increasing local food alternatives and decreasing food transportation, this study emphasizes the environmental advantages of vertical hydroponic urban farming systems for growing herbs and green vegetables.
- In contrast to earlier research, the study highlights the need of integrating urban systems and making advantage of available space in order to minimize environmental consequences. This is mainly because untapped building spaces are being exploited.
- The Hydroponic Farming Ecosystem leverages the Blynk app, Raspberry Pi, Bayesian networks, and LabVIEW for principles to manage multiple crops at a single location employing IoT technologies.
- There is uncertainty around the certification of organic foods cultivated on vertical farms because of concerns with the entire soil ecology and natural system involved.


Conclusion

Growing in popularity globally, vertical farms are a relatively new urban concepts that concentrate on high-value, quick-growing crops. Future developments and technologies that will enhance energy efficiency and profitability are the subject of ongoing research. The pillars of environmental, social, and economic sustainability that are addressed by vertical farming have the potential to significantly influence food sustainability in urban environments. Crop production is being revolutionized by cutting-edge farming techniques including aquaponics, aeroponics, and hydroponics. Innovations in multidisciplinary research, greenhouse technologies, and renewable energy are reshaping industrial systems and encouraging collaboration across several domains. The future of vertical farming in agriculture is uncertain because of barriers including high startup costs, difficult implementation, and information-sharing reluctance, even if there are advantages like reduced water usage and better crop quality. With the goal to monitor significant variables including soil moisture, air humidity, and temperature, as well as allow users to manipulate moisture levels and apply UV light, the paper provides an IoT-based solution for vertical farming operations.

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References

1. Martin M., Molin E. (2019). Environmental assessment of an urban vertical hydroponic farming system in Sweden. *Sustainability*, 11(15), 4124.
2. Mir M. S., Naikoo N. B., Kanth R. H., Bahar F. A., Bhat M. A., Nazir A. ... Ahngar T. A. (2022). Vertical farming: The future of agriculture: A review. *The Pharma Innovation Journal*, 11(2), 1195–1195.
3. Dhawi F. (2023). The Role of Plant Growth-Promoting Microorganisms (PGPMs) and Their Feasibility in Hydroponics and Vertical Farming. *Metabolites*, 13(2), 247.
4. Van Gerrewey T., Boon N., Geelen D. (2021). Vertical farming: The only way is up?. *Agronomy*, 12(1), 2.
5. Hosseini H., Mozafari V., Roosta H. R., Shirani H., van de Vlasakker P. C., Farhangi M. (2021). Nutrient use in vertical farming: Optimal electrical conductivity of nutrient solution for growth of lettuce and basil in hydroponic cultivation. *Horticulturae*, 7(9), 283.
6. Lubna F. A., Lewus D. C., Shelford T. J., Both A. J. (2022). What you may not realize about vertical farming. *Horticulturae*, 8(4), 322.
7. Maurya P. K., Karde R. Y., Bayskar A. S., Charitha N. (2023). Innovative Technologies Such As Vertical Farming and Hydroponics to Grow Crops in Controlled Environments. *Advanced Farming Technology*, 84.
8. Mathur T., Muthukumaraswamy S. A. (2022). On the study and analyses of “Vertical farming—The future of agriculture” via various hydroponic systems. *Intelligent Manufacturing and Energy Sustainability: Proceedings of ICIMES 2021*, 157–165.
9. Kumar R., Rathore S., Kundlas K., Rattan S., Warghat A. R. (2023). Vertical farming and organic farming integration: a review. *Advances in Resting-state Functional MRI*, 291–315.
10. Chole A. S., Jadhav A. R., Shinde V. (2021). Vertical farming: Controlled environment agriculture. *Just Agric*, 1, 249–256.
11. Al-Kodmany K. (2018). The vertical farm: A review of developments and implications for the vertical city. *Buildings*, 8(2), 24.
12. Zhang Z., Rod M., Hosseinian F. (2021). A comprehensive review on sustainable industrial vertical farming using film farming technology. *Sustainable Agriculture Research*, 10(1), 53–53.
13. Chowdhury M. E., Khandakar A., Ahmed S., Al-Khuzaei F., Hamdalla J., Haque F. ... Al-Emadi N. (2020). Design, construction and testing of iot based automated indoor vertical hydroponics farming test-bed in qatar. *Sensors*, 20(19), 5637.
14. Shrivastava A., Nayak C. K., Dilip R., Samal S. R., Rout S., Ashfaque S. M. (2023). Automatic robotic system design and development for vertical hydroponic farming using IoT and big data analysis. *Materials Today: Proceedings*, 80, 3546–3553.
15. Siregar R. R. A., Seminar K. B., Wahjuni S., Santosa E. (2022). Vertical farming perspectives in support of precision agriculture using artificial intelligence: A review. *Computers*, 11(9), 135.
16. Ramakrishnam Raju S. V. S., Dappuri B., Ravi Kiran Varma P., Yachamaneni M., Verghese D. M. G., Mishra M. K. (2022). Design and implementation of smart hydroponics farming using iot-based ai controller with mobile application system. *Journal of Nanomaterials*, 2022, 1–12.
17. Kaur G., Upadhyaya P., Chawla P. (2023). Comparative analysis of IoT-based controlled environment and uncontrolled environment plant growth monitoring system for hydroponic indoor vertical farm. *Environmental Research*, 222, 115313.
18. 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), 346–346.
19. Ng H. T., Tham Z. K., Rahim N. A. A., Rohim A. W., Looi W. W., Ahmad N. S. (2023). IoT-enabled system for monitoring and controlling vertical farming operations. *Int J Reconfigurable Embedded Syst*, 12(3), 461–461.
20. Hassine I. B., Mezghani D., Belkadi A., Sghaier N., Mami A. (2023). DESIGN OF SMART VERTICAL HYDROPONIC SYSTEM. *Engenharia Agrícola*, 43, e20220205.
21. Deepika S., Panicker V. V., Koshy A., Salim S., Philip S. (2020). Enhanced plant monitoring system for hydroponics farming ecosystem using IOT. *GRD J Eng*, 5(2), 20–20.