American Research Journal of Humanities & Social Science (ARJHSS)

E-ISSN: 2378-702X
Volume-07, Issue-07, pp-84-92
www.arjhss.com

Research Paper Open Access

Exploring the Socio-Economics of Philippine Urban Aquaponics: Opportunities, Challenges, and Implications for Sustainable Urban Agriculture

Joseph Christopher C. Rayos*, Jayson G. Candones, Gilda Joannah A. Calderon
National Fisheries Research and Development Institute

ABSTRACT: The novel agri-aqua technique known as urban aquaponics, which is becoming more and more popular in the nation's cities, is the subject of this paper's socioeconomic investigation. Through an analysis of the interplay between economic, social and environmental elements, this review paper aims to discuss the significance of using aquaponics in different set-ups in the urban areas. Different studies were discussed in which the urban aquaponics might aid in food security, simulate economic growth, and build community resilience. To conclude, aquaponics can provide adaptors with another source of revenue generating and serves as an alternate food production method in an urban environment. Given the uniqueness and creativity of the technology, more investigations and data collection are required in order to further evaluate all advantages and disadvantages of aquaponics in an urban setting.

Keywords - Urban aquaponics, sustainable, socio-economics

I. INTRODUCTION

The agriculture sector is one of the main driving forces of the economy, yet it is gravely affected by the growing number of industrializations and climate change, resulting in low productivity and food scarcity (TUP, 2023). According to Arellano 2021, the Philippine government intends to improve food production during COVID-19 by supplying urban residents with aquaponics tools that allow them to raise fish and grow vegetables.

Urbanization has become a major global trend, and supporting it demands provision systems for infrastructure, logistics, communication, commerce, cultural aspects, tourism, and employment generation (Leamer and Storper, 2014). This expansion is accompanied by greater demand for food associated with supply chains from rural areas (Santos, 2016).

Aquaponics combines aquaculture, the cultivation of fish and aquatic organisms, with hydroponics, the cultivation of plants in nutrient-rich water. The plants and fish are the cash crops, while nitrifying bacteria play an important biofiltration role, converting toxic fish waste ammonia (francis-floyd et al., 2012) to nitrate nitrogen (Table 1).

Thus, setting-up aquaponics in an urban areas is an innovative and sustainable farming technique that has gained significant attention in recent years (Rizal et al., 2018). The term "aquaponics" combines the terms "aqua" and "ponics"; "aqua" refers to aquaculture, which raises fish and other aquatic animals. The term "ponics" from Latin for "in a controlled environment," word implies "to labor," because cultivation is done in medium devoid of soil (Kulkarni et al., 2019).

This paper further analyzes the socio-economic dimensions of urban aquaponics and its implications for sustainable urban development.

Importance of urban aquaponics in the Philippines

The adoption of aquaponics systems in the Philippines has been driven by academic institutions, government projects, and community-based initiatives. Researchers and educators have played a crucial role in advancing the technology, developing demonstration projects, and training local communities on the benefits and implementation of aquaponics systems. As the Philippines continues to grapple with food security challenges and the impacts of climate change, the future of aquaponics in the country looks promising.

Urban aquaponics plays a crucial role in the Philippines due to its potential to address food security and sustainable urban development. With the increasing population and rapid urbanization, there is a growing need for innovative solutions to meet the demand for fresh produce. Arable land becomes scarcer, the need for alternative farming methods increases. Aquaponics allows for the simultaneous production of fish and plants, contributing to both protein and vegetable supply in urban areas where traditional agriculture might be limited (Philippines launches urban aquaponics program, 2021).

As urban areas continue to expand, the importance of urban aquaponics in the Philippines cannot be overstated, and its potential impact on food production and environmental sustainability is significant. In addition, the integration of technology further enhances the efficiency and productivity of aquaponics systems in the Philippines, creating economic opportunities for farmers.

Aquaponics designs and system in the Philippines

The most common aquaculture system used in aquaponics is the Recirculating Aquaculture Tank System (RAS) (figure 1). The water and nutrients that go to the hydroponic subsystem are recirculated back into this tank, which serves as the base reservoir. This is an intensive, usually high-fish-density production system (Timmons et al. 2002) that allows for buildup of waste nutrients from fish feed to levels that can benefit plant growth.

The growth performance of water spinach and freshwater prawn using aquaponics and hydroponics setups was studied by Alam et al., in 2022. The results showed that water spinach and freshwater shrimp had significant growth in the aquaponics setup compared to the hydroponics setup, although the growth was still less than in soil units. The study also discusses the use of recyclable materials to construct these systems, aiming to reduce costs and promote aquaponics and hydroponics as viable options for urban agriculture in the Philippines.

In 2020, two units of 6m diameter aquaponics systems were implemented by associations in Valenzuela City, donated by the Department of Agriculture Bureau of Fisheries and Aquatic Resources National Capital Region, to boost the local market. The crops produced included tomatoes, pechay, and tilapia (unpublished data). Various aquaponics units were also distributed throughout the NCR to schools, communities, and government entities. According to BFAR-NCR, they distributed approximately 65 basic units of aquaponics to different cities in the National Capital Region from 2020 to 2023. However, due to the lack of manpower, they were not able to monitor all the aquaponics units to determine whether they were active (producing crops) or inactive (unpublished data). Also, no data have been released to the public regarding the production of the units since their distribution.

Different materials as Planting Bed for Aquaponics System

According to Arroyo et al., 2018, the minimum requirement for the set-up conducted included access to water, electricity, heat and level space. The pH level and temperature were tested during the experiment. Materials such as drum (polyethylene), bamboo, Styrofoam fruit box PVC pipes (1/2" elbow, PVC tee, and threaded coupling), faucet, water pump, growing media (pumice), seeds, seedling tray, tilapia fingerling, fish feed (pellet), digital weighing scale, water thermometer, pH meter and dissolved oxygen meter.

Pellet was used during the feeding of Nile tilapia. It was fed twice daily. Lettuce (Lactuca sativa L.) is the experimental crop used on study (Panfare variety). Data were monitored, collected and evaluated to determine production of lettuce and fish such as growth response of plants, average weekly height of plant, average number of leaves and average weight of plant (Arroyo et al., 2018). The growth response of fish, the average fish weight, and mortality rate was measured. Also, the temperature and pH monitoring was gathered.

The study found out that different materials as planting beds have a significant effect on the growth and yield of lettuce, which is valuable information for optimizing plant production in aquaponics systems. By demonstrating that aquaponics can efficiently use water and nutrients, it contributes to the development of sustainable agricultural practices that can save land and water resources. Also, the study indicated that the type of planting material did not significantly affect the growth and mortality of fish, suggesting flexibility in the choice of material concerning fish health. And the study provides practical data for farmers and practitioners interested in improving or implementing aquaponics systems, offering evidence-based recommendations for planting materials.

Lastly, the study contributes to the optimization of aquaponics systems, advocates for sustainability in agriculture, and provides practical evidence for improving plant yields and fish health without compromising environmental wellness (Arroyo et al., 2018).

A Solar-Powered Aquaponics with IoT-Based

A study of Technological University of the Philippines- Taguig focuses to build a solar-powered enclosed aquaponics unit using a deep-water culture (DWC) type of Aquaponics, which is one of the 3

common methods of aquaponics, also known as the raft method, or floating system method that utilizes nutrient rich water as the medium for the plants, supported by a Styrofoam and net cups (TUP, 2023) (Figure 2).

An IBC tank was the material utilized to construct the fish tank. Additionally, a grow light will be installed above the grow bed in the ceiling. Data was collected by the researchers between the hours of 10 a.m. and 2 p.m., when the sun is at its highest. Because the solar panel can only generate energy when there is enough sunlight, the low ampere observed was the result of insufficient sunlight caused by the overcast weather. As a result, solar panels are more effective when placed in areas with ample sunshine for energy production.

Traditional Aquaponics and reconstructed aquaponics

Drum, grow bed, grow medium, water pump, air pump, bendable PVC pipe, unsealed siphon, tomato seeds and Styrofoam are the materials being used in the traditional aquaponics. The components for the reconstructed aquaponics consists of drum, grow bed, grow media, water pump, air pump, bendable PVC pipe, unseals, siphons and tomato seeds. Additionally, styrofoam, directional control (DC) valves, pressure gauges and small diameter pipes were also used.

The research provides insights into the potential benefits of using reconstructed aquaponics systems over traditional aquaponics, showing improved growth yields, such as more fruits, better height, weight, and girth measurements of tomatoes. The results suggested that aquaponics systems are environmentally friendly, reducing artificial chemical use and minimizing excess water usage by 90% compared to soil-based gardening, which contributes to more sustainable agricultural practices. It also recommends that aquaponics can be an efficient method to grow crops, particularly in areas with limited space or resources, as it consumes less water and may generate higher crop production. Moreover, results in this study provide information on the adaptability of the model to climate challenges since crops produced in aquaponics systems are more resilient to floods and droughts, which could be beneficial in responding to the effects of climate change on agriculture.

The reconstructed aquaponics system includes improvements such as a smaller diameter pipe for better water distribution, the use of DC valves to avoid common problems with solenoid valves, and the installation of pressure gauges to ensure water quality. For practitioners and researchers, the study offers a comparative analysis that may guide future innovations and improvements in aquaponics farming techniques. (Guia et al., 2023).

Socio-Economic Benefits of Urban Aquaponics

The study conducted by Rayos et al. in 2022 determined that a small-scale aquaponics unit with dimensions of 1m x 0.7m x 0.7m can generate an annual income of 9,556 pesos, utilizing 75 catfish and 54 lettuce plants. For a larger scale, a tank measuring 2m x 3m x 1m can yield 23,800 pesos annually. The respective returns on investment were 26.54% and 24.41%.

The fact that urban aquaponics can address both food security and sustainable urban development, it is important to the Philippine economy. The demand for fresh food is rising and creative alternative solutions are becoming more and more necessary to keep up with the pace of urbanization and population growth.

Urban aquaponics systems can maximize land usage in urban environment by being integrated into buildings, small backyard space, and underutilized city spaces. Aquaponics helps more sustainable city expansion by bringing food production closer to where consumers reside, according to Suhl et.al. (2016). Aquaponics can be used to provide additional income for many urban inhabitants and open up new opportunities in the field of sustainable urban farming. It gives city dwellers the chance to participate in local food production, encouraging community involvement and teaching about sustainable practices. Urban aquaponics is important in the Philippines and has a great potential influence on both food production and environment sustainability as urban areas continue to grow. Furthermore, the incorporation of technology improves the effectiveness and productivity of aquaponics systems in the Philippines, creating economic opportunities for farmers.

Challenges and opportunities for urban aquaponics in the Philippines

In the Philippines, this approach is becoming more popular as a solution to the problems of limited agricultural land, insufficient food supply, and the requirement for robust and sustainable food systems. Nonetheless, the Philippines presents a number of potential and obstacles for urban agriculture. Limited access to land, especially in highly crowded urban areas, is one of the nation's problems with urban agriculture. Competing land uses, including residential and commercial development, exacerbate this even more. The lack of knowledge and assistance from municipal governments and urban planning is another major issue.

However, there are a number of advantages to urban agriculture in the Philippines. These opportunities include the possibility for increased self-sufficiency and food security, since urban agriculture can directly supply local populations with wholesome, fresh food. Additionally, it may improve the services provided by

urban ecosystems, reducing the impact of the urban heat island and giving residents access to green areas (Abas et al., 2020). Additionally, through production and Agri-Farm Tourism (AFT), urban agriculture can boost the local economy by creating jobs and revenue. Agri-farm tourism, or combining tourism and agriculture, is starting to gain traction in the Philippines. By utilizing the nation's natural resources and cultural legacy, this has the potential to develop a successful and sustainable economy (Salarda, 2021).

Additionally, by encouraging organic farming methods locally and lowering the dependency on long-distance food transportation, urban agriculture can support environmental sustainability. This event may present a chance to get urban people involved in food production, which could result in more environmentally friendly consumer habits and boost regional economies. Technological breakthroughs brought forth by the development of technologies like aquaponics, vertical farming, and hydroponics.

In the Philippines, urban agriculture has a lot of promise to help with issues like limited agricultural space and food security. Even with the challenges of restricted land availability, inadequate municipal assistance, and the requirement for technical expertise among urban farmers, there exist substantial prospects for improved food security, economic expansion, and environmental sustainability. By making investments in laws that support urban agriculture, providing training and education for urban farmers, and fostering partnerships between local communities and authorities, the Philippines can harness the full potential of urban agriculture for a more sustainable and resilient food system.

II. CHALLENGES AND SOLUTIONS

Regulatory challenges and policies affecting urban aquaponics

Urban aquaponics' development and expansion are significantly influenced by regulatory obstacles and regulations (Estim et al., 2020). Urban aquaponics system setup and operation may be aided or hindered by these obstacles and regulations. For instance, zoning laws may limit the locations of aquaponics systems in cities (Rizal et al., 2018). In addition, running an aquaponics system can entail obtaining the necessary licenses and permits. Urban aquaponics may also be impacted by laws pertaining to requirements for food safety and quality. It is imperative that policy-makers take into account the distinctive characteristics of aquaponics and formulate policies that facilitate and encourage its expansion. Policies pertaining to waste disposal, nutrient management, and water use are also crucial.

Socio-economic challenges for urban aquaponics practitioners

Urban aquaponics practitioners encounter many socio-economic obstacles that may impede the formation and triumph of extensive initiatives. For instance, it may be challenging to locate appropriate sites for aquaponics systems in urban regions due to restricted access to land and sufficient space. Undoubtedly, the substantial initial expenses and financial commitment necessary for aquaponics pose obstacles that may prevent its extensive implementation. These expenses may include constructing grow beds, fish tanks, filtration systems, and the piping and pumping systems that are required. The requirement for specialist equipment to oversee and manage the automated processes within the system results in additional costs. In addition, continuous running costs like energy and fish feed raise the overall cost. These elements may be a significant financial obstacle,

Another issue is the lack of market acceptance and public knowledge, which could affect aquaponics product demand and customer understanding. Issues could surface because of current farming methods and the perception that aquaponics is more challenging than conventional soil-based agriculture. The commercialization of aquaponics carries the risk of overturning established production and marketing systems. Lastly, the absence of laws and government assistance that promote or facilitate the expansion of urban aquaponics, leaving practitioners with limited financial and resource options.

Proposed solutions and strategies to overcome these challenges

The need for efficient and sustainable food production systems is growing as urban populations continue to rise. Adopting urban aquaponics, which combines hydroponics (soilless plant cultivation) and aquaculture (fish farming) to create a symbiotic system that can produce both fish and vegetables in a compact, resource-efficient manner, is one viable approach. Providing thorough training and educational programs to people interested in urban aquaponics is one of the main concerns. Thorough training courses and workshops can guarantee that people possess the abilities and know-how needed to set up and maintain aquaponics systems. Apart from imparting knowledge, it's crucial to spread awareness about the advantages of urban aquaponics among the general population. Increasing consciousness and enlightening the public. Raising awareness and educating the community about the environmental and health benefits of aquaponics, such as its ability to provide fresh and nutritious food in a sustainable manner, can help drive the adoption of this technology.

Conduct educational campaigns and community outreach to promote the environmental and health benefits of aquaponics (Sundari et al., 2021). This can be done through community workshops, educational campaigns, and partnerships with local organizations. Encourage more people to consume aquaponics products by promoting their nutritional value, taste, and quality.

Ensuring the safety and hygiene of aquaponic systems is also crucial for the successful implementation of urban aquaponics. Proper monitoring of water quality, handling of harvested produce, and adherence to food safety guidelines can help mitigate the risks associated with consuming aquaponics products (Okomoda et al., 2022). Develop efficient and sustainable distribution channels for aquaponics products, such as establishing local markets, farm-to-table programs, and strategic partnerships, can help enhance the accessibility and availability of these products to urban consumers. Finally, lowering the obstacles for people or groups looking to begin their own urban aquaponics systems by offering financial assistance and resources to mitigate the initial expenses. Addressing these key challenges improves potential widespread success ensuring sustainable food production in an urban environment (Rizal et al., 2018).

III. FUTURE DIRECTIONS AND OPPORTUNITIES

Potential for scaling up urban aquaponics in the Philippines

Urban aquaponics is a viable method of urban agriculture in the Philippines, where there are issues in food provision due to the country's fast urbanization. The Philippines' densely populated, spatially constrained regions necessitate the development of novel approaches to food production. Because it takes up less land than conventional agriculture and may be installed in underutilized urban spaces like roofs, abandoned lots, and indoor facilities, aquaponics offers a flexible alternative (Philippines initiates' urban aquaponics program, 2021). One obvious benefit that points to aquaponics' spread is its capacity to adapt to environments with limited space. Furthermore, the Philippines' consistent tropical climate provides an ideal setting for aquaponics, enabling year-round fish and vegetable cultivation. Furthermore, the potential for community involvement and education is substantial. Aquaponics can be implemented in schools and urban community centers, providing an opportunity for hands-on learning about sustainable food production and environmental stewardship.

Philippine government programs, such as the urban aquaponics initiative under the "Plant, Plant, Plant Program," indicate an acknowledgment of aquaponics as a component of the national food security strategy. This program highlights efforts to employ aquaponics to enhance self-sufficiency in food production and resilience in supply chains during crises like the COVID-19 pandemic (Philippines launches urban aquaponics program, 2021). Government endorsement is crucial for mobilizing resources towards expanding aquaponics infrastructures.

Aquaponics may be made more efficient, produce higher yields, and use less energy by incorporating modern technologies like the Internet of Things (IoT) and renewable energy sources (Haryanto et al., 2019). For instance, intelligent solar-powered aquaponics systems have proven to operate better under a range of circumstances, indicating that these systems are feasible for widespread usage in the urban Philippine context (Evangelista et al., 2022).

Integration of aquaponics into urban planning and development

The sustainable agricultural technique of aquaponics is included into the layout and operation of urban environments as part of the process of urban planning and development. This can be achieved by discovering urban areas, such as roofs, empty lots, or inside buildings, that can be utilized for aquaponics systems (Hao et al., 2020). Additionally, a framework of policies is required to promote the growth of urban agriculture and the usage of aquaponics. This framework should include detailed recommendations and the strategic regulatory changes required to support the promotion of aquaponics (Pollard et al., 2017). For aquaponics to be seamlessly and successfully integrated into urban planning and development, government agencies, urban planners, environmental specialists, and the aquaponics sector will need to work together. Urban designers ought to think about integrating aquaponics into community gardens and public areas to foster learning and interaction with environmentally friendly food production methods. Furthermore, choosing and allocating appropriate locations for aquaponics systems should be part of the integration of aquaponics into urban planning. This involves taking into account elements like closeness to water sources, sunlight exposure, and compatibility with existing infrastructure. The possible economic benefits that aquaponics may offer should also be taken into account when integrating it into urban planning. This entails assisting in the growth of aquaponics companies and offering tools and instruction to business owners who wish to set up aquaponics systems.

IV. SUMMARY OF KEY FINDINGS

Studies on aquaponics system specific in using spinach and freshwater shrimp compared to hydroponics system set-up showed significant results. The utilization of recyclable materials help and promote environmental friendly aspect which also reduce the costs and promotes urban agriculture. For the developed solar-powered enclosed aquaponics units using deep-water culture methods is reliant on solar energy in order to operate the system which is also dependent on the availability of sunlight. In using different materials of planting beds, the only affected commodity is the yielding of crops while the fish used was not really affected. The utilization of the reconstructed aquaponics shows improved growth yields and reduces the use of chemicals, minimal usage of water and is more resilient to climate issues (Table 2).

The integration of aquaponics systems into urban planning and development requires a multi-faceted approach involving collaboration between government agencies, urban planners, environmental management of aquaponics systems to ensure social acceptance and maximize the benefits for urban food security and educational opportunities. Furthermore, the economic viability of aquaponics systems in urban areas needs to be thoroughly assessed through market research and financial analysis. Exploring various business models is crucial to adapt to different urban contexts and select the most suitable and profitable model for specific circumstances. Research and innovation opportunities for improving aquaponics systems in the Philippines should focus on optimizing growth parameters of plants and fish, exploring novel aquaponics designs, and addressing space limitations in urban areas. Finally, research into modular and scalable design, feeding strategies, water chemistry balances, disease prevention, water treatment, and financial analysis are essential for the advancement of aquaponics systems in the Philippines.

V. CONCLUSION

Urban aquaponics is a timely and significant sustainable solution to the urban growth in the Philippines. A direct replacement for conventional agriculture methods, urban aquaponics is a response to increasing urbanization and land scarcity. Because the water utilized in the system is continuously recycled and reused, it not only offers a sustainable and efficient way to produce food but also lessens the need for synthetic fertilizers, fosters family unity and mental health, and conserves the metro's water resources. Urban aquaponics has the potential to reduce reliance on foreign markets, promote local economic growth, and establish a sustainable system by reducing the need to import fish and vegetables.

In conclusion, there are advantages and disadvantages to the socioeconomics of urban aquaponics. Urban aquaponics can boost local economies, produce jobs, and offer sustainable food sources, but it also has drawbacks such a lack of available land, legal restrictions, and negative public opinion. Harnessing the full potential of urban aquaculture for sustainable urban development and food security would require new legislation, community participation, and coordinated efforts among stakeholders.

VI. TABLES AND FIGURES

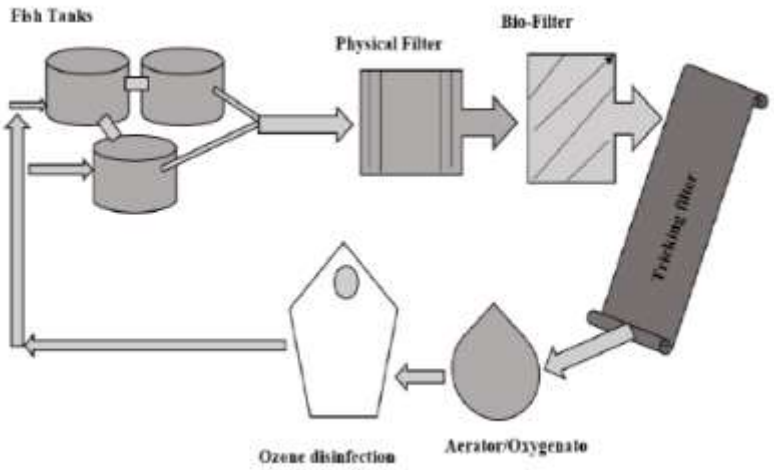

Figure 1. Components if RAS (Sugita et al., 2005)

Figure 2. Front view of the Design for the Aquaponics

Tables

Table 1. Overview of the roles and factors that affect the growth of the major organisms present in the aquaponics system.

Organism	Roles	Sensitive to
Plant	Cash crop, removes water and nutrients from fish tank	Water availability, nutrient concentrations, oxygenation, air temperature, water temperature and pH
Fish	Cash crop, generated bionutrients from feed	Fish density, feed rate, ammonia, oxygenation, water temperature and pH
Nitrifying bacteria	Biofiltration of toxic ammonia to nitrate nitrogen	Water temperature and pH, substrate to grow on, light (keep dark)

Table 2: Summary of Aquaponics system in the Philippines

Title of the Study	Plant Organism	Aquatic Organism	Results
Aquaponics designs and system in the Philippines	Water Spinach	Freshwater Prawn	Significant growth in the Aquaponics set-up compared to hydroponics
Donation of Aquaponics by DA-BFAR-NCR in Valenzuela	Tomatoes, Pechay	Tilapia	No data
Different materials as Planting Bed for Aquaponics System	Lettuce	Tilapia	Significant effect on the growth and yield of lettuce, which is valuable information for optimizing plant production in aquaponics
A solar-powered Aquaponics with IoT-Based	Wild chili, Tomato, eggplant, Bokchoy	Tilapia	More promising length and weight of the plants and fish which were cultivated in the ISFET-monitored setup compared to the other two setups.

Traditional Aquaponics and reconstructed Aquaponics	Lettuce, Tomato	Betta fish	The reconstructed aquaponics system's revealed significance results having more nourished crop rather than the traditional methods.

ACKNOWLEDGEMENTS

We extend our sincere gratitude to the National Fisheries Research and Development Institute, especially to its Executive Director Lilian C. Garcia, CESO V, and to the Bureau of Fisheries and Aquatic Resources. Their steadfast support and invaluable contributions were pivotal in the successful completion of this review article.

REFERENCES

[1]. Kulkarni, A. A., P, D., B. S., C., C.S., T. G., & Shrivastava, P. K. (2019, December 20). A Brief Study on Aquaponics: An Innovative Farming Technology. Indian Journal of Science and Technology, 12(48), 1–5. https://doi.org/10.17485/ijst/2019/v12i48/149387

[2]. Leamer, E.E., Storper, M., 2014. The Economic Geography of the Internet Age. In: Location of International Business Activities. Palgrave Macmillan UK, London, pp. 63–93. https://doi.org/10.1057/9781137472311_4.

[3]. Santos, M.J.P.L., 2016. Smart cities and urban areas—aquaponics as innovative urban agriculture. Urban For. Urban Green. 20, 402–406. https://doi.org/10.1016/j. ufug.2016.10.004

[4]. Francis-Floyd, R., C. Watson, D. Petty and D. Pouder. 2012. "Ammonia in aquatic systems." University of Florida Fisheries and Aquatic Sciences Dept. Document TA16. http://edis. ifas.ufl.edu/fa031.

[5]. Timmons, M., J. Ebeling, F. Wheaton, S. Summerfelt, and B.Vinci. 2002. Recirculating aquaculture systems, 2nd edition. North East Reg. Aquaculture Ctr. Pub. No. 01–002.

[6]. Arroyo, J., Ines, R., 2018. Design and performance evaluation of different materials as planting bed for aquaponics system. International Journal of Agriculture, Environment and Bioresearch. Vol.3 No. 01; 2018.

[7]. Guia, C.A., V. Caraig, R., S. Luna, J.A., De Jesus, B.M., C. Garibay, J.L., De Castro, J.M., & B. Torres, N. (2022). Comparative Analysis between Traditional Aquaponics and Reconstructed Aquaponics Systems in Propagating Tomatoes (Solanum lycopersicum). BOHR International Journal of Civil Engineering and Environmental Science.
https://DOI: 10.54646/bijcees.004

[8]. Rayos JC, Tunacao E ARJ, Calixto I, Lopez AR., 2022.Fish for the People. Advancing Innovative and Sustainable Food Production: urban aquaponics in the Philippines. Volume 20 Number 2: 2022

[9]. Suhl, J., Dannehl, D., Kloas, W., Baganz, D., Jobs, S., Scheibe, G., & Schmidt, U. (2016, December 1). Advanced aquaponics: Evaluation of intensive tomato production in aquaponics vs. conventional hydroponics. https://doi.org/10.1016/j.agwat.2016.10.013

[10]. Abas, S., Rosehan T., Mazlan J. 2020. Enhancement of Urban Ecosystem Services by Urban Agriculture: A Southeast Asian Perspective. Journal of Southeast Asian Studies. 2020. 25(2), 86-108. https://doi.org/10.22452/jati.vol25no2.5

[11]. Salarda, L. M. dP. (2021). Agri-Farm Tourism in Region IV-A: Basis for a Proposed Development Plan. International Journal of Multidisciplinary: Applied Business and Education Research, 2(12), 1314-1325. https://doi.org/10.11594/10.11594/ijmaber.02.12.033

[12]. Estim A., Raehanah S., Shaleh M., Rossita Shapawi R., Saufie S., Mustafa S. 2020. Maximizing Efficiency and Sustainability of Aquatic Food Production from Aquaponics Systems - A Critical Review of Challenges and Solution Options. Aquaculture Studies, 20(1), 65-72 http://doi.org/10.4194/2618-6381-v20_1_08

[13]. Sundari R. S., Arshad A., Sulistyowati L., Trisna Insan Noor T. I., and Setiawan I. 2021. Enhancing Food Security throughout Aquaponics in Urban Farming Development Strategy. Journal of Physics: Conference Series. 1764. DOI 10.1088/1742-6596/1764/1/012209

[14]. Okomoda, V T., Oladimeji, S A., Solomon, S G., Olufeagba, S., Ogah, S I., & Ikhwanuddin, M. (2022, December 18). Aquaponics production system: A review of historical perspective, opportunities, and challenges of its adoption. Wiley-Blackwell, 11(3), 1157-1165. https://doi.org/https://doi.org/10.1002/fsn3.3154

[15]. Rizal, A., Dhahiyat, Y., Zahidah., Andriani, Y., Handaka, A A., & Sahidin, A. (2018, April 1). The economic and social benefits of an aquaponic system for the integrated production of fish and water plants. IOP Publishing, 137, 012098-012098. https://doi.org/10.1088/1755-1315/137/1/012098

[16]. Arellano N. (2021, April 22). Philippines-launches-urban-aquaponics-program. Hatchery International. Philippines launches urban aquaponics program. Hatchery International. https://www.hatcheryinternational.com/philippines-launches-urban-aquaponics-program.
[17]. Haryanto, H., Ulum, M., Ibadillah, A F., Alfita, R., Aji, K., & Rizkyandi, R. (2019, April 1). Smart aquaponic system based Internet of Things (IoT). https://doi.org/10.1088/1742-6596/1211/1/012047
[18]. Evangelista R, Dipay, J. M. (2022). Smart Solar-Powered Indoor Aquaponics. Guangdianzi Jiguang/Journal of Optoelectronics Laser. 41. 46-59. https://DOI: 10050086.2022.08.6
[19]. Pollard, G., Ward, J., & Koth, B. (2017, June 15). Aquaponics in Urban Agriculture: Social Acceptance and Urban Food Planning. Multidisciplinary Digital Publishing Institute, 3(2), 39-39. https://doi.org/https://doi.org/10.3390/horticulturae3020039
[20]. Hao Y, Ding K, Xu Y, Tang Y, Liu D, Li G. 2020. States, Trends, and Future of Aquaponics Research. Sustainability. 12(18):7783. https://doi.org/10.3390/su12187783
[21]. Sugita, H., Nakamura, H., Shimada, T., 2005. Microbial communities associated with filter materials in recirculating aquaculture systems of freshwater fish. Aquaculture, 243, Pp. 403–409. https://doi.org/10.1016/j.aquaculture.2004.09.028

Joseph Christopher C. Rayos*, Jayson G. Candones, Gilda Joannah A. Calderon
National Fisheries Research and Development Institute