Advancing Innovative and Sustainable Food Production: urban aquaponics in the Philippines

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During the COVID-19 pandemic, people were looking for ways to utilize their time while they were compelled to stay at the four corners of their homes. Some dedicated their time to recreation while others spent it on livelihood. Aquaponics has become one of the emerging trends that not only served as a source of income but also contributed to food production and improvement in the well-being of the people. The project "Urban Aquaponics" under the "Plant, Plant, Plant Program" of the Department of Agriculture (DA) was launched in 2020 by the Bureau of Fisheries and Aquatic Resources (BFAR) to address the growing need for sustainable food production during the COVID-19 pandemic. The DA-BFAR conducted a social cost-benefit analysis to assess the costs and benefits of Urban Aquaponics taking into account its social impacts. The social cost-benefit analysis was applied to the small-scale model and large-scale model. In addition, the risks including threats, trade-offs, and opportunity costs were also identified.

Geoponics *vs* Aquaponics

Geoponics or traditional farming refers to the utilization of soil in the cultivation of plants. This farming method is practiced by many Filipinos as the Philippines is considered an agricultural country with vast land areas. But with the rapid population growth and urbanization, land areas are being converted for residential and commercial purposes. Consequently, traditional farming brought adverse effects such as water inefficiency, high land requirements, high nutrient consumption, and soil erosion (Alshrouf, 2017).

On the other hand, aquaponics is a sustainable food production system that combines traditional aquaculture (raising aquatic animals in tanks) with hydroponics (cultivating plants in water) in a symbiotic environment (FAO, 2022). This technology does not require soil to grow plants as it uses water as its growing medium. Through the ecological cycle of reusing the nutrients of the fish feed and waste for plant cultivation, the production of food through aquaponics is considered highly efficient (Konig *et al*., 2016). A large amount of water is conserved and efficiency is observed. Further, the cost of inputs is reduced as synthetic and commercial fertilizer is omitted with the use of fish waste as an organic fertilizer for the plants. With this, the growing problem in geoponics is addressed through aquaponics. **Figure 1** shows the cycle of an aquaponic system where fish and plants simultaneously grow.

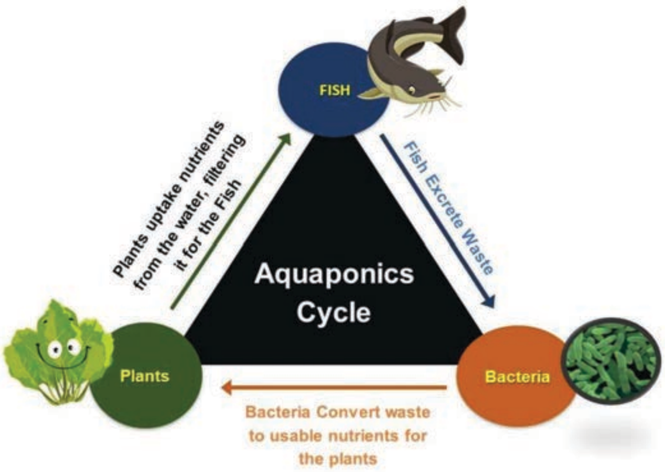

Figure 1. Aquaponics cycle

Urban Aquaponics

In the Philippines, the increased rate of urbanization and scarcity of land area in the metro call for the need for sustainable ways to utilize limited spaces. Under the "Plant, Plant, Plant Program" of the Department of Agriculture (DA), the project "Urban Aquaponics" was launched in 2020 by the Bureau of Fisheries and Aquatic Resources (BFAR) to address the growing need for sustainable food production during the COVID-19 pandemic utilizing a minimal space such as in a household backyard (Rayos and Tuñacao, 2021). Moreover, the Project was intended to introduce a cost-efficient urban aquaculture technology using a solar-powered aquaponics system to ensure food security and give access to clean and healthy food while augmenting the income of urban communities. Since launching the Project, the different regional offices of DA-BFAR have developed several models of aquaponic systems and distributed them to local government units, research institutions, academe, and non-government organizations all over the Philippines.

Social cost-benefit analysis

Since Urban Aquaponics is one of the new development projects implemented by the Government of the Philippines, the DA-BFAR conducted a social cost-benefit analysis in 2020 to assess the costs and benefits of Urban Aquaponics taking into account its social impacts. As an extension of economic cost-benefit analysis, the social cost-benefit analysis was applied to determine the personal or private and social or external effects which are intangible impacts on the society and environment. In addition, the risks including threats, trade-offs, and opportunity costs were also identified. The small-scale model (Model 1) (**Figure 2**) developed by DA-BFAR Central Office and the large-scale model (Model 2) (**Figure 3**) developed by DA-BFAR National Capital Region were used in this study.

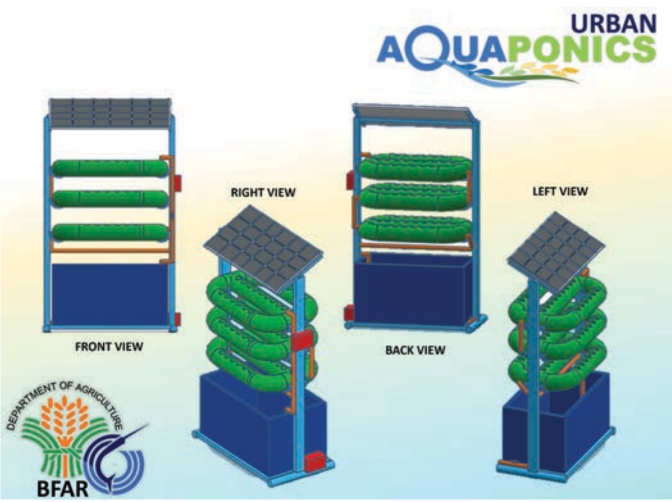

Figure 2. Urban Aquaponics Model 1: small-scale aquaponic system developed by DA-BFAR Central Office

Figure 3. Urban Aquaponics Model 2: large-scale aquaponic unit developed by the DA-BFAR National Capital Region

Model 1 is popularly known as "Isdayan ni Ani at Kita: Munting Palaisdaan at Gulayan sa Syudad" (Small-scale Fishpond and Vegetable Garden in the City). Its fiberglass tank could withstand different weather conditions and other elements. The vertical design of the aquaponic unit is space-saving which is efficient for household backyards. The water pump of Model 1 is using green energy via a solar panel which is movable and can be set to face the direction of the sun. For Model 2, the tank is made of framed canvas while the grow beds are made of PVC pipes with holes to hold the plants. The pump of Model 2 is powered by solar panels and it is also designed to use electricity as an alternative source of energy. In conducting the social cost-benefit analysis of Urban Aquaponics based on technical assumptions, the costs and benefits were identified and measured in terms of monetary value. The assumed commodities for Model 1 and Model 2 were catfish and lettuce. Catfish are vigorous and able to survive adverse conditions in aquaponics (Mamat *et al*., 2016), while lettuce has greater economic value compared to other vegetable greens in terms of yearly crop, diverse production structures, and diversity (Suslow *et al*., 2003).

The fixed cost of an aquaponic unit includes materials and labor. While the inputs such as fish, feeds, and plants are considered variable costs. The annual net income was determined by subtracting the variable cost from the annual gross income. To assess the profitability of an aquaponic unit, the return on investment (ROI) was measured by dividing the annual net income by the fixed cost. Furthermore, the payback period which is the number of years required to recuperate the initial investment was calculated by dividing the fixed cost by the annual net income.

Social Costs and Benefits

The fixed cost, variable cost, and annual net income were lower for Model 1 compared to Model 2 considering the size, materials, and other inputs. Nevertheless, both Model 1 and Model 2 were found to be profitable for having a positive ROI of 26.54 % and 24.41 %, respectively (**Table 1**). This indicated that the computed benefits or revenues exceeded the total costs incurred. With this, a household that decides to invest in Urban Aquaponics will gain profits. The revenue generated from the products sold may then be used as an additional budget and be utilized by the household to buy their basic needs. The proceeds may also be saved by the family for future and emergency use.

Besides, the payback period or the time that the investment is recovered for both Model 1 and Model 2 is less than four years. The initial investment costs spent on building an aquaponic unit could be eventually recovered in a short period. This implies that for the succeeding years, the household will only focus on investing for the production cost of the next culture period. With this, a positive cash flow will be obtained in the succeeding years and more profits will be gained while there is also enough supply of fish and vegetables for household consumption.

Table 1. Cost and return analysis

	Urban Aquaponics Model 1 (Small-scale)	Urban Aquaponics Model 2 (Large-scale)
Tank material	Fiberglass	Framed Canvas
Tank Size (height × length × width)	1.0 m × 0.7 m × 0.7 m	2.0 m × 3.0 m × 1.0 m
Stocking density	Catfish: 75 Lettuce: 54	Catfish: 700 Lettuce: 100
Culture period (no. of days/crop)	Catfish: 120 Lettuce: 30	Catfish: 120 Lettuce: 30
Annual net income (PHP)	9,556	23,800
Return on investment (%)	26.54	24.41
Payback period (no. of years)	3.77	3.79

It is also worth noting that the expected fish production from Model 1 is greater than the fish production from a pond culture. Depending on the design, the stocking rate in Urban Aquaponics ranges from 50 to 80 fish per m^2. In conventional pond culture, the stocking rate is 3–12 fish/m^2. This shows that investing in Urban Aquaponics would yield greater profits compared to growing in pond culture. In addition, vegetables are also cultivated in an aquaponic unit, unlike in pond culture which focuses entirely on fish culture. Thus, there would be more harvested produce or commodity readily available for consumption and livelihood in Urban Aquaponics.

- **Personal or private effects**

The owner of an aquaponic unit could gain personal or private effects from culturing to harvesting fish and vegetables. One is the health benefits since the farmed fish and plant commodities are safe and good quality sources of nutrients as no harmful fertilizer is used in aquaponics. Besides, managing an aquaponic unit may also be considered a simple exercise. Since the unit is built vertically, the owners tend to extend their arms to reach up the vegetables in the pipes and bend their knees when monitoring, cleaning, and harvesting the fish in the tank. These basic bodily movements may help improve the owners' flexibility and agility.

The financial gains that could be obtained from Urban Aquaponics include the income that may be generated by selling the excess fish and vegetables grown in the backyard and

Urban Aquaponics could also enhance family bonding. In carrying out the simple aquaponics process only, all household members including children and elderlies could enjoy together culturing and harvesting the fish and vegetables. Then, they can cook and eat the produce together and have a nice chat or celebration at home. Moreover, the whole family could also help each other in doing business. Each family member could be assigned in doing different tasks in the production, harvesting, processing, and marketing of fresh, cooked, or processed fish and vegetables. With this, the bond, cooperation, and teamwork are strengthened in the family.

Apart from food security and income generation, Urban Aquaponics could maintain good mental health. The COVID-19 pandemic has brought stress to people due to the restrictions on in-person gatherings and conventional assemblies to avoid social movement and prevent the spread of the virus (Tee *et al*., 2020). But with Urban Aquaponics, the owners could make their free time at home healthy and productive as they divert and focus their attention on taking care of the fish and cultivating the plants.

- **Social or external effects**

With regard to social or external benefits, Urban Aquaponics could indirectly affect the society. For instance, when a household decides to sell their excess produce, the people around them could have easy access to food as they opt to buy the produce from Urban Aquaponics. Instead of going to the local markets, people do not need to go far to buy food and their exposure to COVID-19 is minimized.

In addition, Urban Aquaponics also brings environmental benefits because of its closed-loop system. The waste of the fish provides nutrients for the vegetable and in turn, the water from the fish tank is filtered and cleaned. Through the utilization of the waste, the use of commercial fertilizer is eliminated and water is conserved.

- **Risks**

Adverse weather conditions may depreciate an aquaponic unit and degrade its performance. Also, the fluctuation of market prices may affect the projected profits. Further, Urban Aquaponics management requires technical knowledge concerning the installation and management of a unit. An aquaponic unit may not function to its full potential and lead to unfavorable results if not properly installed and maintained. For example, if the pipes are not properly aligned, water may stagnate, accumulate, and become a breeding ground for mosquitoes. This could cause threats to health such as dengue fever.

The trade-offs in investing in Urban Aquaponics that need to be considered are money, time, and space. The money spent on buying an aquaponic unit may have been spent on home appliances or saved in the bank. The time spent in maintaining an aquaponic unit may have been spent doing other recreational activities. Lastly, the space where the aquaponic unit is installed may have been utilized as storage of household materials or an area for small business endeavors.

The opportunity cost in investing in Urban Aquaponics is putting up a "sari-sari" store, a small community variety shop, on the land where an aquaponic unit is installed. In the Philippines, "sari-sari" stores are considered the backbone of the community due to their accessibility to basic household goods. A study made by Velasco (2014) revealed that 75 % of the total generated sales of a particular global food company were gained from "sari-sari" stores. Although "sari-sari" stores are conventional and profitable microbusinesses in the country, it is worth noting that innovations such as Urban Aquaponics are worth the try considering the potential socioeconomic benefits.

Conclusion

The findings from the social cost-benefit analysis of the two small-scale models of Urban Aquaponics are essential as these will help people decide to invest in Urban Aquaponics, especially when there is a need for action to address food security, health safety, and income opportunity while the world is still facing a pandemic. The results from the social cost-benefit analysis showed that the benefits outweighed the costs and risks of investing in Urban Aquaponics. Specifically, Model 1 and Model 2 are profitable and will further yield profits after the investment costs have been recovered in the succeeding years.

From its official launch in 2020, the Urban Aquaponics project of the DA-BFAR has been categorized as a national program where national and regional focal persons were designated through the Fisheries Office Order No. 174, series of 2020. The focal persons could be reached for inquiries or requests for assistance about the management of Urban Aquaponics. The support provided by DA-BFAR including the donation of aquaponic units and the provision of training and seminars would help the beneficiaries reduce start-up costs and effectively manage their aquaponic units. With this, the beneficiaries will only need to invest in production costs in operating their aquaponic units at home.

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Acknowledgments

The authors appreciate the support and management of DA-BFAR and the Philippine National Fisheries Research and Development Institute (NFRDI) to conduct the study on aquaponics.

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