Cost-Benefit Analysis of Soilless Cultivation System in Tagaytay City, Philippines

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Abstract — *The city of Tagaytay is a tourist destination that is mainly reliant on its agricultural center. As the area's commercialization grows, agricultural lands continue to decline, making agriculture's preservation increasingly challenging. Hydroponic farming is an optimal soilless cultivation method that can be presented as an alternative solution for this. This study conducted a cost-benefit analysis of an existing hydroponic farm in Tagaytay. Hydroponic farming does not require the same amount of arable land as traditional farming. Water usage is significantly less but the energy requirements may be higher though it is a more sustainable method in the long run. The findings of this study justified the feasibility of adopting hydroponic farming in the city of Tagaytay through examining the regional implications of the project as well as its environmental and social externalities.*

Keywords — *Soilless Cultivation, Soilless Farming, Tagaytay, Cost-Benefit Analysis, Case Analysis, Land Usage, Economic Viability, Effect on Environment*

I. INTRODUCTION

In 2020, the eruption of the Taal Volcano affected thousands of people residing near the area as well as numerous crops and farms. The Department of Agriculture stated that 15,000 hectares of agricultural lands have been affected and the damage and losses to agriculture are estimated at P3 billion. According to the Philippine Situation Report (2020), the most vulnerable communities are within a 14-kilometer radius which includes the city of Tagaytay. Mendiola (2020) stated that many farmers were not able to secure any of their crops as natural disasters like this are impossible to predict. She further stated that leafy vegetables are the most affected as they are on outdoor field beds and that the best way to recover is to start all over. While some farmers have the luxury of starting over, small farmers are unable to do so because of insolvency. Thus, as Sharma, et al. (2019) stated, methods for growing sufficient food should also evolve to combat natural disasters and sustain the world’s growing population. And it should cover the fast-growing demand with less cost and minimum consumption of natural resources.

As a predominantly agricultural province, the city of Tagaytay should utilize its strength of producing and growing healthy greens. According to the Ecological Profile of Tagaytay (2016), agriculture has been its traditional economic foundation and it will continue to be a significant factor in the city’s economic development. They further stated that the city of Tagaytay is one of the vital tourist destinations that significantly contributes to the country’s tourism economy as it is very accessible and near Metro Manila. As a result, the city has become one of the fastest urbanized areas and the majority of the infrastructures were built on former agricultural lands (Ecological Profile of Tagaytay, 2016). According to Briones (2008), as a result of the government’s continuous efforts to attract foreign investment, provide more job opportunities, and ease congestion on major population areas, thousands of hectares of agricultural lands have been changed to other land uses. Furthermore, large areas of fertile agricultural land are wasted as they are converted to non-agricultural uses, while environmentally sensitive, marginal regions are made available for agricultural use. As such, Sharma, et al. (2019) stated, cultivable land and conventional agricultural practices are decreasing because of rapid urbanization and industrialization.

According to Chow, et al. (2017), the hydroponic system was seen as a viable solution to the limited land area suitable for agriculture to provide better opportunities for a sustainable food supply. They further stated that it has become the fastest growing and second generation of the crop production system in the agricultural industry. Using this method, the potential reuse of treated wastewater for food crops production, governance of national water and land footprint, substantial reduction in the excessive application of agrochemicals, and potential improvement of the quality of food crops and environmental sustainability can be achieved. (Chow, et. al., 2017)

The purpose of this study was to assess the value of the implementation of hydroponic farming and determine its impact on the agricultural sector of the city of Tagaytay by conducting desk research on the current state of the agricultural sector and creating a cost-benefit analysis on hydroponic farming.

Statement of the Problem

The Department of Tourism has identified the city of Tagaytay as a priority area for tourism development. Thus, there will be a continuous increase in its urbanization. With this, preserving its agricultural sector would be more difficult as more agricultural lands would be used for non-agricultural purposes. As an alternative method of farming, hydroponic farming may be implemented to preserve the agricultural sector of the city while still being open to further urbanization for tourism.

Significance of the Study

This paper has significant implications for the preservation of the agricultural sector of the city of Tagaytay as its economic foundation. By doing a cost-benefit analysis, this paper determined the feasibility of hydroponic farming as an alternative way to preserve the city's agricultural sector while still being open for further commercialization. The paper may also be used to justify the feasibility of adopting hydroponic farming in a primarily agricultural region or country which is subject to urbanization or may face the same challenges such as the decline in soil fertility, the rise of climate change, and the adverse effects brought about by natural calamities.

Objectives of the Study

The objective of this research was to conduct a case analysis to review the fiscal and environmental benefits and weaknesses of Hydroponic Farming in the city of Tagaytay. The researchers examined and conducted a cost-benefit analysis that evaluated the efficiency and sustainability of Hydroponics as a farming alternative for regions or countries that experience difficulties in preserving their agricultural sector.

II. LITERATURE REVIEW

2.1 Agriculture in the city of Tagaytay

2.1.2 Arable Land Use in the city of Tagaytay

Based on the data provided by Cavite's Economic Agriculture data in 2009, Tagaytay City belongs to the lower group of cities that have less arable land for crop and vegetable production despite having a wide land area. Tagaytay City has 6,615 hectares of land but only 1,272 hectares are considered agricultural areas. With 2,446 farmers, an 86.29 percent efficiency was harvested with vegetables in 2009. Based on the city's soil suitability study for urban use, 4,901 hectares or 75.4% of the city could be utilized for urban development. On the other hand, 24.6% of the total land area or 1,599 hectares of strongly hilly to mountainous areas along the ridge are rated as not suitable for urban use. These strongly sloping portions of the city are currently being utilized as forests or abandoned as open grasslands. Lands suitable for diversified crops cover a total area of 4,995.25 hectares or 76.85% of the city's total land area. It was also stated that the mountainous areas along the ridge, which is too steep for cultivation, are rated as not suitable for diversified crops.

2.1.3 Vegetable Production in the city of Tagaytay

In Tagaytay City, only 64.72 hectares are planted and harvested with only 948.42 metric tons of vegetables set for production. Vegetable production in this city includes leafy, fruit, legumes, root, and bulb vegetables but for this study, the only type of vegetables to be considered is lettuce, which falls under the category of a leafy vegetable. Though Tagaytay is still primarily an agricultural province, there are inevitable damages that crops planted in this city may sustain. Due to rainfalls and ash falls from neighboring active volcanoes, traditional farming in Tagaytay remains vulnerable to a variety of pollution.

A quarter-hectare vegetable garden that earns P40,000 (about US $930) in 70 days sounds too good to be true in the Philippine hinterland where modern farming technology is wanting. But a group of women and farmers in Tagaytay, a poor farming village in Siocon, Zamboanga del Norte, is the proud owner of just such an enterprise, thanks to the spirit of bayanihan (cooperativism) of its members. A total of 12 types of high-value commercial vegetables are teeming in the group's small yet lush garden – a most welcome sight for the participants to the village's first Modelong Gulayan ng Bayan (Model Community Vegetable Farm) Festival.

2.1.4 Urban Agriculture in the city of Tagaytay

Nitural, P. (n.d.) stated that on a grand scale, urban agriculture can help ease up the problem of food scarcity in centers of population. It can help alleviate the problem and enhance the beauty of communities and homes. Above all, it can start for the future a successful massive "city farming" whose participants have a change in behavior and thinking patterns about the production of food, recycling of wastes, protection of the environment, nutrition, working together, and dignity of labor. The Department of Agriculture (DA)'s Calabarzon Regional Field Office led by Director Arnel de Mesa visited the urban farm in Tagaytay City on October 13, 2020, wherein the model farm features TDSI technology specializations such as greenhouse systems, irrigation systems, hydroponics, or soil-less system, aquaponics, and agri-tourism farm development, among others that apply modern, cost-efficient, and sustainable farm management practices. The urban agriculture farm is owned by Engr. Jose Emie Siojo, who offers farm development projects that suit local conditions and the requirements of individual farmers and agricultural corporations.

Even though the characteristics of the city are highly suitable for cultivation, topography on the other hand, is deemed as the natural constraint as it limits the available land area allotted for crops and harvests. Topography in the ridge area and eastern section of the city, which comprises only about 2,304 hectares of 34.83% of the city's total land area of 6,500 hectares that is deemed highly suitable for cultivation. Due to this natural constraint, farmers then shift to cultivating diversified crops. The adaptability of Tagaytay land to various cultivation methods proves and encourages the shifting of agricultural lands to high-income crops and urban farming can yield more produce. As of 2017, the total number of households with vegetable gardens is 1,870, most of which practice vertical farming and hydroponics.

2.1.5 Hydroponics

Hydroponics is a method of growing plants in nutrient solutions with or without the use of an inert medium such as gravel, vermiculite, rockwool, peat moss, sawdust, coir dust, coconut fiber, etc. to provide mechanical support (Sharma, et al., 2019). The term hydroponic comes from the Greek words hydro, which means water, and ponos, which means labor, and together it literally means water work. The term was coined by Professor William Gericke in the early 1930s. He described it as the growing of plants with their roots suspended in water containing mineral nutrients. Hydroponic systems typically don't require soil, which means these systems can be implemented anywhere without the need for arable land.

According to Omaye et. al., there are only little differences between soil-grown plants and hydroponically-grown plants from the perspective of plant science. In soil-grown plants, the minerals are attached to the soil particles and are passed into the soil solution where they can be absorbed by the roots of the plant. On the other hand, hydroponically grown plants use a nutrient -solution that comes into contact with the plant's roots, absorbing the minerals and water the plant needs to grow. Also, hydroponic systems are automatically operated to control the nutrients, water amount, and photoperiod--which is the period of time each day during which an organism receives illumination--based on the requirements of different crops (Resh, 2013). As a result, the growth of crops in hydroponic systems is faster than crops cultivated in soil-based systems as all the nutrients are readily available and there are no mechanical hindrances to the roots (Sharma, et al., 2019). Soilless cultivation might be commenced successfully and considered as an alternative option for growing healthy vegetables (Butler and Oebker, 2006). In addition, there are various hydroponic systems according to the recycling and reuse of nutrient solutions and supporting media. The common hydroponic systems are the wick system, drip system, ebb & flow system, deep water culture, and nutrient film technique (NFT).

2.2 Economic Viability

Economic viability evaluates various economic effects that result from an implementation of a particular project. To assess the viability of the implementation of hydroponic farming in Tagaytay City, four criteria will be used: break-even point (Zhang et. al., 2020 & Trisnanto et. al., 2020), payback period (Nurhayati & Rinda, 2021), benefit/cost ratio, and revenue/cost ratio (Trisnanto et. al., 2020).

2.2.1 Break-even Point

Break-even Point (BEP) is the time in years it takes from the establishment of the project at which the supply of a good is no longer restricted by the cost structure. (Zhang, et. al., 2020). In the BEP, the total revenue is equal to the total cost, implying that no profit was made. Furthermore, a second BEP value can be determined, which is the Philippine peso (Php) BEP value. If this value is lower than the current price, then the farm is said to be feasible (Trisnanto et. al., 2020).

2.2.2 Payback Period

Payback Period is a method that is used to determine the time it will take to recover the investment cost. It also determines the period it takes for an investment to recover when a break-even point is reached. The shorter the payback period, the more feasible the project, and vice-versa. This can also be used as a risk consideration tool, wherein the shorter the payback period is, the smaller the risk of loss will be (Nurhayati & Rinda, 2021).

2.2.3 Revenue/Cost Ratio

Revenue/Cost Ratio (R/C) is the ratio of the gross income to the total cost. This indicates if the farm is profitable, breaks even, or not profitable. If the R/C is greater than 1, it is profitable. If it is equal to 1, then it breaks even. Lastly, if it is less than 1, then it is not profitable (Trisnanto et. al., 2020).

2.2.4 Benefit/Cost Ratio

Benefit/Cost Ratio (B/C) is the ratio of the net income to the total cost. Similar to the revenue/cost ratio, it indicates if the farm is profitable, breaks even, or not profitable. The difference is if the value is greater than 0, equal to 0, or less than 0. The farm will be profitable, break even, and not profitable respectively (Trisnanto et. al. 2020).

2.2.5 Fixed Costs

Land and Building

"The land being a property or rental must be considered given that it can vary the costs" (Calling, et. al., 2018). Based on the ecological profile provided by the city government of Tagaytay, the city is considered a predominantly rural area with only 10 out of 34 districts considered urban. Tagaytay also belongs to the lower group of cities that have less arable land for crop and vegetable production despite having a wide land area. Due to the nature of hydroponic systems, arable land is no longer a necessity in hydroponic farming. The land used for hydroponic farming is not limited to open land as it can be implemented in closed places as well, such as in a house or a garage (Putra, et. al., 2018). This means that even if there is less arable land for crop and vegetable production, hydroponic systems can be used by the population of Tagaytay or by regions that are predominantly agricultural but have less arable land and/or are being urbanized.

Equipment

Equipment required for hydroponic farming varies from the different hydroponics systems used. The different hydroponics systems require different materials and the scale or size of the system depends on the preference of the individual and the type of vegetable that will be grown. In a study conducted by Putra, et. al. (2018), the Nutrient Film Technique (NFT) hydroponics system is described as the roots of the plants placed on the shallow circulating nutrient water layer, wherein the roots absorb nutrients and oxygen from the nutrient water that flows continuously using a pump. In another study conducted by Carandang, J. S. R. et. al., they used 18.5m2 of space on the rooftop of Saint Joseph Hall at the De La Salle University of the Philippines to install an NFT hydroponics installation to grow lettuce. The system consists mostly of lightweight PVC piping, which amounts to only minimal physical stress on the building. A sun positioning system was also required for the hydroponics installation to work, which consists of a nylon-tented rain and sun shelter. A key element of the system is the solar-panel water pump and aeration system, which provides the system with its own off-grid power supply, preventing energy usage from any fossil-fuel base. Other materials needed include a water and nutrient reservoir, plastic pots, a coco-peat growth medium, floral foam, and lettuce seeds.

2.2.6 Variable Costs

Water and Energy Consumption

Water is one of the most important resources for crop production. However, as water becomes scarce, the use of water conservation technologies is needed. According to Treftz & Omaye (2015), soil-based systems use 30% more water compared to hydroponic systems. Soil-based systems can negatively impact the environment with the high and inefficient use of water and the probability of plants dying are higher because of overwatering (Gashgari, et al., 2018). Moreover, most water given to the plants is inaccessible to their roots because it gets leached deep into the soil (Choi, et al., 2012). Sharma, et al. (2019) implied that in hydroponic systems, water is not wasted as it gets recovered, filtered, replenished, and recycled. The results of their study also showed that hydroponic systems can reduce irrigation water usage by 70% to 90% through recycling the run-off water and that it is possible to grow high-quality vegetables under controlled hydroponic conditions using 85 to 90% less water than soil-based systems. However, since hydroponic systems share the same nutrient, water-borne diseases are much more likely to spread from one plant to another.

Hydroponics can also be more energy-intensive than other greenhouse production systems (Cifuentes-Torres et al., 2020). Efforts to decrease the energy requirements and consumption include new designs for hydroponic greenhouses (Baddadi et al., 2019), which allow for better conservation than traditional greenhouses. The newly designed two packed beds of latent storage energy improved the indoor greenhouse environment when compared to conventional solar heating systems (Cifuentes-Torres et al., 2020). A comparison of environmental impacts between hydroponically grown lettuce in Arizona and traditional open-field agriculture revealed 11 times higher yield and 12 times less water requirement by the former, but 82 times greater energy requirement with heating and cooling as the main causes (Barbosa et. al., 2015).

However, not all hydroponic systems are energy-intensive. In a study conducted by Carandang, et. al. (2016), they set up a hydroponics pilot project on the rooftop of Saint Joseph Hall at the De La Salle University of the Philippines using the NFT system. An important part of the system was the installation of a solar panel water pump and aeration system. This meant that the NFT system would have its off-grid power supply and did not use energy from any fossil-fuel base, which led to energy savings. Another energy-efficient hydroponics system is the Simple Nutrient Addition Program (SNAP), developed by the Institute of Plant Breeding of the University of the Philippines Los Baños. It is a low-cost, low-energy, and low-maintenance hydroponics system that uses passive aeration, which does not require electricity (Ocampo & Santos, 2005). However, it must also be noted that vertical hydroponics can be done in an outdoor greenhouse, which utilizes less energy as it does not require any controlled conditions for plant cultivation.

Labor

Hydroponic agriculture is a labor and equipment-intensive venture (Podolsky, n.d.) A hydroponic farm called Pure Greens laid out its organizational structure with labor costs covering at least 57% of the budget as it is deemed the highest operating expense for all indoor farms. According to Tagle, et. al. (2019), over 60% of the variable operating costs were attributed to utilities and labor charges. Furthermore, each greenhouse unit required between 8 and 28 hours of labor every week because staff can specialize in specific duties, and larger operations were more labor-efficient. In another study by Treftz & Omaye, their hydroponics system was found to be more labor-intensive than soil-grown systems due to the time required to check and monitor the pH and ppm of the solutions. In addition to that, it takes about 1.5 hours every month to change the nutrient solution (Treftz & Omaye, 2016).

Fertilizer and Seed Consumption

Hydroponic Farming uses plant nutrients dissolved in water and are mostly in inorganic and ionic forms. All 17 elements essential for plant growth are supplied using different chemical combinations. (Sharma, et. al., 2019) The chemical combinations used do not reduce the biodiversity of the plants or the environment it is planted in.

Chow, et. al. (2017) stated that hydroponic systems are enclosed in greenhouse-type structures to prevent the control of disease and pest infections. According to Tagle, et. al. (2019), there are only a few Hydroponic Systems that use organic fertilizers in growing plants. As for seed consumption, it was stated that seed cost contributes 40-50% of the total cost of production of hydroponic systems. (Bakshi, et. al., 2017)

2.3 Land Usage and Effect on Environment

2.3.1 Carbon Footprint

Carbon footprint is the increasing amount of carbon dioxide emissions that are produced directly and indirectly by an operation or it is accumulated throughout the production of the good (Wiedmann & Minx, 2008). Rebolledo-Leiva, et al. (2017) stated that the increase of greenhouse gas emissions in the atmosphere has emerged to be one of the most threatening global environmental problems. Agricultural production is considered to be one of the primary factors that contribute to greenhouse emissions as it emits 10 – 12% of the total global greenhouse emissions (Wang, et al., 2019) such as energy consumption by farm machinery, production, and application of fertilizers, and the production of growth regulators (Rebolledo-Leiva, et al. 2017); therefore, it is urgent to reduce agricultural gas emissions and develop low-carbon agriculture. The reduction of greenhouse gas emissions per unit of economic benefits or reducing the greenhouse gas emissions generated by the farmers' activities to achieve a target economic income is one of the methods to accomplish low-carbon agriculture (Wang, et al., 2019). Vinci & Rapa (2019) stated that a farm can achieve less environmental and economic impacts by making use of waste materials and choosing a sustainable substrate, this can also be used to regulate and promote hydroponic cultivation. Furthermore, hydroponic farming has the potential to create the ideal environment and consequently increase efficiency in agricultural production compared to conventional greenhouses (Manos & Xydis, 2019). Recently from 2017 to 2019, the Nutrient Film Hydroponic Technique has been widely used in urban agriculture as it increases productivity and helps reduce carbon footprint (Silva, et al. 2020).

2.3.2 Climatic Conditions

Climate change is now deteriorating agricultural development. According to the Intergovernmental Panel on Climate Change, climate change affects crop production more negatively than positively in many regions of the world and developing countries are particularly vulnerable to more negative impacts. According to Hu, et al. (2019), the development of urban agriculture is of great environmental and economic importance, especially in terms of climate change and population growth. Lipper, et al. (2014) stated that increased climate variability aggravates production risks and threatens farmers' ability to cope, as many researchers have already warned of sharp drops in crop yields when temperatures reach critical physiological thresholds. Furthermore, climate change threatens rural and urban communities' access to food by lowering agricultural productivity and wages, rising risks, and disrupting markets. Extreme weather events can have a long-term impact on investment incentives, as increased risk and uncertainty decrease the probability of successful farm developments while increasing the likelihood of low-risk, low-return practices. However, Mendelsohn (2008) stated that the effects of climate change will be different for every developing county as well as for each region within a country. He further stated that the effects would highly depend on the current local environment, how the climate changes globally, and other local factors such as market access and soil conditions.

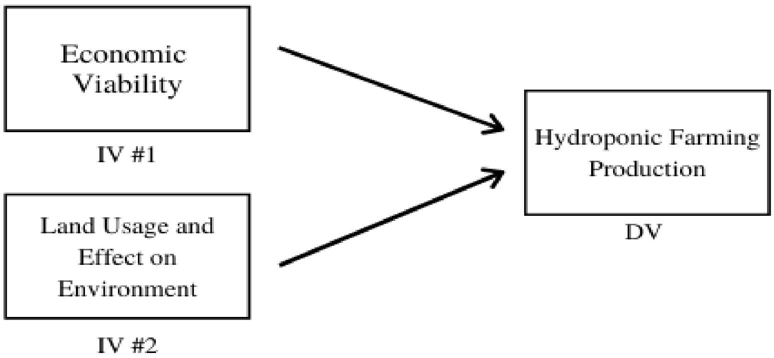
Tagaytay City's climate is characterized by relatively low temperature, low humidity, and abundant rainfall. Like most areas in the Province of Cavite, the city has two pronounced seasons: dry and wet. Almost 30-40% of the typhoons visiting the Philippines affect Tagaytay City and the most probable months of the typhoon season are from June to December, which is when crops are in peak season.

2.3.3 Cultivation of Soil

Soil-based agriculture is currently facing various challenges including urbanization, natural hazards, and climate change (Sharma, et al., 2019). Sardare & Admane (2013) stated that soil is usually the most available growing medium for plants, though it also poses the presence of diseases causing organisms and nematodes, unsuitable soil reaction, unfavorable soil compaction, poor drainage, degradation to erosion, etc. Due to this, the development of soilless agriculture has increased to sustain food production and conservation of resources such as soil and water. Soil conservation is a set of farming techniques that aims to avoid degradation, erosion, and depletion; it targets the long-term use of land by taking proper timely actions (Earth Observing System, 2020). Furthermore, Muller, et al. (2017) stated that soil conservation can decrease the environmental impacts of agriculture in the provision of food for an increasing population. According to Carvalho, et al. (2015), the hydroponic system which is a soilless production is one of the most viable alternatives for soil conservation. However, since such production uses minimal soil, it decreases soil demand for agricultural production, therefore, spares soils and their services elsewhere. Soil no longer serves as a part of the agroecological processes but rather as a support area for the infrastructure needed by the soilless systems.

Since hydroponics is considered as a soilless system, there are no soil-borne insect pests, diseases, or plant infestations to worry about thus reducing the use of pesticides (Sandare & Admane, 2013). Sharma, et al. (2019) stated that pest and disease problems are easily managed whereas weeds are practically non-existent. Soilless systems can be very effective for other countries experiencing a scarcity of arable land for agriculture such as India, where several tracts of wastelands that have poor quality soil but plenty of water can be grown in hydroponic systems (Sharma, et al. 2019).

2.4 Simulacrum



III. METHOD

3.1 Study Design

The researchers conducted a cost-benefit analysis on hydroponic farming and its opportunity costs in Tagaytay City. With this, the researchers were able to assess the benefits and disadvantages of implementing hydroponic farming in Tagaytay City, and have served as a basis in analyzing if hydroponic farming is more efficient, sustainable, and suitable under a series of economic and climatic conditions that take place within the region.

3.2 Subjects

The researchers collected primary data on hydroponic farming practices from a hydroponic farmer in Tagaytay City. The hydroponic farmer must be in Tagaytay City and must be currently conducting hydroponic farming practices. The researchers used purposive sampling as their sampling method. To gather the primary data needed, the subject must fit the profile the researchers are looking for. This makes purposive sampling the most appropriate method to use for this study.

3.3 Study Site

This study is regional as it focuses on hydroponic farms in Tagaytay City.

3.4 Instrumentation/Data Measures

The researchers used a questionnaire as the survey instrument. The purpose of the questionnaire was to acquire the data that is needed from the respondents for the cost-benefit analysis, which is based on the research objectives of this study. The questionnaire that was used is adapted from a similar study on lettuce vertical farming vs. lettuce traditional farming done by Calling, et. al. (2018). Due to the COVID-19 pandemic, the system of administration is online. The researchers reached their respondents through social media platforms such as Facebook and email.

3.5 Data Collection Procedure

The data required for the cost-benefit analysis is primary data on hydroponic farming. The researchers conducted primary data collection in Tagaytay City through the questionnaire that is adapted from a similar study conducted by Calling, et. al. (2018). The primary data was collected from a resident from Tagaytay City that engages in hydroponic farming.

3.6 Ethical Considerations

The respondent associated with hydroponic farming answered a set of questions. The questions aim to meet all the objectives of the study. The respondent is subject to full transparency regarding the study and was informed about the procedures of the study and potential risks that may come with it though there are no foreseen risks in the research conducted.

The following ethical guidelines were implemented for the research period:
1. The dignity and well-being of the respondents will be protected at all times.
2. The research data collected from the responses of the farmers will be kept confidential throughout the study.
3. The researchers will seek permission from the respondents to use the data from their farms and cultivation practices in conducting the study.

3.7 Data Analysis/Mode of Analysis

The researchers conducted a cost-benefit analysis to measure the benefits of implementing hydroponic farming minus its costs in Tagaytay City. The payback period, break-even point, revenue/cost ratio, and benefit/cost ratio was computed, which will determine if implementing hydroponic farms in Tagaytay will be beneficial for the farmers. This method was adopted from three studies entitled: Business Prospects for Hydroponic Vegetables in the Midst of the COVID-19 Pandemic: A Case Study on "Indah Berbagi Foundation" by Nurhayati & Rinda (2021), A Comprehensive Review on Sustainable Industrial Vertical Farming Using Film Farming Technology by Zhang, et. al. (2020), and Production costs and business benefits hydroponics spinach by Trisnanto et. al. (2020). This study features one independent variable (hydroponic farming production) and two dependent variables (economic viability, and land usage, and effect on environment). Hydroponic farming production was measured through its yield, crop quality, water usage, energy consumption, land usage, and fertilizer and pesticide usage. Economic viability was measured through the payback period and break-even point. Land usage and effect on environment indicates how much land was used and their corresponding effects on the environment, this variable is measured through carbon footprint and climatic conditions.

IV. RESULT AND DISCUSSION

This research aims to review the fiscal and environmental benefits and weaknesses of Hydroponic Farming in Tagaytay City by conducting a cost-benefit analysis to evaluate the efficiency and sustainability of Hydroponics as a farming alternative.

Cost-benefit analysis was used as the research method and was done by computing for the payback period and break-even point. Data was gathered from a questionnaire that our respondent, a hydroponic farmer from Gulayan nina Lolo at Lonlon, Tagaytay City, answered. The independent variable is hydroponic farming production, while the dependent variables are economic viability and land usage and effect on environment.

Farm

Gulayan nina Lolo at Lonlon is a hydroponic farm in Maitim II East, Tagaytay City, Philippines. It was established in May 2021 by the owners Nenette Baybay and Angel Jabines. The researchers were able to interview Ms. Nenette Baybay virtually through social media. Coming from a family of farmers, they realized that they had to go back to the basics if they wanted to have a stable supply of food available during the pandemic. Ultimately, going back to farming was one of the ways they saw. The main crop they grow is a variety of lettuce and the crops they grow on the side include spring onion, pechay, and bok choy. The main customers of their hydroponic farm are nearby restaurants, resellers, and regular customers who walk in to purchase. They are known for their farm-fresh lettuce.

Economic Viability

Four methods were used to assess the financial feasibility of the hydroponic farm. These methods are payback period (Nurhayati & Rinda, 2021), break-even point (Zhang, et. al. 2020 & Trisnanto et. al., 2020), revenue/cost ratio, and benefit/cost ratio (Trisnanto et. al., 2020).

4.1 Expenses and Revenue

To determine the break-even point and payback period, the fixed cost, variable cost, and revenues are needed. (Zhang, et. al., 2020). For the peso BEP value, revenue/cost ratio, and benefit/cost ratio, the total cost and total production will also be required (Trisnanto et. al., 2020). The initial investment cost of setting up the farm is Php 226,000. It consists of motor pumps, Atlanta PVC pipes, intermediate bulk containers, miscellaneous materials, and the building cost. This cost also serves as the fixed cost or the capital expense for setting up the farm. The variable cost consists of expenses on seeds, cocopeat, labor, electricity, nutrient solution, and miscellaneous costs, which get a total of Php 210,680 per year. (See Table 4.1.1). Adding the fixed cost and variable cost together gets a total cost of Php 436,680. The farm produces 2,650 cups of lettuce, 400 cups of pechay, 120 cups of bok choy, and 100 cups of spring onion per season, which lasts for 45 days. Per year, the farm produces 21,200 cups of lettuce, 3,200 cups of pechay, 960 cups of bok choy, and 800 cups of spring onion, which gives a total production of 26,160 cups. The unit price per cup for every crop is Php 20 for lettuce, Php 6.67 for pechay, Php 10 for bok choy, and Php 20 for spring onion. For all crops, this earns them a total of Php 58,868 per season or Php 470,944 per year in revenues.

Table 4.1.1

No.	**Description**	**Total Cost (Php)**
1	Seeds	5,600
2	Cocopeat	13,080
3	Labor	96,000
4	Electricity	6,000
5	Nutrient Solution	72,000
6	Miscellaneous	18,000
	Total variable costs	**210,680**

4.2 Break-even Point

Using Zhang et. al. 's method (2020), the break-even point (BEP) was determined by dividing the fixed cost by the difference between revenue and variable cost.

BEP = 226,000/(470,944 - 210,680)
BEP = 226,000/260,264
BEP = 0.87 years

Using Trisnanto et. al. 's method (2020), the Php BEP was determined by dividing the total cost by the total production per year.

BEP (Php) = 436,680/26,160

BEP (Php) = 16.69

The prices of lettuce, pechay, bok choy, and spring onion are Php 20, Php 6.67, Php 10, and Php 20 respectively. Adding these gives a total current price of Php 56.67. A Php BEP value of 16.69 indicates that Gulayan nina Lolo at Lonlon's hydroponic farm is feasible since it is lower than the total current price.

4.4 Payback Period

To determine the payback period (PP), the investment cost would be divided by the net cash flow (Nurhayati & Rinda, 2021). The revenues of Gulayan nina Lolo at Lonlon comes from the sales of their crops namely lettuce, spring onion, bok choy, and pechay. The initial investment cost of setting up the farm is Php 226,000. To get the net cash flow (NCF), the total cash outflow (variable cost) would be subtracted from the total cash inflow (revenues).

NFC = 470,944 - 210,680
NFC = Php 260,264
PP = 226,000/260,264
PP = 0.87 years

With an initial investment of Php 226,000, it will take 0.87 years or 10 months and almost two weeks from the establishment of the farm to return its investment.

4.5 Revenue/Cost Ratio

In Trisnanto et. al. 's study (2020), the revenue/cost ratio was computed by dividing the gross revenue by the total cost.

R/C ratio = 470,944/436,680
R/C ratio = 1.09

A revenue/cost ratio of 1.09 indicates that Gulayan nina Lolo at Lonlon is profitable since the value is greater than 1.

4.6 Benefit/Cost Ratio

The benefit/cost ratio was computed by dividing the net income by the total cost (Trisnanto et. al., 2020). To get the net income, the total cost would be subtracted from the revenues.

Net income = 470,944 - 436,680
Net income = 34,264
B/C ratio = 34,264/436,680
B/C ratio = 0.08

A benefit/cost ratio of 0.08 indicates that the farm is profitable since the value is greater than 0.

Land Usage and Effect on Environment

A hydroponic farm may take up a lot of land depending on the scale of the farm. The farm also has its corresponding effects on the environment, which was measured through climatic conditions and its carbon footprint.

4.6 Land Usage, Climatic Conditions, and Carbon Footprint.

Table 4.6 shows the land usage of Gulayan nina Lolo at Lonlon, as well as its carbon footprint and climatic conditions. With a total land area of 170 square meters, the hydroponic farm only takes up 120 square meters. The whole farm is enclosed in a greenhouse that uses insect-proof nets for the sides, thick ultraviolet-resistant plastic for the roof, and support from metal skeletons. Due to the simple construction of the greenhouse, it is not a temperature-controlled facility, and is therefore affected by weather conditions. This means that the production cycle, which consists of 8 cycles per year, is not consistent throughout the year for Gulayan nina Lolo at Lonlon.

Gulayan nina Lolo at Lonlon does not offer a retail store, but they supply the local restaurants around the area. Their other customers include resellers and regular walk-in customers. The nearest restaurant they supply to is approximately 500 meters away, which is just 5 minutes via car or tricycle. In cases when there is traffic, the travel time increases to 15 minutes.

Table 4.6

Land Usage	
Land Area	170 sq. mts.
Farm Area	120 sq. mts.
Climatic Conditions	
Total cycles per year	8 cycles*
Carbon Footprint	
Estimated Nearest Client	500 meters
Estimated Time of Travel	5 mins via car/tricycle

4.7 Discussion of results

Economic Viability

The hydroponic systems involved in this study required less land than soil-based systems. The hydroponic farm took up 120 square meters, which is equal to 0.012 hectares or 1,291.67 square feet. This much land was able to generate Php 58,868 after 45 days, and after one year, the potential income is Php 470,994. The potential gross income is high considering their initial investment cost of Php 226,000 and the cost of production being 210,680 per year. Constructing and running a farm of this scale requires a lot of capital to begin with. For comparison, In Zhang et. al. 's study (2020), they constructed a 6-level vertical farm that is 18,000 square feet big. That is approximately 14 times bigger than Gulayan nina Lolo at Lonlon's farm. The capital expense for the facility was at Usd 587,526.72, which is approximately Php 30 million (134 times more expensive). Their operating expenses were Usd 208,382 (Php ~11 million) per year and a yearly gross income of Usd 476,637(Php ~24 million). It can be seen here that the higher the investment cost, the higher the returns will be as well. It is also interesting to note that the total cost of Gulayan nina Lolo at Lonlon compared to their gross income is smaller. On the other hand, in Zhang et. al.'s study, their total cost is larger than their gross income. This means it will take them longer to recover the investment made compared to Gulayan nina Lolo at Lonlon's.

Since Zhang et. al. 's farm is much larger, the cost of production is correspondingly larger as well. The biggest difference between the two systems in costs lies in the sheer scale of the 6 story, 18,000 square feet vertical farm. While the operating expenses were not detailed, the capital expense of the facility alone is approximately Php 30 million with more than the Php ~11 million in operating expenses. In Gulayan nina Lolo at Lonlon's farm, labor is the costliest variable cost followed by nutrient solution. While soil-grown produce may seem to be more labor-intensive, Treftz & Omaye's study found the opposite. Their hydroponic system was more labor-intensive due to the time required to check and monitor the pH and ppm of the solutions. Additionally, Gulayan nina Lolo at Lonlon's farm is 120 square meters big, and with 26,160 cups that need monitoring per year, labor will surely be the costliest amongst all expenses. The same can probably be said with Zhang et. al. Their 6-story vertical farm may require a lot of people to operate the farm.

Due to the simple construction of Gulayan nina Lolo at Lonlon's greenhouse, the electricity cost is only at Php 6,000 for a whole year. This is in contrast with Barbosa et. al.'s study, whose energy consumption on their 815 square meter hydroponic system was at 90,000 ± 11,000 kilojoules per kilogram per year. While their paper did not provide data on electricity cost, they mentioned that their energy use consisted of heating and cooling loads, supplemental artificial lighting, and circulating pumps. Comparing this to Gulayan nina Lolo at Lonlon, they only use motor pumps. The electricity cost of a hydroponic system will depend on the scale and features of the system. Systems that are temperature-controlled and take up a lot of land will naturally have more energy usage than systems that are smaller and simpler. Looking at Zhang et. al., their Php ~30 million capital expense may indicate that their system is sophisticated and advanced, which may also indicate that their electricity cost is high as well.

A BEP of 0.87 years or 10 months and almost 2 weeks indicates that Gulayan nina Lolo at Lonlon will have to wait this long to notice a return on investments. It can also be seen that the payback period is the same as the break-even point. Zhang et. al. and Nurhayati & Rinda seem to have used a different variation of the same formula. A payback period of 0.87 years means that it will take 10 months for the investment cost to be recovered. The BEP can be reduced by reducing the costs, and a lower BEP means an improvement in the viability and sustainability of the farm (Zhang et. al., 2020). In an ideal scenario, the farm will earn Php 470,944 every year. However, since Gulayan nina Lolo at Lonlon's farm isn't equipped with features such as temperature control, factors like the weather or climate will affect the break-even point and payback period. They might not be able to produce the whole 21,160 cups a year, which can delay the break-even point and the payback period. The farm will likely take more than 0.87 years to notice a return on investments and to recover the investment cost. Regardless, the payback period and break-even point give these farmers a good idea of when they will recover their investment and notice returns. Roughly 10 months and a half is not a very long time to wait before being able to make a profit from the farm.

Looking at the Revenue/Cost Ratio and Benefit/Cost Ratio results, it can be seen that, under the assumption of ceteris paribus, it is feasible and profitable to continue running the farm. An R/C ratio of 1.09, while not that much higher than 1, is still a good sign that the farm will not be at a loss. Similarly, a B/C ratio of 0.8 is a good sign. However, these results are ideal, meaning this is the best possible outcome for the farm. In reality, several conditions affect Gulayan nina Lolo at Lonlon, especially since their farm is simple with no advanced features such as temperature control. Their farm can still be affected by climate and weather conditions, which may have an impact on production and sales. Their B/C ratio and R/C ratio indicate that the farm is profitable, but since both values are not that high, there may be times when the farm may operate at a loss due to weather and climate conditions affecting production. It is important to note that on paper, the farm may be profitable, but in reality, that won't always be the case. Nevertheless, these results are still a good indication that the farm has a future. Along with the break-even point and payback period, they can further assess if in reality, is it possible to continue running the farm.

Land Usage and Effect on Environment

Land suitable for diversified crops covers a total of 4,995. 25 hectares in Tagaytay. The hydroponic farm of Guluyan ni Lolo at Lonlon only utilizes a total of 120 square meters which is 0.012 hectares but was able to produce Php 58,868 in 45 days as the farm efficiently utilizes its area with multiple levels of Nutrient Film Technique systems.

Unlike most hydroponic systems wherein weather conditions are no longer a factor as the yield and quality of their crops are dependent on LED lights, and cooling and ventilation systems, the hydroponic system of Gulayan nina Lolo at Lonlon is placed outdoors in a greenhouse; thus, weather conditions still affect them. This eliminates one of the advantages of hydroponic farming wherein the environment can be controlled resulting in a more consistent production cycle. However, despite this, the hydroponic system was still able to yield more crops in a short amount of time than soil-based cultivation. This result establishes that hydroponic farming utilizes less land than the arable land available, while still producing more crops than soil-based systems. Moreover, this confirms that hydroponic farming can address the lack of land availability for farms caused by climate change and rapid urbanization.

Gulayan nina Lolo at Lonlon is located at Maitim II East district which is considered as one of the thirteen urban districts in the city. There are numerous restaurants, hotels, churches, terminals, and other institutions situated or nearby; hence, their main customers are restaurant owners and walk-in customers. This result further proves that hydroponic farming can be implemented anywhere without the need for arable land; thus, can be near business districts or urbanized areas. This also proves that hydroponic farming contributes to developing low-carbon agriculture as it reduces the effects of transportation on the environment since it requires a shorter travel time for their customers and less transportation of crops which is usually practiced in rural farming.

V. CONCLUSION

5.1 Conclusion

Based on the data gathered for this study, hydroponic farming has a high potential of becoming a common sustainable practice in agriculture in Tagaytay city. Tagaytay city's arable land for crop and vegetable production is significantly less despite its wide land area. The city's agricultural land is only 1,272 out of 6,615 hectares of land. The need for other agricultural solutions is evident given the challenges presented by the city's agricultural sector. In addition to this, Tagaytay city is prone to abundant rainfalls and ash falls from surrounding active volcanoes, which makes farming vulnerable. Urban agriculture is seen as one of the solutions to help address the problem of food scarcity and since vertical farming and hydroponics are already being used in households with vegetable gardens, it is vital to continue adopting this method to further develop the agricultural sector, as it is one of the traditional economic bases of Tagaytay, and it is a significant sector in the city's economic development.

Hydroponics has several benefits for the environment since it utilizes water more efficiently compared to soil-based systems. Soil-based systems have high and inefficient use of water, and the probability of plants dying is higher due to overwatering. In a hydroponic system, the nutrients' water amount and photoperiod are automatically operated, and the water is not wasted because it is recovered, filtered, and recycled. Since it is also a soilless system, there are no soil-borne insect pests, diseases, or plant infestations. Pest and disease problems are easier to manage, and weeds are non-existent. However, water-borne diseases are more likely to spread from one plant to another, and hydroponics also can be more energy-intensive than other greenhouse production systems, but it can also be less energy-intensive depending on the scale of the farm. But overall, hydroponic systems can potentially create the ideal environment and increase efficiency in agricultural production. It also increases productivity and helps reduce carbon footprint altogether.

Financially, hydroponics may be highly profitable, but high capital is required for high profit. A smaller capital can be used, but the payback period will be longer and it won't be as profitable compared to a system that is well funded. In the data collected, the potential income is Php 470,944 per year. For the investment cost/fixed cost of Php 266,000, the variable cost of Php 210,680, and net cash flow of Php 260,264, the payback period and break-even point would be 0.87 years. This indicates that hydroponics in Tagaytay is worth investing into, as it has a relatively short payback period and break-even point. An R/C Ratio of 1.09 (greater than 1) and a B/C ratio of 0.8 (greater than 0) indicates that the farm is profitable.

5.2 Recommendations

Based on all the information and evidence gathered by the researchers, hydroponics is an urban agricultural technique that is worth investing into. Tahseen, et. al. (2016) also stated that crop production using a hydroponic system gave the highest yields, faster, and with decreased production costs compared to other cultivation methods. In addition, the fiscal and environmental benefits of the technique are more efficient and effective than soil-based cultivation, though there are still some challenges that come with it such as the heightened costs in labor. The researchers recommend that further research in the hydroponic technique be done to further address these challenges, and that hydroponics must be applied to help address the current issues in the agricultural sector of Tagaytay city, or any region of a country, in particular, that is subject to its own environmental and social externalities.

5.3 Summary

This study was created to assess the value of the implementation of hydroponic farming and to determine its impact on the agricultural sector of the city of Tagaytay. The objective was to review the fiscal and environmental benefits and weaknesses of hydroponic farming in the city of Tagaytay. With these in mind, the researchers conducted a cost-benefit analysis on hydroponic farming and its opportunity costs in Tagaytay city. The data collected for this study is primary data, which was obtained through a questionnaire that was adapted from a similar study by Calling, et. al. (2018)

The research site is Gulayan ni Lolo at ni Lonlon, a hydroponic farm in Tagaytay City. The respondent was contacted through social media, and the questionnaire was answered online due to COVID-19 pandemic restrictions. The study used purposive sampling, where the participants had to fit the profile needed for the study.

The results shown by the data gathered were consistent with previous studies. For this study, lettuce, spring onion, bok choy, and pechay are the crops being produced. Per year, all crops could earn Php 470,944, and for an investment cost/fixed of Php 226,000, the variable cost of Php 210,680, and net cash flow of Php 260,264, the payback period and break-even point would be 0.87 years, and an R/C and B/C ratio of 1.09 and 0.8 respectively. The payback period and break-even points are very short, and with the R/C and B/C ratios, the farm is feasible and profitable.

The fiscal and environmental effects found in the previous studies which state that hydroponic farming is a more effective and efficient cultivation method are consistent with the findings in this study. Though more costly in labor expenses, hydroponics is considered more sustainable than soil-based farming since less water is used and every square meter of land is maximized, crops also double in number as well as the corresponding profit earned per harvesting season. There is also no need for pesticide and fertilizer use. As such, a significant amount of additional costs for farming is cut down. The researchers suggest that hydroponic farming techniques should be adapted and further studied to develop the agricultural sector in Tagaytay city and neighboring regions or countries that also face a decrease in soil fertility and arable land brought about by urbanization, commercialization, climate change, or natural calamities.

5.4 Policy Implications

The study is evidence that hydroponic farming is a sustainable agricultural practice that would benefit Tagaytay city. Tagaytay City is facing challenges brought upon by the fast-paced urban development projects and the infrastructures being built on agricultural lands. Thousands of hectares of agricultural lands have been changed to other land uses and due to the decreasing amount of cultivable land and conventional agricultural practices, there is a need to venture into other agricultural techniques to solve the problem.

Currently, there is an Urban Agri Hydro Hub Learning Center at The Pop-Up, Katipunan in Quezon City. This is a project in collaboration of the Department of Agriculture with the Philippine Association of Agriculturists Inc., University of the Philippines Diliman - Institute of Biology, and The Freshest, with the aim to influence people to start their own urban farm. The study can contribute to its lectures on hydroponics, which will be regularly conducted in their center.

APPENDIX

Interviewer Considerations

The interviewer has to inform the farmers before starting the survey that their answers will be anonymous. They may, at any time, withdraw their participation, including the withdrawal of any information they have provided. If they complete the interview, however, it will be understood that they have consented to participate in this research and agree to the publication of the overall results of this research with the understanding that the anonymity of the interviewees will be taken into account.

HYDROPONIC FARMER				
PARTICULARS	**TYPE(s)**	**QUANTITY**	**INITIAL COST**	**CURRENT COST**
Land Area				
Building *(Construction)*				
Equipment: *(note: you may add equipments that are not stated below)*				
LED *(Light Emitting Diode)*				

Auto Dosing System				
Intermediate Bulk Containers *(IBC TANK)*				
NFT Channels				
Employees *(Organizational Structure)*				
Lettuce seeds per production cycle				
Number of cycles per year (lettuce)				
Number of cups per lettuce				
Grams per cup of lettuce				
How many plots are used?				
Fertilizer per production cycle				
Pesticide per production cycle				
Nutrient solution				
Annual water expenses				
Annual electricity expenses				
Price of lettuce per kg or cup				
Unit price per kg				
Number of harvests annually				

Length of growing crops in days				
Total yield per plant				
Depreciation Rate (expected life span of the hydroponic farm)				
Miscellaneous				

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