Economic Analysis of an Urban Vertical Garden for Hydroponic Production of Lettuce (Lactuca sativa)*

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Abstract.

A household module of tropical greenhouse was constructed for leafy vegetable production. The system uses a 35-watt submersible pump to lift the nutrient solution up from the reservoir to the uppermost growing tubes that are configured vertically to accommodate more plants and have cutouts to hold plastic cups for seedlings to be grown hydroponically. The system costs PhP 50,000.00 and grows 560 plants with a net weight of 26.6 kg in 30 days after transplanting. When sold at PhP 150.00 per kg, an annual gross income of PhP 47,900.00 is obtained. A total cost of PhP 23,994.00 per year was determined when fixed cost of PhP 5,550.00 and variable cost of PhP 18,444.00 were added. Unit price, which is computed by dividing total variable cost by the total weight of lettuce per year, is PhP 57.78 per kg. Results revealed that the annual net income and gross margin is PhP 23,906.00 and PhP 29,456.20, respectively; payback period is 2.1 years; break-even point is 60.20 kg per annum; benefit-cost ratio of 1.56 and the net present worth of PhP 129,084.05 per year. These proved that the household module for hydroponic lettuce production is profitable to operate within the locality.

Key words: Economic analysis, urban vertical garden, recirculating hydroponics, household module, lettuce production

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1. INTRODUCTION

The Philippines has been teased as a country of meat-eaters. Though an agricultural country, an increasing trend of meat consumption with 20.3 percent in 1978 to 28 percent in 2003 alarmed the government (Mabutas, 2011). Report from the Food and Nutrition Research Institute (FNRI) showed that Filipinos, who only consume 40 kg of vegetables per capita in 2003, were one of the lowest vegetable consumers in Asia. Data from the National Nutrition Council (NNC) confirmed that, for years, the country's vegetables consumption was way below the recommendation of the FNRI of 69 kg per capita and that of the World Health Organization (WHO) of 146-182 kg per capita. According to the WHO, the country's low vegetable consumption was one of causes of the increased incidence of illnesses in the country (FAO, 2011). The NNC added that children aged 0-10 are height-stunted, underweight and some are suffering from acute malnutrition.

Addressing these issues, the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development of the Department of Science and Technology (DOST-PCAARRD) has embarked on programs called smarter agriculture. One of its objectives is to promote soiless farming in order to increase vegetable productivity of high-value vegetables using earth's limited resources even in unproductive space. A demonstration and experimental station for hydroponics has been developed in an 8,000 sq m rice field at Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines. Aquaponics was also added as a special feature. The aim of the project is to develop technology packages for tomato, melon, cucumber, bell pepper, leafy vegetables like lettuce, water spinach and pak choi and several herbs under protected structure.

2. REVIEW OF LITERATURE

Hydroponic vegetable production is still in its infancy in the Philippines. The technology is only practiced by research institutions and hobbyists as many perceived it as an expensive business venture (Peñaranda, 2007). To encourage Filipinos to invest in this endeavor, a feasibility study is therefore necessary to evaluate its viability and determine what scenario would give the minimum inputs with a maximum output (Hofstarnd and Holz-Clause, 2013).

2.1 History and concept of hydroponics technology

Hydroponics, otherwise known as soiless culture, was derived from two Greek words, *hydro*, meaning water and *ponos* meaning labor - literally "water-working". Dr. William F. Gericke of the University of California coined the word hydroponics in the late 1929. Historically, hydroponics was popularized by the Aztecs, an American wandering tribe (150-1130 CE), by using *chinampas* or "floating garden". The Aztecs established the system when they were harshly treated by their neighbors and driven to the Lake Tenochtitlan, the present day Mexico City. With no land to till, the tribe endured by constructing rafts from branches and reeds and stacking soil scoured from the bottom of the lake. The Aztecs successfully produced various crops that sustained and saved them from hunger. The *chinampas*, which were established in a gamble, have prospered to rebuild the tribe and met the requirements of the growing empire until they capture their oppressors (Rahman, 1994; Barry, 1996). Interestingly, many scientists considered that the concept is the first viable design of sustainable agriculture and predicted that it will play key role in shaping the future agriculture (Sace, and Fitzsimmons, 2013).

Hydroponics has evolved from man's curiosity to determine what substances make plant grow and what compose plants. Plant physiologists discovered in the 1800's that plants absorb essential mineral nutrients as inorganic ions in water. They found out that, in natural conditions, soil acts as a mineral nutrient reservoir, but the soil itself is not essential to plant growth. This means that soil is no longer crucial for the plant to thrive when the required mineral nutrients are introduced artificially into a plant's water supply and plant roots are able to absorb them (Sace, and Agulto, 2013).

The experiment of van Helmont with a willow tree proved that the soil only keeps the plant upright and water is almost all in all to make nutrients available to plants (Weijie, 2001). All of this is made possible by the relationship of a plant with its growing medium showing that it is the reserved nutrients and moisture contained in the soil that nourish the plant, not the soil (Rorabaugh, 2011).

2.2. Monitoring the nutrient solution

Three very important parameters in plant nutrition need to be monitored: the pH, the total dissolved solids and the temperature. Ideally, most plants grow within a pH range of 5.8 to 6.8 with level 6.3 as optimal. At this range, nutrients will be most available for plant to absorb, as shown in Figure 1. It is best to use a nutrient between 800 and 1,200 ppm, unless the specific requirement of a given crop is known. Plant roots function best at a temperature range 18-22ºC. At this temperature range, the water is warm enough to stimulate good growth rates but at the same time cool enough to carry maximum oxygen content (Resh, 2006). However, nutritional problems may occur if these parameters are not sustained (Barry, 1996; Jensen, 1991).

2.3. The lettuce cultivar

Lettuce (*Lactuca sativa*), an annual plant of the daisy family Asteraceae, is one of the vegetables commonly cultivated in the upland. There are five different types of lettuce. Leaf lettuce, also called loose-leaf lettuce, is the most widely cultivated type that produces crisp leaves loosely arranged on the stalk. Cos or Romaine is an excellent addition to salads and sandwiches and forms an upright, elongated head. Crisphead, better known as "iceberg" lettuce, the most popular but is very heat-sensitive. Butterhead type has tender, soft leaves with a delicate sweet flavor is normally small and loose-heading type. Stem lettuce is also called asparagus lettuce and forms an enlarged seedstalk that is used mainly in stewed, creamed and Chinese dishes (Sanders, 2001; Davis, and Kendall 2014; Kerns, et al., 2001).

Lettuce normally thrives when the daily temperature is about 15 to 22°C. Although some varieties withstand heat better than others, stunted growth and leaves have bitter taste when the temperature is high. It is rarely allowed to grow to maturity as it becomes bitter and unsalable because of bolting. It is a good source of vitamin A, potassium, as well as several other vitamins and nutrients. Despite its beneficial properties, contaminated lettuce is often a source of bacterial, viral and parasitic outbreaks in humans, including Escherichia coli and Salmonella (Davis, and Kendall, 2014; Barry, 1996; Jensen, 1991).

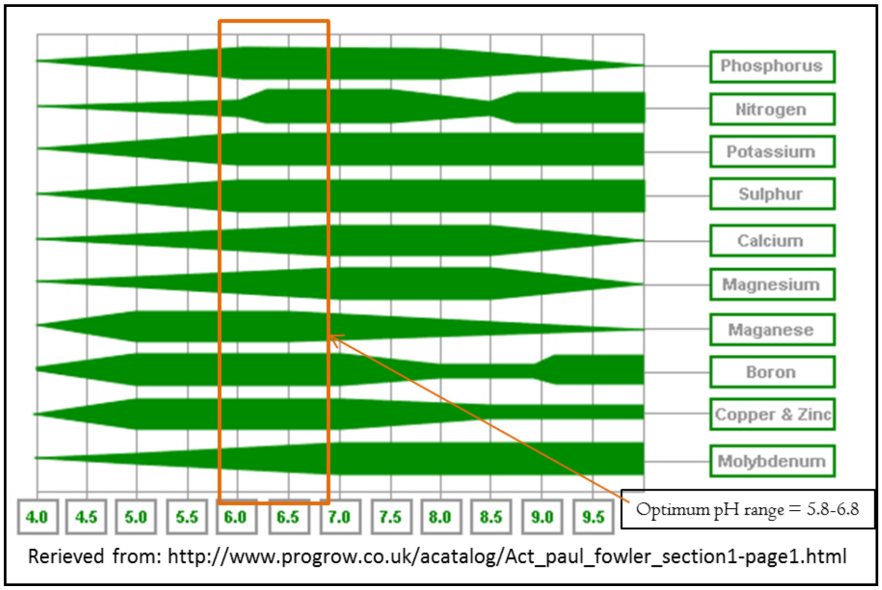

Figure 1. The availability of nutrients as affected by pH

2.4. The economic criteria

This takes into account the opportunity costs of resources used and attempts to measure in monetary terms the costs and benefits of a project. Four criteria used in assessing the viability of an investment are presented below (Sace, 2000; Sace, 2007).

2.4.1. Payback Period

Payback period (PP) is the length of time it will take for the investment to return its original cost or the number of years required for cash inflows to just equal cash outflows. It is often called simple payout method, which indicates the project liquidity rather than profitability. The computation does not address the total profitability of the project, rather it simply calculates how fast a project recovers its cash investment.

2.4.2. Break-even Point

Break-even point (BEP) analysis represents the point where there is just sufficient revenue to cover the costs or the point where the total cost and the total gross revenue intersects. It is a method used more frequently to demonstrate the probable effects of change than to determine what those changes should be. BEP is significantly impacted by fixed and variable costs. By conservatively reducing the cost on inputs, BEP can be reduced thus maximizing the profit.

2.4.3. Benefit/Cost Ratio

Benefit-cost ratio (BCR) is an indicator that summarizes the overall value of money of a project. It is a ratio of discounted benefits to discounted costs expressed in monetary terms. It is an accepted procedure for making go/no-go decisions on projects as compared to alternatives. If the value of BCR > 1, the project is feasible.

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2.4.4. Net Present Worth

Net present worth (NPW) method is based on the concept of equivalent worth of all the cash flows relative to some base or beginning point in time called the present. It is a measure of how much money an individual or a firm could afford to pay for the investment in excess of its costs. If the value of PW >1.0, then the project is feasible.

3. MATERIALS AND METHODS

3.1 The construction of the system

The system is enclosed in a tropical greenhouse measuring 2.5 m high x 3.2 m wide x 3.6 m long and is fabricated from locally available materials. The greenhouse is made up of galvanized iron pipes bended and welded together to form a Quonset-type structure as shown in Figure 2. The structure has three roof covers: the gray woven nets on the outer, the ultra-violet plastic film in the middle and the insect-proof net in the inner. Together, the covers provide strength and improve aerodynamics to withstand strong wind gust and heavy rain. A footbath is installed at the entrance door (Bucklin, 2008).

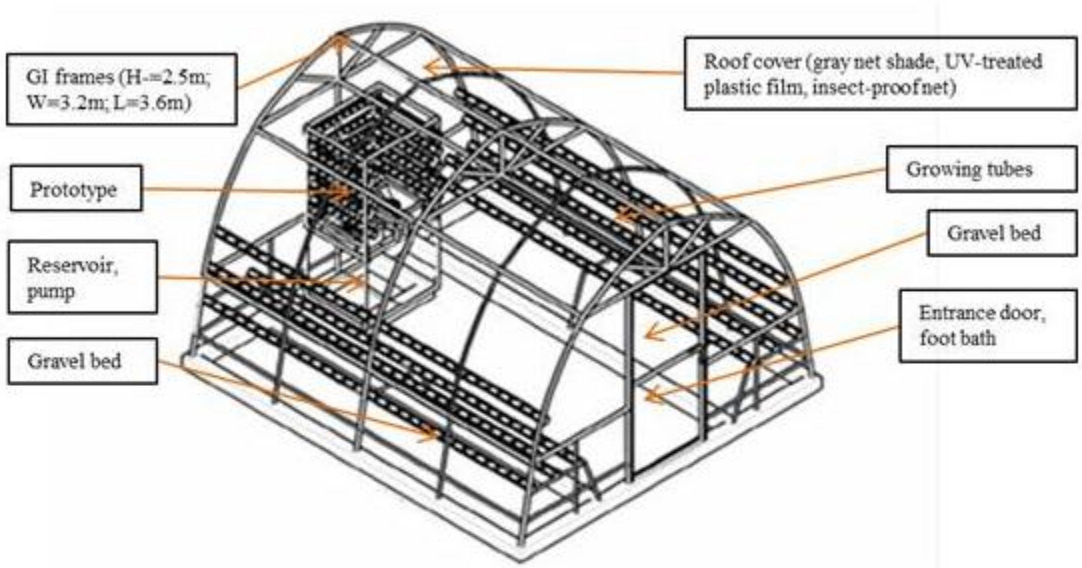

Figure 2. Schematic diagram of the greenhouse showing the production system

The system is comprised of growing tubes made from 2” diameter PVC pipes interconnected by rubber hose, frame made from galvanized iron pipes to set growing tubes vertically, a filter basin containing pumice, a plastic tank to contain the nutrient solution, a submersible pump to lift the nutrient solution and a float switch to automate the system. At the rear end is a vertical frame measuring 1.6 m high x 0.6 m wide x 0.8 m long were five layers of growing tubes rests securely on the frame. Another two layers of growing tubes are hanging on the left and right side walls. The same type of growing tubes rest on the frames on both sides of the greenhouse, about half meter above gravel beds and described on Table 1.

Table 1. Description of the greenhouse

Type:	Tropical greenhouse for vegetable production; Quonset-type
Model:	Household module
Dimension:	2.5 m high x 3.2 m wide x 3.6 m long
Sides and roof cover:	Three layers of cover: insect-proof net, ultra-violet resistant plastic film and 60% gray net shading
Metal frame:	Galvanized iron pipe; Diameter =1/2” 1and 3/4"; S20
Fertigation unit:	Powered by 35-watt submersible pump, AC
Growing systems:	Vertical growing tubes configured to allow nutrient solution to cascade down to the gravel beds and drain back to the tank

The growing tubes contain cutouts each to hold planting cups. The cups were securely seated on each cutout of the frame and contain mixture of coconut peat, rice hull and carbonized rice hull as growing media. Each cup has holes on the side and bottom surfaces to permit capillary action of the nutrient solution into the media as well as to allow the plant roots to extend into the duct and make contact with the nutrient solution. A float switch controls switching mechanism of the low-head submersible pump running intermittently every 15 minutes to lift the nutrient solution from the tank to the uppermost layer of the growing tubes. The nutrient solution enters the uppermost layer of the growing tubes and cascade down to the lowest layer passing through the filter by gravity and back to the tank (Figure 3).

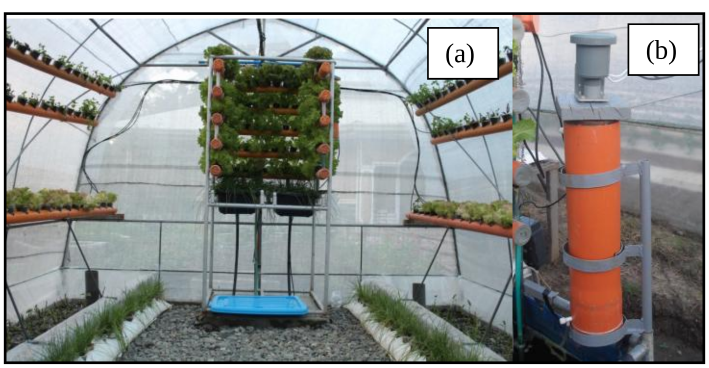

Figure 3. The interior of the structure showing the growing tubes (a) and the float switch (b)

3.2. Nutrient solution management

The nutrient solution is managed by following these procedures:

1. Fill the tank with clean water and run the system for about an hour to check for leaks and whether the float switch is functioning properly. Remove the water from the tank to make sure that the system will start with fresh and clean solution. Fill the tank again with 49 liters of water.

2. Mix 0.5 liter of Solution A and 0.5 liter of \olution B for every 49 liters of water to make a 50-liter solution in the tank. Water from the tap is normally chlorinated and should be allowed to stand for a night to volatilize. Rainwater, when properly harvested, is a better option.

3. Monitor the quality of nutrient solution. The electric conductivity (EC), pH, temperature and dissolved oxygen (DO) should be maintained at optimal level. EC ranges from 1.0 to 1.3 mS/cm, pH from 5.8 to 6.8, and DO of greater than 5 ppm. When pH is high, suitable amount of sulfuric acid (H_2SO_4) is added to bring it down while potash is added to bring the pH up. The nutrient solution is indeed the heart of hydroponics. Maintaining its quality will define the success and failure of any system.

3.3 Data gathering

Lettuce was harvested every 30 days after transplanting. Seedlings, which were propagated 12 days prior to harvesting, were transplanted right after harvest. From October 2014 to March 2015, a record of the weight of harvest was kept as shown in Table 2. The harvest was sold at the local market at prevailing price. Average weight was computed by dividing the total weight by the total number of plants and was used as basis in the computation of income and in the economic analysis.

Table 2. Yield of lettuce during the growing seasons

Months	Yield, g	Average yield, g
October	26,552	47.41
November	27,013	48.24
December	27,020	48.25
January	28,003	50.01
February	26,704	47.69
March	26,003	46.43
Average yield, g		**48.00**

4. RESULTS AND DISCUSSION

4.1 The cultural management

Though several leafy vegetables can be planted, Carlo Rosa variety of lettuce, acquired from a reputed seed distributor in the country, was selected (Figure 4). Carlo Rosa, according company’s description, is a popular heat tolerant lettuce variety with circular crown of heavily frilled medium green leaves tipped with strong, warm red tinge. It has very uniform leave expansion and strong against bolting.

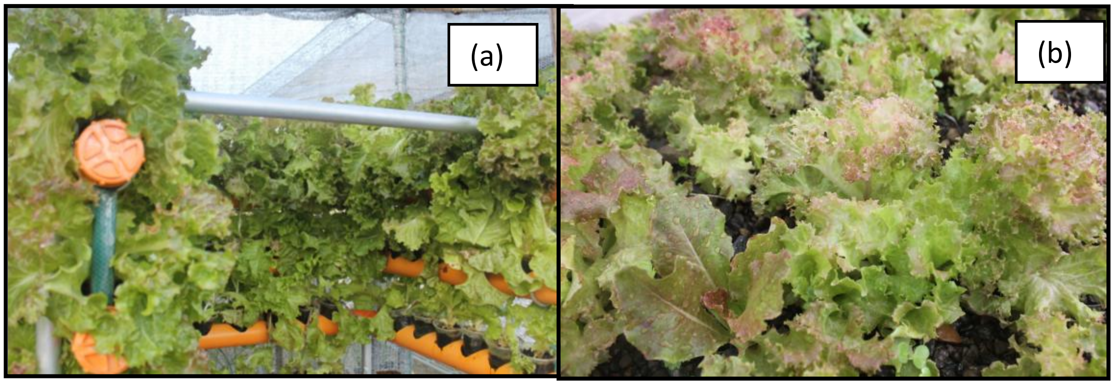

Figure 4. Carlo Rosa variety lettuce growing on the tubes (a) and on the gravel bed (b)

Seeds were evenly sown on seedbed containing an equal ratio of coconut peat, fine sand, rice hull and carbonized rice hull. The bed was regularly sprayed with hydroponic solution with an EC of 0.5 to 1 mS/cm. Seedlings were transplanted on cups filled with similar mixture of growing media used in the seedbed. The cups were inserted on the cutouts of the growing tubes in the prototype, in the sidewalls of the greenhouse and in the gravel bed. The system accommodated 560 cups of lettuce.

The pH of the system was monitored every morning throughout the growing season and set to optimum range of 5.8 to 6.8. The total dissolved solid was maintained in the range of 1 to 2 mS/cm. The temperature inside the greenhouse varies every day; cooler in the morning and gets hotter during the day which range from 20°C to 33°C while that of the nutrient solution ranges from 22°C to 29°C. These temperature levels, recorded during the months of February and March, were above the normal range and resulted to stunted growth, bitter taste and light coloration to some of the leaves of lettuce.

4.2 Potential income

The average harvest of six production cycles was presented in Table 3 shows. The system accommodated a total of 560 cups of lettuce. Lettuce was grown for 30 days and each plant gained an average weight of 48 g or a total weight of 26.6 kg. The harvest was sold at PhP150.00 per kg and a gross sale of PhP 3,991.70 per growing season or PhP 47,900.16 per year.

Table 3. Potential income of lettuce variety Carlo Rosa

Crop grown:	**Lettuce**
Variety:	**Carlo Rosa**
Growing periods:	**Six (6)**
Potential Production	
Total area:	3.2 m x 3.6 m

Number of cups:	560
Maturity:	30 days
Average yield per plant:	48 grams
Total yield:	26.6 kg
Unit price per kg	PhP150.00
Potential gross income per season:	PhP **3,991.70**
Potential gross income per year:	PhP **47,900.40**

4.3 Cost of production

The cost of production, which is composed of total fixed and variable costs, was tabulated in Table 4. Item under total fixed cost is average interest on investment (AII) and depreciation (Dep'n). AII, the effects of inflation on investments and savings, was PhP 275.00 per cropping season. Dep'n, computed using straight line method, was PhP 187.50. The two items, when added, make a total of PhP 462.50.

The repair and maintenance (R&M) and other inputs for seeds, labor, fertilizers, chemicals, electricity and other miscellaneous expenses made up the total variable cost per cropping season. The cost of R&M for the materials and labor for replacing the roof and side plastic covers which are expected to wear and be replaced in five to six years was assumed at PhP 83.00. This cost plus the costs of other inputs of PhP 1,454.00 are equal to PhP 1,537.00. Adding these costs will give the total operating cost that is equal to PhP 1,999.50.

From these values, it is interesting to note that, with 560 hills of lettuce in the greenhouse measuring 3.2 m x 3.6 m, the plant density is about 48.6 hills per square meter per cropping or about 28 kg of lettuce per square meter annually. This also means that there is about or about 2.33 kg of lettuce per square meter of greenhouse floor area. This is equal to annual gross income per square meter of about PhP4,155.00 or PhP 345.00 per cropping season when multiplied by the selling price PhP 150.00 per kilogram. Net income, computed when total cost is subtracted from the gross income, is equal to PhP 1992.20 per cropping season or PhP 23,906.00 annually. Gross margin per cropping season is about PhP 2,454.70 or PhP 29,456.20 annually when the total variable cost is deducted from the gross income. Unit price, which is computed by dividing total variable cost by the total weight of lettuce per year, is only PhP 57.80 per kg.

Table 4. The total fixed cost, total variable cost and total cost of operation of the system

ITEMS	PER SEASON, PhP	PER YEAR
A. Fixed Costs, P		
1. Average interest in investment (AII)	275.00	3,300.00
2. Depreciation (Dep'n)	187.50	2,250.00
Sub-total	**462.50**	**5,550.00**
B. Variable Costs, P		

1. Repair and Maintenance (R&M)	83.00	996.00
2. Seeds	180.00	2,160.00
3. Labor	900.00	10,800.00
4. Electricity	122.00	1,464.00
5. Nutrient solution	52.00	624.00
6. Miscellaneous	200.00	2,400.00
Sub-total	**1,537.00**	**18,444.00**
C. Total Costs, P	**1,999.50**	**23,994.00**

Computation:

A.1 AII = 12% [(Initial cost + salvage value)] / 2
= 12% [(P50,000.00 + P 5,000.00)] / 2
= P 3,300.00 / year
= P 275.00 / cropping

A.2 Dep'n = (Initial Cost – Salvage value) / Life span
= (P 50,000.00 – P 5,000.00) / 20 years
= P 2,250.00 / year
= P 187.50 /cropping

B.1 R & M = 2% / year (Initial cost)
= 0.02 (P 50,000.00) / year
= P 996.00 / year
= P83.00 / cropping

4.3 The economic analysis

Four basic methods were used to assess the financial feasibility of the unit of PhP 50,000.00 hydroponics system. These methods are payback period, break-even analysis, benefit/cost ratio and net present worth method.

4.3.1. Payback Period

Payback period (PP) was computed by dividing the investment cost (IC) by the annual net income (ANI). PP expressed the number of years or months to recover the investment. Using the formula below, the project requires only 2.1 years or 2 years and one month.

PP = IC / ANI
= PhP 50,000/ PhP 23,906.16
= 2.1 years

Where: PP = Payback Period
IC = Investment cost
ANI = Annual net income

4.3.2. Break-even point

The break-even point (BEP) was analyzed by dividing the total fixed cost (TFC) of PhP 5,550.00 by the difference of the selling price (sp) of PhP 150.00 per kg and the unit price (up) of PhP 57.80 per kg. The project has 60.20 kg per year BEP which expresses the point of intersection of the total cost and the total gross income that suggests a no-profit-no-loss situation. When multiplied by the unit price gives PhP 3,479.60 per year. These values were depicted in Figure 5.

BEP = TFC / (sp – up), kg/ year
= PhP 5,550.00/ (PhP 150- PhP 57.76) / kg
= 60.20 kg/yr, or
= PhP 3,479.60/year

Where: BEP = Break-even point; the volume where total equals total cost
TFC = Total fixed cost per year
sp = Selling price per kg
up = Cost per kg
= TVC / (Total wt / yr)
= PhP 18,444.00 / 319.2 kg
= PhP 57.80 / kg

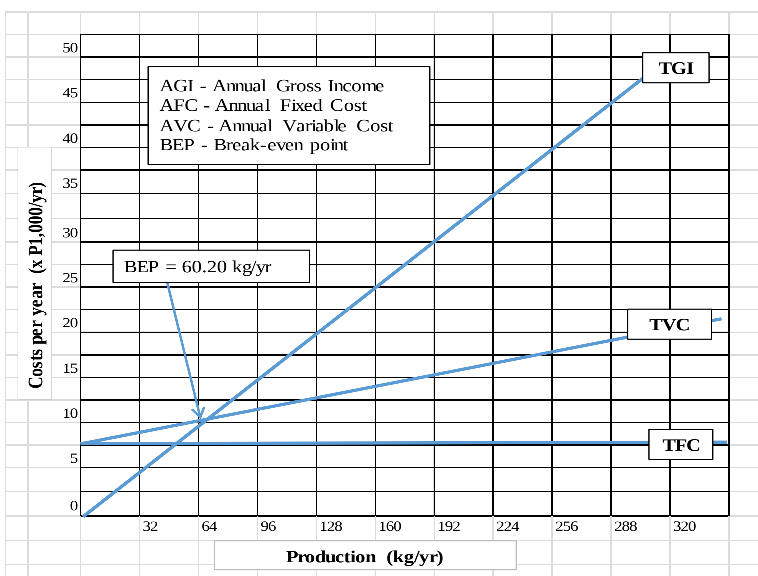

Figure 5. The break-even point showing no-profit-no-loss situation

4.3.3. Benefit/Cost Ratio (BCR) Method

Benefit-cost ratio (BCR) is a ratio of discounted benefits to discounted costs. It is an accepted procedure for making go/no-go decisions on projects as compared to alternatives. If the value of BCR > 1.0 the project is feasible.

BCR = PWB / (PWC + IC)

PWB = AGI (P/A, I%, N)
= PhP 4,7900.16 (P/A, 12%, 20)
= PhP 855, 360.00 (7.46944)
= PhP 357,787.54

PWC = ATC (P/A, I%, N) – SV (P/F, I%, N)
= PhP 23,994.00 (P/A, 12%, 30) – PhP 5000.00(P/F, 12%, 20)
= PhP 23,994.00 (7.46944) – PhP 5000.00(.103667)
= PhP 178,703.50

BCR = PWB / (PWC + IC)
= PhP 357,787.54/ (PhP 178,703.50+ PhP 50,000.00)
= 1.56

Where:

BCR	=	Benefit/Cost Ratio
PWB	=	Present Worth Benefits
PWC	=	Present Worth Costs
IC	=	Investment Cost
ATC	=	Annual Total Costs
SV	=	Salvage Value of investment cost
I%	=	Interest rate in investment cost
N	=	Life Span of the project
AGI	=	Annual Gross Income
I2%	=	Interest rate in investment cost

NOTE: Since BCR = 1.56 > 1.0, then the project is feasible.

4.3.4. Net Present Worth (NPW) Method

Net present worth method is based on the concept of equivalent worth of all the cash flows relative to some base or beginning point in time called the present. It is a measure of how much money an individual or a firm could afford to pay for the investment in excess of its costs. If the value of PW >1.0 then the project is feasible.

NPW = PW of Cash Inflows – PW of Cash Outflows
= PWB – (PWC + IC)
= PhP 357,787.54– (PhP 178,703.50+ PhP 50,000.00)
= PhP 129,084.05

Where: Cash Inflows = WB
Cash Outflows = PWC + IC

NOTE: Since the computed value of PW = PhP 129,084.05 > 1.0; then the project is feasible.

5. SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

The summary of the computation is tabulated in Table 5. A payback period of 2.1 years connotes that 25 cropping seasons are needed to recover the investment of PhP50,000.00. A break-even point of 60.20 kg per year indicates that the project only needs to produce this yield per year in order to be in a no-profit-no-loss scenario. This also suggests that as the project produce more, the more will be the income. A benefit cost ratio of 1.56 means that the project is feasible. It indicates that for every PhP 1.00 investment means a return of PhP1.56. The net present worth also suggests that the project is highly feasible.

5.2 Conclusion

The need to adopt high-technology agriculture is not a choice anymore but a necessity (Murphy, 1984). The visionary book "The Vertical Farm: Feeding the World in the 21st Century," written by Dr. Dickson Despommier, provides a blueprint for rebuilding local farming in urban areas which will help cut down food transportation costs, secure food supply and at the same time confronting one of the gravest environmental crises today.

The challenge starts in every household. By adopting vertical garden, there is no doubt there will be more food and job for every member of Filipino household in the years to come Sustained production of quality fruits, flowers and vegetables will eventually build healthy family, a wealthy nation and ultimately a sustained economy.

Table 5. Summary of computations of economic criteria

METHODS	VALUES	REMARKS
1. Payback period	2.1 year	The project will take only about 2 years and 1 months or 25 cropping seasons to recover the investment
2. Break-even point	60.20 kg/yr	The project needs only 60.20 kg of lettuce to be sold in order to cover the cost
3. Benefit-cost ratio	1.56	Feasible
4. Net present worth	PhP 129,084.05	Feasible

5.3 Recommendation

The following are recommended to improve the performance of the system.

1. Optimize the production system by minimizing the inputs in order to maximize profit. This would even add more value to water and fertilizer at the same time increasing the productivity of the system. Likewise, the economic criteria will be more praiseworthy.

2. Increase the plant density, which is permissible in hydroponics, would also increase the productivity of the system. This can be achieved by adding more growing tubes and by hanging more plants in the structural frames and watering them manually using the solution.

3. Find a high end market that could offer higher price in exchange for good quality, safer and cleaner harvest and sustained production.

6. ACKNOWLEDGEMENT

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