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AN EXPERT SYSTEM FOR SOLAR-POWERED AQUAPONICS SYSTEM REQUIREMENTS AND ECONOMIC ANALYSIS

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Abstract— Aquaponics system is an alternative solution for food generation in urban areas where there is a scarcity of land for food production. With the advent of solar energy technologies, the energy requirement of the system will not be added to the existing power consumption of the house hold. This paper presents an expert system for solar-powered aquaponics that provides users the aquaponics system dimensions, power requirements, bills of materials, cost-benefit analysis and payback period given land area available and the type of plants and fishes to culture.
Keywords— Aquaponics, solar energy, internet of things

I. INTRODUCTION

Urban agriculture is one of the strategies taken up by cities to address food security and poverty. Challenges are present though as full-scale farming in the cities is impossible due to lack of access to land and people who took up gardening are confined to production of vegetables in containers (such as used cans or plastic bottles) or in tiny patches along the roadside [1]. Moreover, some of cities' vacant lots or communal garden sites made available to relatively poor allotment gardeners for little or no rent have since been taken by the land owners because the rental return offered by cut flower growers for example was much higher [2].

Vertical farming is a concept that involves cultivating plants on vertically inclined surfaces in urban areas where there is a lack of available land and space. It is environmentally, socially and economically beneficial, in increasing food production, maintaining high quality and safety and contributing to sustainable urban farming. However, there is a need for huge investment for the nutrient delivery systems which would significantly raise costs [3].

Hydroponics is a method of cultivation where food producers grow plants using mineral nutrients in water and without the use of soil. The root systems of the growing plants may be hung directly in the nutrient solution, sprayed with nutrient-rich solutions by use of an agricultural sprayer or mister, or plants can be enclosed in a trough or other containment system. If plants are held in these containment systems, they are filled with soil replacement materials such as sand, sawdust, pebbles or wood chips. Whatever the medium, it must be porous to let water through and allow gases to escape [4]. However, hydroponic recipes are based on chemical formulations that deliver precise concentrations of mineral elements requiring personnel that have enough knowledge on the formulation. Aquaculture on the other hand produces water that has fish effluents containing sufficient levels of ammonia, nitrate, nitrite, phosphorus and potassium. Integrating hydroponics and aquaculture forms a bio-integrated food production system, aquaponics [5].

The aquaponics technology is a complicated system requiring ability to simultaneously manage the production of two different agricultural products (plants and fish) and intensive management (nutrients, water quality and level, amount of fish feeds and feeding schedule) [5]. Some of the components for aquaponics system are pumps and lamps [6] requiring energy sources. Energy consumption for aquaponics system may be high; thus, integrating renewable energy source such as solar panels can make the aquaponics system operational cost cheaper [7].

Since there are several rules and standards involved in modelling solar-powered aquaponics system, an expert system can be introduced which is capable of reasoning and decision making through reviewing extracted knowledge from the experts [8].

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II. EXPERT SYSTEM ARCHITECTURE

An expert system consists of three main components: knowledge base, inference engine, and user interface, as shown in Fig. 1. The first component, knowledge base, contains all the knowledge where the expert system is designed to work within such as knowledge, facts, rules, etc. Inference engine executes the action if the information provided by users fulfills the conditions in the rules. Lastly, user interface offers interaction with non-expert users, where users answer the questions or input data to start the logical process in the inference engine [9].

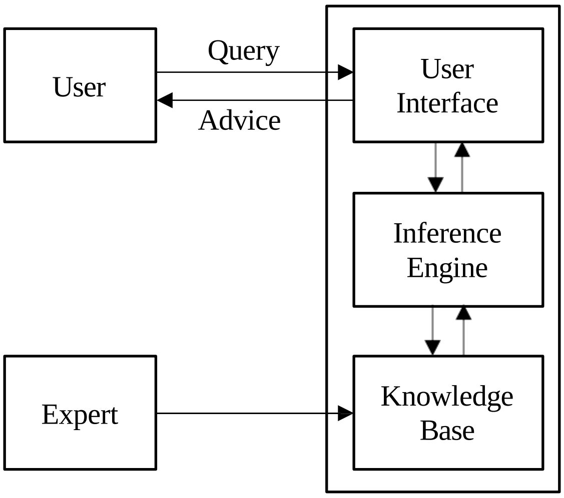

Fig. 1 Typical Expert System

There will be four sources for the knowledge base to be considered in this expert system: (1) aquaponics system, (2) solar power system, (3) vegetable farming and (4) fishery.

For the economic analysis, the cost-benefit analysis and payback period are greatly dependent to the market price of the construction materials, components, vegetables and fishes. A fact database can be integrated to the expert system, as shown in Fig. 2, to store information of the current situation [10].

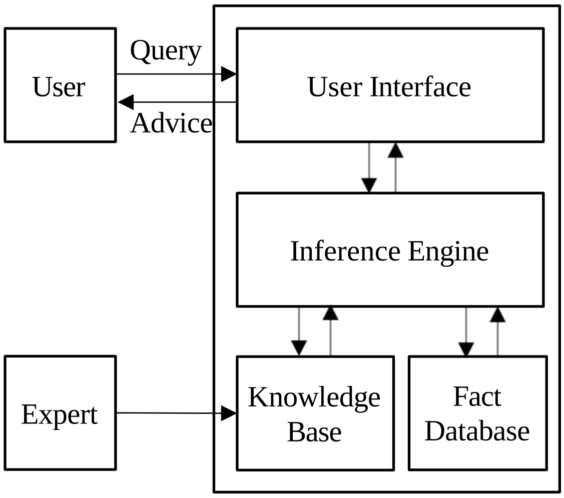

Fig. 2 Expert System with Fact Database

A. *Knowledge Base*

The knowledge base will be designed based on four sources of information. The dimension and components required must be determined for the aquaponics system to function efficiently. The specifications of the solar system components must be determined to efficiently supply the entire aquaponics system. The plants and fish's growth rates and yields must be determined to approximate the production gain.

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1) Aquaponics System Rules

Aquaponics is a modern food production system that symbiotically combines aquaculture and hydroponics in a balanced circulation environment [11].

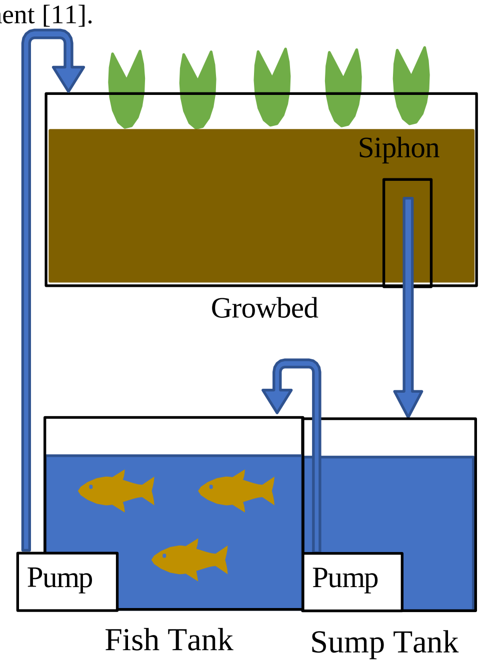

Fig. 3 Typical Aquaponics System

In the aquaponics system (Fig. 3), nutrient-rich water from the aquarium is used as a liquid fertilizer to fertilize the production beds of hydroponics. These nutrients in the water are made from fish manure, algae, and degrading fish baits, which increase the toxicity levels of the aquarium that would otherwise affect fish growth. The hydroponic floor acts as a biofilter to remove ammonia, nitrates, nitrites and phosphorus, allowing freshly washed water to be returned to the aquarium. Nitrifying bacteria, which inhabit gravel and are associated with plant roots, play a decisive role in the nutrient cycle. These nitrifying bacteria convert ammonia to nitrate. Nitrate is a type of nitrogen used by plants. Therefore, when the water returns to the aquarium, the nitrogen level of the fish will be acceptable [12].

For a beginning aquaponic gardener, one of the considerations that needs to be known is the total volume of all growbeds connected to a single fish tank should be at least equal to the volume of the fish tank in order to ensure that the fish tank is adequately filtered. It can be safely driven to a 2:1 rising bed to fish tank ratio and beyond, which provides the system with even more filtration and is even better for the fish's long-term health. Sump tank is added to ensure that the volume of water inside the fish tank is maintained during flooding of the growbeds. The height of the growbeds must be at least 12 inches: 2 inches for dry zone and 10 inches for the gravel to occupied with 2 inches for fish solid waste [13].

The growbeds also need to be flooded and drained. Plant roots need oxygen, water and nutrients. Nutrient water from the aquarium soaks roots and rocks when the bed is filled with water. However, if the roots of the plant are left submerged, the plant will try to adapt and its efforts will consume energy from food production. When the water is sucked out, air flows into the space between the stones in the growing bed. Air is 21% oxygen, which dissolves in water and remains on the surface of rocks and roots, which can be absorbed by organisms in the growing bed. This includes plant roots and bacteria that convert ammonia to nitrates [14].

The maximum height of the aquaponics from the base of the tanks to the topmost surface area of the growbed that provide optimum access to plants must be from the feet to the armpit of an average Filipino body size. The maximum width should be from armpit to the center of the chest of an average Filipino body size for better accessibility to plants with additional space for traffic for people to traverse for at least the shoulder width. The maximum length of the aquaponics will be based on the maximum dimension of the growbed; the pump and standard bell siphon can be flooded and drained at least 15 minutes and 20 minutes respectively [15].

The average height of Filipinos are 62 inches for men and 60 inches for women [16]. The shortest height will be the one to consider to cover both men and women. The height from the feet to the armpit is 3/4 of the height of a person. The length from armpit to chest center is 1/2 of the height of a person. The shoulder width is 1/4 of height of a person. [17]. The maximum height and width therefore based on 60 inches person height are 54 inches and 30 inches as shown in Fig. 2. The width for the pathway is 15 inches.

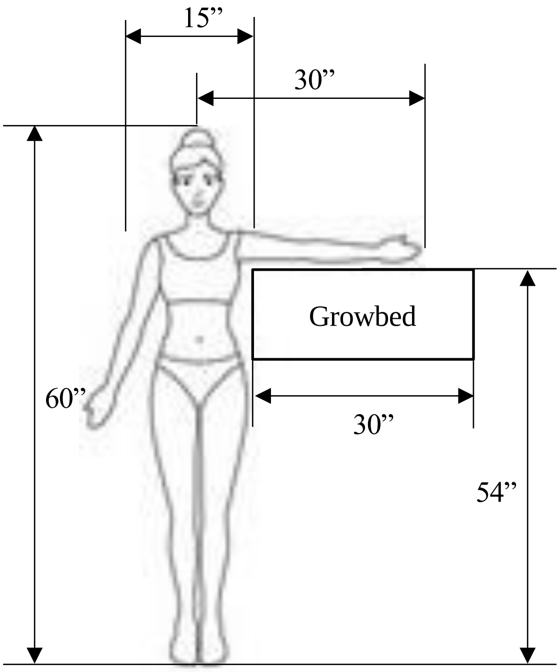

Fig. 4 Width of the Growbed and the Height the Surface of the Growbed is Situated

For the length, the flow rate of the standard bell siphon must be determined first. Flow rate can be computed using Eq.1 [18].

$$V_s = C_d A\sqrt{2gH} \quad (1)$$

Where V is the volume flow (m^3/s), A is the area of the aperture (m^2), g is the gravity acceleration, H is the height of the water to drain and C_d is the discharge coefficient given by:

$$C_d = C_c C_v \quad (2)$$

Where Cc is the contraction coefficient for sharp edge aperture (0.62) and C_v is the contraction coefficient for well-rounded aperture (0.97). Therefore, C_d is equivalent to 0.6.

The aperture of the standard bell siphon is 3/4" of 0.01905 m in diameter [15]. The height of growbed to be flooded is 10” or 0.254 m. Using Eq. 1, the flow rate therefore of the bell siphon 0.0004 m^3/s or 24.4095 in^3/s.

The large volume of the growbed is occupied by the growing media. Pea gravels is the growing medium this system will utilize. The amount of water therefore the siphon should drain is equivalent to the total spaces between the pea gravel granules. This volume can be determined based on the pea gravel porosity which is 40% and using Eq. 3 [19].

$$\emptyset = \frac{V_V}{V_T} \qquad (3)$$

Where $\emptyset$ is the porosity, V_V is the void volume and V_T is the volume total.

The void volume is 21, 968.55 in^3 and is computed using Eq. 4, given that t is the minimum time the growbed should stay flooded which 15 minutes (900 s).

$$V_V = V_s t \qquad (4)$$

The volume total is 300 L, computed using Eq. 5 where W is the maximum width of the growbed which is 30 inches and H is the height of the volume occupied by the growing media which 10 inches.

$$V_T = L \times W \times H \qquad (5)$$

Using Eq. 3, and the computed V_v and V_T, the maximum length is 183".

The maximum dimension of the fish tank is half of the volume of the growbed. To align the fish tank with the growbed and still maintain the tank-growbed ratio of 1:2, height and width will be the same with the growbed with equivalent length of half the length of the growbed, utilizing the other half for the sump tank. The maximum dimension therefore of the tanks will be 91 x 30 x 12 inches.

Table I shows the list of rules for aquaponics system to be included to the knowledge base of the expert system.

TABLE I
KNOWLEDGE BASE RULES FOR AQUAPONICS SYSTEM

Descriptions	**Values**
Growbed and Tanks Fixed Height	12"
Growbed and Tanks Fixed Width	30"
Growbed Fixed Length	183"
Tank Fixed Length	91"
Aquaponic Fixed Height	54"
Land Area Width Divisor	45"
Land Area Length Divisor	198"

To optimize the capacity of the bell siphon and maintaining the minimum flooding and draining time, the maximum dimensions of the aquaponics system will be fixed. The number of aquaponics system to be constructed given land area will be determined using the land area divisors which are just the width and length of the aquaponics system added with the width of the pathways of 15 inches.

2) Solar Power System Rules

A typical solar power system consists of solar module, battery cells and charge controller as shown in Fig. 5 [20].

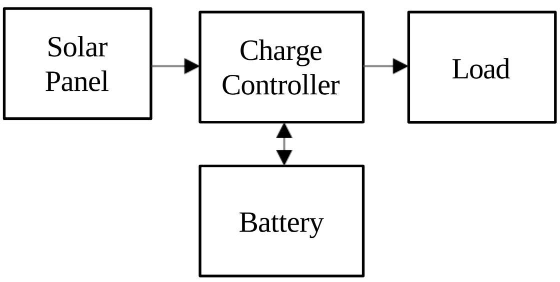

Fig. 5 Typical Solar Power System

Photovoltaics is a combination of two words, photo means light, and voltaic means electricity obtained by the radiation of the sun. Solar energy is always available on Earth. Solar energy is freely available and does not produce gas or ash, so it is free of pollutants. It has low maintenance costs and the only problem with solar systems is that they cannot generate energy in bad weather, but they are more efficient than other energy sources. Initial investment is required.

Aside from solar panels and batteries, another important device of solar power system is charge controller. Basically, this device is used to control voltage and current to charge the battery and protect the battery or cell from overcharging. Provides a way to apply voltage and current from a solar panel to a battery and load. Normally, a 12 V panel outputs in the range of 16 V to 20 V. Therefore, if you do not make any changes, overcharging will damage the electric cell, so a requirement of 14 V to 14.5 V is required to fully charge the cell or battery. Therefore, it has the role and function of the charging controller for protection [21].

The specifications of the solar power system components are based on the power consumption of the aquaponics system. The only loads present in the aquaponics system are the pumps and the lamps. The specifications of the pumps to be used should have the head height necessary for delivering water from the tanks to the growbed which is 54 inches and flow rate that could maintain the draining time of 20 minutes requirement of the aquaponics system which is 18 cubic inch per second. A water pump model HG-028, a 12 volts DC and 20 watts pump is available from the market that can meet the two conditions mentioned above. Two pumps are required for fish tank and sump tank. The maximum area requiring lighting is 8,235 square inches and an E27 type, 12 V and 12 watt lamp is sufficient. Summary of loads is presented in Table II with 12 hours used of pumps in daytime and 12 hours used of lamp in night time.

TABLE II
PUMPS AND LAMP POWER SUMMARY

Components	**Wattage**
Fish Tank Pump	240
Sump Tank Pump	240
Lamp	144
Total Power Required	624

Given daily power consumption of the system, the solar panel specifications can be determined. The most important specification to be considered is the size of the solar panel. According to NASA surface meteorology and solar energy data [22] in the Philippine time zone in Greenwich Mean Time (GMT +8), the 22-year monthly averaged horizontal surface insolation incident is shown in Table III.

TABLE III
MONTHLY AVERAGED HORIZONTAL SURFACE INSOLATION INCIDENT

Months	**Average (kWh/m^2/day)**
January	4.93
February	5.04
March	5.43
April	5.39
May	5.19
June	4.48
July	4.79
August	5.33
September	5.95
October	6.19
November	5.67
December	5.28

Based on Table III, the smallest insolation energy is produced in July at 4.79 kWh/m^2/day and the largest is in October at 6.19 kWh/m^2/day.

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The area of the solar panel can be determined using the Eq. 5 [23]:

$$A = \frac{P}{\alpha E} \tag{6}$$

Where A is the required area of the solar panel, P is the daily power consumption of the system, α is the solar panel energy-conversion efficiency factor (12 – 14 %) and E is the monthly average insolation incident. The energy-conversion efficiency factor and the monthly average insolation incident to be considered are 12 % and the 4.79 kWh/m^2/day average insolation in July to ensure that the generated power is sufficient enough to supply the entire system even if the insolation incident and the energy converted are low [24]. Using these data, the area for the needed solar panel is 1.09 m^2, calculated using Eq. 6

The wattage requirement of the solar panel is based on the daily power requirement of the aquaponics system which is 624 watt at 52 watt per hour. There is an available 670X640 mm 60 watt 12 V solar panel in the market. To meet the required area of solar panel, four panels are needed.

The required specifications for the charge controller and the battery should be equivalent to the voltage requirement of the solar power system and the current requirements of the loads [25]. The solar panel can be connected in series to maintain the current requirement of the aquaponics system and the batteries can be connected in parallel to maintain the voltage requirement of the solar power system as shown in Fig. 4 [26].

Since the operating voltages of the loads and the solar panels is 12 V, this should also be the operating voltage of the charge controller. And since the required wattage for every hour of the aquaponics system, the charge controller should be able to handle 4.33 amperes per hour. The CHR-S032-M model of charge controller with maximum rated voltage of 24 V, maximum rated current of 20A and maximum input voltage of 55 V is capable of handling such current per hour at 5 amperes with operating voltage of 12 V. The switching mechanism used in this model is PWM which is sufficient enough to handle switching from battery to load which only happens twice a day [25]. From switching from lamps to pumps in daytime and pumps to lamps in night time. A battery model YB5L-BS can be utilize as storage having an operating voltage of 12 V and current of 5 amperes per hour. The number of batteries required will based on the lamps consumption only since the batteries will only be used during night time. For 12 hours supply for a single lamp requires a total of 12 amperes at 1 ampere per hour. Three batteries are required to produce a total of 15 amperes.

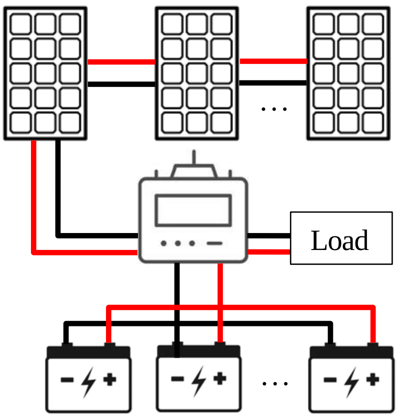

Fig. 6 Series Solar Panel and Parallel Batteries

TABLE IV
KNOWLEDGE BASE RULES FOR SOLAR POWER SYSTEM

Descriptions	Values
System Operating Voltage	12V
System Operating Current	5 A
Pump Wattage	20 W
Lamp Wattage	12 W
Solar Panel Wattage	60 W
Solar Panel Width	670 mm
Solar Panel Length	640 mm
Controller Max No. of System	4

Table IV shows the list of rules for solar power system to be included to the knowledge base of the expert system.

The factor that determine the number of pumps and lamps needed is the number of aquaponics systems to be constructed. The total daily power consumption will be based on the number of pumps and lamps which will determine the needed number of solar panels and batteries. The maximum number of aquaponics system a charge controller can manage is four systems.

3) Vegetable Farming Rules

The rules for the growbed vegetation is divided into two: (1) planting and (2) harvesting. For planting, the distance in rows and the distance of the rows are the consideration. For harvesting, the considerations will be the yield for every 120 inches row and the number of days needed before the plants can be harvested. Tables V and VI shows the rules for the plants being considered in this study [14].

TABLE V
KNOWLEDGE BASE RULES FOR PLANTING

Plants	In Rows	Between Rows
Tomato	18”	36”
Carrot	1”	15”
Lettuce	3”	12”
Cabbage	12”	30”

TABLE VI
KNOWLEDGE BASE RULES FOR HARVESTING

Plants	Yield: 120” Row	Days to Harvest
Tomato	45 lbs	80
Carrot	10 lbs	80
Lettuce	10 lbs	60
Cabbage	40 lbs	60

The number of seedlings required during planting can be determined based on the area of the growbeds and the lengths of the in rows and between rows.

TABLE VII
KNOWLEDGE BASE RULES FOR FISHERY

Fishes	Gallons per Fish	Yield	Months to Harvest
Catfish	10	4 lbs	4
Tilapia	5	1.5 lbs	6

The number of fingerlings required during raising of fishes can be determined based on the volume of the fish tank. The feeding of the fishes requires an increment of 2.5 g of feed per day which must be added to the knowledge base as well [13].

B. Fact Database

The information stored in the fact database are just the approximated market price of the construction materials (plexiglass, wood dowel and pea gravels), aquaponics components (pumps, bell siphon and lamps), solar power components (solar panels, charge controllers and batteries), seedings, fingerlings, fish feeds and selling price of the vegetables and fishes harvested. Table VIII summarizes these prices.

TABLE VIII
SUMMARY OF PRICES FOR THE FACT DATABASE

Items	**Unit**	**Price (Php)**
Plexiglass	Sheet	425.00
Wood Dowel	Length	75.00
Pea Gravel	Kilo	2.50
Pump	pc	500.00
Lamp	pc	75.00
Solar panel	pc	900.00
Charge controller	pc	480.00
Battery	pc	500.00
Tomato seedling	pc	100.00
Carrot seedling	pc	100.00
Lettuce seedling	pc	95.00
Cabbage seedling	pc	95.00
Catfish fingerling	pc	2.00
Tilapia fingerling	pc	0.45
Fish feeds	kilo	20.00
Tomato	kilo	75.00
Carrot	kilo	40.00
Lettuce	kilo	50.00
Cabbage	kilo	40.00
Catfish	kilo	250.00
Tilapia	kilo	180.00

Source: DA, DTI, shoppee.ph, Lazada.com.ph

The dimension of the plexiglass sheet is 4 ft by 8 ft by 0.5 inch and wood dowel is 1 square inch by 36 inches length. Pea gravel granule is about 3/8 inch.

C. Inference Engine

The inference engine is the component of the expert system that processes the query of the user governed by the knowledge base and fact database to provide the user with an approximated expert advise.

The solar-power aquaponics expert system begins with the determination of the number of aquaponics systems that can be accommodated by the land width and length provided by the user. Based on the knowledge base, the minimum width and length are 45 and 198 inches, respectively and the number of aquaponics system that can be constructed is given by Eq. 7.

$$N = N_L N_W \quad (7)$$

Where N is the number of aquaponics system, N_L is the land length divided by 198 inches and N_W is the land width divided by 45 inches.

The construction material requirements for a number aquaponics systems is the number of sheets of plexiglass, S_P (Eq. 8), number of length of wood dowel (Eq. 9) and the amount of pea gravel (Eq. 10). The number of sheets is equivalent to the total surface area of the growbed and tanks with additional surface area dividing the fish tank and sump tank divided by the area of the sheet as shown below.

$$S_P = \frac{N}{4608}\,[5(30)(12)] + 4(12)(183) + 2(30)(183)] \quad (8)$$

$$= 4.6797\,N$$

The number of lengths is equivalent to the necessary frames to support the growbed divided by a length of wood dowel as computed below.

$$L_W = \frac{N}{36}\,[4(54) + 2(183) + 4(30)] \quad (9)$$

$$= 19.5\,N$$

The amount of the gravel is equivalent to the total mass given volume of growbed to fill at the height of 10 inches and the density of the pea gravel at 105 pounds per cubic foot as evaluated below.

$$G_M = \left(\frac{(105)(10)(30)(183)}{(2.2046)(1728)}\right) N \quad (10)$$

$$= 1513\,N$$

The component requirements for a number of aquaponics systems are the number of pumps (Eq. 11), number of bell siphons (Eq. 12) and number of lamps (Eq. 13).

$$N_P = 2N \quad (11)$$
$$N_{BS} = N \quad (12)$$
$$N_{LP} = N \quad (13)$$

The solar power system component requirements for a number of aquaponics systems are the number of solar panels (Eq. 14), number of charge controller (Eq. 15) and number of batteries (Eq. 16).

$$N_{SP} = 4N \quad (14)$$
$$N_{CC} = N/4 \quad (15)$$
$$N_{BT} = 3N \quad (16)$$

The vegetation and fisheries requirements for a number of aquaponics systems are the number of seedlings (Eq. 17-20), number of fingerlings (Eq. 21 & 22) and amount of feeds (Eq. 23 & 24). The number of seedlings is equivalent to the product between the ratio of maximum length and the in row and the ratio of the maximum width and between row as enumerated below.

$$N_{tom} = \left(\frac{183}{18}\right)\left(\frac{30}{36}\right) N \quad (17)$$

$$= 8.47\,N$$

$$N_{car} = \left(\frac{183}{1}\right)\left(\frac{30}{15}\right) N \quad (18)$$

$$= 366\,N$$

$$N_{let} = \left(\frac{183}{3}\right)\left(\frac{30}{12}\right) N \quad (19)$$

$$= 152.5\,N$$

$$N_{cab} = \left(\frac{183}{12}\right)\left(\frac{30}{30}\right) N \quad (20)$$

$= 15.25\ N$

The number of fingerlings is equivalent to the volume of the fish tank divided by the maximum gallon of water per fish as given below.

$$N_{cat} = \frac{(30)(91)(10)}{(10)(231)}\ N \quad (21)$$

$= 11.82\ N$

$$N_{til} = \frac{(30)(91)(10)}{(5)(231)}\ N \quad (22)$$

$= 23.63\ N$

The amount of feeds is computed as the sum of the arithmetic sequence with an increment of 2.5 grams multiplied with the number of days required for the fish to full grow as depicted below.

$$N_{caf} = \frac{120}{1000}\ \frac{(2.5+(120)(2.5))}{2}\ N_{cat} \quad (23)$$

$= 18.15\ N_{cat}$

$$N_{tilF} = \frac{240}{1000}\ \frac{(2.5+(240)(2.5))}{2}\ N_{til} \quad (24)$$

$= 72.3\ N_{til}$

The profit for the vegetation and fishes for a number of aquaponics system can be computed as shown in Eq. 25-30. For the vegetable, the profit is the product between the ratio of the maximum length of growbed and the 120 inches yield, ratio of the maximum width of the growbed and the between row and the price per kilogram as shown in the following computations.

$$P_{tom} = \left(\frac{183}{120}\right)\left(\frac{30}{36}\right)\left(\frac{45}{2.2046}\right)(75)N \quad (25)$$

$= 1945.50\ N$

$$P_{car} = \left(\frac{183}{120}\right)\left(\frac{30}{15}\right)\left(\frac{10}{2.2046}\right)(40)N \quad (26)$$

$= 553.39\ N$

$$P_{let} = \left(\frac{183}{120}\right)\left(\frac{30}{12}\right)\left(\frac{10}{2.2046}\right)(50)N \quad (27)$$

$= 864.67\ N$

$$P_{cab} = \left(\frac{183}{120}\right)\left(\frac{30}{30}\right)\left(\frac{10}{2.2046}\right)(40)N \quad (28)$$

$= 1{,}106.78\ N$

For the fish, the profit is the product between the number of fingerlings, its yield and its price as shown in the following computations.

$$P_{cat} = \frac{(250)(4)}{2.2046}\ N_{cat} \quad (29)$$

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$$= 453.60\ N_{cat}$$

$$P_{til} = \frac{(180)(1.5)}{2.2046} N_{cat} \quad (30)$$

$$= 122.47\ N_{cat}$$

The cost-benefit analysis and payback can be determined given by its initial investment, expenses and income. Let us first determine the initial investment which is the sum of the product of the aquaponics system materials and components and solar power system components with their respective prices shown in Table IX.

TABLE IX
INITIAL INVESTMENT FOR ONE UNIT OF AQUAPONICS SYSTEM

Items	**Quantity**	**Amount (Ph)**
Plexiglass	5	2,125.00
Wood Dowel	20	1,500.00
Pea Gravel	1,513	3,782.50
Pump	2	1,000.00
Bell Siphon	1	1,500.00
Lamp	1	75.00
Aquaponics System Subtotal		9,982.50
Solar Panel	4	3,600.00
Charge Controller	1	480.00
Battery	3	1,500.00
Solar Power System Subtotal		5,580.00
Total		15,562.50

The cost-benefit analysis can be conducted by equating the days of harvest of both the vegetables and fishes. This can be computed by determining their common multiplier of harvest (see Table 10).

TABLE X
VEGETABLE-FISH MULTIPLIER

Vegetable-Fish	**Multiplier**
Tomato-Catfish	240 days
Tomato-Tilapia	240 days
Carrot-Catfish	240 days
Carrot-Tilapia	240 days
Lettuce-Catfish	120 days
Lettuce-Tilapia	120 days
Cabbage-Catfish	120 days
Cabbage-Tilapia	120 days

The cost-benefit analysis [27] of each pair of vegetable and fish is given by Eq. 31:

$$I = M\left[\frac{I_V}{H_V} + \frac{I_F}{H_F}\right] \quad (31)$$

Where I is the cost-benefit, M is the multiplier, I_V (Eq. 32) and I_F (Eq. 33) are the respective income of the vegetable and fish and
H_V and H_F are the number of days the vegetable and fish can be harvested.

$$I_V = P_V - N_V Z_V \quad (32)$$

$$I_F = P_F - (N_F Z_F + N_{FF} Z_{FF}) \quad (33)$$

Where P_V and P_F are the profit every harvest of vegetable and fish, N_V and N_F are the number of seedlings and fingerlings, Z_V and Z_F are the prices of the seedlings and fingerlings and N_{FF} and Z_{FF} are the amount of fish feeds and its price per kilo.

The payback period [28] can be computed using the Eq. 34 below:

$$n = \frac{CM}{3601} \qquad (34)$$

Where n is the payback period in years and C is the capital or the initial investment.

III. RESULTS AND DISCUSSIONS

The expert system will tested in this section using the land area of 33 feet by 8 feet for tomato and catfish. The number of aquaponics systems to be constructed is 4 systems using Eq. 6.

Table 11 is computed using Eq. 8-16. And using Eq. 17-30, the following values can be determined: *PV = 7,782.00; NV = 34; ZV = 100.00; PF = 21,772.66; NF = 48; ZF = 2.00; NFF = 871.20; and ZFF = 20.00.*

TABLE XI
INITIAL INVESTMENT FOR FOUR UNIT OF AQUAPONICS SYSTEM

Items	Quantity	Amount (Php)
Plexiglass	20	8,500.00
Wood Dowel	80	6,000.00
Pea Gravel	6052	15,130.00
Pump	8	4,000.00
Bell Siphon	4	6,500.00
Lamp	4	300.00
Aquaponics System Subtotal		39,930.00
Solar Panel	16	14,400.00
Charge Controller	1	480.00
Battery	12	6,000.00
Solar Power System Subtotal		20,880.00
Total		60,810.00

The income from the vegetables and fishes for every harvest period are Php4,382 and Php4,252, respectively (computed using Eq. 31 and 32). The income for entire 240 days is Php21,651.32.

Using Eq. 34, the payback period can be computed which is 1.87 years.

IV. CONCLUSIONS

The payback period for the solar-powered aquaponics system for a land area of 33 feet by 8 feet growing tomatoes and raising catfish which 1.87 years is acceptable [29]. Since the payback period is the most significant figure aside from the income in systems involving investment, it can be recommended modifying the expert system with capability of conducting advisory when the user queries involve payback period and income. The system should advise the user for the possible dimension of the land area, the vegetables to grow and the fish to raise that can meet the desired payback period and income.

REFERENCES

1. R. J. Holmer, M. T. Clavejo, S. Dongus, and A. Drescher, "Allotment gardens for Philippine cities," *Urban Agriculture Magazine*, vol. 11, pp. 29–31, 2003.
2. A. Hill, "A helping hand and many green thumbs: local government, citizens and the growth of a community-based food economy," *Local Environment*, vol. 16, no. 6, pp. 539–553, 2011.
3. F. Kalantari, O. M. Tahir, R. A. Joni, and E. Fatemi, "Opportunities and challenges in sustainability of vertical farming: A review," *Journal of Landscape Ecology*, vol. 11, no. 1, pp. 35–60, 2018.

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4. T. Tripp, *Hydroponics Advantages and Disadvantages: Pros and Cons of Having a Hydroponic Garden*. Speedy Publishing LLC, 2014.
5. S. Diver and L. Rinehart, "Aquaponics: integration of hydroponics with aquaculture," *ATTRA*, 2000.
6. D. Wang, J. Zhao, L. Huang, and D. Xu, "Design of a smart monitoring and control system for aquaponics based on OpenWrt," in *5th International Conference on Information Engineering for Mechanics and Materials*, Jul. 2015. Atlantis Press.
7. A. M. Nagayo, M. Cesar, V. Eugene, K. S. Raad, and S. Rodrigo, "An automated solar-powered aquaponics system towards agricultural sustainability in the Sultanate of Oman," in *2017 IEEE International Conference on Smart Grid and Smart Cities (ICSGSC)*, Jul. 2017, pp. 42–49.
8. C. F. Tan, L. S. Wahidin, S. N. Khalil, N. Tamaldin, J. Hu, and G. W. M. Rauternerg, "The application of expert system: a review of research and applications," *ARPN Journal of Engineering and Applied Sciences*, vol. 11, p. 2448, 2016.
9. A. Ozden, A. Faghri, and M. Li, "Using knowledge-automation expert systems to enhance the use and understanding of traffic monitoring data in state DOTs," *Procedia Engineering*, vol. 145, pp. 980–986, 2016.
10. K. C. Mondal, B. D. Nandy, and A. Baidya, "Fact-based expert system for supplier selection with ERP data," in *Algorithms in Machine Learning Paradigms*, pp. 43–55. Singapore: Springer, 2020.
11. K. N. Azad, M. A. Salam, and K. N. Azad, "Aquaponics in Bangladesh: current status and future prospects," *Journal of Bioscience and Agriculture Research*, vol. 7, no. 02, pp. 669–677, 2016.
12. A. K. Jena, P. Biswas, and H. Saha, "Advanced farming systems in aquaculture: strategies to enhance the production," *Innovative Farming*, vol. 1, no. 1, pp. 84–89, 2017.
13. S. Bernstein, Aquaponic Gardening: A Step-by-Step Guide to Raising Vegetables and Fish Together. New Society Publishers, 2011.
14. M. Stout, The Complete Idiot's Guide to Aquaponic Gardening. Penguin, 2013.
15. M. A. Romli, S. Daud, R. A. A. Raof, Z. A. Ahmad, and N. Mahrom, "Aquaponic growbed water level control using fog architecture," in *Journal of Physics: Conference Series*, vol. 1018, no. 1, p. 012014, May 2018. IOP Publishing.
16. G. Lasco, "'De estatura regular': Height and Filipino bodily representations during the Spanish colonial period (1521-1898)," *Philippine Studies: Historical and Ethnographic Viewpoints*, vol. 68, no. 1, pp. 57–82, 2020.
17. E. Abu-Taieh and H. S. Al-Bdour, "A human body mathematical model algorithm," *Machine Learning and Biometrics*, vol. 113, 2018.
18. D. P. Song and Q. Zhang, "A fluid flow model for empty container repositioning policy with a single port and stochastic demand," *SIAM Journal on Control and Optimization*, vol. 48, no. 5, pp. 3623–3642, 2010.
19. J. Gong, J. Liu, and L. Cui, "Shear behaviors of granular mixtures of gravel-shaped coarse and spherical fine particles investigated via discrete element method," *Powder Technology*, vol. 353, pp. 178–194, 2019.
20. M. A. Rahaman, M. A. Matin, A. Sarker, and M. R. Uddin, "A cost effective solar charge controller," *International Journal of Research in Engineering and Technology*, vol. 4, no. 03, pp. 314–319, 2015.
21. M. Mustafa, V. Sunil, and U. Bhasker, "Hybrid power generation by solar tracking and vertical axis wind turbine (design and analysis)," *International Research Journal of Engineering and Technology (IRJET)*, vol. 4, no. 8, 2017.
22. A. A. N. M. Narottama, K. A. Yasa, I. W. Suwardana, A. A. N. G. Sapteka, and P. S. Priambodo, "Analysis of AC and DC lighting systems with 150-watt peak solar panel in Denpasar based on NASA data," in *Journal of Physics: Conference Series*, vol. 953, no. 1, p. 012100, Jan. 2018. IOP Publishing Ltd.
23. B. Kan, J. Zhang, F. Liu, X. Wan, C. Li, X. Ke, and Y. Chen, "Fine-tuning the energy levels of a nonfullerene small-molecule acceptor to achieve a high short-circuit current and a power conversion efficiency over 12% in organic solar cells," *Advanced Materials*, vol. 30, no. 3, p. 1704904, 2018.
24. A. Al-Mamun, K. Sundaraj, N. Ahmed, N. U. Ahamed, S. A. M. M. Rahman, R. B. Ahmad, and M. H. Kabir, "Design and development of a low cost solar energy system for the rural area," in *2013 IEEE Conference on Systems, Process & Control (ICSPC)*, Dec. 2013, pp. 31–35.
25. A. Tekale, V. Ware, V. Devkar, and G. Dungahu, "Hybrid power generation by solar & vertical axis wind turbine: A review," 2019.
26. H. G. Lee, J. N. Shah, P. Tyagi, and M. Vigneshwar, "Analysis of partial shading effects of solar PV module configurations using MATLAB/Simulink," *American Journal of Energy Research*, vol. 6, pp. 8–18, 2018.
27. S. M. Petrea, A. C. Bandi, D. Cristea, and M. Neculiţă, "Cost-benefit analysis into integrated aquaponics systems," *Custos e Agronegócio on line*, vol. 15, no. 3, pp. 239–269, 2019.
28. P. R. Adler, J. K. Harper, F. Takeda, and S. T. Summerfelt, "Economic analysis of an aquaponic system for the integrated production of rainbow trout and plants," 2000.
29. J. R. Lohmann and S. N. Baksh, "The IRR, NPV and payback period and their relative performance in common capital budgeting decision procedures for dealing with risk," *The Engineering Economist*, vol. 39, no. 1, pp. 17–47, 1993.

