

Integrating Vertical Farms To Mixed-Use Commercial Residential Condominium To Establish Sustainable Vertical Communities In Davao City

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Received 09.04.2014; Accepted 11.30.2015

ABSTRACT: The human population has been growing at least at the rate of 1.2% annually since 1960 reaching up to 6.4B in 2002 and more than 7.0B in 2012. In Davao City, the annual population growth rate is running at 3.22% in year 1990, at 2.41% last 2007 and recently in 2013 at 2.36%. The alarming problem we confront today is that the increase in land area for human use does not expand in proportion to population density increase. It is the aim of this study to address the future problems on land and food shortage through the efficient integration of vertical farms on mixed-use multi-storied commercial-residential buildings in Davao City in order to provide income generating condominiums and produce organic crops for residents in an urban setting. The result of the computations showed that the integration of farms to mixed-use residential-commercial buildings in Davao City is highly feasible. The gross profit is highest using gross floor area percentage ratio combination of 50:5:20 for residential, commercial and vertical farm units respectively. (i.e., 50% of the building's gross floor area should be allotted to residential units, 5% to commercial units, and 20% to farm units). Moreover the gross profit and ROI of the 50:5:20 gross floor area ratio also generated the highest which amounted to Php 1,785,316,198.00B compared to only Php 501,045,100.00M for the typical commercial-residential buildings in five years. This research has mainly focused on the integration of hydroponics, but the inclusion of aquaponic farms in vertical structures can also be further explored.

Keywords: *Vertical Farms, Multi-Storey, Sustainable, Vertical Communities, Gross Floor Area, Percentage Ratio*

INTRODUCTION

The human population is estimated to take 43 more years to increase by another 50%, to become 9.6 billion by 2050, based from the UN Population Division report. The food requirement for this influx would require an additional 109 hectares of farmland, a land requirement which is already a deficit from the current status of land availability.(Despommier, 2008; Ellingsen, 2008). According to the World Bank Group, the human population has grown at a rate of 1.2% annually since 1960 reaching up to a total population of 6.4 billion in 2002. Fifty percent of these were living in the urban areas. Even the increase of mortality rate and the strict implementation of family planning methods by a lot of countries found it difficult to slow down the population's growth.

In Davao City, the annual population growth rate was computed to be 3.22% from year 1990-1995, 2.83% from year 1995-2000, and 2.41% from year 2000-2007 and recently in 2012 at 2.36%. The population continued to grow followed by the pressure to

produce more food for consumption also to give people a place to live in. Based on this observable fact, it is quite evident that sooner or later, there will not enough land to sustain the living condition of the people. Along with rapid population growth and land use is also the rapid accumulation of pollutants and the problem on environment degradation which resulted to climate change and unfavourable effects on agriculture. Increased variability of rainfall associated with climate change affected soil erosion rates and soil moisture which can negatively impact agricultural productivity. Increased incidence of pests and diseases alongside with the emergence of new ones will exacerbate this problem and further dampen the crop yield of many farmers. Likewise, the fisheries sector faced with the threat of hotter water, high sedimentation and wave activity, sea level rise, decreased oxygen level and ocean acidification had also adversely affected the supply of aquatic resources.

The conventional methods of farming will be unable to produce sufficient food unless the rapid growth of population is stopped. Approximately 19% is left of the arable land, existing water shortages has already occurred and become more severe,

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climate change have affected planting growing seasons, and urbanization strained regional production. Overall, these effects of climate change had posed great threat to any country's food security.

The concept of vertical farming was introduced to solve these agricultural problems. It is an economically efficient and efficient alternative that can meet the rising demand of food particularly applicable in urban centers.

Despommier (2008) and Ellingsen (2008) identified an extensive list of reasons why vertical farming may represent a viable solution to global processes as diverse as hunger, population growth, and restoration of ecological functions and services. Some of these includes a year-round crop production with no crop failures due to pests and calamities, no agricultural run-off, and health risks due to agricultural chemicals. Vertical farming in tall buildings at urban centers involved fully sustainable energy use and new organic relationship between engineering, architecture, technology as an alternative solution in agricultural necessity in local based community. (Despommier, 2008; Ellingsen, 2008).

Although vertical farming had addressed issues on land shortage and agriculture, it also presents some drawbacks since the construction of high rise structures for farms per se may be too costly. The profit gained from the yield of the high rise structure farm would not be enough to cover up the initial construction and maintenance costs.

It was the aim of this study to incorporate multi-storied farming within the vertical high rise structures and produce a vertical community having both the suppliers, the source of food and consumers in one building. This allowed for a more adequate profit gain than from the construction of a stand-alone vertical farm to feed people around the urban setting.

Moreover, vertical communities unlike vertical farms have a more stable and balanced ecosystem where there is a give-and-take relationship between plants and humans. Hydroponics was used as a vehicle for treated wastewater reuse as it contains nutrients required for plant growth (Oyama, 2008). It also presented opportunities in water-recycling, lessening impacts of wastewater from sewage to the surrounding environment.

Statement of the Problem

The purpose of this study was to determine the most economically efficient mixed-use ratio percentage of gross floor area needed when incorporating multi-storied farms in urban vertical structures to address food and land shortage problems, as well as transportation costs from having to deliver goods to urban centers, specifically it seeks to:

- To determine the preferred hydroponic crops that can be grown in multi-storied vertical farms and the annual consumption of Davao City residents that can be included in the proposed mixed-use building structure?
- To compute for the most efficient and effective gross floor area percentage of vertical farm that must be applied in the mixed-use residential and commercial ratio that will supply the

required demand of preferred crops of the residents?

c. To determine the utility ratio percentage of gross floor area combination between the agricultural, commercial and residential use to be applied in a multi-storied vertical building project that would generate income for the multi-storied structure.

d. To compute the comparative annual gross profit of the mixed-use residential, commercial and agricultural condominium compared to the typical commercial - residential condominium. Theoretical and conceptual framework are shown in Fig.1 and Fig.2.

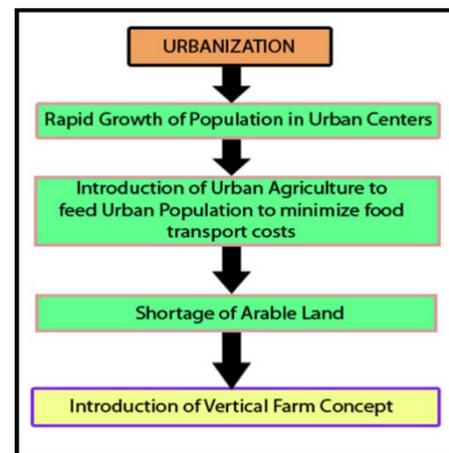


Fig. 1: Theoretical Framework

The core to the vertical farm theories was the rapid population growth in urban areas due to urbanization. Currently, agricultural products were produced far from the major areas of consumption- the cities that currently house half of the world's population (United Nations Environmental Program, 2002). This pattern of growing 'food miles' was far from sustainable, its by-product being increasing air pollution, notably of major greenhouse gases such as carbon dioxide, increasing road congestion and noise, and increasing stress (Bohn, Howe and Viljoen, 2005). Urban Agriculture was then introduced both to compensate for the loss of green and open spaces, and to feed the new arrivals without relying too much on the produce generated by the rural areas. This lessened food transport problems such as fuel costs and pollution.

However, these farms inside the urban periphery also created problems as contributes to the increasing smog and pollution which are generated mainly from daily activities in factories and farms, it has also contributed to loss of land for accommodating residential zones. These problems were addressed when an alternative way of food production was proposed; namely growing of large amounts of produce within the confines of high-rise buildings (Despommier, 2008; Ellingsen, 2008).

Vertical Farms utilized hydroponics or soilless medium

for growing crops inside high-rise buildings. In doing this procedure the pest and weed incidents were lessened, and consequently eliminated the use of pesticides and herbicides.

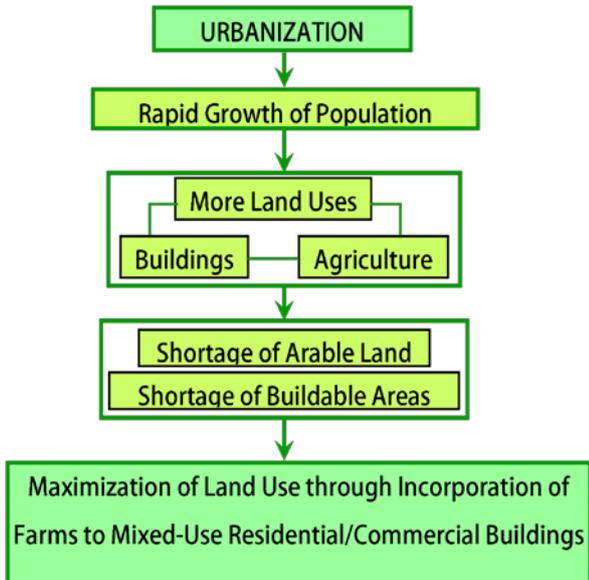


Fig.2: Conceptual Framework

MATERIALS AND METHODS

The main goal of the study is to efficiently integrate farms in mixed-use commercial and residential buildings as a means to provide sustainable multi-storied structures in Davao City while maximizing land use and at the same time making the building beneficial to both the developers and tenants in such a way that it would generate greater income and would let them have a healthy comfortable and sustainable place to live.

To achieve this, various research tactics were used such as survey questionnaires, and key informant interviews, and the methods used to analyze these data include basic statistical analysis, and net profit formula.

Research Instruments Used

This study's research design involved conducting of surveys and key informant interviews.

1. Crop Preferential Survey

This questionnaire aimed to get the preferences of Davao City Urban residents regarding the consumption, planting and buying of common crops found in the country.

a. Respondents

A total of 100 respondents residing in Davao City urban centers were surveyed. This sample size was computed using

Slovin's Formula, $N = \frac{n}{1+ne^2}$, where the N = total number of

population; n= sample population; and e= margin of error. Ten percent (10%) margin of error was used.

b. Survey Questionnaires

The questionnaires were divided into three parts:

i. Respondent's Profile

This area consisted of personal questions which needs definite answers. The respondents' age, gender, and annual family income were asked.

ii. Questions

This section contained questions which are also essential to gather other data needed such as the amount of crops that they usually buy at one time.

iii. Rating Scale

The third part consisted of three tables with rating scales of 1 to 5. The respondents were asked to rate their willingness to consume, plant, and buy the presented crops from 1-5, 5 being the highest (extreme willingness), and 1 the lowest (extreme unwillingness).

2. Market-Price Survey

The Bankerohan Public Market prices in Davao City were made the bases for the average prices of the crops to be included in the farms. This is necessary to find out how much profit the farm will yield basing on the current trend of crop prices in Davao City.

3. Key Informant Interviews

a. Developer

One multi-storied residential developer in Davao City, Filinvest Land Incorporated - Davao City Chapter, was interviewed mainly about the Lot Development Cost of existing One Oasis Condominium in Ecoland Subdivision, Davao City. This included other necessary figures needed for the computation of the net profit of the proposed mixed-use building.

b. Hydroponic Greenhouse Consultant

Gardeners, plant breeders, and other experts who use hydroponics system in greenhouse farming were interviewed mainly to get their ideas and comments about both the application of hydroponics system and greenhouse farming in vertical structures, and for the provision of other data necessary for the computation of the proposed building's Return-On-Investment analysis. This data was acquired by sending them a table listing all crops with some information left blank for them to answer (See Appendix B).

The professionals and experienced people interviewed under this field were:

i. Dr. Primitivo Jose A. Santos & Dr. Eureka Teresa M. Ocampo

Dr. PJA Santos and Dr. ETM Ocampo both are research, extension and professional staff from the Institute of Plant Breeding - Crop Science Cluster (CSC) in the college of agriculture, U.P. Los Baños. The former is expert in Plant Physiology and Mineral Nutrition while the latter is an expert in Agronomy and Plant Physiology. These two scientists developed the SNAP hydroponic solution which is affordable

and suited to the Philippines' tropical climate.

ii. Corbin Dallas

Corbin Dallas is a seller of SNAP hydroponics system.

4. Gross Floor Area Ratio Combination Of Residential, Commercial And Vertical Farm Units

a. Residential Units (RS) Commercial Units (CS) Vertical Farm Units (VF).

The proposed building have three major zones, namely commercial, residential, and agricultural areas referred also as the Vertical Farm units (VF). The building's economic gain and efficiency will be determined mainly by the appropriate designation of ratios for each of these areas.

The standard on non gross and gross floor area allocation of 25% and 75% respectively was chosen and used. The gross floor area (GFA) of 75\$ was allotted for saleable or profitable spaces. This will be used and divided into three parts; each would correspond to any of the three major zones namely residential, commercial, and vertical farms. The assumed ratios used were in multiples of 5, these are designated as RS, CS, and VF for Residential, Commercial, and Vertical farm areas, respective The remaining 25%, which was the Non Gross Floor Area used for non-profitable areas such as utility rooms, lobbies, hallways, and etcetera.

5. Most Efficient Gross Floor Area Ratio that would Generate Profit

To make the building efficient and sustainable, it is necessary to analyze which ratio between Residential, Commercial and Vertical Farms works best based on the projected gross profit and livability of the building. The ratio that would yield greatest profit while being able to supply 75% of the total tenants with food was considered as the most efficient ratio between the three zones and thus, applied to the design of the building.

a. Gross Profit Formula

The basic accounting formula which is being adapted by most businessmen will be used to solve for their annual gross profit. This formula goes:

Annual Gross Profit (GPA) = Annual Revenue (RevA) – Annual Expenses (ExpA),

And, the fixed profit, assuming that it will be paid by the customers immediately, will be solved using this formula:

Fixed Gross Profit (GPf) = Fixed Revenues (Revf) – Fixed Expenses (ExpA),

To solve for the yearly cash flow, the following formula will be used:

$$YN = GPf - (GPa)(N)$$

Where, Yn = Gross Profit after n years

GPf = Fixed Gross Profit

GPa = Annual Gross Profit

N = Number of Years

1. Most Efficient Gross Floor Area Ratio

The efficient gross floor area ratio was calculated in multiples of 5 combination allocated to the residential, commercial and vertical farm units. The gross floor area ratio that yielded the greatest profit while being able to supply the required and

Table 1. Saleable or profitable spaces divided into three major zones namely residential, commercial, and vertical farms.

Saleable (75%)		
Residential Units (RS)	Commercial Units (CS)	Vertical Farm Units (VF)
40	30	5
40	25	10
40	20	15
40	15	20
40	10	25
40	5	30
45	25	5
45	20	10
45	15	15
45	10	20
45	5	25
50	20	5
50	15	10
50	10	15
50	5	20
55	15	5
55	10	10
55	5	15
60	10	5
60	5	10
65	5	5

preferred crops to 75% of the residents was considered as the most efficient ratio combination and thus applied to the design of the building.

2. Gross Profit Formula

The basic accounting formula which is being adapted by and is:

Annual Gross Profit (GP_A) = Annual Revenue (Rev_A) – Annual Expenses (Exp_A),

And, the fixed profit, was assumed to be paid by the buyers in full, and computed using this formula: Fixed Gross Profit (GP_f) = Fixed Revenues (Rev_f) – Fixed Expenses (Exp_A),

To solve for the five year return of investement (ROI) or yearly cash flow, the following formula was used: Y_N = GP_f - (GP_a)(N), Where, Y_n = Gross Profit after n years; and GP_f = Fixed Gross Profit; and GP_a = Annual Gross Profit; and lastly N = Number of Years.

RESULTS AND DISCUSSION

Data Presentation

Average Annual Crop Consumption of Davao City Urban Dwellers

It is shown in the Table 2 that the average amount of ampalaya bought by the households each year reached to about 6 kilograms. Other crops that were bought by the residents that amounted to between 1 to 10 kilograms yearly include cucumber, grapes, kangkong, okra, pechay, and string beans. Crops that exceeded 10 kilograms include Alugbate, bell pepper, cabbage, cauliflower, sayote, eggplant, lettuce, mongo, patola, upo, squash, and tomato. Among these, alugbate, cabbage, eggplant, patola, upo, and tomato belonged to crops

residents buy that amounted to more than 30 kilograms yearly.

Projected Yields and Expenses of Hydroponics System

Since hydroponics system will be used in the farms, data concerning the average yield and expenses out of using it were gathered. The data presented in Table 3 are taken from the key informant interviews and secondary sources.

The crops were classified into three groups. The first group

Table 2. Average Annual Consumption of each Crop per Household

Crops	Ave. Amount of Crops bought yearly (kg)	Crops	Ave. Amount of Crops bought yearly (kg)
Ampalaya	6.161	Lettuce	10.800
Alugbate	30.888	Monggo	10.706
Bell Pepper	12.215	Okra	4.139
Cabbage	48.032	Patola	46.392
Cauliflower	11.232	Pechay	4.106
Sayote	11.779	Upo	42.048
Cucumber	6.914	Squash	20.889
Eggplant	31.475	String Beans	4.680
Grapes	6.240	Tomato	40.140
Kangkong	7.863		

Table 3. Projected Yields from Hydroponic Crops at Minimum Spacing

Category	Crops	Plants/sq. m.	Kg/sq. m.	Croppings/ Yr	Kg/sq. m./year
Vines	Ampalaya	4.6	13	6.3	81.9
	Alugbate	97	1.5	7.3	10.6
	Sayote	4.6	13	6.3	81.9
	Cucumber	4.6	13	6.3	81.9
	Grapes	4	32	3.8	121.6
	Patola	4.6	13	6.3	81.9
	Upo	4.6	13	6.3	81.9
	Squash	5	32	6.8	220
	String Beans	10.9	6.2	5.4	34
	Tomato	4.7	32	3.8	123.6
Leaf Vegetables	Cabbage	10.9	7	5.3	38.7
	Kangkong	97	1.5	7.3	10.6
	Lettuce (Romaine)	43	9.8	4.4	42.9
	Pechay	43	9.8	4.4	42.9
	Cauliflower	7	7.8	6.1	47.5
Shrubs	Bell Pepper	11	11	5.4	58.9
	Eggplant	8	5.4	4.5	67
	Mongo	10.9	6.2	5.4	34
	Okra	8	5.4	4.5	67

consisted of vines. The plants that belong to this category included ampalaya, alugbate, sayote, cucumber, grapes, atola, upo, squash, string beans, and tomato. The second group consisted of the Leaf vegetables. This included the cabbages, kangkong, pechay, lettuce, and cauliflower. The third group were shrubs and consists of the bell pepper, eggplant, mongo, and okra.

The third column of the table showed the amount of plants that could be accommodated per square meter at one time. The leafy vegetables which do not require much spacing between each crop have the most number of plants that could be planted per square meter. Vines, on the other hand occupies the greatest space and thus can only be planted mostly by 4's per square meter.

The fourth column showed the amount of yield produced by one crop per square meter in kilograms. The fifth column is the number of croppings per year. This means the number of harvesting times per year. The last column is the projected yield per square meter in kilograms. If the ampalaya yielded about 81.9 kg, it means that given a space measuring one square meter, the amount of ampalaya one can harvest for one year equals 81.9 kilograms.

Data Analysis and Presentation of Major Findings

The aim of the study was integrating hydroponic vertical farm systems in vertical high and medium rise structures in Davao City. The general objective was maximizing the use of land and generating income for the tenants and developers by optimizing the commercial, residential and agricultural areas for building use while providing a holistic and healthy lifestyle for the residents.

Crop Preference Rating and Consumption

As resulted from the survey the profile targets for the proposed building with vertical farms will be those with families ad with family head age from 26 and above mostly have female members with an annual ranging from family income P

100,000.00 – P 499,999.00. After the acceptability of the project for Davao City residents, a crop preferential survey was taken around the downtown area of Davao City. All edible vegetable crops were presented to each respondent and they were asked to rate each based on how willing they were to plant, eat, and buy them. The average rating of all the respondents gave the result shown in the Fig. 3 and Fig. 4.

The average preference rating of crops in Fig. 4 was obtained

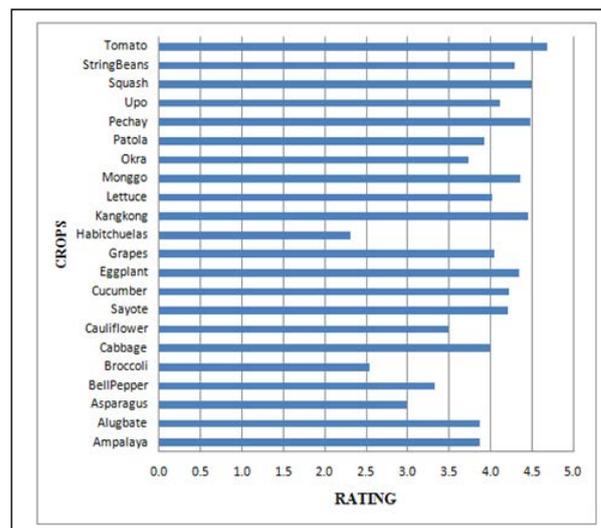


Fig. 4: Average Preference Rating of Each Respondent for each Crop

by combining all the ratings of the respondents for each crop for the three categories. The result showed tomato, string beans, squash, upo, pechay, mongo, lettuce, kangkong, grapes, eggplant, cucumber, and sayote as the most preferred crops which rated a score ranging from 4 – 5. The next most preferred crops have an average rating of 3 – 4, these crops included bell pepper, cabbage, patola, okra and cauliflower. Moreover crops

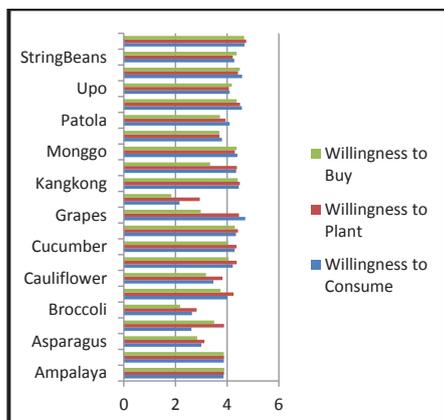


Fig.3: Preferred Crops of Davao City Residents

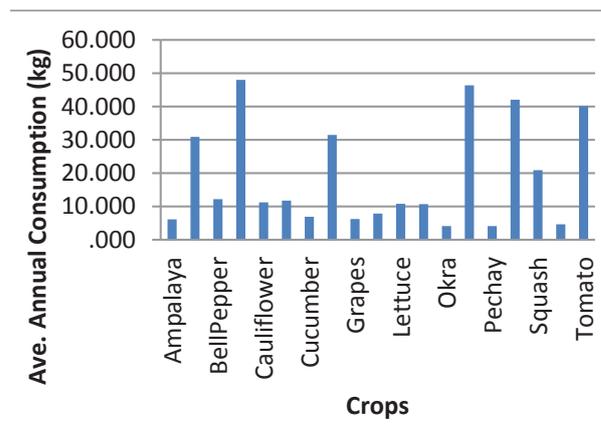


Fig. 5: Average Annual Consumption of each crop per household

mentioned above which were highly priced in Davao City, which were the crops broccoli, asparagus, and habichuelas were also the least preferred.

Another data surveyed were the amount of crops that the household bought at and consumed yearly. As shown in Fig. 5 the average consumption of the households in Davao City in kilograms for ampalaya, cucumber, grapes, kangkong, okra, pechay, and string beans were less than 10kg. Among the green vegetables, cabbage was consumed highly at 48kg followed by patola, upo, and tomato. The crops that were consumed least were grapes, cucumber, ampalaya, pechay, lettuce, mongo, sayote, and cauliflower.

Vertical Farm Area Requirement based on Resident Household Consumption and Annual CROP Produced

After the crop preference survey, the vertical farm needed based on the area requirement of each crop preference was measured and documented. In the installation of vertical farms the green leafy such as lettuce and pechay can be planted in layers with each plant spaced not so far from each other so it would apparently be an advantage of acquiring greater space for the yield not to mention the faster growth of all the crops because of the static hydroponic solution situated below the

roots to be passively aerated.

Projected Yield per Crop

In order to optimize the use of space and minimize structural requirement for the building structure the hydroponics system was used for the vertical farm. The data on the average yield and expenses in the installation of the hydroponics system were collected. The data presented below were taken from the key informant interviews and secondary sources.

The annual projected yield for each crop were computed based from the per unit area utilized for each particular crop then multiplied by the number of cropping or harvest in a year depending on the number of seasonal harvest in a year. The total number of kilos per unit area per year of each crop (kg/sq.m/yr) was computed and tabulated on Table 4.

After the annual yield or produce of crops was computed, the vertical farm area requirement was then calculated according crop type by initially getting the annual harvest needed of a particular crop per household (kg/yr) divided by the annual yield of crops, which resulted to the vertical farm area needed per household. The sum of all the vertical farm area needed of all the crops per household were used in getting the most efficient floor area percentage ratio. (Table 5)

Table 4. Projected Yields from Hydroponic Crops at Minimum Spacing

Category	Crops	Plants/sq.	Kg/sq. m.	Croppings/	Kg/sq. m./year
Vines	Ampalaya	4.6	13	6.3	81.9
	Alugbate	97	1.5	7.3	10.6
	Sayote	4.6	13	6.3	81.9
	Cucumber	4.6	13	6.3	81.9
	Grapes	4	32	3.8	121.6
	Patola	4.6	13	6.3	81.9
	Upo	4.6	13	6.3	81.9
	Squash	5	32	6.8	220
	String Beans	10.9	6.2	5.4	34
	Tomato	4.7	32	3.8	123.6
Leaf Vegetables	Cabbage	10.9	7	5.3	38.7
	Kangkong	97	1.5	7.3	10.6
	Lettuce				
(Romaine)	43	9.8	4.4	42.9	
	Pechay	43	9.8	4.4	42.9
	Cauliflower	7	7.8	6.1	47.5
Shrubs	Bell Pepper	11	11	5.4	58.9
	Eggplant	8	5.4	4.5	67
	Mongo	10.9	6.2	5.4	34
	Okra	8	5.4	4.5	67

Table 5. Farm Area Needed For Every Household

Crops	Kg/m2/year	Annual Harvest Needed per Household (kg)	No. of household that could be fed/m2/year	Area needed per household (m2)
Ampalaya	81.9	6.2	13.2	0.07
Alugbate	10.6	31	0.34	2.9
Sayote	81.9	18	4.55	0.2
Cucumber	81.9	7	11.7	0.09
Grapes	121.6	6.5	18.7	0.05
Patola	81.9	46.5	1.76	0.57
Upo	81.9	42	1.95	0.51
Squash	220	21	10.4	0.02
String Beans	34	4.7	7.2	0.14
Tomato	123.6	40	3.09	0.32
Cabbage	38.7	48	0.80	1.25
Kangkong	10.6	8	1.3	0.77
Lettuce (Romaine)	42.9	11	3.9	0.26
Pechay	42.9	4.5	9.5	0.11
Cauliflower	47.5	11.5	4.1	0.24
Bell Pepper	58.9	12.5	4.7	0.21
Eggplant	67	31.5	2.1	0.48
Mongo	34	11	3.09	0.32
Okra	67	4.5	14.9	0.07
TOTAL				19.36

The assumed gross floor area is 38,520 sq m for the proposed building structure and the floor area for each condominium unit were allocated at 41 sq.m, which was the current average area size of existing condominium units in Davao City. In Figure 1.4 the vertical farm (VF) area needed for each proposed building based on the number of units was computed as follows: the number of household units multiplied by the required farm area required per household, with assumption that 75 percent of the households will regularly buy at the vertical farms. For example a building with 40% of the gross floor area allocated to residential units was obtained by multiplying the gross floor area (GFA) with the allocated percentage for residential use which is 40% divided by 41. And the assumed seventy-five (75%) consumers of this, would be equivalent to 282, would be the number of units to be occupied by tenants that could theoretically be fed by the harvests of the farm. As presented in Figure 1.4, a building with a residential (RS), commercial (CS) and vertical farm (VF) ratio combination respectively of 40,20,15; 40,15,20; 40,10,25; 40, 5,30; 45,5,25 and 50,5 20 can be sufficiently supplied with food from the farm all year round.

Most Efficient Floor Ratio Percentage of Mixed-use Residential, Commercial and Agricultural Areas

The most efficient ratio percentage of mixed use areas was based mainly on satisfying two conditions. Firstly, the vertical farm area must be able to supply 75% of the number of households (assuming one household per unit) residing in the condominium building with farm food supply. The computed values for each residential (RS), commercial (CS) an agricultural (VF) ratio are shown in Table 6 The first three columns show the areas allocated for the residential, commercial, and agricultural areas in ratio percentage, respectively. The fourth column shows the total number of residential units for each given ratio on the first column. The fifth is the 75 percent of the total number of condo units taken from the result in the fourth column. The seventh column shows the farm area needed per residential unit computed from the given farm area value needed per household of 19.36 sq.m. multiplied to the 75 percent of household unit values from the 5th column. Finally, the last column shows the farm area available based on the fixed gross floor area used in the research to effectively compare the gross profits

Table 6. Farm area needed and available for each RS-CS-VF ratio

RATIO			Units	0.75 % of total Units	Farm area needed per Household	Total farm area needed	Farm Area Available (m2)
RS %	CS %	VF %					
40	30	5	376	282	19.36	5,454.38	1925.187
40	25	10	376	282	19.36	5,454.38	3850.374
40	20	15	376	282	19.36	5,454.38	5775.561
40	15	20	376	282	19.36	5,454.38	7700.748
40	10	25	376	282	19.36	5,454.38	9625.935
40	5	30	376	282	19.36	5,454.38	11551.12
45	25	5	423	317	19.36	6,136.18	1925.187
45	20	10	423	317	19.36	6,136.18	3850.374
45	15	15	423	317	19.36	6,136.18	5775.561
45	10	20	423	317	19.36	6,136.18	7700.748
45	5	25	423	317	19.36	6,136.18	9625.935
50	20	5	470	352	19.36	6,817.98	1925.187
50	15	10	470	352	19.36	6,817.98	3850.374
50	10	15	470	352	19.36	6,817.98	5775.561
50	5	20	470	352	19.36	6,817.98	7700.748
55	15	5	517	387	19.36	7,499.78	1925.187
55	10	10	517	387	19.36	7,499.78	3850.374
55	5	15	517	387	19.36	7,499.78	5775.561
60	10	5	563	423	19.36	8,181.58	1925.187
60	5	10	563	423	19.36	8,181.58	3850.374
65	5	5	610	458	19.36	8,863.37	1925.187



Fig.6: Farm Area Needed vs Farm Area Available

of the proposed project and the existing typical residential condominium in Davao City.

Based on the Fig. 6, only 7 out of the 21 ratios were able provide a vertical farm area equal to or greater than the needed farm area. Given that condition the seven (7) floor area percentage

ratios were the only combination considered since it was the only ratio that were able to produce harvests that would be enough to supply the households residing in the condominium building with food all year round.

As per the construction industry practice, the allocation of

the building use must be comprised of profitable and non-profitable areas or also called as the gross floor area (GFA) and non gross floor area (NGFA) respectively. The GFA and NGFA combination usually ranges from 80% – 20%, which has the most saleable areas or 75% - 30% and 75% - 25% combination. The percent ratio combination is usually decided by the owner and or developer as advised by the Architect and must be in accordance to the local government code of building code depending on the location and region the proposed structure would be constructed. In this study a 75% - 25% was applied for the project. The 75% design efficiency means the ratio or percentage of the building to be allotted for saleable areas and the remaining 25% of the floor area left are the non-profitable areas which covered common spaces for utilities, mechanical and electrical spaces, stairways and elevators and the general space circulation.

As shown on the Table 7, the total expected gross profit of a typical condominium would reach up to approximately Php 501,045,100.68. This was obtained by subtracting the total expenses from the net revenues. The estimated revenue

was taken from the average prices of the units per se which is equivalent to Php 2,496,740.00 per unit or 62,000/sq.m. After deducting 4% for VAT, the net revenue equals Php 1,725,746,688.00. The expenses, on the other hand, were taken from the various costs including the acquisition and development of land, design fee, project management, and administrative fees, construction costs, and marketing expenses amounting to Php 1,224,701,587.32.

The second condition that must be sufficed in order for the percentage ratio to be efficient was to guarantee that the gross profit of the mixed-use commercial, residential with vertical farms must be greater than that of a typical mixed use commercial-residential condominium building.

The Annual Gross Profit was computed with a projected return on investment (ROI) of five years. In the computation of the annual gross profit the formula used was Annual Gross Profit (GPA) = Annual Revenue (RevA) – Annual Expenses (ExpA). For the Fixed Gross Profit the formula was used $GPF = \text{Fixed Revenues (Revf)} - \text{Fixed Expenses (ExpA)}$ and finally for the $YN = GPF - (GPA)(N)$, Where, $Y_n = \text{Gross Profit after } n$

Table 7. Estimated Cost and Revenue of a typical commercial- residential condominium in Davao City

LOT DEVELOPMENT		
No. of Lots developed		1
Lot Area		22,900.00 sq.m.
Type of Lot	Residential	
No. of Buildings		6
GFA		38,503.74 sq.m. @ 6,417.29 sq.m./bldg
Design Efficiency	75%	
Saleable Space(net floor area)		28,994.40 sq.m.
Number of Condo Units		720.00 units @120 units/bldg
Average Net Area per Unit		40.27 sq.m.
Equiv. Selling Price/sq.m.		62,000.00 /sq.m
Average Price per Unit		2,496,740.00
Total Expected Revenues		1,797,652,800.00
	Revenues (net of 4% VAT)	1,725,746,688.00
T		
Expenses:		
Lot Acquisition		182,857,500.00
Land Development @3,000/sq.m		68,700,000.00
Design,PM and admin		62,214,805.14
Construction cost @22,000/sq.m.		847,082,280.00
Marketing Expenses		63,847,002.18
Total Expenses		1,224,701,587.32
Expected Gross Profit		501,045,100.68
Return on Investment		41%

years, GPF= Fixed Gross Profit, GPa= Annual Gross Profit, N= Number of Years. A comparative computation of the annual gross profit and return of investment between the typical mixed use commercial-residential condominium and the mixed commercial-residential and agricultural type of condominium was done in order to prove if an integration of vertical farms in typical commercial-residential will generate more income or not. As presented in Table 6 there were seven different floor area percentage ratio that satisfied the vertical farm area requirement. The annual gross profit and ROI for each one of this percentage ratio combination were computed. The gross profit and ROI computation resulted greater with the mixed-use commercial residential with vertical farms than those without. In Table 6 it has been shown that all seven ratios generated a higher income than that of a typical mixed-use condominium. The floor area percentage ratio combinations of residential, agricultural and commercial at 50-5-20 respectively was the ratio that generated the highest income in the amount of P1,785,316,198.00 against only P501,045,100.00. The results of the comparative gross profit computation also showed that the mixed-use residential-commercial with agricultural use consistently generated a higher profit compared to the typical condominium, which showed that it was more feasible and efficient. (Fig.7)

CONCLUSION

In conclusion, the integration of agricultural units in existing mixed-use residential and commercial multi-storied is presented as highly economically efficient. The proposed mixed use residential, agricultural and commercial vertical condominium which recommended the incorporation of vertical farms in residences and offered a healthy and holistic lifestyle was accepted by Davao residents.

Generally, residents were willing to eat, buy and plant hydroponic crops like, pechay, cucumber, tomato and other vegetable crops. There were very few crops that the Davao residents were reluctant to consume and mostly because it was expensive, such as lettuce, grapes, and cauliflower. Households who were not willing to buy those crops were found out to have annual family incomes of not more than Php 99,999.00. The survey result also suggested that the best profile targets for the proposed multi-storied building with vertical farms were those with families aged from 26 and above, and have annual family incomes ranging from P 100,000 – P 499,999.00.

In calculating for the gross floor area percentage ratio of vertical farms that was most efficient to be integrated in the mixed-use residential-commercial, only seven ratios were found efficient. These residential (RS), commercial (CS) and agricultural (VF) ratio combination were respectively the following 40: 15: 20, 40: 20: 15, 40:10:25, 40:5:30, 45:10:20, 45:5:25, and 50:5:20. Finally, in the comparative computation of the annual gross profit and return of investment between the mixed-use residential-commercial with and without vertical farm units,

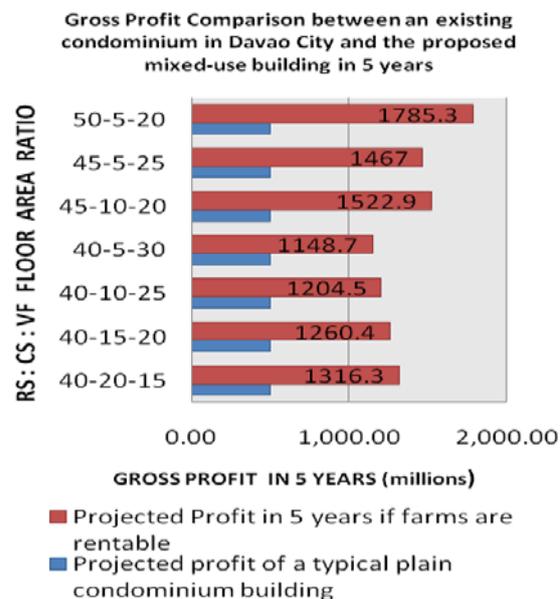


Fig.7: Gross profit comparison between a typical residential-commercial and the mixed use residential commercial with vertical farm unit condominium

the result showed that multi-storied building with vertical farms profited at large compared to the typical existing residential-commercial buildings. Based on the computation the multi-storied vertical structure with farm units generated an ROI of Php,785,316,198.39 compared to the typical residential-commercial structure which was only Php501,045,100.68. In conclusion building vertical farms in Davao City is feasible with the most efficient residential: commercial: agricultural gross floor area percentage ratio of 50: 5: 20.

As final recommendation, the energy efficiency of the building must be thoroughly considered. It is also recommended to further study the application and integration of aquaponics in vertical farms where fishes such as tilapia may be grown to serve as supplementary nutrient source for the hydroponically-grown plants. Furthermore, the details of hydroponic mechanism should be further studied to efficiently integrate it with vertical farms. The costs and expenses of growing the plants hydroponically should be noted annually as market prices vary each year.

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