

Optimization of the Productions of Watermelon and Melon in Candaba, Pampanga

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Abstract

The study develops a linear programming model that enables to maximize the profit of small-scale farmer in Gulap, Candaba, Pampanga in the production of different varieties of watermelon and melon. Three types of watermelon were considered in this study such as seminis, takis, stripes while four types of melon were considered such as brilliant, sweet flavor, jade and Ilocos gold. Each crop has a maximum period of 90 days and the environmental conditions in 1.5 hectares of planting ground are assumed to be normal. The cropping season is from October to December. In the development of the model, several constraints were considered such as budgets for seeds, plant operating expenses, delivery requirements or demands in the market and the area of planting field. It is also assumed based on the farmers that each seed will only have one watermelon fruit of each type. The researchers were able to produce 120 linear programming models for each combination of the seven varieties of watermelon. Using Microsoft Excel Solver, the solution for each model obtained and the best combination was identified. Profit analysis was also done by comparing the profit earned by the traditional way of planting against the developed combination of seeds using linear programming, and it was proved that the developed model produces a higher profit.

Keywords: linear programming model, profit maximization, watermelon, melon

I. INTRODUCTION

Agricultural sector plays an important role in the economic progress of a nation. The materials needed and the economic activities come from this. First, the agricultural sector provides food. The Philippine soil is best suited for root crops such as rice, corn, sugar cane, potatoes and many others. Mangoes, pineapples, coconuts, and bananas also abound. Second, it provides raw materials

needed to create other products. Natural materials from forests, fields, and seas can be made into a different variety of handicraft products. The agricultural sector also contributes to the economic progress through export. Agricultural products that are exported to other countries include sugar, flowers, fruits, seafood and many others. An important source of income for the government is

the exportation of agricultural products. It provides employment to a large number of Filipinos. Those on the countryside depend on agriculture for their livelihood such as farming, fishing, mining and raising livestock. Last, a progressive agricultural sector can support other sectors of the economy like manufacturing, trade and services by supplying the needed raw materials. That is why when a country dreams of industrialization, it needs to expand and improve its agricultural production. (Pulse 101, 2013)

The tropical and subtropical fruit industry is an important sector in many countries in generating income and employment, providing foreign exchange earnings and as an important source of nutrition and dietary requirements for a healthy population. It is a vibrant sector with

progressive expansion in production, international trade and consumption. (Izham & Chua, 2006)

Watermelon (*Citrullus lanatus*) is now widespread in all tropical and subtropical regions of the world. Mostly grown for fresh consumption of the juicy and sweet flesh of mature fruits. Locally known in the country as *pakwan*, it is one of the most popularly grown fruits in the country today during summer. (DA-BPI, 2011)

The researchers consider only the following varieties of watermelon and melon like takis, stripes, seminis, jade, brilliant, Ilocos gold and sweet flavour, which are used by small-scale farmers in Candaba, Pampanga.

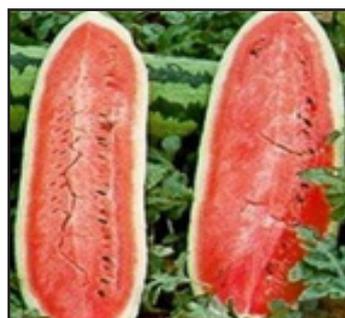
Mathematical programming is a method for solving a problem where one function



a. Takis



b. Seminis



c. Stripes



d. Ilocos Gold



e. Sweet Flavor



f. Brilliant



g. Jade

or objective is maximized or minimized while other functions or constraints are satisfied. As an example, mathematical programming can be used to maximize profit given constraints on available capital and labor. Mathematical programming models developed by agricultural economists can be divided into two main categories: farm models and sector models (Hazell & Norton, 1986). Since the 1960's mathematical programming techniques have been widely used to model farm-level management decisions and to model agricultural sectors.

Linear Programming (LP) is perhaps the most important and best-studied optimization problem. It was used in representing the agroforestry model. The model considered the government sector, production sector, market sector and household sector as components of the system. Participatory rapid rural appraisal was used in gathering data and standard methods for financial analyses. The optimal solution generated a maximum value of ₦373,689.80 which includes ginger, banana and nangka with 122,857 plants, 32 plants and 247 trees respectively. The optimal land allocation of 21,611.57 square meter (70.82%) and 8,906.04 (29.18%) are for agricultural crop production and fruit tree production respectively. The optimal area is 3.0571 hectares. All constraints are non-binding except for maintenance/protection labor. Increasing the area to be planted with trees reduces the objective function value and favours the planting of mango. Increase in objective function and income were observed in varying the farm size from 1 hectare to 3.5 hectares. Limiting the capital requirements resulted to planting of low input crops. Forcing a species to be included in the optimal solution reduces the objective function. Adding erosion constraint drastically reduces the objective function and species composition of the farm. Sensitivity analyses proved that ginger is always an element of the

solution. (Hernandez, 1998)

Linear Programming technique is relevant in optimization of resource allocation and achieving efficiency in production planning particularly in achieving increased agricultural productivity. Igwe, Onyenweaku and Nwaru applied a linear programming technique to determine the optimum enterprise combination. The recommended optimum plan by the LP model achieved a gross income of N342, 763.30 from N188, 736.29, a 44.6 percentage increase. Riddler, Rendel and Baker applied LP to a sheep and cow farm. This led to a new system of how feed is grown and utilized and a refined system to make use of it with breeding cows and ewes. Since the start of the use of the linear programming model, farm income has increased for the past ten years. Mohring and Zimmermann constructed and applied linear programming farm model with an integrated Life Cycle Assessment for the determination of sustainable milk production systems. Linear programming was also applied by Salimonu, et al. to model the efficient resource allocation patterns for food crop farmers in Nigeria. A return of N31, 959.81 per hectare was the actual level of the farmers' income compared with the return of N98, 861.24. If the farmers were to apply profit maximization objective, this will be achieved by applying linear programming.

Linear Programming technique is relevant in optimization of crop mix for a finite-time planning horizon. Given limited available resources such as budget and land acreage, the crop-mix planning model was formulated and transformed into a multi-period linear programming problem. The objective was the maximization of the total returns at the end of the planning horizon. The problem was solved for selected vegetable crops using LINDO. The results indicated promising returns even for a relatively short planning horizon

of 12 months and if properly implemented will enhance farm income and provide beneficial contribution to the farming societies. (Mohamad and Said, 2011).

II. RESULTS AND DISCUSSIONS

The main objective of this study is to develop a Linear Programming model/s. It determines the best combination of watermelon and melon production of small-scale farmers in Candaba, Pampanga so as to maximize their profit. In a 1.5 hectare land, the three varieties of watermelon (seminis, takis and stripes) and 4 varieties of melon (brilliant, Ilocos gold, jade and sweet flavor) were planted. Each crop has a maximum grooming period of 90 days, and the environmental conditions are assumed to be normal. A total of 120 linear programming models of different combinations of watermelon and melon were developed.

Define the following variables:

Let

- x_1 = the number of seeds of seminis to be planted
- x_2 = the number of seeds of takis to be planted
- x_3 = the number of seeds of stripes to be planted
- x_4 = the number of seeds of brilliant to be planted
- x_5 = the number of seeds of jade to be planted
- x_6 = the number of seeds of sweet flavor to be planted
- x_7 = the number of seeds of Ilocos gold to be planted
- Z = the amount of revenue

Formulation of Revenue Function

The revenue function of each linear programming models consisted of each combination of the seven crops. To determine the revenue contribution of each watermelon and each melon to

the total revenue, the researcher got the average weight of each full-grown crops then multiplied it to their price per kilo as shown in Table 1.

Formulation of Linear Constraints

Let c_1 to c_4 be the constraints. Suppose c_1 is the budget for seeds. It is the sum of the cost per seed of each crop which should not exceed to the total budget for seeds. The coefficient was achieved by dividing the price per pack of each crop to the number of seeds per pack as shown in Table 2.

Let c_2 as an operating expense per seed. Operating expenses include machineries, fertilizers, pesticides, herbicides and vitamins which are required to get the maximum growth of each plant. The

Table 1.
Revenue Contribution of Each Watermelon and Melon

Seed	Average Kilo per Piece (kg)	Cost per Kilo (in PhP)	Revenue of each Crop (in PhP)
Seminis	2.25	12.00	27.00
Takis	7.5	10.00	75.00
Stripes	2.25	12.00	27.00
Brilliant	2	30.00	60.00
Jade	2	25.00	50.00
Sweet Flavor	2	20.00	40.00
Ilocos Gold	2	30.00	60.00

Table 2.
Table 2. Budget for each Crops and Delivery Requirements

Seed	Cost of Seed per Pack (in PhP)	Seed per Pack	Cost of each Seeds (in PhP)
Seminis	1,600.00	1,800	0.89
Takis	950.00	1,650	0.58
Stripes	945.00	1,500	0.63
Brilliant	1,250.00	300	4.17
Jade	820.00	250	3.28
Sweet Flavor	820.00	400	2.05
Ilocos Gold	1,400.00	200	7.00

coefficient was computed by dividing the allotted budget for operating expenses to the total number of planting holes that was 17,152. The allotted budget for the seeds was PhP 120,000.00. Thus, each seed cost an operation of approximately PhP 7.00.

Let c_3 be the delivery requirement. The minimum demand of all buyers was at least 10,000 kilos. If it was not achieved, the buyer would no longer continue the transaction. In this case, the farmer would have a problem in selling their products.

Let c_4 as the number of planting holes for cultivation. The number of planting holes limits the number of seeds to be planted. Two planting holes were provided for each seed of watermelon and one planting hole per seed of melon. If the number of the planting holes exceeded in the given limit, it might affect the growing process of the crops because the area will be crowded.

The Linear Programming Models and its Optimal Solution

The researcher presented only the maximum profit for each possible number combinations of crops; that is, from two to seven combinations. Out of 120 possible combinations, there were six best combinations:

1. Combination of Takis and Brilliant (x_2, x_4)

Objective function

$$\text{Max } Z = 75x_2 + 60x_4$$

Subject to

$$\begin{aligned} 0.58x_2 + 4.17x_4 &\leq 15,000 \\ 7(x_2+x_4) &\leq 120,000 \\ 7.5x_2 + 2x_4 &\geq 1,0000 \\ 2x_2 + x_4 &\leq 17,152 \\ x_2, x_4 &\geq 0 \end{aligned}$$

Optimal Solution:

$$\begin{aligned} x_2 &= 7,284, \quad x_4 = 2,584 \\ \text{and } Z &= \text{Php } 701,340 \end{aligned}$$

There are 21 possible combinations of two varieties of watermelon and melon. And based on these possible combinations, the farmer should plant 7,284 seeds of takis and 2,584 seeds of brilliant to amass maximum profit of Php 701,340.

2. Combination of Seminis, Takis and Brilliant (x_1, x_2, x_4)

Objective function

$$\text{Max } Z = 27x_1 + 75x_2 + 60x_4$$

Subject to

$$\begin{aligned} 0.89x_1 + 0.58x_2 + 4.17x_4 &\leq 15000 \\ 7(x_1+x_2+x_4) &\leq 120,000 \\ 2.25x_1 + 7.5x_2 + 2x_4 &\geq 10,000 \\ 2x_1 + 2x_2 + x_4 &\leq 17,152 \\ x_1, x_2, x_4 &\geq 0 \end{aligned}$$

Optimal Solution:

$$\begin{aligned} x_1 &= 0, \quad x_2 = 7,284, \quad x_4 = 2584, \\ Z &= \text{Php } 701,340 \end{aligned}$$

There are 35 possible combinations of three varieties of watermelon and melon. And based on these possible combinations, the farmer should plant 7,284 seeds of takis and 2,584 seeds of brilliant only to have a maximum profit of PhP 701,340.

3. Combination of Seminis, Takis, Stripes and Brilliant (x_1, x_2, x_3, x_4)

Objective Function

$$\text{Max } Z = 27x_1 + 75x_2 + 27x_3 + 60x_4$$

Subject to

$$\begin{aligned} 0.89x_1 + 0.58x_2 + 0.63x_3 + 4.17x_4 &\leq 15,000 \\ 7(x_1+x_2+x_3+x_4) &\leq 120,000 \\ 2.25x_1 + 7.5x_2 + 2.25x_3 + 2x_4 &\geq 10,000 \\ 2x_1 + 2x_2 + 2x_3 + x_4 &\leq 17,152 \\ x_1, x_2, x_3, x_4 &\geq 0 \end{aligned}$$

Optimal Solution:

$$\begin{aligned} x_1 &= 0, \quad x_2 = 7,284, \quad x_3 = 0, \quad x_4 = 2,584 \\ Z &= \text{Php } 701,340 \end{aligned}$$

There are 35 possible combinations of four varieties of watermelon and melon. And based on these possible combinations,

the farmer should plant 7,284 seeds of takis and 2,584 seeds of brilliant only to have a maximum profit of PhP 701,340.

4. *Combination of Seminis, Takis, Stripes, Brilliant and Jade* (x_1, x_2, x_3, x_4, x_5)

Objective Function

$$\text{Max } Z = 27x_1 + 75x_2 + 27x_3 + 60x_4 + 50x_5$$

Subject to

$$\begin{aligned} 0.89x_1 + 0.58x_2 + 0.63x_3 + 4.17x_4 + 3.28x_5 &\leq 15,000 \\ 7(x_1 + x_2 + x_3 + x_4 + x_5) &\leq 120,000 \\ 2.25x_1 + 7.5x_2 + 2.25x_3 + 2x_4 + 2x_5 &\geq 10,000 \\ 2x_1 + 2x_2 + 2x_3 + x_4 + x_5 &\leq 17,152 \\ x_1, x_2, x_3, x_4, x_5 &\geq 0 \end{aligned}$$

Optimal Solution:

$$\begin{aligned} x_1 &= 0, x_2 = 7,284, x_3 = 0, \\ x_4 &= 2584, x_5 = 0, \\ Z &= \text{Php } 701,340 \end{aligned}$$

There are 21 possible combinations of five varieties of watermelon and melon. And based on these possible combinations, the farmer should plant 7,284 seeds of Takis and 2,584 seeds of Brilliant only to have a maximum profit of PhP 701,340.

5. *Combination of Seminis, Takis, Stripes, Brilliant, Jade and Sweet Flavor* ($x_1, x_2, x_3, x_4, x_5, x_6$)

Objective function

$$\text{Max } Z = 27x_1 + 75x_2 + 27x_3 + 60x_4 + 50x_5 + 40x_6$$

Subject to

$$\begin{aligned} 0.89x_1 + 0.58x_2 + 0.63x_3 + 4.17x_4 + 3.28x_5 + 2.05x_6 &\leq 15000 \\ 7(x_1 + x_2 + x_3 + x_4 + x_5 + x_6) &\leq 120,000 \\ 2.25x_1 + 7.5x_2 + 2.25x_3 + 2x_4 + 2x_5 + 2x_6 &\geq 10000 \\ 2x_1 + 2x_2 + 2x_3 + x_4 + x_5 + x_6 &\leq 17152 \\ x_1, x_2, x_3, x_4, x_5, x_6 &\geq 0 \end{aligned}$$

Optimal Solution:

$$\begin{aligned} x_1 &= 0, x_2 = 7,284, x_3 = 0, x_4 = 2,584, x_5 = 0, \\ x_6 &= 0, Z = \text{Php } 701,340 \end{aligned}$$

There are seven possible combinations of six varieties of watermelon and melon. And based on these possible combinations,

the farmer should plant 7,284 seeds of Takis and 2,584 seeds of Brilliant only to have a maximum profit of PhP 701,340.

5. *Combination of Seminis, Takis, Stripes, Brilliant, Jade, Sweet Flavor and Ilocos Gold* ($x_1, x_2, x_3, x_4, x_5, x_6, x_7$)

Objective function

$$\text{Max } Z = 27x_1 + 75x_2 + 27x_3 + 60x_4 + 50x_5 + 40x_6 + 60x_7$$

Subject to

$$\begin{aligned} 0.89x_1 + 0.58x_2 + 0.63x_3 + 4.17x_4 + 3.28x_5 + 2.05x_6 + 7x_7 &\leq 15,000 \\ 7(x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7) &\leq 120,000 \\ 2.25x_1 + 7.5x_2 + 2.25x_3 + 2x_4 + 2x_5 + 2x_6 + 2x_7 &\geq 10,000 \\ 2x_1 + 2x_2 + 2x_3 + x_4 + x_5 + x_6 + x_7 &\leq 17,152 \\ x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 &\geq 0 \end{aligned}$$

Optimal Solution:

$$\begin{aligned} x_1 &= 0, x_2 = 7,284, x_3 = 0, \\ x_4 &= 2,584, x_5 = 0, \\ x_6 &= 0, x_7 = 0, \\ Z &= \text{Php } 701,340 \end{aligned}$$

When it comes to the seven combinations of different varieties of watermelon and melon, there is only one possible combination. And based on this combination, the farmer should plant 7,284 seeds of takis and 2,584 seeds of brilliant only to have a maximum profit of PhP 701,340.

Results show that for each different possible combinations of different varieties of watermelon and melon, they produced the same maximum revenue of PhP 701,340 by planting 7,284 seeds of takis (watermelon) and 2,584 seeds of brilliant (melon).

Table 3 show a comparison of profit in the traditional planting method and the solution using linear programming. Based on this table, budget allocation

Table 3.
Comparison of LP Solution and
Traditional Planting Method

	Traditional Planting Method (in PhP)	Solution using Linear Programming (in PhP)
Budget for Seeds	15,000.00	15,000.00
Operating Expenses	120,000.00	69,076.00
Total Cost	135,000.00	84,076.00
Gross Income	423,690.00	701,340.00
Profit (Net Income)	288,690.00	617,264.00

for traditional planting method and planting using the solution from linear programming are the same, which is PhP 15,000. When it comes to operating expenses, planting using the solution from linear programming is much cheaper than traditional planting method by PhP 50,924. An increase by as much as PhP 277,650 and PhP 328,574 is gained from planting using solution of linear programming compared to traditional planting method when it comes to gross and net income respectively.

III. CONCLUSIONS

Based on the developed linear programming model, it was showed that planting a combination of takis (watermelon) and brilliant (melon) will maximize the revenue and profit of the small-scale farmers in Candava, Pampanga. The profit from traditional planting method has increased by as much as 113.82% for the plant the best combination obtained using linear programming. On the other hand, the combination of other varieties of watermelon and melon such as stripes, seminis and others gives the lowest profit among the other combinations. Linear programming model is a quantitative technique used when it comes to decision making. It is a systematic way of determining our goal that is profit maximization given different constraints or restrictions.

IV. RECOMMENDATIONS

The researchers suggest that the small-scale farmers in Candava, Pampanga should plant 7,284 seeds of takis and 2,584 seeds of brilliant to achieve a maximum profit of PhP 701,340. We also recommend the use of other constraints such as factors that affect the growth of watermelons and melons. Environment conditions in planting should also be considered in future studies. Using linear programming model is highly endorsed to determine the optimal solution when it comes to profit maximization given certain constraints.

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