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RICE PROFIT MAXIMIZATION IN MABITAC LAGUNA FARMS IN THE PHILIPPINES

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ABSTRACT

The study developed a linear programming model that enables to maximize the profit of Rice Farms in Mabitac, Laguna in varieties of Rice. The three varieties of Rice were considered in this study such as dry, wet and average and three hectares of planting ground are assumed to be normal. In the development of the model, several constraints were considered such as cost of seeds per kilo, cost of pesticide, fertilizer, irrigation, fuel and oil, electricity, sacks and tying materials and transportation used per kilogram of seeds. The researchers were able to produce three linear programming models for each variety of rice. Using POM-QM, the solution for each model was obtained and the best combination for every variety of rice was identified. Profit analysis was also done by comparing the profit earned from the data given against the profit earned using linear programming.

Keywords: Linear Programming, Maximization, POM-QM, Profit, Rice

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INTRODUCTION

Rice remains as the main staple food in the country, with 100 million Filipino people eating rice at least three times a day. In 2012, nearly half of world's population more than 3 billion people relied on rice every day. It is also the staple food across Asia where around half of the world's poorest people live and is becoming increasingly important in Africa and Latin America (Maclean, 2013).

Moreover, rice has also fed more people over a longer time than has any other crop. It is spectacularly diverse, both in the way it is grown and how it is used by humans. Rice is unique because it can grow in wet environments that other crops cannot survive in. Such wet environments are abundant across Asia. The domestication of rice ranks as one of the most important developments in history and now thousands of rice varieties are cultivated on every continent except Antarctica.

In the Philippines, rice is also the most important crop to millions of small farmers who grow it on thousands of hectares throughout the region, and to the many landless workers who derive income from working on these farms. In 2013, rice employs 2.5 million households, broken down into 2.1 million farmers, 110,000 workers for post-farming activities and 320,000 for ancillary activities. It has been reported that the Philippines is the world's eighth-largest rice producer (Gonzales, 2013). However, the country's rice area harvested is still very small compared with that of the other major rice-producing countries in Asia. More than two-thirds or 69% of its rice area is irrigated. From April to June 2016, the rice production in the Philippines dropped to 3.71 million metric ton from 3.96 million in 2015 or by 6.10%. Likewise, 2016's harvest area contracted to 848 thousand hectares from 2015's level of 914 thousand hectares. However, yield per hectare improved by 1.16% from 4.33 metric tonin 2015 to 4.38 in 2016 (Ocampo, 2016).

Farm-level rice yields in the Philippines have grown in the last decade without a significant change in inputs and crop establishment methods. It has always been a challenge for them to maximize their profit especially in Mabitac, Laguna. Thus, this study aims to maximize the profit.

Research Paradigm

The researchers aim to maximize the profit of Rice Farms in Mabitac, Laguna. The costs directly affect the profit gained since as materials needed which affect the profit increases, the cost also increases.

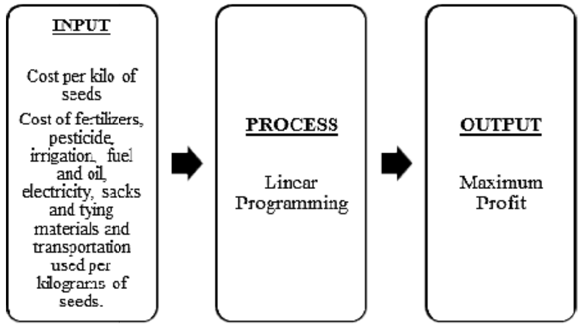

Fig.1. Research paradigm

In this study, the researchers optimize using the unit kilogram, and throughout this study the values for the variables were all converted to cost per kilograms of seeds or cost used per kilogram of seeds.

STATEMENT OF THE PROBLEM

The farmers of Mabitac, Laguna wanted to create more profit in rice production. However, their expenditures continue to grow every year. In response to this problem, our study proposes to use the profit maximization technique to create an optimal solution for rice production to achieve the maximum profit by minimizing the expenditures and loss in rice production.

SCOPE AND LIMITATION

This study only focuses on maximization of profit of Rice Farms in Mabitac, Laguna. The models constructed by the researchers were all based on the data received. The latest data for 2016 were used in this study. Also, only those that are affecting the profit per unit were used.

Table 1. Inventory of Cash Costs Incurred in Rice Production

	Dry	**Wet**	**Average**	**Budget**
Cash costs	22,914	19,372	21,017	70,000
Seeds	908	840	874	3,000
Fertilizer	4,176	3,892	874	13,000
Pesticides	1,499	1,309	1,392	5,000
Fuel and oil	759	442	586	1,800
Transport cost	59	93	77	250
Irrigation fee	9	10	9	30
Electricity	371	304	335	1,100
Sacks and tying materials	6	0	3	10

Table 2. Inventory of Non - Cash Costs Incurred in Rice Production

	Dry	**Wet**	**Average**	**Budget**
Non-cash costs	18.539	16,438	17,452	55,000
Seeds	540	733	645	2,000
Fertilizer	9	11	10	30
Irrigation fee	337	233	281	1,000

Table 3. Inventory of Imputed Costs Incurred in Rice Production

	Dry	Wet	Average	Budget
Imputed Costs	7,380	7,972	7,692	25,000
Seeds	352	268	308	1,000
Fertilizer	136	21	75	250
Pesticides	26	5	16	50
Fuel and oil	6	4	5	20
Transport cost	2	0	1	5
Sacks and tying materials	1	1	1	5
Returns above cast costs	33,517	31,413	32,672	
Return above non-cash costs	14,987	14,975	15,220	
Returns above imputed costs	7,598	7,003	7,528	
Cost per kilogram in pesos	13.43	13.26	13.28	
Yield per hectare in kilograms	3,636	3,302	3,475	

MATERIALS AND METHODS

The researchers used the concept of Linear programming to maximize the pro t based from the data given.

Linear Optimization also known as linear programming (LP) may be defined as the problem of maximizing or minimizing a linear function subject to linear constraints. The constraints may be equalities or inequalities (Ferguson, 1995). It can be defined as the process of minimizing or maximizing a linear function to find the optimum value (minimum or maximum) for linear and non-negative constraints.

The term programming here implies the way of planning and organizing (formulation) to find the optimal solutions. In general, this method is relatively simple technique to find realistic solutions for wide range of optimization problems and includes three essential elements listed below (Goodarzi, 2014):

1. Identify decision variables: decision variables are the unknown variables of the problem statement the need to be determined to solve the problem. Defining decision variables precisely is a fundamental step in formulating a linear optimization model.
2. Obtain the objective function: in this step we need to define the objective of desired problem statement which shows the main goal of the decision-maker. Afterward, the relations between decision variables and objective should be accurately determined. It should be noted that the function cannot include any nonlinear component such as exponential, products, or division of variables, and variables under a root sign. All variables only must be added or subtracted in linear fashion.
3. Determine the constraints: constraints explain the requirement that desired problem shall meet, and it can be in the forms of either equalities (=) or inequalities (≤, ≥).

In vector notation, LP canonical form is the following (Panigrahi, 2013):

$$\begin{array}{cc} \text{Max } c^T x & \text{Min } c^T x \\ Ax \le b & Ax \ge b \\ x \le 0 & x \ge 0 \end{array}$$

In scalar notation, LP standard form is the following:

Maximum (or Minimum)

$$z(-z) = c_1 x_1 + c_2 x_2 + \cdots + c_n x_n$$

Subject to:

$$a_{11}x_1 + a_{12}x_1 + \cdots + a_{1n}x_n = b_1$$
$$a_{21}x_1 + a_{22}x_1 + \cdots + a_{2n}x_n = b_2$$
$$\vdots$$
$$a_{m1}x_1 + a_{m2}x_1 + \cdots + a_{m}x_n = b_n$$

Almost every organization has access to computer programs that are capable of solving enormous LP problems. Although each computer program is slightly different, the approach each takes toward handling LP problems is basically the same. The format of input data and the level of detail provided in output results may differ from program to program and computer to computer, but once the people are experienced in dealing with computerized LP algorithms, people can easily adjust to minor changes. So, to solve for these mathematical models, the researchers used POM-QM (Quantitative Methods, Product Operations Management) for Windows Version 4.

The Prentice Halls Decision Science software package: POM-QM for Windows (also known as POM for Windows and QM for Windows) developed by Howard Weiss is the most user-friendly software package available in the fields of production and operations management, quantitative methods, management science, or operations research.

POM-QM for Windows has been designed to help people to better learn and understand these fields. The software can be used either to solve problems or to check answers that have been derived by hand. POM-QM for Windows contains a large number of models, and most of the homework problems in POM textbooks or QM textbooks can be solved or approached using POM-QM for Windows (Weiss, 2010).

People will find that this software is exceptionally friendly due to the following features (Hanna, 2012)

1. Anyone familiar with any standard spreadsheet or word processor in Windows will be easily be able to use QM for Windows.
2. The screens for every module are consistent, so that when you become accustomed to using one module, people will have an easy time with the other modules.
3. The spreadsheet-type data editor allows full screen editing.
4. Files are opened and saved in the usual Windows fashion, and in addition, files are named by module, which makes it easy to find files saved previously.
5. It is easy to change from one solution method to another to compare methods and answers.
6. Graphs are easily displayed and printed.

Sensitivity Analysis was performed using POM-QM for Windows to determine changes in the parameters of the linear programming model that affects the optimal solution.

RESULTS AND DISCUSSION

To maximize the profit and minimize the cost of rice based on the data given, the researcher made a linear model. The linear model is to identify the maximum profit for every kilogram of seeds with minimum cost. The units used in this study are cost of seeds per kilogram and cost used per kilogram of seeds.

For Cash Cost:

Let x_1 be the number of Kilograms of Dry Rice

Let x_2 be the number of Kilograms of Wet Rice

Let x_3 be the number of Kilograms of Average Rice

Objective Function

$$Z = 495.741x_1 + 495.87x_2 + 496.43x_3$$

Subject to:

Cost of seeds per kilogram

$$13.43x_1 + 13.26x_2 + 13.28x_3 \leq 3000$$

Cost of Fertilizer used per kilogram of seed

$$61.77x_1 + 61.44x_2 + 61.16x_3 \leq 13000$$

Cost of Pesticide used per kilogram of seed

$$22.17x_1 + 20.67x_2 + 21.15x_3 \leq 5000$$

Cost of Irrigation used per kilogram of seed

$$6.77x_1 + 6.79x_2 + 6.75x_3 \leq 1400$$

Cost of Fuel and Oil used per kilogram of seed

$$11.23x_1 + 6.98x_2 + 8.9x_3 \leq 1800$$

Cost of Electricity used per kilogram of seed

$$0.13x_1 + 0.15x_2 + 0.14x_3 \leq 30$$

Sacks and tying used per kilogram of seed

$$4.88x_1 + 4.53x_2 + 4.68x_3 \leq 1000$$

Transportation used per kilogram of seed

$$87x_1 + 1.47x_2 + 1.17x_3 \leq 250$$

$$x_1, x_2, x_3 \geq 0$$

Based on the objective function and the constraints, to maximize the profit the kilograms for dry, wet and average are 0, 23.2802, 183.9892 kilograms respectively. When these solutions are obtained, it will have an optimal value Php 102,881.7 profit for cost per kilogram. Which is larger from the profit they gain which is Php 97,602.

Table 4. Optimal Solutions for Cash Cost

	x_1	x_2	x_3		RHS	Dual
Maximize	495.74	495.87	496.43			
Seeds	13.43	13.26	12.38	≤	3000	0
Fertilizer	61.77	61.44	61.16	≤	13000	0
Pesticide	22.17	20.67	21.15	≤	5000	0
Irrigation	6.77	6.79	6.75	≤	1400	71.204
Fuel and Oil	11.23	6.98	8.9	≤	1800	1.775
Electricity	0.13	0.15	0.14	≤	30	0
Sacks and Tying Material	4.88	4.53	4.68	≤	1000	0
Transpor-tation	0.87	1.47	1.17	≤	250	0
Solution	0	23.280	189.989	≤	102881.7	

A unit change in cost in irrigation used per kilogram of seed will give an increase (or decrease) of Php 71.2047 in the optimal solution and a unit change in cost of Fuel and Oil used per kilogram of seed will give an increase (or decrease) of Php 1.17751 in the optimal solution.

Table 5. Optimality Range for Cash Cost

Variable	Value	Reduced Cost	Original Value	Lower Bound	Upper Bound
x_1	0	6.25	495.74	-∞	501.99
x_2	23.28	0	495.87	389.34	499.37
x_3	183.99	0	496.43	493.56	632.27

The greatest possible value for profit per kilogram of seeds for dry rice is Php 501.9901, the least possible value for profit per kilogram of seeds for wet rice is Php 389.335 greatest possible value for profit per kilogram of seeds for wet is Php 499.3718 and last the least possible value for profit per kilogram of seeds for average rice is Php 493.5603 greatest possible value for profit per kilogram of seeds for average is Php 632.2698.

Table 6. Feasibility Range for Cash Cost

Constraint	Dual Value	Slack/ Surplus	Original Value	Lower Bound	Upper Bound
Seeds	0	247.93	3000	2752.07	∞
Fertilizer	0	316.88	13000	12683.12	∞
Pesticide	0	627.43	5000	4372.57	∞
Irrigation	71.20	0	1400	1365.17	1401.38
Fuel and Oil	1.78	0	1800	1796.56	1845.93
Electricity	0	0.75	30	29.25	∞
Sacks and Tying Material	0	33.47	1000	966.53	∞
Transpor-tation	0	0.51	250	249.49	∞

The minimum requirement for seeds is Php 2752, the minimum requirement for fertilizer is Php 12683.12, the minimum requirement for pesticide is Php 4372.574, the minimum requirement for irrigation is Php 1365.169 and maximum requirement is Php 1401.383, the minimum requirement for fuel and oil Php 1796.562 and maximum requirement is Php 1819.815 the minimum requirement for electricity Php 29.2505, the minimum requirement for Sacks and Tying Material Php 966.529, lastly the maximum requirement for transportation Php 249.4893 and the maximum requirement is Php 252.7639.

For Non-Cash Cost:

Let x_1 be the number of Kilograms of Dry Rice

Let x_2 be the number of Kilograms of Wet Rice

Let x_3 be the number of Kilograms of Average Rice

Objective Function

$$Z = 372.51x_1 + 270.9x_2 + 313.37x_3$$

Subject to:

Cost of seeds per kilogram

$$13.43x_1 + 13.26x_2 + 13.28x_3 \le 2000$$

Fertilizer used per kilogram of seed

$$0.22x_1 + 0.2x_2 + 0.21x_3 \le 30$$

Irrigation used per kilogram of seed

$$68.38x_1 + 4.22x_2 + 5.79x_3 \le 1000$$

$$x_1, x_2, x_3 \ge 0$$

Based on the objective function and the constraints, to maximize the profit kilograms that should be allotted for dry, wet and average are 74.6914, 0, and 64.6091 kilograms, respectively. When these solutions are obtained, it will have an optimal value of Php 48069.82 profit which is larger from the profit they gain which is Php 45,173.

Table 7. Optimal Solutions for Non-Cash Cost

	x_1	x_2	x_3		RHS	Dual
Maximize	372.51	270.9	313.37			
Seeds	13.43	13.26	13.28	≤	2000	0
Fertilizer	0.22	0.2	0.21	≤	30	965.447
Irrigation	8.38	4.22	5.79	≤	1000	19.106
Solution	74.691	0	64.609		48069.82	

A unit change in cost of fertilizer used per kilogram of seed will give an increase (or decrease) of Php 965.4479 in the optimal solution and a unit change in cost of irrigation used per kilogram of seed will give an increase (or decrease) of Php 19.1064 in the optimal solution.

Table 8. Optimality Range for Non-Cash Cost

Variable	Value	Reduced Cost	Original Value	Lower Bound	Upper Bound
x_1	74.69	0	372.51	328.29	377.55
x_2	0	2.82	270.9	-∞	273.72
x_3	64.61	0	313.37	311.54	355.58

The least and greatest possible value for profit per kilogram of seeds for dry rice is Php 328.2924 and Php 37754.97, respectively, the greatest possible value for profit per kilogram of seeds for wet rice is Php 273.7185 and the least and greatest possible value for profit per kilogram of seeds for average rice is Php 311.5378 and Php 355.5777, respectively.

Table 9. Feasibility Range for Non-Cash Cost

Constraint	Dual Value	Slack/ Surplus	Original Value	Lower Bound	Upper Bound
Seeds	0	138.89	2000	1861.11	∞
Fertilizer	965.45	0	30	26.25	32.0133
Irrigation	19.12	0	1000	827.14	1142.73

The minimum requirement for seeds is Php 1861.113, the minimum requirement for fertilizer is Php 26.253 and the maximum requirement is Php 30.1659 and the minimum requirement for irrigation fee is Php 827.1429 and the maximum requirement is Php 1142.727.

For Imputed Cost:

Let x_1 be the number of Kilograms of Dry Rice

Let x_2 be the number of Kilograms of Wet Rice

Let x_3 be the number of Kilograms of Average Rice

Objective Function

$$Z = 289.89x_1 + 346.49x_2 + 324.56x_3$$

Subject to:

Cost of seeds per kilogram

$$13.43x_1 + 13.26x_2 + 13.28x_3 \leq 3000$$

Fertilizer used per kilogram of seed

$$5.19x_1 + 1.04x_2 + 3.23x_3 \leq 250$$

Pesticide used per kilogram of seed

$$0.99x_1 + 0.25x_2 + 0.69x_3 \leq 50$$

Fuel and Oil used per kilogram of seed

$$0.23x_1 + 0.2x_2 + 0.22x_3 \leq 20$$

Transportation used per kilogram of seed

$$0.08x_1 + 0.04x_3 \leq 5$$

Sacks and tying used per kilogram of seed

$$0.04x_1 + 0.05x_2 + 0.05x_3 \leq 5$$

$$x_1, x_2, x_3 \geq 0$$

Based on the objective function and the constraints, to maximize the profit the kilograms that should be allotted for dry, wet and average are 0, 75.4148, 0 kilograms respectively. When these solutions are obtained, it will have an optimal value Php 26130.47 profit. Which is larger from the profit they gain which is Php 22,139.

Table 10. Optimal Solutions for Imputed Cost

	x_1	x_2	x_3		RHS	Dual
Maximize	289.89	346.49	324.58			
Seeds	13.43	13.26	13.28	≤	1000	26.13
Fertilizer	5.19	1.04	3.23	≤	250	0
Pesticide	0.99	0.25	0.68	≤	20	0
Fuel and Oil	0.23	0.2	0.22	≤	20	0
Transpor-tation	0.08	0	0.04	≤	5	0
Sacks and Tying Material	0.04	0.05	0.05	≤	5	0
Solution	0	75.41	0		26130.47	

A unit change in cost per kilogram of seeds will give an increase (or decrease) of Php 26.1305 in the optimal solution.

Table 11. Optimality Range for Non-Cash Cost

Variable	**Value**	**Reduced Cost**	**Original Value**	**Lower Bound**	**Upper Bound**
x_1	0	61.04	289.89	∞	350.93
x_2	75.41	0	346.49	324.09	∞
x_3	0	22.43	324.58	-∞	347.01

The greatest possible value for profit per kilogram of seeds for dry rice is Php 350.9322, the least possible value for profit per kilogram of seeds for wet rice is Php 324.0912 and the greatest possible value for profit per kilogram of seeds for average rice is Php 347.0126.

Table 12. Feasibility Range for Cash Cost

Constraint	Dual Value	Slack/ Surplus	Original Value	Lower Bound	Upper Bound
Seeds	23.13	0	1000	-0.0001	1326
Fertilizer	0	171.57	250	78.43	∞
Pesticide	0	31.15	50	18.85	∞
Fuel and Oil	0	4.92	20	15.08	∞
Transpor-tation	0	5	5	0	∞
Sacks and Tying Material	0	1.23	5	3.77	∞

The minimum requirement for seeds is Php 0 and the maximum requirement is Php 1326, the minimum requirement for fertilizer is Php 78.4314, the minimum requirement for pesticide is Php 18.8537, the minimum requirement for fuel is Php 15.083, the minimum requirement for transportation Php 0 and the minimum requirement for sacks and tying material Php 3.7707.

CONCLUSIONS

The researchers recommend that given a Php 3000 budget for seeds, Rice Farms in Mabitac, Laguna should allot 0, 23.2802, 183.9892 kilograms for cash costs of Dry, Wet and Average respectively. When these values were obtained, it will have an optimal value Php 102,881.7 profit for cost per kilogram, which is the maximum profit. For non-cash cost, Rice Farms in Mabitac, Laguna should allot 74.6914, 0, 64.6091 kilograms for non-cash costs of Dry, Wet and Average respectively when these values were obtained, it will have an optimal value Php

48069.82 profit for cost per kilogram, which is the maximum profit given a Php 2000 budget for seeds. Lastly, Given a Php 1000 budget for seeds, Rice Farms in Mabitac, Laguna should allot 0, 75.4148, 0 kilograms for imputed costs of Dry, Wet and Average respectively when these values were obtained, it will have an optimal value Php 26130.47 profit for cost per kilogram, which is the maximum profit.

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