Review of Socio-Economic Research and Development Studies 2020
Volume 4 No. 1, 70-89

CASE STUDY ON PROFIT-MAXIMIZING COMBINATION OF VEGETABLE CROPS FOR SMALL-SCALE FARMERS IN LEYTE, PHILIPPINES

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Intercropping is one of the potential agricultural practices that can help maximize productivity given limited farm area. This study seeks to compare the production output from the existing vegetable combinations grown under intercropping, which could be useful to farmers in the Visayas, particularly in Leyte. Gross margin analysis was conducted to evaluate the profitability of each crop mix. A linear programming model was used to determine optimal land use options for the identified vegetable mixes. Results show that farmers can increase profit across different crop combinations using linear programming approach. In particular, the gross margin analysis results show that sweet pepper-eggplant intercropping combinations provide farmers the highest profit per m^2. This combination could maximize profit up to PHP211,887 per 608.97m^2 of farm area, as suggested from the linear programming analysis. Farmers can achieve maximum profit using the optimal mix of crops, allocating about 551.28m^2 for eggplant production while allocating 57.69m^2 in producing sweet pepper. This study suggests that the choice of small-scale vegetable farmers in intercropping could be enhanced by utilizing linear programming approach. Through linear programming, profit can be maximized, and this approach should be coupled with technical assistance on horticultural aspects and capacity-building activities for farmers.

Keywords: intercropping, gross margin, linear programming, vegetable production

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Received: November 27, 2020 | Revised: May 25, 2021 | Accepted: June 4, 2021

1. INTRODUCTION

The Philippines' average farm area decreases from 2.84 hectares to 1.29 hectares from 1980 to 2012 (Philippine Statistical Authority, 2015). The Visayas region, where Leyte island is located, has the smallest land area, with an estimated 1.20 million hectares used for agricultural activities (Philippine Statistical Authority, 2015). According to Ouma & Jeruto (2010), increasing farm size would increase the profitability in vegetable farming, but for small-scale farming, increasing farm size needs longer time or is not an immediate solution. Hence, it is useful to examine agricultural practices that may help small-scale farmers increase production output without increasing farm size.

Maximizing profitability with limited resources offers small-scale farmers to get the most out of their production. This is important since farmers in Leyte are constantly facing adverse climatic effect and needs to cope accordingly (Rogers et al., 2007; Cagasan & Centino, 2019; Ruales et al., 2020; Seriño et al., 2020). Agriculture plays a crucial role in economic, social, and cultural activities in the Visayas region. Enhancing agricultural productivity will contribute to reducing inequality (Seriño, 2014); hence, finding an optimum combination of crops subject to production constraints will be beneficial to farmers. One of the possible strategies to maximize profit is to use a linear programming approach. Oni et al. (2013) and Kharisma & Perdana (2019) used linear programming in optimizing land utilization and finding the right vegetable mix for farmers to maximize profit.

Optimal use of scarce resources is the central theme of economics (Dixit, 1990). Optimization in economic theory is a decision-making process that involves maximization and minimization problem-solving. Hong et al. (2020) used linear programming to optimally use the growing scarcity of resources used in intercropping while maximizing gross margins at different scenarios. The study employed sensitivity analysis to see how the optimal crop plan and associated gross margin respond when the resources become more scarce while keeping prices of inputs and outputs the same.

For this study, the intercropping practices of vegetable farmers in Leyte were investigated to assess its potential for profit maximization. Intercropping is a helpful system in optimizing the productivity of a given land (Ouma & Jeruto, 2010). It also makes better use of the available resources such as water, nutrients, and light (Gebru, 2015). Hadidi et al. (2011) and Karlidag & Yildrim (2009) showed that intercropping performed better in terms of yield and productivity compared to sole cropping in several experimental sites. Intercropping is a cropping system in which two or more crops are planted in the same area at the same time (Ouma

& Jeruto, 2010; Hussein & Samad, 1993). Intercropping has benefits other than land-use efficiency and increasing total farm productivity; this system can be an alternative to pesticides, fertilizer, and suppression of diseases (Ramert et al., 2002; McDougall et al., 2019). Usually, farmers do take the trial-and-error method to get the right intercropping combination (Majeke, 2013). Any cropping system that would increase crop yields and lower production costs would provide the farmers with economic opportunity (Adeniyi, 2011). However, failing to intercrop is more detrimental in the long run (Nelson et al., 1998). According to the study conducted by Francis et.al (2003), one of the disadvantages of intercropping includes yield reduction of the main crop because there is competition among intercropped plants for resources. This yield reduction may be economically significant if the main crop has a high market price than the other intercropped plants (Gebru, 2015).

The main objective of this study is to evaluate the intercropping practices of small-scale vegetable farmers and use a linear programming approach to provide inputs to farmers in maximizing profit given limited land area for production. It also aims to compare the current farmers' practices with linear programming models to determine optimal land use options for vegetable mix. Sensitivity analysis will be conducted to provide recommendations for efficient allocation of limited resources like land, labor and material inputs

2. METHODOLOGY

Data collection

At the time of data collection, only three farmers were documented from selected sites in Leyte who qualified our criteria. The basis of selecting these farmers includes the following criteria: (i) practicing vegetable intercropping setups in the last cropping, (ii) small-scale vegetable farmers and have small land area, and (iii) crops used as intercrops were among the top vegetable crops used as intercrops in the Visayas. The main source of data was from a survey conducted among small-scale vegetable farmers in Leyte (McDougall et al., 2019). This survey is part of the research study funded by the Australian Centre for International Agricultural Research (ACIAR). There are various intercropping practices in the Visayas, but the vegetable combinations included in the analysis were the following selected vegetables; okra (Abelmoschus esculentus) -squash (Cucurbita maxima) combination, eggplant (Solanum melongena) - sweet pepper (Capsicum annuum) combination, and bitter gourd (Momordica charantia) – pechay (Brassica rapa) combination. These six vegetables were among the top crops used for intercropping system in the Visayas (McDougall et al., 2019). These vegetables were actual intercropping practices in the Visayas region, particularly in Leyte, and the study results may not be applicable in other areas in the Visayas. The study covers a one-year cropping season from 2015 to 2016.

Three existing intercropping productions were included in the study: okra-squash, eggplant-sweet pepper, and bitter gourd-pechay production. Data analyses included were descriptive analysis, gross margin analysis, linear programming (LP), and sensitivity analysis.

In addition, a key informant interview with one horticulturist from Visayas State University was conducted to confirm whether the three existing intercropping setups were suitable as an intercropping combination.

Descriptive Analysis

The study used descriptive analysis to determine cropping systems practiced in Visayas. The importance of descriptive analysis is to summarize the data and overview the most common crops used in intercropping system. This analysis was also the basis in determining the intercropping setups and farmer-respondents to be included in the study.

Gross Margin Analysis

The profitability of the existing intercropping crop mix was compared using gross margin analysis. The method of gross margin analysis does not include the fixed cost in the computation; only the variable cost is indicated. This approach is more practical in assessing the profitability of small-scale farmers because, for small-scale farmers, it primarily includes the variable cost in the production, such as labor and materials used (Owombo et al.,2012). Gross margin is the difference between the total revenue and the total variable cost. Total revenue was obtained by multiplying the total yield of the vegetables in each intercropping combination was multiplied by the vegetable farm gate prices in the Visayas (Armenia et al., 2013; Preciados et al., 2013; PSA, 2017). Gross margin analysis was evaluated per cropping for each crop's production cycle. The analysis result was converted to per square meter (m^2) for uniformity since there were different sizes of land area. The gross margin is represented by:

$$\text{gross margin} = \text{total revenue} - \text{total variable cost}$$

Linear Programming Analysis

The study employed a linear programming technique to determine the optimal crop mix that would result in higher profit given the limited resources.

Oni et al. (2013) used linear programming approach in maximizing profit among vegetable farmers. According to Oguru et al.,(2006), the linear programming model is no more than a form of budgeting that uses mathematics, ensuring that the optimum budget or input is found. Information and analysis on optimum crop mixture are important in promoting crop production activities.

The linear programming (LP) model used in this study has three crop production activities. The crop production activities in the model were okra-squash production, bitter gourd-pechay production, and sweet pepper-eggplant production. The optimization problem was to maximize the gross margin of each intercropping setup subject to a set of constraints:

Maximize or minimize $Z = c_1x_1 + c_2x_2 + \ldots + c_nx_n$

Subject to

$$a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n \quad (\leq, =, \geq)\ b_1$$
$$a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n \quad (\leq, =, \geq)\ b_2$$
$$a_{31}x_1 + a_{32}x_2 + \ldots + a_{3n}x_n \quad (\leq, =, \geq)\ b_3$$
$$\ldots$$
$$\ldots$$
$$a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n \quad (\leq, =, \geq)\ b_m$$
$$x_i \geq 0.$$

where:

Z = Objective function
x_i = decision variables
b_1 = available resource for j^{th} constraint
c_1 = objective function coefficients
a_{ij} = coefficient for i^{th} decision variable on j^{th} constraint.

The objective function of the model was to maximize the farmer's gross margin in each intercropping production. Decision variables refer to the size of land that should be devoted to each crop. Also, the decision cannot be negative or less than zero. Available resources for constraint refer to the supply available for each material in the farmer's place. Objective function coefficients refer to the gross margins for each crop generated from the gross margin analysis. The coefficient for decision variable on constraint refers to the required amount of resources used in a per square meter production, and it must be lesser or equal to the resources available since any production plan that would consume more than the resources available would violate these constraints and, therefore, not be feasible.

All resources included in the analysis were standardized into per square meter. Labor hours were the available man-hours throughout one cropping season for each crop combination. The analysis included non-negativity constraints for mathematical completeness to define the feasible region of production fully. Furthermore, the term profit used in this study refers to the gross margin.

After determining the profit-maximizing combination of resources, sensitivity analysis was conducted to determine how robust are the solutions to expected changes (Hong et al., 2020). Sensitivity analysis was used to know how the objective function would react to various changes in the supply of constraints and changes in each crop's gross margin per square meter. The analysis report was only valid for a single change or evaluated what happens when only one parameter of the problem changes. The linear programming model was solved using the built-in Solver in Microsoft Excel.

3. RESULTS AND DISCUSSION

Table 1 presents the vegetable intercropping combination practiced by the three farmer-respondents of the study and the corresponding farm size. Results show that the largest farm area was devoted to sweet pepper and eggplant combination, while bitter gourd and pechay had the smallest land area.

Table 1. Vegetable intercropping combinations and land area in Leyte.

Intercropping combination	Land area (m^2)
Okra and squash	300
Sweet pepper and eggplant	1750
Bitter gourd and pechay	80

Profitability Analysis Using Gross Margin

Table 2 shows that the gross margin for okra production amounted to PHP355.98 per square meter while squash generated a gross margin of PHP183.84 per square meter. There is a high insecticide cost for okra since insecticide application was more frequent compared to squash. This is because okra was more prone to pests and insects compared to squash. Also, high labor cost was documented for okra because it is harvested daily (or five times a week). Frequent harvesting for okra is needed because its fruits mature quickly while the squash was harvested once a week.

The total yield for okra is around 1,000 kilograms, while squash yields around 400 kilograms only. The variation in yield is attributed to the limited farm area. There were only 34 squash plants planted. Squash has very long stems that creep along the ground, requiring a much wider planting distance. In this production, the planting distance for squash is about 3 meters by 3 meters, while for okra production, approximately planted at 50 centimeters each.

Table 2. Gross margin analysis for okra-squash production.

Items	Unit	Okra	Squash
Farm area		200 m^2	100 m^2
A. Yield per area in kilograms	kilograms	1,000.00	400.00
Price per kilogram	Philippine peso (PHP)	80.00	60.00
Revenue in pesos	Philippine peso (PHP)	80,000.00	24,000.00
B. Variable cost per area			
Labor[a]	Philippine peso (PHP)	7,281.25	5,093.75
Materials[b]	Philippine peso (PHP)	442.4	82.216
Transportation[c]	Philippine peso (PHP)	120.00	120.00
Marketing[d]	Philippine peso (PHP)	960.00	320.00
Total cost	Philippine peso (PHP)	8,803.65	5,615.97
C. Gross Margin (GM) per area	Philippine peso (PHP)	71,196.35	18,384.03
GM per square meter	Philippine peso (PHP)	355.98	183.84

Note:

[a]Labor cost refers to the number of man-days for family and hired labor incurred in the production

[b]Material cost refers to fertilizer, insecticide and pesticides used

[c]Transportation cost refers to all expenses incurred in transporting materials used in farming

[d]Marketing cost refers to all expenses incurred in marketing of produce

For the eggplant and sweet pepper production, eggplant generated a gross margin of PHP351.21 per square meter, while sweet pepper obtained a gross margin of PHP316.73 per square meter. Comparing this crop mix from the previous intercropping setup, these two crops obtained a higher yield (in kilograms). Also, the selling price of sweet pepper was higher compared to other crops. However, eggplant production was associated with high variable cost because of its high labor cost and application of materials. According to the farmer-respondent, eggplant production could last for a year, while sweet pepper production could last up to six months. Furthermore, for these crops to have a good yield, fertilizer was applied throughout their cropping season, resulting in high production costs. The available land area for this production was 1750m^2, wherein 1000m^2 was planted with eggplant and 750m^2 was planted with sweet pepper.

Table 3. Gross margin analysis for eggplant-sweet pepper production as intercrops.

Items	Unit	Eggplant	Sweet-pepper
Farm area		1000 m^2	750 m^2
A. Yield per area	kilogram	4,762.00	1,417.00
Price per kilograms	Philippine peso (PHP)	80.00	180.00
Revenue in pesos	Philippine peso (PHP)	380,960.00	255,060.00
B. Variable cost per area			
Labor[a]	Philippine peso (PHP)	13,765.63	7,156.25
Materials[b]	Philippine peso (PHP)	14,907	9,758.60
Transportation[c]	Philippine peso (PHP)	120.00	120.00
Marketing[d]	Philippine peso (PHP)	960.00	480.00
Total cost	Philippine peso (PHP)	29,752.63	17,514.85
C. Gross Margin (GM) per area	Philippine peso (PHP)	351,207.40	237,545.20
GM per square meter	Philippine peso (PHP)	351.21	316.73

Note:
[1] Labor cost refers to the number of man-days for family and hired labor incurred in the production
[2] Material cost refers to fertilizer, insecticide and pesticides used
[3] Transportation cost refers to all expenses incurred in transporting materials used in farming
[4] Marketing cost refers to all expenses incurred in marketing of produce

In the case of bitter gourd and pechay setup, farmers knew that bitter gourd and pechay have a huge difference in the production cycle. Hence, farmers already knew that pechay production would obtain lesser yield compared to bitter gourd. However, farmers usually do this setup to make use of the vacant spaces between bitter gourds to provide additional income and food supply. In the case of an 80m^2 land area, 55m^2 was planted with bitter gourd. The vacant spaces in between, which was 25m^2, were planted with pechay.

On a per square meter basis, bitter gourd production obtained a gross margin of PHP111.87, while pechay obtained a gross margin of PHP30.61 (Table 4). Pechay production obtained a lesser yield compared to bitter gourd.

Material cost for bitter gourd production was relatively high since the total cost for pesticide was PHP720 per cropping, and marketing for this production was done eight times per cropping which amounted to PHP40 per marketing. As for pechay production, the variable cost was much lesser since the fertilizer applied with this crop was urea only, and harvesting and marketing were only done once per cropping.

Table 4. Gross margin analysis for bitter gourd and pechay production.

Items	Unit	Bitter gourd	Pechay
Farm area		55 m^2	25 m^2
A. Yield per area in kilograms	kilogram	100.00	25.00
Price per kilogram	Philippine peso (PHP)	90.00	60.00
Revenue in pesos	Philippine peso (PHP)	9,000.00	1,500.00
B. Variable cost per area			
Labor[a]	Philippine peso (PHP)	1,255.32	536.57
Materials[b]	Philippine peso (PHP)	992.10	78.14
Transportation[c]	Philippine peso (PHP)	120.00	80.00
Marketing[d]	Philippine peso (PHP)	480.00	40.00
Total cost	Philippine peso (PHP)	2,847.42	734.71
C. Gross Margin (GM) per area	Philippine peso (PHP)	6,152.58	765.29
GM per square meter	Philippine peso (PHP)	111.87	30.61

Note:
[a]Labor cost refers to the number of man-days for family and hired labor incurred in the production
[b]Material cost refers to fertilizer, insecticide and pesticides used
[c]Transportation cost refers to all expenses incurred in transporting materials used in farming
[d]Marketing cost refers to all expenses incurred in marketing of produce

The gross margin analysis results showed that among the three intercropping systems, sweet pepper and eggplant generated the highest gross margin. This was due to the high selling price of the crops, especially sweet pepper, and its long production cycle, which yields higher than other crops.

Vegetable Profit Maximization through Linear Programming Analysis

The previous result of the gross margin analysis for okra and squash production showed that squash production resulted in a positive gross margin. However, the linear programming analysis showed that it would maximize the profit (gross margin) up to PHP100,794 when the whole 300m² available lands are solely planted with okra. Squash is a vine type of plant that grows along the ground; thus, it requires a broader space when planted. Hence, the analysis results suggested that planting these two crops together is not a good step for a farmer with small farm size.

Comparing the gross margin obtained from the farmer's squash-okra production to the suggested sole production of okra showed that sole production of okra would gain a higher gross margin by PHP11,213.62 than the existing intercropping mix.

Table 5 shows that planting okra in a 300m² will use 345.5 hours from the available hours of labor, 6000 grams of fertilizer 1 (14-14-14 NPK), 24,000 grams of fertilizer 2 urea (46-0-0 NPK), and 450 ml of malathion. Among the five resources included in the analysis, only the land lacks slack or unused available resources.

Table 5. Linear programming analysis for okra-squash production as intercrops.

Resources	Available Supply	Unit	Resource Requirements		Solution		Resource Used	Slacks
			Okra	Squash	Okra	Squash		
Land	300	square meter	1.00	1.00	300.00	0.00	300.00	0.00
Labor	1200	man-hour	1,165.00	1.63	349.50	0.00	349.50	850.00
Fertilizer 1 (14 N + 14 P + 14 K)	50,000	gram	20.00	6.80	6,000.00	0.00	6,000.00	44,000.00
Fertilizer 2 (46 N)	50,000	gram	80.00	27.20	24,000.00	0.00	24,0000.00	26,000.00
Malathion (insecticide)	1,000	milliliter	1.50	2.70	450.00	0.00	450.00	550.00
Profit		peso (PHP)	355.98	183.84		100,794.00		

Table 6 presents the optimization solution for eggplant and sweet pepper combination. Results show that for profit to be maximized, 551.23m² of land will be planted with eggplant and 57.69m² with sweet pepper. Results suggest that the available land area of 1750 m² will not be fully utilized. From this available farm size, profit can be maximized using only 609 m² of land.

If the farmer follows this combination, the potential profit generated will be relatively higher than the farmer's current profit per m². The estimations show that eggplant and sweet pepper can be expected to yield a higher profit when the available resources are optimally used.

Table 6. Linear programming analysis for sweet pepper and eggplant combination.

Resources	Available Supply	Unit	Resource Requirements		Solution		Resource Used	Slacks
			Eggplant	Sweet-pepper	Eggplant	Sweet-pepper		
Land	1750.0	square meter	1.00	1.00	551.28	57.69	609.00	1,141.00
Labor	2880.0	man-hour	0.44	0.35	235.79	24.67	260.50	2,619.54
Fertilizer 1 (15.4 N + 25.9 CaO + 0.3 B)	100.0	kg	0.12	0.09	64.33	6.76	71.10	28.94
Fertilizer 2 (15 N + 9 P + 20 K)	100.0	kg	0.17	0.13	905.27	94.73	100.00	0.00
Fertilizer 3 (16 N +16 P +16 K)	100.0	kg	0.11	0.09	60.35	6.32	66.7 0	33.33
Vermicast	100.0	kg	0.15	0.30	82.69	94.73	100.00	0.00
Abamectin (Insecticide)	250.0	ml	0.00	0.01	0.00	0.54	0.50	249.46
Chlorantrani-liprole (Insecticide)	250.0	ml	0.01	0.00	2.76	0.00	2.80	247.24
Profit		peso (PHP)	351.21	316.76	211,887.00			

Table 7 shows the profit-maximizing combination of bitter gourd and pechay. Farmers often used bitter gourd and pechay combination as intercrops to make use of the available spaces between bitter gourd plants. With this combination, pechay will be harvested first before bitter gourd will start using bigger space. A fully-grown bitter gourd plant creates a shade that would limit sunlight for other crops. Hence, pechay is one of the feasible crops to partner with bitter gourd.

Results show that out of the 80m^2 available land for production, 25.53m^2 is best planted with bitter gourd and 10m^2 for pechay to maximize profit. Farmers' current practice yields around PHP3,072.40, but the linear programming solution can generate an estimated profit of PHP3,161.58. With this optimum combination, only around 44.41% of the available land resource will be used. Table 7 shows that Fertilizer 1 and Lambda-cyhalothrin 1 were the binding constraints suggesting that it the available resources will be fully utilized.

Table 7. Linear programming analysis for bitter gourd and pechay combination.

Resources	Available Supply	Unit	Resource Requirements		Solution		Resource Used	Slacks
			Bitter gourd	Pechay	Bitter gourd	Pechay		
Land	80	square meter	1.00	1.00	25.53	10.00	35.50	44.48
Labor	976	man-hour	0.73	0.73	144.97	56.39	200.30	775.66
14 N + 14 P + 14 K (Fertilizer 1)	1000	gram	38.31	0.00	718.55	281.45	1000.00	0.00
46 N (Fertilizer 2)	1000	gram	18.00	2.20	330.17	129.32	459.00	540.51
Lambda-cyhalothrin (insecticide)	500	milliliter	11.36	0.00	290.08	0.00	290.10	209.92
Methomyl (Insecticide)	100	grams	00.00	10.00	0.00	100.00	100.00	0.00
Profit		peso (PHP)	111.86	25.38		3,168.58		

Sensitivity Analysis

In testing the robustness of the results, sensitivity analysis was conducted. Table 8 presents the result of the sensitivity analysis for squash-okra production. The results showed that if the objective coefficient for squash decreases by 152.14 units, the final value or the optimal solution will change. Among the five resources included in the analysis, only the land had value for shadow price in the constraint section. This shadow price indicates that the gross margin will increase by PHP335.98 for every additional unit of land added, holding other factors constant. The shadow price is only valid if the constraint right-hand (R.H.) side of the land, 300 m^2, will increase by around 325 units. The shadow price will not be valid anymore if the land will increase beyond the allowable increase indicated in the result. Table 8 further shows that resources with zero shadow price (not binding constraints) will not increase the gross margin.

Table 8. Sensitivity analysis report for okra-squash production

Variable Cell					
Crops	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
Unit	m^2	PHP	PHP	PHP	PHP
Squash	300.0	0.00	355.98	0.00	152.14
Okra	0.0	0.00	183.84	0.00	0.00

Constraint					
Resources	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
Land	300.0 m^2	PHP 335.98	300.0 m^2	325.0 m^2	300.0 m^2
Labor	349.5 man-hour	0.00	1,200.0 man-hour	infinity	850.0 man-hour
Fertilizer 1 (14 N + 14 P + 14 K)	6,000.0 g	0.00	50,000.0 g	infinity	44,000.0 g
Fertilizer 2 (46 N)	24,000.0 g	0.00	50,000.0 g	infinity	25,000.0 g
Malathion (insecticide)	450.0 ml	0.00	1,000.0 ml	infinity	550.0 ml

Table 9 shows the sensitivity analysis for eggplant-sweet pepper production. Results show that if the objective coefficient of eggplant will increase by an amount of around 64.50 units, the optimal decision variable of eggplant will not change. If the objective coefficient for sweet pepper increases by 385.69 units, the recommended land area to be planted with sweet pepper will also not change. In the constraint section of Table 9, results show that among the eight resources included in the analysis only fertilizer 2 and vermicast have shadow prices. This tells that these two resources will be fully used. This shadow price indicated that the gross margin would increase by P1,854.27 for every additional unit of fertilizer 2 added as long as the increase is lesser than 12 kilograms. For vermicast, if the change is within the value indicated from the range of feasibility which is the allowable increase and decrease values, the final value will change by 264.60 units.

Table 9. Sensitivity analysis report for eggplant-sweet pepper production.

Variable Cell					
Crops	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
Unit	m^2	PHP	PHP	PHP	PHP
Eggplant	551.28	0.00	351.21	64.50	192.84
Sweet pepper	57.69	0.00	316.73	385.69	49.14

Constraint					
Resources	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
Land	608.97	0.00	1,750.0	infinity	1,141.03
Labor	260.46	0.00	2,880.0	infinity	2,619.54
Fertilizer 1 (15.4 N + 25.9 CaO + 0.3 B)	71.06	0.00	100.0	infinity	57.33
Fertilizer 2 (15 N + 9 P + 20 K)	100.0	PHP1,854.27	100.0	12.0	57.33
Fertilizer 3 (16 N +16 P +16 K)	66.67	0.00	100.0	infinity	33.33
Vermicast	100.0	PHP264.60	100.0	134.38	10.71
Abamectin (Insecticide)	0.54	0.00	250.0	infinity	249.46
Chlorantraniliprole (Insecticide)	2.76	0.00	250.0	infinity	247.24

Table 10 presents the result of the sensitivity analysis for bitter gourd and pechay intercropping. Results show that the allowable increase for bitter gourd is around 421.20 units while pechay production has no limit. This indicates that if the objective coefficient of bitter gourd increases by 421.20 units or more, the optimal decision variable will change. For pechay, the infinity value in the allowable increase indicates that the recommended decision variable will not change even if the objective coefficient of pechay increases by any amount.

Among the constraint variables, fertilizer 1 and methomyl have shadow prices. For fertilizer 1, a unit change of this constraint resource will change the objective by 2.92 units. While for insecticide 2, the unit change of this variable will cause a unit change of 2.42 to the gross margin.

Table 10. Sensitivity analysis report for bitter gourd and pechay production.

Variable Cell					
Crops	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
Unit	m^2	PHP	PHP	PHP	PHP
Bitter gourd	25.53	0.00	111.86	421.20	111.86
Pechay	10.0	0.00	30.62	infinity	24.19

Constraint					
Resources	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
Land	35.53	0.00	80	infinity	44.47
Labor	200.34	0.00	976	infinity	775.66
14 N + 14 P + 14 K (Fertilizer 1)	1,000.0	2.92	1000.0	707.73	978.0
46 N (Fertilizer 2)	59.49	0.00	1000.0	infinity	540.51
Lambda-cyhalothrin (insecticide)	290.08	0.00	500.0	0.0	209.92
Methomyl (Insecticide)	100.0	PHP2.42	100.0	427.88	100.0

To further substantiate the analysis, an expert interview was conducted. A horticulture expert confirmed that the farmers' three combinations could be used as intercrops. For the sweet pepper and eggplant setup, which generated the highest gross margin among the three combinations, the expert stated that farmers usually use this setup since both crops have a more extended cropping season. Also, pests that attack these crops are the same as aphids; that is why pesticides used are the same and can be applied simultaneously. This will reduce production costs related to pesticides. This coincides with the study conducted by Hussein and Samad (1993). The study evaluated the effectiveness of intercropping in suppressing Aphis gossypi, a vector of chili veinal mottle virus (CVMV) which causes severe damage to chili plants. Yields were significantly higher in the intercropping setups (Hussein and Samad, 1993). The study also found out that eggplant is a better companion crop with chili, while maize is a substitute. The result of the study shows that intercropping reduces cost since it lessens the application of fungicide and insecticide (Hussein and Samad, 1993). This coincides with the expert's opinion on the applicability of sweet pepper and eggplant intercropping as a profitable cropping system.

Comparison of farmers' practices and linear programming

Table 11 shows the comparison of profit between the farmers' practices and linear programming approach. Results show that the linear programming approach has a relatively higher profit per m^2 than farmers' practices across different crop combinations. For okra and squash combination, the farmers' practice yields a profit of 298.6 per m^2 while the linear programming approach yields a profit of 335.98 per m^2. For sweet pepper, the baseline results show that the profit of farmers' practice is around 336.43 per $m^{2,}$ while the potential profit for linear programming is around 347.93 per m^2. For bitter gourd and pechay combination, the profit for farmers' practice is 86.47 per $m^2$and the linear programming approach yields a profit of 89.26 per m^2. The highest profit per m^2 is from sweet pepper and eggplant combination. Table 11 shows that linear programming has the potential to increase profit through the optimum combination of resources. The current practice of farmers can be further optimized to maximize profit given a limited farm area for vegetable production.

Table 11. Comparison of profit between farmers' practices and linear programming approach.

Crop Combination	Farmers' Practice (PHP / m^2)	Linear Programming (PHP / m^2)
Okra and Squash	298.60	335.98
Sweet pepper and Eggplant	336.43	347.93
Bitter gourd and Pechay	86.47	89.26

4. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The study was conducted to identify a profit-maximizing combination of vegetable crops for small-scale farmers in the Visayas, particularly in Leyte island. It aimed to identify a cropping mix that yields the highest gross margin subject to limited resources. The linear programming approach showed the potential to increase farmers' profit by optimizing farmers' resources. Linear programming showed that it yields relatively higher profit compared to the current practice across different crop combinations. The study showed that among the three existing intercropping practices of farmers, sweet pepper and eggplant production was the most profitable with the highest total gross margin per m2. For sweet pepper and eggplant combination, farmers can expect a maximum profit of up to PHP211,887 per farm (or PHP347.93 per m2). To achieve this, farmers should allocate 551.28 m2 for eggplant and 57.69 m2 for sweet pepper.

Results showed that the current intercropping practice of farmers such as the squash and okra intercropping yields lower profit compared to a sole production of okra. Linear programming simulation showed that the limited land area is better planted with okra alone rather than combining it squash. This situation can be explained by the production possibility frontier (PPF), suggesting that it is impossible to produce more of one good without decreasing the amount produced for the other good. Therefore, a trade-off exists (Dixit, 1990).

The sensitivity analysis result showed that there were critical constraints, which means changes in the supply of these constraints considerably affect profit. Farmers should take caution in increasing fertilizers or pesticides since it contributes to the reduction in profit.

Considering these linear programming results, support for capacity building activities is necessary for small-scale farmers to help them decide and best allocate limited resources. Small-scale farmers will not bother to compute for optimum combination thru linear programming. Farmers will do trial and error in achieving the best outcomes. Hence, support from agricultural technicians and experts are essential to guide farmers in maximizing production. In addition, the analysis here is dependent on the assumption that all vegetables produced will be marketed at competitive prices. Hence, there is a need to continually improve the quality of vegetables produced so that farmers can capture better prices. It is further suggested that integrated crop management is crucial to enhance vegetable profitability and food security in the Visayas region, particularly in Leyte (McDougall et al., 2019). Research on developing innovative extension systems focusing on intercropping systems is crucial for small-scale vegetable farmers to be more productive.

Furthermore, the results of the study will be beneficial to agricultural technicians, researchers, policymakers, and other stakeholders aiming to enhance the productivity and profitability of small-scale vegetable farmers in the Visayas. The vegetable industry has a significant part in the domestic and export markets (Rogers et al., 2007). The result of the study shows that the proper practice of intercropping system would help improve the productivity of vegetable farmers. This will not only improve the economic aspect of farmers but will also support the supply of vegetables in the community.

5. LIIMITATIONS

This study had several limitations. Results of the study captured only gross margin analysis; that is, only the variable costs were included. For future studies, it is recommended to conduct cost and return analysis to cover all expenses (variable and fixed cost) in the production. For the linear programming analysis, the variables included were land, labor, and materials used. Other factors such as farm practices, managerial abilities, weather conditions are not taken into consideration. A larger sample size is also recommended for further studies.

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