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# OPTIMUM COMBINATION OF CROP FARM ENTERPRISES: A CASE STUDY OF A SMALL-SCALE FARM IN MARONDERA, ZIMBABWE

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## ABSTRACT

Small scale farmers are often confronted with the problem of how to allocate farm resources. Their objective is to maximize net income through optimal crop enterprise combination subject to resource constraints. In this paper, a linear programming planning model was developed for a farm to address the resource allocation problem. Crops included were tobacco, maize, soya beans and potatoes. The results showed that tobacco gained acreage by 128% and potatoes by 38%. The model suggested no production of maize and soya beans. The overall crop acreage decreased by 30% while income increased by 35% as compared to the farmer's plan. The optimal solution increased income. The results show that the linear programming model suggestions are worthy putting into practice.

**Keywords:** Linear Programming; Small Scale farm; Gross margin; Optimal Crop Combination; Marondera, Zimbabwe

## 1. INTRODUCTION

Osburn (1983), demonstrated how linear programming (LP) is used in solving the problem of maximizing profits in farming subject to constraints. His application of LP to determine optimum cropping patterns created an initial basis for this study. Traditionally, farmers rely on traditional methods like experience, intuition and comparison with neighbors to make their decisions. This does not guarantee optimal results (Alsheikh and Ahmed, 2002). Effective techniques like LP can address the farm resource allocation problem and produce optimal solutions (Alsheikh and Ahmed, 2002). Hassan *et al* (2005) used LP to calculate crop acreage, production and income of the Dera Khan Division of Punjab province. The optimal crop acreage decreased by 1.64% and income increased by 2.91% compared to the existing plans. Hassan *et al* (2005) said, "The results show that the LP model suggestions are worth exercising". Igwe *et al* (2011) applied LP to determine optimum combinations of semi-commercial arable and fishery enterprises in Abia state, Nigeria. Gross margin increased by 0.26%. The optimal enterprise combination in cassava based food crop farming system in Nigeria was obtained by using LP by Bamiro *et al* (2012). The results showed that cassava/maize and cassava/maize/vegetable are the optimal combinations. The two combinations contributed to the increase in gross income.

Mohamad and Said (2011) formulated an LP crop mix model for a finite time planning horizon. The model successfully maximized the total returns at the end of the planning horizon. Scarpari and Beauclair (2010) optimized agricultural planning of sugarcane using LP. The results supported the optimized planning model as being a very useful tool for sugarcane management (Mohamad and Said, 2011). An LP model was also formulated by Kaur *et al* (2010) to suggest the optimal cropping pattern for maximizing net returns and ensuring significant savings of groundwater in Punjab, Pakistan. The study suggested some techniques which can save water. Dey and

Mukhopadhyay (2010) used the LP technique to find the optimum allocation of resources in different situations of resource constraints. The net return earned from the optimal crop plan exceeded the net return obtained from existing allocation of resources by 43%. Abdelaziz *et al* (2010) obtained the optimal cropping pattern in North Darfur State, Sudan by applying the LP technique. The optimal cropping pattern was different from the farmers' production plan. The LP model solutions resulted in a profitable objective function while the farmers' plan gained them a loss. Babatunde *et al* (2007) used LP to obtain an optimal crop combination in small-scale vegetable irrigation farming scheme in the Niger Republic. Ibrahim and Omotesho (2011) determine an optimal enterprise combination for vegetable production under Fadama in north central Nigeria. Their optimal plan achieved 88% of the goals considered.

The objective of this paper was to develop an LP model that maximizes net income for a small scale farm in Marondera, Zimbabwe. The farm specializes in growing tobacco, maize, soya beans and potatoes. The manager is interested in an efficient allocation of resources at the farm through an optimal crop enterprise combination. His main concern is to maximize net income.

## 2. THE LINEAR PROGRAMMING MODEL

The farm has 30 ha of land that is meant for tobacco, maize, soya beans and potato production. His expected net income for 2011/12 production sale was \$7,194.78/ha from tobacco, \$1,169.81/ha from maize, \$555/ha from soya beans and \$7,194.78/ha from potatoes. The objective of the manager was to produce optimal crop enterprise combination for the 2011/12 season. His objective is to maximize the total net income.

Before the optimization model was constructed, the manager had made a plan based on experience. He had planned to allocate 8 ha for tobacco, 13 ha for maize, 5 ha for soya beans and 4 ha for potato production. His concern is to see whether this crop enterprise production combination is optimal? Does it yield him maximum returns? His resources include land, labor and capital. The manager must decide how many hectares that should be allocated for each crop. So the decisions are:

$x_1$  = hectares allocated for tobacco production

$x_2$  = hectares allocated for maize production

$x_3$  = hectares allocated for soya beans production

$x_4$  = hectares allocated for potato production

The goal of the objective function was to maximize the gross income subject to the given constraints.

**Table 1.** Linear Programming Matrix

	Tobacco (ha)	Maize (ha)	Soya beans (ha)	Potatoes (ha)	
Objective function (\$)	4,066.11	1,169.81	555.00	7,194.78	Maximize
<b>Resource</b>					<b>Available</b>
Land (ha)	1.00	1.00	1.00	1.00	30.00
Labor (days)	30.00	14.00	10.00	25.00	480.00
Capital (\$)	1,183.89	1,110.19	770.00	4,805.22	40,000.00

Table 1 represents the basic structure of the LP matrix. The right hand side represents the constraints on the resources.

The LP is given by:

$$\text{Max } z = \sum_{j=1}^4 c_j x_j$$

$$\text{subject to } \sum_{i=1}^3 a_{ij} x_j \leq b_i, \quad x_j \geq 0,$$

where,

$z$  = the objective function (\$)

$c_j$  = gross income per unit of  $j^{\text{th}}$  activity (\$)

$x_j$  = level of the  $j^{\text{th}}$  activity

$a_{ij}$  =  $j^{\text{th}}$  resource required per unit of the  $j^{\text{th}}$  activity

$b_i$  = supply level of the  $i^{\text{th}}$  resource.

### 3. RESULTS AND DISCUSSION

The optimal cropping pattern resulting from the LP model in comparison to the farmer's plan are presented in Table 2. Tobacco gained acreage by 128% and potatoes by 38%. The LP model suggests no production of maize and soya beans. On the whole optimal cropped acreage decreased by 30% as compared to the farmer's plan.

**Table 2.** Comparison of Cropping Pattern under Optimal Solutions with the Farmer's Plan

Crops	Farmer's plan (ha)	LP solution (ha)	% of Farmer's plan
Tobacco	5	11.40	228
Maize	10	0	0
Soya beans	5	0	0
Potatoes	4	5.51	138
<b>Total</b>	24	16.91	70

The optimal production levels as compared to the farmer's plan are presented in Table 3. The results show that production of various crops at the farm behaved in the order of acreage variations discussed above.

**Table 3.** Comparison of Cropping Production under Optimal Solutions with the Farmer's Plan

Crops	Farmer's plan (\$)	LP solution (\$)	% of Farmer's plan
Tobacco	20330.55	46372.43	228
Maize	11698.10	0	0
Soya beans	2775.00	0	0
Potatoes	28779.12	39675.42	138

**Table 4.** Comparison of Resource Utilization under Optimal Solutions with the Farmer's Plan

Resources	Farmer's plan			LP solution		
	Land (ha)	Labor (days)	Capital (\$)	Land (ha)	Labor (days)	Capital (\$)
Available	30	480	40,000	30	480	40,000
Usage	24	440	40,000	16.91	480	40,000
% Usage	80	92	100	56	100	100
Left over	6	40	0	13.09	0	0
% Left over	20	8	0	44	0	0

Comparison of resource utilization under optimal solutions with the farmer's plan is presented in Table 4.

As a result of the optimal solution, the farmer's income would be increased by \$22,464.98. Income increased from \$63,582.77 to \$86,047.75 showing an improvement of 35%. The optimal income level as compared to the one planned by the farmer is presented in Table 5. The optimal solution increased income. The results show that the LP model suggestions are worthy putting into practice.

**Table 5.** Comparison of Income Level under Optimal Solution with the Farmer's Plan

Income		
Farmer's plan (\$)	Optimal solution (\$)	% of Farmer's plan
63,582.77	86,047.75	135

#### 4. CONCLUSION

In this paper, a LP model was developed that solves the problem of how to select a combination of farm enterprises that is feasible given a set of fixed constraints and maximizes net income. Comparison of results obtained by using traditional methods of planning and the LP model reveal that results obtained from the LP model were more superior. The income difference was 35%.

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