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Optimizing Farm Plans: A Case Study of a Rural Farmer in Zimbabwe

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Abstract

Small scale farmers in rural areas are often faced with the problem of how to allocate resources. Their objective is to maximize income through the best crop combinations subject to resource constraints. These farmers often use traditional methods like trial and error, instinct and experience to solve this problem. This does not guarantee optimal results. In this paper, a linear programming planning model was developed to address the problem. The goal of the objective function was to maximize the gross income subject to land and labor constraints. The linear programming model solved the resource allocation problem. The linear programming problem was solved using Microsoft Excel (2007) a computer application software package and the results obtained were tabled. The optimal plan was developed for a farmer without restrictions on capital. The results obtained by the use of the linear programming model were compared with the results obtained from existing farm plans. The land allocation criteria obtained by using the linear programming model yielded more income than from traditional methods often used by rural farmers to handle the resource allocation problem. The income difference is 100.15%.

Keywords: Linear programming, rural farmers, optimal plans, net returns, crops.

Introduction

Small scale farmers in rural areas are often faced with the problem of how to allocate resources. Their objective is to maximize income through the best crop combinations subject to resource constraints. These farmers often use traditional methods like trial and error, instinct and experience to solve this problem. This does not guarantee optimal results[1]. Effective techniques such as Linear Programming (LP) can address such problems and produce optimal solutions[1].

Bamiro et al[2], actualized by linear programming model the optimal cassava based combination which showed that cassava/maize and cassava/maize/vegetable are the optimal combination. The two combinations contributed to the gross margin and also added zero opportunity cost to the total cost of production. Linear programming is a useful and easily available method for describing and analyzing family farm livelihood systems[3]. Richards and Musgrave[4] say that, "The accumulation of experience in the application of linear programming and its extensions by the farm management workers, together with the growth of the farm advisory profession, should ultimately result in a fruitful interaction". Kebede and Gan[5], successfully applied LP to perform a whole farm analysis of a representative farm developed from collected data. The vegetable mixes obtained from the LP solution significantly increase the annual income of the farmers. Nedunchezhian and Thirunavukkarasu[6] conducted a study to optimize farm plans in different farming systems in Orathanadu block of the Thanjavur district in Tamil Nadu. They developed an LP model to arrive at the optimal farm plans for different categories of farms separately. The optimal plans yielded more income. The optimal combination of enterprises obtained could also reduce unemployment. Igwe et al[7], say, "Linear programming technique is relevant in optimization of resource allocation and achieving efficiency in production planning particularly in achieving increased agricultural productivity". Igwe et al[7], applied LP technique to determine the optimum enterprise combination using 2009/2010 farm data. Out of ten cropping activities and two fish enterprises, only two, that is one for crop and livesstock enterprises were recommended by the LP model. The gross income was N342, 763.30. This helps to enhance food security among rural farmers in the study area. Linear programming technique can also help rural farmers in Zimbabwe to increase income and enhance food security.

The objective of this study was to develop an LP planning model that would help a rural farmer in Bindura District, Zimbabwe to determine optimal cropping patterns. The goal of the objective function was to maximize the net income subject to land and labor constraints. The LP model was solved using MS Office Excel 2007 a computer application software package. The optimal plan was developed for the farmer without restrictions on capital. The results obtained by the use of the LP model were compared with the results obtained from existing farm plans often determined by traditional methods.

Methodology

The Linear Programming Formulation: Bindura rural district was selected for the study, where rainfall is high, making the district reliable for arable agriculture.

The data on farm activities for the year 2011-2012 were gathered from a farmer. The household has 5 hectares of land that is meant for crop production. Crops which were considered are maize, sweet potato, sorghum, groundnut, round nut. The household expected net return was; \$1213/ha from maize, \$3002/ha from sweet potato, \$2325/ha from sorghum, \$1229/ha from ground nuts, \$415/ha from round nuts. The household is interested in cropping combinations that helps them to maximize their total annual net returns. Before the optimization model was constructed, a household's existing plan was to allocate 3 ha for maize, 0.5 ha for sweet potato, 0.5 ha for sorghum, 0.5 ha for groundnuts, 0.5 ha for round nuts. Of prime importance is whether this crop enterprise production combination is optimal? Does it yield maximum net returns? The farmer is also interested in satisfying the family maize consumption requirement of two tons. The resource constraints that will be considered in this study are land and labor only. An optimal plan will be determined for the household without restrictions on capital.

The farmer must decide how many hectares that should be allocated to each activity. So the decisions are:
x_1 = hectares allocated for maize production.
x_2 = hectares allocated for sweet potato production.
x_3 = hectares allocated for sorghum production.
x_4 = hectares allocated for groundnut production
x_5 = hectares allocated for round nut production.

The goal of the objective function is to maximize the annual net return subject to land and labor constraints.

Table 1 represents the basic structure of the linear programming matrix. The Right Hand Side (RHS) represents the constraints on the resources.

The LP model is given by:

$$Max\ z = \sum_{j=1}^{5} c_j x_j$$

$$subject\ to$$

$$\sum_{i=1}^{2} a_{ij} x_j \leq b_i,$$

$$x_j \geq 0,$$

where, z = Total annual net returns (\$), c_j = Annual net returns per unit of j^{th} activity (\$), x_j = Level of the j^{th} activity, a_{ij} = i^{th} resource required per unit of the j^{th} activity, b_i = Supply level of the i^{th} resource.

Results and Discussion

The LP problem is solved using Microsoft Excel (2007), a computer application software package. The results are as shown in table 2.

Table-1
Linear Programming Matrix

	Activities	**Maize**	**Sell Maize**	**Transfer Maize**	**Sweet Potatoes**	**Sorghum**	**Groundnuts**	**Round nuts**	
Resources	**Units**	**ha**	**ton**	**ton**	**ha**	**ha**	**ha**	**ha**	**RHS**
Land	ha	1			1	1	1	1	≤ 5
Labor	days	30			15	20	20	20	≤ 312
Maize Accounting	ton	-8	1	1					≤ 0
Maize Consumption	ton			-1					≤ -2
Net Returns	dollars		285		3002	2325	1229	415	

Table-2
LP Solution

	Maize (ha)	**Sweet Potato (ha)**	**Sorghum (ha)**	**Groundnuts (ha)**	**Round nuts (ha)**
Production	0.25	4.75	0	0	0
Net Income (\$)	14,259.50				

Without Table

The LP results show that the household should apportion 0.25 ha for maize, 4.75 ha for sweet potato, no sorghum, no groundnuts and no round nuts. The annual net return obtained is $14,259.50.

Table-3
Resource Utilization

Resources	Available	Usage	Left Over
Land (ha)	5.00	5.00	0.00
Labour (days)	312.00	78.75	233.25

Table 3 shows that all the land is utilized. Out of the 312 man days available, 78.75 are utilized and 233.25 are left over.

The strategies and resource utilization obtained by the farmer by using traditional methods are displayed in table 4 and table 5.

Table-4
Cropping Pattern obtained by using Traditional Methods

	Maize (ha)	Sweet Potato (ha)	Sorghum (ha)	Groundnuts (ha)	Round nuts (ha)
Production	3	0.5	0.5	0.5	0.5
Net Income ($)	7,124.50				

Without Table

From Table 4, the farmer allocated 3 ha towards maize production, 0.5 ha for sweet potato, 0.5 for sorghum, 0.5 for groundnuts and 0.5 for round nuts.

Table-5
Resource Utilization from the Farmer's Plan

Resources	Available	Usage	Left Over
Land (ha)	5.00	5.00	0.00
Labour (days)	312.00	127.50	233.25

From Table 5, all the land is utilized. Out of the 312 man days available, 127.50 are used and 233.25 are left over.

The land allocation criteria obtained using the LP yields more net returns than using traditional methods. The income difference is 100.15%. The LP solution provides the rural farmer with an opportunity to realize more net returns from sweet potato production. The household can also manage to secure two tons of maize for food consumption. The household can realize more income if they utilize LP solutions from the same piece of land. Farmers invariably employ traditional methods to determine their resource allocation plans. This does not guarantee optimal crop combinations.

Conclusion

In this paper, an LP planning model was developed to address the resource allocation problem often faced by rural a farmer. The goal of the objective function was to maximize the annual net return subject to land and labor constraints. The LP model solved the resource allocation problem. The LP problem was solved using Microsoft Excel (2007) a computer application software package and results were tabled. The optimal plan was developed for the farmer without restrictions on capital. The results obtained by the use of the LP model were compared with the results obtained from existing farm plans. The land allocation criteria obtained by using the LP model yields more annual net returns than from traditional methods often used by rural farmers to handle the resource allocation problem.

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