A LINEAR PROGRAMMING APPROACH TO CROPS AND LIVESTOCK ENTERPRISES PLANNING FOR A MODEL A2 FARMER IN BINDURA, ZIMBABWE

F. Majeke*

M. T. Mubvuma*

K. Makaza*

T. Hungwe*

R. Gwazani*

Abstract

Farmers need to make decisions on cropping patterns that would yield them maximum profits. This is a decision that most farmers make by intuition, experience and by comparison with other farmers. However, this does not result in optimal solutions. Linear programming can be used to determine optimum cropping patterns. In this study, a linear programming model was developed in order to determine the optimum combination of stocker cattle and crops for a Model A2 farmer in Bindura, Zimbabwe. Stocker cattle considered were beef cows and stocker steers. The crops considered were maize, soya beans and cotton. The linear programming model solution showed that the acreage of maize could be increased by 100 percent. It suggests no production of soya beans and cotton. The total acreage on overall crop production showed an increase by 14 percent compared with the farmer's existing plan. The results also suggest no production of beef cows. The production of steers did not increase compared to the farmer's existing plan. The model suggested an overall decrease of cattle production by 43 percent. The farmer's income could be increased from existing level of $8,189.00 to $11,461.02 showing an improvement of 40 percent. The results suggest that linear programming solutions are worthy putting into use.

Keywords: Linear Programming, Food Crops, Livestock, Farm Enterprises, Model A2

* Great Zimbabwe University, ZIMBABWE

1. Introduction

When planning production on a farm the question which arises is: which crops to grow or livestock to keep and in what quantities? As resources are usually scarce, it is important to plan on how to combine crops and livestock on a farm. It may be difficult to come out with optimal solutions without efficient calculation means (Pukkala & Pohjonen, 1990). Pukkala & Pohjonen (1990) demonstrated on how to apply linear programming (LP) to a typical land use planning problem in the Ethiopian highlands. Pukkala & Pohjonen (1990) say, "Mathematical programming is an easy and flexible method for assessing different ways to use limited resources under variable objectives and constraints". The LP technique gives optimal values of decision values, that is, production alternatives (Pukkala & Pohjonen, 1990). Igwe, Onyenweaku, & Tanko (2013) applied a LP approach to a combination of crop, monogastric farm animal and fish enterprises in Ohafia Agricultural zone, Abia State, Nigeria. The optimum gross margin was 72.90 percent greater than obtained in the existing plan. Propoi (1979) considered a dynamic LP model for multispecies livestock farming with a feed production subsystem. The problem on how to determine the optimal livestock mix in order to obtain the maximum profit for a given horizon was successfully solved. Igwe, Onyenweaku, & Nwaru (2011) say, "Linear programming technique is relevant in optimization of resource allocation and achieving efficiency in production planning particularly in achieving increased agricultural productivity". Igwe, Onyenweaku, & Nwaru (2011) applied the LP technique to determine the enterprise combination using 2009/2010 farm data. An optimal combination of crop and livestock enterprises was recommended by the model for the farmers to achieve a gross income of N342, 763.30. This had an advantage of enhancing food security among rural farmers in the study area (Igwe, Onyenweaku, & Nwaru, 2011).

Jansen & Wilton (1984) demonstrated with examples on how to apply LP as a tool for the selection of breeding stock in a production unit facing constraints of resources, marketing, or preference. Jansen & Wilton (1984) argue that, "Direct consideration of constraints and alternative production possibilities is the chief advantage of linear programming over a profit equation". The optimal population structure and the optimal slaughter program of Tibetan sheep, improved sheep and yak were determined by means of LP in Qinghai province, China (Yiming, Zuwang, Nanlin, & Li, 1992). The economic revenues could be increased based on the strategy obtained (Yiming, Zuwang, Nanlin, & Li, 1992). Minh, Ranamukhaarachchi, & Jayasuriya

(2007) used LP to optimize the effect of animal and green manures and their combination together with heat-compost technique on the improvement of the quality of organic manure, soil fertility and yield in three farm categories. Minh, Ranamukhaarachchi, & Jayasuriya (2007) say, “The optimized livestock herd holding and sugarcane cultivation area resulted in 88.7% increase of the return from livestock and 62.5% from crops in the small farm size, 25% from livestock and 9% from crops in the medium farm size and 171% from livestock while unchanged from crops in the large farm size”.

The objective of this study was to apply the LP approach to food crops and livestock enterprises planning for a Model A2 farmer in Bindura, Zimbabwe. Model A2 is a commercial farming settlement scheme intended to create a cadre of black commercial farmers (Zikhali, 2008). The Zimbabwean Government embarked on a land distribution programme in 2000, which led to the creation of a new agrarian structure (Matondi & Dekker, 2011). Matondi & Dekker (2011) say, “The fast track has resulted in a new agrarian formation dominated by small to medium scale farms. The Ministry of Land and Rural Resettlement noted that programme reduced the oversized commercial farms to average of 500 hectares from high of 2,000 hectares before the reforms. In the process the government created 2 new models of resettlement known as the A1 and A2. Though a few large scale commercial farms remain, and some were distributed and left as whole farms, a significant amount of land was set aside for these 2 models”. The individual plots under the Model A2 scheme are classified as small, medium and large scale commercial schemes (Matondi & Dekker, 2011). These farmers need to make decisions on cropping patterns that would yield them maximum profits. This is a decision that most farmers make by intuition, experience and by comparison with other farmers (Hazell & Norton, 1986). However, this does not result in optimal solutions (Alsheikh & Ahmed, 2002). Linear programming can be used to determine optimum cropping patterns (Hassan, Raza, Khan, & Ilahi, 2005).

The objective of this study was to apply the LP approach to food crops and livestock enterprises planning for a Model A2 farmer in Bindura, Zimbabwe. The farmer’s wish was to invest in beef cattle and crop production. The farmer’s intention was to buy, fatten beef cows and stocker steers and sell them off for a profit. The crops considered were maize, soya beans and cotton. The problem for the farmer was to determine the optimal number of beef cows and stocker steers to carry, and the optimal cropping pattern.

2. Linear programming formulation

The Model A2 farmer considered in this study was interested in investing in beef cattle and crop production. The land available for crop production was 20 ha. Crops considered were maize, soya beans and cotton. The problem for the farmer was how to determine the optimal number of beef cows and stocker steers to carry and the optimal crop pattern. Data for the 2012/13 agricultural season was used for the study. The linear programming model was formulated.

Table 1. Linear programming matrix

		Crops (ha)			**Livestock (per head)**	
Resource	**Quantity Available**	Maize	Soya beans	Cotton	Beef cows	Stocker steers
Land (ha)	20	1	1	1		
Labor (days)	280	35	35	45	0.7	0.7
Capital ($)	9,000	930	750	380	558	408
Net Income ($)		1350	575	445	700	600

Table 1 represents the LP matrix.

The LP model in algebraic form is given by:

$$Z = \sum_{j=1}^{5} c_j X_j$$

subject to

$$\sum_{i=1}^{4} a_{ij} X_j \leq b_i,$$

$$X_j \geq 0$$

where,

Z = Total income,

c_j = Income per unit of j^{th} enterprise,

X_j = Level of the j^{th} enterprise,

b_i = Amount of the i^{th} resource required,

a_{ij} = Amount of the i^{th} resource required per unit of the j^{th} enterprise.

3. Results and Discussion

The optimal crop combination resulting from the LP model is presented in Table 2. The results showed that the acreage of maize could be increased by 100 percent. The model suggests no production of soya beans and cotton. The total acreage on overall production showed an increase by 14 percent compared with the farmer's existing plan.

Table 2. Cropping Patterns

Crops	**Existing (ha)**	**Optimal solution (ha)**	**% of existing**
Maize	4	8	200
Soya beans	2	0	0
Cotton	1	0	0
Total	7	8	114

The optimal stocker cattle combination resulting from the LP model is presented in Table 3. The results suggested no buying and selling of beef cows. The production of steers remained the same. The model suggested an overall decrease of cattle production by 43 percent.

Table 3. Livestock Combination

Livestock	**Existing (head)**	**Optimal solution (head)**	**% of existing**
Beef cows	3	0	0
Stocker steers	4	4	100
Total	7	4	57

Table 4. Income Levels

Existing Income ($)	Optimal solution ($)	% of existing
$8,189.00	$11,461.02	140

As a result of the optimal solution, a farmer's income could be increased by $3,272.00 as shown in Table 4. The farmer's income could be increased from existing level of $8,189.00 to $11,461.02 showing an improvement of 40 percent. The results suggest that LP model solutions are worthy putting into use.

4. Conclusion

Farmers are often faced by the problem of how to determine cropping patterns that would help them to achieve maximum profits from their farm enterprises. In this study, an LP model was developed for a Model A2 farmer in Bindura, Zimbabwe. The LP model solved the problem of determining the optimal number of beef cows and stocker steers to carry, and the optimal cropping pattern. The income that could be obtained by using the LP model was 40 percent greater than that obtained from the farmer's existing plan. Optimum cropping patterns can help farmers to realize maximum profit and efficient utilization of available resources (Hassan, Raza, Khan, & Ilahi, 2005).

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