Research Journal of Management Sciences ISSN 2319–1171
Vol. **2(5),** 20-23, May **(2013)** *Res. J. Management Sci.*

Modeling a Small Farm Livelihood System using Linear Programming in Bindura, Zimbabwe

Majeke Felix, Majeke Judith, Mufandaedza Jonathan and Shoko Munashe
Department, Great Zimbabwe University, Masvingo, ZIMBABWE

Available online at: www.isca.in
Received 30th January 2013, revised 15th February 2013, accepted 30th April 2013

Abstract

A livelihood system is the full range of activities available to an individual farmer. Communal farmers are often faced with the problem of how to select the optimal cropping patterns that significantly contribute to sustainable production. In this study, a linear program that reflects these choices by selecting a combination of farm activities that is feasible given a set of fixed farm constraints and that maximizes income while achieving other goals such as food security is developed. Results obtained by using linear programming and traditional methods are compared. The results obtained by using the linear programming model are more superior. The difference in gross income is 44.65%.

Keywords: Communal farmer; linear programming; whole-farm plan; optimal crop combination; maximizing income.

Introduction

Communal farmers are usually faced with the problem of how to allocate their limited production resources among cropping and livestock activities[1]. These farmers always seek an optimal mix of farming activities that maximizes their income[1]. Farmers, often, follow their instinct and experience to handle this problem[1]. Hazel and Norton[2] also say, "Traditionally, farmers have relied on experience, intuition and comparisons with their neighbors to make their decisions". Instinct and experience do not guarantee optimal results; however, farm planners can offer effective techniques, such as, linear programming (LP), to address such a problem and produce optimal solutions[1]. Alsheikh and Ahmed[1] demonstrated how LP can be used as a tool to obtain optimal results. Their application of LP as a tool for farm resource allocation created an initial basis for this study.

Businesses have saved thousands of millions of dollars by using LP[3]. Annetts and Audsley[4] developed an LP model to consider a wide range of farming situations, which allows optimization of profit or environmental outcome(s) or both. The modeling considered the problem of planning a farming system within a world where environmental considerations are increasing. Their objective was to identify the best cropping and machinery options which are profitable and result in improvements to the environment, depending upon the farm situation of market prices, potential crop yields, soil and weather characteristics. The results showed that large reductions in environmental impact can be achieved for reductions in farm profit which are insignificant relative to the annual variation due to yields and prices. Mohamad and Said[5] developed an LP crop mix model for a finite-time planning horizon. Given limited available resources such as budget and land acreage, the crop-mix planning model was formulated and transformed into a multi-period linear programming problem. The objective was the maximization of the total returns at the end of the planning horizon. The problem was solved for selected vegetable crops using LINDO. The results indicated promising returns even for a relatively short planning horizon of 12 months and if properly implemented will enhance farm income and provide beneficial contribution to the farming societies[5].

An LP model was successfully constructed by a team of advisers at the ADAS Bedford office[6]. The application of the model had quite significant effects on profitability, increasing the total gross 'margin' by £38,000, from £138,000 to £176,000. Linear programming technique is relevant in optimization of resource allocation and achieving efficiency in production planning particularly in achieving increased agricultural productivity[7]. Igwe, Onyenweaku and Nwaru[7] applied an LP technique to determine the optimum enterprise combination. The recommended optimum plan by the LP model achieved a gross income of N342, 763.30 from N188, 736.29, a 44.6 percentage increase. Riddler, Rendel and Baker[8] applied LP to a sheep and beef farm. This led to a new system of how feed is grown and utilized and a refined system to make use of it with breeding cows and ewes[8]. Since the start of the use of the LP model, farm income has increased for the past 10 years. Mohring and Zimmermann[9] constructed and applied an LP farm model with an integrated Life Cycle Assessment for the determination of sustainable milk production systems. Realistic production systems with coordinated herd management, buildings, feeding and mechanization systems were reproduced in the model by means of binary variables[9]. The income of the farms was maximized. The model optimized land use and the combination of production methods, as well as, the number of animal housing places. Linear programming was also applied by Salimonu et al[10] to model efficient resource allocation patterns for food crop farmers in Nigeria. A return of N31, 959.81 per hectare was the actual level of the farmers' income compared with the return of N98, 861.24 if the farmers were to apply profit maximization objective achieved by applying LP.

Scarpari and Beaclair[11] argue that, "Optimized agricultural planning is a fundamental activity in business profitability because it can increase the returns from an operation with low additional costs". They developed an optimized planning model for sugarcane farming using an LP tool. The results obtained supported that the optimized planning model is a very useful tool for sugarcane management.

The use of operations research tools in agricultural activities by farmers and agricultural advisers is limited resulting in decision-making being primarily empirical. The goal of this work is to develop an optimized model for a small-scale livelihood system in Bindura using an LP tool. MS Office Excel ® is used to solve the problem. The objective of the paper is to develop optimal cropping pattern for a communal farmer. The communal farmer, produce mostly for subsistence and sell their surplus produce.

Study Area: The study was conducted in Bindura district. This district is found in Mashonaland Central province of Zimbabwe. It has a population of 156,842[12]. Mashonaland central province is mainly a rural province. Agriculture forms the economic base and the province is known for its rich soils[12]. According to Musundire[12], "The district houses one of Zimbabwe's town which is Bindura. The town is approximately 90 km from Harare. There are also mining companies that provide employment, thus keeping the town running. The district also provides employment for people from Harare."

Traditionally, farmers depend on traditional methods, such as, instinct and experience, and comparisons with neighbors in order to make decisions about what commodities to produce and in what quantities. This does not guarantee optimal crop patterns[1]. Effective tools like LP can address this problem. According to Hilderbrand and Cabrera[13], "Linear programming is a useful, and with the wide availability of laptop computers, easily available method for describing and analyzing family farm livelihood systems." Linear programming can be used to select optimal crop combinations subject to fixed farm constraints. The objective of this study is to address the resource allocation problem faced by a small-scale farmer in Bindura by applying LP.

The Linear Programming Formulation: The household considered in the study has 5 hectares of land that is meant for maize, soya beans, cotton, and tobacco production. The household expected gross income was; $285 per ton from maize, $1325/ha from soya beans, $525/ha from cotton, $5250/ha from tobacco. The household is interested in cropping combination that helps them to maximize their total annual net returns. Before the optimization model was constructed the household's existing plan was to allocate 1.5 ha for maize, 0.5 ha for soya beans, 0.5 ha for cotton and 0.9 ha of tobacco. Of prime importance is whether this crop enterprise production combination is optimal? Does it yield maximum net returns? The resource constraints considered in this study, are land, labor, maize consumption and operating capital.

The decision variables are:
$x_1 = hectares\ allocated\ for\ maize\ production.$
$x_2 = tons\ of\ maize\ produced\ for\ sale.$
$x_3 = tons\ of\ maize\ stored\ for\ family\ consumption.$
$x_4 = hectares\ allocated\ for\ soya\ bean\ production.$
$x_5 = hectares\ allocated\ for\ cotton\ production.$
$x_6 = hectares\ allocated\ for\ tobacco\ production.$

The goals of the objective function are to maximize cash income at the end of the year and to store maize for family consumption subject to land, labor and cash available for production constraints.

Table 1 represents the LP matrix. The Right Hand Side (RHS) represents the constraints on the resources.

The LP model is given by: $Max\ z = 285x_2 + 1325x_4 + 525x_5\ 5250x_6,\ (objective\ function)\ \ subject\ to,\ \ x_1 + x_4 + x_5 + x_6 \leq 5, (crop\ land\ constraint),\ 30x_1 + 30x_4 + 40x_5 + 40x_6 \leq 312,\ \ (labor\ constraint), -8x_1 + x_2 + x_3 \leq 0, (maize\ accounting) - x_3 \leq -2,\ (maize\ consumption)$ $918x_1 + 730x_4 + 365x_5 + 1183x_6\ 3000, (cash\ constraint)$ $x_1, \dots, x_6 \geq 0, (non-negativity\ constraint)$

Table-1
Linear Programming Matrix

	Activities	**Maize**	**Sell Maize**	**Transfer Maize**	**Soya Beans**	**Cotton**	**Tobacco**	
Resources	**Units**	**ha**	**ton**	**Ton**	**ha**	**ha**	**ha**	**RHS**
Crop Land	ha	1			1	1	1	≤ 5
Labor	days	30			30	40	40	≤ 312
Maize Accounting	ton	-8	1	1				≤ 0
Maize Consumption	ton			-1				≤ -2
Operating Capital	dollars	918			730	365	1183	≤ 3000
Gross Income	dollars		285		1325	525	5250	

Results and Discussion

The LP problem was solved using MS Excel 2007, a computer application software package. The solution as in table 2 shows that the strategies for this farm as specified in the model are to produce 0.25 ha of maize, no soya beans, no cotton and 2.34 ha of tobacco. The gross income is $12,295.10.

Table-2
Optimum Cropping Pattern Suggested by LP Model

	Maize (ha)	Soya Beans (ha)	Cotton (ha)	Tobacco (ha)
Production	0.25	0.00	0.00	2.34
Gross Income ($)	12,295.10			

As shown in table 3, 2.59 ha of the land are used up while 2.41 ha are unused. 101 days of labour is utilized and 211 days are left over. All the capital, $3,000.00 is used up. If more capital is sourced, more land could be utilized, thus, increasing gross income.

Table-3
Resource Utilization

Resources	Available	Usage	Left Over
Crop Land (ha)	5.00	2.59	2.41
Labour (days)	312.00	101.00	211.00
Operating Capital ($)	3,000.00	3,000.00	0.00

The strategies and resource utilization obtained by using traditional methods are displayed in Table 4 and Table 5 respectively.

Table-4
Cropping Pattern Suggested by the Farmer's Plan

	Maize (ha)	Soya beans (ha)	Cotton (ha)	Tobacco (ha)
Production	1.50	0.50	0.50	0.9
Gross Income ($)	8,500.00			

Table-5
Resource Utilization Suggested by the Farmer's Plan

Resources	Available	Usage	Left Over
Crop Land (ha)	5.00	3.40	1.60
Labour (ha)	312.00	116.00	196.00
Operating Capital ($)	3,000.00	3,000.00	0.00

The strategies suggested by the farmer, are to produce 1.5 ha of maize, 0.5 ha of soya beans, 0.5 ha of cotton and 0.9 ha of tobacco. All the capital is used up. Out of the 5 ha of land available, only 3.40 ha of the land is used up and the left over is 1.60 ha. Out of the 312 labour days available, 116 days are used and 196 days are left over. If capital could be increased, more land would be utilized.

The results that we obtain from using the LP model yield a gross income of $12,295.10 as compared to $8,500.00 that we obtain by using traditional methods. The difference in the gross incomes is 44.65%. The "what if" land allocation plan obtained by using LP, yields more income than from traditional methods.

The strategies obtained by using LP, provides the farmer with an opportunity to make more gross income from tobacco and satisfy the maize consumption requirement for the family. The solution from the LP model suggests that the farmer should use LP for making cropping pattern decisions in order to make more income. Traditional methods do not guarantee optimal strategies.

Conclusion

In this paper, a small farm livelihood system in Zimbabwe is modeled with LP. The LP model developed solves the problem of how to select a combination of farm activities that is feasible given a set of fixed constraints and that maximizes profit while achieving other goals such as food security. Comparison of results obtained by using traditional method of planning and LP model reveal that results obtained from the LP model are more superior.

References

1. Alsheikh S.M. and Ahmed A.M., Development of Mixed Farming System in a Newly Reclaimed Area in Egypt. Session No. LMP3.12. Abstract No. **107 (2002)**

2. Hazell P.B.R., Norton R.D., Mathematical Programming for Economic Analysis in Agriculture. New York: Macmillan Publishing Company **(1986)**

3. Winston W., Introduction to Mathematical Programming (Applications and Algorithms), California: Duxbury Press **(1995)**

4. Annetts J.E. and Audsley E., Multiple Objective Linear Programming for Environmental Farm Planning, *Journal of the Operational Research Society*, **.53**, 933-943 **(2002)**

5. Mohamad N.H.J. and Said F., A Mathematical Programming Approach To Crop Mix Problem. *African journal of Agricultural Research*, **6(1)**, 191-197 **(2011)**

6. Butterworth K., Practical Application of Linear/Integer Programming in Agriculture, *Journal of Operational Research Society*, **36(2),** 99-107 **(1985)**

7. Igwe K.C., Onyenweaku C.E. and Nwaru S., Application Of Linear Programming To Semi-Commercial Arable And Fishery Enterprises In Abia State, Nigeria, *International Journal of Economics And Management Sciences*, **1(1),** 75-81 **(2011)**

8. Riddler B.J., Rendel J.M. and Baker A., Driving Innovation of Linear Programming to Improving Farm

Systems. *Proceedings of the New Zealand Grassland Association.* **63,** 295-298 **(2001)**

9. Möhring A. and Zimmermann A., Construction and Application of an LP Farm Model with an Integrated Life Cycle Assessment for Determination of Sustainable Milk ProductionSystems, *European Association of Agricultural Economics*, 24-25 **(2005)**

10. Salimu K.K., Falusi A.O., Okoruwa V.O. and Yusuf S.A., Modeling Efficient Resource Allocation Patterns for Food Crop Farmers in Nigeria: An Application of T-MOTAD Analysis, *International Journal of Agricultural Economics andRural Development* , **1(1) (2008)**

11. Scarpari M.S. and Beauclair E.G.F., Optimized Agricultural Planning Of Sugarcane Using Linear Programming, *Revista Investigacion Operacional*, **31(2)**, 126-132 **(2010)**

12. Musundire V., Focus on The Mashonaland Central Market Brief , *Zimtrade*, **(2011)**

13. Hilderbrand P.E. and Cabrera V.E., *Modeling and Analyzing Small Farm Livelihood Systems with Linear Programming.* Staff Paper Series: Food and Resources Economics Department, University of Florida, Gainesville **(2003)**