INTERNATIONAL

RESEARCHERS

OPTIMUM ALLOCATION OF A SMALL SCALE CROP FARMLAND IN CHEGUTU OF MASHONALAND WEST PROVINCE, ZIMBABWE

George Buzuzi and Addlight Ngonidzashe Buzuzi

Volume No.7 Issue No.3 September 2018

www.iresearcher.org

ISSN 2227-7471

THE INTERNATIONAL RESEARCH JOURNAL “INTERNATIONAL RESEACHERS”

www.iresearcher.org

INTERNATIONAL RESEARCHERS is peer-reviewed, supported by rigorous processes of criterion-referenced article ranking and qualitative commentary, ensuring that only intellectual work of the greatest substance and highest significance is published.

INTERNATIONAL RESEARCHERS is indexed in wellknown indexing diectories

with ICV value 5.90

and moniter by

OPTIMUM ALLOCATION OF A SMALL SCALE CROP FARMLAND IN CHEGUTU OF MASHONALAND WEST PROVINCE, ZIMBABWE

George Buzuzi[1], Addlight Ngonidzashe Buzuzi[2]

Cape Peninsula University of Technology
(SOUTH AFRICA)
buzuzig@cput.ac.za[1], addlightbuzuzi@gmail.com[2]

ABSTRACT

This paper assesses the economic activity on a small scale farm in which maize, tobacco and vegetables (cabbages, tomatoes and beans) are grown. An operation research model was used to optimize the limited resources available. By comparison with the farmer's farming practices based on intuition and experience the Linear programming method developed showed that the available resources were not optimally allocated. By implementing the linear programming model the optimal crop pattern revealed a rise in the profit margin by 40.3%.

1. INTRODUCTION

Optimization using linear programming methods is widely used in agriculture. For instance, in India approximately 70% of the population relies on agriculture for their livelihood (Fazile and Ashraf, 2006; Sofi et al., 2015).To accommodate the ever increasing Indian population its government provided more agricultural land for cultivation. However over the years there has also been a high demand for residential and industrial land which greatly constrained the expansion of agricultural land. In order to efficiently and effectively utilize the available yet limited farming land the agricultural experts had to resort to operation research techniques to resolve the impending food crisis and consequently improve its people's livelihood (Sofi et al, 2015). A similar scenario is observed in Zimbabwe where the majority of the population depends on agriculture for their livelihood (Mugabe, et al 2014). The bulk of the land allocated to new farmers in Zimbabwe are underutilized because of a number of reasons which among them are, the use of traditional farming methods which may not follow the optimal path, insecure land tenure system which incentivize investment, limited access to input and output market, credit and off farm employment (Rukuni, 2006; Mugabe et al., 2014). Linear programming is an effective technique to produce optimal solutions in rural farms in Zimbabwe (Majeke, 2013; Mugabe, 2014). The planning of crop farming entails consideration of resources such as land, accessibility to irrigation water, labour, capital, cropping patterns, cropping intensity, topography and climate (Sarker and Quaddus, 2002; Sofie et al, 2015). Of the several optimization techniques available the Linear Programming model (LP) is the most used because of its proportionate allocation characteristic (Sofie et al, 2015). In the past and even now many small scale farmers rely on intuition and experience to allocate the farm resources available (Kumari et al., 2014, Majeke, 2013). We however want to demonstrate that using the Linear programming models gross income returns are optimal. Nordin Mohamad and Fatimah Said (2011) introduced an LP crop mix model for a finite time planning horizon under limited land and monetary resources to maximize the gross margin at the end of the planning period. An LP problem to determine optimal structure of crops and different method which take into account the income and expenditure of crops per hectare were used for optimizing profit by Ion Raluca, Andreen and Turek Rahdranu Adrian (2012). Majeke (2013) demonstrated how Linear programming (LP) is used to find the optimum combination of crop farm enterprise. His study focused on small scale farmers who often lack operation research techniques to resource allocation problems. Majeke found out that by using the LP technique the gross income rose by 44.65%. A linear programming approach to combination of crop, monogastric farm animals and fish enterprises in Ohafia agricultural zone, Nigeria was studied by Igwe *et al*. (2013) and the optimum gross margin rose by 72.90% compared to the existing plan then. A farm resource allocation problem using LP was also investigated by Kwaku Dei Antwi (2016) who used LP to determine the optimal crop allocation plan for women farmers under land, labor and capital constraints. The LP showed a 13.6% increase in the gross income.
Additional literature contributing to the development and use of operation research include (Hossan et al., 2012; Tanko et al., 2011; Day and Mukhopadhajay, 2010; Hossan et al., 2005; Ibrahim et al., 2004; Campbell et al., 1996; Osborn, 1983; Montazemi and Wright, 1982). Using LP model, this study seeks to determine the optimal crop pattern under labor, land and capital constraints allowing the farmer to have optimal profit margin.

2. METHODOLOGY

The study was conducted at a farm in Chegutu, located in Mashonaland West province of Zimbabwe. The 5 ha small farm grows maize, tobacco, beans, cabbages and tomatoes as dictated by market forces in the area. Although

the farmer realized profits in his farming activity the rising costs of living in the country has prompted the farmer to find ways of maximizing profits so as to cushion the ever rising cost of living in the country.
To eliminate doubt on the applicability of the result generated by the LP model the following assumptions were adopted.

1. The prize of the crop and its yield does not change during the planning period.
2. Availability of farm land, irrigation water, fertilizer, labour, and seed does not change during the planning period.
3. The land is equally suitable for all the selected crops. You can substitute any one crop with another for any hectare piece of land on the farm.

The linear Programming Model

The objective function, z in a Linear Programming Problem (LPP) reads

Maximize $z = \sum_{i=1}^{n} c_i x_j \quad x_j \geq 0, \quad j = 1, 2 \cdots, n$

Subject to the constraints

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \cdots + a_{1n}x_n &\leq b_1 \\ a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \cdots + a_{2n}x_n &\leq b_2 \\ a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + \cdots + a_{3n}x_n &\leq b_3 \\ \vdots \qquad\qquad\qquad & \vdots \\ a_{m1}x_1 + a_{m2}x_2 + a_{m3}x_3 + \cdots + a_{mn}x_n &\leq b_m \end{aligned}$$

$$x_i \geq 0, \quad i = 1, 2, \cdots n$$

The Linear Programming Problem (LPP) may be written in a more compact way as,

Maximize $z = \sum_{i=1}^{n} c_i x_j \quad x_j \geq 0, \quad j = 1, 2 \cdots, n$

Subject to $\sum_{j=1}^{n} A_{ij} x_j \leq b_i \quad i = 1, 2, \cdots m; \; j = 1, 2, \cdots, n; \; x_j \geq 0,$

where the input variables are represented by x_j, the cost coefficients of the objective function z are represented by c_i, the constraints are bounded above by b_i and the coefficients of the constraints equations, referred to as the 'production coefficients' are represented by a_{ij} and the coefficient matrix for the constraints inequalities is given by $A_{ij.}$

The farm under study has 5 ha of available farming land. The farmer grows a variety of crops which includes maize, tobacco, cabbages, beans, and tomatoes. The farmer's plan prior using LP technique is depicted in **Table 1**.

Table 1: Farmer's plan before optimization for the period 2016-2017

	maize	Cabbages	tobacco	beans	Tomatoes	available
Land (ha)	2	0.5	1.4	0.6	0.3	5.0
Gross income (US$)	7 000	4 833.50	10 500	4 000.20	1 500	24 334
Labour (US$)	200	206	2100	240	135	3 000
Pesticides/fungicides/fertilizer(US$)	920	450	1 428	480	270	4 500
Other operations($)	1100	1675	3472	864	285	9 000
Total expenses(US$)	2 220	2 331	7 000	584	690	13 825

To determine the production coefficients, a_{ij} , it is necessary to find the amount of particular input x_j required to produce 1ha of maize, cabbage, tobacco, beans and tomatoes. A matrix of these coefficients including the expected output per hectare is shown in **Table 2**.

Table 2: Farmer's plan per hectare of each crop

	maize	cabbages	tobacco	Beans	tomatoes	available
land (ha)	1	1	1	1	1	≤ 5
Gross income (US$)	3 500	9 667	7 500	6 667	5 000	
Labour (US$)	100	411	1 500	400	450	≤ 3 000
Pesticides/fungicides/fertilizer(US$)	460	900	1 020	800	900	≤ 4 500
Other operations(US$)	550	3350	2480	1440	950	≤ 9 000

Intuition and farming experience over the years $2014 - 2016$ has prompted the farmer to allocate the 5 hectares of land as follows: 2 ha for maize production, 0.5 ha for cabbage production, 1.4 ha for growing tobacco, 0.6 ha for beans production and 0.3 ha for growing tomatoes. Prior LP, the farmer's expected income was US$7 000 from 2ha of maize, US$4 833 from 0.5 ha of cabbage, US$10 500 from 1.4 ha of tobacco, US$4 000 from 0.6 ha of beans and US$1 5 00 from 0.3ha of tomatoes. The farmer realized a gross income of US$ 27 833.70. The size of land allocated for maize and tomatoes were determined by the immediate neighborhood demand and so the farmer had to grow at least 1 ha of maize and 0.2 ha of tomatoes.
In order to apply the LP technique the farmer had to decide on the size of land allocated to each crop. The decision or input variables are:
$x_1 =$ hectares of land allocated for maize production
$x_2 =$ hectares of land allocated for cabbage production
$x_3 =$ hectares of land allocated for tobacco production
$x_4 =$ hectares of land allocated for beans production
$x_5 =$ hectares of land allocated for tomatoes production

The farmer's objective is to maximize total gross margin of producing the crops less costs of transport, fertilizer, pesticides, fungicides, insecticides, seed, irrigation, labour and other operational costs such as electricity, insurance and marketing. The LP model is derived from **Table 2** which depicts the farmer's gross income, expenses and limitations per hectare of each crop type. The LP model is given by
$Max\ z = 3\,500x_1 + 9\,667x_2 + 7\,500x_2 + 6\,667x_4 + 5\,000x_5$ (Objective function)
Subject to,
$x_1 + x_2 + x_3 + x_4 + x_5 + \leq 5$ (Land constraint)
$1\ 00x_1 + 411x_2 + 1\,500x_3 + 4\ 00x_4 + 450x_5 \leq 3\,000$ (labour constraint)
$460x_1 + 900x_2 + 1\,020x_3 + 800x_4 + 900x_5 \leq 4\,500$ (pesticides/fungicides& fertilizer constraint)
$550x_1 + 3350x_2 + 2480x_3 + 1\,440x_4 + 950x_5 \leq 9\ \ 000$ (other operations)
$x_1 \geq 1.0$ (maize land constraint)
$x_4 \geq 0.2$ (tomatoes land constraint)
$x_1, x_2, x_3, x_4, x_5, x_6 \geq 0$ (non-negativity constraint)

3. RESULTS AND DISCUSSIONS

The crop planning scheme was formulated as a Linear Programming Problem and solved using simplex method using a software package found in Microsoft excel 2017. The farmer's plan without optimization is depicted in **Table 1.** The expenditure, gross income and profit realized by the farmer using the traditional approach are shown in Table **3.**

Table 3: Expenditure, gross income and profit before optimization

	Maize	cabbages	tobacco	Beans	Tomatoes	Total
land (ha)	2	0.5	1.4	0.6	0.3	5
Gross income (US$)	7000	4 833.50	10 500	4 000.20	1 5 00	**27 833.70**
Expenditure (US$)	2220	2331	7000	1 584	690	**13 825**
Net income/Profit (US$)						**14 008.70**

Using intuition and experience (traditional approach) the farmer was realizing a net profit of US$14 008.70. **Table 4** shows the crop planning scheme as suggested by the LP model. The LP approach suggests that the farmer should grow 1ha of maize, 1.46ha of cabbages, 2.34 ha of beans, 0.2 ha of tomatoes and reserve no piece of land for tobacco.

Table 4: Optimum farming pattern using LP approach

	Maize	cabbage	beans	tomatoes	total
land (ha)	1	1.46	2.34	0.2	5
Labour (US$)	100	600.06	936	90	1726.06
pesticides/fertilizer(US$)	460	1 314	1872	180	3826
Other operations(US$)	550	4891	3369.60	190	9000
Expenditure (US$)	1110	6805.06	6177.60	460	**14 552.66**
gross income (US$)	3500	14 113.82	15 600.78	1 000	**34 214.6**
Profit (US$)	2390	7 308.76	9423.18	540	**19 661.94**

Table 5 depicts the proportion of land allocated for each of the crops in both the existing and optimal plan.

Cropping pattern	Existing Plan (ha)		Optimal plan (ha)	
	Size of farm	%	size of farm	%
1. maize	2	40	1	20
2. cabbages	0.5	10	1.46	29.2
3. tobacco	1.4	28	0	0
4. beans	0.6	12	2.34	46.8
5. Tomatoes	0.3	6	0.2	4
6. unused farm land	0.2	4	0	0
Total	5	100	5	100

It is deduced from **Table 5** that the farmer was using **96%** of the available farm land in the existing plan whereas in the optimal plan (LP model) the farmer should use all of the available land (**100%**). In the optimal plan **20%** of the available plan is reserved for growing maize compared to **40%** in the existing plan. Although maize is a staple food in Zimbabwe whose demand can never be exhausted the LP technique suggests that growing cabbages and beans is more profitable.

Information displayed in **Table 5** and depicted more clearly in **Figure 1** shows the proportion (expressed as a percentage) of land allocated for each of the crops in both the farmers plan and the LP optimal plan.

Figure 1: Bar chart depicting the percentage of land allocated for each of the crops in both the existing and optimal plan

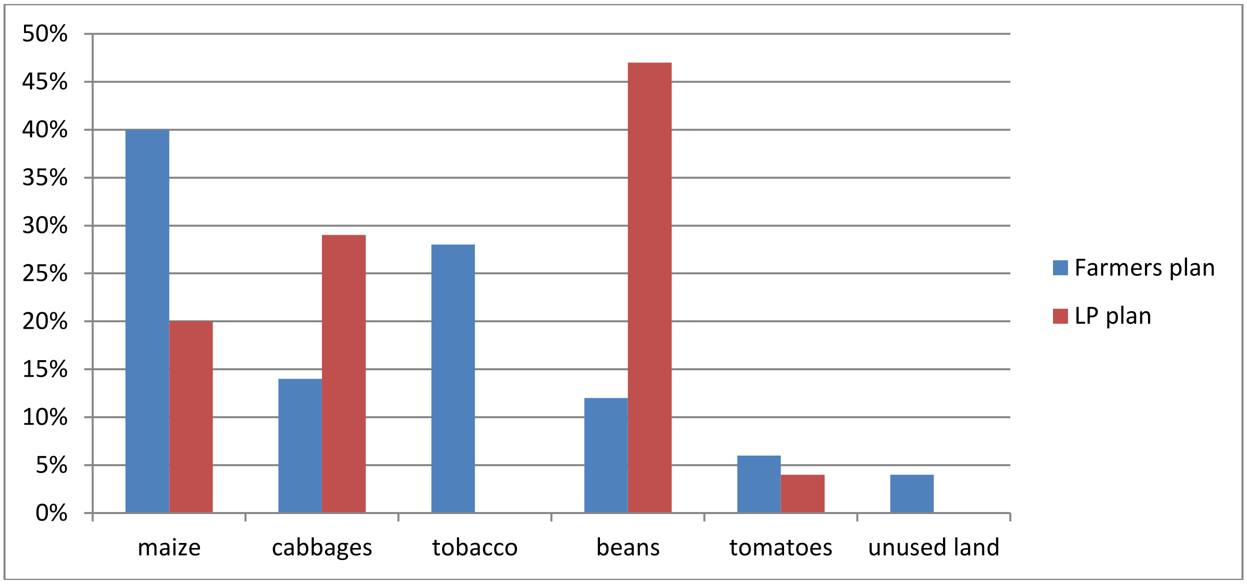

Table 6 gives a comparison of the gross income, expenditure and profit of the traditional and LP approaches.

Table 6: **Comparison of the Gross income, expenditure and net income of the traditional and LP approaches**

	Gross income(US$)	Expenditure(US$)	Net income/profit (US$)
Traditional approach	27 833.70	13 825.00	14 008.70
LP approach	34 213.66	14 552.66	19 661.00

Using LP technique the gross income is **US$34 213.66** compared to **US$27 833.70** realized from the traditional approach. Less expenses the LP technique has increased the profit margin by **40.3%**. Without maize and tomatoes land constraint the LP technique suggests growing **0.94** ha of cabbage, **4.06** ha of beans and none of tobacco, maize and tomatoes. The gross income would be **US$ 36 162.23** which raises the profit margin to **50.4%**. The last option is unlikely because in as much as the farmer would like to make profit, he also has to meet the demands of his immediate neighborhood for provision of their staple food as a way of appreciating the community in which the business is based.

4. CONCLUSION

The objective of this study was to implement the Linear programming model to the optimal allocation of farm resources which are subjected to labor, land and capital constraints so as to maximize the profit margin by a small scale farmer in Chegutu which is located in Mashonaland West province of Zimbabwe.

The study revealed that the existing farming plan which is based on intuition and experience has resulted in suboptimal allocation of available resources although the farmer was making some profit. A comparative analysis of results obtained using the LP model and the existing farming method showed that the LP model increased the profit margin by **40.3 %**, by growing maize, cabbages, tomatoes, beans and no tobacco. The results of the study suggest the use of the LP model for optimal profit margins.

REFERENCES

Adres, W., & Romero, C. (2006). Operation Research Models and the Management of Agriculture and Forestry Resources: A Review and Comparison, *INFORMS*, 36(5): 446-457

Antwi, K.D. (2016). Optimal Resource Allocation Decision Among Women Farmers in the Northern Region of Ghana, *African Journal of Agriculture and Food Security: International Scholars Journals*, 4(3):161-166.

Ashraf Iqbal Fazile & Hussan Ashraf, S. (2006). Tourism in Indian Planning and Development. Sarup and Sons Book Company, India, 2006, pp. 34, http://books.google.co.in/books?isbn=817625665x

Campbell, J.C., Radke, J.,Gless, J.T., Wirtshafter, R,M (1992). An Application of Linear Programming and Geographic Information Systems: Cropland Allocation in Antigua, *Environment and Planning A*, 24:3-49.

Dey, G., & Mukhopadhyay S. (2010). Optimum Allocation of Resources in Different Situations of Resource Constraints, Economic Affairs, 55 (2): 153-158.

Hassan, I., Raza, M. A., Khan, I. A., & LLahi, R. (2005). Use of Linear Programming Model to Determine the Optimal Cropping Pattern, Production and Income level: A Case Study from Dera Ghazi Khan Division. *Journal of Agriculture & Social Sciences*: 1813-2235/2005/01-1-32-345.

Ibrahim, H.,Alamu, J.F., & Ahmed, B. (2004). Optimal Farm Plans in Cotton Production: A Linear Programming Approach, *Journal of Resources in Agriculture*, 1(1):21-26.

Igwe, K.C., Onyenweuku, C. E, & Tanko, L.(2013). A Linear Programming Approach to Combination of Crop, Monogastric Farm Animal and Fish Enterprises in Ohafia Agricultural Zone, Abia State, Nigeria, *Global Journal of Veterinary Sciences*, 13(3): 23-31.

Ion, R.A., & Turek, R.A.,(2012). Linear Programming in Agriculture: Case Study in Region of Development South – Mountenia, *International Journal of Sustainable Economic Management*, 1(1):51-60.

Kumari, P.L., Reddy, G.K., & Krishna, T. G. (2014). Optimum Allocation of Agricultural Land to the Vegetable Crops under Uncertain Profits using Fuzzy Multiobjective Linear Programming, IOSR Journal of Agriculture and Veterinary Science, 7(2): 19-28.

Majeke, F (2013). Optimum Combination of Crop Farm Enterprises: A Case Study of a Small- Scale Farm in Marondera, Zimbabwe, *The International Research Journal: International Researchers*, 2(1): 61-65.

Mohamad, N., Said, F. (2011). A Mathematical Programming Approach to Crop Mix Problem, *African Journal of Agricultural Research*, 6(1): 191-197.

Mugabe, D.,Chipunza, N., Mupaso, N., Munyati, V.T., Makarudze, F. V. (2014). Estimation of Optimal Land Use Allocation Among Small Holder (A1) Farm Allocation Among Small Holder (A1) Farm Households in Zimbabwe. A Case Study of Long Croft Farm, in Mazowe District. Journal of Agricultural Science, 6(2): 170-181.

Rukuni, M., Eicher, C.K. (2006). Zimbabwe's Agricultural Revolution Revisited. UZ pubications, Harare, Zimbabwe.

Osborn, D.D. (1983). Modern Agricultural Management. New Jersy: Prentice-Hall Inc.

Sarker, R.A. & Quaddus, M.A., (2002). Modellinga Nationwide Crop Planning Problem using a multiple criteria decision Making tool. Computers and Industrial Engineering, 42:541-553.

Sofi, N. A., Ahmed, A., Ahmad, M., & Bhat, B. A. (2015). Decision Making in Agriculture: A Linear Programming Approach, International Journal of Modern Mathematical Sciences, 13(2): 160-169.

Tanko, L, Baba, K. M., A deniji, O. B. (2011). Analysis of the Competitiveness of Mono-Crop and Mixed Crop Enterprises in Farming System of Smallholder Farmers in Niger State, Nigeria, *International Journal of Agriculture*, 1(6): 344-255.