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Incorporating the Credit Constraint in a Linear Programming Model: A Case Study of a Rural Farmer in Zimbabwe

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ABSTRACT: The available working capital required to finance purchase of inputs on a farm like seeds for instance, can be an important constraint on a farm. Some working capital may be available from the farm family‘s savings. The farmer may have an option for increasing his working capital by borrowing. In this study, a linear programming model was developed in order to determine the optimal crop combination for a rural farmer. The linear programming model incorporated the credit constraint. The objective was to maximize income. Crops considered were maize, soya beans, cotton and tobacco. Tobacco gained acreage by 291.33%. Soya beans and cotton lost acreage completely. Maize lost acreage by 73.5%. The optimal income increased from $9,877.00 to $22,774.60. The optimal income showed an improvement of 130.58% compared to the farmer‘s existing plan. The results show that LP model solutions are worthy implementing because they increase income.

Keywords: Credit Constraint; Linear Programming; Optimal Crop Combination; Income; Rural Farmer.

1. INTRODUCTION

The available working capital required to finance purchase of inputs on a farm like seeds for instance, can be an important constraint on a farm (Hazell and Norton, 1986). Hazell and Norton (1986) say that, ―Some working capital may be available from the farm family‘s savings, but this can be supplemented by borrowing‖. The farmer may have an option for increasing his working capital by borrowing. Adebayo and Adeola (2008) argue that, ―Agricultural credit enhances productivity and promotes standard of living by breaking vicious cycle of poverty of small scale farmers‖. Adegeye and Ditto (1985) in Adebayo and Adeola (2008) describe agricultural credit ―as the process of obtaining control over the use of money, goods and services in the present in exchange for a promise to repay at the future‖. The efficient use of credit is an important factor in order to increase productivity (Adebayo and Adeola, 2008).

The credit constraint can be incorporated in a linear programming (LP) model in order to determine the optimal crop combination for small scale farmers. Ohajianya and Oguoma (2009) used an LP technique for optimizing resources. Their results showed a divergence between the existing and optimum farm plans under limited and borrowed capital situations. After optimization, farm income could be increased. Tanko *et al* (2011) used an LP model for optimizing gross margins. Their

results showed that resources were not optimally allocated and after optimization the gross margins could be increased. The gross margins were higher in the borrowed capital as compared to the limited capital situation. Bamiro *et al* (2012), in their study examined the enterprise combination in cassava based food farming system in Ogun state. The optimal cassava based combination was actualized by an LP model. The results show that land and capital were the limiting resources. Mohammed and Ndanitsa (2012) determined the optimal farm plan for Fadama tree-crop farmers in Niger State, Nigeria. A linear programming model was used to analyze the data collected. Their results showed that capital was the only limiting resource in the study area and had a shadow price of N8.453k. The study recommended farm families to direct their resources towards the production of only citrus lemon, which both governments and non-governmental organizations should assist in providing infrastructure and soft loans to the farm families. Mahendran *et al* (2006) developed a linear programming model to determine optimal crop plans. The constraints considered were water, land and capital. The net income of the farms sampled increased marginally or considerably in the optimal crop plans. Agbonlahor *et al* (2009) carried out a study to model an optimal arable crop plan that minimizes child farm labor use in Ogun Sate, Nigeria. An LP model developed was used to come out with an optimal arable crop farm that maximizes economic returns to the farmers. The optimal farm model showed that the optimal crop plan could increase the annual farm income by about 15.3 percent. Singh *et al* (2003) developed an LP model to formulate optimal cropping pattern for producing minimum food requirement. The optimal cropping pattern showed that it was possible to achieve food security with minimum investment.

Ibrahim and Omotesho (2011) determined an optimal enterprise combination for vegetable production under Fadama in north central Nigeria. Their LP model considered both economic and environmental goals simultaneously in a composite function. The optimal plan achieved 88 percent of the goals considered. Kaur *et al* (2010) formulated an LP model to suggest the optimal cropping pattern for maximizing net returns and ensuring significant savings of groundwater in the Punjab agriculture. The solution ensures groundwater savings of almost 25 percent. Mohamad and Said (2011) proposed an LP crop mix model for a finite-time planning horizon. The objective was the maximization of the total returns at the end of the planning horizon. The LP model solved the problem normally faced by farmers which include what to plant, how much to plant and when to plant (Mohamad and Said, 2011). Abdelaziz *et al* (2010) used the LP technique to analyze data. The results showed that the models gave a different cropping pattern from the farmers‘ production plan. The model solutions gave a profitable income while in reality the farmers gained a loss (Mohamad and Said, 2011). Dey and Mukhodhay (2010) formulated two optimal crop plans by LP technique. The net returns obtained from the optimal plans exceeded the existing plans by 43 percent and 13 percent respectively. Farmers face the problem of allocating their limited resources to alternatives (Dey and Mukhodhay, 2010). Dey and Mukhodhay (2010) say, ―Scarcity of resources necessitates judicious allocation for maximizing of return‖.

The objective of this study was to develop an LP model that resulted in an optimal cropping for a rural farmer in Bindura, Zimbabwe. The LP model developed incorporated the credit constraint. The farmer currently determines cropping pattern using traditional methods like trial and error, and experience.

2. LINEAR PROGRAMMING FORMULATION

The farmer in our study contemplated on supplementing his working capital available from his farm family's own savings by borrowing from a financial institution. The interest rate was 22 percent per annum. The area available for production of maize, soya beans, cotton and tobacco was 6 hectares for the 2011/12 agricultural season. The farmer's plan was to allocate 2 ha for maize, 1.5 ha for soya beans, 1 ha for cotton and 1.5 ha for tobacco production. The farmer planned to borrow $3000.00 from a financial institution to supplement working capital. This would allow the farmer to utilize all the 6 ha of land available for crop production. The question is whether this crop combination maximizes net income?

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.

$x_7 =$ credit.

The goals of the objective function were to maximize net income and to store maize for family consumption subject to land, labor, cash and credit constraints. The working capital was introduced in the farm model by adding the working capital constraint.

Table 1: Linear Programming Matrix

	Maize (ha)	Sell maize (ton)	Transfer maize (ton)	Soya beans (ha)	Cotton (ha)	Tobacco (ha)	Borrow credit (dollars)	
Objective function (dollars)	-918	285		595	160	4067	-0.22	Maximize
Resources								**Available**
Crop land (ha)	1			1	1	1		≤ 6
Labor (days)	30			30	40	40		≤ 295
Maize	-8	1	1					≤ 0

accounting (ton)								
Maize consumption (ton)			-1					≤ -1
Credit row (dollars)	918			730	365	1183	-1	≤ 2500

Table 1 represented the LP matrix. The right hand side represented the production constraints.

The LP model is given by:

$$\text{Max } z = -918x_1 + 285x_2 + 595x_4 + 160x_5 + 4067x_6 - 0.22x_7, \quad \text{(objective function)}$$

subject to

$$x_1 + x_4 + x_5 + x_6 \leq 6, \quad \text{(crop land constraint)}$$

$$30x_1 + 30x_4 + 40x_5 + 40x_6 \leq 295, \quad \text{(labor constraint)}$$

$$-8x_1 + x_2 + x_3 \leq 0, \quad \text{(maize accounting)}$$

$$-x_3 \leq -1, \quad \text{(maize consumption)}$$

$$918x_1 + 730x_4 + 365x_5 + 1183x_6 - x_7 \leq 2500, \quad \text{(working capital)}$$

$$x_1, \ldots, x_7 \geq 0, \quad \text{(non-negativity constraint)}$$

3. RESULTS AND DISCUSSION

MS Excel (2007) a software package was used to solve the LP problem and the results are shown in Table 2. Tobacco gained acreage by 291.33%. Soya beans and cotton lost acreage completely. Maize lost acreage by 73.5%. The optimal cropped acreage did not change as compared to the existing plan.

Table 2: Cropping Patterns

Activities	Farmer's plan (ha)	LP solution (ha)	% of Farmer's plan
Maize	2.00	0.13	6.50
Soya beans	1.50	0.00	0.00
Cotton	1.00	0.00	0.00
Tobacco	1.50	5.87	391.33
Total	6.00	6.00	100.00

The production levels are shown in Table 3.

Table 3: Production

Activities	Farmer's plan ($)	LP solution ($)	% of Farmer's plan
Maize	2,724.00	0.00	0.00
Soya beans	892.50	0.00	0.00
Cotton	160.00	0.00	0.00
Tobacco	6100.50	23,893.63	391.67

The income levels are shown in Table 4. The optimal income increased from $9,877.00 to $22,774.60 showing an improvement of 130.58%. The results show that LP model solutions are worthy implementing because they increase income.

Table 4: Income Levels

Income		
Farmer's plan ($)	**Optimal solution ($)**	**% of Farmer's plan**
9,877.00	22,774.60	230.58

4. CONCLUSION

In this study an LP model that determines the optimal crop combination for a rural farmer in Zimbabwe was developed. The income obtained by using the LP model was compared to the

income obtained by using the farmer‘s existing plan. The income difference was 130.58% compared to the farmer‘s existing plan. The results show that the LP model solutions are worthy implementing because they increase income.

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