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A FARM RESOURCE ALLOCATION PROBLEM: CASE STUDY OF SMALL SCALE-COMMERCIAL FARMERS IN ZIMBABWE

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ABSTRACT

Managers in the farming sector are faced with the problem of how to allocate resources. Their objective is to maximize income through optimal crop enterprise combination subject to input constraints. In this paper, an LP planning model is developed. The LP solves the farm resource allocation problem. Numerical data is input into the model and results are obtained. Comparison is made between the results obtained from the use of the LP model and the traditional method of planning. The results obtained from using the LP model are more superior to the ones obtained from using traditional methods.

Key Words: Farm Resource Allocation; Linear Programming; Small Scale-Commercial Farming; Maximizing Profits; Optimal Crop Combination

INTRODUCTION

Managers are always confronted with the problem of how to allocate resources. Tools used for making such decisions vary from simple economic principles to detailed processes. Linear Programming (LP) is one of those tools (Osburn, 1983). Osburn (1983), demonstrated how Linear Programming (LP) is used in solving the problem of maximizing profits in farming subject to given constraints. His application of LP to a farming resource allocation problem created an initial basis for this study.

LP is a mathematical tool that has helped companies and businesses of even moderate sizes to save thousands of millions of dollars (Winston, 1995). Its use in other sectors of the societies has been spreading widely (Winston, 1995). It has been applied to a very wide range of practical planning problems which include agriculture, banking, government services, mining and transport (Wright, 1996).

Using linear programming, and integer programming, a method was devised to schedule patrol officers for the San Francisco Police Department (Taylor & Huxley, 1989). The department has saved $11 million per year by using their method. Their revenue increased from traffic citations by $3 million. LP was used to reduce Blue Bell's average inventory level by 31% (Edwards, Wagner & Wood, 1985). Linear programming was successfully used to determine how a creamery should process buttermilk, raw milk, sweet whey, and cream into cream cheese, cottage cheese, sour cream, and whey cream (Sullivan & Secrest, 1985).

Since the development of the simplex algorithm, LP has been used to solve optimization problems in industries as diverse as banking, education, forestry, petroleum and trucking (Winston, 1995). These days LP is utilized by all sorts of firms in making decisions about establishment of new industries and in deciding upon different methods of production, distribution, marketing and policy decision making (Kapur & John, 2001). LP is being progressively utilized in finding solutions to various farm problems and in planning farm enterprise with a view of maximizing profits (Anaman, 1988). LP is used to determine the farm plans that will yield profits under different conditions (Anaman, 1988). A farmer's production is constrained by resources such as land, labor, machinery, transport, capital, seed and fertilizers. Any choice that a farmer makes must be implemented within the constraints of the available resources.

The objective of this paper is to describe an optimization model that is constructed for a commercial farm in Beatrice, Zimbabwe using LP. The results obtained are also tabled. The farm specializes in growing maize, soya beans and cotton in summer, and wheat, cabbages, beans, tomatoes, potatoes and onions in winter. The manager is interested in the efficient allocation of resources at the farm through an optimal crop enterprise combination. His main objective is to maximize profit.

THE LP FORMULATION

The manager has 95 hectares of land that is meant for wheat, bean, potato, cabbage and potato production. His expected gross income for winter 2004 production sale was; $17,000,000/ha from wheat, $11,000,000/ha from beans, $25,000,000/ha from potatoes, $16,000,000/ha from cabbages, $20,000,000/ha from tomatoes. The manager is interested in an optimization model that would help him to achieve an optimal crop enterprise combination for the 2004 winter season. His goal is to maximize

the total gross income. Before the optimization model was constructed, the manager had made a plan to allocate 30 ha for wheat, 30 ha for beans, 20 ha for potatoes, 5 ha for cabbages and 10 ha for tomatoes using his traditional methods. His concern is whether this crop enterprise production combination is optimal? Does it yield him maximum returns? His resources include land, fertilizers, seed, water (irrigation), labor, machinery and transport.

The manager must decide how many hectares that should be allocated to each crop. So the decisions are:

x_1 = *hectares allocated for wheat production*

x_2 = *hectares allocated for bean production*

x_3 = *hectares allocated for potato production*

x_4 = *hectares allocated for cabbage production*

x_5 = *hectares allocated for tomato production*

The goal of the objective function is to maximize the gross income subject to the given constraints. Table **1: LP Formulation Table for the 2004 Winter Season**

Below, shows the LP formulation for the 2004 winter season Resource Allocation Plan.

Table 1: LP Formulation Table for the 2004 Winter Season

Resource	**Crop**					**Resource Limit**
	Wheat	**Beans**	**Potatoes**	**Cabbages**	**Tomatoes**	
Land(ha)	1	1	1	1	1	95
Compound S	600	200	1000	1000	1100	60 000
A.N	200	100	100	200	200	13 000
Lime			300	300	300	23 000
Labor	10	13	15	15	20	1 500
Fuel	200	120	150	100	110	20 000
Capital	5 000 000	4 000 000	8 000 000	4 000 000	8 000 000	543 000 000
Water	6 000	5 000	5 000	6 000	6 000	600 000
Seed	100	90	1 000	.45	.15	36 600
Herbicides	1.5	1.5	1.5	1.5	1.5	200
Gross Income/ha	$17 000 000	$11 000 000	$25 000 000	$16 000 000	$20 000 000	

The LP is given by:

$$\max z = 17x_1 + 11x_2 + 25x_3 + 16x_4 + 20x_5, \qquad (objective\ function)$$

$$subject\ to$$

$$x_1 + x_2 + x_3 + x_4 + x_5 \leq 95, \qquad (land\ constraint)$$

$$6x_1 + 2x_2 + 10x_3 + 10x_4 + 11x_5 \leq 600, \qquad (compound\ S\ constraint)$$

$$2x_1 + x_2 + x_3 + 2x_4 + 2x_5 \leq 130, \qquad (AN\ fertilizer\ constraint)$$

$$3x_3 + 3x_4 + 3x_5 \leq 230, \qquad (lime\ constraint)$$

$$2x_1 + 2.6x_2 + 3x_3 + 3x_4 + 4x_5 \leq 300, \qquad (labour\ constraint)$$

$$20x_1 + 12x_2 + 15x_3 + 10x_4 + 11x_5 \leq 600, \qquad (fuel\ constraint)$$

$$5x_1 + 4x_2 + 8x_3 + 4x_4 + 8x_5 \leq 543, \qquad (capital\ constraint)$$

$$6x_1 + 5x_2 + 5x_3 + 6x_4 + 6x_5 \leq 600, \qquad (water\ constraint)$$

$$0.1x_1 + 0.09x_2 + x_3 + 0.00045x_4 + 0.00015x_5 \leq 36.5, \qquad (seed\ constraint)$$

$$1.5x_1 + 1.5x_2 + 1.5x_3 + 1.5x_4 + 1.5x_5 \leq 200, \qquad (herbicide\ constraint)$$

$$x_1, \ldots, x_5 \geq 0, \qquad (non-negativity\ constraint)$$

RESULTS AND DISCUSSION

The LP problem is solved using TORA a computer software package.

Below displays the results obtained for the winter 2004. Comparison is made of results obtained by using both the traditional methods and LP.

Table 2: Results for 2004 Winter Season

Crop	Land Area (ha)		Price/ha	Difference in Gross Income
	Traditional method (Plan)	LP		
Wheat	30	30	$17 000 000	
Beans	30	29	$11 000 000	
Potatoes	20	31	$25 000 000	
Cabbages	5	3	$16 000 000	
Tomatoes	10	2	$20 000 000	
Gross Income	$1 620 000 000	$1 692 000 000		$72 000 000

The LP results show that the manager should apportion 30 ha for wheat, 29 ha for beans, 31 ha for potatoes, 3 ha for cabbages and 2 ha for tomatoes on the 95 ha of land set aside for the 2004 winter season. The results show that a gross income of $1,692,000,000 using LP compared to $1,692,000,000 obtained by using traditional methods. The manager can make an income difference of $72,000,000 if he uses LP. The difference in the gross incomes is 6.7%.

Data was also collected for the year 2000 to 2003 productions. The LP model was used to determine the "what if" land allocation plan that could have been suggested by planning using LP. The percentage difference between results obtained from using the LP method and the traditional methods are summarized in Table 3 (below).

Table 3: Percentage Income Differences

Year	% difference
2000	21
2001	19
2002	5.6
2003	10.7
2004	6.7

The land allocation criteria obtained using the LP yields more income than using the traditional methods which are more or less of trial and error methods. Results obtained so far reveal that the optimal crop combinations the farmer should have considered to make more income.

The LP solution provided the farmer with an opportunity to realize more income from growing; wheat, beans, potatoes, cabbages and tomatoes on a 95 ha land area for the 2004 winter season. Had the farmer used LP solutions before, he could have realized more income from the same piece of land. Since 2000, the manager invariably employed a trial and technique to work out his resource allocation plans.

Conclusion

In this paper an LP planning model is developed. The LP solves the resource allocation problem. Numerical data is input into the model and results are obtained. Comparison is made between the results obtained from the LP model and the traditional method of planning. The results obtained from using the LP model are more superior to the ones obtained from using traditional methods.

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