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Use of Linear Programming Model to Determine the Optimum Cropping Pattern for an Irrigation Scheme in Masvingo, Zimbabwe

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ABSTRACT: Agricultural systems are often faced by challenges such as crop selection and irrigation planning which can be formulated as optimization problems. Decisions have to be made on the proper set of crops to be cultivated and a proper irrigation scheme. The objectives of such decisions are to maximize net profit or to minimize water waste. In this study, a linear programming model was developed that helped to determine the optimal cropping pattern for an irrigation scheme in Masvingo, Zimbabwe. Crops which considered were wheat, sugar beans for winter and cotton and maize for summer for the 2012/13 agricultural season. The linear programming model was solved by using Microsoft Excel (2007). The model recommended no production of wheat and cotton. Sugar beans and maize gained acreage by 50 percent and 88 percent respectively. On the whole, the optimal cropped acreage did not change as compared to the existing cropping plan. As a result of the optimal solution, a farmer‘s income could be increased by $1,668.60. The optimal income increased from existing level of $1,919.40 to $3,588.00 showing an improvement of 87 percent. The results show that LP models solutions are worthy implementing.

Keywords: Linear Programming; Cropping Pattern; Irrigation; Income; Masvingo

1. INTRODUCTION

Agricultural systems are often faced by challenges such as crop selection and irrigation planning which can be formulated as optimization problems (Gomaa, Harraz, & ElTawil, 2011). Decisions have to be made on the proper set of crops to be cultivated and a proper irrigation scheme (Gomaa, Harraz, & ElTawil, 2011). The objectives of such decisions are to maximize net profit or to minimize water waste (Gomaa, Harraz, & ElTawil, 2011). The linear programming (LP) technique has been used extensively in solving irrigation management problems (Gomaa, Harraz, & ElTawil, 2011). Jabeen, Ashfag & Baig (2006) estimated the marginal value of irrigation water through LP technique. Linear programming models were developed to estimate the short run marginal value of water and predict the impact of different water supply scenarios on cropping pattern, cropping intensity and net income of the farms under study (Jabeen, Ashfag, & Baig, 2006). Jabeen, Ashfag & Baig (2006) say, ―Results revealed that scarcity of water adversely affects the cropping intensity and net income of representative farms‖. Hassan, Raza, Khan & Ilahi (2005) applied an LP model to calculate the crop acreage, production and income of the Dera Ghazi Khan Division of Punjab province. The study was carried on irrigated areas from the four districts. Crops which were included in the study were wheat, rice, cotton and sugar cane. Cotton gained acreage by 10 percent. Income increased by 2.91 percent as compared to the existing situations.

Karamouz, Ahmadi & Nazif (2009) developed a model to optimize a water resources allocation scheme considering the conjunctive use of surface water and groundwater resources, as well as determining a suitable crop pattern. A genetic algorithm was used to solve the optimization model. The proposed model was successfully applied to the Varamin plain to determine the optimal crop mix and water allocation from surface and groundwater. A study was carried out in Nigeria in Kogi State to examine the impact of small scale irrigation technology in crop production under Fadama areas. The LP analysis revealed that opportunities exist for increasing profit through resources re-organization (Ohikere & Ejeh, 2012). Alminnana, Escudero, Landete, Monge & Sanchez-Soriano (2008) developed mixed 0-1 a separable nonlinear program for irrigation scheduling. These are being used as a decision support system tool to determine water irrigation scheduling by The Agriculture Community of Elche (ACE), Elche a city in the southeast of Spain. In a research conducted in Mpumalanga, South Africa, an LP model capable of economically evaluating a farm expansion decision making process for farmers faced with investment decisions was established (Haile, Grove, & Oosthuizen, 2003). An LP model was successfully used to assign a mainline for a total of twelve irrigation system combinations based on the assumption that the farmer wishes to start with a 30 ha centre-pivot investment (Haile, Grove, & Oosthuizen, 2003).

The economic value of irrigation water used in a crop farm (paddy and chillies) was successfully estimated using an LP approach in the Senanayake Samudra (Gal-Oya Irrigation Scheme) Right Bank System area in the Ampara District (Sivarajah & Ahamad, 2010). Budiasa (2011) developed a Sustainable Irrigated Farming System (SIFS) Model at the household level in the north coastal plain, Bali. Primary data from farmers were used to specify parameters of the model. Linear programming technique was used to solve the problem. Raju, Kumar & Duckstein (2006) in their study had an objective to select the best compromise irrigation planning strategy for the case study of Jyakwadi irrigation project, Maharashtra, India. They employed a four-phase methodology to solve the problem. In phase 1, separate LP models were formulated for the three objectives, that is, net economic benefits, agricultural production and labor employment. Tzimopoulos, Balioti, Evangelides & Yannopoulos (2011) determined optimal cropping patterns in the territory of

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Agios Athanasios irrigation network, Greece by the proposed method based on an LP model. Their results showed that the proposed LP model gives the optimum crop pattern for the region, obtaining the highest profit.

The objective of this study was to develop the optimal cropping pattern for an irrigation scheme in Masvingo, Zimbabwe, and to assess the farmers‘ income level under optimal cropping pattern and its comparison with the existing income level.

2. THE LINEAR PROGRAMMING FORMULATION

The study area selected for this is an irrigation scheme in Masvingo, Zimbabwe. The irrigation scheme, 624 hectares in extent, is located 20 kilometers south of Masvingo town (Ndamba, Sakupwanya, Makadho, & Manamike, 1999). The scheme lies in agro-ecological zone IV, which receives an annual rainfall of about 650 mm per year (Ndamba, Sakupwanya, Makadho, & Manamike, 1999). The scheme is supplied by water from a 25 kilometer canal, of which 17 kilometers are concrete-lined and 8 kilometers are unlined (Ndamba, Sakupwanya, Makadho, & Manamike, 1999). (Ndamba, Sakupwanya, Makadho, & Manamike, 1999) say, ―The average plot holding per family is 1.5 hectares. The irrigators at this scheme utilize rotational water supply to each irriga tion block. Their major crops are cotton and grain maize in summer and wheat and beans in winter. A block consists of the same crop and is partitioned to accommodate every irrigator. This system is called block irrigation‖. Water from the dam has been used to irri gate crops such as cotton, wheat, sugar beans, soya beans, paprika, maize, tomatoes and cabbages (Gwazani, et al., 2012).
An LP model was developed to arrive at an optimal plan of production for a typical farmer at the irrigation scheme. The objective of the LP model was to maximize the total net income subject to resource constraints. The LP model patterns after the model by Bamiro, Afolabi and Daramola (2012). The objective function is given by:

$$Z =$$
$$=1$$

Subject to

$$= \quad i \leq ,$$
$$1 \qquad \geq 0$$

where,
Z = Total annual net returns,
m = Number of resources,
n = Number of activities,
Cj = Net returns per unit of jth activity,
Xj = Level of the jth activity,
bi = Amount of the ith resource required,
aij = Amount of the ith resource required per unit of the jth activity.

3. RESULTS AND DISCUSSION

The linear programming model was solved by using Microsoft Excel (2007). The optimal cropping pattern resulting from the LP model for a single farmer in comparison to the existing cropping pattern are presented in Table 1 for the 2012/13 agricultural season. It was noted that sugar beans and maize gained acreage by 50 percent and 88 percent respectively. The LP recommended no production of wheat and cotton. On the whole, the optimal cropped acreage did not change as compared to the existing cropping plan.

Table 1. Cropping Patterns

Crops	Existing (ha)	Optimal solution (ha)	% of existing
Winter:			
Wheat	0.5	0.0	0
Sugar beans	1.0	1.5	150
Total	1.5	1.5	100
Summer:			
Cotton	0.7	0.0	0
Maize	0.8	1.5	188
Total	1.5	1.5	100

Table 2. Income Levels

Existing Income ($)	Optimal solution ($)	% of existing
$1,919.40	$3,588.00	187

As a result of the optimal solution, a farmer‘s income could be increased by $1,668.60. The optimal income increased from existing level of $1,919.40 to $3,588.00 showing an improvement of 87 percent. The results show that LP models solutions are worthy implementing. Optimal cropping patterns increase income.

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4. CONCLUSION

In this study, a linear programming model was developed that helped to determine the optimal cropping pattern for an irrigation scheme in Masvingo, Zimbabwe. Crops which considered were wheat, sugar beans for winter and cotton and maize for summer. The farm income could be increased by 87 percent if the optimal cropping was applied.

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