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LEXICOGRAPHIC GOAL PROGRAMMING APPROACH FOR THE OPTIMIZATION OF CROPPING PATTERN IN YASIN REGION GILGIT, PAKISTAN

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ABSTRACT

The prosperity of the agricultural sector is crucial not only for the national economy but also for regional development. For the purpose of agricultural planning and decision making, mathematical programming models are widely used. This paper aims to formulate, apply and evaluate a Lexicographic Goal Programming (LGP) model for the best allocation of land under cultivation for the major crops of central Yasin. It is an extension of the research work [1] which was conducted in this area to maximize the profit of the three crops using Linear Programming (LP). Using the LP model the target was achieved but all the land was allocated for alfalfa being the most beneficial crop among the three. But wheat is a basic need which must be cultivated to a specific amount. Considering this problem we extended the previous work by implementing the LGP approach to satisfy multiple goals such as the allocation of land for wheat, maximization of profit and minimization of capital in the agricultural activity. The LGP model is solved using the Simplex method. The LGP model provided the most satisfactory set of allocations possible and satisfied all three goals. It gave optimum profit of Rs.170003 and capital is minimized to Rs. 73687.678. Compared with the farmer's plan, the profit of the LGP model increased by 49.39% but compared with the LP model, the profit decreased by 13.11%. Likewise, the total crop production expenditure increased by 4.97% and 1.39% respectively in comparison with the farmer's plan and LP model.

KEYWORDS: Cropping pattern; Optimization; Lexicographic Goal Programming; Simplex method.

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1. INTRODUCTION

Agricultural planning problems are of great importance from both social and economic points of view. The available agricultural land and resources are reducing day by day because of the growing population. Due to these limitations, optimal use of land and agricultural resources is needed to optimize. Mathematical programming models are widely used in agricultural planning. Agricultural problems generally contain multiple and conflicting objectives or goals such as minimization of cost, minimization of labor expenditure, increasing crop yields, and maximization of profits [2]. Farmers use their past experiences for agricultural planning but mathematical programming is the best tool

that can be employed for this purpose. LGP appeared as the most popular method for multi-objective decision-making problems and is used widely in multi-objective decision-making situations [3]. LGP was first introduced by Charnes and Cooper [4]. The basic idea used in Goal Programming is to change multiple objectives into a single goal [5]. LGP introduces the desired target of each goal and optimizes the deviation from these goals to reach the desirable solution. The unwanted deviations are measured using positive and negative deviations for each of the goals [6]. The fame of LGP and its use in decision-making policies, objects to optimize farming land and other agricultural resources [7].

There is a range of literature on resource allocation and decision making in agricultural sector using LGP approach. Joolaie et al. [8] used Fuzzy Goal programming (FGP) technique to determine an optimal cropping pattern in North Iran by considering economic, social and environmental goals. A FGP approach was used by Mohammadian & Heydari [9] to determine an optimal cropping pattern for the selected crops of Mazadaran province under three different scenarios. LGP approach is applied to tea industry in Barak Valley of Assam India by Sinha & Sen [10]. They presented six different plans of GP approach. The model is developed to maximize the production quantity, maximize the profit, demand and to minimize the expenditure and processing time of machines considering the environmental conditions. Jafari et al. [11] developed an optimal model for the rice farm in Maydansar Koshleti village of north Iran using Lexicographic Goal Programming. A similar is tackled by Vivekanandan et al. [12]. They formulated a GP model for the optimization of cropping patterns for the Barna command area. The objectives were maximization of net return and maximization of protein and calories. To give a better cropping plan Rezayi & Mardani [13] used the FGP approach for the agricultural planning of the Atrak Watershed Agricultural development plan. The three objectives or goals considered in this model were maximization of profit, employment maximization and minimization of erosion under 88 constraints. Hassan & Sahrin [14] developed a GP model to determine the rate of mixed fertilizers and leaf fertilizers to produce the best quality pineapple. Haq et al. [15] conducted a study in District Hunza intending to explore the most beneficial cropping pattern for the three major crops wheat, potato and alfalfa grown the region and to maximize the net profit per year. The obtained results show that profit increased by 10% as compared with former's plane.

This study aims to apply an LGP model for the allocation of land for the major crops of central Yasin to get an optimal solution in the context of both objectives and constraints which give us an optimal net return by maximizing the profit and minimizing the crop production cost. Also, the basic requirements of the wheat crop will be fulfilled.

2. THEORETICAL FRAMEWORK AND MODEL

LGP is one of the oldest multi-criteria decision-making techniques and the most frequently used method in agricultural planning that aims to minimize deviations from the desired target to achieve the goals. The LGP technique is employed for the study and the data used is secondary data. This data was used by Haq et al. [1] to apply the Linear programming model

in the agricultural sector to maximize the profit of the major crops.

2.1 Study area

The research area is Central Yasin. Yasin is a valley situated in the Ghizer district which is the northernmost part of Gilgit Baltistan, Pakistan. Climatically it is a colder region. Most of the people in the study area depend on agriculture for their livelihood. Different vegetables like potatoes, tomatoes, onions, and carrots are grown there. But the major crops which are grown largely are wheat, maize and alfalfa. Farming is their occupation therefore there is an imminent need to formulate an efficient cropping pattern in that region to meet the overall objectives based on the availability of agricultural resources.

2.2: LGP Model

The method of formulating the LGP model is similar to that of Linear Programming. The only difference is that LP optimizes a single objective function whereas LGP always minimizes the deviation of the goal $\left(d_i^+ \text{ and } d_i^-\right)$ from the target value. We are using the LGP approach. In the LGP method goals are categorized into different priority levels P_i. A goal of a high-priority level is more important than a goal of a low-priority level. Thus it is significant to achieve the goal of the priority level before considering the goal of the second priority. A general LGP model can be expressed mathematically as;

Minimize $Z = \sum_{i=1}^{n} P_i(d_i^+ + d_i^-)$

Subject to linear constraints:

Goal constraints; $\sum_{j=1}^{n} a_{ij}x_j - d_i^+ + d_i^- = g_i, \text{ for } i = 1,2,...n$

System consraints; $\sum_{j=1}^{n} a_{ij}x_j (\leq, =, \geq)\ b_i, \text{ for } i = m+1,...,m+p$

$d_i^+, d_i^-, x_j \geq 0$

$\forall\ i = 1,2,...,m$

$j = 1,2,...,n$

where Z is the objective function.

2.2.1: The Goals

The goals for the LGP problem with their priority level are described in Table 1.

Table 1: Description of goals

Goal	Priority Level	Description	Mathematical Form
Wheat Production	1st Priority	The production of wheat crops should be less or equal to the estimated target. (20% of agricultural land)	$x_1 \leq 0.47$
Profit Maximization	2nd Priority	The estimated target of profit from the crops must be achieved(Rs 170,000)	$33375x_1 + 30423x_2 + 83676x_3 \geq 170000$
Capital Minimization	3rd Priority	The capital target for the crops must not exceed the reserved amount. (88440)	$33840x_1 + 23517x_2 + 31984x_3 \leq 85000$

2.2.2: Constraints

Labor Requirement

Labors required for agricultural work including ploughing, cutting and other activities. Labor days required for wheat, maize and alfalfa crops for a season in the available land are given as 25 days, 26 days and 36 days respectively. Labor constraints can be written as

$$25x_1 + 26x_2 + 36x_3 \leq b_1$$

Fertilizer Requirement

The amount of fertilizer bags used for wheat crops is 28 bags, 25 bags for maize and 32 bags for alfalfa for one season. The fertilizer constraint is given as;

$$28x_1 + 25x_2 + 32x_3 \leq b_2$$

Area Constraint

The total land available for agricultural purposes is 2.338 acres. The land used for the cultivation of all crops must not exceed the total land available. The constraint can be written as;

$$x_1 + x_2 + x_3 \leq 2.338$$

Wheat Requirement

To meet the people's food requirement some area of the land should be kept for wheat cultivation that is;

$$x_1 \leq 0.47$$

This becomes

$$x_1 + d_1^- - d_1^+ = 0.47$$

Net Profit

The net profit obtained from wheat, maize and alfalfa is Rs. 33375, Rs. 30423 and Rs. 83676 respectively. The profit constraint can be written as;

$$33375x_1 + 30423x_2 + 83676x_3 \geq 170000$$

It becomes

$$33375x_1 + 30423x_2 + 83676x_3 + d_2^- - d_2^+ = 170000$$

Capital

Capital is the amount used for crop production. Capital used for wheat, maize and alfalfa is Rs. 33840, Rs. 23517 and Rs. 31084. The capital constraint is written as

$$33840x_1 + 23517x_2 + 31984x_3 \leq 85000$$

It becomes

$$33840x_1 + 23517x_2 + 31984x_3 + d_3^- + d_3^+ = 85000$$

The variables appeared in the above sections are defined as follows;

x_1 = land allocation in acres for wheat crop

x_2 =land allocation in acres for maize crop

x_3 =land allocation in acres for alfalfa crop

d_i^+ =overachievement of i^{th} goal

d_i^- = underachievement of i^{th} goal

b_1 = labor days required

b_2 =fertilizer used for the three crops

b_3 =total available agricultural land

g_1 = goal of land allocation for wheat

g_2 =goal of profit maximization

g_3 =goal of capital minimization

s_1 =unneeded labors

s_2 =unused fertilizers

s_3 =unused land

2.2.4: LGP Model for the Problem

The lexicographic goal programming model formulated for the current problem is given as;

$$\text{Minimize } Z = P_1 d_1^- + P_2 d_2^- + P_3 d_3^+$$

Subject to linear constraints;

$$x_1 \le 0.47$$
$$25x_1 + 26x_2 + 36x_3 \le 87$$
$$28x_1 + 25x_2 + 32x_3 \le 85$$
$$x_1 + x_2 + x_3 \le 2.338$$
$$33375x_1 + 30423x_2 + 83676x_3 \le 17000$$
$$33840x_1 + 23517x_2 + 31084x_3 \le 85000$$

The coefficients of the above GP model are summarized in Table 2.

Table 2: Description of resources

Resources Crop	Profit (Rs.)	Fertilizers used (bags)	Capital (Rs)	Man days (days)	Land used (acres)
Wheat	33375	28	33840	25	0.924
Maize	30423	25	23517	26	0.664
Alfalfa	83676	32	31084	36	0.75
Total	**147474**	**85**	**88441**	**87**	**2.338**

3. RESULTS AND DISCUSSION

The LGP model formulated for the problem is solved using the Simplex method. According to the cropping pattern suggested by the LGP model all the goals are achieved successfully. It allocates 0.47 acres of land for wheat, 0.03745 acres for maize and 1.8306 acres of total agricultural land for alfalfa crops. A profit of Rs. 170003 is obtained and the capital is minimized to Rs. 73687.88. Compared with the farmer's plan the profit of the LGP model's result increased by 49.39% but compared with the LP model's result the profit decreased by 13.11% because of wheat cultivation. The total crop production expenditure is increased by 4.97% and 1.39% compared with the cost of farmers' plan and LP results respectively. The results are given in tabular form in Tables 3 and 4. Graphical representation of tables 3 and 4 is represented in figures 1 and 2 respectively.

Table 3: Comparison of land allocation of GP model with LP and farmer's plan

Crop	Farmer plan (acres)	LP result (acres)	GP result (acres)	% of farmers plan (%)	% of LP result (%)
Wheat	0.924	0	0.47	50.86	-
Maize	0.664	0	0.0375	5.65	-
Alfalfa	0.75	2.338	1.8306	244	78.29

Table 4: Comparison of profit and capital of GP model with LP and farmer's plan

Crop	Farmer plan (Rest)	LP result (Rs)	GP result (Rs)	% of farmers plan (%)	% of LP result (%)

Profit	113796.37	195634.48	170003	149.39	86.89
Cost	70196.45	72674.392	73687.88	104.97	101.39

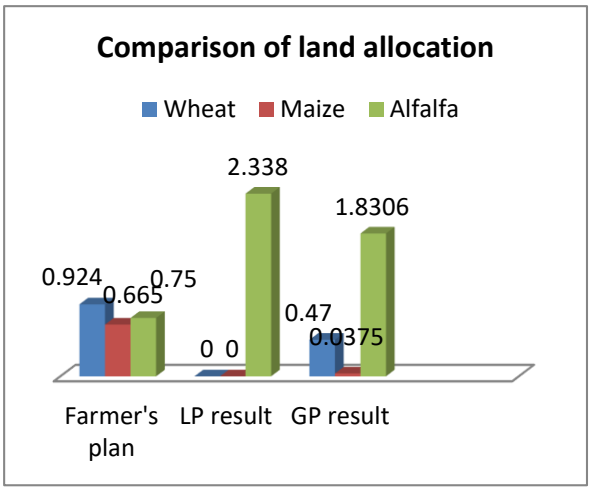

Fig. 1. Comparison of Land allocation

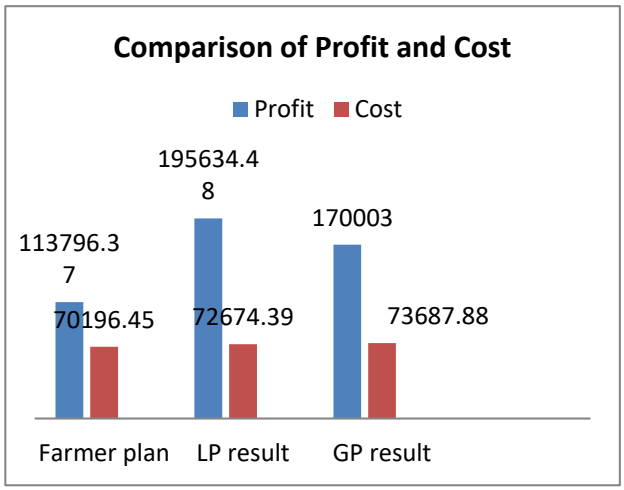

Fig.2. Comparison of Profit and Cost

4. CONCLUSION

The Lexicographic Goal Programming model developed for the problem provided the best possible solution subject to the given constraints and priority levels of the goals. After the study, it was demonstrated that the LGP model is a better approach than the LP approach when the problem involves multiple and conflicting objectives. This result is based on the maximum satisfaction of the objective function subject to available resources and conditional constraints. Using this model the basic requirement of wheat is fulfilled which cannot be achieved using the LP technique. LGP best allocates the land giving maximum profit with the lowest cost.

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