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Using Fuzzy Goal Programming Technique in Optimal Cropping Pattern

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Abstract Determination of optimal cropping pattern is essential for arid and semiarid regions. Lorestan province is located in the west part of Iran with mean annual precipitation from 50 to 1000 mm and in most parts of this province water resources for agriculture are deficit. Khoramabad region with semi-arid climate is located in Lorestan province with mean annual rainfall of 373 mm. The purpose of this paper is to handle fuzzy goal programming model (FGP) for optimal allocation of agricultural acreage and annual program offers for variety of products. This approach not only increases the applicability of goal programming in real world situations but also provides useful insight about the solution. In the model formulation of the problem, production and net profit achievement, and man power, machine-hour, seed, fertilizers and pesticides requirement goals from the farm are fuzzily described. The output of our study may become a useful analytical tool for agricultural managers, who are using traditional LP and GP methods for recommendations to the farmer on optimal land allocation for different crops in the planning process.

Keywords: Optimal Cropping Patterns, Fuzzy Goal Programming, Khorramabad Region, Iran.

1 Introduction

The farming crops represent the main alimentary resource for 6.7 billion people. So agriculture represents that fundamental division of the world economy that has to provide foodstuff for all mankind [1]. With increasing the globe's population, problems about the shortage of all kinds of resources and environmental pollution are becoming more and more serious [2]. The problem of decreasing ground fertility, use of high doses of inorganic manure and increasing the cost of inorganic fertilizers are factors considered harmful for sustainability of production systems [3]. Due to the growth in population, there is always a need of more production to meet the increasing needs. One way of achieving high productivity is to increase the area under cultivation [4]. With farming production system, a cropping prototype or allocation of land to different type of crops varies with the farmer perspective of his ground holding. Further, it is observed that net proceed per acre is greater in vegetable crops (cash

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crops) rather than food crops. Thus for each farmer, profit becomes an objective function which he wishes to maximize. These problems of allocation of land for different crops, maximization of production of crops, maximization of profit, minimization of cost are addressed in agricultural management system. Initially, these problems of agriculture sector were modeled as single objective linear programming problem by dealing with one objective at a time. But with changing scenario of the complex natural life problem, several objectives require to be linked in the agricultural preparation and management. Thus, some alternative methods are needed to handle this complex problem of decision making, as the maximization of crop production can't assurance the maximization of profit. In the agriculture sector, profit or damage also depend on fluctuating command, provide and pricing of a particular crop with minimization of cost of cultivation needed for that crop. Thus, the maximization of profit turns out to be a multi-objective decision making problem. There is increasing information observed in new times to make the best use of water as well as a rare and precious resource for all economic activities [5]. Many researchers have used mathematical programming for determination of the optimal cropping pattern [6-8]. In irrigated agriculture, where different crops are competing for a limited amount of ground and water resources, linear programming (LP) is one of the best tools for optimal allocation of ground and water resources [9]. LP is the most widely used technique in agriculture planning. These models have been used for maximization of production of crops for allocating the land under cultivation and for minimizing cost to a farmer. Mathematical programming pattern is close to a true pattern, if the decision making process can be adequately represented such that observed production activities can be reproduced [4]. In actual planning practice, the input data and other parameters such as demand, resources, cost and objective functions are also imprecise (fuzzy) because some observations are incomplete or un obtainable [10, 11]. Over the last few decades, several operations research techniques have been used in agricultural planning. Optimization techniques provide a powerful tool for analysis of problems that are formulated with single, quantifiable objectives. However, the real world decision making problems usually require consideration of multiple, conflicting and non-commensurable criteria [12]. These are called multiple-criteria decision problems, where the decision maker generally follows a satisfying solution rather than the maximization of objectives [13]. Multi objective programming is a reliable tool for working with complicated systems. It can incorporate various system components in a single framework and efficiently coordinate and optimize objectives [4]. The verity that actual living problems combine multitude objective and landscape lead off recently to the use of goal programming and multi-criteria decision making [12]. The plain models of linear programming for planning agricultural area have been progressively substituted by more advanced and realistic mathematical programming models. At present, many models are used, among which multi criteria mathematical programming models are well known [14]. Goal programing is one of the leading tools for analysis and decisions in farm management. GP is a multi-objective simultaneous access to several of the features that are based on prioritization [12, 15]. Charnes and Cooper initially proposed this technique [16]. Later on, Lee contributed significantly in the field of GP [17]. Most of the applications in agricultural planning correspond to the problem of determining an optimum-cropping pattern with multiple goals. GP techniques have been successfully used for these purposes. In conventional GP, parameters of the problems need to be defined precisely. In most agricultural planning problems, values of some parameters may not be known precisely. They are rather defined in a fuzzy sense. For successfully handling such problems, fuzzy goal programing (FGP) must be used. The use of fuzzy set theory in goal programming was first introduced by Narasimhan [18]. Chen and Tsai [19] presented an intensive review of FGP.

Saraj and Sadeghi used fuzzy goal programming approach in quadratic bi-level programming problems [20]. Fuzzy linear programming (FLP) is having advantages over the other existing multiobjective optimization methods. On the other hand, FLP approach requires only one additional constraint for each additional objective function. Also the flexibility to convert the fuzzy model into existing optimization software makes the approach more attractive [21, 22].

This study follows the optimization of crop pattern and allocation of scarce resources such as water in Khoramabad region located in Hamedan province, Iran. This study presents a tolerance based fuzzy goal programming (FGP) model for optimal allocation of land under cultivation and proposes an annual agricultural plan for different crops. Minimizing the weighted sum of tolerance variables for the highest membership grades, results in the most satisfactory decision. In order to obtain all possible solutions, sensitivity analysis on different weight structures for the goals as specified by the decision maker has been performed.

2 FGP problem formulation

To determine the optimal cropping pattern a tolerance based fuzzy goal programming (FGP) model is used. The main objective is maximizing net returns for farmers with a view to maximizing production, profit, and workforce and minimizing seed, fertilizers, pesticides, water and machines requirement [21].

The linear programming for crop production and the case of maximizing can be expressed as:

$$
\begin{aligned}
& MAXZ = f(x) = C'x \\
& s.t. \\
& \quad \mathrm{AX} \le b \\
& \quad \mathrm{X} \ge 0
\end{aligned}
\tag{1}
$$

The objective function is obtained by multiplying C' by x, x is a vector of decision variables, C' gross margin per unit, b the vector of physical, institutional or personal constraints and A defines the technical relationship between variables and constraints, or the matrix of technical coefficients. Widespread use of linear programming in the agricultural economy suffers from several shortcomings.

1) All relationships are linear.
2) Different parameters have only one expected value.
3) Choose can be done with only one criterion.

Considerable progress has been made to overcome these shortcomings. Albeit the detection of the objective function that has a criterion doesn’t always authenticity, little attention has been made to develop a suitable method to overcome it. Decision makers are often interest to optimize several objectives that are in conflict to reach rather than optimize just an objective. In addition, in real life, so it's not hard to access resources that under no circumstances should it be violated, as it is in linear programming. The need to balance multiple objectives in agricultural planning is well established. Several methods of multi-criteria decision making in knowledge management is recommended. One of these techniques is a goal programming.

2.1 Goal programming model is composed of four parts

2.1.1 Decision variables
2.1.2 Goal constraints
2.1.3 System limitations
2.1.4 Objective function
System limitations, decision variables and constants used in any kind of linear programming are not flexible and must be met. Goal constraints have a positive or negative deviation that aim is to minimize the deviations from the goals. The objective function is also minimizing positive and negative deviations from targets.
Definitions of Variable and Parameters
Index:
C: Index of product: $c \in \{1,2,...,9\}$

2.1.1 Decision variable

X_C: allocation of the land for cultivating the crop *c*
Fuzzy productive resources:
L: total area of cultivated land (ha)
TL: expected labor availability (Man-day)
TM: expected total available machine-hours (hrs.)
N: expected net profit for all products (million Rials)
TP_c: expected production of crop c (Metric ton)
W: expected total water available for irrigation (m^3)
TS_c: expected total seed of crop c (kg)
TFPH: expected total phosphate fertilizer (kg)
TFP: expected total potash fertilizer (kg)
TFN: expected total nitrogen fertilizer (kg)
TH: expected total herbicide (kg)
TF: expected total fungicide (kg)
Crisp coefficients:
P_c: average production per ha of land (Metric ton / ha)
L_c: labor requirement per ha of land for crop c (Man-day / ha)
F_c: amount of fungicide requirement per ha of land for crop c (kg / ha)
H_c: amount of herbicide requirement per ha of land for crop c (kg / ha)
FP_c: amount of potash fertilizer requirement per ha of land for crop c (kg / ha)
FN_c: amount of nitrogen fertilizer requirement per ha of land for crop c (kg / ha)
FPH_c: amount of phosphate fertilizer requirement per ha of land for crop c (kg / ha)
S_c: amount of seed requirement per ha of land for crop c (kg / ha)
N_c: net profit per ha of land for crop c (Million Rials / ha)
W_c: amount of water requirement per ha of land for crop c (m^3 / ha)
M_c: machine hours requirement per ha of land for crop c (hours / ha)

2.1.2 Goals constraints

The fuzzy goals of the formulated model are as follows:

(1) *Production achievement goal*: The decision maker will try to maximize its expected production. The target area was obtained by multiplying the average production to the area of land cultivated. Total production for all products must be greater than or equal to the expected production during the year. Production target for the equation can be written as:

$$P_C X_C \succ \sum_{C=1}^{C} TP_C \qquad \forall C \in \{1,2,...,9\} \tag{2}$$

Net profit goal: decision-maker requires a certain level of profit from agriculture. Net profit of the equation can be written as:

$$\sum_{C=1}^{C} N_C X_C \succ N \tag{3}$$

(2) *Man power goal*: A number of laborers are to be employed throughout the year to avoid the trouble with hiring of more laborers at the peak times and involvement of extra cost for it. For workers, the equation can be written as:

$$\sum_{C=1}^{C} L_C X_C \succ TL \tag{4}$$

(3) *Seed requirement goal*: The decision maker will require a certain level of seed. The equation of Need to seed can be written as:

$$\sum_{C=1}^{C} S_C X_C \prec TS \tag{5}$$

(5) *Water consumption goal*: To encounter the production target of each crop, adequate water supply should be ensured. Equation for the supply of water can be written as:

$$\sum_{C=1}^{C} W_C X_C \prec W \tag{6}$$

(6) *Phosphate fertilizers requirement goal*: decision-maker requires a certain level of phosphate fertilizer for growing crops. Phosphate fertilizer requires equation can be written as follows:

$$\sum_{C=1}^{C} FPH_C X_C \prec TFPH \tag{7}$$

(7) *Potash fertilizer requirement goal*: plant crops require a certain amount of potassium. The potassium requirement equation can be written as:

$$\sum_{C=1}^{C} FP_C X_C \prec TFP \tag{8}$$

(8) *Nitrogen fertilizer requirement goal*: decision-maker requires a certain level of nitrogen fertilizer for growing crops. The nitrogen fertilizer equation can be written as:

$$\sum_{C=1}^{C} FN_C X_C \prec TFN \tag{9}$$

(9) *Herbicides requirement goal*: a decision requires a certain amount of herbicides for agricultural crops. The herbicides requirement equation can be written as:

$$\sum_{C=1}^{C} H_C X_C \prec TH \tag{10}$$

(10) *Fungicides requirement goal*: decision-maker requires a certain level of fungicides for growing crops. The fungicides requirement equation can be written as:

$$\sum_{C=1}^{C} F_C X_C \prec TF \tag{11}$$

(11) *Machine-hour goal*: for fallow land during the year, there is an estimated annual hour car. The time allocated for the equation system can be written as:

$$\sum_{C=1}^{C} M_C X_C \prec TM \tag{12}$$

2.1.3 System Limitations

Farm requires fixed resources such as land available for cultivation. The available land for all crops ought not to exceed total cultivable land available. The equation for cultivable land availability can be written as:

$$\sum_{C=1}^{C} X_C \leq L \tag{13}$$

$$x_1,...,x_9 \leq \{max\, x_1,...,x_9\} \tag{14}$$

$$x_1,...,x_9 \geq \{min\, x_1,...,x_9\} \tag{15}$$

Transformation of Fuzzy Goals

The fuzzy goal programming, a fuzzy membership function corresponding to the k-th fuzzy goal of type $z_k(x) \succ b_k$ is written as:

$$\mu_{z_k}(x) = \begin{cases} 1 & \text{if} \quad z_k(x) \geq b_k \\ \dfrac{z_k(x) - (b_k - t_k^l)}{t_k^l} & \text{if} \; b_k - t_k^l \leq z_k(x) < b_k \\ 0 & \text{if} \quad z_k(x) < b_k - t_k^l \end{cases} \tag{16}$$

t_k^1 indicate the lower tolerance limit and corresponding to the k-th fuzzy goal of type $z_k(x) \succ b_k$ that can be written as:

$$\mu_{z_k}(x) = \begin{cases} 1 & \text{if} \; z_k(x) \leq b_k \\ \dfrac{(b_k + t_k^u) - z_k(x)}{t_k^l} & \text{if} \; b_k < z_k(x) \leq b_k + t_k^u \\ 0 & \text{if} \quad z_k(x) > b_k + t_k^u \end{cases} \tag{17}$$

and t_k^u indicate the upper tolerance limit.

Where $\mu_{z_k}(x) \in [0,1], \forall k$ indicate the membership grade of achieving the goal with 0 and 1 representing the lowest and highest grade, respectively. The membership grade depends on the specified tolerance value given in the decision making context. Regarded FGP model of the land allocation problem, the crop production goal (Eq.2) and the net profit goal (Eq.3) and labor(Eq.4) are of type $z_k(x) \succ b_k$ And the amount of seed required (Eq.5), water requirement (Eq.6), the fertilizers requirement (Eq. 7, 8 and 9) and the use of herbicides (Eq.10), the use of fungicides (Eq.11), machinery (Eq.12) and the goals are of type $z_k(x) \succ b_k$. If crop production and net profit goals are completely achieved, then no tolerances for them are needed and the grades of membership for the goals should be unity. When these goals are either perfectly or partially unachieved, tolerances for them are required. If $u_i^-, i = 1,2,3$ are the low tolerance and

$\lambda_i^- \in [0,1], i = 1,2,3$ are membership degree of the product and profit goals and objectives of the labor force equation can be written as:

$$P_C X_C - \lambda_1^- u_1^- \geq \sum_{C=1}^{C} TP_C - u_1^- \quad \forall \text{C} \in \{1,2,...,9\} \tag{18}$$

Namely:

$$P_C X_C + \theta_{C1}^- u_{C1}^- \geq \sum_{C=1}^{C} TP_C \ \forall \text{C} \in \{1,2,...,9\} \tag{19}$$

And

$$\sum_{C=1}^{C} N_C X_C + \theta_2^- u_2^- \geq N \tag{20}$$

$$\sum_{C=1}^{C} L_C X_C + \theta_3^- u_3^- \geq TL \tag{21}$$

$$\theta_i^- = 1 - \lambda_i^-, i = 1,2,3 \tag{22}$$

If $u_i^+, i = 4,...,11$ is high tolerance and λ_i^+ is the membership degree of goals seeds, water, fertilizers and the amount of pesticide needed to use the device as well as the objectives of the equation can be written as follows:

$$\sum_{C=1}^{C} S_C X_C - \theta_4^+ u_4^+ \leq TS \tag{23}$$

$$\sum_{C=1}^{C} W_C X_C - \theta_5^+ u_5^+ \leq W \tag{24}$$

$$\sum_{C=1}^{C} FPH_C X_C - \theta_6^+ u_6^+ \leq TFPH \tag{25}$$

$$\sum_{C=1}^{C} FP_C X_C - \theta_7^+ u_7^+ \leq TFP \tag{26}$$

$$\sum_{C=1}^{C} FN_C X_C - \theta_8^+ u_8^+ \leq TFN \tag{27}$$

$$\sum_{C=1}^{C} H_C X_C - \theta_9^+ u_9^+ \leq TH \tag{28}$$

$$\sum_{C=1}^{C} F_C X_C - \theta_{10}^+ u_{10}^+ \leq TF \tag{29}$$

$$\sum_{C=1}^{C} M_C X_C - \theta_{11}^+ u_{11}^+ \leq TM \tag{30}$$

$$\theta_i^+ = 1 - \lambda_i^+, i = 4,...,11 \tag{31}$$

2.1.4 The objective function

The fuzzy goals for the problem are transformed to their respective linear constraint form. In this formulation, as the tolerance variables are to be minimized, the tolerances be needed will be close to unity for each fuzzy goal. This causes the grade of membership to become larger. In particular, if the tolerance variables are zero, then there is no need to assign tolerances to fuzzy goals. Hence, the objective function for optimal cropping patterns can be written as follows:

$$min \quad \sum_{i=1}^{3} W_i \theta_i^- + \sum_{4}^{11} W_i \theta \tag{32}$$

Where $w_i, i = 1,...,11$ are the respective weights corresponding to the fuzzy goals and the sum of all weights is 1.

The final LP form of the agricultural land allocation problem is obtained as follows:

$$Min \quad \sum_{i=1}^{3} W_i \theta_i^- + \sum_{4}^{11} W_i \theta_i^+ \tag{33}$$

s.t.

$$P_C X_C + \theta_1^- u_1^- \geq TP_C \qquad \forall C \tag{34}$$

$$\sum_{C=1}^{C} N_C X_C + \theta_2^- u_2^- \geq N \tag{35}$$

$$\sum_{C=1}^{C} L_C X_C + \theta_3^- u_3^- \geq TL \tag{36}$$

$$\sum_{C=1}^{C} S_C X_C - \theta_4^+ u_4^+ \leq TS \tag{37}$$

$$\sum_{C=1}^{C} W_C X_C - \theta_5^+ u_5^+ \leq W \tag{38}$$

$$\sum_{C=1}^{C} FPH_C X_C - \theta_6^+ u_6^+ \leq TFPH \tag{39}$$

$$\sum_{C=1}^{C} FP_C X_C - \theta_7^+ u_7^+ \leq TFP \tag{40}$$

$$\sum_{C=1}^{C} FN_C X_C - \theta_8^+ u_8^+ \leq TFN \tag{41}$$

$$\sum_{C=1}^{C} H_C X_C - \theta_9^+ u_9^+ \leq TH \tag{42}$$

$$\sum_{C=1}^{C} F_C X_C - \theta_{10}^+ u_{10}^+ \leq TF \tag{43}$$

$$\sum_{C=1}^{C} M_C X_C - \theta_{11}^+ u_{11}^+ \leq TM \tag{44}$$

$$x_1,...,x_9 \leq \{max\, x_1,...,x_9\} \tag{45}$$

$$x_1,...,x_9 \geq \{min\, x_1,...,x_9\} \tag{46}$$

$$\sum_{i=1}^{3} W_i + \sum_{i=4}^{11} W_i = 1 \tag{47}$$

$$0 \leq \theta_1^-, \theta_2^-, \theta_3^-, \theta_4^+, \theta_5^+, \theta_6^+, \theta_7^+, \theta_8^+, \theta_9^+, \theta_{10}^+, \theta_{11}^+ \leq 1 \tag{48}$$

$$X_C \geq 0 \qquad \forall C \tag{49}$$

This study uses fuzzy goal programing to determine optimal cropping pattern for a number of crops in Khorramabad region (west part of Iran) located in Lorestan province with mean annual precipitation from 50 to 1000 mm and in most parts of this province water resources for agriculture are deficit. Khoramabad region with semi-arid climate and mean annual rainfall of 373 mm is one of the most important regions in agricultural production. The writers collected the data from different agricultural planning units [23, 24].

In this study, we use C = 1 for wheat, C = 2 for barley, C = 3 for lentil, C = 4 for canola, C = 5 for hay, C = 6 for bean, C = 7 for tomato, C = 8 for cucumber and C = 9 for pea. The total area is 115,100 hectares, whereas 100,490 hectares of land are devoted for these crops. There is the highest level of cultivation for wheat, barley and peas.

The data for the aspiration levels of the goals and their respective tolerance limits are presented in Table 1. The data description for productive resource utilization, production rate and market price are given in Table 2. The different types of crops and the decision variables representing them in the formulated model are given in Table 3.

Table 1 Description of the Goals

Description goals	Target (Aspiration levels)	Tolerance
Production (Metric ton)	396678	79335
Net income (Million Rials)	776479	77648
Required to operate (Man-day)	2136300	320445
Seed requirement (kg)	11499570	1724936
Water required (m^3)	544165000	81624750
Phosphate fertilizer requirement (kg)	111170	16675
Potash fertilizer requirement (kg)	12660	1819
Nitrogen fertilizer requirement (kg)	174940	26241
The use of herbicides (kg)	155280	23292
Fungicide use (kg)	33297	4994
Machine hours (hours)	950230	142535

Table 2 Descriptions Data

Production activity	P_C	N_C	L_C	S_c	W_C	FPH_c	FP_c	FN_c	H_{cg}	F_c	M_C
Wheat	1.8	0.766	17	140	5000	1	0	2	2	0.5	10
barley	2	0.53	17	120	5000	1	0	2	2	0.5	10
Lentil	0.7	2.725	20	70	4000	1	0	1	0	0	6
Rape	3.5	5.51	25	15	9500	2	2	4	2	0.25	15
Alfalfa	10	4.5	40	25	11000	2	1	1	0	0	16
Beans	3	9	30	120	5500	2	1	2	1	0.5	10
Plum	50	310.7	120	3	8500	3	4	6	2	0.25	17
Cucumber	60	380.4	130	4	9500	3	3	6	2	0.25	17
Pea	0.8	2.38	20	100	5000	1	0	1	1	0	6

Note: P_C = Total production target of crop c (Metric ton / ha), N_C = Net profit (Million Rials/ ha), L_C = Labor requirement per unit area for crop c (Man-day / ha), Sc = Amount of seed requirement for crop c (kg / ha), W_C= Amount of water requirement for crop c (m^3 / ha), FPHc= Amount of phosphate fertilizer requirement for production (kg / ha), FPc= Amount of potash requirement for production (kg / ha), FNc= Amount of nitrogen fertilizer requirement for crops (kg / ha), H_{cg}= the amount of herbicide requirement for production (kg / ha), F_c= Amount of fungicide requirement for production (kg / ha), M_C= Machine hours per unit area for the crop c (hours / ha).

Table 3 Variables of the model

Membership degree for the purpose of profit	Wheat
Membership degree for purpose of labor	barley
Membership degree for the purpose of seed	Lentil
Membership degree for the use of water	Rape
Membership degree for the use of phosphate fertilizer	Alfalfa
Membership degree for the purpose of Potash	Beans
Membership degree for the use of nitrogen fertilizer	Tomatoes
Membership degree for the use of herbicides	Cucumber
Membership degree for the use of fungicides	Pea
Membership degree for the use of Machines	Membership degree for the purpose of producing

3 Results

The model is formulated using the above data and is performed using Excel-Solver software which consists of six different weights corresponding to the fuzzy goals. The values of weights for the fuzzy goals are presented in Table 4.

Table 4 Descriptions weights of the fuzzy goals

Description goals	weights for the fuzzy goals					
	w_1 (Equal weights)	w_2	w_3	w_4	w_5	w_6
Production (Metric ton)	0.091	0.100	0.200	0. 190	0.200	0.100
Net profit (Million Rials)	0.091	0.100	0.100	0. 180	0.100	0.200
Labor requirement (Man-day)	0.091	0.200	0.100	0. 170	0.190	0.180
Seed requirement (kg)	0.091	0.075	0.080	0.050	0.100	0.020
Water requirement (m³)	0.091	0.075	0.090	0.040	0.020	0.070
Phosphate fertilizer requirement (kg)	0.091	0.075	0.070	0.060	0.030	0.080
Potash fertilizer requirement (kg)	0.091	0.075	0.060	0. 110	0.040	0.190
Nitrogen fertilizer requirement (kg)	0.091	0.075	0.190	0.020	0.050	0.060
The use of herbicides (kg)	0.091	0.075	0.040	0.010	0.060	0.050
Fungicide use (kg)	0.091	0.075	0.050	0.080	0.090	0.040
Machine hours (hours)	0.091	0.075	0.020	0.090	0.120	0.010

Goal achievement values and land allocations corresponding to six different weight structures are presented in Table 5. In the case of identical weight (w_1) and the weights w_2, w_3, and w_4 results indicate that there is no tolerances for profit, labor, seed, fertilizer, phosphate, nitrogen fertilizer, herbicides, fungicides and machine utilization because they are achieved completely. But for production, water requirement and potash fertilizer requirement goals, the required tolerances are 1, 0.0037 and 0.8195. Similarly, for the weight structure w_6 net profit, labor, seed, phosphate and nitrogen fertilizer requirement goals are achieved completely and tolerance values for water, potassium, herbicides, fungicides and machine utilization goals are 0.0389, 0.3218, 0.0087, 0.0283 and 0.0408 respectively. Furthermore, the weight of the structure w_5 net profit, labor, seed, phosphate and nitrogen fertilizer, herbicides, fungicides and machine utilization goals are fully achieved and tolerance values for production, water and potassium fertilizer requirement goals are 0.953, 0.0085 and 0.8904 respectively.

In six different weight structures, four crops, namely wheat, canola, bean, and tomato were grown with the same allocated area each. For example, in all different weight structures, the area under wheat cultivated marginally to 46000 ha.

Table 5 Membership grades and the allocation of land

Variables	Land Allocation					
	w_1	w_2	w_3	w_4	w_5	w_6
λ_1^-	0.00	0.00	0.00	0.00	0.05	0.00
λ_2^-	1.00	1.00	1.00	1.00	1.00	1.00
λ_3^-	1.00	1.00	1.00	1.00	1.00	1.00
λ_4^+	1.00	1.00	1.00	1.00	1.00	1.00
λ_5^+	1.00	1.00	1.00	1.00	0.99	0.96
λ_6^+	1.00	1.00	1.00	1.00	1.00	1.00
λ_7^+	0.18	0.18	0.18	0.18	0.11	0.68

Variables	Land Allocation					
	w_1	w_2	w_3	w_4	w_5	w_6
λ_8^+	1.00	1.00	1.00	1.00	1.00	1.00
λ_9^+	1.00	1.00	1.00	1.00	1.00	0.99
λ_{10}^+	1.00	1.00	1.00	1.00	1.00	0.97
λ_{11}^+	1.00	1.00	1.00	1.00	1.00	0.96
x_1	46000.00	46000.00	46000.00	46000.00	46000.00	46000.00
x_2	14000.00	14000.00	14000.00	14000.00	14000.00	19500.00
x_3	4269.35	4269.35	4269.35	4269.35	4000.00	4000.00
x_4	70.00	70.00	70.00	70.00	70.00	70.00
x_5	8481.44	8481.44	8481.44	8481.44	8614.95	7470.20
x_6	500.00	500.00	500.00	500.00	500.00	500.00
x_7	110.00	110.00	110.00	110.00	110.00	110.00
x_8	1551.58	1551.58	1551.58	1551.58	1551.93	1573.61
x_9	23000.00	23000.00	23000.00	23000.00	23000.00	20473.62

Land allocations values for each crop corresponding to six different weight structures are presented in fig 1. The graph clearly shows that, in all weight structures, the crops of barley, wheat and lentil have the most allocation of land.

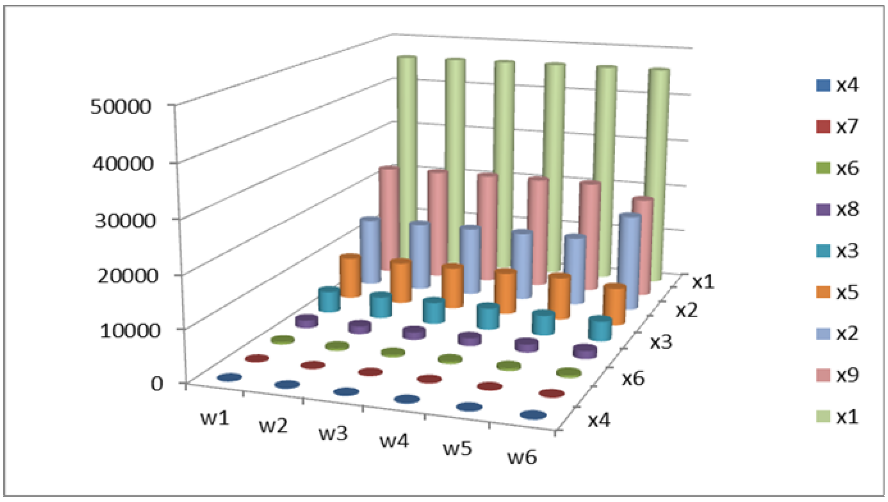

fig 1 Land allocations values for each crop in different weight structures of the fuzzy goals

4 Discussion and conclusion

The purpose of this study is to provide a FGP model for optimal allocation model for various agricultural crops. The results of our study might be a useful analytical tool for agricultural managements, who are using LP and GP techniques for recommendations to the farmer on optimal allocation for different crops in the planning process. This study shows that the FGP approach is a better technique over a single objective criterion when multiple conflicting objectives are involved. This developed model provides the best possible solution subject to the model constraints.

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