A FUZZY ENVIRONMENT STRATEGY FOR OPTIMAL AGRICULTURAL LAND ALLOCATION IN KRISHNA DELTA

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Abstract— In India, Krishna delta is termed as a Rice bowl for supply of food grains in the country. In this paper, the data relating to the land and the different crops raised in the kharif and rabi seasons and the availability of water are considered and fuzzy logic, Genetic Algorithm is applied through different strategies and finally the optimistic land allocation for cultivation is proposed.

Keywords— Fuzzy Logic; Competitive Strategy; Compensation Strategy; Preferential Strategy; Genetic Algorithm;

I. INTRODUCTION

Development of agricultural strategies is important for optimal land allocation in agriculture planning. Single and multi-objective optimization models have been developed for four agricultural strategies. Societal, economic and environmental strategies are developed by considering maximization of production, maximization of profit and minimization of fertilizer consumption objectives respectively. Several authors applied FGP in agriculture planning in multi criteria Slowinski (1986) used FGP technique for a farm planning problem. Sinha et al. (1988), Pal and Moitra (2003) proposed FGP for agriculture planning problems. Biswas and Pal (2005) applied FGP to a land use planning problem in an agricultural system. Dinesh K Sharma et al. (2007) used a tolerance based Fuzzy Goal Programming technique. Bijaya Krushna Mangaraj and Deepak Kumar Das (2008) have applied an Interactive Fuzzy Multi-Objective Programming in Land Re-Organizational Planning for Sustainable Rural Development.

Mostefa et al. (2009) presented an application of a fuzzy goal programming approach with different importance and priorities (FGPIP) for the state-run enterprise of iron manufacturer's non-metallic and useful substances. In initial studies, researchers simply transformed multi-objective decision making problems into equivalent LP problems by using max-min operators and compensation operators. Most of the land allocation models are developed ignoring the vagueness in the objectives. However, in real world, optimal land allocation is effected by the objectives which are vague in nature and creates uncertainty in the formulation of the models. Goal Programming (GP), Lexicographic Programming, weighted additive method, etc. are some of the techniques to solve multi-objective problems. But these approaches do not consider the vagueness in objectives or constraints. At this situation, a suitable way to model this abstraction is to use *fuzzy sets.* Fuzzy sets are useful in agricultural planning decisions involving multiple objectives which are indistinguishable in nature. However, in real world, optimal land allocation is effected by the objectives which are indistinct in nature and creates uncertainty in the formulation of the models. it is observed that there is limited research in developing the agricultural strategies basing on the objectives. Hence in this paper, three strategies namely; competitive, compensation and preferential strategies are developed in fuzzy environment by simultaneous consideration of production, profit and fertiizer consumption as objectives. The models developed for the three strategies are presented with the case study considering data in Krishna district. Parametric GA is implemented to solve the models under four constraints.

FUZZY GOAL PROGRAMMING

The complexity of a system increases, the ability to make precise and yet significant statements about its behaviour diminishes until a threshold is reached, beyond which precision and significance become almost mutually exclusive characteristics. The vagueness concerning the description of the semantic meaning of the events, phenomena or statements themselves is called *fuzziness*. The first publication in *fuzzy set theory* by Zadeh (1965) show the intention of the author to generalize the classical notion of a set and a proposition to accommodate fuzziness in sense was described. As its name suggests, *fuzzy logic* is the logic underlying modes of reasoning which are approximate rather than exact. The importance of *fuzzy logic* derives from the fact that most modes of human reasoning and especially common-sense reasoning are approximate in nature. In fuzzy logic, exact reasoning is viewed as a limiting case of approximate reasoning and everything is a matter of degree.

Decision Making in Fuzzy Environment

The basic problem in decision making is how to choose a course of action when multiple decision criteria need to be taken into account. There is no optimal solution in which all the objectives are simultaneously maximized. The objectives are frequently incompatible and a decision maker must find a compromise solution. Moreover, in most of the real world MODM problems, goals and/or constraints which constitute the environment of the decision process are usually not precise. Fuzzy mathematical programming can be regarded as an example of such a method. It can model problems which can be described by either crisp or fuzzy relations and it can solve multi-objective models with reasonable effort.

II. MODEL FORMULATION FOR COMPENSATION STRATEGY

For the aggregation of multiple objectives for considering the risk Mathematical model is formulated by using Werner's compensation (μ_{and}) operator in fuzzy environment as shown below.

$$\text{Maximize } \mu_{and} = \lambda + (1-\gamma)\,(\lambda_1 + \lambda_2 + \ldots\ldots + \lambda_i) / I$$
$$\text{Subject to} \quad \mu\,[\,Z_i\,(x)\,] \geq \lambda + \lambda_i$$
$$\lambda + \lambda_i \leq 1$$

Competitive Strategy:

In multi-objective decision making problem, Zadeh's minimum operator approach can be considered as competitive strategy.

Model formulation for Competitive Strategy:

Mathematical model is formulated by using Zadeh's minimum operator in fuzzy environment as shown below.

$$\text{Maximize } \lambda$$
$$\text{Subject to} \quad \lambda \leq \mu\,[\,Z_i\,(x)\,] \qquad i = 1,2,\ldots\ldots I$$
$$\lambda \geq 0$$
$$\lambda \leq 1$$

Where $\lambda = \text{Min}\ (\ \mu\ [\ Z_i\,(x)\ ]\ )$ $\mu\ [\ Z_i\ (x)\ ]$ is the linear membership function of the goals and also subject to the constraints from equation

Compensation Strategy:

Sometimes, the decision-making problems involve multiple objectives which are compensatory in nature. Several operators have been proposed attitude or compensatory behaviour of the decision maker. Compensation operator is one among them.

Hence, the model formulated by compensation operator ensures the compensation

$$\lambda\ \forall\ \lambda_i\ \in\ [\,0,1\,]\,,\ i = 1,2,\ldots\ldots I$$
$$\gamma\ \in\ [\,0,1\,]$$

and also subject to the constraints from equations

Preferential Strategy:

In general, the environment that governs the land allocation is highly influenced by the multiple objectives, which are vague in nature creating uncertainty in the formulation of the model. Further, the decision maker can assign weights to the objectives, which is very common in multi objective decision-making problems. Hence, the objectives may be assumed as fuzzy goals with a weight structure. The weights of the various objectives are interpreted so as to represents the relative preferences of the decision maker. In this context, the weighted additive approach can be considered as preferential strategy.

Model formulation for Preferential Strategy:

Mathematical model is formulated by assigning weights to the membership functions of objectives in fuzzy environment by weighted additive approach as shown below.

Maximize $Z = \sum W_i * \lambda_i$

Subject to $\lambda_i = \mu\,[\,Zi\,(x)\,]$ $i = 1,2,\ldots\ldots\ldots\ldots\ldots I$

and also subject to the constraints from equations 3.2 to 3.6 The assigned weights may be obtained through fuzzy prioritization method (Mikhailov, 2003).

Fuzzy prioritization method to calculate the relative weights of objectives:

The solution procedure of the proposed method is based on the maximum decision rule, known from the game theory. Zimmermann (1978) uses the same decision rule for fuzzy linear problems with soft constrains and shows that if the membership functions representing the soft constraints are linear, the maximization problem can be transformed into the following prioritization problem.

Maximize λ

Subject to $\lambda \le \mu_{ij}(w)$ $i = 1, 2, \ldots, n-1,\ j = 2, 3, \ldots n,\ j > i,$

$$\sum_{j=1}^{n} w_l = 1,\ w_1 > 0,\ l = 1, 2, \ldots, n.$$

$\mu_{ij}(w)$ = Membership function of weight ratio

$\lambda = \mathrm{Max}\,(\mathrm{Min}\,(\mu_{ij}(w)));\ \mu_{ij}(w) = \mu_{ij}(w_i/w_j)$

$$\mu_{ij}\left(\frac{w_i}{w_j}\right) = \frac{\left(w_i/w_j - l_{ij}\right)}{\left(m_{ij} - l_{ij}\right)} \quad \text{if } w_i/w_j <= m_{ij}$$

$$\mu_{ij}\left(\frac{w_i}{w_j}\right) = \frac{\left(u_{ij} - w_i/w_j\right)}{\left(u_{ij} - m_{ij}\right)} \quad \text{if } w_i/w_j >= m_{ij}$$

The optimal solution to the above problem (λ^*, w^*) might be obtained by employing some appropriate method for non-linear optimization. The optimal value λ^*, if it is positive, indicates that all solution ratios completely satisfy the fuzzy judgment, i.e. $l_{ij} \le \frac{w_i^*}{w_j^*} \le u_{ij}$, which means that the initial set of fuzzy judgments is rather consistent. A negative value of λ^* shows that the solution is inconsistent.

III. CASE STUDY

The mathematical models formulated for the competitive, compensation and preferential strategies are presented with a case study considering the agricultural data of Krishna Dist., Extreme solutions of the objectives are obtained by optimizing individual objectives subjected to the given constraints by using Genetic Algorithm approach. These solutions are useful in setting up the aspiration levels. The solutions are shown in table 1.

Table 1: Extreme solutions obtained from single objective optimization

Objectives	Production (quintals)	Profit (Rupees)	Fertilizer consumption (kg)
Max Production (Z_1)	2,35,32,072	149,22,16,509	3,29,18,096
Max Profit (Z_2)	2,35,32,161	149,34,27,936	3,29,20,473
Min Fertilizer consumption (Z_3)	1,42,83,859	91,11,55,279	1,85,63,650

From the extreme solutions, higher and lower aspiration levels obtained for the objectives are shown below.

Z_{1min} =1,42,83,859; Z_{1max} = 2,35,32,161, Z_{2min} = 91,11,55,279; Z_{2max} = 149,34,27,936, Z_{3min} = 1,85,63,650; Z_{3max} = 3,29,20,473

3.1.2 Formulation of Membership Functions

Membership functions of fuzzy objectives are defined from the extreme solutions and are shown below.

i) Membership function of Production

$$\mu_{Z_1} = \begin{cases} 0 & \text{if } Z_1 \le 14283859 \\ \dfrac{Z_1 - 14283859}{23532161 - 14283859} & \text{if } 14283859 < Z_1 < 23532161 \\ 1 & \text{if } Z_1 \ge 23532161 \end{cases}$$

ii) Membership function of Profit

$$\mu_{Z_2} = \begin{cases} 0 & \text{if } Z_2 \le 911155279 \\ \dfrac{Z_2 - 911155279}{1493427936 - 911155279} & \text{if } 911155279 < Z_2 < 1493427936 \\ 1 & \text{if } Z_2 \ge 1493427936 \end{cases}$$

iii) Membership function of Fertilizer consumption

$$\mu_{Z_3} = \begin{cases} 0 & \text{if } Z_3 \ge 32920473 \\ \dfrac{32920473 - Z_3}{32920473 - 18563650} & \text{if } 18563650 < Z_3 < 32920473 \\ 1 & \text{if } Z_3 \le 18563650 \end{cases}$$

3.1.3 Model formulation for competitive Strategy

Maximize λ

Subjected to $Z_1 - 9248302\,\lambda - 14283859 \ge 0$

$Z_2 - 582272657\,\lambda - 911155279 \ge 0$

$- Z_3 - 14356829\,\lambda + 32920473 \ge 0$ and also subject to the constraints given in equations

Model Formulation for Compensation Strategy

$$\text{Maximize } \mu_D(x) = \lambda + \frac{1}{3}(1-\gamma)(\lambda_1 + \lambda_2 + \lambda_3)$$

Subjected to $Z_1 - 9248302\,(\lambda + \lambda_1) - 14283859 \ge 0$

$Z_2 - 582272657\,(\lambda + \lambda_2) - 911155279 \ge 0$

$Z_3 - 14356829\,(\lambda + \lambda_3) + 32920473 \ge 0$

and also subject to the constraints given in equations 3.11 to 3.18

3.1.4 Model formulation for Preferential Strategy:

A single objective function is formulated by assigning relative weights of the objectives determined through fuzzy prioritization approach as discussed below.

Parametric Study

Parametric study is carried out for the competitive strategy as presented below by varying different GA parameters; crossover probability (Pc), mutation probability (Pm), population size (Ps) and number of generations (Gn) to obtain the best set of GA parameters. Initially, the crossover probability is varied from 0.75 to 0.95 in steps of 0.01, keeping the other parameters constant as Pm = 0.01, Ps = 30 and Gn = 100. The variation of the fitness value and crossover probability is shown in figure 1. It indicates that the maximum value of fitness is obtained at crossover probability 0.88.

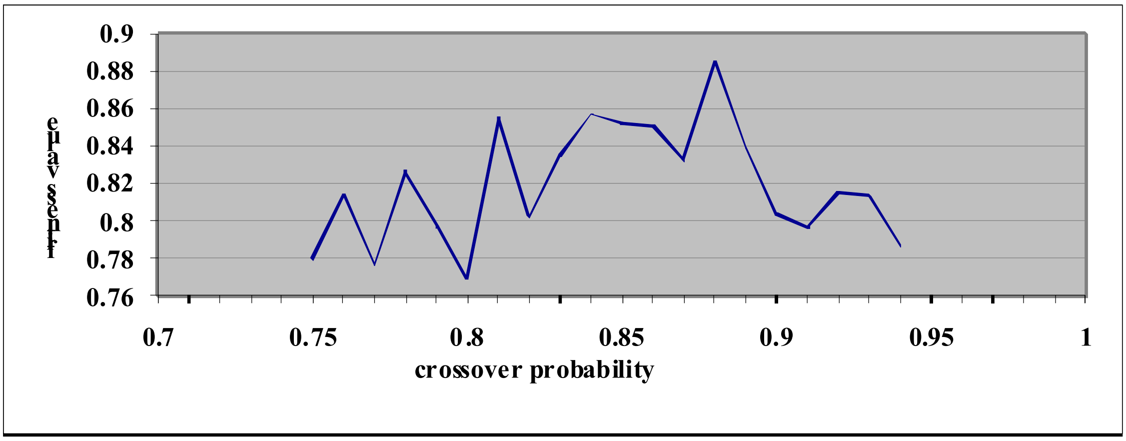

Figure 1: Crossover probability and fitness value

Similarly, mutation probability varies from 0.001 to 0.02 in steps of 0.001, keeping the other parameters constant to the values of Pc= 0.88, Ps=30 and Gn=100. The sensitivity of mutation probability on fitness value is shown in figure 2. It is observed that the maximum fitness value is obtained at mutation probability 0.01.

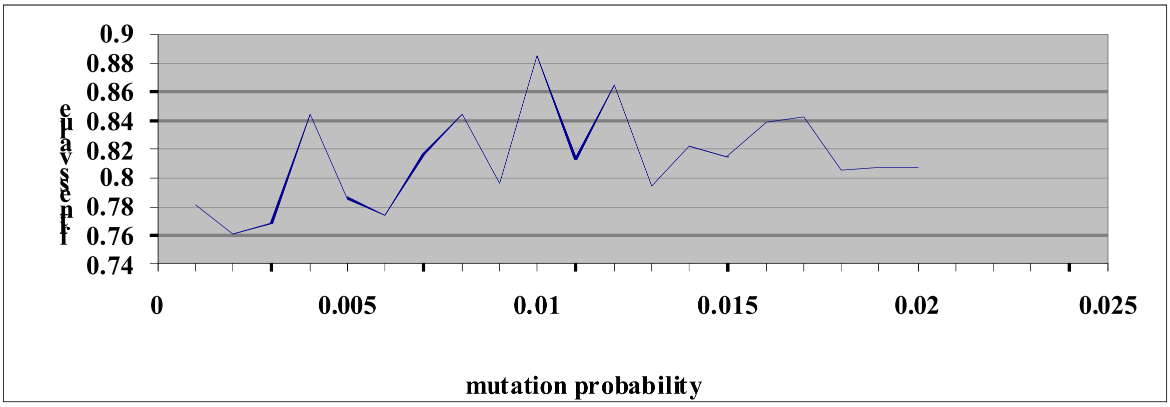

Figure 2: Mutation probability and fitness value

Now by keeping the parameters Pc=0.88, Pm=0.01, Gn=100 the other parameter population size is varied from 4 to 36 in steps of 4. The sensitivity of the population size on fitness value is shown in figure 3. It is observed from the figure the population size is 30 for the maximum fitness value.

Figure 3: Population size and fitness value

Finally the numbers of generations are varied from 10 to 150 in steps of 10, keeping the other parameters constant as Pc=0.88, Pm=0.01 and Ps=30. The sensitivity of the number of generations on fitness value is shown in figure 4. From the figure it is observed that the optimum number of generations is 130.

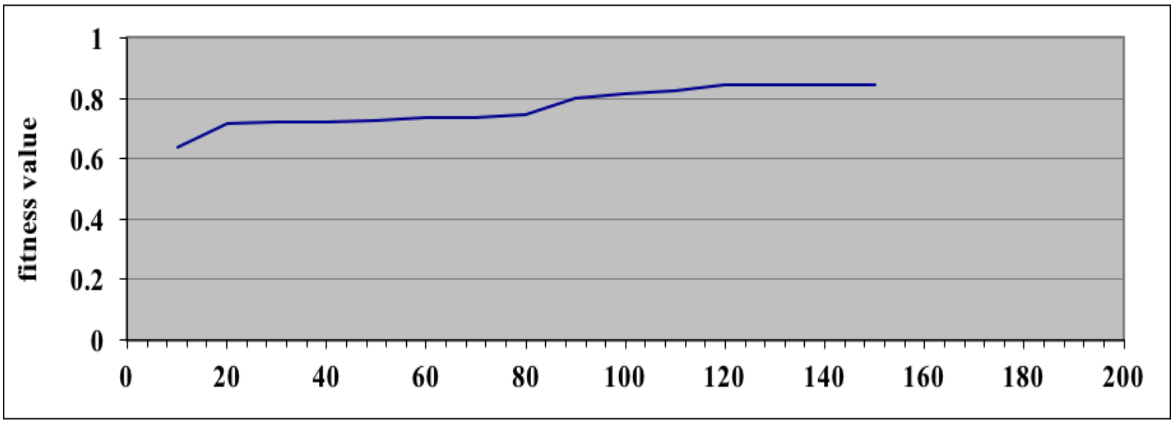

Figure 4. Generations

3.1.5 Generations and fitness value

Thus, the best GA parameters obtained are Pc=0.88, Pm=0.01, Ps=30, Gn=130. Similar procedure is adopted for the other two strategies and the best set of GA parameter values is obtained. The models presented with a case study are solved through real parameter GA by using the above best GA parameters.

IV.RESULTS AND DISCUSSION

The optimal land allocation results obtained for eight major crops in two seasons under competitive, compensation and preferential strategies are presented in table 2.

Table 2: Optimal land allocation values in hectares for 8 major crops

S.No	Crops	Decision variables	Competitive strategy	Compensation Strategy	Preferential strategy
1.	Paddy	H_{111} H_{112}	53445.00 2649.33	82170.28 3948.28	90639.29 3930.61
2.	Black Gram	H_{211} H_{212} H_{222}	3534.03 2835.38 2781.79	2260.50 2761.29 2618.56	3628.25 2747.11 2938.55
3.	Green Gram	H_{311} H_{312} H_{322}	1851.50 3964.49 3589.89	1577.70 2786.26 2580.23	1956.19 3937.63 3244.58
4.	Ragi	H_{411} H_{412}	25847.50 927.01	22525.90 586.09	28438.50 978.57
5.	Maize	H_{511} H_{512} H_{521}	6968.72 1769.83 6582.62	6834.33 1456.56 6317.41	6885.16 1975.08 6509.53
6.	Ground nut	H_{611} H_{612}	5278.27 1980.96	4029.17 865.59	5458.00 1709.62
7.	Chillies	H_{711} H_{712}	935.20 2742.91	888.91 534.11	989.16 1897.51
8.	Sugarcane	H_{811}	48021.37	41504.37	49347.86
Total land allocation in hectares			175705.8	186245.54	220211.2

The results exhibit that the total land allocated for eight major crops in two seasons for two varieties with competitive, compensation, and preferential strategies are 45.66%, 48.53% and 56.39% of land available respectively. It shows that there is an improvement of land allocation for majority crops in preferential strategy compared to the other two strategies. The results also show that there are notable changes occurred in the land allocations for various crops in different strategies.

In case of competitive strategy, it is observed that 80% of land allocation contributed by paddy, sugar cane, ragi, maize crops in kharif season and maize in rabi season. Further in this strategy 81% of the profit is contributed by paddy, sugarcane, ragi, ground nut in kharif season and maize in rabi season. Fertilizer consumption contributed by paddy, sugar cane, ragi and maize crops in kharif season is 80%.

From the results, it is observed that in compensation strategy, 82.1% of land allocation and 80% of profit is contributed by paddy, sugar cane, ragi and maize crops in kharif season. Fertilizer consumption contributed by paddy, sugar cane and ragi crops in kharif season is 80%.

Results obtained with preferential strategy indicate that 81% of land allocation is due to paddy, sugar cane, ragi and maize crops in kharif season. Paddy, sugar cane, ragi, maize in kharif season and maize in rabi season contributes 81% of profit in this strategy. Fertilizer consumption is contributed by paddy, sugar cane, ragi and maize in kharif season is 83%. Table 3 compares the objective values of profit, production and fertilizer consumption for three strategies and shows the attainment values of objectives.

Table 3: Level of attainment of objectives

S.No	Objectives	Competitive strategy	Compensation strategy	Preferential strategy
1	Profit (Rupees)	1316321213 (92.23%)	1214141100 (85.07%)	1427154652 (100%)
2	Production (Quintals)	22261122 (96.26%)	19571778 (84.63%)	23125408 (100%)
3	Fertilizer Consumption (Kg)	25867892 (100%)	27166982 (95.22%)	31424708 (82.32%)

Note: Figures within the parenthesis indicate the Percentage of attainment to its maximum or minimum value as of the case of the objective.

Comparison of land allocation for eight major crops among three strategies is shown in the figure 5.

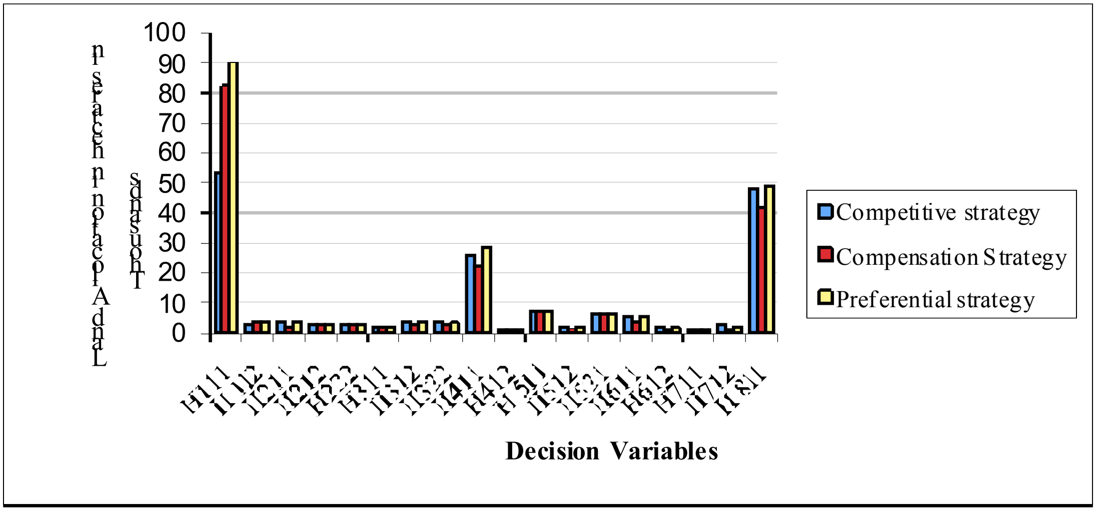

Figure 5: Land allocation for eight major crops

From the figure 6, it is observed that there is marked difference of land allocation in preferential strategy for the crops - Paddy (H_{111}), Ragi (H_{411}) and Sugarcane (H_{811}) when compared with the other strategies.

Level of achievement of objectives under different strategies is shown in figure 6.

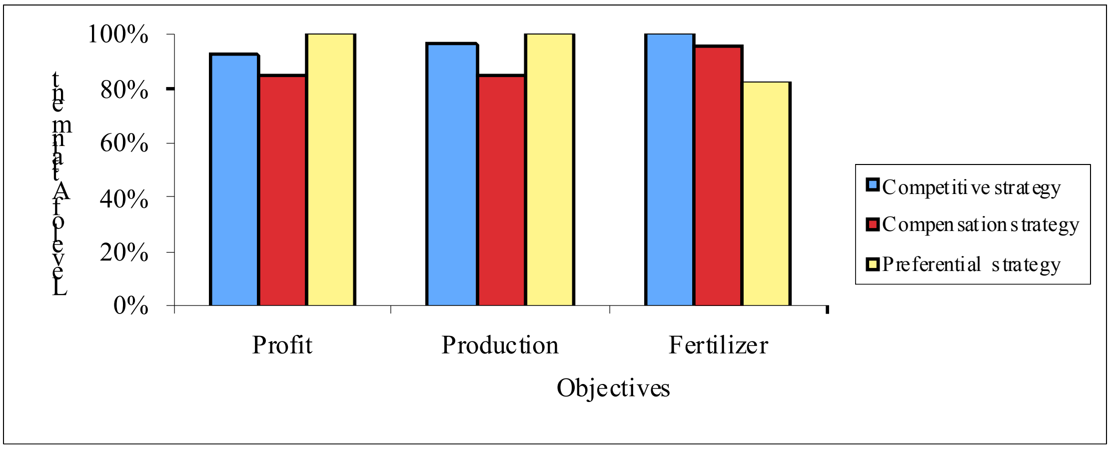

Figure 6: Level of achievement of Objectives

From the figure 6, it is observed that there is variation in level of achievement of the objectives with competitive strategy when compared to the other two strategies. It is also observed that production and profit are maximum with preferential strategy and fertilizer consumption is minimum with competitive strategy.

V. CONCLUDING REMARKS

In this paper, three strategies are developed for optimal land allocation by considering production, profit and fertilizer consumption objectives in fuzzy environment. The multiple objectives are assumed as fuzzy goals and are aggregated through minimum operator, compensation operator and fuzzy weighted additive approaches to develop competitive, compensation and preferential strategies. Models proposed in this paper are solved through real parameter GA for optimal solution by conducting parametric study. The results show that there is an improvement of land allocation for majority crops in preferential strategy compared to the competitive and compensation strategies. It is observed that basing on the level of attainment of the objectives; preferential strategy competes with the other two strategies in attaining the maximum profit and production. In case of fertilizer consumption objective, competitive strategy competes with the compensation and preferential strategy. These models may be further enriched by considering circular economy in the formulation of a model to reduce the fertilizer consumption for the benefit of environment and also to reduce the cash exposure towards cultivation of crops.

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