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DETERMINATION OF OPTIMAL LAND ALLOCATION FOR MAJOR CROPS USING TEACHING-LEARNING BASED OPTIMIZATION TECHNIQUE – A CASE STUDY OF VISAKHAPATNAM DIST. IN ANDHRA PRADESH

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Abstract
Agriculture is the main stray of nearly 70% of the households in our country. It is focal point of rural life for centuries, In India, the rural economy is dependent on agriculture. The present study deals with how to optimally allocate land to eight major crops to improve production, profits to farmers and to minimize fertilizer consumption to reduce pollution in Visakhapatnam district of Andhra Pradesh. The study was made developing four strategies like Social Strategy (increase production of all food crops), Economical Strategy (increase income of farmers), Environmental Strategy (minimizing the fertilizer consumption) and Preferential Strategy (giving relative weight to each strategy). For the present study TLBO (Teaching-learning based optimization) technique is used. Teaching-learning based optimization optimizes the considered objectives and final solution is relative land allocation for different major crops in two seasons of Rabi and Khariff.

Keywords: Optimal Land Allocation, Major Crops, Strategies, TLBO.

1. INTRODUCTION

Agriculture has been feeding entire world's population. Agriculture is the main stray of nearly 70% of the households in our country. The rural economy is almost exclusively determined by agriculture. The majority of our country's population depends on agriculture for their livelihood. According to census 2011, around 69% is in rural areas and depend on agriculture. At the time of First Five Year Plain in 1950-51, agriculture sector has contributed more than half of the output of Indian economy. During these seven decades, the share of agriculture has declined to 15 percent. The performance of agriculture sector is the main concern to government.

The agriculture and allied sector has contributed approximately 22.39% of India's GDP (2004-05 prices in 2001-02. And it has gradually declined to 13.94 % in 2013-14. More than one lakh small farmers has given up the farming since 1992. The area under cultivation is also declining gradually. The Government of India and various state governments have taken up measures to improve agriculture and encourage farming and to bring more land into farming and increase production. The Government of India has set up National Commission on Farmers in February, 2004 under the chairmanship of famous agricultural scientist Dr. M S Swaminathan with declaration 'Serving farmers and saving farming'. The National Policy on Agriculture has aimed only over 4 per cent annual growth rate during the next two decades.

The study was undertaken in Vishakhapatnam district of Andhra Pradesh. Visakhapatnam District is one of the North Eastern Coastal districts of A.P. and it lies between 170 - 15' and 180-32' Northern latitude and 180 - 54' and 830 - 30' in Eastern longitude. It is bounded on the North partly by the Orissa State and partly by Vizianagaram District, on the South by East Godavari District, on the West by Orissa State and on the East by Bay of Bengal. Visakhapatnam has a tropical wet and dry/ savanna climate with a pronounced dry season in the low-sun months, no cold season, wet season is in the high-sun months. The mean temperature is 28.4 degrees Celsius.

Rice is a staple food of the people and Paddy is therefore the principal food crop of the district followed by Ragi, black gram and green gram and Cash Crops such as Sugarcane, Groundnut and Chillies are important. Since there is no Major Irrigation system, only about 36% of the cropped area is irrigated under the Ayacut of the Medium Irrigation System and Minor Irrigation Tanks. The rest of the cultivated area is covered under dry crops depending upon the vagaries of the monsoon. The productivity of the crops is low. The crops which are grown during the monsoon (july-october) are called kharif crops. Seeds of these crops are sown in the beginning of the

monsoon. After maturation, these crops are harvested at the end of the monsoon season (oct-nov). Crops which are grown during winter season (October-march) are called Rabi crops. Seeds of these crops are sown in the beginning of the winter season. After maturation, they are harvested at the end of the winter season (april-may).
Since land is a limited resource, optimal allocation of land to principal crops is necessary to improve the production. The present work, ‘optimal land allocation to principal crops’, is taken with an objective to improve the production and profit levels in agriculture sector. Teaching-learning-based optimization (TLBO) algorithm is applied for this purpose. In pursuance of the said objective, a case study is done in the district of Visakhapatnam.

2.1 FOCUS OF THE PROBLEM
The productivity of our major agricultural and horticultural crops is very low in comparison to other countries. Our agriculture is still technology deficit. Yields per hectare of food grain, fruits and vegetables are far below the global averages. India’s population is expected to reach 1.5 billion by 2025, making food security most important social issue and food production has to be increased considerably. The productivity of our crops likes food grains, oilseeds, pulses, sugarcane etc., can be increased more than two times through optimal allocation of land, improving soil fertility, pest management, healthy seeds, crop lifesaving irrigation and post harvesting technology.

2.2. NEED FOR THE STUDY
Many studies in this area have shown how to increase agriculture production. By many researchers. But there is not a study to determine the optimum land allocation for major crops using TLBO (Teaching learning based optimization technique) in Visakhapatnam district of Andhra Pradesh. This study will help the farmers of Vissakhapatnam district to increase agriculture production, income, minimize the use of fertilizers and pesticides and to reduce environmental pollution.

2.3. SCOPE OF THE STUDY
The study has been conducted in the Visakhapatnam district of Andhra Pradesh for optimal land allocation for major crops. It will help the farmers to bring more land in to agricultural production, maximize their income and profits, minimize the use of the fertilizers and reduce the environmental pollution.

3.NOMENCLATURE

L_1 - Total area of land (hectares) available under cultivation in kharif season

L_2 - Total area of land (hectares) available under cultivation in rabi season

MD - Number of man days available throughout the year

MH- Number of machine hours available throughout the year

$[A]_{cs}$- Area of land required for cultivating crop ‘c’, during season ‘s’

$[P]_{cs}$- Production per unit area of land (quintal/ha) cultivated for the crop ‘c’, during season‘s’

$[md]_{cs}$- Man days required per unit area of the land cultivated for the crop ‘c’, during season ‘s’

$[mh]_{cs}$- Machine hours required for tillage per unit area of land cultivated for the crop ‘c’, during season ‘s’

$[WA]_{s}$- Total amount of water (cm) available during season ‘s’

$[H]_{cs}$- Harvest price (Rs/quintal) of the crop ‘c’, during the season ‘s’

$[MSP]_{cs}$- Minimum support price (Rs) declared by the govt. for crop ‘c’, during season’s’

$[WC]_{cs}$- Amount of water consumed (cm) per hectare of land cultivated during season s' for the crop 'c'

$[N+P+K]_{cs}$- Nitrogen, Phosphorous and Potassium (kg/ha) requirement for crop 'c' during the Season 's'.

4. OBJECTIVES OF THE STUDY

The main objective of the study is to Optimal land allocation for major crops in Visakhapatnam district by using TLBO (Teaching learning based optimization)

4.1.1. Production

To meet the demand of the food stuff for the burgeoning population, annual production of all the crops must be maximized

$$Z_1 = \sum_{c=1}^{C}\sum_{s=1}^{S}[P]_{cs}[A]_{cs} \quad (4.1)$$

4.1.2. Profit

In order to rise the living conditions (economic conditions) of the farmers, net profit (income) of the farmers must be maximized

$$Z_2 = \sum_{c=1}^{C}\sum_{s=1}^{S}[P]_{cs}[A]_{cs}[MSP]_{cs} - \sum_{c=1}^{C}\sum_{s=1}^{S}[H]_{cs}[P]_{cs}[A]_{cs} \quad (4.2)$$

4.1.3. Fertilizer Consumption

The objective function concerns consumption of fertilizer. To reduce environmental pollution and cost of fertilizer, the fertilizer consumption must be minimized.

$$Z_3 = \sum_{c=1}^{C}\sum_{s=1}^{S}[A]_{cs}[N+P+K]_{cs} \quad (4.3)$$

4.3. RESEARCH DESIGN & METHODOLOGY

In order to optimally allocate the land to principal crops to boost production, profit and to minimize fertilizer consumption, Teaching-learning-based optimization (TLBO) methodology is developed. The following content deals with the procedure in formulating the problem and arriving to the optimum solution.

Visakhapatnam city is industrially developing, the rural areas continued to be backward. Four strategies are developed. First one is to increase production of all food crops, second strategy is to increase the income of farmers, third strategy is to minimize the fertilizer consumption and the last one is preferential strategy, where optimization is done by giving relative weight to each strategy.

Teaching-learning based optimization technique is used for present thesis. This optimization technique performs based on the dependency of the learners in a class on the quality of teacher in the class. The teacher raises the average performance of the class and shares the knowledge with the rest of the class. The individuals are free to perform on their own and excel after the knowledge is shared. Teaching-learning based optimization optimizes the considered objectives and final solution is relative land allocation for different major crops in two seasons.

4.5. CONSTRAINTS

4.1. Land Availability

Fertile land is scarce resource for agriculture. To effectively utilize, it must be used in both seasons. The total land allocated to crops should not be more than the available land in that season.

$$C_{1a} = \sum_{c=1}^{c}[A]_{c1} \leq L_1 \quad (4.4)$$

$$C_{1b} = \sum_{c=1}^{c}[A]_{c2} \leq L_2 \quad (4.5)$$

4.2. Labour Availability

Because of the limited availability of work force, the total man days obtained should not be more than the total available man days

$$C_2 = \sum_{c=1}^{C}\sum_{s=1}^{S}[md]_{cs}[A]_{cs} \leq MD \quad (4.6)$$

4.3. Machine Availability

It is necessary to utilize the agriculture machinery (tillage) for all seasons. Total machine hours used should not be more than the available machine hours

$$C_3 = \sum_{c=1}^{C}\sum_{s=1}^{S}[mh]_{cs}[A]_{cs} \leq MH \quad (4.7)$$

4.4. Water Availability

Effective utilization of water in all seasons is vital to increase the production level of each crop. Total water consumption in particular season should not be more than the available water in that season.

$$C_4: \sum_{c=1}^{C}\sum_{s=1}^{S}[wc]_{cs}[A]_{cs} \leq [WA]_s \quad (4.8)$$

4.6. MODEL FORMULATION

Four strategies are developed for the present work optimum land allocation. First one is to increase production of all food crops, second strategy is to increase the income of farmers, third strategy is to minimize the fertilizer consumption and the last one is preferential strategy, which is a weighted additive approach.

First strategy is societal strategy, second is economical strategy, third is environmental strategy and the final one is preferential strategy.

4.6.1. Societal Strategy

Increase in agriculture production must be accelerated to curtail the levels of food insecurity and to meet the demand of food stuff for the population. In this strategy, objective is to maximize the production of all food crops. Mathematical formulation of with societal strategy is

$$\text{Maximize production } (Z_1): \sum_{c=1}^{C}\sum_{s=1}^{S}[P]_{cs}[A]_{cs} \quad (4.9)$$

Subject to constraints given in equations from (4.4) to (4.8)

4.6.2. Economic Strategy

This strategy is developed to ameliorate the distress of farmers by increasing their income levels. Here the objective is to maximize the profit of farmers. Mathematical formulation of objective with economical strategy is

$$\text{Maximize profit } (Z_2): \sum_{c=1}^{C}\sum_{s=1}^{S}[P]_{cs}[A]_{cs}[MSP]_{cs} - \sum_{c=1}^{C}\sum_{s=1}^{S}[H]_{cs}[P]_{cs}[A]_{cs} \quad (4.10)$$

Subject to constraints given in equation from (4.4) to (4.8)

4.6.3. Environmental Strategy

The challenge relating to this, land area is to maintain its fertility status and protect against degradation due to soil erosion, and environmental pollution due to chemical problems. Use of chemical fertilizer is held responsible for soil degradation and environmental pollution. The reason for adverse impact of chemical fertilizer is because of excessive, indiscriminate and non-judicious use. To reduce the degradation of soil, environmental pollution and cost of fertilizer the fertilizer consumption must be minimized. The mathematical formulation of the objective with environmental strategy is shown below.

$$Z_3 = \sum_{c=1}^{C}\sum_{s=1}^{S}[A]_{cs}[N+P+K]_{cs} \quad (4.11)$$

Subject to constraints given in equations from (4.4) to (4.8)

In addition to above constraints, another constraint is added for this strategy to maintain at least present productivity.

According to FAO(Food and Agricultural organization) fertilizer and plant nutrition bulletin, fertilizer consumption should be atleast 50kg/ha for 17.45qtl/ha yield of paddy. Minimum fertilizer consumption should not be less than minimum fertilizer consumption per hectare times the total land available ie., 15265830kgs

$$\sum_{c=1}^{C}\sum_{s=1}^{S}[A]_{cs}[N+P+K]_{cs} \geq 15265830 \quad (4.12)$$

4.6.4. Preferential Strategy

This strategy is weighted additive approach. The weights of the objectives are interpreted so as to represent the relative preference of the decision maker. Weighted additive method transforms multi objectives into an aggregated scalar objective by multiplying each objective function by a weighing factor and summing up all contributors. The mathematical model formulation of the preferential strategy is

Maximize (Z_4): $w_1 Z_1 + w_1 Z_2 + w_3 Z_3$ (4.13)

Subject to constraints given in equations from (4.4) to (4.8)

Where w_1, w_2 and w_3 are weights given to the objectives Z_1, Z_2 and Z_3 respectively.

4.6.5. Eigen Vector Method to Determine Relative Weights

Saaty (1977) has suggested a numerical scale to be used in representing the judgment made in pair wise comparison of the criteria (objectives). This numerical scale shows various levels of relative importance of objectives. The numerical scale computes the principal Eigen vector of a positive matrix with reciprocal entries obtained by pair wise comparison of the criteria. The Eigen vector provides an estimate for the assumed underlying ratio scale, Saaty scheme to construct a ratio scale a'_{ij} by comparing the i^{th} objective with the j^{th} is one is as follows:

i) $a'_{ij}=1/a'_{ji}$

ii) If the i^{th} objective is more important than the j^{th}, then gets a'_{ij} assigned a number as shown in the following table.

Table - 4.1. Saaty scale

Interpretation	Intensity of Importance
i^{th} and j^{th} objectives are of equal importance	1
Weak importance of i^{th} objective over j^{th}	3
Strong importance of i^{th} objective over j^{th}	5
Demonstrated importance of i^{th} objective over j^{th}	7
Absolute importance of i^{th} objective over j^{th}	9
Intermediate values between two adjacent judgements	2,4,6,8

The above models are solved through Teaching-Learning-based optimization.

4.7. TLBO

The TLBO algorithm is a very new algorithm recently introduced in (R.V.Rao et al., 2011). This optimization technique performs based on the dependency of the learners in a class on the quality of teacher in the class. The teacher raises the average performance of the class and shares the knowledge with the rest of the class. The individuals are free to perform on their own and excel after the knowledge is shared.

4.7.1. Initialization

Initially, a matrix of *N* rows and *D* columns is initialized with randomly generated values within the search space. The value N represents the population size of the "class size" in this case. *D* represents the number of "subjects or courses offered", which is same as the dimensionality of the problem taken. The procedure being iterative is set to run for *G* number of generations. The *jth*parameter of the *ith*vector (learner) in the initial generation is assigned values randomly using the equation

$$X^1_{(i,j)} = X^{min}_j + rand_{(i,j)} \times \left(X^{max}_j - X^{min}_j\right)$$

Where $rand_{(i,j)}$represents a uniformly distributed random variable within the range (0,1). The parameters of the *ith*vector (or learner) for the generation *g* are given by

$$X^g_{(i)} = \left[X^g_{(i,1)}, X^g_{(i,2)}, \dots \dots X^g_{(i,j)} \dots \dots X^g_{(i,D)}\right]$$

The objective values at a given generation form a column vector

$$[Y_i^g] = \left[f\left(X_{(i)}^g\right)\right]$$

For all the equations used in the algorithm i=1,2,….N, j=1,2……D and g=1,2,….G. The random distribution followed by all the *rand* values is the uniform distribution.

4.7.2. Teacher Phase

The mean vector containing the mean of the learners in the class for each subject is computed. The mean vector M is given as

$$M^g = \begin{bmatrix} mean[x_{(1,1)}^g, \dots\dots x_{(i,1)}^g, \dots\dots x_{(N,1)}^g] \\ \dots \\ mean[x_{(1,j)}^g, \dots\dots x_{(i,j)}^g, \dots\dots x_{(N,j)}^g] \\ \dots \\ mean[x_{(1,D)}^g, \dots\dots x_{(i,D)}^g, \dots\dots x_{(N,D)}^g] \end{bmatrix}^T$$

Which effectively gives us

$$M^g = \left[m_1^g, m_2^g, \dots m_j^g \dots\dots m_D^g\right]$$

The best vector with the minimum objective function value is taken as the teacher ($X_{teacher}^g$) for that iteration. The algorithm proceeds by shifting the mean of the learners towards its teacher. A randomly weighted differential vector is formed from the current mean and the desired mean vectors and added to the existing population of learners to get a new set of improved learners.

$$X_{new(i)}^g = X_{(i)}^g + rand^g \times (X_{teacher}^g - T_F M^g)$$

Where T_F is a teaching factor which is randomly taken at each iteration to be either 1 or 2. The superior learners in the matrix *Xnew* replace the inferior learners in the matrix *X* using the non-dominated sorting algorithm.

4.7.3. Learner Phase

This phase consists of the interaction of learners with one another. The process of mutual interaction tends to increase the knowledge of the learner. Each learner interacts randomly with other learners and hence facilitates knowledge sharing. For a given learner, $X_{(i)}^g$ another learner $X_{(r)}^g$ is randomly selected ($i \neq r$). The i^{th} vector of the matrix *Xnew* in the learner phase is given as

$$X_{new(i)}^g = \begin{cases} X_{(i)}^g + rand_{(i)}^g \times \left(X_{(i)}^g - X_{(r)}^g\right) & if\left(Y_{(i)}^g > Y_{(r)}^g\right) \\ X_{(i)}^g + rand_{(i)}^g \times \left(X_{(r)}^g - X_{(i)}^g\right) & otherwise \end{cases}$$

4.7.4. Constraint Handling

For constraint handling Deb's heuristic method is used. Deb's method uses a tournament selection operator in which two solutions are selected and compared with each other. The following three heuristic rules are implemented on them for the selection:

- If one solution is feasible and the other infeasible, then the feasible solution is preferred.
- If both the solutions are feasible, then the solution having the better objective function value is preferred.
- If both the solutions are infeasible, then the solution having the least constraint violation is preferred.

4.7.5. Algorithm Termination

The algorithm is terminated after *G* iterations are completed.

5. CASE STUDY

In order to increase the production of crops and income levels of farmers the present case study, 'optimum land allocation', is done on Visakhapatnam district. According to climatic conditions, two seasons kharif and rabi are considered. Main crops grown during these seasons are paddy, black gram, green gram, ragi, maize, groundnut, chillies and sugarcane. Sugarcane is a perennial crop and occupies land in both the seasons. In model formulation, crops are numbered as c=1 for paddy, c=2 for black gram, c=3 for green gram, c=4 for ragi, c=5 for maize, c=6 for groundnut, c=7 for chillies and c=8 for sugarcane. Seasons are denoted as s=1 for kharif and s=2 for rabi.

The data of production of crops (quintal/hectare), minimum support price [MSP] (Rs/hectare) for each crop and their harvest price (Rs/hectare), machine hours (hours/hectare) required, man days required (days/hectare), land availability (hectares), water availability (cm) for all crops are obtained from statistical year book (2011) from Agro Economic Research Centre, Andhra university.

Table 5.1: Data of available resources

Land under cultivation in kharif season (hectares)	L_1	230068
Land under cultivation in rabi season (hectares)	L_2	68359
Man days (days)	MD	58300000
Machine hours (hours)	MH	15292800
Water during kharif season(cm)	$[WA]_1$	23656516
Water during rabi season(cm)	$[WA]_2$	15265830

Table 5.2: Data for the coefficients of objectives and constraints

coefficients	season	Paddy	Black gram	Green gram	Ragi	Maize	Groun-dnut	Chillies	Sugar--cane
Production (qtl/ha)	Kharif Rabi	17.44 12.92	6.60 5.34	2.49 3.51	1.62 14.62	16.04 91.16	11.16 22.41	33.16 34.32	335.28
Market Price (Rs/qtl)	Kharif Rabi	850 850	2520 2520	2520 2520	915 915	840 840	2100 2100	2200 2200	108
Harvest price(Rs/ha)	Kharif Rabi	8836 9975	6002 9574	5630 4859	2874 7487	7330 45386	16104 32338	63046 17552	35280
m/c hours (hrs/ha)	Kharif Rabi	4 6	0 0	0 0	4 4	4 4	6 6	4 4	8 8
Man days (days/ha)	Kharif Rabi	150 175	52 60	54 45	52 54	96 98	75 75	603 658	155
Fertilizer (kg/ha)	Kharif Rabi	135 135	100 100	100 100	100 100	180 180	110 110	160 160	200 200
Water (cm/ha)	Kharif Rabi	130 130	35 40	35 40	40 45	50 55	45 60	55 60	180

Objective functions and constraints are formulated as described in methodology and optimized using TLBO

6. RESULTS AND DISCUSSIONS

The optimum land allocation results obtained for eight crops in two seasons for four strategies are shown in table 6.1.

Table 6.1: Optimal Land allocation for 8 Major Crops in 2 Seasons for 4 Strategies

SL.NO	Crops	Decision variables	Societal strategy	Economical Strategy	Environmental Strategy	Preferential strategy
1	Paddy (hectares)	A_{11} A_{12}	84198.33 3978.01	59216.09 9093.27	55846.47 1195.60	56830.01 6127.23
2	Black gram (hectares)	A_{21} A_{22}	41.74 4.52	8992.50 815.26	2000.00 3951.82	14400.68 6172.42
3	Green gram (hectares)	A_{31} A_{32}	1999.99 3998.86	1993.14 3999.96	6350.82 6157.66	10579.09 8631.44

4	Ragi (hectares)	A_{41} A_{42}	1360.43 2.20	29999.24 5416.98	0.22 4867.88	44002.84 4422.21
5	Maize (hectares)	A_{51} A_{52}	6104.22 54.63	6999.99 7292.29	16619.28 2000.01	14975.67 14766.47
6	Groundnut (hectares)	A_{61} A_{62}	33141.19 12.20	15999.48 899.64	40885.50 740.66	14841.17 1740.49
7	Chillies (hectares)	A_{71} A_{72}	60570.62 12.11	28185.30 14006.56	0.05 9422.85	14996.43 2438.64
8	Sugarcane (hectares)	A_8	38159.40	28158.28	10000.03	24060.1
Total land allocation			223770.66	211068.00	153688.05	274115.71

The results exhibit that the total land utilization for eight major crops in two seasons with societal, economic, environmental and preferential strategies are 74.98%, 70.72%, 51.49% and 91.83% respectively. It also shows that there is a maximum land allocation of 274115.71 hectares by preferential strategy. Land allocation (153688.05 hectares) is minimum with environmental strategy.

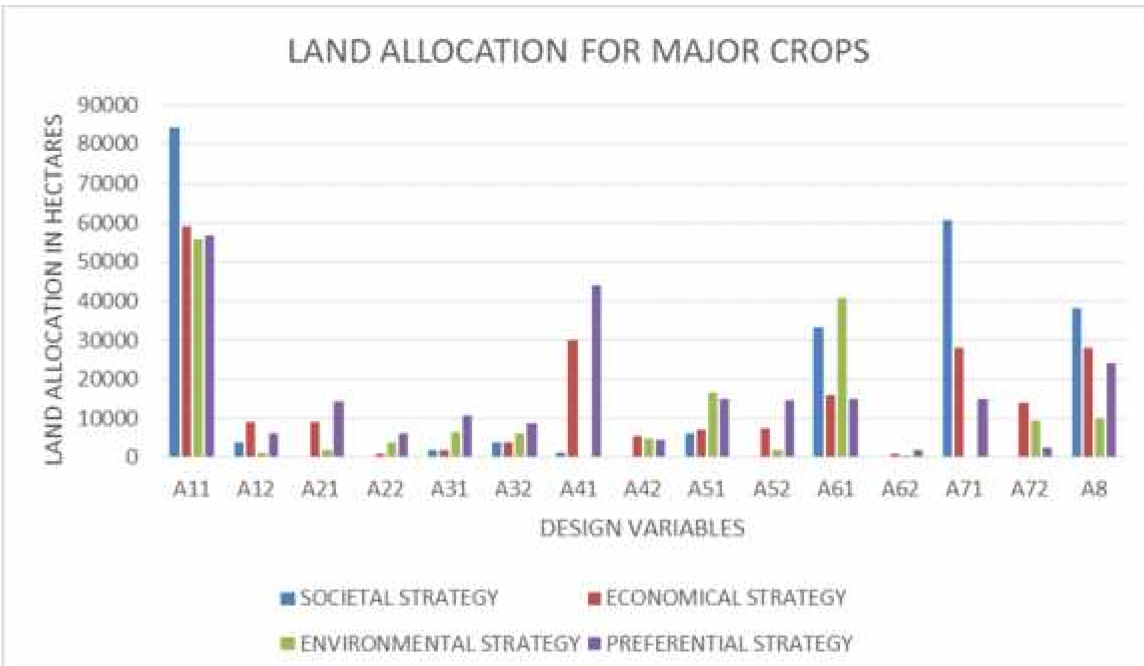

Fig.6.1. Optimum Land Allocation for 8 Major Crops

The attainment of various objectives in percentage are given in table 6.2 and are shown in fig.6.2

Table 6.2: Level of Achievement of Objectives Under Different Strategies

Objectives	Societal strategy	Economic strategy	Environmental strategy	Preferential strategy
Production (quintals)	$1.6818*10^7$ (71.31%)	$1.5881*10^7$ (67.34%)	$1.2436*10^7$ (52.73%)	$2.3583*10^7$ (100%)
Profit (rupees)	$1.440*10^9$ (92.14%)	$2.0079*10^9$ (100%)	$1.4792*10^9$ (73.66%)	$1.5628*10^9$ (77.83%)
Fertilizer consumption(kg)	$3.4725*10^7$ (54.22%)	$3.5157*10^7$ (53.55%)	$1.8830*10^7$ (100%)	$3.9125*10^7$ (48.12%)

Note: Figures within the parenthesis indicate the percentage of attainment of its maximum or minimum value as the case of the objectives.

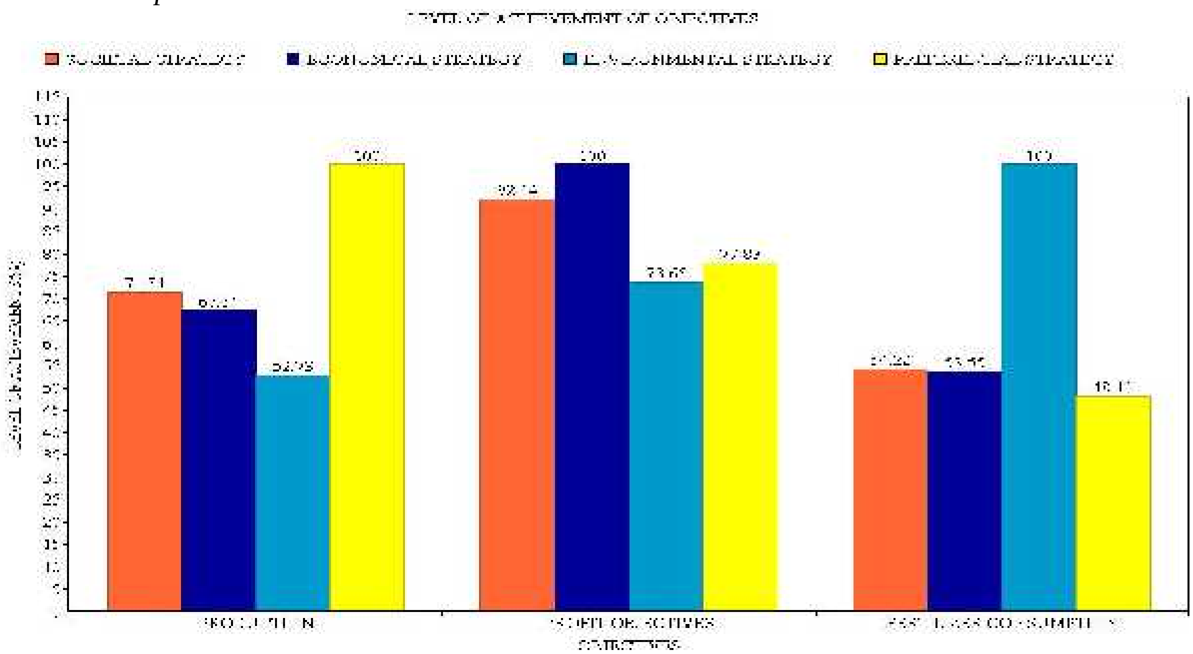

Fig 6.2. Level of achievement of objectives

From table 6.2 and figure 6.2 it is observed that production is maximum with preferential strategy, profit objectives is maximum with economic strategy and fertilizer consumption is minimum with environmental strategy.

7. CONCLUSION

In this study, an attempt is made to develop four agricultural strategies for optimal land allocation in crisp environment. Initially social, economic and environmental aspects are viewed separately and social, economic and environmental strategies are developed. Later preferential strategy is developed by considering three objectives simultaneously through weighted additive approach. These strategies have been developed under pressure to increase the profit by maximizing production and decrease environmental pollution by minimizing the fertilizer consumption of crops. The outcome of the research indicates that the proposed strategies yields improved solution in terms of land allocation, production and profit objectives. The results show that there is a maximum land allocation of 274115.71 hectares by preferential strategy. It is also observed that production is achieved maximum with preferential strategy, profit objective is maximum with economic strategy and fertilizer consumption objective is achieved with environmental strategy. The models developed in this chapter may be further enriched by considering vagueness in objectives to make them more realistic in agriculture sector.

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