Optimal Land Allocation in Krishna District without Circular Economy in Crisp Environment

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ABSTRACT: The agricultural sector's performance determines overall economic growth, trade expansion, and increased income-earning opportunities. Agriculture planning depends on several resources like availability of land, water, labor, machinery and capital. Land resources have great importance for supporting social and economic development. Due to the limited land resources, determining how to use land rationally and efficiently has been one of the key issues. Agricultural planning problems generally involve multiple goals such as maximizing production, profit, ecological benefit and minimizing expenditure, fertilizer consumption, environmental pollution, etc. These goals are conflicting in nature and it is not possible to maximize or minimize all goals simultaneously. In this article a fertile land in a particular district where the land is very fertile is considered and studied for optimal allocation.

Key words: Land Resources, Production, Profit, Crop Land, Expenditure

1. Introduction

In developing countries, the agricultural sector's performance determines overall economic growth, trade expansion, and increased income-earning opportunities. Implementing policies that encourage greater agricultural productivity, profitability and sound environmental management is very much needed. Agriculture planning depends on several resources like availability of land, water, labor, machinery and capital. Land resources have great importance for supporting social and economic development. Due to the limited land resources, determining how to use land rationally and efficiently has been one of the key issues and was paid increasing attention by researchers. The economic development has taken priority at the expense of land resources consumption, especially cropland. Optimizing the existing land use structure and using other resources in a sustainable way is essential to release the land stress on economy and society. Optimizing land use structure means to adjust the land use quantity andAgricultural planning problems generally involve multiple goals such as maximizing production, profit, ecological benefit and minimizing expenditure, fertilizer consumption, environmental pollution, etc. These goals are conflicting in nature and it is not possible to maximize or minimize all goals simultaneously. Several authors developed multiple objective optimization models spatial distribution rationally on the basis of the characteristics of land resources.

2. Literature:

Single objective optimization models may be implemented to obtain optimal land allocation under given constraints. Ahmad et al. (1990) used LP model for developing optimal farm plans for small farmers. Srinivasa Raju and Nagesh Kumar (2000) developed a LP irrigation planning model with the objective of maximization of net benefits. Singh et al., 2001, Ishtiaq Hassan et al., 2005, Mohmoud et al., 2009) adopted single objective optimization models for optimum cropping pattern. Debasis Ghosh et al. (1995) presented a case study for determination of optimal solution for a MCDM model in Agricultural Planning through goal programming approach. Kim and Weck (2006) used adaptive weighted sum method for multi objective optimization. Sayed (2007) applied parametric and multi objective optimization technique to study the cropping pattern. Sharma et al. (2008) presented a Lexicographic Goal Programming model for optimal land allocation problems in agricultural planning. Vivekanandan et al. (2009) applied Goal Programming approach for optimization of cropping pattern.

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The classical optimization approaches suggest converting the multi-objective problem to a single objective problem by emphasizing one parameter optimal solution at a time. It is in this paper we used widely the method for multi-objective optimization i.e weighted additive method. Weighted additive method provides a compromise solution in decision making perspective.

There are a number of traditional methods to solve the single and multi-objective mathematical models. But Genetic algorithms (GAs) are computerized search and optimization algorithms to solve the single or multi-objective problems. An important difference between genetic algorithms and most of the traditional optimization methods is that GA uses a population of points at one time in contrast to the single point approach by traditional methods.

There is limited research in considering the objectives basing on the agricultural strategies. Hence in thispaper, optimal land allocation models are developed basing on the four agricultural strategies by considering three objectives and four constraints in crisp environment. The models developed for four strategies are presented with a case study. Further, the solution approaches adopted for solving the optimization models for optimal land allocation in agriculture planning through GA is also limited. Real parametric GA is implemented to the case study to solve the models developed

Two important methods of GA are Binary GA and Real parameter GA. The binary representation of decision variables used in genetic algorithms has some drawbacks when applied to multi-dimensional, high precision numerical problems.

3. Methodology:

Development of Agricultural Strategies

In agriculture planning, the optimal land use structure can be determined based on the comprehensive consideration of natural resources, peoples′ living requirement, development of economy and society, and environment protection. Land use benefit can be reflected from the aspects of society, economy and ecosystem. The objectives for the set up models include production of crops in the society aspect, net profit with economic consideration and fertilizer consumption to reduce the impact on ecosystem. These objectives are optimized under various constraints namely; availability of land, agriculture labour, agriculture machinery and water.

4. Objectives

***Production of crops (Z_1)*:** To meet the demand of food-stuff for the growing population and society needs, the objective-function of the model, annual production of all the major crops must be maximized.

***Profit (Z_2)*:** In order to obtain maximum economic benefits and also to increase the economical and social status of the farmers, the net profit must be maximized.

***Fertilizer consumption (Z_3)*:** The objective-function concerns consumption of fertilizer. To reduce the environmental pollution and cost of fertilizer, the fertilizer consumption must be minimized.

4.1. Constraints

***Land available (C_1)*:** It is necessary to utilize the land in all seasons because of its limited availability. The total land allocated to the crops in a particular season should not be more than the available land for cultivation in that season. After harvesting a crop in a particular season, the same land can be reutilized for cultivating the late variety of the same crops in the same season.

***Agriculture labour available (C_2)*:** It is necessary to utilize the available agriculture labour in all seasons, because of the limited availability of labourers. The total number of labour used for all kinds of land should be less than the total amount of labour available.

***Agriculture machinery available (C_3)*:** Because of the limited availability of machinery, it is necessary to utilize the agriculture machinery for tillage in all seasons. The total number of machinery used for all kinds of land should be less than the total amount of machinery available.

***Water available (C_4)*:** To meet the production level of each crop, it is necessary to utilize available water in all seasons. The total water consumption in a particular season should not be more than the available water resources in that season.

Mathematical models for four strategies namely; societal, economic, environmental and preferential are developed in this study for optimal land allocation. Societal, economic and environmental strategies are modelled with social, economic and environmental sense by considering the single objectives; maximization of production, maximization of profit and minimization of fertilizer consumption respectively. Since agricultural planning problems generally involve multiple objectives, preferential strategy is modelled using weighted additive method by simultaneous consideration of three objectives.

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Societal Strategy: To meet the demand of food-stuff for the population, the annual production of all the major crops must be maximized. The mathematical formulation of the objective with societal strategy is shown below.

$$Max\ Production\ (Z_1) = \sum_{c=1}^{C}\sum_{v=1}^{V}\sum_{s=1}^{S}[H]_{cvs} * [PR]_{cvs} \qquad (3.1)$$

Subject to the following constraints

***Land available (C_1)*:** The total land allocated to the crops in a particular season should not be more than the available land for cultivation in that season.

$$\sum_{c=1}^{C}\sum_{v=1}^{V}[H]_{cvs} \leq L \ \forall\ s = 1,2,\ldots\ldots,S \qquad (3.2)$$

After harvesting a crop in a particular season, the same land can be reutilized for cultivating the late variety of the same crops in the same season.

$$\sum_{c=1}^{C}\sum_{v=1}^{V}[H]_{cvs} - \sum_{c=1}^{C}\sum_{v=2}^{V}[H]_{cvs} = 0 \qquad (3.3)$$

***Agriculture labour available (C_2)*:** The total number of labour used for all kinds of land should be less than the total amount of labour available.

$$\sum_{c=1}^{C}\sum_{v=1}^{V}\sum_{s=1}^{S}[md]_{cvs}\ X\,[H]_{cvs} \leq\ EMD \qquad (3.4)$$

***Agriculture machinery available (C_3)*:** The total number of machinery used for all kinds of land should be less than the total amount of machinery available.

$$\sum_{c=1}^{C}\sum_{v=1}^{V}\sum_{s=1}^{S}[mh]_{cvs}\ X\,[H]_{cvs} \leq\ EMH \qquad (3.5)$$

***Water available (C_4)*:** The total water consumption in a particular season should not be more than the available water resources in that season.

$$\sum_{c=1}^{C}\sum_{v=1}^{V}\sum_{s=1}^{S}[WC]_{cvs}\ X\,[H]_{cvs} \leq [WA]_s\ \forall\ s = 1,2,\ldots S \qquad (3.6)$$

Economical strategy: To increase the economical and social status of the farmers, the net profit must be maximized. The mathematical formulation of the objective with economical strategy is shown below.

$$Max\ Profit\ (Z_2) = \sum_{c=1}^{C}\sum_{v=1}^{V}\sum_{s=1}^{S}[MSP]_{cvs} * [PR]_{cvs} * [H]_{cvs} - \sum_{c=1}^{C}\sum_{v=1}^{V}\sum_{s=1}^{S}[HP]_{cvs} * [PR]_{cvs} * [H]_{cvs} \qquad - (3.7)$$

Subject to constraints given in equations 3.2 to 3.6

Environmental strategy: 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.

Min Fertilizer Consumption (Z_3) =

$$\sum_{c=1}^{C}\sum_{v=1}^{V}\sum_{s=1}^{S}[H]_{cvs} * [N+P+K]_{cvs} \qquad (3.8)$$

Subject to constraints given in equations 3.2 to 3.6

Preferential strategy: A multi objective problem may be transformed into a single objective optimization problem by assigning weights to the various objective functions. The weights of the objectives are interpreted so as to represent the relative preferences of the decision maker. In this context, the weighted additive approach for agriculture planning can be considered as preferential strategy. Weighted additive method transforms multiple objectives into an aggregated scalar objective function by multiplying each objective function by a weighting factor and summing up all contributors. The mathematical model formulation of the preferential strategy is shown below.

$$\text{Maximize } (Z) = \sum_{i=1}^{m}[W]_i\ X\,[Z]_i \quad i = 1,2,\ldots\ldots m \qquad (3.9)$$

Subject to constraints given in equations 3.2 to 3.6

Where *Z* is the single objective function formulated,

$[Z]_i$ is the i th objective function,

and $[W]_i$ is the weight attatched to i th objective function.

Weights of objectives are determined through Eigen vector method (Ram Narasimhan, 1982) using the pair wise comparison matrix of the objectives. Satty scale (1977) is used in preparing the pair wise comparison matrix.

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. Saaty's scheme to construct the ratio scale a'_{ij} by comparing the i^{th} objective with the j^{th} one is as follows:

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

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.

iii) **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
The intermediate values between two adjacent judgments	2,4,6,8

Saaty suggests that if that ratio exceeds 0.1, the set of judgments may be too inconsistent to be reliable. In practice, CRs of more than 0.1 sometimes have to be accepted. A CR of 0 means, that the judgments are perfectly consistent.

The formulated models are solved through real parameter GA.

5. CASE STUDY

In exploring the motivations for sustainable agricultural development and its impacts on ecological, economic, and social outcomes, the case study approach has been and qualitative analysis of the data is reported. The development of ecological agriculture at the district level can be regarded as a long-term process of economic activities, land use, population growth, material-energy-information flows and human-natural interactions that satisfies regional sustainable development demands. It emphasises the sustainable use of internal resources with ecological, economic and social sense rather than external flows to support long-term agricultural development. In view of the above, Krishna district of Andhra Pradesh, India was selected as the case study area for optimal land allocation in agriculture planning.

Data on the Case Study

According to the climatic conditions, two cropping seasons Kharif and Rabi are considered. The main crops cultivated during Kharif (June to September) and Rabi (October to February) seasons are Paddy, Black Gram, Green Gram, Ragi, Maize, Groundnut, Chillies and Sugarcane. Sugarcane is a perennial crop and occupies the land in both the seasons. After harvesting the crops of short period in the Kharif season, the same land is utilized for cultivating late variety of Maize. Similarly in the Rabi season after harvesting the early variety of crops Black Gram and Green Gram, the same land is utilized for cultivating late variety of the same crops. In the model formulation, the 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 Sugar Cane; Seasons are denoted as S = 1 for Kharif and S = 2 for Rabi; Varieties are denoted as V = 1 for first variety or early variety and V = 2 for second variety or late variety.

The data of the production of crops (quintal/hectare), market price (Rupees/quintal) of each product, crop harvest price (Rupees/hectare), requirement of machine hours (hrs/hectare), man days required (days/hectare), amount of water available in two seasons (cm), the total area of land available (hectares) under cultivation in two seasons, available man days (days/annum), machine hours available (hrs/annum) of all the crops have been obtained from the Chief Planning Officer, Visakhapatnam district. Data related to fertilizer consumption of each crop (kg/hectare), quantity of crop residue (kg/kg of crop) and nutrients available in each crop residue (% by weight) are down loaded from different sources through internet.

The data for the available resources, defined coefficients of objectives and constraints are presented in Table 3.2 and 3.3.

Table 3.2: Data of available resources

Land under cultivation in Kharif season (hectares)	L_1	**230068**
Land under cultivation in Rabi Season (hectares)	L_2	**38359**
Man days(days)	EMD	**58300000**
Machine hours (hrs)	EMH	**15292800**
Water during Kharif season (cm)	$[WA]_1$	23656516
Water during Rabi season (cm)	$[WA]_2$	15265830

Table 3.3: Data for the co-efficients of objectives and constraints

Coefficients	Season	Paddy	Black Gram	Green Gram	Ragi	Maize	Groundnut	Chilli	Sugarcane
Production (qtl/he	Kharif Rab	16.83 19	4.2 6.7 (6.5)	3.94 3.4(3.5)	5.95 15.5	14.26 (13.5)	11.16 22.4	44.65 12.43	420

ct)	i					88.3	1		
Market price (Rs/qtl)	Kharif Rabi	850 850	2520 2520 (2520)	2520 2520(2520)	915 915	840 (840) 840	2100 2100	2200 2200	108
Harvest price (Rs/hect)	Kharif Rabi	8836 9975	6002 9574 (9289)	5630 4859(5002)	2874 7487	7330 (6939) 45386	16104 32338	63046 17552	35280
M/c hours (hrs/hect)	Kharif Rabi	4 6	0 0 (0)	0 0 (0)	4 4	4 4	6 6	4 4	8 8
Man days (days/hect)	Kharif Rabi	150 175	52 60 (58)	54 45 (48)	52 54	96 (92) 98	75 75	603 658	155
Fertilizer (kg/hect)	Kharif Rabi	135 135	100 100 (100)	100 100 (100)	100 100	180 (180) 180	110 110	160 160	200
Water (cm/hect)	Kharif Rabi	130 130	35 40 (40)	35 40 (40)	40 45	50 (50) 55	45 60	55 60	180

Note: The data shown in brackets corresponds to the late variety of crops.

Model formulation for Societal Strategy: A single objective function is formulated for this model using equation 3.1 to maximize the production of crops with society sense.

Maximize Production (Z_1) =

$$(16.83*H_{111}+19*H_{112}+4.2*H_{211}+6.7*H_{212}+6.5*H_{222}+3.94*H_{311}+3.4*H_{312}+3.5*H_{322}+5.95*H_{411}+15.5*H_{412}+14.26*H_{511}+88.3*H_{512}+13.5*H_{521}+11.16*H_{611}+22.41*H_{612}+44.65*H_{711}+12.43*H_{712}+420*H_{811}) \quad (3.10)$$

Subject to the following constraints

(i) The total land allocation for all crops of first variety in kharif season must be less than or equal to the land available in that season.

$$H_{111}+H_{211}+H_{311}+H_{411}+H_{511}+H_{611}+H_{711}+H_{811}<=230068 \quad (3.11)$$

(ii) The land allocation for late variety of maize in kharif season must be equal to the land used by early variety of maize in that season.

$$H_{511}-H_{521}=0 \quad (3.12)$$

(iii) The total land allocation for all crops of first variety in rabi season must be less than or equal to the land available in that season.

$$H_{112}+H_{212}+H_{312}+H_{412}+H_{512}+H_{612}+H_{712}<=38359 \quad (3.13)$$

(iv) The land allocation for late variety of black gram and green gram in rabi season must be equal to the land used by early variety of same crops in that season.

$$H_{212}+H_{312}-H_{222}-H_{322}=0 \quad (3.14)$$

(v) The agriculture labour required to cultivate the crops in a year must be less than or equal to the man days available.

$$150*H_{111}+175*H_{112}+52*H_{211}+60*H_{212}+58*H_{222}+54*H_{311}+45*H_{312}+48*H_{322}+52*H_{411}+54*H_{412}+96*H_{511}+98*H_{512}+92*H_{521}+75*H_{611}+75*H_{612}+609*H_{711}+658*H_{712}+155*H_{811}<= 58300000 \quad (3.15)$$

(vi) The total number of machine hours required to cultivate the crops in a year must be less than or equal to the machine hours available.

$$4*H_{111}+6*H_{112}+4*H_{411}+4*H_{412}+4*H_{511}+5*H_{512}+4*H_{521}+6*H_{611}+6*H_{612}+4*H_{711}+4*H_{712}+8*H_{811}<=15292800 \quad (3.16)$$

(vii) The amount of water required for the crops in kharif season must be less than or equal to the water available in that season.

$$130*H_{111}+35*H_{211}+35*H_{311}+40*H_{411}+50*H_{511}+50*H_{521}+45*H_{611}+55*H_{711}+180*H_{811}<=23656516 \quad (3.17)$$

(viii) The amount of water required for the crops in rabi season must be less than or equal to the water available in that season.

$$130*H_{112}+40*H_{212}+40*H_{222}+40*H_{312}+40*H_{322}+45*H_{412}+55*H_{512}+60*H_{612}+60*H_{712}+180*H_{811}<=15265830 \quad (3.18)$$

3.4.4 Model formulation for Economical Strategy: A single objective function is formulated using equation 3.7 to maximize the profit with economic consideration.

Maximize Profit (Z_2) =

$$(14306*H_{111}+16150*H_{112}+10584*H_{211}+16884*H_{212}+16830*H_{222}+9929*H_{311}+8568*H_{312}+8820*H_{322}+5444*H_{411}+14183*H_{412}+11978*H_{511}+74172*H_{512}+11340*H_{521}+23436*H_{611}+47061*H_{612}+98230*H_{711}+27346*H_{712}+45360*H_{811}) -(8836*H_{111}+9975*H_{112}+6002*H_{211}+9574*H_{212}+9289*H_{222}+5630*H_{311}+4859*H_{312}+5002*H_{322}+2874*H_{411}+7487*H_{412}+7330*H_{511}+45386*H_{512}+6939*H_{521}+16104*H_{611}+32338*H_{612}+63046*H_{711}+17552*H_{712}+35280*H_{811}) \quad (3.19)$$

Subject to the constraints given in equations 3.11 to 3.18

3.4.5 Model formulation for Environmental Strategy: A single objective function is formulated using equation 3.8 to minimize the fertilizer consumption with environment aspect.

Minimize Fertilizer consumption (Z_3) =

$H_{111}*(70+35+30)+H_{112}*(70+35+30)+H_{211}*(20+50+30)+H_{212}*(20+50+30)+H_{222}*(20+50+30)+H_{311}*(20+50+30)+H_{312}*(20+50+30)+H_{322}*(20+50+30)+H_{411}*(50+30+20)+H_{412}*(50+30+20)+H_{511}*(100+50+30)+H_{512}*(100+50+30)+H_{521}*(100+50+30)+H_{611}*(30+40+40)+H_{612}*(30+40+40)+H_{711}*(80+50+30)+H_{712}*(80+50+30)+H_{811}*(80+20+100)$ (3.20)

Subject to the constraints given in equations 3.11 to 3.18

3.4.6 Model formulation for Preferential strategy

A single objective function is formulated using equation 3.9 by assigning relative weights of the objectives determined through Eigen vector method.

Determination of weights

The relative importance of the objectives is quantified by the following method.

- Formulate the pair wise comparison matrix basing on Saaty scale as in table 3.4 and determine the column sum of the matrix.

Table 3.4: Pair wise comparison matrix of objectives with column sum

Objectives	Production	Profit	Fertilizer consumption
Production	1	¼	4
Profit	4	1	8
Fertilizer consumption	1/4	1/8	1
Column sum	5.25	1.375	13

Table 3.5: Normalized Pair wise comparison matrix with row average

Objectives	Production	Profit	Fertilizer consumption	Row average
Production	0.19	0.18	0.31	0.23
Profit	0.76	0.73	0.62	0.70
Fertilizer consumption	0.05	0.09	0.08	0.07

Weights of the three objectives obtained from the above normalized pair wise comparison matrix are 0.23, 0.70 and 0.07. These weights are assigned to the objectives with six weight structures as shown in table 3.6 and the problem is solved for optimal land allocation.

Table 3.6: Land allocation values for different weight structures

Sl No	Production	Profit	Fertilizer consumption	Land allocation (hectares)
1	0.23	0.70	0.07	297737.31
2	0.23	0.07	0.70	288195.72
3	0.70	0.23	0.07	281743.12
4	0.70	0.07	0.23	281978.88
5	0.07	0.23	0.70	282680.32
6	0.07	0.70	0.23	294259.43

The weight structure for which the land allocation is more, which is taken as the optimum weight structure and the model is formulated as below.

Maximize (Z) = $0.23*(Z_1) +0.7*(Z_2) +0.07*(Z_3)$ (3.21)

Subject to the constraints given in equations 3.11 to 3.18

SOLUTION THROUGH GA

The real parameter GA used to find the optimum solution of the developed mathematical models, which implements a tournament selected scheme, where two solutions are compared and the best in terms of objective function value is selected. Crossing over is done by the simulated binary crossover SBX operator which works with two parent solutions and creates two offspring (Deb and Agarwal, 1995). To create a mutated value, the polynomial mutation operator (Deb, 2001) is used. The exponents used for SBX and mutation are 2 and 300 respectively. Constraints are handled using Deb's parameter-less approach (Deb, 2000).

3.6.1 Parametric Study

The best value of the objective function can be found with the best set of GA parameters obtained by conducting parametric study. The parameters varied in this study are crossover probability (Pc), mutation probability (Pm), population size (Ps), and number of generations (Gn). Parametric study carried out for societal strategy is presented below.

Initially the crossover probability is varied from 0.75 to 0.95 in steps of 0.01, keeping the other parameters constant to the values of Pm = 0.01, Ps = 30 and Gn = 100. The variation of the fitness value with respect to crossover probability is shown graphically in figure 3.2. It indicates that the maximum value of fitness is obtained at crossover probability of 0.81.

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The above procedure is repeated for different values of mutation probability from 0.008 to 0.017 in steps of 0.001, keeping the other parameters constant to the values of Pc= 0.81, Ps=30 and Gn=100. The sensitivity of mutation probability on fitness value is shown graphically in figure 3.3. It is observed that the maximum fitness value is obtained at mutation probability 0.01.

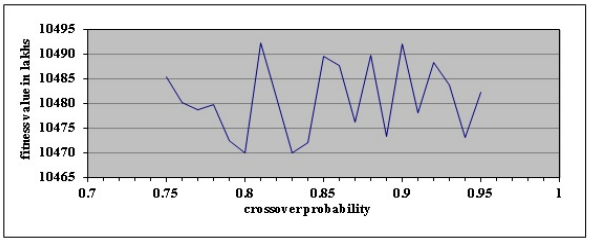

Figure 3.2:Crossover probability & Fitness value

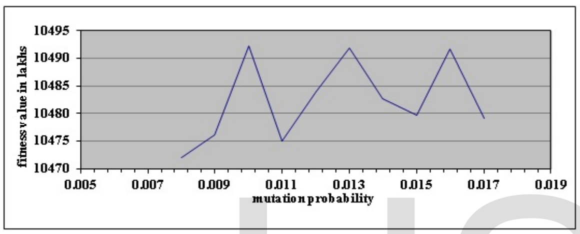

Figure 3.3: Mutation probability & Fitness value

Now by keeping the parameters Pc=0.81, 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 3.4. It is observed from the figure that the population size is 30 for the maximum fitness value.

Finally, the number of generations are varied from 50 to 150 in steps of 10, keeping the other parameters constant as Pc=0.81, Pm=0.01 and Ps=30. The sensitivity of the number of generations on fitness value is shown in figure 3.5. From the figure, it is observed that the optimum number of generations is 130.

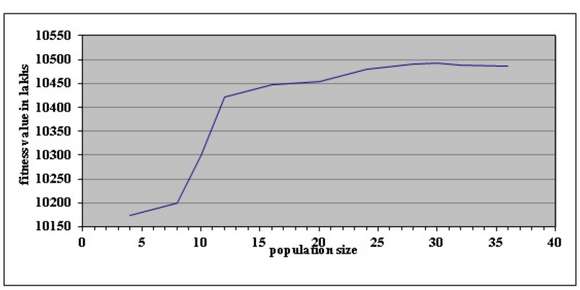

Figure 3.4: Population size & Fitness value

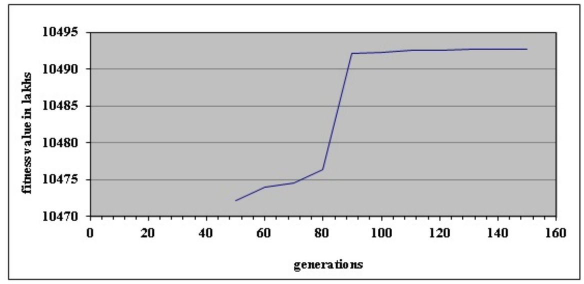

Figure 3.5: Generations & Fitness value

Thus the best GA parameters obtained are Pc=0.81, Pm=0.01, Ps=30, Gn=130.

Similar procedure is adopted for the other three strategies (economical, environmental and preferential strategies) to obtain the best set of GA parameters. The models for societal, economical, environmental and preferential strategies presented with a case study are solved through real parameter GA by using the above best GA parameters for optimal land allocation results and are presented below.

3.6 RESULTS AND DISCUSSION

The optimal land allocation results obtained for eight major crops with two varieties in two seasons for four strategies are shown in table 3.7.

Table 3.7: Optimal land allocation for 8 major crops in 2 seasons of 4 strategies

Sl. No.	Crops	Decision variables	Societal Strategy	Economical Strategy	Environmental Strategy	Preferential Strategy
1.	Paddy.	H_{111}	95717.06	95591.79	50000.18	56830.01
		H_{112}	3998.39	3841.48	1000.15	6127.23
2.	Black Gram	H_{211}	4000.00	3993.85	2000.00	14400.68
		H_{212}	2999.86	2999.75	7428.50	6172.42
		H_{222}	2999.70	2999.99	2373.28	9402.40
3.	Green Gram	H_{311}	1999.99	1993.14	1000.00	10579.09
		H_{312}	3998.56	3999.96	2000.00	8631.44
		H_{322}	3997.85	3986.55	2065.34	5394.55
4.	Ragi	H_{411}	29999.84	29999.24	20001.00	44002.84
		H_{412}	997.78	998.40	0.22	4422.21
5.	Maize	H_{511}	6976.73	6999.99	6000.18	14975.67
		H_{512}	1986.27	2000.00	1000.00	14766.47
		H_{521}	6999.99	6999.99	6000.00	8824.62
6.	Ground nut	H_{611}	5674.11	5999.48	2000.01	14841.17
		H_{612}	1999.97	1999.83	0.62	1740.49
7.	Chillies	H_{711}	997.95	999.98	0.05	14996.43
		H_{712}	2999.98	2999.89	740.66	2438.64
8.	Sugar	H_{811}	49999.97	49999.97	30000.03	59190.93
Total land allocation			228344.01	228403.28	133610.21	297737.28

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The results exhibit that the total land utilization for eight major crops in two seasons with societal, economical, environmental and preferential strategies are 59.31%, 59.33%, 34.79% and 77.52% respectively. It also shows that there is a maximum land allocation of 297737.28 hectares by preferential strategy is and minimum land allocation of 133610.21 hectares with environmental strategy.

In case of societal strategy, it is observed that the 80% of land allocation, 82.6% of fertilizer consumption is contributed by paddy, sugar cane, ragi and maize crops in kharif season. Further in this strategy, 81% of the profit is contributed by paddy, sugar cane, ragi, ground nut in kharif season and maize in rabi season.

From the results it is observed that with economical strategy, 80% of land allocation, 80% of production and 82.5% of fertilizer consumption is contributed by paddy, sugar cane, ragi and maize crops in kharif 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.

With environmental strategy it is observed that the 83.3% of land allocation, 85.3% of fertilizer consumption contributed by paddy, sugar cane, ragi and maize crops in kharif season. Further in this strategy, 82.2% of the profit is contributed by paddy, sugarcane in kharif season and maize in rabi season.

Results obtained with preferential strategy indicate that paddy, sugar cane, ragi, ground nut, chillies in kharif season and maize in rabi season contributes 81% of profit. Fertilizer consumption contributed by paddy, sugar cane, ragi, maize, chillies, and ground nut crops in kharif season and maize in rabi season is 83%.

Comparison of land allocation for eight major crops among four strategies is shown in the figure 3.6.

From the figure 3.6 it is observed that there is marked difference in land allocation for the crops - paddy (H_{111}), ragi (H_{411}) and sugarcane (H_{811}) when compared with the other crops. Land allocation for paddy is more with societal and economical strategy, for ragi and sugarcane it is more with preferential strategy. It shows that there is some consistency in land allocation for the crops with preferential strategy.

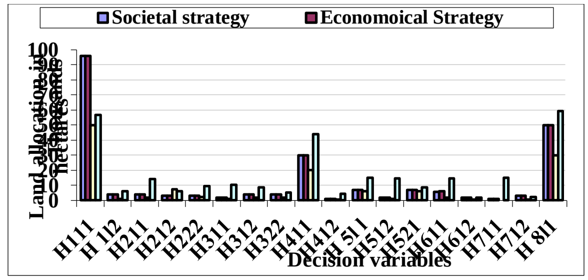

Figure 3.6: Land allocation for eight major crops

The attainment levels of various objectives in percentage are given in table 3.8 and the achievement of objectives under different strategies is shown in figure 3.7.

Table 3.8: Level of achievement of objectives under different strategies

Objectives	Societal strategy	Economical strategy	Environmental strategy	Preferential strategy
Production (Quintals)	23532072 (80.99%)	23532161 (80.99%)	14283859 (49.16%)	29057381 (100%)
Profit (Rupees)	1492216509 (57.76%)	1493427936 (57.81%)	911155279 (35.27%)	2583376288 (100.00%)
Fertilizer consumption (Kg)	32918096 (56.39%)	32920473 (56.39%)	18563650 (100.00%)	42193586 (44.00%)

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

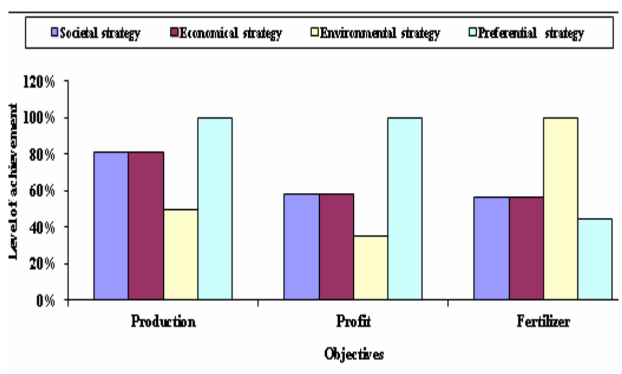

Figure 3.7: Level of achievement of Objectives

From table 3.8 and figure 3.7 it is observed that production and profit objectives are maximum with preferential strategy and fertilizer consumption is minimum with environmental strategy. Further, it is observed that the achievement of production and profit with societal strategy and economical strategy are almost same.

CONCLUDING REMARKS

In this paper, an attempt is made to develop four agricultural strategies for optimal land allocation in crisp environment. Initially societal, economical and environmental aspects are viewed separately and societal, economical and environmental strategies are developed. Later preferential strategy is developed by considering the 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 yield improved solution in terms of land allocation, production and profit objectives. The results show that there is a maximum land allocation of 297737.28 hectares by preferential strategy. It is also observed that production and profit objectives are achieved maximum with preferential 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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