Crop planning using Fuzzy Optimization Technique-A case study of Hazaribag district, Jharkhand

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Abstract: The present study is an adaption of the application of Fuzzy optimization technique in agriculture planning especially for the farmers of the Hazaribag District within the state of Jharkhand. Though for simplicity the application is designed as a linear programming problem but in surreal life situations the elements of uncertainties in agricultural production planning play dominant roles and aggravate the problems. Therefore, the main objective of this study is to evaluate and predict future agricultural planning that is production and the amount of profitability thereby. Crop planning data has been modelled and a compromise optimum solution is obtained using Lingo 18.0.

Keywords- **Crops, Fuzzy Multi-Objective liner programming mathematical Model**.

I.INTRODUCTION

The economy of Hazaribag is dominated to a great extent by agricultural activities providing maximum employment. Though the topography consists mainly of high lands and low lying lands by the rivers and rivulets on the southern side, other geographical conditions are relatively favourable for agriculture. Assured irrigation is scanty but rain fall is satisfactory. Application of innovative technology and scientific implements is the hall mark of the farmers of Hazaribag District. They are constantly upgrading their techniques to increase agricultural production. The highest challenge faced by the farmers is to maximize their profits within the existing constraints and minimum of investment. The present paper aims to study this important aspect of the problem faced by farmers and their efforts to maximize profits through optimized utilization of available resources through planning based on single and/or multi-objective optimization goals. These problems are foreseen and so adequate adjustments made through allocation of land best suited for different crops, suitable season and timings selected for maximization of agricultural production. Concepts of the agricultural management system are implemented for maximum profit achievement point of view. One must realize that the maximum of crop production does not necessarily guarantees maximization of profit. Profit or loss, even after maximum agricultural production, is as yet subjected to pricing factor for calculation of profit and loss. The price of the product ultimately determines whether the profit goals are achieved or not. With the factors of uncertainty playing important roles in the process of agricultural planning the maximization of profit turns out to be Fuzzy Multi Objective Decision Making Problem.

II.Literature Review

In management sciences numerous approaches have been developed over the years to address the multi-objective decision making problems. The three important methodology generally used in dealing with the multi objective linear planning (MOLP) problems are enumerated as Vector Maximum Method, Goal planning and Interactive Technique. In most practical problems the numbers of the decision variable have fewer extreme points. Bellmann and Zadeh [3] were able to advocate a basis for decision making in Fuzzy environment. Later based on their findings and given proposition, Zimmermann [2] initiated new approaches to find a compromise solution to MOLP problems. The methodologies were further improved to obtain compromise solutions. Burkley [23], Luhandjula [13], Sakawa and Yano [4], Chanas [9] applied various directions in developing it further. The domain of agriculture was not left unaltered and uncertainties play decisive roles in the domain of agriculture and decision making. For it, numerous researchers such as Slowinski [5], Sinha et al [6], Sher and Amir [7], Sumpsi [21] et al, Pal [14], Moitra [12], Vasant [8], Biswas and Pal [14], Sarkar et al [11], preferred to use Fuzzy Goal Programming Techniques for farm planning problems. Kruse and Meyes [20] were instrumental in drawing the attention of researchers to study agricultural crop planning with stochastic values to solve linear programming problems. Hulsurkar et. al. [22] studied the Fuzzy Programming approaches to multi objective stochastic linear programming problem. The comparative study made by Lodwick et. al [19] in a case of crop planning problem based on fuzzy stochastic and deterministic methods were done assiduously followed by a study conducted by Itoh and Ishir [18] based on possibility measure. Itoh et. al's [18] case study of a problem pertained to crop planning under uncertainty, as discrete random variable and put forward a model, to obtain maximum and minimum values of profits for decision makers. Toyonaga et. al. [17] conducted a study of crop planning problem with fuzzy random profit co-efficient. Sharma et. al. [16] too conducted a study on Fuzzy Goal Programming for agricultural and allocation problem and suggested his own annual agricultural plans for crops of different kinds.

In this paper, an attempt is made to arrive at a solution considering multi objective linear programming problem of crop planning with respect to profit as a discrete random variable. The problem has been transformed into a deterministic model addressing fuzzy programming to find a model of crop planning to support the decision maker with the prospect of an optimal profit.

III.Methodology

In general, the multi-objective optimization problem MOLP with k objectives, n variables and p constraints is given by

$\text{Max}\ \{Z_1, Z_2, \ldots, Z_k\}$

Such that

$A_j(X) \leq b \quad j = 1, 2, \ldots, p$

$X = \{x_1, x_2, x_3, x_4, \ldots, x_n\}$

$x_i \geq 0,\ i = 1, 2, \ldots, n$

Further, a general FMOLP problem with n decision variables, m constraints and k objectives can be written as:

$\text{Max}\ Z_1(x) = \sum_{j=1}^{n} c_{1j} x_j$

$\text{Max}\ Z_2(x) = \sum_{j=1}^{n} c_{2j} x_j$ (1)

……………………..

$\text{Max}\ Z_k(x) = \sum_{j=1}^{n} c_{kj} x_j$

$k = 1, 2, 3, 4, \ldots, m.$

Subject to

$Ax \leq b,\ x \geq 0$

Wherever x is a n- dimensional vector of decision variables.

$Z_1(x), Z_2(x), \ldots, Z_k(x)$ are k distinct linear objective functions of the decision variable x

C_{ij} is the cost vector, where i=1, 2……, m, j=1, 2……, n, A is m×n constraint matrix, b is k dimensional vector of total resources available.

To find decision vector x,

$\exists\ Z_k(x) \geq Z_k(x^*)\ \forall\ k$

Where $Z_k(x^*)\ \forall\ k$ are different goals and all objective functions to be maximized.

Objective functions of equation (1) are to be Fuzzy.

The membership functions $\mu_k(x)\ \forall\ k$ of the objective functions are estimated by finding pay off matrix of positive ideal solutions such that

$\therefore\ \mu_A(x) = \min\ \{\mu_1(x), \mu_2(x), \mu_3(x), \mu_4(x) \ldots \mu_k(x)\}$

The solution can be obtained by solving the problem of maximizing $\mu_A(x)$ subject to $x \epsilon X$.

$\text{Max}\ (\text{Min}_k\ \mu_k(x))$ such that $x \epsilon X$.

Let $\gamma = \text{Min}_k\ \mu_k(x)$ be in common accurate level of compromise solution then we get the equivalent model is

$\text{Max}\ \gamma$

Such that $\gamma \leq \mu_k(x)\ \forall\ k,\ x \epsilon X$.

$Ax \leq b,\ x \geq 0$ (2)

Problem (2) can be solved using Lingo 18.0 software.

IV.Algorithm

Solving each objective function for its max and min values, the fuzzy aspiration levels are determined and thus membership functions are defined and problem reduced to its crisp form. Using max-min operator, suggested by Zimmermann an optimum solution is tried. It is thus expected that Fuzzy multi-objective programming approach will give a flexible realistic optimum compromise solution. There are two important seasons namely the kharif which begins in June and ends in October-November, the Rabi season begins in November and ends in the February-March. In the present study data has been used provided by Agricultural Technology Management Agency (ATMA), Krishi Bhawan, Kanhari Hill Road, Hazaribag and Statistics Department, Government of Jharkhand, Hazaribag and presented in Table-1 showing per unit (in hectares) optimum crop production, labour required and the returns from these crops etc. For a particular crops say i^{th} crop all information's viz, land area for cultivation, the amount of seeds, cost of fertilizer, cost of pesticides, cost of human energy (labour), cost of animal energy (Ox etc), unforeseen expenses, total investment cost and the return per unit land are required. Objective functions and constraints are formulated on the basis of available statistical data and solved using LINGO 18.0 software.

Step-1

Each objective is solved subject to the constraints using linear programming techniques.

Step-2

Lower bound Z_k' and Upper bound Z_k'' are obtained for each objective function.

Let μ_k be a linear non decreasing membership function between Z_k' and Z_k'' ∀k

$$\text{Where } \mu_k(x) = \begin{cases} 1 & \text{if } Z_k = Z_k'' \\ \dfrac{Z_k - Z_k'}{Z_k'' - Z_k'} & \text{if } Z_k' \leq Z_k \leq Z_k'' \\ 0 & \text{if } Z_k < Z_k' \end{cases}$$

Step-3

Now change the problem of multi objective linear programming problem in the linear programming problem as

$$\mu_k(x) = \frac{Z_k - Z_k'}{Z_k'' - Z_k'} \geq \gamma,\ x\epsilon X,$$

Max $Z_k(x) = \sum_{j=1}^{n} c_{k_j} x_j$, $0 \leq \gamma \leq 1$

i.e. $Z_k - \gamma(Z_k'' - Z_k') \geq Z_k'$

i.e. $\sum_{j=1}^{n} c_{k_j} x_j - (Z_k'' - Z_k') \geq Z_k'$, $\forall$ k, $x\epsilon X$.

It can simply solve by Simplex Method.

V.Mathematical formulation of crop production problem

The objectives of the problem are to maximize the production and profit. The computational algorithm upgraded step by step to find an optimal solution for crop production in the Hazaribag District, Jharkhand. In this region farmers grow Paddy, Jawar, Bajra, Maize, Ragi, Tur, Urad, Kulthi, Moong during the kharif season. Gram, Wheat, Mustard, Masur, Pea, Groundnut, Linseed in the time of the rabi season. Available land is 152395 hectares. Labour availability for Kharif season is given a total of 325 mandays and also Rabi season 325 mandays. A small farm owner needs at least 400 kg of paddy, 350 kg of Wheat and 70 kg of moong+Urad+Kulthi+Masur for his annual grain requirements.

Table-5.1

Minimum requirements for Labour, Production and Return per/ha

Crops	Labour (manday/ha.)	Production (Kg. /ha.)	Return (Rs. /ha.)
Paddy ($x_{1,1}$)	130	2530	7160
Wheat ($x_{2,1}$)	86	2500	8025
Jowar ($x_{1,2}$)	72	680	5602
Bajra ($x_{1,3}$)	66	500	2450
Maize ($x_{1,4}$)	78	2500	19080
Ragi ($x_{1,5}$)	96	690	10880
Tur (Arhar) ($x_{1,6}$)	62	1200	36415
Urad ($x_{1,7}$)	49	750	28945
Kulthi ($x_{1,8}$)	33	740	32045
Moong ($x_{1,9}$)	36	850	40171
Gram ($x_{2,2}$)	146	1500	45337
Masur ($x_{2,3}$)	42	730	15280
Pea ($x_{2,4}$)	79	1030	26050
Groundnut ($x_{1,10}$)	86	1240	49355
Rapeseed and Mustard ($x_{2,5}$)	78	900	26240
Linseed ($x_{2,6}$)	46	300	1945

Where

$x_{i,j}$ = the land area for crop growing of crop j (1 to 10) in Season (=1, 2) (hectares) i=1= kharif season, i =2=Rabi season.

The objective functions are**:**

Production:

$Maximize\ Z_1 = 2530x_{1,1} + 680x_{1,2} + 500x_{1,3} + 2500x_{1,4} + 690x_{1,5} + 1200x_{1,6} + 750x_{1,7} + 740x_{1,8} + 850x_{1,9} + 1240x_{1,10} + 2500x_{2,1} + 1500x_{2,2} + 730x_{2,3} + 1030x_{2,4} + 900x_{2,5} + 300x_{2,6}$

Profit:

$Maximize\ Z_2 = 7160x_{1,1} + 5602x_{1,2} + 2450x_{1,3} + 19080x_{1,4} + 10880x_{1,5} + 36415x_{1,6} + 28945x_{1,7} + 32045x_{1,8} + 40171x_{1,9} + 49355x_{1,10} + 8025x_{2,1} + 45337x_{2,2} + 15280x_{2,3} + 26050x_{2,4} + 26240x_{2,5} + 1945x_{2,6}$

Subject to constraints:

Labour:

$130x_{1,1} + 72x_{1,2} + 66x_{1,3} + 78x_{1,4} + 96x_{1,5} + 62x_{1,6} + 49x_{1,7} + 33x_{1,8} + 36x_{1,9} + 86x_{1,10} \leq 325$

$86x_{2,1} + 146x_{2,2} + 42x_{2,3} + 79x_{2,4} + 78x_{2,5} + 46x_{2,6} \leq 325$

Land:

$x_{1,1} + x_{1,2} + x_{1,3} + x_{1,4} + x_{1,5} + x_{1,6} + x_{1,7} + x_{1,8} + x_{1,9} + x_{1,10} \leq 152395$

$x_{2,1} + x_{2,2} + x_{2,3} + x_{2,4} + x_{2,5} + x_{2,6} \leq 152395$

Food requirements:

$2530x_{1,1} \geq 400$

$2500x_{2,1} \geq 350$

$750x_{1,7} + 740x_{1,8} + 850x_{1,9} + 730x_{2,3} \geq 70$

Where all $x_{i,j} \geq 0$, $i = 1, 2$ & $j = 1$ to 10

Solving this linear programming problem by simplex method

For objective function

Production $Z_1 = 19,581$

$X^{(1)} =$

$X_{1,1}$	0.158103 ha. Land for Paddy
$X_{1,4}$	3.865153 ha. Land for Maize
$X_{1,9}$	0.082353 ha. Land for Moong
$X_{2,1}$	3.779070 ha. Land for Wheat

Profit $Z_2 = 4, 55,834$

$X^{(2)} =$

$X_{1,1}$	0.158103 ha. Land for Paddy
$X_{1,9}$	8.456851 ha. Land for Moong
$X_{2,1}$	0.140000 ha. Land for Wheat
$X_{2,3}$	7.451429 ha. Land for Masur

Positive Ideal Solution:

	Z_1	Z_2
$X^{(1)}$	19581	108514
$X^{(2)}$	13378	455834

From the pay-off matrix, lower bound and upper bound are projected as

$13378 \leq Z_1 \leq 19581$

$108514 \leq Z_2 \leq 455834$

The above problem is converted into the fuzzyfied form as

Maximize μ

Such that

Production:

$2530x_{1,1} + 680x_{1,2} + 500x_{1,3} + 2500x_{1,4} + 690x_{1,5} + 1200x_{1,6} + 750x_{1,7} + 740x_{1,8} + 850x_{1,9} + 1240x_{1,10} + 2500x_{2,1} + 1500x_{2,2} + 730x_{2,3} + 1030x_{2,4} + 900x_{2,5} + 300x_{2,6} - 6203\mu \geq 13378$

Profit:

$7160x_{1,1} + 5602x_{1,2} + 2450x_{1,3} + 19080x_{1,4} + 10880x_{1,5} + 36415x_{1,6} + 28945x_{1,7} + 32045x_{1,8} + 40171x_{1,9} + 49355x_{1,10} + 8025x_{2,1} + 45337x_{2,2} + 15280x_{2,3} + 26050x_{2,4} + 26240x_{2,5} + 1945x_{2,6} - 347320\mu \geq 108514$

Labour:

$130x_{1,1} + 72x_{1,2} + 66x_{1,3} + 78x_{1,4} + 96x_{1,5} + 62x_{1,6} + 49x_{1,7} + 33x_{1,8} + 36x_{1,9} + 86x_{1,10} \leq 325$

$86x_{2,1} + 146x_{2,2} + 42x_{2,3} + 79x_{2,4} + 78x_{2,5} + 46x_{2,6} \leq 325$

Land:

$x_{1,1} + x_{1,2} + x_{1,3} + x_{1,4} + x_{1,5} + x_{1,6} + x_{1,7} + x_{1,8} + x_{1,9} + x_{1,10} \leq 152395$

$x_{2,1} + x_{2,2} + x_{2,3} + x_{2,4} + x_{2,5} + x_{2,6} \leq 152395$

Food requirements:

$2530x_{1,1} \geq 400$

$2500x_{2,1} \geq 350$

$750x_{1,7} + 740x_{1,8} + 850x_{1,9} + 730x_{2,3} \geq 70$

Solving above linear programming problem using Lingo18.0, the result for the optimal crop planning model for area of different crops (in hectares) is as follows:

$X_{1,1}$	0.158103 ha. Land for Paddy
$X_{1,4}$	0.551864 ha. Land for Maize
$X_{1,9}$	7.261147 ha. Land for Moong
$X_{2,1}$	3.779070 ha. Land for Wheat

μ= 0.648284

VI.Conclusion

In the District of Hazaribag, majority of farmers fall into the category of semi-middle class or middle class. From the comparative study of the annual production reports of different crops during the Kharif season and the Rabi season we make conclusive decisions. Production of Maize and Groundnuts are maximum during Kharif season. Bajara and Jawar are the minimum. During the Rabi season, at Hazaribag District, the production of Wheat, Pea and Gram are recorded to be substantial, whereas linseed is expressed in the minimum production category. According to the findings, as reflected in the results, a farmer at best may earn a maximum profit of Rs 4, 55,834 only. Similarly, a farmer may achieve his goal of maximum production 19581 kg by planning his course of action through the multiple objective tasks.

In the cropping pattern expecting high economic return with variable factors of uncertainty and imprecision, application of the fuzzy concept in decision making has been successfully used to arrive at the aimed profit and the quantum of production.

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