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APPLICATION OF INTUITIONISTIC FUZZY OPTIMIZATION TECHNIQUES TO STUDY MULTI-OBJECTIVE LINEAR PROGRAMMING IN AGRICULTURAL PRODUCTION PLANNING IN BAKSA DISTRICT, ASSAM, INDIA

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Abstract

This paper aims to present a computational algorithm to solve multi-objective linear programming problems (MOLPP) with intuitionistic fuzzy optimization (IFO) in agricultural production planning problems. It also contains operations on intuitionistic fuzzy sets (IFS) as well as the fundamental properties of them. The algorithm is based on the idea of intersecting various intuitionistic fuzzy decision sets corresponding to obtaining an optimal decision set. In this study, Agricultural data from Baksa District was used to demonstrate the developed algorithm. The results obtained by the proposed approach are satisfying the constraints and achieve the defined goals in the most efficient manner possible by utilizing all of the farmer's property. This study shows the developed model and farmer's profit which is more than the farmer's aspiration level.

I. Introduction

In the Indian economy, one of the main objectives of agricultural production planning is to maximize profit with minimum investment and limited land. However, profit maximization and cost minimization isn't the only issue with agricultural production planning. A practical crop production planning issue has many objectives, including the optimization of input

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resources such as man-days (labor), machine hours, fertilizers, water requirements, etc. In nature, these objectives are also conflicting. Furthermore, the cost of cultivation and food grain prices fluctuate naturally due to various uncontrollable factors. As a result, these constraints are imprecise, ambiguous, and uncertain. The solutions to which problems are generally compromising solutions that satisfy the several objective functions that give rise to membership and non-membership.

Zimmermann [3], [4] were the first to apply the fuzzy set (FS) introduced by Zadeh [1] to a fuzzy multi-objective linear programming problem (FMOLPP).

Several researchers such as Tanaka [5], Luhandjula [7], Sakawa [9], and others have studied and applied optimization in a fuzzy environment. Sahinids [11] contains a brief analysis of various research worker's studies on optimization under uncertainty.

Atanassov [6] introduced the concepts of intuitionistic fuzzy sets (IFS) as a powerful extension of FS. In his research, Atanassov [8] emphasized that when dealing with imprecision, vagueness, or ambiguity in knowledge, the degree of membership (DOM) and the degree of non-membership (DONM) should be treated as two separate properties; they are not complementary. Angelov [10] proposed an intuitionistic fuzzy (IF) approach to optimizing problems using this concept of membership and non-membership in an optimization problem. Jana and Roy [12] investigated the intuitionistic fuzzy multi-objective linear programming (IFMOLPP) and applied it to the problem of transportation. To solve a multi-criteria decision-making problem (MCDM), Luo [13] used the inclusion degree of an IFS.

Many researchers, including Mahapatra et al., [14], Nachammai [17], and Nagoorgani [18], have investigated linear programming problems (LPPs) in IF environments. The LPP in the sense of the IF environment has been studied by Dubey et al. [15, 16] using IF numbers and interval ambiguity in fuzzy numbers. Bharati and Singh [19, 20] recently studied MOLPP in an IF environment.

This paper aims to develop a computational algorithm for solving MOLPP using an IFO method. In section two, preliminaries of IFO have been covered. The third section covers the computational algorithm for the crop production planning problem. Four sections cover the algorithm that has been implemented on an illustration. In the last section the result obtained has been placed followed by references [19, 20].

2. Preliminaries

2.1 Multi-Objective Linear Programming Problem (MOLPP).

A MOLPP with m objectives, n constraints, and s decision variables is described as follows:

$$\left.\begin{array}{c} \text{Max } \{Z_1, Z_2, \ldots, Z_m\} \\ \text{Subject to } g_j(X) \leq 0,\ j = 1, 2, \ldots, n \\ X = \{\chi_1, \chi_2, \ldots, \chi_s\} \\ \chi_i \geq 0,\ i = 1, 2, \ldots, s \end{array}\right\} \tag{1}$$

2.2 Intuitionistic fuzzy sets (IFS).

An IFS $\widetilde{A}_I$ in non-empty set X is defined as $\widetilde{A}_I = \{(\chi, \mu_{\widetilde{A}_I}(\chi), \upsilon_{\widetilde{A}_I}(\chi)) \mid \chi \in X\}$, where the functions $\mu_{\widetilde{A}_I} : X \to [0, 1]$ and $\upsilon_{\widetilde{A}_I} : X \to [0, 1]$ are denotes the DOM and the DONM to each element $\chi \in X$, respectively and for every $\chi \in X$ such that $0 \leq \mu_{\widetilde{A}_I}(\chi) + \upsilon_{\widetilde{A}_I}(\chi) \leq 1$.

Further, any FS A on a non-empty set X with Membership Function (MF) $\mu_{\widetilde{A}_I}$ is clearly an IF with Non-Membership Function (NMF) $\upsilon_{\widetilde{A}_I}(\chi) = 1 - \mu_{\widetilde{A}_I}(\chi)$, and thus IFS is a FS generalization.

The following are union and intersection of two IFS:

$$\widetilde{A} \cap \widetilde{B} = \{(\chi, \min(\mu_{\widetilde{A}}(\chi), \mu_{\widetilde{B}}(\chi)), \max(\upsilon_{\widetilde{A}}(\chi), \upsilon_{\widetilde{B}}(\chi))) \mid \chi \in X\}$$

$$\widetilde{A} \cup \widetilde{B} = \{(\chi, \max(\mu_{\widetilde{A}}(\chi), \mu_{\widetilde{B}}(\chi)), \min(\upsilon_{\widetilde{A}}(\chi), \upsilon_{\widetilde{B}}(\chi))) \mid \chi \in X\}$$

The max-min method is a FOT. For solving MOLP problems, Zimmermann first applied the max-min operator given by Bellman and Zadeh [2], and problem (1) is formulated as follows:

$$\left.\begin{array}{l}\text{Find } X \\ \text{Subject to } \; Z_k(\chi) \geq g_k,\; k = 1, 2, \ldots, m \\ g_j(\chi) \leq 0,\; j = 1, 2, \ldots, n \\ X \geq 0\end{array}\right\} \tag{2}$$

Where g_k, $\forall\chi$ denotes goals and all objective functions are assumed to be maximized. In this situation, the objective functions are considered as fuzzy constraints. First, we construct PIS from the obtaining objective values to determine the MF of objective functions. In the concept of min-operator, the interaction of the fuzzy objective set describes the feasible solution set. This set of feasible solutions is then defined by its membership $\mu_D(\chi)$, which is $\mu_D(\chi) = \min(\mu_1(\chi), \ldots, \mu_k(\chi))$.

Furthermore, in the feasible decision set, a decision-maker decides with the maximum μ_D value. The decision solution can be obtained by solving the maximize problem $\mu_D(\chi)$ while taking subject to the constraints i.e.

$$\text{Max } [\min \mu_k(\chi)]$$

Such that $g_j(\chi) \leq 0,\; j = 1, 2, \ldots, n$

Now, if we consider $\rho = \min_k \mu_k(\chi)$ being the overall acceptable degree of compromise, we get the following equivalent model:

$$\left.\begin{array}{l}\text{Max } \rho \\ \text{Such that } \; \mu_k(\chi) \geq \rho,\; \forall k \\ g_j(\chi) \leq 0,\; j = 1, 2, \ldots, n \\ X \geq 0\end{array}\right\} \tag{3}$$

2.3 Intuitionistic Fuzzy Optimization Technique (IFOT)

As a generalization of the previous problem, consider the IFO problem given by Angelov [3]

$$\left.\begin{array}{l}\text{Min } Z_i(\chi), \\ \text{Such that } \; g_j(\chi) \leq 0,\; j = 1, 2, \ldots, n\end{array}\right\} \tag{4}$$

Where χ, $Z_i(\chi)$, $g_j(\chi)$ are the decision variables, the objective functions, the constraint functions, and m and n are the number of objectives and constraints, respectively.

The solution to this model must exactly satisfy all constraints. As a result of an analogous fuzzy optimization model of the problem, the level of acceptance of objectives and constraints is maximized as follows:

$$\left.\begin{array}{l} \widetilde{\text{Min}}\ Z_i(\chi), \quad i = 1, 2, \ldots, m \\ \text{Such that} \quad g_j(\chi) \lesssim 0,\ j = 1, 2, \ldots, n \end{array}\right\} \tag{5}$$

Here $\lesssim$ denotes fuzzy inequality and $\widetilde{\text{Min}}$ represents fuzzy minimization.

Bellman and Zadeh [5] used a fuzzy set to solve such a system (5), maximizing the DOM of the objectives and constraints.

$$\left.\begin{array}{l} \text{Min}\ \mu_k(\chi), \quad k = 1, 2, \ldots, m+n \\ \text{Such that} \quad 0 \le \mu_k(\chi) \le 1 \end{array}\right\} \tag{6}$$

Where $\mu_k(\chi)$ denotes the DOM to which respective FS.

It's important to remember that the DONM in a FS is the complement of membership, so maximization of the MF would automatically minimize non-membership. However, in an IFS, the DONM is described simultaneously as the DOM, and the two degrees are not complementary, so IFS may provide a more general method for explaining this uncertainty based optimization model. As a result, the following is an IFO model for (6):

$$\left.\begin{array}{l} \max\limits_{\chi} \mu_k(\chi),\ k = 1, 2, \ldots, m+n \\ \min\limits_{\chi} \nu_k(\chi),\ k = 1, 2, \ldots, m+n \\ \text{Such that}\ \ \chi \in X \\ \nu_k(\chi) \ge 0,\ k = 1, 2, \ldots, m+n \\ \mu_k(\chi) \ge \nu_k(\chi),\ k = 1, 2, \ldots, m+n \\ \mu_k(\chi) + \nu_k(\chi) \le 1,\ k = 1, 2, \ldots, m+n. \end{array}\right\} \tag{7}$$

Where $\mu_k(\chi)$ be the DOM of χ to the k^{th} IFS and $\nu_k(\chi)$ be the DONM of χ from the k^{th} IFS. Intuitionistic fuzzy objectives (IFOs) and constraints are included in these IFS.

Now the decision set $\widetilde{D}_I$, which consists of intuitionistic fuzzy objectives and constraints, is now defined as follows:

$$\widetilde{F}_I \cap \widetilde{C}_I = \{\langle \chi, \min(\mu_{\widetilde{F}_I}(\chi), \mu_{\widetilde{C}_I}(\chi)), \max(\upsilon_{\widetilde{F}_I}(\chi), \nu_{\widetilde{C}_I}(\chi))\rangle\}, \tag{8}$$

Where $\widetilde{F}_I$ and $\widetilde{C}_I$ are denotes the integrated IFOs and the integrated IFOs are defined as follows:

$$\widetilde{F}_I = \{\langle \chi, \mu_{\widetilde{F}_I}(\chi), \nu_{\widetilde{F}_I}(\chi)\rangle \mid \chi \in X\} = \cap_{i=1}^{m} \breve{F}^i$$

$$= \{\langle \chi, \min_{i=1}^{m} \mu_i^f(\chi), \max_{i=1}^{m} \nu_i^f(\chi)\rangle \chi \in X\},$$

$$\widetilde{C}_I = \{\langle \chi, \mu_{\widetilde{C}_I}(\chi), \nu_{\widetilde{C}_I}(\chi)\rangle \mid \chi \in X\} = \cap_{i=1}^{n} \breve{C}^i$$

$$= \{\langle \chi, \min_{i=1}^{n} \mu_i^g(\chi), \max_{i=1}^{n} \nu_i^g(\chi)\rangle \chi \in X\}.$$

Now, the intuitionistic fuzzy decision set (IFDS) is denoted by $\widetilde{D}_I$ and is defined as:

$$\widetilde{D}_I = \widetilde{F}_I \cap \widetilde{C}_I = \{\langle \chi, \mu_{\widetilde{D}_I}(\chi), \nu_{\widetilde{D}_I}(\chi)\rangle \mid \chi \in X\} \tag{9}$$

$$\mu_{\widetilde{D}_I}(\chi) = \min\{\mu_{\widetilde{F}_I}(\chi), \mu_{\widetilde{C}_I}(\chi)\} = \min_{k=1}^{m+n} \mu_k(\chi) \tag{10}$$

$$\nu_{\widetilde{D}_I}(\chi) = \max\{\nu_{\widetilde{F}_I}(\chi), \nu_{\widetilde{C}_I}(\chi)\} = \min_{k=1}^{m+n} \upsilon_k(\chi) \tag{11}$$

Where $\mu_{\widetilde{D}_I}(\chi)$ denotes the DOM of IFDS and $\upsilon_{\widetilde{D}_I}(\chi)$ represents the DONM of IFDS.

For the feasible solution, the DOM of IFDS is always less than or equal to the DOM of any objective and constraint, whereas the DONM of IFDS is always greater than or equal to the DONM of any objective and constraint.

$$\mu_{\widetilde{D}_I}(\chi) \le \mu_k(\chi)$$

$$\nu_{\widetilde{D}_I}(\chi) \ge \upsilon_k(\chi) \ \forall k = 1, 2, \ldots, m+n.$$

Thus the above given inequalities system can be converted as follows:

As a consequence, the inequalities system above can be interpreted as follows:

$$\left.\begin{array}{l} \mu_k(\chi) \geq \rho,\ k = 1, 2, \ldots, m+n \\ \nu_k(\chi) \leq \sigma,\ k = 1, 2, \ldots, m+n \\ \rho + \sigma \leq 1 \\ \rho \geq \sigma \\ \sigma \geq 0 \\ \chi \in X \end{array}\right\} \tag{12}$$

Where ρ be the minimum DOM of objectives and constraints, and σ be the maximum DONM of objectives and constraints.

Now, problem (1) is converted into the LPP by using the IFO, which is given below:

$$\left.\begin{array}{l} \text{Maximize } (\rho - \sigma) \\ \text{Subject to } \mu_k(\chi) \geq \rho,\ k = 1, 2, \ldots, m+n \\ \nu_k(\chi) \leq \sigma,\ k = 1, 2, \ldots, m+n \\ \rho + \sigma \leq 1 \\ \rho \geq \sigma \\ \sigma \geq 0 \\ \chi \in X \end{array}\right\} \tag{13}$$

The simplex method for solving MOLPP by IFO will easily solve (13). Figure (a) depicts the MF and NMF for the maximization form objective function:

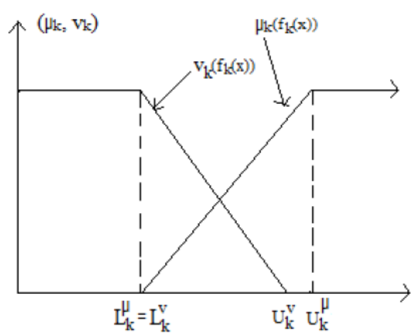

Figure (a).

3. Crop Production Planning Problem

Let m be the number of crops and $\chi_1, \chi_2, \ldots, \chi_m$ be the decision variables, denotes the cultivation for the crops $1, 2, \ldots, m$ and P_i, c_i, S_i and F_i be production, profit, labour (man-day) and fertilizer co-efficient for the crop's cultivation per hectare, respectively. Since land is limited and hence $\chi_1 + \chi_2 + \ldots + \chi_m$ is always less than or equal to a fixed number (say L). Also, let S be available labour (man-day). In order to maximize profits while minimizing costs of agricultural production then the mathematical formulation of MOLPP is given below:

$$\text{Max } Z_1(\chi) = P_1\chi_1 + P_2\chi_2 + \ldots + P_m\chi_m \text{ (Production)}$$

$$\text{Max } Z_2(\chi) = C_1\chi_1 + C_2\chi_2 + \ldots + C_m\chi_m \text{ (Profit)}$$

Such that

$$\chi_1 + \chi_2 + \ldots + \chi_m \le L \text{ (Land constraint)}$$

$$S_1\chi_1 + S_2\chi_2 + \ldots + S_m\chi_m \le S \text{ (Labour constraint)}$$

$$\sum_{i=1}^{m} f_i\chi_i \le F_i \quad \text{(Fertilizer constraints)}$$

$$\chi_1, \chi_2, \ldots, \chi_m \ge 0$$

4. Computational Algorithm

Step I. From the k objectives function, taking the first objective function and solving it as a single objective under the constraints given. Determine the value of decision variables and objective functions.

Step II. Calculate the values of the remaining $(k\text{-}1)$ objectives using the values of these decision variables.

Step III. For the remaining $(k\text{-}1)$ objective functions, repeat Steps I and II.

Step IV. To form a PIS table, tabulate the values of the objective functions obtained in Steps I, II, and III.

Step V. Determine the lower and upper bounds from Step IV for each objective function.

Table (A). Positive Ideal Solution (PIS).

	$1\ 2\ \ldots\ k$
Max $Z_1(\chi)$	$Z_1^*(\chi)\ Z_1^2(\chi)\ \ldots\ Z_1^k(\chi)$
Max $Z_2(\chi)$	$Z_2^1(\chi)\ Z_2^*(\chi)\ \ldots\ Z_2^k(\chi)$
$\vdots$	
Max $Z_k(\chi)$	$Z_k^1(\chi)\ Z_k^2(\chi)\ \ldots\ Z_k^*(\chi)$
	$Z_1^l(\chi)\ Z_2^l(\chi)\ \ldots\ Z_k^l(\chi)$

Where Z_k^* be the maximum value and Z_k^l be the minimum value, respectively.

Step VI. Set $U_k^{\mu} = \max(Z_k(\chi_t)),\ L_k^{\mu} = \min(Z_k(\chi)),\ 1 \leq t \leq m$ for MF and $U_k^{\upsilon} = U_k^{\mu} - \omega(U_k^{\mu} - L_k^{\mu}),\ L_k^{\nu} = L_k^{\mu},\ 0 < \omega < 1$ for NMF, respectively. In our problem, we have taken $\omega = 0.3$.

Step VII. For each objective function, the following $\mu_k(Z_k(\chi))$ is used for linear MF and $\nu_k(Z_k(\chi))$ is used for NMF:

$$\mu_k(Z_k(\chi)) = \begin{cases} 0 & \text{if } Z_k(\chi) \leq L_k^{\mu} \\ \dfrac{Z_k(\chi) - L_k^{\mu}}{U_k^{\mu} - L_k^{\mu}} & \text{if } L_k^{\mu} \leq Z_k(\chi) \leq U_k^{\mu} \\ 1 & \text{if } Z_k(\chi) \leq U_k^{\mu} \end{cases}$$

and

$$\nu_k(Z_k(\chi)) = \begin{cases} 0 & \text{if } Z_k(\chi) \leq U_k^{\nu} \\ \dfrac{U_k^{\nu} - Z_k(\chi)}{U_k^{\nu} - L_k^{\nu}} & \text{if } L_k^{\nu} \leq Z_k(\chi) \leq U_k^{\nu} \\ 1 & \text{if } Z_k(\chi) \leq L_k^{\nu} \end{cases}$$

Step VIII. Now, for MOLPP (1), using linear MF and NMF, the IFO approach gives the following LPP:

Maximize $(\rho - \sigma)$

Subject to

$$\left.\begin{array}{l}\mu_k(Z_k(\chi)) \geq \rho \\ \nu_k(Z_k(\chi)) \geq \rho \\ \rho + \sigma \leq 1 \\ \rho \geq \sigma \\ \sigma \geq 0 \\ g_j(\chi) \leq b_j,\ x \geq 0,\ k = 1, 2, \ldots, m; j = 1, 2, \ldots, n\end{array}\right\} \quad (14)$$

Step IX. By using the simplex method, the aboveLPP (14) can be easily solved.

5. Study Area

Baksa district is one of the four district of Bodoland Territorial Region of located at $26^0 35^/$ North to $26^0 83^/$ North latitude and $90^0 80^/$ East to $91^0 85^/$ East longitude in Bodoland Territorial Area Districts (BTAD), Assam India. Baksa district covers an area of 2400 sq. km. and is situated on the northern bank of the River Brahmaputra. It has the international and state boundaries with Bhutan on the north and also in the west side bounded by Chirang district, on the south by Nalbari, Barpeta and Kamrup (Rural) districts and on the east side by Udalguri district.

5.1 Numerical Illustration of Crop Production planning problem

According to the year of 2016-17, farmers growin the Baksa District, BTAD, Assam are winter rice, rape and master, jute during Khar if season, summer rice, lentil, ginger, turmeric, chilli, garlic, potato during Rabi season, autumn rice, maize during Summer season. The available cultivated land is 137955 ha with given labour hour constraint and available fertilizer for each season for nitrogen (N) are 4643300 kg, 99200 kg, 271000 kg, for Phosphorus (P) are 530500 kg, 140700 kg, 302200 kg and for Murate of potash (K) are 169400 kg, 92200 kg, 88600 kg. The available labour for each season is given to be 310 workers in the district. A small farm holder has taken from [21] at least 40 kg of Lentil, 650 kg of Rice, 450 kg of potato for his annual food grains requirement. The planning of farmers is a suitable crop combination model for his land to get maximum profit and his aspiration level of annual income is Rs. 148650/-. The above algorithm is implemented step by step to find an optimal solution of crop production for Baksa District, BTAD Assam. The objectives of the problem are to maximize the production and profit.

Table (B). Data is collected from District Agriculture Office, Baksa, for the year 2016-17.

Seasons	Name of Crops	Labour (/ha)	Fertilizer (kg/ha)			Production (Kg/ha)	Profit (Rs./ha)
			N	P	K		
Kharif Season	Winter Rice (χ_1)	150	60	20	40	3849	75265
	Rape and Master (χ_2)	80	40	35	15	1880	13322
	Jute (χ_3)	170	20	20	20	2290	18009
	Gram (χ_4)	80	15	35	0	870	40777
Rabi Season	Summer rice (χ_5)	150	40	20	20	4460	95992
	Lentil Lentil (χ_6)	80	15	35	0	1122	41064
	Ginger (χ_7)	188	20	60	20	17212	695142
	Turmeric (χ_8)	300	30	50	60	27910	1504078
	Garlic (χ_9)	120	100	80	60	5410	132746

	Potato (χ_{10})	120	60	50	50	25015	118245
Summer season	Autumn Rice (χ_{11})	150	40	20	20	3155	49955
	Maize (χ_{12})	100	60	40	40	3079	37842

Now using the above table, we have the mathematical formulation as a MOLP problem is as follows:

Production:

$$\text{Max } Z_1(\chi) = 3849\chi_1 + 1880\chi_2 + 2290\chi_3 + 870\chi_4 + 4460\chi_5 + 1122\chi_6$$
$$+ 17212\chi_7 + 27910\chi_8 + 5410\chi_9 + 25015\chi_{10} + 3155\chi_{11} + 3079\chi_{12}$$

Profit:

$$\text{Max } Z_2(\chi) = 75265\chi_1 + 13322\chi_2 + 18009\chi_3 + 40777\chi_4 + 95992\chi_5$$
$$+ 41064\chi_6 + 695142\chi_7 + 1504078\chi_8 + 132746\chi_9 + 118245\chi_{10}$$
$$+ 49955\chi_{11} + 37842\chi_{12}$$

Subject to the constraints:

$$\left.\begin{array}{l} 150\chi_1 + 80\chi_2 + 170\chi_3 + 80\chi_4 \le 310 \\ 150\chi_5 + 80\chi_6 + 188\chi_7 + 300\chi_8 + 120\chi_9 + 120\chi_{10} \le 310 \\ 150\chi_{11} + 100\chi_{12} \le 310 \end{array}\right\}$$

(Labour Constraints)

$$\left.\begin{array}{l} \chi_1 + \chi_2 + \chi_3 + \chi_4 \le 137955 \\ \chi_5 + \chi_6 + \chi_7 + \chi_8 + \chi_9 + \chi_{10} \le 137955 \\ \chi_{11} + \chi_{12} \le 137955 \end{array}\right\} \text{(Land Constraint)}$$

$$1122\chi_6 \ge 40$$
$$3849\chi_1 + 4460\chi_5 + 3155\chi_{11} \le 650$$
$$25015\chi_{10} \ge 450$$

$$\left.\begin{array}{l}60\chi_1 + 40\chi_2 + 20\chi_3 + 15\chi_4 \le 464300\\ 40\chi_5 + 15\chi_6 + 20\chi_7 + 30\chi_8 + 100\chi_9 + 60\chi_{10} \le 99200\\ 40\chi_{11} + 60\chi_{12} \le 271000\end{array}\right\}$$

(Fertilizer N constraints)

$$\left.\begin{array}{l}20\chi_1 + 35\chi_2 + 20\chi_3 + 35\chi_4 \le 530500\\ 20\chi_5 + 35\chi_6 + 60\chi_7 + 50\chi_8 + 80\chi_9 + 50\chi_{10} \le 140700\\ 20\chi_{11} + 40\chi_{12} \le 302200\end{array}\right\}$$

(Fertilizer P constraints)

$$\left.\begin{array}{l}40\chi_1 + 15\chi_2 + 20\chi_3 + 0\chi_4 \le 169400\\ 20\chi_5 + 0\chi_6 + 20\chi_7 + 60\chi_8 + 60\chi_9 + 50\chi_{10} \le 92200\\ 20\chi_{11} + 40\chi_{12} \le 88600\end{array}\right\}$$

(Fertilizer K constraints)

$$\chi_1, \chi_2, \ldots, \chi_{12} \ge 0$$

To this crisp linear programming problem, using Step I, we have an optimal solution that is

$(Z_1)_1 = 81567.05$ kg. and $\chi_1 = 2.066667$, $\chi_6 = 0.3565062$, $\chi_{10} = 2.559566$, $\chi_{12} = 3.1$

By putting these decision variables in the second objective applying Step II, we have

$$(Z_2)_1 = 590153.3440218 \text{ Rs.}$$

As mentioned in Step III, we can repeat Step I for the second objective function with the same constraints; we have

$(Z_2)_2 = 1807803$ Rs. and $\chi_1 = 0.1688750$, $\chi_4 = 3.558350$, $\chi_6 = 0.3565062$, $\chi_8 = 1.0116631$, $\chi_{10} = 0.1798921$; $\chi_{12} = 3.1$

By Step II, putting these decision variables in the first objective, we have

$$(Z_1)_2 = 46564.9068605 \text{ kg.}$$

The PIS has been given in Table (C) by Step IV from the above solutions:

Table (C). Positive Ideal Solution (PIS).

	1	2
Z_1	81567.05	46564.9068605
Z_2	590153.3440218	1807803

From table (C) we have $(Z_1)_1 = 81567.05$ kg. and $(Z_2)_2 = 1807803$ Rs. are maximum value for production and profit and $(Z_1)_2 = 46564.9068605$ kg.; $(Z_2)_1 = 590153.3440218$ Rs. Are minimum value for production and profit.

Now using Step VI, Step VII and Step VIII the above MOLP problem becomes $\text{Max}(\rho - \sigma)$

Such that

$$3849\chi_1 + 1880\chi_2 + 2290\chi_3 + 870\chi_4 + 4460\chi_5 + 1122\chi_6 + 17212\chi_7 + 27910\chi_8 + 5410\chi_9 + 25015\chi_{10} + 3155\chi_{11} + 3079\chi_{12} - 46564.91 \geq 35002.14\rho$$

$$75265\chi_1 + 13322\chi_2 + 18009\chi_3 + 40777\chi_4 + 95992\chi_5 + 41064\chi_6 + 695142\chi_7 + 1504078\chi_8 + 132746\chi_9 + 118245\chi_{10} + 49955\chi_{11} + 37842\chi_{12} - 590153.34 \geq 1217649.66\rho$$

$$78066.836 - 3849\chi_1 + 1880\chi_2 + 2290\chi_3 + 870\chi_4 + 4460\chi_5 + 1122\chi_6 + 17212\chi_7 + 27910\chi_8 + 5410\chi_9 + 25015\chi_{10} + 3155\chi_{11} + 3079\chi_{12} \leq 31501.926\sigma$$

$$1686038.034 - 75265\chi_1 + 13322\chi_2 + 18009\chi_3 + 40777\chi_4 + 95992\chi_5 + 41064\chi_6 + 695142\chi_7 + 1504078\chi_8 + 132746\chi_9 + 118245\chi_{10} + 49955\chi_{11} + 37842\chi_{12} \leq 1095884.694\sigma$$

$$150\chi_1 + 80\chi_2 + 170\chi_3 + 80\chi_4 \le 310$$
$$150\chi_5 + 80\chi_6 + 188\chi_7 + 300\chi_8 + 120\chi_9 + 120\chi_{10} \le 310$$
$$150\chi_{11} + 100\chi_{12} \le 310$$

$$1122\chi_6 \ge 40$$
$$3849\chi_1 + 4460\chi_5 + 3155\chi_{11} \le 650$$
$$25015\chi_{10} \ge 450$$

$$\chi_1 + \chi_2 + \chi_3 + \chi_4 \le 137955$$
$$\chi_5 + \chi_6 + \chi_7 + \chi_8 + \chi_9 + \chi_{10} \le 137955$$
$$\chi_{11} + \chi_{12} \le 137955$$

$$60\chi_1 + 40\chi_2 + 20\chi_3 + 15\chi_4 \le 464300$$
$$40\chi_5 + 15\chi_6 + 20\chi_7 + 30\chi_8 + 100\chi_9 + 60\chi_{10} \le 99200$$
$$40\chi_{11} + 60\chi_{12} \le 271000$$

$$20\chi_1 + 35\chi_2 + 20\chi_3 + 35\chi_4 \le 530500$$
$$20\chi_5 + 35\chi_6 + 60\chi_7 + 50\chi_8 + 80\chi_9 + 50\chi_{10} \le 140700$$
$$20\chi_{11} + 40\chi_{12} \le 302200$$

$$40\chi_1 + 15\chi_2 + 20\chi_3 + 0\chi_4 \le 169400$$
$$20\chi_5 + 0\chi_6 + 20\chi_7 + 60\chi_8 + 60\chi_9 + 50\chi_{10} \le 92200$$
$$20\chi_{11} + 40\chi_{12} \le 88600$$

$$\chi_1, \chi_2, \ldots, \chi_{12} \ge 0$$

Now, solving the above problem using Lingo software, the results for the optimal crop planning model for land of different crops (in hacter) is as follows:

Land for Winter Rice in Kharif Season: $\chi_1 = 2.067$,

Land for Rape and Master in Kharif Season: $\chi_2 = 0$,

Land for Jute in Kharif Season: $\chi_3 = 0$,

Land for Green Gram in Kharif Season: $\chi_4 = 0$,

Land for Summer rice in Rabi Season: $\chi_5 = 0$,

Land for Lentil in Rabi Season: $\chi_6 = 0.3565062$

Land for Ginger in Rabi Season: $\chi_7 = 0$,

Land for Turmeric in Rabi Season: $\chi_8 = 0.5100635$,

Land for Garlic in Rabi Season: $\chi_9 = 0$,

Land for Potato in Rabi Season: $\chi_{10} = 1.284407$,

Land for Autumn Rice in Summer Season: $\chi_{11} = 0$,

Land for Maize in Summer Season: $\chi_{12} = 3.1$,

Degree of membership: $\rho = 0.4953958$ and Degree of non- membership: $\sigma = 0.2922917$.

Now, putting the values of $\chi_1, \chi_2, \chi_3, \chi_4, \chi_5, \chi_6, \chi_7, \chi_8, \chi_9, \chi_{10}, \chi_{11}, \chi_{12}$ in objective functions, we get the maximum production $Z_1(\chi)$ and maximum profit $Z_2(\chi)$ whose values are 64266.10 kg and Rs. 1206572.52/-.

6. Conclusion

In this study, we used intuitionistic fuzzy inequalities to describe objective functions and constraints to represent the farmers crop planning problems in practical scenarios because production and profit cannot be established as crisp inequalities due to parameter imprecision. As a result, MOLPP naturally becomes IFMOLPP. Using developed algorithms, we converted an IFMOLPP into a crisp linear programming issue using an IF approach. To obtain an ideal crop production model, the developed algorithm was implemented. The results obtained by the proposed approach are interesting because they satisfy the constraints and achieve the defined goals in the most efficient manner possible by utilising all of the farmer's property. Further, the developed model gives farmers a profit of Rs. 1206572.52/-, which is more than the farmer's aspiration level of Rs. 148650/-. As a result, the proposed method can be used to effectively deal with crop modelling issues.

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