A Fuzzy Approach to Linear Programming in Agriculture Land Allocation

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ABSTRACT
The agri-supply chain involves a number of highly uncertain factors, such as soil content, rainfall, humidity, and production forecasts, which may be addressed using fuzzy logic, which has proved to be helpful in managing uncertainty in a number of Concerns pertaining to agriculture. While establishing the best option for agriculture production planning, land constraints play a vital role. In agriculture, "land constraint" refers to limits or conditions placed on agricultural activities based on the quantity and quality of available land. This restriction may have a major effect on the agricultural sector's overall growth, sustainability, and productivity. The output function is the primary purpose of agricultural land; yet, as technology advances, the risk associated with land output is rising, particularly in places that produce a lot of grain and in urban suburbs. The proposed study suggest a fuzzy linear mathematical programming method (FLMP) aimed at the best distribution of arable land. FLMP is a more practical as well as adaptable way to find the optimal solution under uncertain circumstances like determining agricultural land distribution for different crops to optimize profit. The proposed model administrate the decision-making issues which are constructed with aspects of uncertainty and defined using fuzzy linear programming (FLP) models. For this purpose, A numerical example is also illustrated by using triangular fuzzy membership function. Making decisions by using this type of approximation can be practical and more profitable for land owners.

Keywords: Fuzzy linear programming (FLP), Triangularmembership function, Parametric Form,LINGO 20.0, Land distribution

INTRODUCTION

Agriculture is undoubtedly the back bone of Indian economic system. In agriculture domain, uncertainty like weather, rain, crop diseases, changing demands etc. is a vital factor which cannot be ignored. An expert system which can suitably minimize risks and optimize productions and profits can help farmers to do right things at right times. Generally, the challenge in agricultural production planning is to optimize profit while meeting labor, land, and food requirements. Due to the tremendous strain that population expansion is placing on agricultural resources, food security has become a global problem. To fulfill the growing demands of the population, there is always a need for increased manufacturing. More production does not guarantee more profits. We have to determine optimal combination of variables involved in production planning in order to best use of available resources and maximize profits. One effective strategy for managing land use risk in the context of sustainable agriculture is land use management. A classic example of a systematic project is the management of agricultural land and ecological environmental risk control. In agriculture, "land constraint" refers to limits or conditions placed on agricultural operations based on the quantity and quality of available land. The availability of arable land fit for agriculture is a prerequisite for agricultural activity. When there is a restricted quantity of arable and productive land, land restriction results. The productivity, sustainability, and general growth of the agriculture industry may all be strongly impacted by this restriction. While using land, we should carefully evaluate the significant impact on the ecological environment as well as the real needs of social and economic growth. In order to ensure that agricultural land usage is environmentally and ecologically friendly, managers must also deal with this practical issue: how to allocate land resources rationally and achieve benefits for the economy, society, and ecology. Choosing the optimal land distribution, labor cost and capital management to place crops in their fields in order to achieve the best potential results frequently presents a challenge for farmers. In considering land use, it is important to consider both the real demands for economic and social development and the reflective ecological impact. In agricultural land management, this is also a very realistic problem; how to realistically assign land resources in order to ensure ecological and environmental sustainability. Agricultural potential is defined as the land's maximum production capacity under current farming technologies. Agricultural productivity can be boosted by properly using resources. Linear programming is the technique most commonly employed in agricultural planning. Also agriculture is field associated with issue of risks and uncertainty at any moment of time. So, optimization of productivity and profits in agriculture production planning can be ideally dealt with Fuzzy objective decision making. Here we opted for Fuzzy linear programming problem (FLPP) for constructing the model with the help of triangular membership function. A linear programming model also includes parameters, much like in real-world circumstances whose values are yet to be known but allocated by problem solver as these assigned values are imprecise, the expert must cope with ambiguity. The concept of Fuzzy in decision making was initially introduced by Lotfi Zadeh [1] .Zimmermann [2] and Ross [6] suggested to solve linear optimization problem to find optimal solution of several objective function. A parametric approach can be found in S.Chanas [3]. Maleki et.al. [4] and K. Ganesan et.al. [5] also proposed study about fuzzy linear programming using fuzzy variables and trapezoidal membership function represented different membership functions for multi objective FLPP respectively.Senthilkumar and G. Rajendran [7]has developed the technique to solve FLPP consisting fuzzy variables by using parametric form. . H.M.I.U.Herath and D.M.Samarthunga [8] and Yang G et.al.[12] presented different membership functions for multi objective FLPP . M.A.Lone et al.[9] gave an approach for finding optimum allocation for FLPP by using trapezoidal membership function. Bharati et.al. [10] proposed computational algorithm for the solution of multiobjective goal programming in interval valued fuzzy programming method. Ren[11] proposed multiobjective stochastic fuzzy programming methods that can be used to find the optimal allocation of agricultural water. Mitlif [13 and 18] optimized the goal function by using ranking function and fuzzy fractional programming in decision-making. Land allocation for optimum production planning through multi objective LPP is suggested by Basumatary et.al [14].Wang y. [15] described a mathematical model of fuzzy LPP under the restrictions of elastic constraints. Hakamanage et.al. [16] proposed multicorp cultivation programming approach by fuzzy goal programming. Nawaki [17] andI.U. Khan [19] also used fuzzy programming to solve multi objective goal programming to improve agriculture crop production. Fakhrahmad et.al [20]addressed the current technique for predicting neighborhood satisfaction under ambiguous conditions.Mahmudirad [21] provided an innovative Method for Resolving Linear Programming Issues Using Intuitionistic Fuzzy Numbers. Mahmud et.al. [22] created a modeling system that uses machine learning to forecast activity concentration.Hamadameen et.al.[23]implemented a novel method to address the fully fuzzy multiobjective linear programming (FFMLP) conundrum. The transformation of the fuzzy number linear programming problem (FNLPP) into an interval number linear programming problem was introduced by G. Wang et al. [24].

As a result, the decision support system for using land can be suggested by combining the aforementioned relevant models and research findings with the ideas for building a decision support system. Under a variety of ecological constraints, decision makers can intuitively determine the optimal land use structure using predicted results. This paper proposes an approach to solving fuzzy linear programming (FLP) with triangular membership functions.

Fuzzy logic architecture

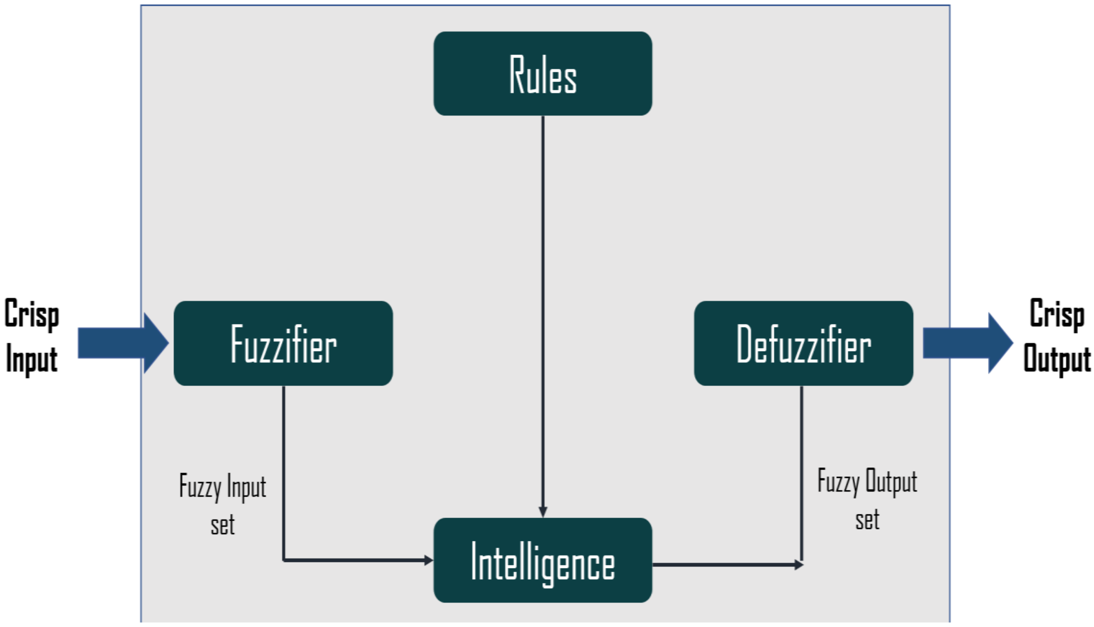
There are four components to its architecture:

1. Rule base: It is a collection of rules and IF-THEN conditions that are offered by experts to regulate a decision-making system. These rules are based on linguistic information.

2. Fuzzification: This is the process of transforming crisp numerical inputs into fuzzy sets.Essentially, crisp inputs are precise inputs that are detected by sensors and sent to the control system for processing.

3. The interference: selects which rules should be executed based on the input field by calculating the degree to which the current fuzzy input matches each rule.

4. Defuzzification: It is the process of transforming the fuzzy sets generated by the inference engine into a precise, non-fuzzy value.Multiple defuzzification strategies are available, and the most appropriate one is selected for usage with a particular expert system.



Model formulation

The general form of linear programming problem is given by

Maximize Z = CY

Subjected to AY ≤ B (1)

Y≥ 0

Where C is row vector of the form 1x n, A is m x n coefficient matrix, B is column vector of all crisp parameters of the form n x 1 and Y is a n x 1 column vector of decision variables.

Fuzzy multi objective linear programming problem (FMOLPP)

A FMOLPP with K objective functions can be expressed as

Maximize /Minimize $\tilde{Z}_P(Y) = (\tilde{Z}_1(Y), \tilde{Z}_2(Y), \ldots, \tilde{Z}_K(Y))$
$= (\tilde{C}_1 Y, \tilde{C}_2 Y, \ldots, \tilde{C}_K Y)$

Subject to

$\tilde{\alpha}_i Y \approx \tilde{\beta}_i$ i = 1,2,……..,m_1

$\tilde{\alpha}_i Y \leq \tilde{\beta}_i$ i =$m_1 + 1, m_1 + 2, \ldots, m_2$

$\tilde{\alpha}_i Y \geq \tilde{\beta}_i$ i =$m_2 + 1, m_2 + 2, \ldots, m$

$Y \geq 0$.

Here,

$\tilde{C}_P = (\tilde{C}_{P1}, \tilde{C}_{P2}, \ldots, \tilde{C}_{Pm})$, P = 1,2,……..,K denote the fuzzy parameters involved in the objective function.

$A = \tilde{\alpha}_i = (\tilde{\alpha}_{i1}, \tilde{\alpha}_{i2}, \ldots, \tilde{\alpha}_{im})$ and $B = \tilde{\beta}_i = (\tilde{\beta}_1, \tilde{\beta}_2, \ldots, \tilde{\beta}_m)$ represents the fuzzy parameters involved in the constraints correspondingly.

$Y = (Y_1, Y_1, \ldots, Y_m)T$

Definitions

1.If a fuzzy vector Y satisfies set of constraints AY≤ B, it is referred to as the FLPP's basic solution.

2. If a fuzzy vector Y satisfies a set of restrictions and non negativity conditions, it is called feasible solution of the FLPP.

3.In FLPP, an optimal solution is one in which fuzzy vector Y optimizes the objective function Z=CY.

4. The optimal value of FLPP refers to the outcome value of the objective function that is attained by the best solution.

5. The Characteristic function χ_A of crisp set A subset of universal set X assigns every element of X a value of either 0 or 1. A fuzzy membership function of set A on universe of discourse X is defined as $\mu_A : X \rightarrow [0,1]$ where each value of X is assigned value between 0 and 1 called degree of membership.

Fuzzy number

If a fuzzy set Ã that is defined on the set of real numbers R satisfies the following criteria , it is considered a fuzzy number:

(i)$\mu_{\tilde{A}}$ (y_0) is peicewise continuous.

(ii)∃ at least one y ∈ ℝ with $\mu_{\tilde{A}}$ (y) =1

(iii) if $y_1, y_2 \in \mathbb{R}$, it satisfies the condition:

$\tilde{A}(\lambda y_1 + (1-\lambda)y_2) \geq \min[\tilde{A}(y_1), \tilde{A}(y_2)]$ $\forall y_1, y_2 \in \mathbb{R}$ and $\lambda \in \mathbb{R}$.

Generalised triangular fuzzy number

A generalized triangular fuzzy number F is denoted by (a,b,c,w_0) and its membership function is given by

$$\mu_A(X) = \begin{cases} 0, & Y < a \\ \frac{w_0(Y-a)}{b-a}, & a \leq X \leq b \\ \frac{w_0(c-Y)}{c-b}, & \text{b} \leq X \leq c \\ 0, & X > c \end{cases} \tag{2}$$

Triangular fuzzy number

A fuzzy number F is referred to be triangular fuzzy number denoted by (Y,a, b, c) if its membership function is given by

$$\mu_A(X) = \begin{cases} 0, & Y < a \\ \frac{Y-a}{b-a}, & a \leq X \leq b \\ \frac{c-Y}{c-b}, & \text{b} \leq X \leq c \\ 0, & X > c \end{cases}$$

(3)Parametric form of triangular fuzzy function

The parametric form of a fuzzy number is defined as ordered pair of functions $a_{\min}(\alpha)$ and $a_{\max}(\alpha)$, $0 \leq \alpha \leq 1$ where $a_{\min}(\alpha)$ and $a_{\max}(\alpha)$ are bounded left increasing and bounded right decreasing functions defined on [0,1].

Let A= $(\alpha^1, \alpha^2, \alpha^3)$ be any fuzzy triangular number, its parametric form can be written as

A = $((a^2 - a^1)\alpha + a^1, a^3 - \alpha(a^3 - a^2))$

LPP (1) can be expressed in parametric form as

Max Z = $C_1 (X_{1L}, X_{1R})$+…………+ $C_n (X_{nL}, X_{nR})$

Subjected to

$a_{k1} (X_{1L}, X_{1R})$+…………+ $a_{kn} (X_{nL}, X_{nR}) \leq (b_{nL}, b_{nR})$

$X_{jL}, X_{jR} \geq 0$, $\forall$ k=1,2,3…..,m and j=1,2,3,…,n

Numerical illustration

A land owner has approximately 20 acres land on which he wants to plant three crops: wheat, pulse and millet. Each of the crops has specific capital (in dollars) and labour (in hours) requirements presented in table I:

Table 1

Crop(peracre)	Capital($)	Labor (hrs.)
Wheat	60	9
Pulse	55	8
Millet	45	5

In this illustration, the profit earned per acre of wheat is \$45, the profit per acre of pulse is \$38, and the profit per acre of millet is \$30.The total amount of money and time that can be used to cultivate these crops is is approximately \$920 and 102 hours, respectively.Now, to maximize the farmer's profit, it is necessary to calculate the number of acres that should be planted with each crop. Assume that X_1 is the area planted with wheat, X_2 is the area planted with pulses, and X_3 is the area planted with millet. A triangular fuzzy number is used to represent each vague piece of information as 20 hectares = (18,20,22); about 920\$ = (870,920,960); around 102 hours = (100,102,105)

This information can be modeled in the form of Fuzzy linear programming problem (FLPP) as

$MaxZ=45 X_1 + 38 X_2+ 30X_3$

Subjected to

$60 X_1 + 55 X_2+ 45 X_3 \leq (870,920,960)$

$9X_1 + 8X_2+ 5X_3 \leq (100,102,105)$

$X_1+X_2+X_3 \leq (18, 20, 22)$

$X_1,X_2,X_3 \geq 0$

The aforementioned FLPP's crisp multi-objective linear programming can be stated as

$MaxZ_L= 45 X_{L1}+38X_{L2}+30 X_{L3}$and

$MaximizeZ_R= 45 X_{R1}+38X_{R2}+30X_{R3}$

Subjected to

$60 X_{L1}+ 55 X_{L2} +45 X_{L3} \leq 50\alpha + 870$

$60X_{R1}+ 55 X_{R2} +45X_{R3} \leq 960 - 40\alpha$

$9 X_{L1}+ 8 X_{L2} + 5 X_{L3} \leq 2\alpha + 100$

$9 X_{R1}+ 8 X_{R2} + 5 X_{R3} \leq 105 - 3\alpha$

$X_{L1}+ X_{L2} + XL3 \leq 2\alpha + 18$

$X_{R1}+ X_{R2} + X_{R3} \leq 22 - 2\alpha$

$X_{L1}, X_{L2}, X_{L3}, X_{R1}, X_{R2}, X_{R3} \geq 0; 0 \leq \alpha \leq 1$

Table II shows the outcomes of different values of α, we have considered four values of α(two boundary values and two intermediate values)

Table 2

α	**0**	**0.50**	**0.75**	**1**
X_{L1}	2.5	1.5	1	0.5
X_{L2}	0	0	0	0
X_{L3}	15	17.5	18.5	19.5
X_{R1}	0	0.547	0.625	0.5
X_{R2}	0	0	0	0
X_{R3}	21	19.714	20.437	19.5
Maximize Z_L	577.5	592.5	600	607.5
Maximize Z_R	630	616.07	615.93	607.5

RESULT AND DISCUSSION

LINGO 20.0 [25] is used to solve given LPP and obtain the optimum results to acquire the ideal solutions across varying degrees of fuzziness, denoted by distinct values of α. The parameter α, generally ranging from 0 to 1, pertains to the confidence level or degree of membership within the fuzzy set. Elevated values of α signify a greater confidence in the solution (approaching a crisp scenario), whereas diminished values of α reflect increased uncertainty or fuzziness in the data.For the different values of α presented, Table II provides outcomes of crisp linear programming.

The optimal solution of given original problem is obtained X_1=(2.5,1.5,1,0.5), X_2=(0,0,0,0), X_3=(15,17.5,18.5,19.5) and optimum value is Z= (577.5,592.5,600,607.5). These figures reflect the area assigned to various crops (designated as X_1, X_2, and X_3) across varying levels of α. From Table II, it can be observed that which cropping combinations provide the best optimal solution under the fuzzy based environment for various values of α.

CONCLUSION

Agricultural production planning is the subject of this study, which discusses the application of fuzzy linear programming as a solution to the problem involved.It elucidates the methods employed by the farmer to optimize outcomes given the constraints of limited assets andhow a crisp multi-objective linear programming problem is created from an FLPP. We have used fuzzy triangular number in order to fuzzification of the problem. Compared to precise values, these fuzzy numbers are more useful in modeling the inherent uncertainties. The use of fuzzy linear programming in agricultural production facilitates the integration of uncertainty and adaptability in the planning process.Other membership functions as trapezoidal, Z-shaped, pi function etc. can also be considered to obtain best possible optimal solutions. Optimizing agricultural outcomes is the ultimate aim. This is achieved by turning the fuzzy issue into a crisp, multi-objective linear programming problem that can be solved and provide useful solutions for farmers.

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