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A Review on Fuzzy Systems and Its Application in Agriculture

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ABSTRACT

Nowadays agriculture is characterized by the various optimization techniques that take a crucial role in the making decisions during the planning related to agriculture production.In India, agriculture has a long and important history. India is currently the world's second-largest producer of agricultural products. Agriculture has made a significant contribution to India's GDP over the past year, but because of a lack of efforts, it is slowly shrinking as the nation's economy grows. Numerous developments and experiments have been conducted in this subject over the years.One of these is fuzzy systems, which are utilized in agriculture for a variety of tasks, such as seed selection, soil preparation, pesticide management, water scheduling, weed control etc. with the goal of improving crop yields.To reason about data, the fuzzy expert system uses a set of rules and membership functions. Fuzzy expert systems are focused on numerical processing, in contrast to traditional expert systems, which are primarily symbolic reasoning engines. The goal of the paper is to shed light on what fuzzy systems are,what are the applications,how these applications are applied in different fields and how these systems are helping mankind and to analyze the various fuzzy systems, its applications, different approaches and various membership functions that are used to optimize the crop yield.

Keywords: Crops,Agriculture,Membership function,MCDM,Cluster Analysis, FAHP, FTopsis.

1. INTRODUCTION

Professor and computer scientist Lotfi Zadeh is universally famous as the creator of a conceptual framework known as fuzzy logic, an early method of dealing with artificial intelligence.The basis for human survival is agriculture, which has a significant impact on economic and social development[2].Economic and social development is being greatly impacted by the growing problem of food shortage due to the ever-increasing population[3,4]. It's critical to focus on protecting water and soil resources during agricultural production[5]. We must ensure that the production conditions and economic benefits are maintained and improved environment and natural resources while maximizing the profit.Sustainable development requires the wise development and use of water and land resources, as well as the preservation of agricultural economic development.FL is an approach that can swiftly compile the necessary knowledge in the field of Agriculture and arrive at sound diagnostic conclusions. Based on risk factors and symptoms, agricultural plants' probable diseases will be calculated and predicted.

In 1978,H.J.Zimerman presented the idea of fuzzy programming in his research paper FP and LP with multiple goal functions published in the journal of FSS.In that he showed the uses of FLP method to untwisted vector maximum problem. It is evident that the solutions found through fuzzy linear programming are consistently effective. Different methods of combining objective functions are demonstrated to show the consequences of identifying an 'optimal' compromise solution[10].In 1986,Tiwari,Dharmer and Rao introduced The hierarchy of priorities within FGP.This is an efficient computational algorithm for solving FGP and is achieved by utilizing the lexicographic order of GP[13].In 2003, Pal, Monitor and maulik presented that MOLFP problems can be solved by using an FGP procedure[12].J.F.Webb, T. Ganesan, I.Elamvazuthi, P. Vasant played a role in 2009 and showed that a FLPP with fuzzy quantities and logistic membership functions as parameters can be solved[11].A FMCGDM model was presented by Jayakumar and Ganesh in 2012 to choose rice varieties and also developed sixteen criteria from literature to select rice varieties After reviewing literature and conducting practical examination. Consolidation of

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decision-making processes is achieved through the use of a fuzzy set,new fuzzy ranking method,analytic hierarchy process, and the linguistic values[8]. In 2014,S. Jayakumar and Hari Ganesh proposed a modern path for the generalized fuzzy ranking of TFNs established on the centroid's radius of gyration point.The proper sequence of the generalized and common trapezoidally twisted numbers is one of the major advantages of this method. The benefits of the suggested method for ranking fuzzy numbers have also been demonstrated through a few comparative examples[14] and they also gave new method for the problems faced by farmers while paddy cultivation by ranking fuzzy numbers using radius of gyration centroid point[7].They also developed a method to calculate the minimum cost of cultivating different crops from every region within a given realm and to identify the crop's lowest price field for farming.[6]. A fuzzy clustering model has been created to assess the appropriateness of land for farming established on the nutrient requirements of different agronomy crops[9]. In 2021,Doan,Massa,Tison and Naceur proposed the combination of the method of homotopy perturbation along with the kriging surrogate model is utilized to enhance efficiency of fuzzy linear buckling analysis in the context of additively manufactured lattice structures.The purpose of this study is re view the developments of the various MCDM,Fuzzy methods.

We began with some basic definitions,membership functions and fuzzy numbers and explored various methods of fuzzy MCDM models and lastly we present a few examples on fuzzy logic in Agriculture as well as in other fields.

2. PRELIMINARIES

All definitions in the section are taken from literature [6 8 15 16].

3.1. Definition: Fuzzy Set:

A FS on X is a function $\mu : X \rightarrow [0, 1]$. Where μ is known as membership function, $\mu(x)$ is membership grade of x in μ and we can write it as $\mu = \{(x, \mu(x))\} : x \in X\}$

3.2. Definition:Fuzzy Number:A

Fuzzy set $A$is a fuzzy number if its membership function is piecewise continuous,is a normalised fuzzy set and is a fuzzy convex set.

3.3 Membership Functions(MF):

The MF graph illustrates the assignment about a membership value between 0 and 1 to every point in the input space.It enables us to measure linguistic terms and visually represents fuzzy set.The MF spans from 0 to 1.The number 0 is utilized to indicate full absence in the function while The complete membership function is represented by the value 1 and the value between is utilized to represent membership tiers in between.

Fuzzy set A's membership function on X is formally described as , μ(x) = X → [0, 1]. The element's membership degree in X is quantified to FS 'A' whereas X symbolizes the cosmos of discourse and the Y signifies level of membership within scope of [0,1].The design of fuzzy logic consists of four major components.

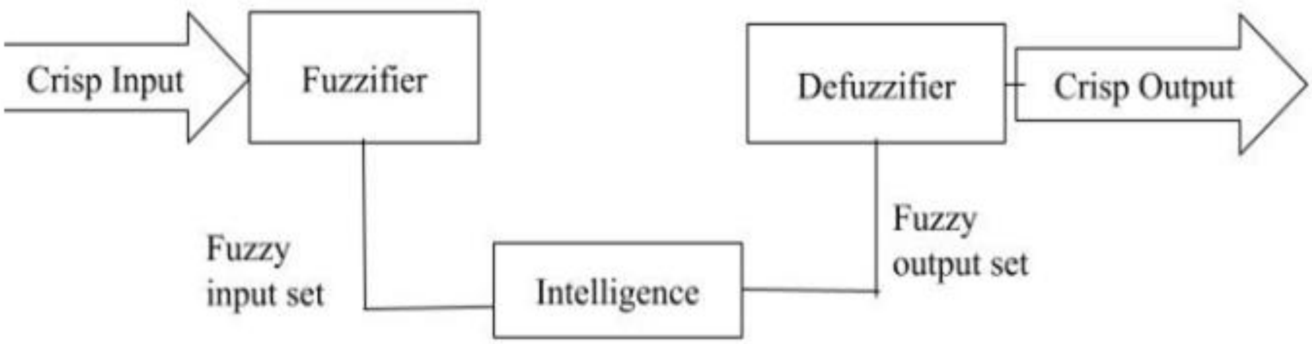

Image 1: Components of fuzzy logic

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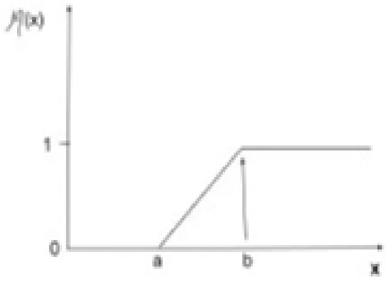
3.3.1 Linear Membership Function:

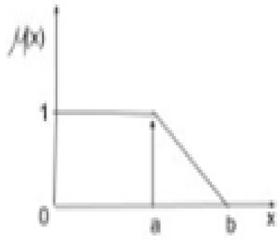
A monotonically increasing linear MF is provided by μ(x)

$$\mu(x)=\begin{cases}1, & if \quad x>a\\ \frac{x-a}{b-a}, & if \quad a\leq x\leq b\\ 0, & if \quad x<a\end{cases}$$



A linear Membership function that decreases monotonically is given by μ(x),

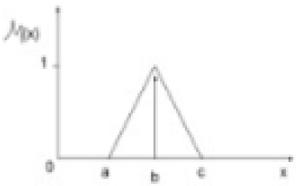
$$\mu(x)=\begin{cases}1, & if \quad x<a\\ \frac{x-b}{b-a}, & if \quad a\leq x\leq b\\ 0, & if \quad x>b\end{cases}$$



3.3.2. Triangular Membership Function (TMF):

The TMF is defined by three parameters (a, b, c) and membership function μ(x) is given by,

$$\mu(x)=\begin{cases}0, & if \quad x<a\\ \frac{x-a}{c-a}, & if \quad a\leq x\leq b\\ \frac{b-x}{b-c}, & if \quad b\leq x<c\\ 0, & if \quad x\geq b\end{cases}$$



$Let \quad \bar{L}=[l_1 \quad l_2 \quad l_3] \quad and \quad \bar{M}=[m_1 \quad m_2 \quad m_3]$ be both non negative triangular fuzzy Numbers and $\alpha\in\mathbb{R}_+$ then ,

$$Addition: \quad \bar{L}+\bar{M}=[l_1 \quad l_2 \quad l_3]+[m_1 \quad m_2 \quad m_3]=[l_1+m_1 \quad l_2+m_2 \quad l_3+m_3]$$

$$Subtraction: \bar{L}(-)\bar{M}=[l_1 \quad l_2 \quad l_3]-[m_1 \quad m_2 \quad m_3]=[l_1-m_3 \quad l_2-m_2 \quad l_3-m_1]$$

$$Multiplication: \quad \bar{L}(.)\bar{M}=[l_1 \quad l_2 \quad l_3].[m_1 \quad m_2 \quad m_3]=[l_1m_1 \quad l_2m_2 \quad l_3m_3]$$

$$Division: \quad \bar{L}(/)\bar{M}=[l_1 \quad l_2 \quad l_3]/[m_1 \quad m_2 \quad m_3]=[l_1/m_3 \quad l_2/m_2 \quad l_3/m_1]$$

$$Addition: \quad \bar{L}^{-1}=[1/l_3 \quad 1/l_2 \quad 1/l_1]$$

$$Scalar Multiplication: \alpha\bar{L}=[\alpha l_1 \quad \alpha l_2 \quad \alpha l_3]$$

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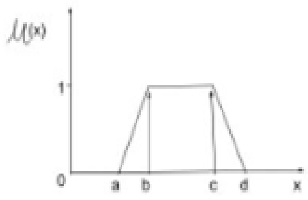
3.3.3. Trapezoidal Membership Function (TrMF):

The TrMF is defined by four criterions (a, b, c, d) and membership function μ(x) is given by,

$$\mu(x) = \begin{cases} 0 \quad , & if \quad x < a \\ \frac{x-a}{c-a}, & if \quad a \le x < b \\ 1, & if \quad b \le x \le c \\ \frac{b-x}{b-c}, & if \quad c < x \le d \\ 0 \quad , & if \quad x \ge d \end{cases}$$



Let $\bar{L} = [l_1 \quad l_2 \quad l_3 \quad l_4]$ and $\bar{M} = [m_1 \quad m_2 \quad m_3 \quad m_4]$ be both non negative trapezoidal fuzzy Numbers and $\alpha \in \mathbb{R}_+$ then ,

$Addition: \quad \bar{L} + \bar{M} = [l_1 + m_1 \quad l_2 + m_2 \quad l_3 + m_3 \quad l_4 + m_4]$

$Subtraction: \quad \bar{L} + \bar{M} = [l_1 - m_4 \quad l_2 - m_3 \quad l_3 - m_2 \quad l_4 - m_1]$

$Multiplication: \quad \bar{L}(.)\bar{M} = [l_1 m_1 \quad l_2 m_2 \quad l_3 m_3 \quad l_4 m_4]$

$Division: \quad \bar{L}(/)\bar{M} = [l_1/m_4 \quad l_2/m_3 \quad l_3/m_2 \quad l_4/m_1]$

$Inverse: \quad \bar{L}^{-1} = [1/l_4 \quad 1/l_3 \quad 1/l_2 \quad 1/l_1]$

$ScalarMultiplication: \alpha\bar{L} = [\alpha l_1 \quad \alpha l_2 \quad \alpha l_3 \quad \alpha l_4]$

3.3.4 Hexagonal Fuzzy Number(HxFN):

Hexagonal Fuzzy Number is specified by six tuples $\bar{A}$ = (a, b, c, d, e, f) , where a,b,c,d,e and f are real numbers and a ≤ b ≤ c ≤ d ≤ e ≤ f with membership function is given by $\mu_{\bar{A}}(x)$ is given by,

$$\mu_{\bar{A}}(x) = \begin{cases} \frac{1}{2}\left(\frac{x-a}{b-a}\right) \quad , & if \quad a \le x \le b \\ \frac{1}{2} + \frac{1}{2}\left(\frac{x-b}{c-b}\right) \quad , & if \quad b \le x \le c \\ 1, & if \quad c \le x \le d \\ 1 - \frac{1}{2}\left(\frac{x-d}{e-d}\right) \quad , & if \quad d \le x \le e \\ \frac{1}{2}\left(\frac{f-x}{f-e}\right) \quad , & if \quad e \le x \le u \\ 0 \quad , & if \quad x \ge b \end{cases}$$

Let $\bar{L} = [l_1 \quad l_2 \quad l_3 \quad l_4 \quad l_5 \quad l_6]$ and $\bar{M} = [m_1 \quad m_2 \quad m_3 \quad m_4 \quad m_5 \quad m_6]$ be both non negative Hexagonal fuzzy Numbers and $\alpha \in \mathbb{R}_+$ then ,

$Addition: \quad \bar{L} + \bar{M} = [l_1 + m_1 \quad l_2 + m_2 \quad l_3 + m_3 \quad l_4 + m_4 l_5 + m_5 l_6 + m_6]$

$Subtraction: \quad \bar{L} + \bar{M} = [l_1 - m_6 \quad l_2 - m_5 \quad l_3 - m_4 \quad l_4 - m_3 \quad l_5 - m_2 \quad l_6 - m_1]$

$Multiplication: \quad \bar{L}(.)\bar{M} = [l_1 m_1 \quad l_2 m_2 \quad l_3 m_3 \quad l_4 m_4 \quad l_5 m_5 \quad l_6 m_6]$

$Division: \quad \bar{L}(/)\bar{M} = [l_1/m_6 \quad l_2/m_5 \quad l_3/m_4 \quad l_4/m_3 \quad l_5/m_2 \quad l_6/m_1]$

$Inverse: \quad \bar{L}^{-1} = [1/l_6 \quad 1/l_5 \quad 1/l_4 \quad 1/l_3 \quad 1/l_2 \quad 1/l_1]$

$ScalarMultiplication: \alpha\bar{L} = [\alpha l_1 \quad \alpha l_2 \quad \alpha l_3 \quad \alpha l_4 \quad \alpha l_5 \quad \alpha l_6]$

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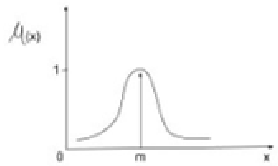
3.3.5 Gaussian Membership function:

The Gaussian membership function adopts the parameters (x,c,m) and its membership function is given by,

$$\mu_A(x, c, s, m) = \frac{1}{e^{\frac{1}{2}\cdot\left(\frac{x-c}{s}\right)^m}}$$



3.3.6 Intuitionistic fuzzy set (IFS):

IFS I_f in X is given by,

$$\bar{I}_f = \{< x, \mu_{\bar{I}_f}(x), \nu_{\bar{I}_f}(x) >: x \in X\}$$

, where $\mu_{\bar{I}_f}, \nu_{\bar{I}_f}$: $X \longrightarrow [0,1]$ such that $0 \leq \mu_{\bar{I}_f}(x) + \nu_{\bar{I}_f}(x) \leq 1$ and symbolize the level of participation and the degree.

3.3.7 Interval Valued intuitionistic fuzzy set:

Let R([0, 1]) be the set of all closed subinterval of [0, 1]. An interval valued intuitionistic fuzzy set (IVIFS) in X is given by,

$$\bar{A} = \{< x, \mu_{\bar{A}}(x), \nu_{\bar{A}}(x) >: x \in X\}$$

,where

$$\mu_A, \nu_A : X \longrightarrow D([0,1]) \quad such \quad that \quad 0 \leq \sup_{x \in X} \mu_{\bar{A}}(x) + \sup_{x \in X} \nu_{\bar{A}}(x) \leq 1$$

4. SOME FUZZY LOGIC METHODS:

4.1 Fuzzy MCDM Method:

The fuzzy MCDM model is acclimated to determine alternatives versus preferred parameters over the decision making committee,where the appropriateness of alternatives versus parameter and Linguistic values expressed as fuzzy numbers allow one to taste the useful weights of criteria. In this method m alternatives $A_1 A_2 \ldots. A_m$which can be assessed by applying n attributes $C_1 C_2 \ldots. C_n$and is expressed by the decision Matrix.

$$X = \begin{bmatrix} x_{11} & x_{12} & \ldots & x_{1n} \\ x_{21} & x_{22} & \ldots & x_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ x_{m1} & x_{m2} & \ldots & x_{mn} \end{bmatrix}$$

where the value of the i^{th} alternative in relation to the j^{th} criterion is represented by the numeric data x_{ij} and w_j represents the weights of the criterion cj to the choice. The empirical technique outlined in [83], which presents an equivalency between the importance of an attribute and a triangular FN, can be employed in fuzzy MCDM to assign the importance degree to the criteria.

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Table 1. Rank Attributes and TFN

Rank	Attribute Grades	TFN
vl-Very low	1	(0.0000,0.1000,0.3000)
l-Low	2	(0.1000,0.3000,0.5000)
m-Medium	3	(0.3000,0.5000,0.7500)
h-High	4	(0.5000,0.7500,0.9000)
vh-Very High	5	(0.7500,0.9000,1.0000)

The linguistic terms are used to indicate the performance ratings of alternatives on qualitative criteria, trapezoidal FNs or IVIFS can be used to represent these linguistic terms, as shown in the following tables.For the criteria taken into consideration, decision makers frequently find it challenging to give an alternative an exact value. In this case, the decision matrix can be used to define the fuzzy MCDM problem.

$$\bar{X} = \begin{bmatrix} \bar{x}_{11} & \bar{x}_{12} & \cdots & \bar{x}_{1n} \\ \bar{x}_{21} & \bar{x}_{22} & \cdots & \bar{x}_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \bar{x}_{m1} & \bar{x}_{m2} & \cdots & \bar{x}_{mn} \end{bmatrix}$$

where x_{ij} are fuzzy values.

Table 2. Linguistic Variables and TFN

Linguistic variables for alternatives rating	TFN
vg-Very Good	(9.0,10.0,10.0)
g-Good	(7.0,9.0,10.0)
m-Medium	(3.0,5.0,7.0)
p-Poor	(1.0,3.0,5.0)
vp-Very Poor	(1.0,1.0,3.0)

Table 3. Linguistic Variable and Trapezoidal Fuzzy Number

Linguistic variables	Trapezoidal FN
vl-Very low	(0.000,0.000,0.000,0.100)
l-Low	(0.100,0.200,0.250,0.300)
ml-Medium low	(0.300,0.400,0.450,0.500)
m-Medium	(0.500,0.600,0.650,0.700)
mh-Medium high	(0.700,0.800,0.850,0.900)
h-High	(0.900,0.950,1.000,1.000)
vh-Very high	(1.000,1.000,1.000,1.000)

4.2 Analytical Hierarchy Process (AHP):

There are several ways to get criteria weights [84,85], but the most widely used is the AHP created by Saaty [21].In order to obtain FAHP, Buckley [58] integrated fuzzy theory with AHP.In the study, a novel approach to determining fuzzy weights is provided, which is based on the direct fuzzification of Saaty's method[25].The following is the process for fuzzy AHP.

Step 1: Create fuzzy comparison matrices for pairs.

Each decision maker gives the pairwise comparison of all criteria linguistic terms denoted by triangular FN.Using the fuzzy performance scale displayed in the accompanying matrix, let $\bar{A} = \bar{a}_{ij}$ be a n × n matrix, where $\bar{a}_{ij}$ represents the significance of criteria C_i with regard to C_j .

$$\bar{A} = \begin{bmatrix} (1,1,1) & \bar{a}_{12} & \dots & \bar{a}_{1n} \\ \bar{a}_{21} & (1,1,1) & \dots & \bar{a}_{2n} \\ \dots & \dots & \dots & \dots \\ \bar{a}_{m1} & \bar{a}_{m2} & \dots & (1,1,1) \end{bmatrix} = \begin{bmatrix} (1,1,1) & \bar{a}_{12} & \dots & \bar{a}_{1n} \\ \frac{(1,1,1)}{\bar{a}_{21}} & (1,1,1) & \dots & \bar{a}_{2n} \\ \dots & \dots & \dots & \dots \\ \frac{(1,1,1)}{\bar{a}_{m1}} & \frac{(1,1,1)}{\bar{a}_{m2}} & \dots & (1,1,1) \end{bmatrix}$$

Step 2: Normalize the fuzzy weights and compute them.

The weights of criterion Ci denoted by wi is carried out by

$$\bar{w}_i = \bar{r}_i \times (\bar{r}_1 + \bar{r}_2 + \dots + \bar{r}_n)^{-1}, where \bar{r}_i = [\bar{a}_{i1} \times \bar{a}_{i2} \times \dots \times \bar{a}_{in}]^{\frac{1}{n}}$$

Thus FAHP is a method that combines qualitative and quantitative approaches. One key distinction between AHP and FAHP is that FAHP has the ability to categorize evaluation factors into factor level, target level, and criterion level.

4.3 The Topsis Method:

TOPSIS is a commonly used MCDM technique that was initially developed by Hwang and Yoon in 1981 and then expanded upon by Yoon in 1987 [90]. This method may be used to evaluate the performance of alternatives by comparing them to an ideal solution [91].The basic tenet of TOPSIS is that the alternative being selected is the one that is closest to the PIS and the one that is furthest from the NIS.Benefit characteristics should be minimized and cost attributes should be maximized for the NIS.On the other hand, the PIS should maximize its benefit features while minimizing its cost attributes[92].Numerous research have been conducted in the past to use the TOPSIS approach.The study demonstrates that this methodology may be applied both alone and in combination to address the issues. In order to assess the financial performance of thirteen technological companies listed on the Istanbul Stock Exchange Market, Bulgurcu [93] used the TOPSIS approach. In the meanwhile, Zhongyou [94] used this technique to evaluate the international athletes competing in the Chinese Basketball Association (CBA) games.However, Kamalakannan et al. [95] solved the supplier selection problem using the TOPSIS technique. The results were then contrasted with those derived from the AHP approach. To overcome the MCDM challenges, several scholars are interested in combining the TOPSIS method with another approach.Chu and Su [96], for example, used the TOPSIS approach to choose the permanent seismic shelter for evacuation in cities and the combination of AHP and entropy methods to calculate the weights of the assessment criteria. There are several benefits to using the TOPSIS technique, which is well-known for its capacity to rank the options in MCDM situations. The TOPSIS method has the benefit of quickly ranking the best options and handling contradictory circumstances.Subsequently, the judgment data may be placed directly without requiring complex computations [97]. Notwithstanding its benefits, the approach has many drawbacks. Decision-makers' subjective assessments are represented by numerical values in the traditional TOPSIS [91]. However, because human judgments are imprecise and unpredictable, this approach is ineffective for estimating people's decisions using precise facts [89]. In order to address TOPSIS's drawbacks, the Fuzzy TOPSIS approach is advised.

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4.4 Fuzzy Topsis Method:

FTOPSIS stands out as a top method for achieving an ideal solution from a set of similar options. Furthermore, it offers the ability to streamline the process and address any ambiguity or uncertainty that may arise during the selection process.An extension of the TOPSIS principle, the Fuzzy TOPSIS approach addresses a variety of MCDM issues in an uncertain environment [89]. In 1992, Chen and Hwang developed the Fuzzy TOPSIS method by introducing fuzzy integers into the TOPSIS approach. In 2000, Chen proposed a vertex approach to calculate the distance between two TFNs [98].The decision makers' opinions about qualities and alternatives will be represented by TFNs in this technique, which ranks the alternatives according to their distance from ideal solutions and selects depending on the ranking result [99].In a hazy context, the Fuzzy TOPSIS technique operates on the same premise as the TOPSIS method [92].The Fuzzy TOPSIS approach has several benefits when used to MCDM situations.In order to reconcile the ambiguity that frequently occurs in information derived from human judgment, the Fuzzy TOPSIS approach was first presented [92]. Furthermore, it has been discovered that employing TFNs to represent a variety of uncertain scenarios improves the outcome of MCDM problem solving.Additionally, using the Fuzzy TOPSIS approach to solve MCDM issues with imprecise data is simple and straightforward [97]. According to a review of earlier research, this method can be used alone to address MCDM issues like analyzing shopping websites and determining what factors enhance the competitive advantage of those websites [100] and evaluating and ranking domestic Turkish airlines, such as Turkish Airlines, Out Air, Pegasus, and Atlas Jet, according to the most crucial factors for success in the domestic airline sector [101].It is possible to hybridize this approach with other MCDM techniques. Rajak and Shaw [97] evaluated the effectiveness of several mobile health (mHealth) applications using the AHP and fuzzy TOPSIS methods. mHealth applications are cutting-edge, system-based mobile applications that help consumers better manage their health. The Fuzzy TOPSIS approach was used to rank the mHealth applications, and the AHP method was used to assess the weights of the criterion and sub-criteria. In the meanwhile, Seng¨ul et al. [102] ranked the renewable energy supply systems in Turkey using the Fuzzy TOPSIS approach and the integration of the Interval Fuzzy Shannon's Entropy to assess the weights of the criterion. In conclusion, because the Fuzzy TOPSIS technique uses the fuzzy set theory notion, it is appropriate and effective for addressing MCDM issues in a fuzzy environment. Chen [103] used triangular FNs to expand TOPSIS. In order to determine the separation between two triangular FNs, Chen developed a vertex approach.

$$If \underset{-}{x} = (l_1, m_1, n_1), \underset{-}{y} = (l_2, m_2, n_2) are two triangular FNs then,$$

$$d(\bar{x}, \bar{y}) := \sqrt{\frac{1}{3}[(l_1 - l_2)^2 + (m_1 - m_2)^2 + (m_1 - n_2)^2]}.$$

TOPSIS process is described as follows:

Step 1. Assign ratings to the alternatives and criteria. We assume that we have a decision group with K members. The fuzzy rating of the k^{th} decision maker about alternative A_i w.r.t. criterion C_j is denoted $\underset{-}{x}_{ij}^k = (a_{ij}^k, b_{ij}^k, c_{ij}^k)$ and the weights of the criterion C_j is denoted by $\underset{-}{w}_j^k = (w_{j1}^k, w_{j2}^k, w_{j3}^k)$

Step 2. Analyze the combined fuzzy weights for the criterion and the combined fuzzy rating for the alternatives.

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The i^{th} alternative w.r.t. j^{th} criteria for fuzzy rating x_{ij} is given by,

$$a_{ij} = \min_k \{a_{ij}^k\}, \quad b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b_{ij}^k, \quad c_{ij} = \max_k \{c_{ij}^k\}$$

The criteria C_j of aggregated fuzzy weights $wj = (w_{j1}, w_{j2}, w_{j3})$ is calculated by,

$$w_{j1} = \min_k \{w_{j1}^k\}, \quad w_{j2} = \frac{1}{K}\sum_{k=1}^{K} w_{j2}^k, \quad w_{j3} = \max_k \{w_{j3}^k\}$$

Step 3. Calculate normalized fuzzy decision matrix as

$$\bar{R} = [\bar{r}_{ij}] \quad where \quad \bar{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \quad and \quad c_j^* = \max_i \{c_{ij}\}\,(criteria \quad benifit)$$

or

$$\bar{R} = [\bar{r}_{ij}] \quad where \quad \bar{r}_{ij} = \left(\frac{\bar{a}_j}{c_{ij}}, \frac{\bar{a}_j}{b_{ij}}, \frac{\bar{a}_j}{a_{ij}}\right) \quad and \quad \bar{c}_j = \min_i \{a_{ij}\}\,(criteria \quad cost)$$

Step 4. Calculate normalised weighted fuzzy decision matrix as

$$\bar{V} = (\bar{v}_{ij}) \text{ where } \bar{v}_{ij} = \bar{r}_{ij} \times w_j.$$

Step 5. Determine the fuzzy negative and fuzzy positive ideal solutions as follows:

$$A^+ = (\bar{v_1}^+, \bar{v_2}^+, ..., \bar{v_n}^+) \quad where \quad \bar{v_j}^+ = \max_i \{v_{ij}\}$$

$$A^- = (\bar{v_1}^-, \bar{v_2}^-, ..., \bar{v_n}^-) \quad where \quad \bar{v_j}^- = \min_i \{v_{ij}\}$$

Step 6. Determine how far each option is from the fuzzy positive and fuzzy negative ideal solutions.Let us assume the distance from each alternative Ai to the FPIS and to FNIS respectively.

$$d_i^+ = \sum_{j=1}^{n} d(\bar{v}_{ij}, \bar{v}_j^+), \quad d_i^- = \sum_{j=1}^{n} d(\bar{v}_{ij}, \bar{v}_j^-)$$

Step 7. For every option, determine the proximity coefficient CC_i as follows:

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+}$$

Step 8. Lastly, the best option is indicated by ranking the alternatives with the highest closeness coefficient.

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4.5 The Fuzzy Matrix Model:

Thomson was the first to define a fuzzy matrix in 1977.Kim and Roush proposed fuzzy matrix theories as an extension of Boolean matrices [20]. Iterates of fuzzy circulation matrices were studied by Hemashina et al. A matrix whose elements have values within the closed interval [0, 1] is called a fuzzy matrix. The steps in the fuzzy matrix model are as follows.

Step 1. Collect the Raw Data and classify it into several groups as needed.

Step 2. To create the average time dependent matrix (ATDM) divides each entry of the data by the respective length of the class interval.

Step 3. Find the mean and Standard Deviation of each column of the ATD Matrix.

Step 4. Create Refined Time Dependent Data Matrix (RTDM) by using the following algorithm.

$$\begin{aligned} &" \quad if \quad b_{ij} \leq (\mu_j - \alpha * \sigma_j) \quad then \quad e_{ij} = -1, \\ &else \quad if \quad b_{ij} \in (\mu_j - \alpha * \sigma_j, \mu_j + \alpha * \sigma_j) \quad then \quad e_{ij} = 0, \\ &else \quad if \quad b_{ij} \geq (\mu_j + \alpha * \sigma_j) \quad then \quad e_{ij} = 1, [106] \\ &where \quad b_{ij} \quad 's \quad are \quad the \quad entries \quad of \quad ATD \quad Matrix. " \end{aligned}$$

you can create any number of RTDM by varying the value of α

Step 5. Create Combined Effect Time Dependent Data Matrix (CETD Matrix) which is the collective result of all those matrices created in the previous step.

5. SOME FUZZY LOGIC APPLICATIONS IN DIFFERENT FIELDS

Fuzzy logic finds applications in a wide range of fields including Environment control, consumer commodities,Automotive Systems. Here are some common Applications-

1] Control of speed and traffic in automotive systems.

2] Fuzzy logic emulates the way humans make decisions,but a lot quicker as a result it can be used with neural networks.

3] By using fuzzy logic control the chemical industry utilizes pH control,chemical distillation processes and drying techniques.

4] Assistance systems and individual assessment concerning decision making in big enterprises.

5] The aerospace industry focuses on managing the altitude of spacecraft and satellites.

6. APPLICATIONS OF FUZZY IN AGRICULTURE

6.1 A model of FLP is utilized to count minimum cost in agriculture:

A linear programming model represents a mathematical approach to optimize the allocation of limited sources and achieves very good possible outcome and also used for calculating base level agriculture cost in transportation model.This model focuses on determining the lowest cost of cultivating agricultural commodities across all agronomy regions within its area, considering number of crops farming in each region.Statistics for this model includes following characteristics.The cultivation level in every region along with the demand for each variety in the area are correlated with regions.The cultivating cost of the commodity varies across different regions and crops.

6.2 The Centroid point of Fuzzy Numbers is utilized to rank technical parameters that came across farmers in agronomy:

This is utilization of fuzzy ranking methods to prioritize the technical limitations encountered by farmers in rice farming. Initially an experiment was carried out to showcase the practicality of this approach, aiming to gather linguistic evaluations regarding the significance of constraints encountered by paddy farmers,where experts were farm scientist,some educated farmers, a few progressive farmers,some literate farmers,some agriculture officers, some farm workers, and one agriculture engineer. Decision makers were requested to provide their viewpoint regarding the significance of the limitations encountered by farmers in paddy cultivation, which have an impact on the overall rice production output.A questionnaire consisting of nine constraints was utilized to assess the situation, requiring decision makers to determine the severity of constraints in the field of agriculture.

Decision makers must provide their views on the experience of farmers' constraints in paddy cultivation using five linguistic levels: vl-very low,l-low, n-normal,h-high,vh-very high.Linguistic experts' responses regarding the severity of limitations were compromised by utilizing the arithmetic mean to derive the average weight score.The centroid point was calculated using a computer algebra system. Ultimately, the centroid point is acquired.Ranking of constraints is in descending order depending on magnitude of the centroid point.

6.3 Expert systems for Water Irrigation:

Using soil moisture level and greenhouse air temperature as variables, a fuzzy controller (FC) has been used for monitoring drip irrigation time to save water [105]. In this study, electrical circuits were used to assess soil moisture, and LABVIEW was used to provide a user interface for collecting the data and tracking the drip irrigation system. As a result, this study created a system that would determine the soil's present moisture content and then feed the crop the appropriate quantity of water to aid with timely irrigation.

6.4 Expert system for Fertilizer Management:

Using verified fertilizer adjustment equations (produced by AICRP on soil test crop response correlation and geographic information system), this method was created for fertilizer recommendation purposes [104].This system determined the equivalent soil nutrient values for nitrogen (N), phosphorous (P), and potassium (K) based on index values of these elements.

6.5 Expert system for climate Control:

The LabVIEW program was used to create this control system, which used fuzzy logic to manage a number of greenhouse climate factors by heating and cooling to maintain the necessary range of humidity and temperature.LabVIEW software was used to create graphics user interfaces for real-time greenhouse system monitoring [104].

7. CONCLUSION

Agriculture has seen significant development over time, with expert systems developing necessary technical techniques.Traditional systems are currently being outperformed by expert systems.A technology method of delivering agricultural knowledge from books, research papers, theses, and other sources to the real implementation level that is, at the farmer level is through expert systems. Fuzzy logic has proven to be beneficial and effective when incorporated into expert systems to manage imprecise information in the field of agriculture. Above mentioned methods Fuzzy Ranking,Fuzzy Cluster analysis,Fuzzy relation,Fuzzy AHP,Fuzzy Topsis are very useful for decision making in various natural world situations and it can be utilized to resolve the problems not only in agriculture but also in various fields wherever multi criteria decisions needed.Therefore, in the proposed study, we would create an expert system that would help farmers make judgments about agriculture management. This system would be helpful to not only farmers but also the decision makers in a variety of disciplines.

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