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Fuzzy Multi Criteria Group Decision Making (Mcgdm) Approach for Variety Selection in Rice Farming

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Abstract: Rice Variety Selection is one of the important processes in paddy cultivation. On the other hand, selecting the suitable variety for season and field condition among the many alternatives is the multi criteria decision making problem. The main purpose of this paper is to present a fuzzy multi-criteria group decision making (FMCGDM) model for rice variety selection. In this article we have created sixteen criteria for selecting the rice variety acquired from literatures review and practical investigations. And the method of fuzzy set theory, linguistic value, analytic hierarchy process and a new fuzzy ranking method are used to consolidate decision-makers' assessments about criteria weightings. Finally, an empirical study for selecting the rice variety in cauvery delta region of Tamil Nadu, India is conducted to demonstrate the computational process and effectiveness of FMCGDM proposed in this paper.

Key words: Rice Variety Selection, Multicriteria decision making, AHP, Fuzzy Set Theory, Fuzzy ranking method.

INTRODUCTION

Success of agriculture depends on various factors such as congenial climate and soil for particular crop or variety. Selection of high yielding crop variety use of inputs such as seed, water, fertilizers, pesticides etc., at appropriate time. Crop cultivation practices such as ploughing, weeding, time of manuring, harvesting etc. All these factors are interdependent. Among the above said factors selection of a crop variety to a particular locality and season, rational and timely used inputs have domineering effect on crop production. Considering the above aspects, the present study was contemplated with the main objective selection of best crop variety for the given soil and climatic condition.

There is a large literature dedicated to the rice variety selection problem. It concludes several approaches, which take into account various aspects of the problem. Strategic intent of the rice variety selection, factors for rice variety selection, and various qualitative and quantitative rice variety selection models have been thoroughly discussed by Ponnusamy and Thenmathi *et al* (2004), Witcombe (21). Joshi *et al* (2002) and Bellon (2001) surveyed some of the variety selection methodologies. Various articles discussed application of statistics in the rice variety selection. Virk and Witcombe (2002), used ANOVA. Grisley *et al* (1993), Salam *et al* (2002), Javier *et al* (2002), Joshi *et al* (2002), Ikehasi (1978) and Ortiz *et al* (2001), used survey and trial methods. In many decision models in the literature, only statistical and survey methods have been used for variety selection.

This paper proposes a fuzzy multi-criteria decision making with FAHP and a new fuzzy ranking method for variety selection problem. The importance of the criteria and the impact of alternatives on criteria provided by decision makers are difficult to precisely express by crisp data in the selection of variety selection problem. Fuzzy sets introduced by L.A. Zedha (1965) are suitable way to deal with this challenge and applied many decision making problems under uncertain environment.

One of the most outstanding MCDM approaches is the Analytic Hierarchy Process (AHP), which has its roots in obtaining the relative weights among the factors and the total values of each alternative based on these weights. In comparison with other MCDM methods, the AHP method has widely been used in multi-criteria decision making and has been applied successfully in many practical decision making problems.

In fuzzy decision analysis, fuzzy numbers are frequently employed to describe the performance of alternatives in modeling a real world problem. The decision makers assess the alternatives with fuzzy numbers and the selection of alternatives will eventually lead to the ranking of the corresponding fuzzy numbers. Furthermore, the concept of optimum and best choice to come true are also completely based on the ranking or comparison of fuzzy numbers. Thus, specific ranking of fuzzy numbers is an important procedure for decision making in a fuzzy environment.

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Finally, in group decision making problems, aggregation of expert opinions is very important to appropriately perform evaluation process. Therefore, Fuzzy Weighted Product (FWP) operator is utilized to aggregate all individual decision makers' opinions for rating the importance of the alternative.

Rest of this paper is organized as follows: In section 2, basic definitions have been mentioned. Section 3 briefly describes the proposed methods. In section 4, proposed model for rice variety selection is presented and the stages of the proposed approach are explained in details. How the proposed model is used in a real world example is explained in section 5. Finally, concluding remarks are provided in section 6.

2. Preliminaries:

In this section, the notation and basic definitions of most important conception are recalled.

Definition 1:

A fuzzy set $\widetilde{A}$ in a universe of discourse X is characterized by a membership function $\mu_{\widetilde{A}}(x)$ which associates with each element x in X a real number in the interval [0, 1]. The function value $\mu_{\widetilde{A}}(x)$ is termed the grade of membership of x in $\widetilde{A}$ (Zadeh, L.A., 1997).

Definition 2:

Let R be the set of all real numbers. We assume a fuzzy number $\widetilde{A}$ that can be expressed for all $x \in R$ in the form

$$A(x) = \begin{cases} A_L(x) & a \le x \le b \\ w & b \le x \le c \\ A_R(x) & c \le x \le d \\ 0 & otherwise \end{cases} \quad (1)$$

Where $0 \le w \le 1$ is a constant, a, b, c, d are real numbers, such that $a < b \le c < d$, $A_L(x):[a,b] \to [0,w], A_R(x):[c,d] \to [0,w]$ are two strictly monotonic and continuous functions from R to the close interval $[0,w]$.

Since $A_L(x)$ is continuous and strictly increasing, the inverse function of $A_L(x)$ exists. Similarly $A_R(x)$ is continuous and strictly decreasing, the inverse function of $A_R(x)$ also exist. The inverse functions of $A_L(x)$ and $A_R(x)$ can be denoted by $A_L^{-1}(x)$ and $A_R^{-1}(x)$, respectively. $A_L^{-1}(x)$ and $A_R^{-1}(x)$ are continuous on [0,w] that means both $\int_0^w A_L^{-1}(x)$ and $\int_0^w A_R^{-1}(x)$ exist.

Definition 3:

A fuzzy number $\widetilde{A}$ = (a, b, c, d; w) is called a trapezoidal fuzzy number if its membership function A(x) has the following form:

$$A(x) = \begin{cases} \frac{w(x-a)}{b-a} & a \le x \le b \\ w & b \le x \le c \\ \frac{w(d-x)}{d-c} & c \le x \le d \\ 0 & otherwise \end{cases} \quad (2)$$

In this case, the inverse functions $A_L^{-1}(x)$ and $A_R^{-1}(x)$ can be expressed analytically as

$$A_L^{-1}(x) = a + (b-a)/w \qquad 0 \le y \le w \quad (3)$$

$$A_R^{-1}(x) = d - (d-c)/w \qquad 0 \le y \le w \quad (4)$$

Definition 4:

A fuzzy number $\widetilde{A}$ = (a, b, c; w) is called a triangular fuzzy number if its membership function A(x) has the following form:

$$A(x) = \begin{cases} \frac{w(x\text{-}a)}{b\text{-}a} & a \le x \le b \\ \frac{w(d\text{-}x)}{d\text{-}c} & b \le x \le c \\ 0 & otherwise \end{cases} \quad (5)$$

Definition 5:

Let $\widetilde{A}_1 = (a_1, b_1, c_1, d_1 : w_1)$ and $\widetilde{A}_2 = (a_2, b_2, c_2, d_2 : w_2)$ be two generalized trapezoidal fuzzy numbers.

(i) The addition of $\widetilde{A}_1$ and $\widetilde{A}_2$:

$$\widetilde{A}_1(+)\widetilde{A}_2 = (a_1 + a_2, b_1 + b_2, c_1 + c_2, d_1 + d_2; \min(w_1, w_2)) \quad (6)$$

(ii) The subtraction of $\widetilde{A}_1$ and $\widetilde{A}_2$:

$$\widetilde{A}_1(-)\widetilde{A}_2 = (a_1 - d_2, b_1 - c_2, c_1 - b_2, d_1 - a_2; \min(w_1, w_2)) \quad (7)$$

(iii) The multiplication of $\widetilde{A}_1$ and $\widetilde{A}_2$:

$\widetilde{A}_1(\times)\widetilde{A}_2 = (a_1 \times a_2, b_1 \times b_2, c_1 \times c_2, d_1 \times d_2; \min(w_1, w_2))$, if a_1, b_1, c_1, d_1, a_2, b_2, c_2, d_2 are all positive real numbers. (8)

(iv) The division, $\widetilde{A}_1$ and $\widetilde{A}_2$:

$\widetilde{A}_1(/)\widetilde{A}_2 = (a_1 / d_2, b_1 / c_2, c_1 / b_2, d_1 / a_2; \min(w_1, w_2))$, if a_1, b_1, c_1, d_1, a_2, b_2, c_2, d_2 are all positive real numbers.

(9)

Methods:

3.1. The AHP Method:

In this section we present AHP, developed by Saaty (1980), addresses how to determine the relative importance of a set of activities in a multi-criteria decision problem (Saaty, T.L., 1980). The process makes it possible to incorporate judgments on intangible qualitative criteria alongside tangible quantitative criteria (Badri, M.A., 2001). The AHP method is based on three principles: first, structure of the model; second, comparative judgment of the alternatives and the criteria; third, synthesis of the priorities. In the literature, AHP, has been widely used in solving many complicated decision-making problems (Chan, F.T.S., 2007; Dagdeviren, M., I. Yuksel, 2008; Kahraman, C., *et al*., 2003; Kulak, O., C. Kahraman, 2005).

In the first step, a complex decision problem is structured as a hierarchy. AHP initially breaks down a complex multi-criteria decision- making problem into a hierarchy of interrelated decision elements (criteria, decision alternatives). With the AHP, the objectives, criteria and alternatives are arranged in a hierarchical structure similar to a family tree. A hierarchy has at least three levels: overall goal of the problem at the top, multiple criteria that define alternatives in the middle, and decision alternatives at the bottom (Albayrak, E., Y.C. Erensal, 2004).

The second step is the comparison of the alternatives and the criteria. Once the problem has been decomposed and the hierarchy is constructed, prioritization procedure starts in order to determine the relative importance of the criteria within each level. The pairwise judgment starts from the second level and finishes in the lowest level, alternatives. In each level, the criteria are compared pairwise according to their levels of influence and based on the specified criteria in the higher level (Albayrak, E., Y.C. Erensal, 2004). In AHP, multiple pairwise comparisons are based on a standardized comparison scale of nine levels (Table 1).

Let C = {Cj | j = 1, 2, . . . , n} be the set of criteria. The result of the pair wise comparison on n criteria can be summarized in an (n × n) evaluation matrix A in which every element a_{ij} (i,j = 1,2, . . . ,n) is the quotient of weights of the criteria, as shown:

$$A=\begin{bmatrix} a_{11} & a_{12} & .... & a_{1n} \\ a_{21} & a_{22} & .... & a_{2n} \\ .... & .... & .... & .... \\ a_{n1} & a_{n2} & .... & a_{nn} \end{bmatrix}, \qquad a_{ii}=1, a_{ji}=1/a_{ij}, a_{ij}\neq 0 \tag{10}$$

At the last step, the mathematical process commences to normalize and find the relative weights for each matrix. The relative weights are given by the right eigenvector (w) corresponding to the largest eigenvalue

($\lambda_{\max}$), as

$$A_w=\lambda_{\max} w. \tag{11}$$

If the pairwise comparisons are completely consistent, the matrix A has rank 1 and $\lambda_{\max}$ = n. In this case, weights can be obtained by normalizing any of the rows or columns of A (Wang, J.J. and D.L. Yang, 2007).

It should be noted that the quality of the output of the AHP is strictly related to the consistency of the pairwise comparison judgments. The consistency is defined by the relation between the entries of A: $a_{ij} \times a_{jk} = a_{ik}$. The consistency index (CI) is

$$CI=(\lambda_{\max}-n)/(n-1) \tag{12}$$

The final consistency ratio (CR), usage of which let someone to conclude whether the evaluations are sufficiently consistent, is calculated as the ratio of the CI and the random index (RI), as indicated.

$$CR = CI / RI \tag{13}$$

The number 0.1 is the accepted upper limit for CR. If the final consistency ratio exceeds this value, the evaluation procedure has to be repeated to improve consistency. The measurement of consistency can be used to evaluate the consistency of decision makers as well as the consistency of overall hierarchy (Tong, M. and P.P. Bonissone, 1980).

Table 1: Nine-point intensity of importance scale and its description.

Definition	Imtensity of Importance
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9
Intermedia te values	2,4,6,8

3.2. The new method for Ranking Fuzzy Numbers:

This section proposes a new fuzzy ranking method of generalized fuzzy number based on centroid and radius of gyration.

3.2.1. Radius of Gyration:

Radius of gyration is a concept in Mechanics. Deng *et al* (2006) gave a new area method to rank fuzzy numbers with radius of gyration (ROG) point. Here we keep all preliminary discussions of them.

Definition 6:

Let A be an area in the xy plane (Figure 1) and dA be an area of element of coordinates x and y. The moment of inertia of the area A with respect to the x axis, and the moment of inertia of the area A with respect to the y axis are defined respectively as

$$I_x=\int_A y^2 dA \tag{14}$$

$$I_y = \int_A x^2 dA \qquad (15)$$

Definition 7:

The radius of gyration of an area A with respect to the x axis is defined as the quantity r_x, that satisfies the relation.

$$I_x = r_x^2 A \qquad (16)$$

Where I_x, is the moment of inertia of A with respect to x axis.
Solving equation **(16)** for r_x, we have

$$r_x = \sqrt{\frac{I_x}{A}} \qquad (17)$$

In a similar way, we define the radius of gyration of an area A with respect to the y axis is

$$I_y = r_y^2 A \qquad (18)$$

$$r_y = \sqrt{\frac{I_y}{A}} \qquad (19)$$

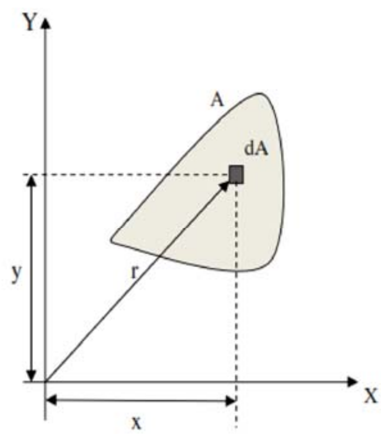

Fig. 1: The moment of inertia of an area.

3.2.2. The Main Idea of Ranking Fuzzy Numbers:

The centroid of a trapezoidal is considered as the balancing point of the trapezoid (Figure 2). Divide the trapezoid into three plane figures. The plane figures are a triangle (APB), a rectangle (BPQC), and a triangle (CQD), respectively. The radius of gyration of the centroids of these plane figures is taken as the point of reference to define the raking of generalized fuzzy members. The reason for selecting this point as a point of reference is that each centroid point (G_1 of triangle APB, G_2 of rectangle BPQC, and G_3 of triangle CQD) are balancing points of each individual plane figure, and the ROG of these centroid points is much more balancing point for a generalized trapezoidal fuzzy number. Therefore, this point would be a better reference point than the centroid point of a trapezoid.

Consider a generalized trapezoidal fuzzy number $\widetilde{A}$ = (a, b, c, d; w) (Figure 2). The centroids of the three plane figures are $G_1 = \left(\frac{(a+2b)}{3}, \frac{w}{3}\right), G_2 = \left(\frac{(b+c)}{2}, \frac{w}{2}\right)$ and $G_3 = \left(\frac{(2c+d)}{3}, \frac{w}{3}\right)$ respectively.

Equation of the line $\overline{G_1G_3}$ is y = w/3 and G_2 does not lie on the line $\overline{G_1G_3}$. Therefore, G_1, G_2 and G_3 are non – collinear and they form a triangle.

We define the radius of gyration point $\left(r_x^{\tilde{A}}, r_y^{\tilde{A}}\right)$ of a triangle with vertices G_1, G_2 and G_3 of the generalized trapezoidal fuzzy number $\tilde{A} = (a, b, c, d; w)$ as

$$\left(r_x^{\tilde{A}}, r_y^{\tilde{A}}\right) = \left(\sqrt{\frac{\left(2(c-b)+(d-a)\right)^2}{162} + \frac{\left(2(a+d)+7(b+c)\right)^2}{324}},\ \sqrt{\frac{11}{72}}w\right) \tag{20}$$

As a special case, for triangular fuzzy number $\tilde{A} = (a, b, c, d; w)$ that is, c = b the radius of gyration point of centroids is given by

$$\left(r_x^{\tilde{A}}, r_y^{\tilde{A}}\right) = \left(\sqrt{\frac{(d-a)^2}{162} + \frac{\left(2(a+d)+14b\right)^2}{324}},\ \sqrt{\frac{11}{72}}w\right) \tag{21}$$

For any decision maker whether pessimistic, optimistic, or netural the ranking function of the generalized (trapezoidal or triangle) fuzzy number $\tilde{A}$ is presented as follows:

$$\mathrm{RI}(\tilde{A}) = \sqrt{\left(r_x^{\tilde{A}}\right)^2 + \left(r_y^{\tilde{A}}\right)^2} \tag{22}$$

Which is the Euclidean distance from the radius of gyration point of the centroids and the original point.

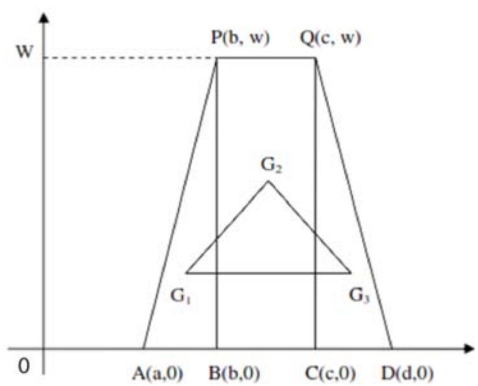

Fig. 2: Radius of gyration of centroids.

4. The Proposed Model:

In this section, we propose a new fuzzy group decision making method based on new fuzzy ranking method. This method is very suitable for solving the group decision-making problem under fuzzy environment. In this paper the importance weights of various criteria is found by AHP and the rating of qualitative criteria are considered as linguistic variables. These linguistic variables can be expressed in positive triangular fuzzy numbers as Table 2.

Assume that a decision group has K persons, then the important of the criteria and the rating of alternatives with respect to each criterion can be calculated as

$$\tilde{x}_{ij} = \frac{1}{K}\left[\,\tilde{x}_{ij}^1 (+) \tilde{x}_{ij}^2 (+) \ldots\ldots\ldots (+) \tilde{x}_{ij}^K\,\right] \tag{23}$$

$$\tilde{w}_{ij} = \frac{1}{K}\left[\,\tilde{w}_{j}^1 (+) \tilde{w}_{j}^2 (+) \ldots\ldots\ldots (+) \tilde{w}_{j}^K\,\right] \tag{24}$$

As stated above, a fuzzy multi-criteria group decision-making problem which can be concisely expressed in matrix format is

$$D=\begin{bmatrix}\tilde{x}_{11} & \tilde{x}_{12} & ..... & \tilde{x}_{1n}\\ \tilde{x}_{21} & \tilde{x}_{21} & ..... & \tilde{x}_{2n}\\ .... & ..... & ..... & ....\\ \tilde{x}_{m1} & \tilde{x}_{m2} & ..... & \tilde{x}_{mn}\end{bmatrix} \quad (25)$$

Where $\tilde{x}_{ij}, \forall i, j$ and $\tilde{w}_j, j=1,2,.....,n$ are linguistic variables. These linguistic variables can be described by triangular fuzzy number, $\tilde{x}_{ij}=(a_{ij}, b_{ij}, c_{ij})$.

The proposed group fuzzy decision making method based on new fuzzy ranking method is now presented as follows:

Step 1: construct the decision matrix D, which is shown as follows:

$$D=[\tilde{x}_{ij}]_{m\times n}=\begin{array}{c} \\ C_1\\ C_2\\ ....\\ C_m\end{array}\begin{array}{c}\begin{array}{cccc}A_1 & A_2 & ..... & A_n\end{array}\\ \begin{bmatrix}\tilde{x}_{11} & \tilde{x}_{12} & ..... & \tilde{x}_{1n}\\ \tilde{x}_{21} & \tilde{x}_{22} & ..... & \tilde{x}_{2n}\\ .... & ..... & ..... & ....\\ \tilde{x}_{m1} & \tilde{x}_{m2} & ..... & \tilde{x}_{mn}\end{bmatrix}\end{array} \quad (26)$$

Where $\tilde{x}_{ij}$ denotes the evaluating value of alternative A_j with respect to criteria C_i. The value of $\tilde{x}_{ij}$ is the triangular fuzzy number, where $1 \le i \le m$ and $1 \le j \le n$.

Step 2: Based on equation (22) calculate the ranking score $P_{ij}=RI(\tilde{x}_{ij})$ of each $\tilde{x}_{ij}$, where $1 \le i \le m, 1 \le j \le n$, to construct the ranking score matrix P, shown as follows:

$$P=[P_{ij}]_{m\times n}=\begin{array}{c} \\ C_1\\ C_2\\ ...\\ C_m\end{array}\begin{array}{c}\begin{array}{cccc}A_1 & A_2 & ...... & A_n\end{array}\\ \begin{bmatrix}P_{11} & P_{12} & ..... & P_{1n}\\ P_{21} & P_{22} & ..... & P_{2n}\\ .... & ..... & ..... & ....\\ P_{m1} & P_{m2} & ..... & P_{mn}\end{bmatrix}\end{array}. \quad (27)$$

Step 3: Aggregate the criteria's ranking score with weights to rank for each alternative A_j, shown as follows:

$$R(A_j)=\prod_{i=1}^{m}\left(P_{ij}\right)^{w_i}. \quad (28)$$

Where $1 \le j \le n$. The larger value of $RI(A_j)$, the higher preference of the alternative A_j, where $1 \le j \le n$.

Table 2: Linguistic variables for the ratings.

Linguistic variables	Fuzzy numbers
Very low	(0, 0, 0.2)
Low	(0, 0.2, 0.4)
Medium	(0.3, 0.5, 0.7)
High	(0.6, 0.8, 1)
Very high	(8, 1, 1)

5. A Numerical Application of Proposed Model:

Proposed model is applied to a real problem in agriculture. The aim of the present study is to determine the potential rice varieties which will help the farmers to choose the best one for cultivation in their fields. In India, scores of rice varieties are available and farmers will be choosing the rice variety depending on season, yielding ability and tolerance to pests and diseases. So there is confusion in the minds of the farmers with regard to choice of best variety suitable for season and field conditions. Fuzzy decision making model will be highly useful to the farmers in choosing the best one among the varieties available in their areas. Further, it will help the farmer in making a quick decision in respect of choice of variety for his locality. The decision making model will be handy to the farmers community.

To demonstrate the capability of the proposed Fuzzy decision making model, a rice variety selection carried out in cauvery delta region of Tamil Nadu, India is presented. At the beginning stage of paddy cultivation, the farmer wanted to determine the most appropriate rice variety alternative among three candidates, ATD37 (A_1), ADT36 (A_2) and ADT(R)48 (A_3). The evaluation was performed by a decision-making group that consists of six evaluators as follows: Farm Scientist, progressive farmer, educated farmer, illiterate farmer, agricultural officer, farm worker. These evaluators have variable experience of more than 15 years in rice cultivation in cauvery delta region of Tamil Nadu. By virtue of his or her experience, expertise, etc these evaluators are capable of making rational judgment in choice of rice variety for the locality concerned.

5.1. Identification of Criteria:

Criteria to be considered in the selection of rice varieties are determined by the expert team. These sixteen criteria are as follows; digestibility (C1), tolerance for weed infestation (C2), labor use (C3), tolerance for water stress (C4), duration (C5), taste (C6), parboil rice making quality (C7), profitability (C8), compatibility with weather (C9), yield (C10), seed availability (C11), grain size (C12), susceptibility to pest and diseases (C13), yield stability (C14), straw yield (C15), risk in cultivation (C16). As a result, only these sixteen criteria were used in evaluation and decision hierarchy is established accordingly (Table 3).

Table 3: Rice Variety evaluation criteria and its definition.

Criteria	Criterion	Definition
C1	Compatibility with weather	Conducive climate for crop growth in terms of rainfall, temperature and sunshine.
C2	Tolerance for water stress	Ability of the crop to over come lack of moisture at critical stages of crop growth.
C3	Susceptibility to pest and diseases	Proneness of a crop to the attack of insects, bacteria and fungi. A crop susceptible to pests and diseases will give low yields.
C4	Tolerance for weed infestation	Ability of the crop to put up growth and also give yield in spite of the presence of weeds which will compete with crop for water and nutrients.
C5	Risk in cultivation	Monsoon failure or lack of irrigation water at critical stage of Crop growth will be set back for crop production.
C6	Grain size	Grain size is expressed in terms of long, short, bold etc.
C7	Seed availability	Availability of quality seeds from Agriculture Depos, Agricultural Universities and Seed Corporations etc.
C8	Yield stability	Consistency in crop production.
C9	Yield	Crop production / output per unit area (Economic produce)
C10	Straw yield	Yield of byproduct which is generally known as fodder after harvesting of grains i.e. economic produce.
C11	Profitability	Income derived from sale of crop produce – cost of cultivation of a crop. (i.e. Receipts – Expenditure)
C12	Duration	The exact age or period of the crop right from sowing to harvest.
C13	Labor use	Use of agricultural workers for various agricultural operations such as sowing, planting, harvesting.
C14	Digestibility	This is the parameter deciding the digestion of cooked rice.
C15	Taste	It depends on the fineness of variety, starch content etc. For e.g. White Ponni tastes much better than Ponmani rice.
C16	Parboil rice making quality	It is process by which whole grains of rice are soaked in water, steamed and then dried. This parboil rice is good for making tiffin and also it is nutritious compared to raw rice.

5.2. The Weight of Criteria:

After forming the decision hierarchy for the problem, the weight of the criteria to be used in evaluation process are calculated by using AHP method. In this phase, the experts in the expert team are given the task of forming individual pairwise comparison matrix by using the scale given in Table 1. Decision hierarchy structured in Figure 3. Geometric means of these valued are found to obtain the pairwise comparison matrix on which there is a consensus (Table 4).

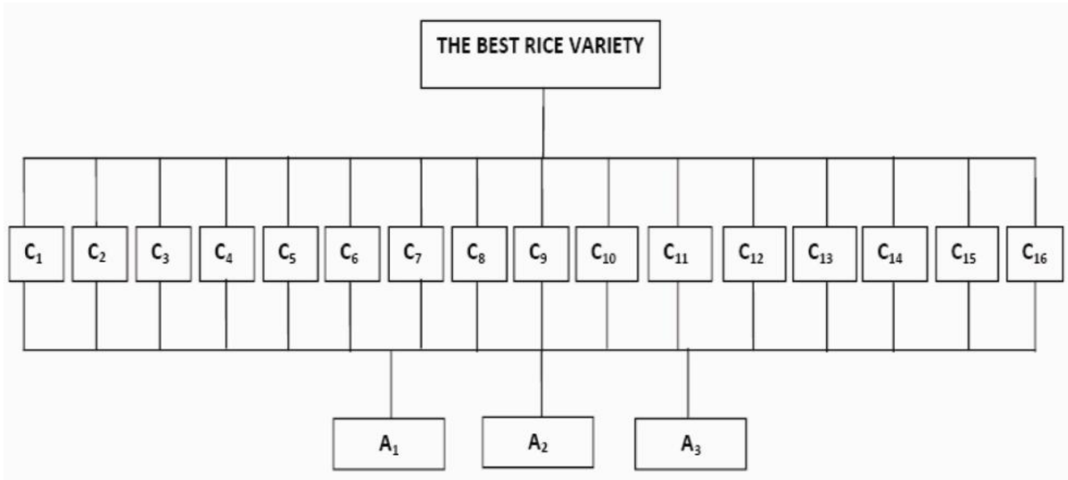

Fig. 3: The decision hierarchy of rice variety selection.

Table 4: Matrix for criteria (pairwise comparison).

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
C_1	1	0.4	0.4	0.5	0.7	0.3	2.0	0.4	0.4	0.5	0.3	0.4	0.3	2.0	0.5	0.4
C_2	2.1	1	1.7	1.9	0.3	2.3	1.2	2.0	0.7	2.4	1.9	2.0	2.3	0.7	2.4	2.3
C_3	2.2	0.5	1	2.1	0.5	3.2	2.1	0.5	2.3	0.4	0.4	2.2	1.2	0.7	3.3	1.2
C_4	1.8	0.5	0.4	1	2.1	1.7	0.4	1.2	0.5	0.4	2.1	2.0	0.7	1.3	1.5	2.4
C_5	1.2	0.3	1.7	0.4	1	1.2	2.4	2.3	1.9	2.4	1.2	2.0	0.5	1.2	0.7	1.2
C_6	0.3	0.4	0.3	0.5	0.7	1	0.4	0.7	0.5	0.7	1.4	2.1	2.2	2.4	1.7	1.9
C_7	0.5	0.8	0.4	2.3	0.4	2.1	1	2.1	1.9	2.3	0.4	2.3	2.1	0.5	3.2	0.5
C_8	1.7	0.5	1.9	0.9	0.4	1.9	0.4	1	3.2	0.4	0.5	0.4	0.3	1.4	2.3	1.7
C_9	2.3	1.2	0.4	1.9	0.5	1.7	0.5	0.2	1	2.1	1.2	2.0	2.1	0.7	1.9	2.3
C_{10}	1.7	0.3	1.9	0.9	0.4	1.2	0.4	1.9	0.4	1	2.1	2.3	0.5	0.3	0.4	1.3
C_{11}	1.7	0.5	2.3	0.4	0.7	0.6	2.1	1.7	0.7	0.4	1	1.2	2.1	1.8	1.4	1.2
C_{12}	2.1	0.5	0.3	0.5	0.5	0.4	0.4	2.1	0.5	0.4	0.7	1	0.5	2.1	2.3	1.9
C_{13}	3.2	0.4	0.7	1.2	1.7	0.3	0.4	3.1	0.4	1.9	0.3	1.9	1	2.3	0.4	1.2
C_{14}	0.5	1.1	1.2	0.9	0.7	0.4	1.9	0.7	1.8	2.1	0.4	0.4	0.4	1	3.4	0.4
C_{15}	2	0.4	0.5	0.6	1.2	0.5	0.3	0.4	0.5	2.4	0.7	0.4	2.1	0.2	1	0.5
C_{16}	2.3	0.3	0.7	0.4	0.9	0.5	1.7	0.5	0.2	0.9	0.7	0.5	0.7	2.3	1.9	1

Table 5: Result obtained with AHP.

Criteria	W	λ_{max}	CI	RI	CR
C_1	0.0364	18.085	0.139	1.5978	0.087
C_2	0.0892				
C_3	0.0770				
C_4	0.0648				
C_5	0.0741				
C_6	0.0562				
C_7	0.0754				
C_8	0.0626				
C_9	0.0705				
C_{10}	0.0561				
C_{11}	0.0679				
C_{12}	0.0502				
C_{13}	0.0654				
C_{14}	0.0596				
C_{15}	0.0446				
C_{16}	0.0498				

The results obtained from the comparisons based on the pairwise comparison matrix provided in Table 4, are presented in Table 5.

Consistency ration of the pairwise comparison matrix is calculated as 0.087 < 0.1. So the weight are shown to be consistent and they used in the selection process.

5.3. Evaluation of Alternatives and Determine the Final Rank:

At this stage, average fuzzy evaluation matrix established by the evaluation of alternatives by linguistic variables in Table2, is presented in Table 6. After the average fuzzy evaluation matrix was determined, the second step is to obtain the ranking score matrix P is presented in Table 7. Using the criteria weights calculated by AHP (Table 5) in this step, the ranking value of the alternative is found by the equation (28) is presented in Table 8.

Table 6: The average fuzzy evaluation matrix for the alternative rice variety.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
A_1	(.5,.7,.9)	(.4,.6,.8)	(.6,.8,.8)	(.5,.7,.9)	(.3,.5,.7)	(.6,.8,.9)	(.5,.7,.9)	(.6,.8,.9)	(.5,.7,.9)	(.4,.6,.8)	(.6,.8,1)	(.6,.8,.9)	(.6,.8,1)	(.6,.8,.9)	(.6,.8,.9)	(.3,.5,.7)
A_2	(.4,.6,.8)	(.5,.7,.8)	(.7,.9,1)	(.7,.9,1)	(.4,.6,.8)	(.4,.6,.8)	(.4,.6,.8)	(.5,.7,.9)	(.4,.6,.8)	(.4,.6,.8)	(.4,.6,.8)	(.4,.6,.8)	(.5,.7,.9)	(.3,.5,.7)	(.5,.7,.8)	(.4,.6,.8)
A_3	(.5,.7,.9)	(.6,.8,.9)	(.5,.7,.9)	(.6,.8,1)	(.5,.7,.9)	(.5,.7,.9)	(.6,.8,1)	(.4,.6,.8)	(.4,.6,.8)	(.6,.8,.9)	(.7,.9,1)	(.5,.7,.9)	(.7,.9,1)	(.5,.7,.9)	(.5,.7,.7)	(.5,.7,.7)
W	0.0364	0.0892	0.0770	0.0648	0.0741	0.0562	0.0754	0.0626	0.0705	0.0561	0.0679	0.0502	0.0654	0.0596	0.0446	0.0498

Table 7: Ranking score matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
A_1	0.8023	0.7168	0.8706	0.8023	0.6354	0.8807	0.8023	0.8807	0.8023	0.7168	0.8909	0.8807	0.8909	0.8807	0.8807	0.6354
A_2	0.7168	0.7924	0.9713	0.9713	0.7168	0.7168	0.7168	0.8023	0.7168	0.7168	0.7168	0.7168	0.8023	0.6354	0.7924	0.7168
A_3	0.8023	0.8807	0.8023	0.8909	0.8023	0.8023	0.8909	0.7168	0.7168	0.8807	0.9713	0.8023	0.9713	0.8023	0.7826	0.7826

Table 8: Weighted rankings.

	R	Ranking order
A_1	0.8027	2
A_2	0.7640	3
A_3	0.8320	1

The result of this investigation shows that ranking of the rice varieties is $A_3 \prec A_1 \prec A_2$.

Conclusion:

The evaluation and selection of rice varieties at the beginning of paddy cultivation was formerly done using quantitative and qualitative information.

The case study using Fuzzy Multi-Criteria decision making concerned an effective selection of rice variety for agriculture.

It may be conclude that multi criteria decision making in agriculture is essential. The selection of best alternative can be used neither on single criteria nor on individual farmer's opinion.

The case study proves that the proposed fuzzy decision making model is effective in a real life situation and could be successfully applied to solve the utility problems and not only in agriculture but also in industries.

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