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Multicriterion Fuzzy Decision Making in Irrigation Planning

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Abstract- Relative importance or weight of criterion indicate the main concern assigned to the condition by the decision-maker while ranking the alternatives in a multicriterion decision making (MCDM) environment. Multicriterion decision making (MCDM) has emerged as an effective methodology due to its ability to merge quantitative and qualitative criteria selection of the best option. Concurrently, fuzzy logic is in advance significance due to its flexibility in managing imprecise individual data. In the present study two fuzzy logic-based MCDM methods, namely similarity analysis (SA) and Decision analysis (DA), are adopted and developed as a fuzzy decision system(FUDS) and applied to a case study of the Aringar Anna Sugar Project(AASP),Thanjavur,Tamilnadu,India,for selecting the best-performing irrigation subsystem. It is found that both SA and DA recommended the same irrigation subsystem as the most excellent. It is fulfilled that application of fuzzy logic methodology for real-world decision-making problems is create to be efficient.

Keywords**:** Multi criteria decision making, Fuzzy logic, FUDS, SA,DA.

I. INTRODUCTION

Decision making is the study of identifying and choosing alternatives based on the values and preferences of the decision maker. Making a decision implies that there are different choices to be measured, and in such a case we want not only to recognize as many of these alternatives as possible but to choose the one that best fits with our goals, objectives, requirements, values, and so on. According to baker et al(2001), decision making must establish with the classification of the decision maker(s) and stakeholder(s) in the decision, reducing the possible dissimilarity about problem definition, requirements, goals and criteria. Relative importance or weight of a criterion indicates the main concern assign to the condition by the decision–maker while ranking the alternatives in a Multi criterion Decision-Making (MCDM) environment. For example, let there be three incompatible criteria net benefits, agricultural production and labor employment in an irrigation planning problem. The economy – based specialist may give additional importance to the net benefits and give less significance to the other two. This outlook may be contrary to those of the agricultural experts or social scientists. A number of methods are presented in writing for computing the weights (Romero and Romero, 2000). Notable among them that are used frequently, are Rating Method, Entropy Method, Analytic Hierarchy Process, etc. These methods are described in detail in this chapter. Before moving further, a brief summary of the normalization method which is necessary in the estimation of weights, multi objective optimization, MCDM, etc.

1. *NORMALIZATION METHODS*

Normalization is the process by which the values of the various alternatives available for a given criterion can be transformed to lie between 0 and 1, so that the criteria of different units fall within the same range. This process also helps to ensure that the criterion with a larger range will not dominate the criterion with smaller range. Romero and Romero (2000) suggested four methods for normalization with salient features which are explained briefly as follows: If f_j (a) is the value of criterion j for alternative a and M_j and m_j are maximum and minimum values of criterion j in the alternative set N, then the normalized value of criterion j for the alternative a, v_j (a) is defined as

$$\text{Method 1: } v_j(a) = \frac{f_j(a)}{M_j}$$

The decision – maker may choose a relevant normalization method depending on the available data and planning problem under consideration More details and application of normalization methods are available in Opricovic and Tzeng (2004) and Shih et.al. (2007).Chen (2000) used the normalization method based on linear scale transformation in fuzzy environment to transform Triangular Fuzzy Numbers (TFN) into normalized TFN .Methodology proposed by Chen (2000) is briefly explained as follows:

2. *ANALYTIC HIERARCHY PROCESS*

Analytic Hierarchy process (AHP) is an MCDM method based on priority theory. It deals with complex problems which involve the consideration of multiple criteria / alternatives simultaneously. Its ability (1) to incorporate data and judgments of experts into the model in a logical way, (2) to provide a scale for measuring intangibles and method of establishing priorities, (3) to deal with interdependence of elements in a system, (4) to allow revision of judgments in a short time, (5) to monitor the consistency in the decision – makers judgments and (6) to accommodate group judgments if the groups cannot reach a natural consensus, makes this method a valuable contribution to the field of MCDM (Saaty and Gholamnezhad, 1982; Saaty, 1990). The methodology is capable of

(a) Breaking down a complex, unstructured situation into its component parts,

(b) Arranging these parts into a hierarchic order (criteria, sub criteria, alternatives, etc.),

(c) assigning numerical values from 1 to 9 to subjective judgments on the relative importance of each criterion based on the characteristics as presented in Table 1.2, and

(d) Synthesizing the judgments to determine the overall priorities of criteria / sub criteria / alternatives. Eigenvector approach is used to compute the priorities / weights of the criteria / sub criteria / alternatives for the given pair wise comparison matrix. In order to fully specify reciprocal and square pair wise comparison Matrix, $\frac{N(N-1)}{2}$ pairs of criteria / sub criteria / alternatives are to be evaluated. The eigenvector corresponding to the maximum eigenvalue (λ_{max}) is required to be computed to determine the weight vectors of the criteria / sub criteria / alternatives. Small changes in the elements of pair wise comparison matrix imply a small change in λ_{max} and the deviation of λ_{max}..

From N is a deviation of consistency. This is represented by Consistency Index (CI),

$$\frac{(\lambda_{max} - N)}{(N-1)}$$

.

Random Index (RI) is the consistency index for a randomly – filled matrix of size and presented in Table 1.3. Consistency Ratio (CR) is the ratio of CI to average RI for the same size matrix. A CR value of 0.1 or less is considered as acceptable (Saaty, 1990). Otherwise, an attempt is to be made to improve the consistency by obtaining additional information. It was requested to fill in the pair wise comparison matrix based on saaty's nine point scale. Filled up pair wise comparison matrix as presented. Is solved using power method (saaty) And Gholamnezhad, 1982). Maximum eigenvalve (λ_{max}) and consistency Index (CI) are found. Consistency ratio (CR) which is the ratio of consistency index (CI) to random index (random index value for matrix size 8) is indicating that judgments given by expert 1 are satisfactory. Weights of the criteria, on-farm development works, adequacy of water, supply of inputs, conjunctive use of water resources, productivity, farmers participation, economic impact, social impact. It is observed that economic impact, productivity and social impact are given top priorities by both the experts. Maximization of net benefits is selected as the main objective in the constraint method formulation because of higher importance it is attributed. In this method the other two objectives, agricultural production and labor employment are placed as the constraints in the constraint set. Non – dominated set of policies are generated by parametrically varying the bounds of the constraints (transformed objective functions of agricultural production and labor employment) obtained from the individual optimal solution.

3. *STUDYAREA*

The Aringar Anna Sugar Project (AASP) is a state division most important irrigation project in, Tamil Nadu, India, to be found on the river Cauvery. The project is generally meant for irrigation. Global coordinates of the location are 20, 60 latitude north and 65, 25 longitude east. The ASSP project has canal system, namely the, Cauvery and Grand River, Vennar, serving a number of irrigation subsystems. Crops grown in the particular area are paddy (rice), groundnut, sugarcane and pulses in both summer (kharif) and winter (Rabi) seasons. Soils of the particular area are priority under red soil and black soil. Climate of the area is subtropical and semi-arid. There is different variation in temperature with average maximum and minimum values of 36.5^{o} and 27.8^{o}C. The relative humidity difference from 70 to 85%. The present study, four irrigation subsystems under the Cauvery canal are measured and these are denoted as I_1, I_2, I_3 and I_4. These irrigation subsystems differ from each other in terms of acres, farmers and other conditions. Figure 1 presents the location map of the Aringar Anna Sugar Project, Tamil Nadu, and India.

4. *FARMERS' RESPONSE SURVEY*

A farmers' response survey is conduct to recognize the irrigation management individuality, constraint in the irrigation subsystem and to identify performance indicators. response from 47 farmers from the four irrigation subsystems are predictable. Questions were asked concerning canal gate opening details, timing, adequacy and distribution prototype 9 such as equitable, etc.) of water supply, status of supplementing canal supplies with groundwater, usage of high-yield variety seeds, knowledge of critical periods of crops, cost of canal water, contribution in operation and management works, relationship with co-farmers and authorities and position of farmers' associations for effective participatory irrigation management. Question were also asked about constraint which may decrease yield such as poor drainage, land development work, availability of marketing facilities, fertilizers and water, and the equivalent effect on economic and social scenarios. suggestion from farmers are also solicit which can be useful for additional improvement of the project. The main conclusion emanate from the response survey are: (1) all farmers have articulated their satisfaction with the performance of the project and agreed that they benefit from the project; (2) they also agreed that the participatory approach in the developmental aspects of the projects yielded very good results in terms of increasing coordination among themselves and expressed that more is to be done in this regard; (3) formation of farmers' associations helps to organize themselves to utilize the resource such as water, fertilizers and seeds more effectively. The response survey also helped the authors to get acquainted with the project in terms of farmers' interaction, interview responses and formulation of performance criteria (indicators).

5. FORMULATION OF INDICATORS AND PAYOFF MATRIX

In the present study, instead of a single indicator of how the input (water) is being used, other indicators such as agricultural, economic and social issues are also considered. Eight performance criteria, namely ON form developments work (C1), Supply inputs (seeds, fertilizers) (C2), conjunctive use of surface and groundwater resources (C3) , participation of farmers (C4), social impact (C5), productivity (C6) and financial impact (C7), Environmental impact (C8) are formulated and evaluated for selecting the best irrigation subsystem. Out of the eight, three criteria, namely environmental impact, conjunctive use of surface and groundwater resources and social impact are related to suitability (Raju and Duck stein, 2002). Even though many of the criteria such as productivity and economic impact are correlated or interdependent to some extent, these are assumed to be independent to assess their effect on the overall planning scenario. Brief details of the criteria are given below. Environmental impact issues analyzed after introduction of irrigation facilities are rise in groundwater table and salinity level. Conjunctive use of surface and groundwater is essential to provide more reliable supply of water to crops when needed as well as to reduce the water logging effect. Information on the above criteria has been obtained from primary sources such as marketing societies and irrigation, groundwater and agricultural departments. Additional information is also obtained from secondary sources such as interviews with farmers, discussions with officials of the project, economic and statistics reports etc. criteria C1, C2, C3, C4 are qualitative in type. Through the remaining criteria C5,C6,C7,C8 are qualitative in type, these criteria are also assumed to be qualitative, as converting productivity (yield) values of eight crops to a base equivalent for two seasons under surface and well irrigation for different landholding becomes complex and similar difficulties are faced for C7 and C8 also.

Payoff matrix on fuzzy rating basis given by individual experts

Irrigation Sub System	Expert	C1	C2	C3	C4	C5	C6	C7	C8
I 1	E1	0.4	0.6	0.6	0.8	0.8	1.0	0.6	0.6
	E2	0.6	0.4	0.4	0.8	0.8	0.8	1.0	0.6
	E3	0.4	0.2	0.4	0.6	0.6	1.0	0.6	0.4
I 2	E1	0.2	0.4	1.0	1.0	1.0	0.8	0.6	1.0
	E2	0.2	0.2	1.0	0.8	0.8	0.8	0.6	0.8
	E3	0.2	0.2	0.8	1.0	1.0	0.6	0.4	0.8
I 3	E1	0.4	0.2	0.8	0.8	0.6	0.8	1.0	0.8
	E2	0.6	0.0	0.6	0.8	0.4	0.6	0.8	0.8

	E3	0.4	0.2	0.6	0.6	0.6	0.6	0.8	1.0
I 4	E1	0.4	0.2	0.4	0.8	0.8	0.8	0.8	0.6
	E2	0.4	0.0	0.0	0.6	1.0	0.8	0.8	1.0
	E3	0.4	0.0	0.6	0.6	0.8	0.6	1.0	0.6

Contribution of farmers: farmers' knowledge:

Contribution of farmers: farmers' knowledge of technology and new developments and contribution are essential for optimum consumption of possessions. It is the ways in which farmers use the irrigation water that determine the success of an irrigation project. Social impact includes labor employments, which is calculated in terms of man days employed per hectare for each crop grown. Productivity of various crops for different season for different landholdings is to be determined. Financial impact include farmers' income and revenue collected for provide of irrigation water. Information on the over criteria has been obtain from main sources such as marketing societies and irrigation, groundwater and agricultural departments. supplementary information is also obtained from minor sources such as interview with farmers, discussions with official of the project, economic and statistics reports etc. Criteria C1, C2, C3, and C4 are qualitative in type. However the outstanding criteria C5, C6,C7,C8 are quantitative in type, these criteria are also assumed to be qualitative, as converting productivity (yield) values of Eight crops to a base corresponding for two seasons under surface and well irrigation for different landholdings becomes complex and parallel difficulties are faced for C7 and C8 also (Raju, 1995). All the above irrigation systems those have a high-quality knowledge of working of the subsystem are request to fill in the payoff matrix with evaluation ranging from 1 for excellent to 0 for unsatisfactory. Farmers' involvement is not considered for formulating this payoff matrix as they may have less or no information about other irrigation subsystems. However, responses from their interviews and discussions with them form the backbone of the formulation process. Table I presents the payoff matrix corresponding to the four irrigation subsystems and the eight routine indicators on a fuzzy rating basis for three experts.

II. ESTIMATION OF WEIGHTS OF THE CRITERIA

The analytic hierarchy procedure is used to estimation weights of the criterion (Saaty and Gholamnezhad, 1982). The technique deals with complex problems, which engage the concern for multiple criteria concurrently. The methodology is capable of:

(a) Breaking downward a complex, unstructured situation into its factor parts,
(b) arrange these parts or variables into a hierarchic order,
(c) Assigning numerical values 1 to 9 to individual judgments on the relative significance of each criterion
(d) 1 =uniformly significant or chosen;
 3 =slightly more significant or chosen;
 5 =strongly or important or chosen;
 7 =very strongly more significant or preferred;
 9 =particularly more significant or chosen;
 2, 4, 6, 8 =intermediate values between the two adjacent judgments)
(e) synthesize the judgment to establish the overall priorities of the criteria.

Pair wise comparison matrix and weights of criteria

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	Weights
C1	1.000	0.166	1.000	0.333	0.333	0.500	0.166	0.333	0.0367
C2		1.000	2.000	3.000	0.500	2.000	0.111	0.200	0.0923

C3			1.000	2.000	0.200	2.000	0.125	0.166	0.0511
C4				1.000	0.333	1.000	0.166	0.143	0.0456
C5					1.000	2.000	0.333	0.333	0.1267
C6						1.000	0.333	0.500	0.0616
C7							1.000	2.000	0.3496
C8								1.000	0.2365

An eigenvector approach that can be solved by the power method is used to compute the priorities of the criteria in a pair wise comparison matrix. The eigenvector corresponding to maximum eigenvalue (λmax) is computed. Since small changes in elements of a pair wise comparison matrix imply a small change in λmax, the deviation of the latter from matrix size N is a deviation of consistency. This is represented by [(λmax-N)/ (N-1)] and termed as the consistency index (CI). Random index (RI) is the consistency index of the random matrix obtained by calculating the consistency index for a randomly filled matrix of size N. The ratio of CI to average RI for the same order matrix is called the consistency ratio (CR). A CR of 0.1 or less is considered acceptable. Contact with farmers and conversation with official helped the decision maker to evaluate the significance of criteria. For example, it was mention throughout discussion and communications that the financial impact was slightly additional important than the environmental impact. Accordingly, values were chosen from Sati's scale and noted. Table II presents the pair wise comparison matrix for criterion. Maximum eigenvalue, consistency index, random index and consistency ratio for the pair wise comparison matrix are 8.937, 0.134, 1.41 and 0.09599 respectively. It is originate that the reliability ratio is less than 0.1, indicating that judgments give by the decision maker are satisfactory. Weights of the criteria for environmental impact, conjunctive use of water resources, farmers' contribution, social impact, productivity and financial impact are found to be 0.0367, 0.0923, 0.0511, 0.0456, 0.1267, 0.0616, 0.2365, and 0.3496 respectively. It is practical that financial impact and productivity are given the top two priorities by the decision maker, whereas farmers' participation occupied the last position. These weights are further used in decision-making analysis. However, equal weights are also considered to observe the sensitivity of ranking. The real time operating conditions of the irrigating system differ from those valid for strictly technical systems. They are significantly subjective by natural conditions, varying on the scale from regular to hazard. Irrigating system is usually very sensitive to natural conditions and biological parameters related to irrigated crops. Good examples of hazardous natural conditions are frequent temperature changes, prolonged droughts, intensive summer showers or over-moisture of heavy soils. It is very difficult, or even impossible, to forecast such event situations which put a stress on the system and make control decisions at least changeable from the long term control point of view.

III. FUZZY MULTICRITERION DECISION MAKING APPROACH

Two fuzzy multi criterion decision making methods, namely similarity analysis (SA) and decision analysis (DA), are applied to the present planning problem.

5.4.5. SIMILARITY ANALYSIS (SA)

Similarity analysis (SA) uses the conception of degree of correspondence measure and the different with a higher degree of similarity with respect to a position different is considered to be the best (Chen, 1994). In this methodology, criterion is represented by interval-valued fuzzy sets (real interval) between zero and one. Characteristics of the different a(a=1,2,…A) for various criteria C1,C2,…Cj (with weight age of the criteria W=w1,w2,,…wj) are represented as interval-valued fuzzy sets as below:

a= (C1 [ya1, y'a1], C2 [ya2, y'a2]….cj[yaj, y'aj]) (1)

Where [yaj, y'aj] represents the fuzzy interval for the a^{th} alternative for then j^{th} criteria within the ranges of [0≤yaj≤y'aj≤1] with 1≤a≤A. Here A and j represent the number of alternative and criterion. Equation (1) can, also be represented in matrix notation as below:

A= [ya1, y'a1], [ya2, y'a2]… [yaj, y'aj] (2)

The objective is to decide such an different as the best, whose individuality are most parallel to the interval-valued fuzzy position different set, R, which is articulated in the matrix notation as below,

R=[x1, x'1], [x2, x'2]… [Xi, x'j] (3)

Where [xj, x'j] represents the fuzzy interval for the reference alternative for j^{th} criteria. parallel between the interval-valued fuzzy reference alternative set give different A for a specified weight set W is compute in the form of parallel measure, S (A,R,W), as follows (Chen, 1994):

IV. FUZZY MULTICRITERION DECISION MAKING APPROACH

Two fuzzy multi criterion decision making methods, namely similarity analysis (SA) and decision analysis (DA), are applied to the present planning problem.

V. SIMILARITY ANALYSIS (SA)

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a= (C1 [ya1, y'a1], C2 [ya2, y'a2]….cj[yaj, y'aj]) (1)

Where [yaj, y'aj] represents the fuzzy interval for the a^{th} different for then j^{th} criterion within the ranges of [0≤yaj≤y'aj≤1] with 1≤a≤A. Here A and j represent the number of alternative and criterion. Equation (1) can, also be represented in matrix data as below:

A= [ya1, y'a1], [ya2, y'a2]… [yaj, y'aj] (2)

The objective is to decide such an alternative as the best, whose individuality are most parallel to the interval-valued fuzzy situation different set, R, which is articulated in the matrix data as below,

R=[x1, x'1], [x2, x'2]… [xi, x'j] (3)

Where [xj, x'j] represents the fuzzy interval for the reference different for j^{th} criterion. parallel between the interval-valued fuzzy reference alternative set Radn give different A for as pacify weight set W is compute in the form of parallel measure, S (A,R,W), as follows (Chen, 1994):

$$\frac{S(A,R,W)=\sum_{j=1}^{j}[1-(|yaj-xj|+|y'aj-x'j|2*wj]}{\sum_{j=1}^{j}wj}$$

(4)

parallel measure values be different from zero to one. The higher the value of S(A,R,W), the higher the parallel between the interval-valued fuzzy sets A and R. In the present study the parallel measure is aimed at for selection of the best alternative. More information about parallel measures. parallel measure S(X, Y) between two real values X and Y can be measured S(X, Y) = 1-|X-Y|where S(X, Y) € (0, 1). Larger value of s(X, Y) represents higher parallel between X and Y. If S(X, Y) equals 1, it indicate that X and Y are the same. If X and Y are two real intervals in [0,1], where X = [X1 ,X2] and Y = [Y1 ,Y2],then S(X,Y) or S([X1,X2],[Y1,Y2])=1-|X1-Y1|+|X2-Y2|/2. Normalization is the process in which values of alternative for a given criterion are transformed to lie between 0 and 1 so those criterions of different units fall within the same range. This process also helps to ensure that criterion with larger range will not dominate criterion with smaller range.

VI. DECISION ANALYSIS (DA)

Decision analysis (DA) uses the perception of decision function and the different with a higher value of decision function is measured to be the best (Ross, 1995). In this methodology the decision function D is defined as

D=M (C1, w1) ∩ M (C2, w2) ∩ …….∩M (Cj, wj) (5)

Where M is a decision calculate connecting criterion and weights. The decision calculate for a different value a is defined as

M (Cj (a), wj) =wj→Cj (a) = w̄ j U Ci (a) (6)

The decision function for the above situation is given as

D=∩ j=1 to J (w̄ j U Cj) (7)

And the optimum explanation a* is the different that maximizes D. essential dummy variable Ej as

Ej= (w̄ j U Cj) (8)

The decision function form μej (a) for variable Ej is

μ_{Ej} (a)=max[μwj(a), μ_{cj}(a)] (9)

The optimum decision function, expressed in membership form, is give as

μD (a*) =min{μ_{E1} (a), μ_{E2} (a),…μ_{Ej}(a)} (10)

VII. RESULTS AND DISCUSSION

Two fuzzy MCDM methods, viz. parallel analysis (SA) and decision analysis (DA), are programmed in a Visual Basic environment (Cornell, 2001) in the form of a decision support system and named as FUDS (Fuzzy Decision Systems)

Table III. Payoff matrix in the fuzzy interval form.

Irrigation					Degree of function				Decision similarity
Sub									and rank and rank
System	C1	C2	C3	C4	C5	C6	C7	C8	

I1[0.4,0.6][0.2,0.6][0.4,0.6][0.6,0.8][0.6,0.8][0.8,1.0] [0.6,1.0] [0.4,0.6] 0.68064(3) 0.466(3)

I2[0.2,0.2][0.2,0.4][0.8,1.0][0.8,1.0] [0.8,1.0][0.6,0.8][0.4,0.6][0.8,1.0] 0.64963(4) 0.266(4)

I3[0.4,0.6][0.0,0.2][0.6,0.8][0.6,0.8][0.4,0.6][0.6,0.8] [0.8,1.0][0.8,1.0] 0.77538(2) 0.666(2)

I4[0.4,0.4][0.0,0.2][0.0,0.6][0.6,0.8][0.8,1.0][0.6,0.8][0.8,1.0][0.6,1.0] 0.81177(1) 0.866(1)

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Figures 2 and 3 present the sample screen of SA and DA approach module of FUDS respectively. In both the modules common inputs are number of alternative, criteria, payoff matrix and weights of criterion.

VIII. SIMILARITY ANALYSIS (SA) MODULE

Based on the evaluations give by the three experts (Table I) for each criterion for each alternative (i.e. three values), the lowest and highest values are considered for the interval for that scenario. For example, for alternative 1 and criterion 2, three experts have given their fuzzy rating as 0.4, 0.6 and 0.4. Accordingly the interval was given as [0.4, 0.6]. If all the experts gave the same rating such as 0.2, 0.2 and 0.2 then the interval was given as [0.2, 0.2]. Presents the payoff matrix in the interval form. Weights of the criteria are estimated from the analytic hierarchy process. The reference alternative for each criterion is taken as (1, 1). The module computes the degree of similarity between the give alternative and the reference alternative (as per Equation 4). High degrees of sample calculation of degree of similarity of I1 are shown in the Appendix. Calculations of degree of similarity are with reference to Table III using Equation (4). Normalized weights of the eight criteria are 0.3496, 0.2365, 0.1267, 0.0923, 0.0616, 0.0511, 0.0456, and 0.0367. Substituting values in Table III for irrigation subsystem I_1 and substituting $\sum^{J}_{j=1}$wj=1, in Equation (4), the degree of similarity for irrigation subsystem I_1 is computed as follows,

[1-(|0.4-1.0| + |0.6-1.0|)/2]x0.0367 + [1-(|0.2-1.0| + |0.6-1.0|)/2]x0.0923 + [1-(|0.4-1.0| + |0.6-1.0|)/2]x0.0511 + [1-(|0.6-1.0| + |0.8-1.0|)/2]x0.0456+[1(|0.61.0|+|0.81.0|)/2]x0.1267+[1(|0.81.0|+|1.0-1.0|)/2]x0.0616+ [1-(|0.6-1.0| + |1.0-1.0|)/2]x0.3496 + [1-(|0.4-0.8| + |0.6-1.0|)/2]x0.2365 =0.68064

Similarity measures for irrigation subsystems I_1 to I_4 are computed and found to be 0.68064, 0.64963, 0.77538 and 0.81177 indicating that $I_4$is the best.

presents degree of similarity measures and corresponding ranking pattern for the four irrigation subsystems. Similarity measure S (A, R, W) of alternative A with reference to R for a given weight set W (W=w1, w2 …wj) is given as (Chen, 1994)

S (A, R, W) = $\sum^{J}_{j=1}$ [1-(|yaj-xj| + |y'aj-x'j|)/2*wj]

____

$\sum^{J}_{j=1}$ wj

Where A and R are two real intervals in [0, 1] and represented as

A= [ya1, y'a1], [ya2, y'a2]… [yaj, y'aj]

R=[x1, x'1], [x2, x'2]….[xj, x'j]

w̄ j=1-wj where wj are weights of eight criteria. (0.0367, 0.0923, 0.0511, 0.0456, 0.1267, 0.0616, 0.3496, 0.2365);

Wj values for eight criteria are 0.963, 0.907, 0.949, 0.954, 0.873, 0.938, 0.650, and 0.763)

= [(w̄ 1 U C1) ∩ (w̄ 2 U C2) ∩ (w̄ 3 U C3) ∩ (w̄ 4 U C4) ∩ (w̄ 5 U C5) ∩ (w̄ 6 U C6) ∩ (w̄ 7 U C7) ∩ (w̄ 8 U C8)]

Ej= (w̄ j U Cj) (8)

Equation (8) can be expressed in the memberships function from resulting equation (9)

μEj (a) = max [μ w̄ j(a), μcj(a)]

μEj (a) = {max [$\mu_{\bar{w}1}$(a), μ_{c1}(a)] max[$\mu_{\bar{w}2}$(a), μ_{c2}(a)] max[$\mu_{\bar{w}3}$(a), μ_{c3}(a)]

Max [$\mu_{\bar{w}4}$ (a), μ_{c4} (a)], max [$\mu_{\bar{w}5}$ (a), μ_{c5} (a)], max [$\mu_{\bar{w}6}$ (a), μ_{c6} (a)],

Max [$\mu_{\bar{w}6}$ (a), μ_{c6} (a)], max [$\mu_{\bar{w}7}$(a), μ_{c7}(a)], max[$\mu_{\bar{w}8}$(a), μ_{c8}(a)]}

= [(0.963 U 0.2)(0.907 U 0.466)(0.949 U 0.866)(0.954 U 0.266)

(0.873 U 0.666)(0.938 U 0.866)(0.933 U 0.533)(0.866 U 0.333)]

= [0.963, 0.907, 0.949, 0.954, 0.873, 0.938, 0.933, and 0.866 as per equation (10)

μ_D (a*) = min {μ_{Ej}(a)}

= min {μ_{E1} (a), μ_{E2} (a)… μ_{Ej} (a)}

= min [(0.963, 0.907, 0.949, 0.954, 0.873, 0.938, 0.933, 0.866)]

= 0.866.

IX. SENSITIVITY ANALYSIS

The result of altering the weights of criterion on the ranking pattern for both SA and DA is also considered. These changes of weights may also correspond to scenario that refers to different situations that may be predictable in the planning condition. For this purpose, the value of each weight of the criterion is increased and then decreased as much as probable without changing the comparative order of the criterion. Productivity is the second-largest criterion occupy a weight age of 0.202.The earlier values are 0.331 (economic impact) and 0.187 (social impact). Therefore two sensitivity runs are perform for this criterion to examine the influence of values up to 0.330 and 0.188 on the ranking respectively. This represents the range that maintains the same order. Parallel studies are also done for other criterion. Table IV shows the ranges of weights of criterion employed. In total, 10 combinations of weight are evaluated for each method.

Table IV. Ranges of weights for sensitivity analysis.

Criteria	Weight	Min	Max
Economic impact	0.3496	0.3496	------
Productivity	0.2365	0.2161	0.3495
Social Impact	0.1267	0.1966	0.2364
Environmental impact	0.0923	0.0997	0.1266
Conjunctive use of	0.0616	0.0717	0.0921
Water Participation	0.0511	0.0410	0.0615
On farm			
Developments works	0.0456	0.0396	0.0510
Supply of			
Inputs (seeds etc)	0.0367	0.0366	--------

Weights are evaluated for each method. It is observed that all 10 combinations fell into two groups of ranking pattern 3, 4, 2, 1 and 4, 3, 2, 1 (in the order of alternatives) for SA and one group 3, 4, 2, 1 in case of DA. Similarly, study is also made with equal weight for each of the criterion. It is found that the ranking pattern is 1, 2, 4, 4 in the case of SA and 1, 1, 1, 1 (tie for all alternatives) in the case of DA. Sensitivity analysis indicated that the rankings of the irrigation subsystems remained essentially the same as far as the first position is concerned. It is thus observed that integration of fuzzy logic with real-world irrigation planning problems is very effective, particularly with multiple experts and in a subjective data environment.

Description of similarity measure

Chen (1994) proposed the concept of similarity measure. These are explained in three situations.

Case 1. Similarity measure S(X, Y) between two real values X and Y can be measured S(X, Y) =1-|X-Y| where S(X, Y) € (0, 1). Larger value of S(X, Y) represents higher similarity between X and Y. If S(X, Y) equals 1, it indicates that X and Y are the same.

Case 2. If X and Y are two real intervals in [0, 1], where X=[x1, x2] andY= [y1, y2], then S(X, Y) or S ([x1, x2], [y1, y2]) =1-|x1-y1|+|x2-y2|/2.

X. CONCLUSION

A decision support system, FUDS, is developed connecting two fuzzy multi criterion decision-making method and practical to a presented irrigation system in Tamilnadu, India. It is found that weights of the criterion have a significant result on the ranking pattern. However, the first position remains unchanged. It is practical that integration of fuzzy logic with real-world irrigation planning problems is very effective, particularly with multiple experts and in a individual data environment. The fuzzy decision support system, FUDS, is found to be useful due to its interactive nature, flexibility in advance and evolving graphical features and can be adopt for any similar situation to rank alternative. The present study is limited to four irrigation subsystems due to resource restrictions. However, more irrigation subsystems may be studied in a multi measure context to explore the full potential [50] Bender MJ, Simonovic SP. 2000. A fuzzy compromise advance to water resource systems planning under improbability. Fuzzy sets and Systems

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[19] Raju, K.S. and C.R.S. Pillai, (1999) Multicriterion Decision Making in Performance Evaluation of an Irrigation System, European Journal of Operational Research, 112(3), pp. 479-488.al of FUDS.

