Neutrosophic OCRA application in Fertilizer Selection to Amplify Agricultural Output

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Abstract

Decision making models based on neutrosophic theory are highly compatible in designing optimal solutions to the selection based decision making problems. This paper proposes Neutrosophic Operational Competitiveness Rating (NOCRA) which is an improvised and extended version of OCRA. The proposed method is applied to a decision making problem of fertilizer selection with ten alternatives and four core criteria. Sensitivity analysis of the ranking results is in favour of the neutrosophic version of OCRA in comparison to the conventional OCRA. The newly developed method in this paper is more promising as it yields more consistent ranking results.

Keywords: Neutrosophy, OCRA, fertilizer, optimal

Introduction

Formulation of a deterministic kind of decision making model is highly constrained with factors associated with impreciseness and indeterminacy. The theory of neutrosophy developed by Smarandache is preferred to accomplish the objective of obtaining optimal solutions to the decision making problems, especially selection based. The decision making methods are generally of two genres in which one set of methods are used to determine the criterion weights and the other is to rank the alternatives. The conventional multi criteria decision making methods are discussed under neutrosophic environment. The neutrosophic based MCDM methods are applied generally in the ranking process but a very few methods are applied in performance analysis.

OCRA is one of the MCDM methods employed in making optimal decisions on productivity based analysis. This method originated a few decades back by Parkan [8] and it is applied to several decision making scenarios by the researchers. Parkan [9,10] to evaluate the operational efficacy of the hotels, subway system, software development [12] and selection processes of semiconductor manufacturers. Parkan integrated the method of OCRA with TOPSIS and DEA in assessing the performance of banking industries [11]. Bakucs et al [2] combined the method of OCRA with stochastic frontier analysis to handle farm accountancy data. Ozbek [7] associated OCRA with AHP in evaluating the public banking performance. Demiric [3],TusIsık and AytacAdalı [16] integrated OCRA with SWARA to select the optimum hotels based on their performance metrics. Gbegnin and Gurbuz [4] compared the efficacy of OCRA with different

MCDM methods and it is found that the OCRA method is more flexible as it is an approach of measuring relative importance of the decision units.

Dragisa et al [14] used the concept of grey numbers to OCRA. Fuzzy OCRA models are developed by Ulutas [17] to make decisions on supply chain management. Mishra et al [6] formulated Intuitionistic OCRA in making decisions on transportation problems. Hence the method of OCRA is applied both in deterministic and extended fuzzy senses. On intense analysis from the literature the following limitations are identified

(i) The number of applications of OCRA and its extension method are limited.

(ii) The method of neutrosophic OCRA is not applied in decision making scenarios of selection based problems.

This has encouraged the authors to formulate a new genre of decision model based on neutrosophic theory. In this research work the neutrosophic data representations together with neutrosophic operators and deneutrosophication approaches are applied to conventional methods of OCRA. The efficacy of the proposed method is tested by applying to fertilizer selection problem, which is deliberated as a decision makinginstance. Fertilizers consist of the essential supplements to promote agricultural yield. MCDM methods are applied to make optimal decisions on choice making of the fertilizers of various kinds.

Agarwal et al [1] applied fuzzy AHP TOPSIS in fertilizer supply selection problem, Le et al [5] used fuzzy AHP CODAS in fertilizer supply chain management. Sumaryanti et al [15] compared the efficacy of SMART and AHP methods in fertilizer selection problems for paddy growth, but have not given any specific description of the alternatives and criteria considered for decision making. The method of AHP is commonly used to determine the criterion weights. The literature on the applications of MCDM in fertilizer supply selection and fertilizer recommendations are very limited. This has also induced the authors to explore the concept of fertilizer selection in the context of modern agricultural framework with the applications of the NOCRA method.

The contents of the paper are segmented into the below sections. Section II explains the basic definitions of neutrosophy and neutrosophic operators. Section IIIsketches the NOCRA method. Section IV elucidates the application of NOCRA in fertilizer selection based problems. Section V compares the results and concludes the work with scope and futuristic perspective. Fertilizers consist of the essential supplements to promote agricultural yield. MCDM methods are applied to make optimal decisions on choice making of the fertilizers of various kinds.

2. Preliminaries

This section comprises of the fundamental aspects of neutrosophic set, operators and deneutrosophic measures.

2.1 Neutrosophic set[13]

Let X be a universal set. A single valued neutrosophic set N is a triplet of the form $\{(x, P(x), Q(x), R(x)) \mid x \in X\}$, where $P(x), Q(x), R(x) : X \rightarrow [0,1]$ and $0 \leq P(x) + Q(x) + R(x) \leq 3$.

2.2 Arithmetic laws of Neutrosophic sets[13]

2.2.1 Addition law

The sum of two neutrosophic sets N_1 and N_2 is defined as

$N_1 + N_2 = \{(x, P_1(x)+P_2(x) - P_1(x)P_2(x), Q_1(x)Q_2(x), R_1(x)R_2(x)) \; x \in X\}$

2.2.2 Subtraction Law

The difference of two neutrosophic sets N_1 and N_2 is defined as

$N_1 - N_2 = \{(x, \frac{P_1(x)-P_2(x)}{1-P_2(x)}, \frac{Q_1(x)}{Q_2(x)}, \frac{R_1(x)}{R_2(x)} \; x \in X\}$

2.2.3 Multiplication Law

The product of two neutrosophic sets N_1 and N_2 is defined as

$N_1 * N_2 = \{(x, P_1(x)P_2(x), Q_1(x)+Q_2(x) - Q_1(x)Q_2(x), R_1(x)+R_2(x) - R_1(x)R_2(x)) \; x \in X\}$

2.2.4 Division Law

The division of two neutrosophic sets N_1 and N_2 is defined as

$\frac{N_1}{N_2} = \{(x, \frac{P_1(x)}{P_2(x)}, \frac{Q_1(x)-Q_2(x)}{1-Q_2(x)}, \frac{R_1(x)-R_2(x)}{1-R_2(x)} \; x \in X\}$

2.3 Deneutrosophication[18]

It refers to the process of converting neutrosophic values to crisp values. The score value of a neutrosophic set N is defined as $S(N) = P(x) - 2Q(x) - R(x)$

3. Methodology

This section sketches the steps involved in NOCRA

Step 1: Formulation of neutrosophic decision making matrix with u alternatives and v criteria

$$M = [m_{kl}]_{u\times v} = \begin{bmatrix} (Px_{11}, Qx_{11}, Rx_{11}) & \cdots & (Px_{1v}, Qx_{1v}, Rx_{1v}) \\ \vdots & \ddots & \vdots \\ (Px_{u1}, Qx_{u1}, Rx_{u1}) & \cdots & (Px_{uv}, Qx_{uv}, Rx_{uv}) \end{bmatrix} \; k = 1,2,..,u \;\; l = 1,2,\ldots v$$

Step 2: The aggregate preference of the substitutespertaining to non-benefit criteria is determined using$C_k = \sum_{l=1}^{v} z_l \frac{max\,(x_{kl}) - x_{kl}}{min\,(x_{kl})}$ k = 1,2,..,u l = 1,2,…v, z_l is the weight of the criteria. The maximum & minimum of the neutrosophic data is determined using the score values of the values of $[m_{kl}]_{u\times v}$.

Step 3: The linear preference rating of the substitutessubjected to non-beneficial criteria is $\overline{C_k} = C_k - \min(C_k)$

Step 4 : The aggregate preference of the substitutes with respect to benefit criteria is determined using$B_k = \sum_{l=1}^{v} z_l \frac{x_{kl} - \min\,(x_{kl})}{min\,(x_{kl})}$ k = 1,2,..,u l = 1,2,…v, z_l is the weight of the criteria. The maximum &minimum of the neutrosophic data is determined using the score values of the values of $[m_{kl}]_{u\times v}$.

Step 5: The linear preference rating of the alternatives with respect to beneficial criteria is $\overline{B_k} = B_k - \min(B_k)$

Step 6: The total preference rating of the alternatives is determined by

$TP_k = \overline{C_k} + \overline{B_k} - \min\left(\overline{C_k} + \overline{B_k}\right)$

The alternatives with maximum TP_k values is given first priorities.

4. NOCRA in Fertilizer selection

In this section the method discussed in the above section is applied to the solution seeking problem on fertilizer selection. The decision making problem comprises ten alternatives and four criteria. The criteria considered for decision making are costs (CO), ecofriendly (EF), compatibility (CM), consistency (CN). The neutrosophic decision making matrix based on the experts is presented as followsin Table 4.1 with linguistic terms set {Very High (VH), High (H), Moderate (M), Low (L), Very Low (VL)}

Table 4.1 Decision matrix with linguistic variables

Alternatives/ Criteria	**CO**	**EF**	**CM**	**CN**
F1	H	L	M	M
F2	VH	H	L	M
F3	H	M	VH	L
F4	H	H	H	M
F5	M	M	H	L
F6	H	M	L	VL
F7	VH	L	L	M
F8	L	H	M	M
F9	H	H	M	L
F10	L	M	L	M

The matrix with equivalent neutrosophic representations is as follows in Table 4.1

Table 4.2 Neutrosophic Decision matrix

Alternatives/ Criteria	CO	EF	CM	CN
F1	(0.8,0.2,0.1)	(0.4,0.5,0.6)	(0.70.1,0.2)	(0.7,0.1,0.2)
F2	(0.9,0.1,0.1)	(0.8,0.2,0.1)	(0.4,0.5,0.6)	(0.7,0.1,0.2)
F3	(0.8,0.2,0.1)	(0.7,0.1,0.2)	(0.9,0.1,0.1)	(0.4,0.5,0.6)
F4	(0.8,0.2,0.1)	(0.8,0.2,0.1)	(0.8,0.2,0.1)	(0.7,0.1,0.2)
F5	(0.7,0.1,0.2)	(0.7,0.1,0.2)	(0.8,0.2,0.1)	(0.4,0.5,0.6)
F6	(0.8,0.2,0.1)	(0.7,0.1,0.2)	(0.4,0.5,0.6)	(0.3,0.4,0.7)
F7	(0.9,0.1,0.1)	(0.4,0.5,0.6)	(0.4,0.5,0.6)	(0.7,0.1,0.2)
F8	(0.4,0.5,0.6)	(0.8,0.2,0.1)	(0.7,0.1,0.2)	(0.7,0.1,0.2)
F9	(0.8,0.2,0.1)	(0.8,0.2,0.1)	(0.70.1,0.2)	(0.4,0.5,0.6)
F10	(0.4,0.5,0.6)	(0.70.1,0.2)	(0.4,0.5,0.6)	(0.70.1,0.2)

The cost criteria is non –beneficial and the other criteria are beneficial in nature. Also the criterion weights are considered to be equal.

The total preference rating of the alternatives with respect to both beneficial and non-beneficial criteria is given in the following table 4.3

Table 4.3 Total Preference rating values of the alternatives with equal criterion weights

F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
1.25	1.3125	1.5	2.5	1.25	0	0	1.25	0.3125	0

From the above table 4.3 the F4 occupies the first priority. In this case the criterion weights are presumed to be equal. The above procedure is repeated with other MCDM methods of finding the criterion weights such as AHP, CRITIC (CRiteria Importance ThroughIntercriteria Correlation), SWARA (Stepwise Weight Assessment Ratio Analysis). The respective criterion weights are presented in Table 4.4

Table 4.4 Criterion weights using different methods

Methods	CO	EF	CM	CN
AHP	0.492	0.246	0.098	0.164
CRITIC	0.483	0.214	0.122	0.181
SWARA	0.465	0.241	0.119	0.175

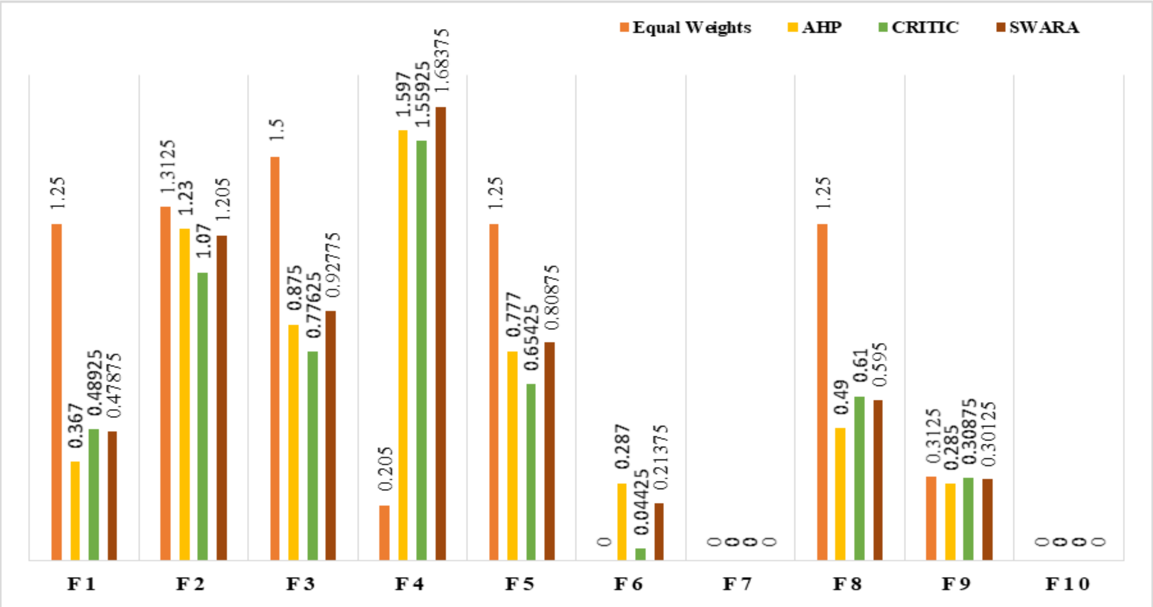
The total preference rating of the alternatives with respect to both beneficial and non-beneficial criteria is given in the following table 4.5

Table 4.5 Total Preference rating values of the alternatives with different criterion weights

Alternatives	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
AHP & NOCRA	0.367	1.23	0.875	1.597	0.777	0.287	0	0.49	0.285	0
CRITIC & NOCRA	0.489	1.07	0.776	1.559	0.654	0.044	0	0.61	0.309	0
SWARA & NOCRA	0.479	1.205	0.927	1.683	0.809	0.214	0	0.595	0.301	0

5. Comparative Analysis

From the total preference rating values of the alternatives with equal and unequal criterion weights the alternatives are ranked. The graphical representation of the alternatives ranking is presented in the following figure 5.1



5.1 Aggregate Ranking of the Alternatives

It is very evident that the ranking results are more promising in the proposed NOCRA method. Also the results obtained are highly consistent in almost all the combinations of the methods applied in ranking of the alternatives. The alternative

F4 occupies the first ranking position and the alternatives F7 and F10 occupy the least position in the ranking. The ranking results are presented in Table 5.1

Table 5.1 Ranking Results of the Alternatives

NOCRA with Equal Weights	F4 > F3 > F2 > F1,F5,F8 >F9>F6,F7,F10
AHP & NOCRA	F4>F2>F3>F5>F8>F1>F6>F9>F7,F10
CRITIC & NOCRA	F4>F2>F3>F5>F8>F1>F9>F6> F7,F10
SWARA & NOCRA	F4>F2>F3>F5>F8>F1>F9>F6> F7,F10

The consistency of the ranking results are determined by the ranking correlation coefficient presented in Table 5.2

Table 5.2 Correlation Coefficient of the Alternatives ranking

	NOCRA with Equal Weights	**AHP & NOCRA**	**CRITIC & NOCRA**	**SWARA & NOCRA**
NOCRA with Equal Weights	1	0.8942271	0.9533067	0.9353142
AHP & NOCRA		1	0.9745941	0.9944435
CRITIC & NOCRA			1	0.9907143
SWARA & NOCRA				1

The above correlation coefficient values strongly indicate the reliability of the ranking results.

Conclusion

This paper proposes a new decision making method of NOCRA which is an extended version of the conventional OCRA in a neutrosophic environment. The efficiency of this proposed method in ranking based decision making problems is high in comparison with other decision making methods. The consistency of the ranking results are validated using different combinations of criterion computing methods. The proposed method is simple in approach and it alleviates indeterminacy in making optimal decisions.

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