Plithogenic CRITIC-MAIRCA Ranking of Feasible Livestock Feeding Stuffs

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Abstract

The objective of any decision-making method in a plithogenic environment is to make an optimal ranking of the alternatives subjected to core essential criteria. The preference for plithogenic decision-making methods is gaining momentum in recent times as plithogenic representations are more comprehensive and efficient in handling uncertain and imprecise decision-making data. In this paper, a plithogenic CRITIC-MAIRCA decision-making model is developed and applied to decision-making on livestock feeding stuff. A total of 20 alternatives under three major feed categories of green fodder, subsidiary fodder and concentrate feed are ranked using MAIRCA (The Multi Attributive Ideal-Real Comparative Analysis) method and the criterion weights are determined using the method of CRITIC (CRiteria Importance Through Inter-criteria Correlation). The final results of the plithogenic ranking are compared with fuzzy and crisp ranking methods and it is observed that the plithogenic CRITIC-MAIRCA method is highly efficient in making a feasible ranking.

Keywords: CRITIC-MAIRCA; plithogenic decision making; livestock; feeding stuff

1. Introduction

Multi-criteria decision-making (MCDM) is a conflict -resolving process characterized by alternatives, criteria and suitable methods of processing data represented in the form of a decision matrix. It is the choice of the experts and their opinions that play a key role in determining the nature of decision making. Deterministic decision making occurs when the input decision matrix is quantitative with precise data, but in many instances only a qualitative decision matrix with uncertain and imprecise data is available. To handle such circumstances, fuzzy decision-making methods are introduced and later they are extended to intuitionistic and neutrosophic decision-making systems.

The fuzzy and its extended decision-making methods are differentiated by various forms of data representations. Zadeh [1] introduced the theory of fuzzy sets. In fuzzy MCDM, the values of the decision matrix are either fuzzy values or linguistic variables represented using fuzzy numbers. Intuitionistic fuzzy sets developed by Atanassov [2] are characterized by membership and non-membership values. The intuitionistic fuzzy MCDM decision matrix consists of intuitionistic representations of data. The concept of hesitancy also forms a part of intuitionistic fuzzy sets. Smarandache [3] coined neutrosophic sets as an extended version of intuitionistic fuzzy sets. The neutrosophic sets consist of truth, falsity and intermediate membership values. In neutrosophic MCDM, the representations of data with intermediate membership values facilitate optimal ranking. In addition to these major types of data representations in MCDM, the other forms of representing data as interval-value sets, Pythagorean sets, are also used based on the decision needs.

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Smarandache [4] introduced the plithogenic set, which is the most generalized and comprehensive form of a set encompassing crisp, fuzzy, intuitionistic and neutrosophic sets. A plithogenic set is characterized by a quintuple of the form (P,a,V,d,c), where P is a plithogenic set with attributes, V set of attribute values, d degree of appurtenance and c degree of contradiction. In Plithogenic MCDM, the representations of data are made using any type of set and a unified decision matrix is obtained by applying plithogenic operators. Researchers have applied Plithogenic sets in different decision making environments, Shazia et al [5] developed a ranking model using Plithogenic Hypersoft sets, Smarandache and Nivetha [6,7] framed a multi-attribute decision making model using plithogenic-n-super hypergraph; introduced Plithogenic Cognitive maps and applied the same in decision making , Sankar et al [8] constructed Plithogenic TOPSIS decision –making model in the context of COVID-19, Sujatha et al [9] applied Plithogenic Fuzzy Cognitive Map approach in making COVID models, Priyadharshini et al [10] introduced Plithogenic cubic sets and illustrated the real-time applications, Nivetha et al [11,12] have integrated the MCDM method of PROMTHEE with Plithogenic Pythagorean hypergraphs to make decision on material selection and developed corona disease decision making model using Plithogenic Hypersoft sets with dual dominant attributes. Prem Kumar Singh [13-15] has applied Plithogenic sets in multi-variable data analysis and Plithogenic graphs in estimating air quality index, dark data analysis and to handling multi-attribute data. Thus, the Plithogenic sets are applied to decision-making problems of different dimensions.

The methods of MCDM are generally grouped into categories. One is to determine the criterion weights and the other is to rank the alternatives. There are many MCDM methods used to find the criterion weights and one of the most feasible methods is CRITIC. Diakoulaki et al [16] introduced CRITIC in 1995 and it has been extensively applied in different decision-making situations. The method of CRITIC is applied in combination with other MCDM methods. Kazan and Ozdemir [17] applied the combined method of TOPSIS (The Technique for Order of Preference by Similarity to Ideal Solution) & CRITIC in making decisions on financial performance assessment. Madic and Radovanović [18] used CRITIC in combination with ROV (Range of Value) to rank non-traditional machining processes. Adali [19] developed CRITIC and MAUT (Multi Attribute Utility Theory) methods of combination in making an optimal selection of contract manufacturers. Kahraman et al [20] extended CRITIC to fuzzy CRITIC (F-CRITIC) to prioritize the suppliers. Xindong et al [21] combined F-CRITIC with COCOSO (Combined Compromise Solution) to evaluate 5G industries. Mishra et al [22] formulated F-CRITIC with EDAS (Evaluation based on Distance from Average Solution) for making an optimal selection of the third-party reverse logistics. Wan et al [23] integrated F-CRITIC and WASPAS (Weighted Aggregated Sum Product Assessment) to make group decisions. Reza et al [24] framed a fuzzy TOPSIS – CRITIC decision-making model to make optimal evaluations on sustainable supply chain management. Shihuli et al [25] framed Intuitionistic Fuzzy EDAS and CRITIC methods to make decisions on evaluating algorithms of sensor networks. Pratibha et al [26] developed neutrosophic -CRITIC-MULTIMOORA (Multi-Objective Optimization based on a Ratio Analysis plus the full MULTIplicative form) MCDM framework to make optimal decisions on food waste treatment methods. Abdel-Basset et al [27] formulated plithogenic TOPSIS-CRITIC for making feasible decisions in supply chain management. The method of CRITIC is combined with other MCDM methods in almost all environments of crisp, fuzzy, intuitionistic, neutrosophic and plithogenic.

The MAIRCA method was proposed by Prof. D. S Pamucar [28] in the Logistics Research Centre at the Belgrade-Defence University and the main purpose of this technique is to evaluate the difference between actual and theoretical values of every alternative. The feasibility nature of the method of MAIRCA has facilitated the combination with other MCDM methods. Aycin and Orcum [29] have developed the combined method of Entropy and MAIRCA to evaluate the performance of banking sectors. Badi et al [30] applied BWM (Best –Worst Method)-MAIRCA in supplier selection of pharmaceuticals., Chatterjee., et al [31] used R'AMATEL (Rough Decision Making Trial and Evaluation Laboratory Model)-MAIRCA in the green supplier selection process, Dragan et al [32] applied FUCOM (Full Consistency method)-MAIRCA in evaluating level crossings, Gigović [33] used GIS (Geographic Information System)-MAIRCA in site selection, Pamucar et al [34] devised DEMATEL (Decision Making Trial and Evaluation Laboratory Model)-MAIRCA to make an optimal selection on logistics center. Pamučar et al [35] framed DEMATEL-ANP (The Analytic Network process) -MAIRCA model using interval rough numbers in group decision making. Ulutas [36] developed the integrated SWARA (Stepwise Weight Assessment Ratio Analysis) and MAIRCA methods to make decisions on management problems. Boral et al [37] have constructed an integrated fuzzy MAIRCA (F-MAIRCA) with AHP (The Analytic Hierarchy process) to analyze failure modes and effects. Zhu et al [38] framed DEMATEL-MAIRCA MCDM using fuzzy rough numbers. Gul

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and Fatih [39] devised a fuzzy BWM-MAIRCA to make decisions on environmental perspectives. Fatih Ecer [40] extended fuzzy MAIRCA to intuitionistic fuzzy MAIRCA and applied it to make decisions on the COVID vaccine selection age. Dragan et al [28] framed neutrosophic MAIRCA to prioritize energy storage technologies. A. Ozcil et al [41] developed plithogenic MAIRCA, which is a more generalized MCDM method of MAIRCA.

Guler [42] has developed the CRISP CRITIC-MAIRCA combination model to make optimal decisions on material selection. To the best of our knowledge, it is determined from the literature that the combination of CRITIC-MAIRCA has not been discussed so far under fuzzy and its extended environments. To bridge this gap, this paper attempts to develop a plithogenic CRTIC-MAIRCA decision-making model to construct a more comprehensive blended model. The proposed plithogenic model will be generalized and, in this paper, the plithogenic representations are made using neutrosophic sets. The proposed method is applied to make optimal decisions on the selection of feasible fodder for livestock.

The paper is organized into the following sections. Section 2 consists of the methodology of plithogenic CRITIC-MAIRCA; section 3 presents an application of the proposed plithogenic method to make a decision on livestock feed selection; section 4 compares the results obtained using plithogenic model with fuzzy and crisp models and the last section concludes the work.

2. Plithogenic CRITIC-MAIRCA

This section presents the steps involved in the Plithogenic CRITIC-MARICA integrated method of decision-making. The graphical representation of Plithogenic CRITIC-MAIRCA is represented in Fig.2.1.

2.1 Plithogenic CRITIC (CRiteria Importance Through Inter-criteria Correlation)

The following steps are used in CRITIC model

Step 1: Formulate a Decision matrix based an expert's opinion with alternatives and criteria

$$DM= X=\begin{bmatrix} x_{11} & x_{12} & \dots & x_{1s} \\ x_{21} & x_{22} & \dots & x_{2s} \\ \dots & \dots & \dots & \dots \\ x_{r1} & x_{r2} & \dots & x_{rs} \end{bmatrix}, i=1, 2 ,\dots r ;\ j = 1,2,\dots s$$

Where, x_{rs} is the membership function of each criterion. Select beneficial and non-beneficial criteria and choose the ideal value (b_j^+) which is the best performance of criteria and the anti-ideal (b_j^-) is the worst performance of criteria. Linguistic variables used are quantified by neutrosophic representations.

Step 2: Obtain an aggregate matrix using plithogenic aggregate operators

The plithogenic aggregate operators are defined by [43]

$$\left(a \wedge_F d, \frac{1}{2}\left(b \wedge_F e + b \vee_F e\right), c \vee_F f \right) \qquad \text{--------(2.1)}$$

$$a \wedge_F d = ad, a \vee_F d = a + d - ad$$

a $\wedge_F$ b is t_{norm} & a $\vee_F$ b is $t_{-conorm}$.

Neutrosophic set N of the form (T, I, F) is converted in to intuitionistic fuzzy set (T, f) by the method of impression membership method [44], is given below

$$f_A = \begin{cases} F_A + \frac{[1-F_A-I_A][1-F_A]}{[F_A+I_A]} & if\ F_A = 0 \\ F_A + \frac{[1-F_A-I_A][F_A]}{[F_A+I_A]} & if\ 0 < F_A \le 0.5 \\ F_A + [1-F_A-I_A]\left[0.5 + \frac{F_A-0.5}{F_A+I_A}\right] & if\ 0.5 < F_A \le 1 \end{cases} \qquad \text{----(2.2)}$$

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$$<\Delta(A)> = <\frac{T_A}{[T_A + f_A]}>.$$

is determined by using median membership fuzzy values [44].

Plithogenic aggregated operators are used to formulate initial decision matrix

Step 3 : Form the Normalization matrix from the below relation

$$x^{*}_{rs} = \frac{x_{rs} - b_j^-}{b_j^+ - b_j^-} \; ; b_j^+ = \max(x_{rs}) \; \& \; b_j^- = \min(x_{rs}) \qquad \text{------- (2.3)}$$

Step 4: Calculate Standard deviation (σ_j)

Step 5: Determine the correlation coefficient ($\rho_{jj'}$) between two criteria x_j & $x_{j'}$

Step 6: Using the below equation, evaluate the measure of conflict criteria

$$\sum_{j'=1}^{s}(1 - \rho_{jj'}) \qquad \text{------ (2.4)}$$

Step 7: Determine the objective weights of criteria

$$C_j = \sigma_j * \sum_{j'=1}^{s}(1 - \rho_{jj'}) \qquad \text{----- (2.5)}$$

$$\omega_j = \frac{C_j}{\sum_{j=1}^{s} C_j} \qquad \text{----- (2.6)}$$

2.2 Plithogenic MAIRCA (The Multi Attributive Ideal-Real Comparative Analysis)

Step :1 The plithogenic aggregate matrix determined in Plithogenic CRITICA is used as the initial matrix at this stage.

Step :2 Calculate the Preferences of alternatives

$$\text{P}(A_i) = \frac{1}{r} \; , \sum_{i=1}^{r} \text{P}(A_i) = 1 \qquad \text{------- (2.7)}$$

Step: 3 Calculate the Expected theoretical matrix

$$T_P = \text{P}(A_j) * \omega_j \qquad \text{- - - -- (2.8)}$$

Step:4 Determine the Actual matrix

$$T_R = \begin{pmatrix} t_{r11} & t_{r12} & \ldots. & \ldots. & t_{r1s} \\ t_{r21} & t_{r22} & \ldots. & \ldots. & t_{r2s} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ t_{rs1} & t_{rs2} & \cdots & \cdots & t_{rrs} \end{pmatrix} \qquad \text{--------(2.9)}$$

For benefit criteria, take maximum value of preference and non-benefit (cost type), choose minimum value of preference

$$T_{Rij} = T_{Pij} * \left(\frac{x_{ij} - \min(x_i)}{\max(x_i) - \min(x_i)}\right) \; ; \qquad T_{Rij} = T_{Pij} * \left(\frac{x_{ij} - \max(x_i)}{\min(x_i) - \max(x_i)}\right) \qquad \text{----- (2.10)}$$

Step:5 Construction of Total Gap matrix (T_G)

$$T_G = T_P - T_R; \text{ where } G = g_{ij} \in (0, (T_{Pij} - T_{Rij})) \; \& \; T_{Pij} > T_{Rij} \qquad \text{-------- (2.11)}$$

Step:6 Ranking the Alternatives

$$Q_i = \sum_{j=1}^{n} g_{ij} \; ; \text{i} = 1, 2\ldots\ldots \text{m} \qquad \text{------ (2.12)}$$

Arrange the alternatives in Descending order and select the smallest rate is the uppermost value.

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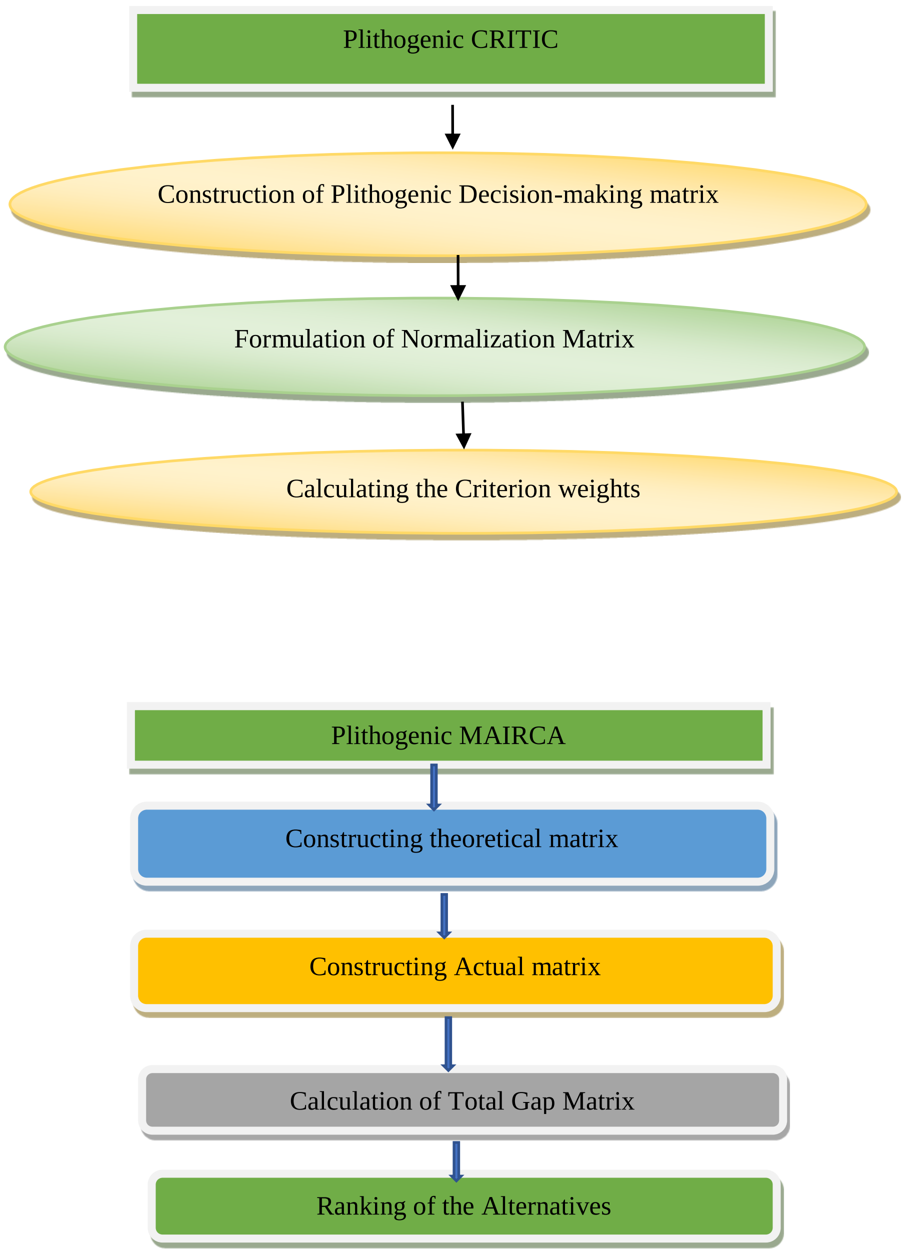

Figure 1: Integrated Plithogenic CRITIC-MARICA Method

3. Illustration to Plithogenic ranking of the fodder alternatives of Livestock

Livestock rearing is one of the basic occupations in most of the rural regions and it is especially one of the primary means of livelihood for the rural populace of Karumathur region in the district of Madurai in the country, India. The economic sustainability of these people is dependent on livestock products and henceforth, it is very essential for them to enhance their productivity by feeding their livestock with quality food stuff called fodder or provender. In general, three types of fodder are most commonly used in this region to feed livestock. The fodder classifications are presented in Table 3.1. The people of this region are not very aware of the best feeding stuff for each of the fodder, as they are less educated and they use feeding stuff that is commonly available. This leads to problems of productivity and there arises the problem of making optimal decisions about the best food stuff. The above decision-making problem is identified and a suitable decision-making matrix is constructed with feed stuffs under each of the fodders as alternatives. The criteria are decided based on the experts from the department of Animal Husbandry and it is tabulated in Table 3.2

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Table 1: Fodders and its Classifications

Green fodder	Subsidiary fodder	Concentrate feeds
G1 Guinea grass	S1 Bankli	CO1 Black gram
G2 Sorghum	S2 Neem	CO 2 Cotton Seed
G3 Maize	S3 Gram straw	CO 3 Groundnut-cake
G4 Napier	S4 Sorghum Kadbi	CO 4 Horse gram
G5 Para grass	S5 Rice Straw	CO 5 Maize
G6 Sunflower	S6 Wheat Straw	CO 6 Rice bran
	S7 Subabool	CO 7 Soyabean seed

Table 2: Criteria for Fodder Selection

L 1	CP	Crude Protein	Beneficial
L 2	CF	Crude Fiber	Beneficial
L 3	NFE	Nitrogen Free Extract	Non-beneficial
L 4	EE	Energy Evaluation	Non-beneficial
L 5	DCP	Digestible Crude Protein	Beneficial
L 6	TDN	Total Digestible Nutrient	Beneficial
L 7	TA	Total Ash	Beneficial
L 8	CA	Calcium	Beneficial
L 9	P	Phosphorous	Non-beneficial

Table 3: The neutrosophic representation of the linguistic variables are 3.1 Green Fodder

Very Low Satisfied	VLS	(0.25,0.6,0.65)
Low Satisfied	LS	(0.45,0.65,0.5)
Satisfied	S	(0.6,0.45,0.5)
Highly Satisfied	HS	(0.85,0.35,0.2)
Extremely Satisfied	ES	(0.95,0.5,0.3)

Table 4: The linguistic initial decision-making matrix is constructed based on the expert's opinion.

Criteria/ Alternatives	DM'S	L1	L2	L3	L4	L5	L6	L7	L8	L9
A1	DM1	HS	ES	VLS	S	HS	LS	HS	ES	S
	DM2	S	ES	LS	HS	ES	S	LS	HS	VLS
	DM3	S	ES	HS	ES	HS	LS	LS	S	HS
A2	DM1	LS	HS	ES	S	VLS	S	HS	S	LS
	DM2	S	VLS	S	HS	ES	S	S	LS	ES
	DM3	HS	VLS	ES	ES	HS	LS	ES	LS	ES
A3	DM1	ES	S	HS	ES	LS	LS	VLS	LS	S
	DM2	S	HS	LS	ES	S	VLS	HS	LS	VLS
	DM3	HS	LS	HS	S	HS	LS	S	S	VLS
A4	DM1	LS	ES	S	VLS	HS	LS	HS	VLS	S
	DM2	S	LS	HS	ES	ES	S	VLS	HS	VLS
	DM3	HS	S	ES	S	LS	S	VLS	HS	ES
A5	DM1	VLS	ES	S	LS	HS	HS	S	VLS	S
	DM2	HS	VLS	ES	S	LS	ES	S	VLS	HS
	DM3	S	VLS	S	LS	S	VLS	S	HS	S
A6	DM1	ES	HS	LS	ES	S	VLS	HS	HS	S
	DM2	S	LS	HS	HS	ES	VLS	S	ES	LS
	DM3	HS	LS	HS	S	HS	VLS	S	S	VLS

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Table 5 : The Plithogenic aggregated matrix is obtained by the equation (2.1 & 2.2) and the Max & Min values are obtained from (2.3)

Criteria/ Alternatives	L1	L2	L3	L4	L5	L6	L7	L8	L9
Guinea grass	0.33	0.61	0.15	0.48	0.59	0.19	0.3	0.55	0.33
Sorghum	0.27	0.1	0.48	0.48	0.34	0.26	0.58	0.32	0.49
Maize	0.44	0.31	0.4	0.56	0.33	0.05	0.24	0.32	0.1
Napier	0.27	0.31	0.47	0.2	0.48	0.22	0.12	0.34	0.25
Para grass	0.17	0.1	0.39	0.19	0.35	0.37	0.31	0.1	0.52
Sunflower	0.44	0.23	0.4	0.53	0.5	0.03	0.43	0.58	0.14
Max	0.44	0.61	0.15	0.19	0.59	0.58	0.58	0.58	0.1
Min	0.17	0.1	0.48	0.56	0.33	0.03	0.12	0.1	0.52

Table 6: The Normalized Decision Matrix and the Standard deviation is calculated from (2.3) & using Step 4

Criteria/ Alternatives	L1	L2	L3	L4	L5	L6	L7	L8	L9
Guinea grass	0.59	1.00	1.00	0.22	1.00	0.29	0.39	0.94	0.45
Sorghum	0.37	0.00	0.00	0.22	0.04	0.42	1.00	0.46	0.07
Maize	1.00	0.41	0.24	0.00	0.00	0.04	0.26	0.46	1.00
Napier	0.37	0.41	0.03	0.97	0.58	0.35	0.00	0.50	0.64
Para grass	0.00	0.00	0.27	1.00	0.08	0.62	0.41	0.00	0.00
Sunflower	1.00	0.25	0.24	0.08	0.65	0.00	0.67	1.00	0.90
Standard deviation SD (σ_j)	0.393	0.370	0.363	0.451	0.412	0.235	0.345	0.367	0.417

Table 7: Correlation between two criterions

	L1	L2	L3	L4	L5	L6	L7	L8	L9
L 1	1	0.353	0.133	-0.825	0.211	-0.992	0.023	0.700	0.891
L 2	0.353	1	0.826	-0.268	0.776	-0.332	-0.436	0.626	0.383
L 3	0.133	0.826	1	-0.248	0.665	-0.071	-0.137	0.460	0.024
L 4	-0.825	-0.268	-0.248	1	-0.061	0.755	-0.471	-0.629	-0.490
L 5	0.211	0.776	0.665	-0.061	1	-0.236	-0.237	0.774	0.252
L 6	-0.992	-0.332	-0.071	0.755	-0.236	1	0.041	-0.700	-0.930
L 7	0.023	-0.436	-0.137	-0.471	-0.237	0.041	1	0.138	-0.394
L 8	0.700	0.626	0.460	-0.629	0.774	-0.700	0.138	1	0.554
L 9	0.891	0.383	0.024	-0.490	0.252	-0.930	-0.394	0.554	1

Table 8: Measure of the conflict created by criterion is obtained from (2.4)

	L1	L2	L3	L4	L5	L6	L7	L8	L9	$\sum_{j'=1}^{s}(1-\rho_{jj'})$
L 1	0.000	0.647	0.867	1.825	0.789	1.992	0.977	0.300	0.109	7.506
L 2	0.647	0.000	0.174	1.268	0.224	1.332	1.436	0.374	0.617	6.072
L 3	0.867	0.174	0.000	1.248	0.335	1.071	1.137	0.540	0.976	6.348

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L 4	1.825	1.268	1.248	0.000	1.061	0.245	1.471	1.629	1.490	10.238
L 5	0.789	0.224	0.335	1.061	0.000	1.236	1.237	0.226	0.748	5.858
L 6	1.992	1.332	1.071	0.245	1.236	0.000	0.959	1.700	1.930	10.465
L 7	0.977	1.436	1.137	1.471	1.237	0.959	0.000	0.862	1.394	9.473
L 8	0.300	0.374	0.540	1.629	0.226	1.700	0.862	0.000	0.446	6.077
L 9	0.109	0.617	0.976	1.490	0.748	1.930	1.394	0.446	0.000	7.708

Table 9: To find the quantity of the information in relation to each criterion C_j an Objective weight w_j from (2.5 &2.6) is given below

Criterian	Standard Deviation (σ_j)	$\sum_{j'=1}^{s}(1-\rho_{jj'})$	$C_j = \sigma_j * \sum_{j'=1}^{s}(1-\rho_{jj'})$	$w_j = \frac{C_j}{\sum_{j=1}^{n} C_j}$
CP (L1)	0.393	7.506	2.95	0.1148
CF (L2)	0.37	6.072	2.25	0.0874
NFE (L3)	0.363	6.348	2.30	0.0896
EE (L4)	0.451	10.238	4.62	0.1796
DCP (L5)	0.412	5.858	2.41	0.0939
TDN (L6)	0.235	10.465	2.46	0.0957
Total Ash (L7)	0.345	9.473	3.27	0.1272
CA (L8)	0.367	6.077	2.23	0.0868
P (L9)	0.417	7.708	3.21	0.1251

Table 10 Weights of each criterion are

Criteria	L1	L2	L3	L4	L5	L6	L7	L8	L9
Weights	0.1148	0.0874	0.0896	0.1796	0.0939	0.0957	0.1271	0.0868	0.1251

Table 11: Initial decision matrix obtained from Plithogenic aggregated value uusing equation (2.1, 2.2)

Criteria/ Alternatives	L1	L2	L3	L4	L5	L6	L7	L8	L9
Guinea grass	0.33	0.61	0.15	0.48	0.59	0.19	0.3	0.55	0.33
Sorghum	0.27	0.1	0.48	0.48	0.34	0.26	0.58	0.32	0.49
Maize	0.44	0.31	0.4	0.56	0.33	0.05	0.24	0.32	0.1
Napier	0.27	0.31	0.47	0.2	0.48	0.22	0.12	0.34	0.25
Para grass	0.17	0.1	0.39	0.19	0.35	0.37	0.31	0.1	0.52
Sunflower	0.44	0.23	0.4	0.53	0.5	0.03	0.43	0.58	0.14

Let us take the preference of alternative is $\frac{1}{6} = 0.167$ which is calculated from (2.7)

Table 12: Theoretical Ranking Matrix (T_{pij}) is obtained from (2.8)

	0.1148	0.0874	0.0896	0.1796	0.0939	0.0957	0.1271	0.0868	0.1251
0.167	0.019	0.015	0.015	0.030	0.016	0.016	0.021	0.014	0.021
0.167	0.019	0.015	0.015	0.030	0.016	0.016	0.021	0.014	0.021
0.167	0.019	0.015	0.015	0.030	0.016	0.016	0.021	0.014	0.021
0.167	0.019	0.015	0.015	0.030	0.016	0.016	0.021	0.014	0.021
0.167	0.019	0.015	0.015	0.030	0.016	0.016	0.021	0.014	0.021
0.167	0.019	0.015	0.015	0.030	0.016	0.016	0.021	0.014	0.021

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Table 13: Calculate Real Rating Matrix (T_r) using (2.10)

0.011	0.015	0.015	0.006	0.016	0.005	0.008	0.013	0.010
0.007	0.000	0.000	0.006	0.001	0.007	0.021	0.006	0.002
0.019	0.006	0.004	0.000	0.000	0.001	0.005	0.006	0.021
0.007	0.006	0.000	0.029	0.009	0.006	0.000	0.007	0.014
0.000	0.000	0.004	0.030	0.001	0.010	0.009	0.000	0.000
0.019	0.004	0.004	0.002	0.010	0.000	0.014	0.014	0.019

Table 14: represents the Determination of Total Gap Matrix (G) from (2.11)

	L1	L2	L3	L4	L5	L6	L7	L8	L9
A1	0	0.000	0.000	0.024	0.000	0.011	0.013	0.001	0
A2	0.012	0.015	0.015	0.024	0	0.009	0.000	0	0.019
A3	0.000	0.009	0.011	0.030	0.016	0	0.016	0	0.000
A4	0.012	0.009	0.015	0.001	0.006	0.010	0.021	0.007	0.007
A5	0.019	0.015	0.011	0	0.014	0.006	0	0.014	0.021
A6	0.000	0	0	0.028	0.005	0.016	0.007	0.000	0.002

Table 15: Ranking the Alternatives obtained from (2.12)

Alternatives	**Q_i**	**Rank**
Guinea grass	0.0683	1
Sorghum	0.1174	6
Maize	0.1049	4
Napier	0.0891	3
Para grass	0.1132	5
Sunflower	0.0807	2

By applying the same technique to the initial decision -making matrices corresponding to other types of subsidiary fodder and concentrate feeds the alternatives under each type are ranked as follows

3.2 Subsidiary fodder

Table 16: The linguistic initial decision-making matrix is constructed based on the expert's opinion.

Criteria/ Alternatives	DM'S	L1	L2	L3	L4	L5	L6	L7	L8	L9
A1	DM1	S	LS	HS	S	LS	HS	S	S	VLS
	DM2	S	S	S	LS	ES	LS	VLS	ES	S
	DM3	HS	LS	HS	ES	S	LS	VLS	S	ES
A2	DM1	VLS	S	LS	HS	ES	VLS	ES	HS	ES
	DM2	ES	LS	VLS	S	HS	ES	S	LS	HS
	DM3	VLS	LS	HS	HS	ES	LS	HS	S	S

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A3	DM1	S	LS	ES	ES	S	LS	HS	ES	HS
	DM2	ES	HS	HS	ES	LS	S	ES	HS	LS
	DM3	LS	HS	S	ES	ES	LS	S	VLS	HS
A4	DM1	HS	ES	S	VLS	HS	S	LS	LS	S
	DM2	VLS	S	ES	ES	VLS	ES	LS	LS	ES
	DM3	S	HS	ES	S	HS	LS	VLS	HS	ES
A5	DM1	ES	HS	S	LS	ES	HS	ES	S	S
	DM2	LS	VLS	HS	HS	S	ES	LS	VLS	S
	DM3	VLS	ES	S	VLS	LS	HS	ES	LS	ES
A6	DM1	LS	S	VLS	S	HS	ES	VLS	S	LS
	DM2	S	LS	S	ES	HS	ES	LS	S	HS
	DM3	S	HS	ES	S	HS	LS	VLS	HS	ES
A7	DM1	ES	S	LS	HS	ES	ES	LS	LS	HS
	DM2	ES	LS	LS	VLS	S	LS	HS	S	S
	DM3	HS	ES	LS	HS	VLS	S	S	ES	LS

Table 17: Ranking of Subsidiary Fodder Alternatives

	Bankli	Neem	Gram straw	Sorghum Kadbi	Rice Straw	Wheat Straw	Subabool
Plithogenic MAIRCA	6	3	1	7	2	4	5

3.3 Concentrate Feed

Table 18: The linguistic initial decision-making matrix is constructed based on the expert's opinion.

Criteria/ Alternatives	DM'S	L1	L2	L3	L4	L5	L6	L7	L8	L9
A1	DM1	HS	S	HS	LS	S	HS	ES	S	LS
	DM2	S	ES	ES	HS	ES	LS	VLS	LS	S
	DM3	S	HS	ES	LS	VLS	S	HS	S	HS
A2	DM1	HS	ES	HS	S	LS	VLS	ES	S	S
	DM2	VLS	S	S	ES	HS	ES	S	S	ES
	DM3	ES	VLS	LS	S	HS	ES	S	ES	LS
A3	DM1	S	LS	HS	S	ES	LS	HS	HS	ES
	DM2	ES	LS	S	ES	LS	VLS	ES	HS	ES
	DM3	HS	S	LS	VLS	LS	HS	ES	HS	S
A4	DM1	VLS	HS	S	ES	HS	S	S	VLS	S
	DM2	S	HS	VLS	LS	S	S	ES	S	LS
	DM3	ES	LS	S	S	HS	HS	LS	HS	S
A5	DM1	S	S	LS	HS	S	ES	LS	LS	VLS
	DM2	HS	HS	ES	VLS	ES	LS	LS	VLS	HS
	DM3	S	VLS	S	ES	HS	S	HS	ES	LS
A6	DM1	S	HS	S	LS	S	S	VLS	ES	HS
	DM2	HS	S	LS	LS	VLS	HS	S	LS	S
	DM3	ES	HS	VLS	HS	S	VLS	ES	S	LS
A7	DM1	HS	LS	VLS	S	VLS	HS	ES	ES	HS
	DM2	LS	ES	HS	S	HS	S	HS	ES	VLS
	DM3	LS	S	ES	VLS	LS	ES	S	LS	S

Table 19: Ranking of Concentrate Feed Alternatives

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	Ranking of Concentrate Feed Alternatives						
	Black gram	Cotton Seed	Groundnut - cake	Horse gram	Maize	Rice bran	Soybean seed
Plithogenic MAIRCA	5	6	1	3	7	3	2

4. Discussion

The proposed method of Plithogenic CRITIC & Plithogenic MAIRCA resolves the uncertainty in decision-making. The proposed plithogenic decision-making method is compared with integrated crisp CRITIC & MAIRCA method and integrated Fuzzy CRITIC & MAIRCA method. The criteria weights obtained under crisp, fuzzy and plithogenic sense are presented in Table 4.1

Table 20: Comparison of criterion weights under Crisp, Fuzzy& Plithogenic CRITIC

	Criterion Weights								
Crisp CRTIC	CP	CF	NFE	EE	DCP	TDN	Total Ash	CA	P
	0.111	0.1079	0.1222	0.116	0.109	0.099	0.123	0.106	0.107
Fuzzy CRITIC	0.009116	0.269865	0.297273	0.05252	0.04187	0.003105	0.015894	0.192116	0.118241
Plithogenic CRITIC	0.1148	0.0874	0.0896	0.1796	0.0939	0.0957	0.1271	0.0868	0.1251

Table 21: The rankings of the alternatives of green fodder under crisp, fuzzy and plithogenic MAIRCA methods

	Ranking of Green Fodder Alternatives					
	Guinea Grass	Sorghum	Maize	Napier	Para grass	Sunflower
Crisp MAIRCA	1	4	2	6	3	5
Fuzzy MAIRCA	1	6	4	3	5	2
Plithogenic MAIRCA	1	6	4	3	5	2

Table 22: presents the rankings of the alternatives of Subsidiary Fodder under Crisp, Fuzzy and Plithogenic MAIRCA methods

	Ranking of Subsidiary Fodder Alternatives						
	Bankli	Neem	Gram straw	Sorghum Kadbi	Rice Straw	Wheat Straw	Subabool
Crisp MAIRCA	7	4	1	6	2	3	5
Fuzzy MAIRCA	6	3	1	7	2	4	5
Plithogenic MAIRCA	6	3	1	7	2	4	5

Table 23: presents the rankings of the alternatives of concentrate feed under Crisp, Fuzzy and Plithogenic MAIRCA methods

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	Ranking of Concentrate Feed Alternatives						
	Black gram	Cotton Seed	Groundnut - cake	Horse gram	Maize	Rice bran	Soybean seed
Crisp MAIRCA	6	3	1	5	7	4	2
Fuzzy MAIRCA	5	6	1	3	7	4	2
Plithogenic MAIRCA	5	6	1	3	7	4	2

It is observed that, from Table 4.2, 4.3 & 4.4 the ranking of the alternatives differ between crisp & fuzzy methods. But the results of both fuzzy and plithogenic are same. Also on comparing all the three different sets (Green Fodder, Subsidiary and Concentrate feeds) of ranking of the alternatives the extent of deviation of crisp ranking results from fuzzy & plithogenic results is less. But still in the context of data representation, and computations plithogenic sets and operators are highly flexible. One of the reasons for the occurrence of slight deviations in the ranking results is the different criterion weights obtained in respective crisp, fuzzy and plithogenic CRITIC methods, but still not much differences have occurred in the criterion weights. This shows that the plithogenic results obtained using neutrosophic representations are quite in consensus with the fuzzy results. Also this generalized model shall be validated with other different types of representations such as intuitionistic fuzzy sets, interval-valued sets, Hypersoft sets and their extensions.

5. Conclusion

This paper presents an integrated Plithogenic CRITIC - MAIRCA decision-making model to find an optimum alternative for livestock feeds. The proposed model is used to select the best alternative that will helps the farmers to increase the productivity of animal milk and milk products. On comparing with other integrated crisp and fuzzy methods, the proposed plithogenic model is more comprehensive and flexible to determine the optimal ranking of the alternatives. As an extension of this research work, other combinations of MCDM methods with CRITIC and MAIRCA shall be developed to find the best integrated plithogenic model

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