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A Hybrid Neutrosophic Entropy-Based Multi-Criteria Decision Model with Application to Agricultural Plant Evaluation: plant in Abyan-Yemen

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Abstract—**This study proposes a hybrid neutrosophic entropy based multi criteria decision- making (MCDM) model for evaluating agricultural plants under uncertainty. The model integrates neutrosophic logic with entropy weighting and is applied to six plant types in Abyan Governorate, Yemen. Statistical analysis using SPSS is conducted to validate the results. The findings demonstrate the robustness and reliability of the proposed model.**

Keywords—Neutrosophic sets, Entropy, MCDM, Agricultural evaluation, SPSS, MATLAB.

I. INTRODUCTION

Decision-making in agricultural systems involves uncertainty and incomplete information. Classical approaches are limited in handling such complexity. This complexity is particularly

Evident in the agricultural sector of Abyan governorate, Yemen, which faces significant challenges, including sever climate fluctuation, water scarcity, and a lack of precise statistical data.

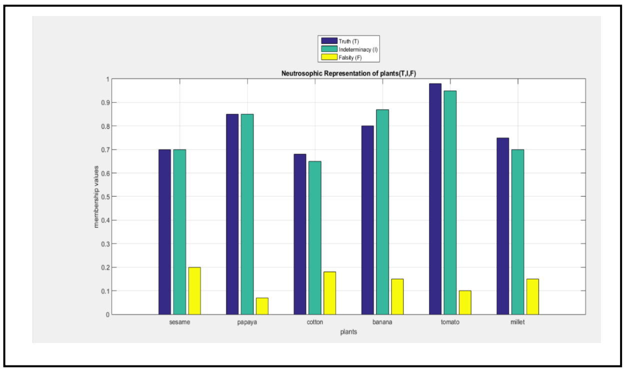
These environmental and informational uncertainties make traditional decision – making methods impractical. therefore, this study applies the proposed Neutrosophic entropy model to help local decision – makers evaluate agricultural plants effectively despite incomplete information

Fuzzy set theory introduced by Lotfi Zadeh provides a mathematical framework for uncertainty [1]. However, it cannot explicitly represent indeterminacy

Fig. 1 Ranking of Agricultural Plants Based on Final Weights By using Neutrosophic Graph.

II. LITERATURE REVIEW

Neutrosophic decision making has been widely studied. Ye proposed several methods for Neutrosophic MCDM[4] .Broumi and Smarandache studied correlation measures in Neutrosophic sets[5].Peng et al .developed outranking approaches under neutrosophic environments [6].



Entropy based approaches have also been used to reduce subjectivity in decision making models [7].

A. Study Area And Data Collection

The study was conducted in Abyan Governorate, Yemen. Six plants were evaluated: Sesame Papaya Cotton Banana Tomato Millet.

. Three criteria were considered: growth rate, heat tolerance, and productivity. Three criteria were considered: growth rate ,heat tolerance ,and productivity. These criteria are critical for agricultural decision – making in arid and semi- arid zones like Abyan, where high temperature and fluctuating yields directly affect crops success [11,12,13]. To process these criteria within the proposed framework, qualitative data and expert judgments were quantified into single- valued Neutrosophic numbers, utilizing the three independent membership function: truth (T), indeterminacy (I), and falsity (F)

III. METHODOLOGY

A. Neutrosophic Representation

(Ti ,Ii ,Fi)

Each alternative is represented by a neutrosophic number

Where

T_i: degree of truth

I_i : :degree of indeterminacy

F_i: : degree of falsity

B. .Entropy Definition

To measure uncertainty entropy is defined for each criterion
$E_i = I_i + F_i$

C. Weighting Model

The weight of each criterion is calculated using

is $w_i = \frac{(1-E_i)T_i}{\sum_{j=1}^{n}(1-E_j)T_j}$

$1 - E_i$: it represents the level of certainty
T_i : it represents the strength of the criterion terms of truth
The product reflects the effects of both certainty and the value of the criterion
Division by the total ensures that the sum the weight

IV. Theoretical Analysis

Normalization property:

$$\sum_{i=1}^{n} w_i = 1$$

V. Results

TABLE1: NEUTROSOPHIC INPUT DATA

Plant	Growth	Heat	Prod	I	F
Sesame	0.70	0.90	0.65	0.10	0.20
Papaya	0.85	0.75	0.88	0.08	0.07
Cotton	0.68	0.92	0.72	0.12	0.18
Banana	0.80	0.70	0.85	0.10	0.15
Tomato	0.90	0.65	0.87	0.05	0.10
Millet	0.75	0.95	0.70	0.10	0.15

TABLE2: FINAL WEIGHTS

Plant	Weight
Sesame	0.135
Papaya	0.200
Cotton	0.132
Banana	0.166
Tomato	0.212
Millet	0.155

Table 2: Final Weights

VI. . Graphical Representation

The graphical representation provides a visual interpretation of the ranking results obtained from the proposed model

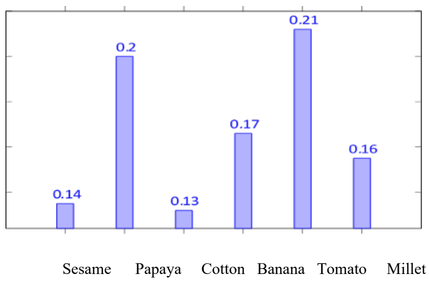


Fig2: Ranking of Agricultural Plants Based on Final Weights

VII. Statistical Analysis

To validate the results of the proposed model, statistical analysis was conducted using SPSS.

TABLE 3: DESCRIPTIVE STATISTICS

Variable	Mean	Std. Deviation
Growth	78.00	8.60
Heat	81.17	12.73
Productivity	77.83	10.00

Table 3: Descriptive Statistics

VIII. Discussion

As shown in Figure 1, Tomato achieves the highest ranking, followed by Papaya and Banana.
The results indicate that Tomato performs best due to its high truth membership and lower uncertainty. Statistical analysis confirms a strong

TABLE 4: CORRELATION MATRIX

	Growth	Heat	Productivity
Growth	1.00	-0.88	0.88
Heat	-0.88	1.00	-0.90
Productivity	0.88	-0.90	1.00

positive relationship between growth and productivity, while heat tolerance shows a negative relationship with productivity

IX. Comparative Analysis

To demonstrate the validity, capability, and superiority of the proposed hybrid Neutrosophic entropy model, a comparative analysis was conducted against the traditional TOPSIS method using the same agricultural dataset form Abyan governorate. Table 5 illustrates the precise comparison of the final weights and ranking results between the two approaches

TABLE 5: FINAL RESULT OF AGRICULTURAL PLANT EVALUATION USING NEUTROSOPHIC PARAMETER:

Plant type	Proposed model(weight)	Proposed model(Rank)	Traditional TOPSIS	Discrepancy/stability
Tomato	0.212	1	1	Stable &best Alternative
Papaya	0.200	2	3	Sensitive to indeterminacy
Banana	0.166	3	2	Vague criteria effect
Millet	0.155	4	4	Stable
Sesame	0.135	5	5	Stable
Cotton	0.132	6	6	Least recommended

As clearly show in table 5, both models successfully identify 'Tomato' as the optimal agricultural plant for Abyan governorate due to its exceptionally high truth value *(T=0.90)* and very low indeterminacy and falsity values *(I=0.05, F=0.10)*
However, a noticeable rank reversal occurs between papaya and Banana. Traditional TOPSIS ranks Banana second and papaya third because it only processes deterministic values

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and fails to incorporate the uncertainty factor. Conversely, the proposed model ranks papaya second utilizes

entropy weights to penalize uncertainty, proving a more reliable, realistic, and stable decision -making tool in unpredictable environments

X. SENSITIVITY ANALYSIS AND MODEL STABILITY

$$\frac{\partial w_i}{\partial T_i} > 0 \quad , \frac{\partial w_i}{\partial E_i} < 0$$

To further expand the sensitivity analysis and evaluate the structural stability of the model under varying parameter priority, three distinct operational scenarios were tested. in Scenarios 1(Growth Rate Dominated):

The weight of growth rate was increased by 20%, while decreasing heat tolerance and productivity.

scenarios 2(Heat Tolerance Dominated):

The weight of heat tolerance was set as the highest priority to simulate extreme conditions in Abyan

Scenarios 3(Productivity Dominated)

The weight of Productivity was maximized to reflect pure economic objective.

As illustrated in the result, across all three scenarios, Tomato consistently maintained its first-rank position, followed closely by *Papaya* in the second position. Minor variation occurred only in the lower ranks (between sesam*e* and cotton). This consistency confirms that the proposed neutrosophic

Entropy model possesses a very high degree of stability and is not overly sensitive to subjective shifts in criteria weights, making it a highly reliable tool for agriculture planning in unpredictable dynamic environments

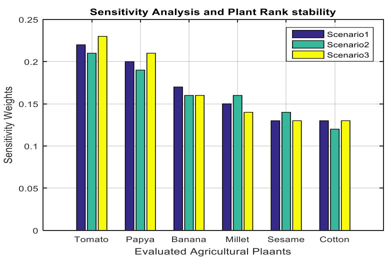

Fig3 sensitivity analysis results across 3 distinct operational scenarios

XI. DISCUSSION OF LIMITATIONS AND FUTURE RESEARCH

While the proposed hybrid neutrosophic entropy model provides robust framework, it has certain limitations. The evaluation currently operates within static decision -making environment. future research could extend this framework into dynamic decision -making environments to observe variations across consecutive agriculture seasons, or integrate other advanced forms

XII. CONCLUSION

This study presented a hybrid neutrosophic entropy-based MCDM model. The results confirm its effectiveness and reliability for agricultural evaluation.

Neutrosophic logic, introduced by Florentin Smarandache ,extends fuzzy logic by introducing three independent components :truth (T) , indeterminacy(I), and falsity (F) [2]. Allowing a more comprehensive representation of uncertain information.

Entropy-based weighting method, introduced by Shannon, are widely used to measure uncertainty and determine objective weights for decision criteria [3]. Therefore, this study propose a hybrid Neutrosophic entropy based multi criteria decision making model for Agricultural plant evaluation under

Uncertainty.

The proposed model integrates Neutrosophic representation with entropy based weighting to objectively assess and rank agricultural alternatives, aiming to improve decision making reliability in complex and uncertain environments.

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