Multi-Criteria Decision-Making Methodology for Sustainable Crop Selection

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Abstract:

Choosing the best biomass crop option for producing biofuel requires a decision-making model because of the many factors involved, the subjective nature of human judgement, and the inherent unpredictability. The neutrosophic type 2 is a valuable tool for handling the ambiguous, inconsistent, and uncertain data often appearing in real-world decision-making situations. Therefore, this study aims to provide a new framework for weighted aggregated sum product assessment (WASPAS) that can be used to solve multi-criteria decision-making (MCDM) issues using neutrosophic type 2 data. The criteria weights are computed. The results show the economic factor has the highest importance in all requirements. This study used nine criteria and twenty alternatives. The WASPAS method was used to rank the other options. The sensitivity analysis is performed under different cases to show the stability of the results. The results show the rank is stable under different cases in this study.

Keywords: MCDM; Crop Selection; Sustainability; Decision Making; Uncertainty; Neutrosophic Type-2

1. Introduction

Looking into the best global energy source to support ongoing economic and environmental development is crucial. Given that the supply of energy is growing, and that fossil fuel-based energy is becoming scarcer and less ecologically friendly, there will eventually be a need for a specific sustainable energy source. Since ethanol can replace energy derived from fossil fuels, it is widely used in many countries[1]–[3]. As a result of the depletion of fossil fuel resources, biomass-based energy has emerged as one of the most promising sustainable energy solutions in recent times[4]–[7]. The evaluation of the most sustainable resource for producing ethanol has gained importance among specialists due to the heterogeneity of biomass resources in various countries[8]–[10].

The biomass crop type may change depending on the technical capabilities and geographic circumstances. Choosing the proper biomass crop substitute is so crucial to the generation of ethanol. As such, using suitable procedures to identify the optimal biomass crop substitute is very important[11]–[13]. Sustainability is a significant problem in bioenergy production, encompassing the three interconnected and interdependent domains of economics, environment, and society[14]–[16]. The best crop substitute impacts the environment and the general population in addition to the economic viability of ethanol production. As a result, the present research focuses on the sustainable alternative selection of biomass crops[17]–[19].

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The biomass crop alternative selection process is a challenging and uncertain multi-criteria decision-making (MCDM) issue since it involves many competing criteria. The traditional MCDM techniques have been used extensively in this context. A few research spoke about how human cognition's complexity may lead to uncertain information in the biomass crop evaluation process. The fuzzy set (FS) theory was developed in the literature to deal with these uncertainties while evaluating biomass crop substitutes. According to FS theory, an element's non-belongingness degree is equal to the complement of its belongingness degree, which is not accurate in practice. The researchers have presented numerous generalizations of FS theory to address this weakness. Atanassov developed the intuitionistic fuzzy set (IFS), which considers both the degrees of non-belongingness and belongingness as a generalized form of FS. IFSs have recently achieved remarkable success across various disciplines due to their capacity to manage uncertainty[20]–[22].

It is clear from the study that the FS and IFS theories need to be equipped to handle vague and contradictory data. An expert may, for instance, express their opinion about a given statement in the following way: 0.6 represents the "possibility that the statement is true," 0.8 represents the "possibility that the statement is false," and 0.3 represents the "possibility that he or she is not sure." This scenario thus falls outside of the purview of FS and IFS. It has been discovered that the theory of the neutrosophic set (NS) is a more helpful instrument for handling this kind of circumstance. Smarandache claims NS theory is an expanded form of FS, IFS, and interval-valued IFS[23]. "Sustainability" encompasses several social, environmental, and economic aspects. The sustainable growth of ports is also characterized by several competing factors and dimensions that must be considered while choosing the best crop. The ability of multiple criteria decision-making (MCDM) to handle both qualitative and quantitative information makes it a widely used approach. Researchers have gradually used MCDM techniques to rate the port sustainability performance over the last ten years[24].

Varying degrees of ambiguity, lack of knowledge, and uncertainty may exist. The T2NFN is chosen because it can manage uncertainties and ambiguity in a more trustworthy and realistic framework than single-values neutrosophic sets (NS) and interval-valued NS. It can understand every facet of a language assessment, including the degree of falsehood, indeterminacy, and truth. The extended Delphi approach under T2NFNs is used in the first stage to choose the influential criteria. This technique leverages the benefits of the NS to express uncertainties like ambiguity, vagueness, and inconsistency[25]–[27].

The contribution of this study:

This study employed the neutrosophic set under the decision-making problem for crop selection.

The neutrosophic type-2 set is used to overcome the uncertainty and vague information in the selection process.

The neutrosophic type-2 set was used with the WASPAS method to rank the alternatives.

The crop selection is used under sustainability criteria.

The criteria weights of sustainability and crop factors are computed.

2. Mathematical Equations of Neutrosophic Sets

The essential ideas about T2NFNs are covered in this section. Because of their capacity to reflect a variety of features, including as truth, indeterminacy, and falsehood degree intrinsic to them, neutrophilic sets are frequently used and acknowledged in the literature to depict uncertainties such as ambiguity and inconsistency[28], [29].

Definition 1

The type-2 neutrosophic set can be defined as:

$$N2N = (a, T_{N2N}(a), I_{N2N}(a), F_{N2N}(a) | a \in A)$$

$$\begin{Bmatrix} T_{N2N}(a): A \rightarrow F[0,1], \\ I_{N2N}(a): A \rightarrow F[0,1], \\ F_{N2N}(a): A \rightarrow F[0,1] \end{Bmatrix}$$

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The triangular neutrosophic number based on single valued neutrosophic set defined as:

$$\begin{Bmatrix} T_{N2N}(a) = \left(T_{N2N(T)}(a), T_{N2N(I)}(a), T_{N2N(F)}(a)\right), \\ I_{N2N}(a) = \left(I_{N2N(T)}(a), I_{N2N(I)}(a), I_{N2N(F)}(a)\right), \\ F_{N2N}(a) = \left(F_{N2N(T)}(a), F_{N2N(I)}(a), F_{N2N(F)}(a)\right) \end{Bmatrix}$$

$$0 \leq T_{N2N}(a)^3 + I_{N2N}(a)^3 + F_{N2N}(a)^3 \leq 3$$

Definition 2

$$N2N_1 \oplus N2N_2 = \begin{Bmatrix} \left(T_{N2N(T_1)}(a) + T_{N2N(T_2)}(a) - T_{N2N(T_1)}(a) \cdot T_{N2N(T_2)}(a)\right), \\ T_{N2N(I_1)}(a) + T_{N2N(I_2)}(a) - T_{N2N(I_1)}(a) \cdot T_{N2N(I_2)}(a), \\ T_{N2N(F_1)}(a) + T_{N2N(F_2)}(a) - T_{N2N(F_1)}(a) \cdot T_{N2N(F_2)}(a), \\ I_{N2N(T_1)}(a) \cdot I_{N2N(T_2)}(a), \\ I_{N2N(I_1)}(a) I_{N2N(I_2)}(a), \\ I_{N2N(F_1)}(a) I_{N2N(F_2)}(a) \\ F_{N2N(T_1)}(a) \cdot F_{N2N(T_2)}(a), \\ F_{N2N(I_1)}(a) F_{N2N(I_2)}(a), \\ F_{N2N(F_1)}(a) F_{N2N(F_2)}(a) \end{Bmatrix}$$

$$N2N_1 \otimes N2N_2 = \begin{Bmatrix} T_{N2N(T_1)}(a) \cdot T_{N2N(T_2)}(a), \\ T_{N2N(I_1)}(a) \cdot T_{N2N(I_2)}(a), \\ T_{N2N(F_1)}(a) \cdot T_{N2N(F_2)}(a), \\ I_{N2N(T_1)}(a) + I_{N2N(T_2)}(a) - I_{N2N(T_1)}(a) I_{N2N(T_2)}(a), \\ I_{N2N(I_1)}(a) + I_{N2N(I_2)}(a) - I_{N2N(I_1)}(a) \cdot I_{N2N(I_2)}(a), \\ I_{N2N(F_1)}(a) + I_{N2N(F_2)}(a) - I_{N2N(F_1)}(a) \cdot I_{N2N(F_2)}(a), \\ F_{N2N(T_1)}(a) + F_{N2N(T_2)}(a) - F_{N2N(T_1)}(a) \cdot F_{N2N(T_2)}(a), \\ F_{N2N(I_1)}(a) + F_{N2N(I_2)}(a) - F_{N2N(I_1)}(a) \cdot F_{N2N(I_2)}(a), \\ F_{N2N(F_1)}(a) + F_{N2N(F_2)}(a) - F_{N2N(F_1)}(a) \cdot F_{N2N(F_2)}(a) \end{Bmatrix}$$

$$\curlyvee N2N_1 = \begin{Bmatrix} \begin{pmatrix} \left(1 - \left(1 - T_{N2N(T_1)}(a)\right)^{\curlyvee}\right), \\ \left(1 - \left(1 - T_{N2N(I_1)}(a)\right)^{\curlyvee}\right), \\ \left(1 - \left(1 - T_{N2N(T_F)}(a)\right)^{\curlyvee}\right) \end{pmatrix}, \\ \left(I_{N2N(T_1)}(a)^{\curlyvee}, I_{N2N(I_1)}(a)^{\curlyvee}, I_{N2N(F_1)}(a)^{\curlyvee}\right), \\ \left(F_{N2N(T_1)}(a)^{\curlyvee}, F_{N2N(I_1)}(a)^{\curlyvee}, F_{N2N(F_1)}(a)^{\curlyvee}\right) \end{Bmatrix}$$

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$$N2N_1^{\Upsilon} = \left\{ \begin{array}{c} \left(T_{N2N(T_1)}(a)^{\Upsilon}, T_{N2N(I_1)}(a)^{\Upsilon}, T_{N2N(F_1)}(a)^{\Upsilon}\right), \\ \left(\begin{array}{c} \left(1-\left(1-I_{N2N(T_1)}(a)\right)^{\Upsilon}\right), \\ \left(1-\left(1-I_{N2N(I_1)}(a)\right)^{\Upsilon}\right), \\ \left(1-\left(1-I_{N2N(T_F)}(a)\right)^{\Upsilon}\right) \end{array} \right), \\ \left(\begin{array}{c} \left(1-\left(1-F_{N2N(T_1)}(a)\right)^{\Upsilon}\right), \\ \left(1-\left(1-F_{N2N(I_1)}(a)\right)^{\Upsilon}\right), \\ \left(1-\left(1-F_{N2N(T_F)}(a)\right)^{\Upsilon}\right) \end{array} \right) \end{array} \right\}$$

3. MCDM Methodology

This section introduces the steps of the SWARA method under neutrosophic set[30], [31]. Figure 1 shows the steps of the suggested approach.

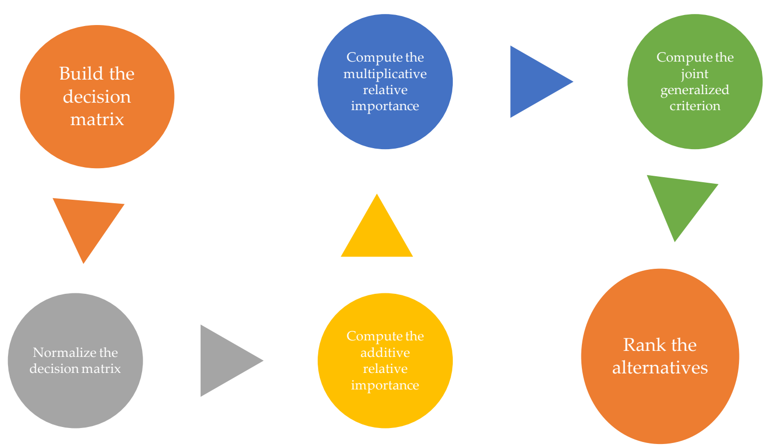

Figure 1. The steps of the SWARA method.

3.1 Build the decision matrix.

$$X = \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix}$$

Where $i = 1,2, \ldots m; j = 1,2, \ldots n$

3.2 Normalize the decision matrix

$$t_{ij}^{*} = \frac{x_{ij}}{\max\limits_{i} x_{ij}}$$

$$t_{ij}^{*} = \frac{\min\limits_{i} x_{ij}}{x_{ij}}$$

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3.3 Compute the additive relative importance

$$A_i^{(1)} = \sum_{j=1}^{n} t_{ij}^{*} \cdot w_j$$

3.4 Compute the multiplicative relative importance

$$A_i^{(2)} = \prod_{j=1}^{n} \left(t_{ij}^{*}\right)^{w_j}$$

3.5 Compute the joint generalized criterion

$$A_i = \frac{1}{2}\left(A_i^{(1)} + A_i^{(2)}\right) = \frac{1}{2}\left(\sum_{j=1}^{n} t_{ij}^{*} \cdot w_j + \prod_{j=1}^{n} \left(t_{ij}^{*}\right)^{w_j}\right)$$

$$A_i = \curlywedge \sum_{j=1}^{n} t_{ij}^{*} \cdot w_j + (1 - \curlywedge) \prod_{j=1}^{n} \left(t_{ij}^{*}\right)^{w_j}$$

4. Results and Discussion

This section introduces the results of the neutrosophic SWARA method. This study used the neutrosophic scale to evaluate the criteria and alternatives by the decision makers and experts. There are nine criteria as shown in Figure 2 are used in this study and twenty alternatives. We show the results of steps of the SWARA method.

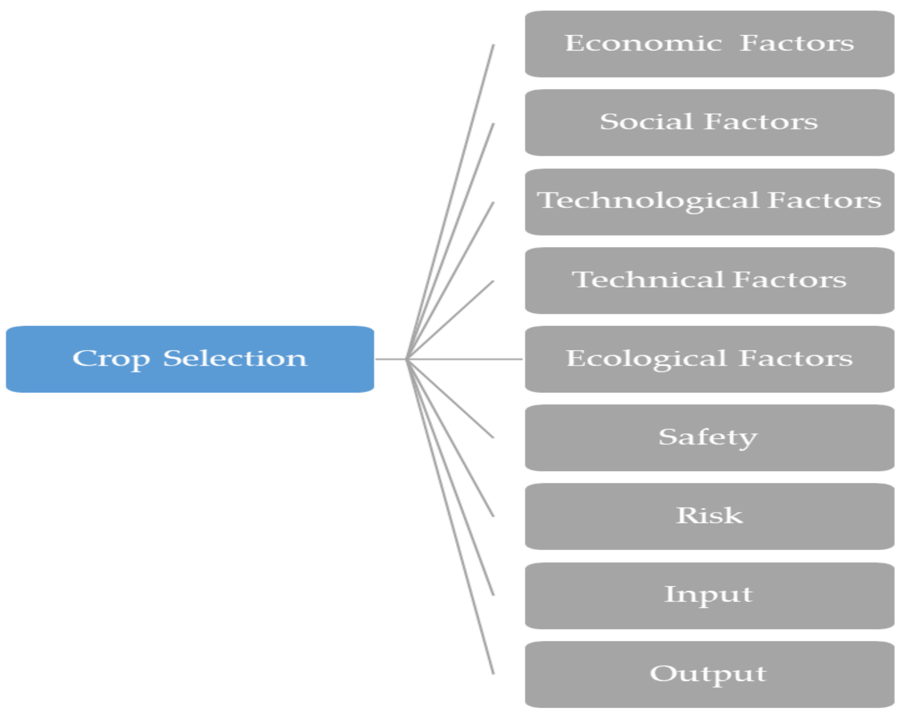

Figure 2. The sustainable crop selection criteria.

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4.1 Build the decision matrix between nine criteria and twenty alternatives. The experts are evaluated the criteria and alternatives. Then we compute the criteria weights by the mean method as shown in Figure 3. The results show the economic factor has the highest importance.

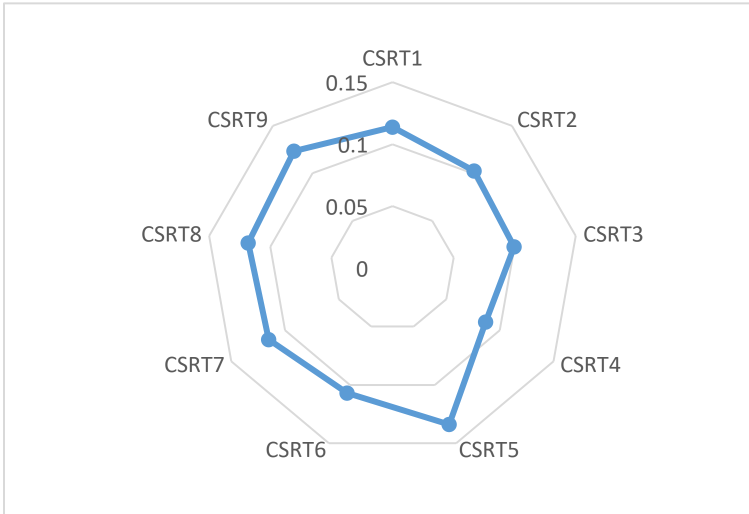

Figure 3. The criteria weights

4.2 Normalize the decision matrix for positive and cost criterion. The all criteria are positive except the economic factor is cost criterion. Table 1 shows the normalization decision matrix.

Table 1: The normalization decision matrix.

	$CSRT_1$	$CSRT_2$	$CSRT_3$	$CSRT_4$	$CSRT_5$	$CSRT_6$	$CSRT_7$	$CSRT_8$	$CSRT_9$
$CSRA_1$	0.376531	0.259372	0.538776	0.265836	0.662039	0.466321	0.662176	0.53401	0.000597
$CSRA_2$	0.537041	0.532928	0.644898	0.54621	0.997721	0.545078	0.561658	0.642132	0.000533
$CSRA_3$	1	0.532928	0.423469	0.543094	0.723166	0.779275	0.642487	0.642132	0.000977
$CSRA_4$	0.536735	0.867275	0.536735	0.543094	0.544965	0.545078	0.647668	0.708629	0.000533
$CSRA_5$	0.982653	0.666667	0.984694	0.656802	0.654787	0.542591	0.543005	0.53401	0.000644
$CSRA_6$	0.610204	0.647416	0.536735	0.54621	0.999793	0.545078	0.997927	0.329949	0.000537
$CSRA_7$	0.954082	0.535968	0.647959	0.656802	0.26523	1	0.545078	0.124873	0.000974
$CSRA_8$	0.536735	0.374671	0.536735	0.473728	0.675508	0.468394	0.412435	0.53401	0.000555
$CSRA_9$	0.981633	0.98075	0.671429	0.54621	0.999793	0.723316	0.545389	0.979695	0.000868
$CSRA_{10}$	0.536735	0.535968	0.533673	1	0.544965	0.658031	0.265285	0.909645	0.000976
$CSRA_{11}$	0.987755	0.975684	0.465306	0.602285	0.654787	0.268394	0.996891	0.53401	0.000537

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$CSRA_{12}$	0.536735	1	0.672347	0.998962	0.886863	1	0.545389	0.462944	1
$CSRA_{13}$	0.984694	0.535968	0.533673	0.54621	0.997203	0.472746	0.66114	0.909645	0.000974
$CSRA_{14}$	0.536735	0.992908	1	0.656282	0.675508	0.675959	0.545078	0.53401	0.000597
$CSRA_{15}$	0.536735	0.643364	0.536735	0.54621	0.657895	0.675648	1	0.564467	0.000641
$CSRA_{16}$	0.982653	0.870314	0.536735	0.383178	0.999793	0.410363	0.607254	0.64467	0.000999
$CSRA_{17}$	0.69898	0.97771	0.240816	0.590862	0.544965	0.545078	0.906736	0.869036	0.000421
$CSRA_{18}$	0.464286	0.532928	0.536735	0.547144	0.545897	0.265585	0.545078	0.571777	0.000233
$CSRA_{19}$	0.60102	0.647416	0.465306	0.54621	0.713842	0.545078	1	1	0.00037
$CSRA_{20}$	0.712245	0.532928	0.981633	0.888889	1	0.673575	0.545078	0.708629	0.000533

4.3 Compute the additive relative importance as shown in Table 2.

Table 2: The relative importance

	$CSRT_1$	$CSRT_2$	$CSRT_3$	$CSRT_4$	$CSRT_5$	CSR_6	$CSRT_7$	$CSRT_8$	$CSRT_9$
$CSRA_1$	0.042865	0.026609	0.053665	0.023038	0.088697	0.04983	0.076159	0.063013	7.37E-05
$CSRA_2$	0.061138	0.054674	0.064235	0.047336	0.133671	0.058246	0.064598	0.075771	6.59E-05
$CSRA_3$	0.113842	0.054674	0.04218	0.047066	0.096887	0.083272	0.073894	0.075771	0.000121
$CSRA_4$	0.061103	0.088975	0.053462	0.047066	0.073012	0.058246	0.07449	0.083618	6.59E-05
$CSRA_5$	0.111867	0.068395	0.098081	0.05692	0.087726	0.05798	0.062453	0.063013	7.95E-05
$CSRA_6$	0.069467	0.06642	0.053462	0.047336	0.133948	0.058246	0.114774	0.038934	6.62E-05
$CSRA_7$	0.108614	0.054986	0.06454	0.05692	0.035535	0.106859	0.062691	0.014735	0.00012
$CSRA_8$	0.061103	0.038438	0.053462	0.041054	0.090502	0.050052	0.047435	0.063013	6.85E-05
$CSRA_9$	0.111751	0.100617	0.066878	0.047336	0.133948	0.077293	0.062727	0.115604	0.000107
$CSRA_{10}$	0.061103	0.054986	0.053157	0.086663	0.073012	0.070316	0.030511	0.107338	0.00012
$CSRA_{11}$	0.112448	0.100097	0.046347	0.052196	0.087726	0.02868	0.114655	0.063013	6.62E-05
$CSRA_{12}$	0.061103	0.102592	0.066969	0.086573	0.118819	0.106859	0.062727	0.054627	0.123452
$CSRA_{13}$	0.112099	0.054986	0.053157	0.047336	0.133601	0.050517	0.07604	0.107338	0.00012
$CSRA_{14}$	0.061103	0.101864	0.099605	0.056875	0.090502	0.072232	0.062691	0.063013	7.37E-05

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CSRA$_{15}$	0.061103	0.066004	0.053462	0.047336	0.088142	0.072199	0.115013	0.066607	7.91E-05
CSRA$_{16}$	0.111867	0.089287	0.053462	0.033207	0.133948	0.043851	0.069842	0.076071	0.000123
CSRA$_{17}$	0.079573	0.100305	0.023987	0.051206	0.073012	0.058246	0.104286	0.102546	5.2E-05
CSRA$_{18}$	0.052855	0.054674	0.053462	0.047417	0.073137	0.02838	0.062691	0.067469	2.88E-05
CSRA$_{19}$	0.068421	0.06642	0.046347	0.047336	0.095638	0.058246	0.115013	0.118	4.57E-05
CSRA$_{20}$	0.081083	0.054674	0.097776	0.077033	0.133976	0.071977	0.062691	0.083618	6.59E-05

4.4 Compute the multiplicative relative importance as shown in Table 3.

Table 3: The multiplicative relative importance

	CSRT$_1$	CSRT$_2$	CSRT$_3$	CSRT$_4$	CSRT$_5$	CSRT$_6$	CSRT$_7$	CSRT$_8$	CSRT$_9$
CSRA$_1$	0.894764	0.870709	0.940258	0.891529	0.946243	0.921714	0.953695	0.928648	0.399965
CSRA$_2$	0.931673	0.937472	0.957248	0.94894	0.999694	0.937213	0.935807	0.949073	0.394418
CSRA$_3$	1	0.937472	0.917972	0.94847	0.957505	0.973702	0.95039	0.949073	0.424991
CSRA$_4$	0.931613	0.985497	0.939902	0.94847	0.921891	0.937213	0.951269	0.960173	0.394418
CSRA$_5$	0.99801	0.959256	0.998465	0.964225	0.944848	0.936755	0.932178	0.928648	0.403695
CSRA$_6$	0.945318	0.956377	0.939902	0.94894	0.999972	0.937213	0.999761	0.877358	0.394695
CSRA$_7$	0.994663	0.938019	0.957699	0.964225	0.837104	1	0.932587	0.782319	0.424828
CSRA$_8$	0.931613	0.904191	0.939902	0.937304	0.9488	0.922151	0.903152	0.928648	0.396329
CSRA$_9$	0.997892	0.998008	0.961099	0.94894	0.999972	0.96598	0.932648	0.997582	0.418856
CSRA$_{10}$	0.931613	0.938019	0.939367	1	0.921891	0.956265	0.858459	0.988888	0.424937
CSRA$_{11}$	0.998598	0.997478	0.926627	0.957011	0.944848	0.868879	0.999642	0.928648	0.394695
CSRA$_{12}$	0.931613	1	0.96123	0.99991	0.984043	1	0.932648	0.91313	1
CSRA$_{13}$	0.998246	0.938019	0.939367	0.94894	0.999625	0.923063	0.953524	0.988888	0.424828
CSRA$_{14}$	0.931613	0.99927	1	0.964159	0.9488	0.959015	0.932587	0.928648	0.399965
CSRA$_{15}$	0.931613	0.955761	0.939902	0.94894	0.945447	0.958968	1	0.934746	0.403459
CSRA$_{16}$	0.99801	0.985851	0.939902	0.92023	0.999972	0.909209	0.944245	0.949515	0.426178
CSRA$_{17}$	0.960049	0.99769	0.867786	0.955425	0.921891	0.937213	0.988803	0.983573	0.383044

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CSRA18	0.91636	0.937472	0.939902	0.949081	0.922102	0.867903	0.932587	0.936166	0.356128
CSRA19	0.943688	0.956377	0.926627	0.94894	0.955842	0.937213	1	1	0.377021
CSRA20	0.962106	0.937472	0.998155	0.989845	1	0.958653	0.932587	0.960173	0.394418

4.5 Compute the joint generalized criterion as shown in Figure 3.

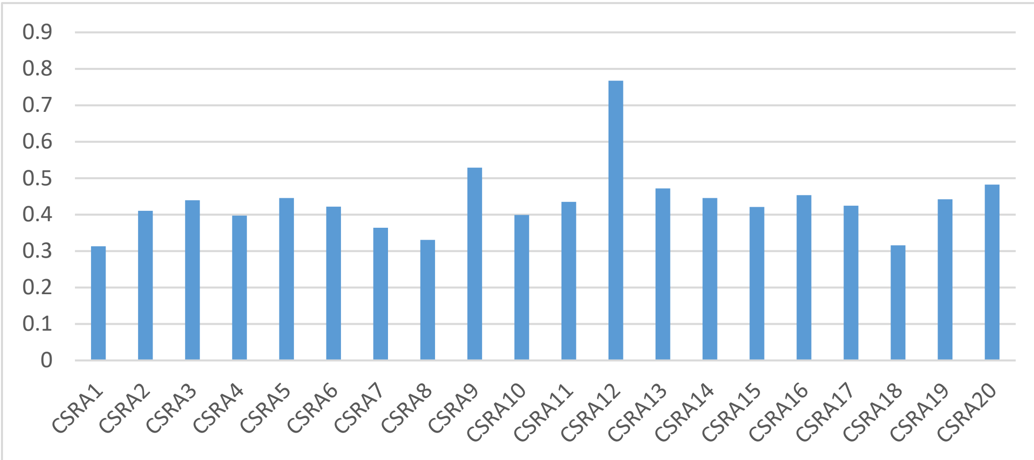

Figure 3. The values of joint generalized criterion.

5. Sensitivity Analysis

In this section, the sensitivity analysis is performed to show the stability of the results. This study changes in value of ⅄ between 0 and 1. The values of joint generalized criterion are shown in Figure 4. The rank of alternatives under different cases shown in Figure 5. The results show the rank is stable under different cases.

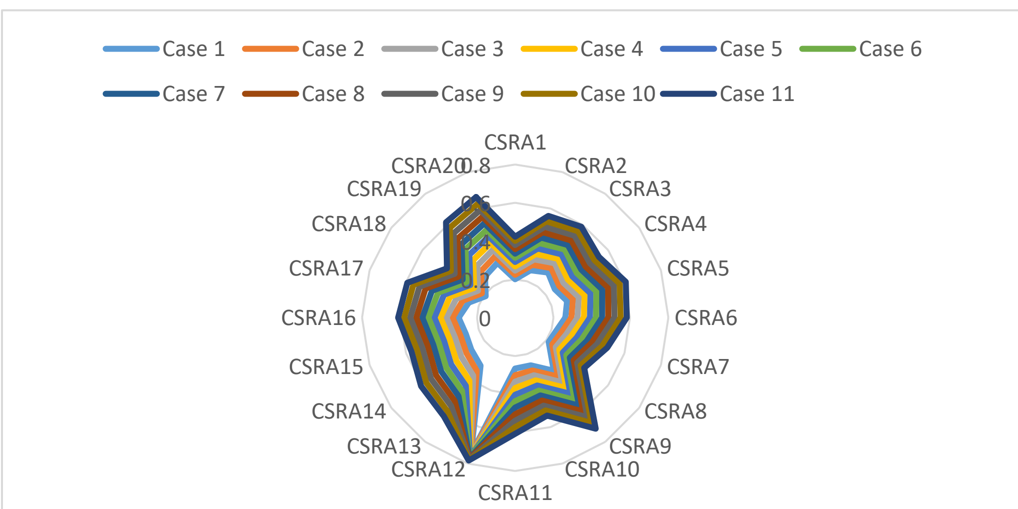

Figure 4. The values of joint generalized criterion under different cases.

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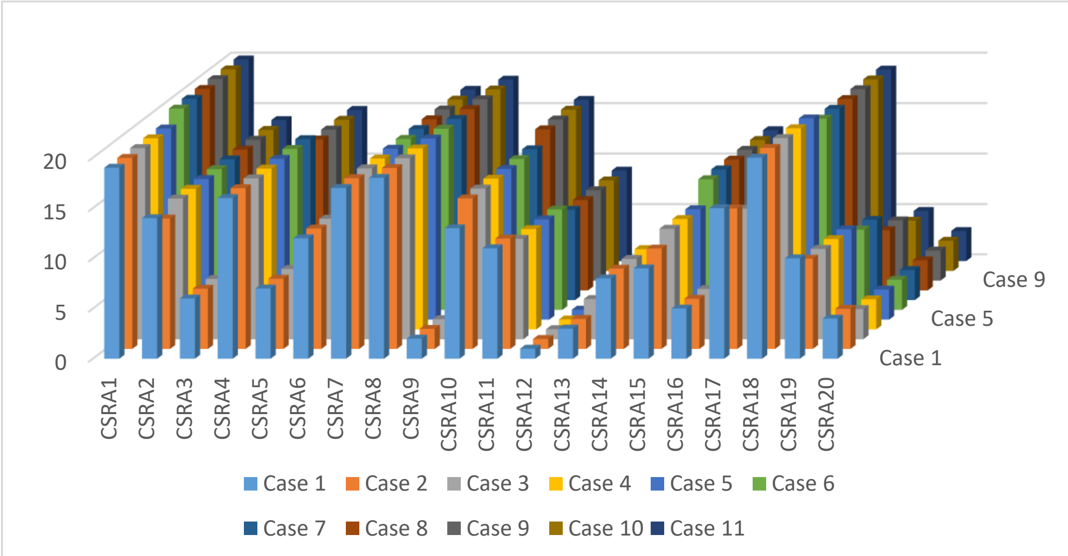

Figure 5. The rank of alternatives under different cases.

6. Conclusion

This work's primary goal is to develop a hybrid technique for classifying and assessing sustainable biomass crops in environments that are unpredictable, imprecise, unpredictable, and inconsistent. A thorough analysis of recent research has been done in order to determine the important criteria for evaluating biomass crops. This study proposed a neutrosophic type 2 under MCDM methodology. The MCDM method used to deal with various criteria in this study. The WASPAS method is a MCDM method used to rank the alternatives. The WASPAS method used under neutrosophic type 2. This study used the nine criteria and 20 alternatives. The criteria weights of this study show the economic factors has the highest rank. The results of alternatives show the alternative one is the worst and alternative 12 is the best. The sensitivity analysis is conducted to show the stability of the result. The results show the ranks are stable.

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