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Prioritizing Local Biomass Resources for Biofuel Production by a Fuzzy Hybrid Decision Making Approach (The Case of Hormozgan Province in Iran)

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ABSTRACT

In recent years, increasing in energy demand and the importance of using energy with minimum green- house gas emission (GHG) leads researchers to study about renewable energy resources such as biomasses. Biomasses can be converted to biofuels by applying the appropriate technologies. In this study, a hybrid group fuzzy multi-criteria decision making (MCDM) approach based on step-wise weight assessment ratio analysis (SWARA), technique for order preference by similarity to ideal Solution (TOPSIS), additive ratio assessment (ARAS), weighted aggregated sum product assessment (WASPAS) and simple additive weighting (SAW) in the fuzzy environment is applied to rank biomasses in the case of Hormozgan province in Iran, because of being a coastal area and the access to different types of first, second and third generation resources of biofuel. After ranking these resources by mentioned methods, two aggregated multi-criteria decision making (MCDM) methods (mean rank method and Copeland method) are employed to prioritize these biomasses. Results of mean rank show that municipal solid wastes (MSW), fish wastes and microalgae have the minimum average rank, respectively and the results of Copeland method show that MSW, fish wastes and microalgae have the maximum (wins-loses), respectively. So, these biomasses are the most suitable ones in biofuel production in this province.

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INTRODUCTION

It is anticipated that the population of the world will be 9 billion by the year of 2050 (Awasthi et al., 2022). Increasing the population of the world results in the increase of energy demand that affects and reduces the non-renewable resources reserves (Sindu et al., 2017). Therefore, researchers are motivated to study about renewable sources of energy such as biofuels (Naeini et al., 2020). Different kinds of biomasses are used to produce biofuels by applying an appropriate bioenergy technology such as transesterification, anaerobic digestion, hydro-processing, and so on. These biomasses are grouped into three classes as the first, second and third generation (Saratale et al., 2019). The first generation biomasses are edible feedstock such as corn, switchgrass,….The second generation biomasses are non-edible ones such as lignocellulosic biomass, municipal solid waste (MSW), forest and agricultural residues. The third- generation biomasses are wet biomasses such as algae and sea weed (Khishtandar et al., 2017; Mohseni & Pishvaee, 2016).

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Iran is a country that has large amount of non-renewable energy resources with exploiting them at an enormous rate (Naeini et al., 2020). It was reported that Iran has a great role in Green House Gas (GHG) emissions in the Middle east and disregard the Kyoto protocol tolerance (Zareei, 2018; Panahi et al., 2019). Biofuels have great role in reducing GHG emissions and enhancing the environmental conditions. In recent years, multi-criteria decision making (MCDM) has become an increasingly popular tool for aiding decision-making processes in the biofuel industry. A classification of bioenergy decision making studies in Iran are shown in Table (1). Iran as a country with different climate conditions has the occasion of growing different variety of biomasses in different regions (Naeini et al., 2020).

Owing to possibility of growing different kinds of biomasses (first, second and third generation) and being a coastal area, Hormozgan province can have great role in biofuel production in Iran. This province is located in south of Iran between the geographical peculiarities of 25° 24′ to 28° 57′ N latitudes and 53° 41′ to 59° 15′ E longitudes. Its area is about 70,000 Km2 and has a population of 1.7 million. Hormozgan province has 11 cities, including Jask, Bashagard, Sirik, Rudan, Minab, Bandar Abbas, Hajiabad, Khamir, Bastak, Bandar Lengeh and Parsian (Mohammadpour et al., 2021)

As mentioned before, due to the possibility of growing a lot of biomasses in Hormozgan province, in this study, the local biomasses of this province are prioritized by a hybrid group fuzzy multi-criteria decision making based on SWARA, ARAS, TOPSIS, SAW, and WASPAS in the fuzzy environment. Based on studying the literature review, different MCDM methods were applied in the field of bioenergy. Each MCDM method has its advantage and defect and its efficiency could be enhanced by integrating two or more methods (Sakhtival & Ilangkumaran, 2015). Therefore, in this study, the local biomasses of Hormozgan province are ranked by integrating MCDM methods that are mean ranking and Copeland methods.

MATERIAL AND METHODS

In this paper, a hybrid group multi-criteria decision-making approach is proposed in the fuzzy environment based on SWARA, TOPSIS, WASPAS, SAW, and ARAS. Fuzzy SWARA is employed to weight the criteria. and two integrating approaches including mean ranking and Copeland methods are used to prioritize alternatives by integrating the methods mentioned above. The steps of this methodological approach are as follows:

The related data are collected from the literature review. Afterwards, a questionnaire is designed and a five-option Likert scale is used to reflect the experts' agreement with the questionnaire items. The validity of the questionnaire is analyzed by the qualitative and quantitative measures. A group of experts accomplished qualitative evaluation and quantitative analysis was performed by CVR and CVI. The requirement of each component of the questionnaire was analyzed by employing CVR according to Lawshe scale (1975) based on a three-point graph, using Equation (1) in which, the total number of the experts and the number of experts with the option of "essential" are N and n_E, respectively.

$$CVR = \frac{n_E - \frac{N}{2}}{\frac{N}{2}} \tag{1}$$

Moreover, CVI as another measure to evaluate the questionnaire calculates the content validity of it and taking into account its simplicity, relevance, specificity, and clarity (Fadavi-Ghaffari et al., 2017). CVI is calculated using Equation (2), in which CVR_i is the content validity ratio of component i, and K is the number of retained components in the questionnaire.

Table 1. Bioenergy decision making problems in Iran

Reference	MCDM methods	Objective of the study
Eskandari etal., (2012)	Analytic Hierarchy Process (AHP)	Evaluating landfill siting
Rezaeiniya etal., (2012)	COmplex PRoportional Assessment (COPRAS) and ANP	Selecting the best site for greenhouse applications
Davoudpour etal., (2012)	AHP	Ranking renewable technology portfolios
Zolfani & Saparauskas, (2013)	step-wise weight assessment ratio analysis (SWARA) and COPRAS	Alternatives for sustainable development in rural areas
Yazdani-Chamzini etal., (2013)	AHP and COPRAS	Analyzing different types of wind powers, hydroelectric systems, solar thermo-electric, biomasses, and biofuels
Azizi etal., (2014)	Analytic network Process (ANP) and Decision-Making Trial and Evaluation Laboratory (DEMATEL)	Ranking wind energy sites
Azarnivand etal.,(2015)	Fuzzy AHP	Evaluating environment and water management systems
Azadeh etal., (2014)	Fuzzy data envelopment analysis	Performing location optimization for wind power generation systems
Vafaeipour etal., (2014)	SWARA and weighted aggregated sum product assessment (WASPAS)	Analyzing potential regions for solar projects
Malekmohammadi & Blouchi (2014)	AHP	Analyzing ecological risk factors
Nosratinia etal., (2015)	AHP and decision support system	Commercialization strategies for utilization of biogas
Khishtandar etal., (2017)	Elimination and Choice Expressing the Reality (ELECTRE)	Ranking biofuel technologies
Babazadeh etal., (2016)	Fuzzy data envelopment analysis	Evaluating locations for Jatropha cultivation
Abadi etal., (2018)	Best worst	Analyzing development strategies for medical tourism
Askarifar etal., (2018)	Best worst and technique for order preference by similarity to ideal Solution (TOPSIS)	Analyzing investment opportunities in Morkan coasts to identify necessary infrastructures and promote entrepreneurial activities
Rabbani etal., (2018)	Mixed integer linear programming and TOPSIS	Designing a sustainable Switchgrass-based bioenergy supply chain network
Kheybari etal., (2019)	AHP	Ranking energy production technologies from biomass
Shahnazari etal., (2020)	AHP and TOPSIS	Determining effective factors in selecting MSW-based energy recovery technologies
Firouzi etal., (2021)	TOPSIS, additive ratio assessment (ARAS), WASPAS, BORDA, Copeland, Rank mean	Ranking suitable resources of biomass to produce biofuel
Mostafaeipour etal., (2021)	Fuzzy best worst	Determining the weights of criteria in solar energy development
Soleymani etal., (2022)	Geographic Information System (GIS) and fuzzy AHP	Selecting the suitable location for power plant
Shokatpour etal., (2022)	TOPSIS	Evaluating conventional renewable energy systems for power generation

$$CVI = \frac{\sum_{i=1}^{K} CVR_i}{K} \tag{2}$$

The reliability of the questionnaire is employed to analyze the internal consistency of the questionnaire by applying Cronbach's alpha reliability test with the range of [0,1]. The questionnaire will be reliable, if the value of Cronbach's alpha will be in the range of [0.6,0.9] (Kazaz et al., 2015).

The final questionnaire is valid and reliable, where all the criteria and alternatives are defined.

The criteria are weighted using SWARA method. SWARA as a subjective weighting method can be easily applied in group decision-making and is not time consuming (Mardani et al., 2017). In this method, criteria are ranked by experts based on their knowledge and experience. In comparison with other subjective weighting methods such as the analytic network process (ANP), AHP, and factor relationship (FARE), SWARA is employed when the priority of the criteria is recognized in advance (Zolfani & Saparauskas, 2013). In this paper, fuzzy SWARA is applied and the significance ratio of the criteria are determined by the experts in linguistic terms which are quantified by numeric ratings according to Table (2).

Afterwards, the average of these crisp values for relative decreases is calculated. Finally, the criteria weights are derived by SWARA as a subjective method in a group decision-making.

Real world problems involve some uncertainty and vagueness and fuzzy set theory can deal with. Moreover, in real world situations, there are widespread use of linguistic variables and fuzzy numbers are appropriate tools to describe them. In the fuzzy set X={$(\boldsymbol{a}, \boldsymbol{\mu_{\tilde{X}}}(\boldsymbol{a}) | \boldsymbol{a} \in \boldsymbol{A}$},, A is a subset of the real numbers $\boldsymbol{R}$, and $\boldsymbol{\mu_{\tilde{X}}}(\boldsymbol{a})$ is known as a membership function of element $\boldsymbol{a}$ in $\boldsymbol{A}$ and its value is in the range of [0, 1]. A fuzzy number is a convex and normal fuzzy set that triangular fuzzy numbers and trapezoidal fuzzy numbers are more popular. The membership function of a triangular fuzzy number $\tilde{x} = \left(x^l, x^m, x^u\right)$ is defined in Equation (3).

$$\mu_{\tilde{X}}(a) = \begin{cases} \dfrac{a - x^l}{x^m - x^l} & x^l \le a \le x^m \\ \dfrac{x^u - a}{x^u - x^m} & x^m \le a \le x^u \\ 0 & otherwise \end{cases} \tag{3}$$

In which, x^l , x^m , and x^u are the lower limit, the mid-value, and the upper limit, respectively.

The algebraic operations for the two positive triangular fuzzy numbers $\tilde{d} = (d^l, d^m, d^u)$ and $\tilde{b}$ $= \left(b^l, b^m, b^u\right)$, and a positive real number λ , are presented in Equations (4)-(8).

Table 2. Linguistic terms and their crisp values.

The scale of the relative importance	Crisp value
Equally important	1
Moderately less important	0.3330
Less important	0.2000
Very less important	0.1430
Extremely less important	0.1110

Table 3. The values of the CVRs for the elements of the questionnaire

Sub- criteria	CVR
C1) The relative advantage of biofuel production over other biomass applications	0.82
C2) Conservation of non-renewable energy resource	0.94
C3) Creating related jobs	0.77
C4) Costs of biomass conversion to biofuel	1.00
C5) The complexity of the process of converting biomass into biofuel	0.85
C6) environmental impacts	0.71
C7) Regional development and	0.71
C8) Investment cost	1.00

$$\tilde{d} \oplus \tilde{b} = \left(d^l + b^l, d^m + b^m, d^u + b^u\right) \tag{4}$$

$$\tilde{d} \otimes \tilde{b} \cong \left(d^l b^l, d^m b^m, d^u b^u\right) for d^l, b^l \succ 0, d^m, b^m \succ 0, d^u, b^u \succ 0 \tag{5}$$

$$\frac{\tilde{d}}{\tilde{b}} \cong \left(\frac{d^l}{b^u}, \frac{d^m}{b^m}, \frac{d^u}{b^l}\right) for d^i \succ 0, b^i \succ 0, i = l, m, u \tag{6}$$

$$\tilde{d}^{-1} \cong \left(\frac{1}{d^u}, \frac{1}{d^m}, \frac{1}{d^l}\right) for d^i \succ 0, i = l, m, u \tag{7}$$

$$r \otimes \tilde{d} \cong \left(rd^l, rd^m, rd^u\right) \tag{8}$$

In fuzzy problems, defuzzification methods should be applied to obtain the best non-fuzzy performance (BNP) value, such as maxima methods, distribution methods, and area methods (Naeini et al., 2020). One of the formulas in defuzzification is according to Equation (9).

$$\mathrm{X} = \frac{\left(x^l + 4x^m + x^u\right)}{6} \tag{9}$$

Ranking alternatives is performed using the TOPSIS method in the group decision-making process in a fuzzy environment.

The situation of alternative i to the criterion j by decision maker k is represented in decision matrix in fuzzy linguistic terms and are shown as a triangular fuzzy number according to Table 4. These fuzzy numbers are shown in the form of $\tilde{x}_{ijk} = \left(x_{ijk}^l, x_{ijk}^m, x_{ijk}^u\right)$, where x_{ijk}^l is the left threshold value, x_{ijk}^m is the midpoint, and x_{ijk}^u is the right threshold value of x_{ijk}.

The average of decision makers opinions is calculated according to Equation (10) to obtain the elements of the group decision matrix. In Equation (10), a_{ij} is the left threshold value, b_{ij} is the midpoint, and c_{ij} is the right threshold value of averaging decision maker opinions ($\tilde{x}_{ij}$).

$$\tilde{x}_{ij} = \frac{1}{k}\sum_k \tilde{x}_{ijk} = \left(a_{ij}, b_{ij}, c_{ij}\right) \tag{10}$$

Table 4. The opinions of decision-makers (DMs) about the relative importance of criterion j to criterion k.

The relative decrease in importance of criterion j to criterion k	DM1	DM2	DM3	DM4	DM5	DM6	The average value of decision maker's opinions in crisp value
C1 to C8	LI	MLI	MLI	LI	MLI	MLI	0.2887
C2 to C1	MLI	LI	LI	LI	LI	VLI	0.2127
C5 to C2	EI	MLI	EI	EI	MLI	EI	0.7777
C6 to C5	VLI	VLI	LI	VLI	LI	VLI	0.1620
C4 to C6	MLI	LI	LI	VLI	LI	LI	0.2127
C3 to C4	VLI	ELI	VLI	VLI	VLI	ELI	0.1323
C7 to C3	EI	MLI	MLI	MLI	EI	EI	0.6665

Afterwards, normalization of the decision matrix components is performed and normalized elements are represented by $\tilde{r}_{ij}$. In normalizing, the type of criteria (i.e., benefit $\left(B\right)$ or cost$\left(C\right)$) should take into account, and elements are normalized according to Equations (11)-(14). In Equation (11-14), c_j^+ is the maximum value of c_{ij} (benefit type) and a_j^- is the minimum value of a_{ij} (cost type) of criteria.

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+}\right) \qquad j \in B \tag{11}$$

$$c_j^+ = \max_i c_{ij} \qquad j \in B \tag{12}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \; j \in C \tag{13}$$

$$a_j^- = \text{ü}_{i} \; a_{ij} \quad j \in C \tag{14}$$

The normalized components of decision matrix (n_{ij}) are weighted according to Equation (15). where, w_j is the weight vector of criterion j and V_{ij} is the component of fuzzy weighted normalized decision matrix.

$$V_{ij} = w_j \otimes n_{ij} \tag{15}$$

Then, the fuzzy positive and the fuzzy negative ideal solutions for each criterion are defined according to Equations (16)-(19), in which A^+ and A^- are the set of fuzzy positive and fuzzy negative ideal solutions and $\tilde{V}_j^+$ and $\tilde{V}_j^-$ are positive and negative ideal solutions, respectively. $\tilde{V}_j^+$ is the maximum value and $\tilde{V}_j^-$ is the minimum value of $\tilde{V}_{ij}$ in positive criteria, shown in Equation (18), and vice versa for the negative criteria shown in Equation (19).

$$A^+ = \left(\tilde{V}_1^+, \tilde{V}_2^+, \ldots, \tilde{V}_n^+\right) \tag{16}$$

$$A^- = \left(\tilde{V}_1^-, \tilde{V}_2^-, \ldots, \tilde{V}_n^-\right) \tag{17}$$

$$\tilde{V}_j^+ = \widetilde{\max V_{ij}} \;,\; \tilde{V}_j^- = \widetilde{\min V_{ij}} \quad \text{if } j \in B \tag{18}$$

$$\tilde{V}_j^+ = \widetilde{\min V_{ij}} \;,\; \tilde{V}_j^- = \widetilde{\max V_{ij}} \quad \text{if } j \in C \tag{19}$$

The distances from positive and negative ideal solutions are computed according to Equations (20) and (21), respectively. The distance between two triangular fuzzy numbers $(\boldsymbol{a}_1, \boldsymbol{b}_1, \boldsymbol{c}_1)$ and $(\boldsymbol{a}_2, \boldsymbol{b}_2, \boldsymbol{c}_2)$ is computed according to Equation (22).

$$d_i^+ = \sum_j d(V_{ij}, V_j^+) \qquad \forall i \tag{20}$$

$$d_i^- = \sum_j d(V_{ij}, V_j^-) \qquad \forall i \tag{21}$$

$$d\left(\tilde{a}, \tilde{b}\right) = [1/3*[(a_1 - b_1)^2 + (a_2 - b_2)^2 + \left(a_3 - b_3\right)^2]]^{1/2} \tag{22}$$

Ranking alternatives is performed according to the descending values of CC_i that is calculated according to Equation (23) and defuzzified based on Equation (9).

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{23}$$

The alternatives are also prioritized by ARAS method. First, the decision matrix is created as in the TOPSIS method. Afterwards, the decision matrix is normalized. Normalization of the decision matrix elements is performed using Equations (24) and (25), where B and N are the benefit and the negative criterion, respectively and n_{ij} is the normalized element of alternative (i) in criterion (j).

$$n_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}} \qquad j \in B \tag{24}$$

$$n_{ij} = \frac{\frac{1}{x_{ij}}}{\sum_{i=0}^{m} \frac{1}{x_{ij}}} \qquad j \in N \tag{25}$$

Then, the normalized components of the decision matrix are weighted using Equation (15). The optimality function is computed using Equation (26)

$$S_i = \sum_{j=1}^{n} V_{ij} \qquad i = 1, 2, \ldots, m \tag{26}$$

Where S_i is the value of the optimality function of alternative i.
Afterwards, the utility degree of each alternative is calculated according to Equation (27), (28).

$$K_i = \frac{S_i}{S_o} \tag{27}$$

$$S_o = \max_i S_i \tag{28}$$

Finally, K_i is defuzzified according to Equation (9). The largest value of the utility degree is related to the best and the smallest value is related to the worst alternative, respectively.

Also, the alternatives are ranked by WASPAS method. The decision matrix is created and normalized as in the TOPSIS method. Afterward, the total relative importance of the $i-th$ alternative ($Q_i^{(1)}$) is calculated using Equation (29).

$$WSM = Q_i^{(1)} = \sum_{j=1}^{n} n_{ij} * w_j \tag{29}$$

Then, the total relative importance of the $i-th$ alternative ($Q_i^{(2)}$) is computed according to Equation (30).

$$WPM = Q_i^{(2)} = \prod_{j=1}^{n} n_{ij}^{w_j} \tag{30}$$

In Equations (29) and (30)**,** w_j is the weight of the $j-th$ criterion.

Afterwards, the weighted aggregation of WSM *and* WPM, as a generalized criterion (Q_i), is computed using Equation (31) and the alternatives are ranked according to the descending values of Q_i after defuzzification based on Equation (9).

$$Q_i = 0.5Q_i^{(1)} + 0.5Q_i^{(2)} = 0.5\sum_{j=1}^{n} n_{ij} w_j + 0.5\sum_{j=1}^{n} n_{ij}^{w_j} \tag{31}$$

SAW is another method that is applied for ranking alternatives. In this method, after creating decision matrix and normalizing it as in the TOPSIS method, the normalized weighted values for each alternative are computed according to Equation (32).

$$SW_i = \sum_{j=1}^{n} V_{ij} \qquad i = 1, 2, ..., m \tag{32}$$

Finally, alternatives are prioritized based on the descending values of SW_i after defuzzification based on Equation (9).

Since, different single decision-making methods have their positive and negative properties, integrating the results of them can be beneficial to obtain better ranking. Therefore, some integrated ranking methods are recommended such as ranks averaging method, Copeland and so on (Ghafari et al., 2020).

Decision-making process may not be limited to only a single method and various methods can be integrated to achieve a better result and therefore, techniques have already been suggested to integrate the rankings obtained from various methods, such as Borda's count, Copeland's, and rank mean method (Sakhtival & Ilangkumaran, 2015; Ghafari et al., 2020).

In rank mean approach, the average of the ranks obtained from the SAW, ARAS, WASPAS, and TOPSIS is calculated for each alternative to obtain the final ranking. The alternative with the minimum average rank is prioritized higher and vice versa (Banihabib et al., 2017).

Copeland, as another integrating approach, is based on a non-diagonal M×M matrix in which the description of the ith row to the jth column ($i \neq j$) is determined based on the number of wins. Prefer of the row to the column is coded with M when the number of the wins in techniques is more, but prefer of the column to the row and equality of wins are coded with X. In this method, the number of wins (the number of M's in the row) and the number of losses (the number of M's in the column) for each alternative is calculated. Ranking alternatives is performed based on the difference between the number of M's in rows and the number of M's in the columns (Firouzi et al., 2021).

RESULTS AND DISCUSSION

In this paper, local biomasses to convert biofuels in Hormozgan Province of Iran are assessed by taking into account some criteria after in-depth review of the relevant literature and interviewing with a panel of experts to design the first questionnaire. 8 criteria and 8 alternatives are considered in this questionnaire. The criteria are C1) The relative advantage of biofuel production over other biomass applications, C2) Conservation of non-renewable energy resource, C3) Creating related jobs, C4) Costs of biomass conversion to biofuel, C5) The complexity of the process of converting biomass into biofuel, C6) environmental impacts, C7) Regional development and C8) Investment cost. Afterwards, another questionnaire is created to evaluate the experts' compromise with questionnaire components according to a five-option Likert scale. The validity of the questionnaire is evaluated based on qualitative and quantitative measures. CVR and CVI are computed to assess the assessment was performed by calculating content validity ratio (CVR) and content validity index (CVI). Table (3) represented CVR value for each component.

35 experts are participated in this evaluation and the minimum value for CVR is 0.31 (according to Lawshe, 1975) that is smaller compared with all numbers in Table 5. In addition, the value of CVI (according to Equation (2)) is obtained as 0.857143 (larger than the minimum threshold value of 0.79) (Fadavi-Ghaffari et al., 2017). Therefore, the validation of the questionnaire is proved. The reliability of the questionnaire is assessed by calculating Cronbach's alpha coefficient. Since, its value is obtained as 0.752, which is larger than 0.7, it can be concluded that the questionnaire is reliable (Er kara & Oktay,2018).

the local biomasses that are considered as alternatives are A1) fish wastes, A2) waste cooking oil (WCO), A3) Jatropha, A4) citrus wastes, A5) municipal solid wastes (MSW), A6) low-quality date, A7) microalgae, and A8) manure. Low-quality date is a first- generation biomass,

Table 5. Weighting criteria by SWARA method

Criterion Averaging of decision maker' s opinions in crisp value	Criterion Averaging of decision maker' s opinions in crisp value (s_j)	Coefficient k_j=s_j+1	Recalculated weight w'_j=$\frac{w'_j}{k_j}$	Subjective weight q_j=$\frac{w'_j}{\sum_j w'_j}$
C8		1	1	0.27012
C1	0.2887	1.2887	0.7760	0.2096
C2	0.2127	1.2127	0.6399	0.1729
C5	0.7777	1.7777	0.3600	0.0972
C6	0.1620	1.1620	0.3098	0.0837
C4	0.2127	1.2127	0.2555	0.0690
C3	0.1323	1.1323	0.2256	0.0609
C7	0.6665	1.6665	0.1354	0.0366

Jatropha, manure, citrus wastes, MSW and (WCO) are second-generation, and microalgae are the third- generation ones that produce biofuels such as biodiesel, bioethanol, biogas, … by applying the appropriate bioenergy technology such as transesterification, metathesis, anaerobic digestion, and so on.

After fixing the questionnaire, the criteria are weighted based on fuzzy SWARA method. The relative importance of criteria determined by the experts are represented in linguistic terms, which are quantified by the crisp values according to Table 3. The relative significance of criteria by the experts and the criteria weights which are calculated by SWARA method are shown in Table (4) and (5), respectively.

Afterwards, based on the decision matrix that are filled by the experts in linguistic term and using fuzzy theory to deal with linguistic terms according to Table (6), the decision matrix with fuzzy elements is obtained which is shown in Table (7).

Finally, the alternatives are prioritized by applying fuzzy SAW, fuzzy WASPAS, fuzzy ARAS, and fuzzy TOPSIS and by considering the criteria weights obtained by fuzzy SWARA

Table 6. Converting linguistic variables to triangular fuzzy numbers in evaluating the alternatives' performances according to each criterion

Linguistic term	Triangular fuzzy number
Very low (VL)	(0.0, 0.1, 0.3)
Low (L)	(0.1, 0.3, 0.5)
Medium (M)	(0.3, 0.5, 0.7)
High (H)	(0.5, 0.7, 0.9)
Very High (VH)	(0.7, 0.9, 1.0)

Table 7. The opinions of the experts about the situation of criteria to alternatives

Criteria Alternative	C1	C2	C3	C4	C5	C6	C7	C8
A1	VVH, H, VH, H, VH, VVH	VVH, H, VH, H, H, H	H, H, VH, H, H, VH	M, L, M, M, H, M	L, VL, L, M, L,H	L, VL, L, L, H, M	VVH, VH, VVH, H, H, H	VH, H, H, M, M, H
A2	M, M, L, H, M,M	VH, H, M, H, H, H	M, H, M, M, M, M	M, M, L, M, L, L	L, VVL, M, L,L,M	L, VVL, M, M, L, L	VH, H, VH, M, M, H	H, M, H, H, H, M
A3	M, M, M, L, L, L	VVH, H, H, H, VH, H	L, M, M, L, L, VL	VH, H,VH,H,M,H	M, M, M, L, H,VH	L, L, L, M, L, L	H, H, M, H, H, H	VVH, H, H, H, H, M
A4	M, H, M, M,L,M	M, M, M, L, M, M	L, L, L, VL, M, L	H, H, M, VH, H, L	M, M, M, VH, H, M	VL, L, L, VVL,M, M	M, M, M, H, M, M	VH, H, H, H, M,VH
A5	H, H,VH,H,M, H	H, H, H,M,VVH,M	L, M, M, H, L, L	M, M, L,H,H,M	M, L, L, M, M, M	L, M, M, L, M, M	M, L, M, M, M, M	L, L, M, L, L, M
A6	M, L, M, M, H, L	H, H, H, M, VH, M	VH, M, H, H, M, H	H, VH,H,H,H,VHL,L,VL,M, M,VH	M, H, M, H, M, H	M, L, L, M, L, L	VH, H, H, VH, VH, VH	H, M, H, H, M, M
A7	H, H, M, M, H, M	M, H, L, L, VH, M	M, M, M, M, H, M	L, L, VL, M, M, VH	L, VL, L, M, L, L	L, M, L, L, L, M	VH, H, H, H,H,VH	L, M, L, M, M, M
A8	M, M, M, H, M, M	M, M, M, M, VL, M	L, L, L, M, VL, L	M, L, M, M, M, L	M, H, M, M, M, M	H, M,H,H, M,M	VH, H, VH, VH, H, H	M, H, M, M, M, H

Table 8. Ranking criteria by TOPSIS, WASPAS, ARAS, and SAW methods

Alternatives	TOPSIS		WASPAS		ARAS		SAW	
	C	Rank	Q	Rank	K	Rank	SW	rank
A1	0.5995	2	0.8864	2	0.9990	2	0.8957	2
A2	0.5703	4	0.8173	4	0.9128	5	0.8262	4
A3	0.3878	7	0.7051	7	0.7888	7	0.6827	8
A4	0.3254	8	0.6764	8	0.7667	8	0.7169	7
A5	0.7907	1	0.8932	1	1.0000	1	0.9015	1
A6	0.5446	5	0.7477	6	0.9694	6	0.7547	5
A7	0.5796	3	0.8794	3	0.9843	3	0.8859	3
A8	0.4927	6	0.7267	5	0.8418	4	0.7332	6

Table 9. Ranking alternatives with Copeland method

z	A1	A2	A3	A4	A5	A6	A7	A8	wins	loses	Wins-loses	Rank
A1	-	M	M	M	X	M	M	M	6	1	5	2
A2	X		M	M	X	M	X	M	4	3	1	4
A3	X	X		M	X	X	X	X	1	6	-5	6
A4	X	X	X		X	X	X	X	0	7	-7	7
A5	M	M	M	M		M	M	M	7	0	7	1
A6	X	X	M	M	X		X	X	2	4	-2	5
A7	X	M	M	M	X	M		M	5	2	3	3
A8	X	X	M	M	X	X	X		2	4	-2	5

method. The results are shown in Table (8).

Having reliable ranking for alternatives, two integrated ranking methods (Ranks mean and Copeland) are employed and the final ranking of alternatives are obtained. The matrix of Copeland and the final ranking obtained by this method and mean rank are shown in Tables (9), (10), respectively.

Results show that MSW, fish wastes and microalgae are selected as the first, second and the third rank of local energy resources to convert biofuel in Hormozgan province. The population of Hormozan province is about 1800000 that live in 13 cities of this province and generating about 1450 tons of MSW per day. The waste components should dispose to prevent environmental problems. The disposal waste is subject to different biochemical and physical reactions that make the emission of some kinds of gases such as carbon dioxide and methane which are greenhouse gases. It is crucial to install an equipment to exploit these gases and forbid their emission into the atmosphere. Biogas is the combination of gases yield from MSW after anaerobic digestion process. It is reported that about 250 kg of biogas is generated per each ton of waste (Talaiekhozani et al., 2016).

Table (10) shows that fish waste has the second rank to produce biofuel in this region. Hormozgan Province is one of the main regions for fishing in Iran (Gholami et al., 2019). Fish wastes are parts of fishes which are not used as food, including head, tail, abdomen and intestines, scales, fins, skin, and bones (Greggio et al., 2018; Yano et al., 2008; Mo et al., 2018; Saranya et al., 2020). A large amount of fish wastes is produced in fish-processing plants and stores (Nagai & Suzuki, 2000). Disposing fish wastes may results in environmental problems in the seas or coatal water (Greggio et al., 2018; Kannan et al., 2017). Therefore, appropriate management methods should be employed to use these wastes and preventing their environmental problems such as animal feed, anaerobic digestion, incineration, biogas and biofuel production, composting and landfill (Ravanipour et al., 2021).

Table 10. Ranking alternatives by mean ranking method

z	Ranking by TOPSIS	Ranking by WASPAS	Ranking by ARAS	Ranking by SAW	Rank mean	Final ranking
A1	2	2	2	2	2	2
A2	4	4	5	4	4	4
A3	7	7	7	8	7.25	7
A4	8	8	8	7	7.75	8
A5	1	1	1	1	1	1
A6	5	6	6	5	5.25	5
A7	3	3	3	3	3	3
A8	6	5	4	6	5.75	6

The priority of alternatives by Copeland and rank mean are A5>>A1>>A7>>A2>>A6, A8>>A3>>A4 and A5>>A1>>A7>>A2>>A6>>A8>>A3>>A4, respectively.

From Table (10), it can be concluded that microalgae are the third most preferred biomasses to produce biofuel in this region. High growth rate, short life cycle, generating high lipid content, and capability of enhancing the environmental conditions are the advantageous of Microalgae (Alam et al., 2014; Sankaran et al., 2016). The possibility of growing microalgae in fresh, salty, or wastewater, can refine their nutrients that results in improving its quality (Cuellar-Bermudez et al., 2015). They are viable resources to produce biofuels and can satisfy the current demand of diesel (Tabatabaei et al., 2011; Mohseni & Pishvaee, 2016). The microalgae from natural mediums, have the minimum costs that demonstrate the viability of growing microalgae in Iran (Ghorbani et al., 2018). The coasts of the Persian Gulf and the Oman Sea has the potential of growing 540000 tons of microalgae in each cultivation period and there are about 4 cultivation periods in Hormozgan province (Ravanipour et al., 2021).

From the results, it can be highlighted that the first-generation biomass (low-quality date) has the final priority because of the potential of creating competition between food and energy. In addition, using MSW and fish wastes as second -generation biomasses with lower cost and microalgae as the third- generation biomass are more appropriate to produce biofuel in this province. As a general result, applying the second- generation biomasses with lower cost and the third- generation one is more suitable in biofuel production because of no any competition between food and energy.

CONCLUSIONS

Biofuel as renewable source of energy has a great role in sustainability of the societies which can be produced from local biomass resources. Therefore, it is crucial to select an appropriate local biomass resource because of their ability. In this regard, a hybrid group fuzzy multi-criteria decision-making (FMCDM) method is employed to prioritize local biomasses of Hormozgan province in Iran. . In this decision process, criteria are weighted based on fuzzy SWARA method and alternatives are prioritized by applying four MCDM approaches, i.e., TOPSIS, ARAS, WASPAS, and SAW and then two aggregated MCDM approaches (mean ranking and Copeland) were employed to combine the final rank of alternatives. From the results it can be concluded that MSW, fish wastes and microalgae are on the top ranks and the low-quality date has the final rank to produce biofuel in the region of Hormozgan province. As a general result, applying the second- generation biomasses with lower cost and the third- generation one is more suitable in biofuel production, because of no any competition between food and energy.

Further research can be investigating techno-economic aspects and life cycle assessment (LCA) of biofuel production from these local biomasses. Moreover, other novel MCDM techniques can be used in ranking alternatives.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/ or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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