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Sustainable Supplier Selection Using Fuzzy AHP (AHP-F) and Fuzzy ARAS (ARAS-F) Techniques for Fertilizer Supply in the Agricultural Supply Chain

Hüseyin Fatih Atlı[1,a,*]

[1]*Department of Accounting and Tax, Vocational School, Iskenderun Technical University, 31200 Hatay, Türkiye*
[*]*Corresponding author*

A R T I C L E I N F O

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A B S T R A C T

Implementing the right strategies in the agricultural supply chain in the supply of seeds, pesticides, fertilizer, energy, fuel and agricultural mechanization tools and equipment has a great role in increasing agricultural productivity. The main purpose of the study is to rank and evaluate alternatives in choosing a sustainable fertilizer supplier in the agricultural supply chain by using AHP-F and ARAS-F techniques. In an environment of uncertainty and complex supply chain structure, multi-criteria decision making (MCDM) methods are widely used to solve supplier selection problems. In this study, the importance levels and weights of the criteria in the selection of sustainable fertilizer suppliers were measured by the AHP-F method. The criteria that are important for fertilizer supplier selection were evaluated by taking expert opinions, the uncertain and uncertain opinions of the decision makers were modeled with the AHP-F approach and the weights of the criteria were determined. Among the criteria, resource consumption (FSC05) has the highest weight. Then, alternative rankings were obtained with the ARAS-F method. Fertilizer supplier alternatives in the agricultural supply chain were ranked with the ARAS-F method, using the criterion weights found with AHP-F. In the ranking of alternatives, alternative fertilizer supplier FS03 ranked first with the highest value. This study provides a resource for businesses and other stakeholders to make decisions regarding sustainable fertilizer supplier selection.

[a] *hfatih.atli@iste.edu.tr* *https://orcid.org/0000-0002-1397-1514*

Introduction

The agricultural sector has a significant impact in many aspects, especially in meeting people's nutritional and clothing needs. Activities such as soil cultivation, fertilization, pesticide spraying, processes in the product-food supply chain, change of use of agricultural lands, energy consumption and manure of raised animals are directly related to the agricultural sector. Agriculture has been a means of development from past to present (He et al., 2019; Harwood, 2020; Zin and Badaluddin, 2020). The agricultural sector continues to be the focus of attention of many researchers as always (Puri et al., 2017; Ayaz et al., 2019; Zambon et al., 2019; Liu et al., 2020; Misra et al., 2020; Van Huis, 2020).

Supply chain management has emerged as one of the most important tools for companies to gain competitive advantage (Lee, 2002). In particular, supply chain flexibility leads to sustainable competitive advantage of companies (Ponomarov and Holcomb, 2009). Recently, the concepts of sustainability and supply chain have become more used together (Giannakis and Papadopoulos, 2016; Ahmadi et al., 2017; Chen et al., 2017; Genovese et al., 2017; Rajeev et al., 2017; Geissdoerfer et al., 2018; Luthra and Mangla, 2018; Koberg and Longonı, 2019; Manavalan and Jayakrishna, 2019; Paksoy et al., 2019; Saberi et al., 2019). Rapid change in customer expectations and environmental impacts have accelerated change in the supply chain. Sustainability in the supply chain structure is receiving more attention from researchers and practitioners due to increasing environmental impacts (Esmaeilian et al., 2020; Sarkis, 2020; Bag et al., 2021; Karmaker et al., 2021; Khan et al., 2021; Kouhizadeh et al., 2021; Saurabh and Dey, 2021; Ivanov, 2022; Bag and Rahman, 2023; Joshi et al., 2023; Kamble et al., 2023; Meredith and Shafer, 2023). For this reason, especially in agricultural supply chains, companies need to be faster and more flexible than their competitors, as well as implement sustainable paradigms, to meet customer expectations.

Supplier selection is an important decision problem that includes many criteria such as cost, quality, performance, technology, etc. This process will both shorten the selection process and enable more accurate decisions to be made. There are many studies in the literature examining the supplier selection problem, which has an important place in supply chain research (Govindan et al., 2013; Kannan et al., 2014; Govindan et al., 2015a; Govindan et al., 2015b; Hashemi et al., 2015; Rezaei et al., 2016; Zimmer et al., 2016; Kannan, 2018; Cavalcante et al., 2019; Schramm et al., 2020; Alavi et al., 2021; Fallahpour et al., 2021). Many studies have suggested the use of the Analytical Hierarchy Process (AHP) method for the supplier selection problem (Calik, 2021; Junior et al., 2014; Dweiri et al., 2016; Awasthi et al., 2018; Jain et al., 2018; Chen, 2020; Ali et al., 2023; Kansara et al., 2023; Saputro et al., 2023; Sathyan et al., 2023; Singh et al., 2023). In this study, TBL and fuzzy MCDM integration is proposed to solve the fertilizer supplier selection problem in the agricultural supply chain. After the TBL application, MCDM techniques including AHP-F and ARAS-F were applied to determine the most suitable fertilizer supplier in fertilizer supplier selection.

This research contributes to the literature as follows: It is the first study in which AHP-F and ARAS-F methods are applied together in fertilizer supplier selection in the agricultural supply chain. However, there are modeling studies that examine the supplier selection problem on a sectoral basis using classical MCDM methods. The criteria were adapted from the study of Wang and Van Thanh (2022) to provide an overall assessment of fertilizer supplier selection in the agricultural supply chain, taking into account the opinions of decision makers. Criteria and alternatives are shown in (Figure 2). AHP-F method, which provides ease of application, was preferred in determining the criterion weights. The ARAS-F method was used to rank alternative fertilizer suppliers with the criterion weights obtained by the AHP-F method. The research proposes a framework for determining the weights of appropriate criteria for fertilizer supplier selection in the agricultural supply chain and ranking fertilizer supplier alternatives through the combined approach of fuzzy multi-criteria decision making involving relevant stakeholders.

Material and Method

The main purpose of the study is to determine the weights of appropriate criteria for fertilizer supplier selection in the agricultural supply chain and to rank fertilizer supplier alternatives using MCDM techniques. With the results of the study, a guide was created for both decision makers and other stakeholders. It is thought that this study will also be encouraging for agricultural supply chain stakeholders. For each of the five alternatives, the decision makers' task is to identify potential criteria that will complete the decision-making process. The flow chart of the MCDM process is shown in (Figure 1). The fertilizer supplier selection decision is inherently an MCDM problem. Today, various studies on MCDM methods focus on supplier selection problems. Fertilizer supplier selection poses a complex problem due to the influence of many factors. In the methodology section, AHP-F and ARAS-F techniques and application steps used in working with fuzzy numbers are given. Scales used to blur numbers are also presented. The weights of the criteria were calculated by the AHP-F method. Then, alternative rankings of fertilizer supplier selection were obtained using the ARAS-F method.

In recent studies, MCDM methods have been applied together for the supplier selection problem (Gupta and Barua, 2017; Hamdan and Cheaitou, 2017; Qin et al., 2017; Yazdani et al., 2017; Abdel-Basset et al., 2018; Banaeian et al., 2018; Abdel-Baset et al., 2019a; Abdel-Baset et al., 2019b; Memari et al., 2019; Wu et al., 2019; Yu et al., 2019; Javad et al., 2020; Kannan et al., 2020; Nasr et al., 2021; Giri et al., 2022; Pamucar et al., 2023). There are studies in the literature based on AHP-F or ARAS-F techniques. There are studies in the literature that are based on the fuzzy AHP technique and contribute to the literature (Mavi, 2015; Nguyen et al., 2015; Shafiee, 2015; Turskis et al., 2015; Zavadskas et al., 2015; Kubler et al., 2016; Nguyen et al., 2016; Prakash and Barua, 2016; RazaviToosi and Samani, 2016; Wang et al., 2016; Emrouznejad and Marra, 2017; Turskis et al., 2019; Liu et al., 2020; Bakır and Atalık, 2021; Fu et al., 2021; Wang et al., 2021). There are also important studies in the literature that are based on the fuzzy ARAS technique and contribute to the literature (Ghadikolaei and Esbouei, 2014; Ghadikolaei et al., 2014; Keršulienė and Turskis, 2014a; Keršulienė and Turskis, 2014b; Zamani et al., 2014; Zavadskas et al., 2015; Nguyen et al., 2016; Dahooie et al., 2018; Iordache et al., 2019; Turskis et al., 2019).Fuzzy logic is a logic structure formed by the article "fuzzy sets and systems" published by Zadeh (1965) and the article "fuzzy logic and approximate reasoning" by Zadeh (1975). Fuzzy sets, basic operations, concepts and properties are given in this article. Fuzzy logic; It is based on the concepts of fuzzy set and subset (Zadeh, 2015). In this study, triangular fuzzy numbers were used.

AHP was first proposed by Myers and Alpert (1968). Method is a MCDM method based on pairwise comparison developed by Thomas L. Saaty (1977 and 1982) for the solution of complex measurement and decision-making problems involving a large number of criteria and alternatives. Since it is not sufficient to evaluate situations of uncertainty and imprecision (Deng, 1999); The AHP method was combined with fuzzy logic and the AHP-F approach started to be used as a new method. In this study, the AHP-F application method, which is more practical and easier to apply, was used. The process steps of the AHP-F method (Soberi and Ahmad, 2016) were applied according to Atlı (2024).

ARAS (Additive Ratio ASsesment) method was presented by Zavadskas and Turskis (2010) as a new approach to solving MCDM problems. Fuzzy logic serves to take into account the existing uncertainty. ARAS-F is a method developed by Zavadskas and Turskis (2010) for logistics center location selection. In this study, criterion weights were calculated with the AHP-F method. Fuzzy numbers were used to evaluate supplier alternatives for fertilizer supplier selection in agricultural supply chain. ARAS-F method was used to rank the alternatives using the criterion weights obtained by AHP-F. In order to rank the alternatives with the fuzzy ARAS method, the evaluations of the decision makers will be converted into triangular fuzzy numbers with the TFN scale of Liang et al. (2021). The process steps of the ARAS-F method were applied according to Kersuliene and Turskis (2011).

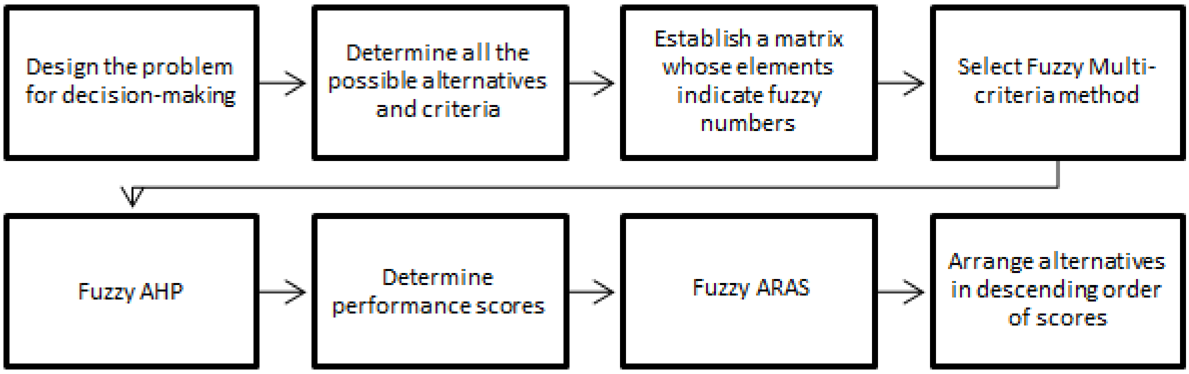

Figure 1. Research flowchart for fertilizer supplier selection

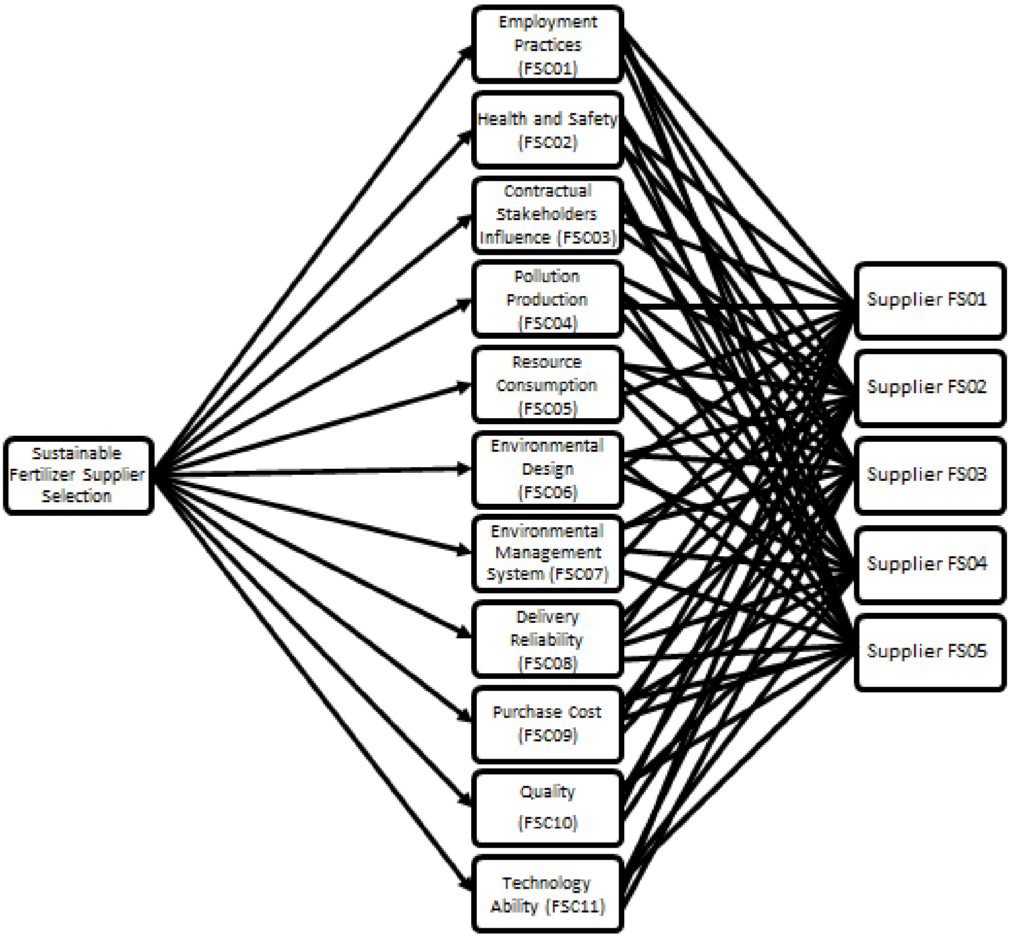

Figure 2. Hierarchical model

Results and Discussion

Calculation of Criterion Weights with The AHP-F Method

A hierarchical model has been created that allows decision makers to enter their problems from a comprehensive framework and includes the purpose of the problem, 11 criteria and 5 alternatives. The hierarchy created for the research problem is shown in (Figure 2). To create the pairwise comparison matrix, nine decision makers were interviewed to compare the criteria using the AHP-F method. Decision makers were asked to make pairwise comparisons of the criteria according to the AHP-F scale (Chang, 1996). Pairwise comparisons between all criteria were made by decision makers (Equation 1, 2). A common opinion was obtained by combining the pairwise comparisons made by the ground transmitters by taking the geometric mean of the collected data suggested by Saaty.

In creating the dual pairwise comparison matrix, fuzzy geometric means and fuzzy weights of each criterion were determined by using the geometric mean method of Buckley (1985). In this step, the fuzzy comparison value $\tilde{r}_i$ was found using Equation (3) (Table 1). Then, the geometric mean of the fuzzy comparison value $\tilde{r}_i$ was taken.

Table 1. Geometric means of fuzzy comparison values ($\tilde{r_i}$)

Criteria	l	m	u
FSC01	0.239	0.288	0.393
FSC02	1.335	1.747	2.110
FSC03	0.296	0.359	0.505
FSC04	1.186	1.600	1.974
FSC05	1.858	2.354	2.702
FSC06	0.574	0.756	0.999
FSC07	0.676	0.906	1.213
FSC08	0.914	1.184	1.496
FSC09	1.044	1.353	1.797
FSC10	1.672	2.227	2.772
FSC11	0.497	0.592	0.755
Total	10.290	13.366	16.717
P (-1)	0.097	0.075	0.060
INCR	0.060	0.075	0.097

Table 2. Relative fuzzy weight of each criteria ($\widetilde{w}_i$)

Criteria	l	m	u
FSC01	0.014	0.022	0.038
FSC02	0.080	0.131	0.205
FSC03	0.018	0.027	0.049
FSC04	0.071	0.120	0.192
FSC05	0.111	0.176	0.263
FSC06	0.034	0.057	0.097
FSC07	0.040	0.068	0.118
FSC08	0.055	0.089	0.145
FSC09	0.062	0.101	0.175
FSC10	0.100	0.167	0.269
FSC11	0.030	0.044	0.073

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \dots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ 1/\tilde{a}_{12} & 1 & \dots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}_{1n} & 1/\tilde{a}_{2n} & \dots & 1 \end{bmatrix} \quad (1)$$

$$\tilde{a}_{ij} = \begin{cases} \tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9} & Criterion\ i\ is\ more\ important\ than\ criterion\ j \\ 1, & i = j \\ \tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1} & Criterion\ i\ is\ less\ important\ than\ criterion\ j \end{cases} \quad (2)$$

$$\tilde{r_i} = \left(\prod_{j=1}^{n} \tilde{d}_{ij}\right)^{1/n} \quad (3)$$

$$\widetilde{w}_i = \tilde{r}_i \otimes [\tilde{r}_1 \oplus \dots \oplus \tilde{r}_i \oplus \dots \tilde{r}_n]^{-1} \quad (4)$$

The geometric means of fuzzy values were then converted to relative fuzzy of weight as shown in Table 2 by multiplying them with the total of reverse fuzzy geometric means in increasing order by using Equation (4)

Finally, the relative non-fuzzy weight of each criteria (M_i) is calculated by averaging the fuzzy numbers for each criteria. The normalized weights of each criteria, , (N_i) were calculated by dividing the each value of relative fuzzy weight with the total of all criteria's value. Hence, the averaged and normalized weight of criteria are shown in Table 3 (Figure 3).

Ranking of Alternatives with the ARAS-F method

Step 1. The fuzzy decision matrix showing the ideal values is shown in (Table 4).

Step 2. Creating the Normalized Fuzzy Decision Matrix: Using Equations (5) and (6), the normalized decision matrix shown in Equation (7) was created (Table 5).

Step 3. Using Equation (8), the weighted normalized decision matrix shown in (Table 6) was created.

Step 4. Calculation of fuzzy and defuzzified function values of alternatives (Equation 9, 10): (The fuzzy function value $\tilde{S}_i$)

Step 5. Calculating the utility degrees of the alternatives: The utility degree K_i of the alternative was calculated as shown in Equation (11). Fuzzy and defuzzified function values of the alternatives and their utility degrees are shown in (Table 7).

$$\bar{x}_{ij} = \frac{\tilde{x}_{ij}}{\sum_{i=0}^{m} \tilde{x}_{ij}} \quad (5)$$

$$\bar{x}_{ij} = \frac{1/\tilde{x}_{ij}}{\sum_{i=0}^{m} 1/\tilde{x}_{ij}} \quad (6)$$

$$\bar{X} = \begin{bmatrix} \bar{x}_{01} & \cdots & \bar{x}_{0j} & \cdots & \bar{x}_{0n} \\ \bar{x}_{i1} & \cdots & \bar{x}_{ij} & \cdots & \bar{x}_{in} \\ \vdots & \cdots & \vdots & \ddots & \vdots \\ \bar{x}_{m1} & \cdots & \bar{x}_{m1} & \cdots & \bar{x}_{mn} \end{bmatrix} \quad (7)$$

$$\hat{x}_{ij} = \bar{x}_{ij}\tilde{w}_j \quad (8)$$

$$\tilde{S}_i = \sum_{j=1}^{n} \bar{x}_{ij} \quad (9)$$

$$S_i = \frac{1}{3}(\tilde{S}_{il} + \tilde{S}_{im} + \tilde{S}_{iu}) \quad (10)$$

$$K_i = \frac{S_i}{S_0} \quad (11)$$

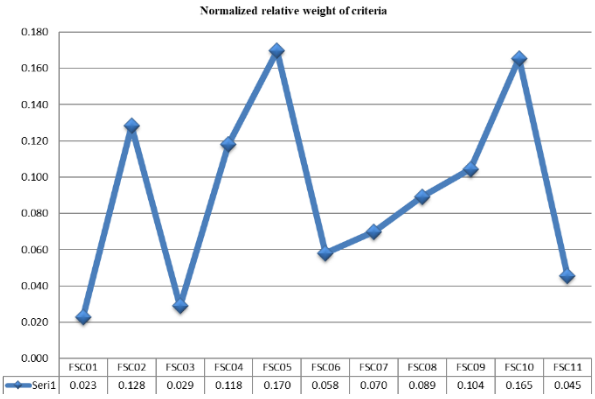

Figure 3. Normalized relative weight of criteria (N_i)

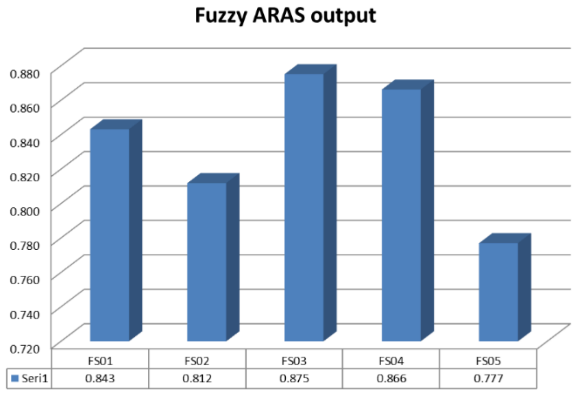

Figure 4. ARAS-F output

Table 3. Averaged and normalized relative weight of criteria

Criteria	(M_i)	(N_i)	Rank
FSC01	0.025	0.023	11
FSC02	0.139	0.128	3
FSC03	0.031	0.029	10
FSC04	0.128	0.118	4
FSC05	0.183	0.170	1
FSC06	0.063	0.058	8
FSC07	0.075	0.070	7
FSC08	0.096	0.089	6
FSC09	0.113	0.104	5
FSC10	0.179	0.165	2
FSC11	0.049	0.045	9
Total	1.080		

Table 4. Fuzzy decision matrix

Criteria	FSC01			FSC02			FSC03			FSC04			FSC05			FSC06		
IV	0.60	0.70	0.80	0.70	0.80	0.90	0.70	0.80	0.90	0.40	0.50	0.60	0.50	0.60	0.70	0.70	0.80	0.90
FS01	0.20	0.30	0.40	0.50	0.60	0.70	0.70	0.80	0.90	0.40	0.50	0.60	0.70	0.80	0.90	0.70	0.80	0.90
FS02	0.60	0.70	0.80	0.60	0.70	0.80	0.70	0.80	0.90	0.50	0.60	0.70	0.70	0.80	0.90	0.70	0.80	0.90
FS03	0.30	0.40	0.50	0.50	0.60	0.70	0.40	0.50	0.60	0.50	0.60	0.70	0.60	0.70	0.80	0.50	0.60	0.70
FS04	0.60	0.70	0.80	0.60	0.70	0.80	0.50	0.60	0.70	0.70	0.80	0.90	0.50	0.60	0.70	0.70	0.80	0.90
FS05	0.20	0.30	0.40	0.70	0.80	0.90	0.70	0.80	0.90	0.70	0.80	0.90	0.60	0.70	0.80	0.70	0.80	0.90

Criteria	FSC07			FSC08			FSC09			FSC10			FSC11		
IV	0.70	0.80	0.90	0.70	0.80	0.90	0.50	0.60	0.70	0.70	0.80	0.90	0.70	0.80	0.90
FS01	0.70	0.80	0.90	0.70	0.80	0.90	0.70	0.80	0.90	0.70	0.80	0.90	0.40	0.50	0.60
FS02	0.70	0.80	0.90	0.70	0.80	0.90	0.60	0.70	0.80	0.70	0.80	0.90	0.70	0.80	0.90
FS03	0.50	0.60	0.70	0.60	0.70	0.80	0.50	0.60	0.70	0.20	0.30	0.40	0.10	0.20	0.30
FS04	0.70	0.80	0.90	0.70	0.80	0.90	0.50	0.60	0.70	0.70	0.80	0.90	0.50	0.60	0.70
FS05	0.70	0.80	0.90	0.70	0.80	0.90	0.60	0.70	0.80	0.50	0.60	0.70	0.60	0.70	0.80

IV: Ideal value

Table 5. Normalized fuzzy decision matrix

Criteria	FSC01			FSC02			FSC03			FSC04		
	max			max			max			min		
IV	0.240	0.280	0.320	0.280	0.320	0.360	0.280	0.320	0.360	29.640	19.670	14.020
FS01	0.080	0.120	0.160	0.200	0.240	0.280	0.280	0.320	0.360	29.640	19.670	14.020
FS02	0.240	0.280	0.320	0.240	0.280	0.320	0.280	0.320	0.360	23.710	16.390	12.020
FS03	0.120	0.160	0.200	0.200	0.240	0.280	0.160	0.200	0.240	23.710	16.390	12.020
FS04	0.240	0.280	0.320	0.240	0.280	0.320	0.200	0.240	0.280	16.940	12.290	9.350
FS05	0.080	0.120	0.160	0.280	0.320	0.360	0.280	0.320	0.360	16.940	12.290	9.350
Criteria	FSC05			FSC06			FSC07			FSC08		
	min			max			max			max		
IV	20.380	14.480	10.830	0.280	0.280	0.320	0.360	0.280	0.320	0.360	0.320	0.360
FS01	14.560	10.860	8.420	0.280	0.280	0.320	0.360	0.280	0.320	0.360	0.320	0.360
FS02	14.560	10.860	8.420	0.280	0.280	0.320	0.360	0.280	0.320	0.360	0.320	0.360
FS03	16.980	12.410	9.470	0.200	0.200	0.240	0.280	0.240	0.280	0.320	0.240	0.280
FS04	20.380	14.480	10.830	0.280	0.280	0.320	0.360	0.280	0.320	0.360	0.320	0.360
FS05	16.980	12.410	9.470	0.280	0.280	0.320	0.360	0.280	0.320	0.360	0.320	0.360

Criteria	FSC09			FSC10			FSC11		
	min			max			max		
IV	21.520	15.180	11.280	0.280	0.320	0.360	0.280	0.320	0.360
FS01	15.370	11.380	8.770	0.280	0.320	0.360	0.160	0.200	0.240
FS02	17.940	13.010	9.870	0.280	0.320	0.360	0.280	0.320	0.360
FS03	21.520	15.180	11.280	0.080	0.120	0.160	0.040	0.080	0.120
FS04	21.520	15.180	11.280	0.280	0.320	0.360	0.200	0.240	0.280
FS05	17.940	13.010	9.870	0.200	0.240	0.280	0.240	0.280	0.320

IV: Ideal value

Table 6: Weighted normalized decision matrix

Criteria	FSC01			FSC02			FSC03			FSC04		
w	0.014	0.022	0.038	0.080	0.131	0.205	0.018	0.027	0.049	0.071	0.120	0.192
IV	0.003	0.006	0.012	0.022	0.042	0.074	0.005	0.009	0.018	2.103	2.355	2.690
FS01	0.001	0.003	0.006	0.016	0.031	0.057	0.005	0.009	0.018	2.103	2.355	2.690
FS02	0.003	0.006	0.012	0.019	0.037	0.066	0.005	0.009	0.018	1.683	1.962	2.306
FS03	0.002	0.003	0.008	0.016	0.031	0.057	0.003	0.005	0.012	1.683	1.962	2.306
FS04	0.003	0.006	0.012	0.019	0.037	0.066	0.004	0.006	0.014	1.202	1.472	1.793
FS05	0.001	0.003	0.006	0.022	0.042	0.074	0.005	0.009	0.018	1.202	1.472	1.793
Criteria	FSC05			FSC06			FSC07			FSC08		
w	0.111	0.176	0.040	0.068	0.118	0.055	0.089	0.145	0.263	0.034	0.057	0.097
IV	2.265	2.551	0.011	0.022	0.042	0.015	0.028	0.052	2.843	0.010	0.018	0.035
FS01	1.618	1.913	0.011	0.022	0.042	0.015	0.028	0.052	2.211	0.010	0.018	0.035
FS02	1.618	1.913	0.011	0.022	0.042	0.015	0.028	0.052	2.211	0.010	0.018	0.035
FS03	1.888	2.186	0.008	0.016	0.033	0.013	0.025	0.047	2.488	0.007	0.014	0.027
FS04	2.265	2.551	0.011	0.022	0.042	0.015	0.028	0.052	2.843	0.010	0.018	0.035
FS05	1.888	2.186	0.011	0.022	0.042	0.015	0.028	0.052	2.488	0.010	0.018	0.035

Criteria	FSC09			FSC10			FSC11		
w	0.062	0.101	0.175	0.100	0.167	0.269	0.030	0.044	0.073
IV	1.344	1.537	1.970	0.028	0.053	0.097	0.008	0.014	0.026
FS01	0.960	1.153	1.533	0.028	0.053	0.097	0.005	0.009	0.018
FS02	1.120	1.317	1.724	0.028	0.053	0.097	0.008	0.014	0.026
FS03	1.344	1.537	1.970	0.008	0.020	0.043	0.001	0.004	0.009
FS04	1.344	1.537	1.970	0.028	0.053	0.097	0.006	0.011	0.021
FS05	1.120	1.317	1.724	0.020	0.040	0.075	0.007	0.012	0.023

Table 7. Ranking of alternatives

	$\tilde{S}_i$			S_i	K_i	Ranking
ideal value	5.815	6.634	7.861	6.770	1.000	
FS01	4.772	5.593	6.760	5.708	0.843	3
FS02	4.520	5.379	6.590	5.496	0.812	4
FS03	4.972	5.803	7.000	5.925	0.875	1
FS04	4.907	5.740	6.946	5.864	0.866	2
FS05	4.301	5.148	6.332	5.260	0.777	5
			S_0	6.770		

The FS03 alternative, which has the highest degree of benefit, was chosen as the best alternative fertilizer supplier (Table 7, Figure 4). The evaluation results using the proposed method show that the sequence is FS03>FS04>FS01>FS02>FS05. The best alternative is FS03. This is followed by FS04 and FS01 respectively. This situation is consistent with the real situation, because it also coincides with the current situation. An initial assessment of the feasibility of fertilizer supplier selection in the agricultural supply chain was conducted using ARAS-F. The analysis compared five alternatives based on eleven weighted decision criteria. Based on the decision maker's decision, a ranking of alternative priorities is compiled (Table 7): priority 1 = FS03, priority 2 = FS04, priority 3 = FS01, priority 4 = FS02, priority 5 = FS05. According to the feasibility of fertilizer supplier selection in the agricultural supply chain using ARAS-F, the best alternative is FS03.

Luthra et al. (2017) stated that environmental costs, product quality, price, health and safety systems and environmental competencies are the main key criteria in decision-making for sustainable supplier selection. In the study of Đalić et al. (2020) pollution control was determined as the most important criterion. In a similar study in the literature, Wang and Van Thanh (2022) used a TBL, SF-AHP and CODAS hybrid MCDM model for sustainable supplier selection in an uncertain environment in agriculture. In this study, the best alternatives among six alternative suppliers were determined as SP02 and SP01. It can be concluded that the difference in agricultural enterprises had an impact on obtaining this result. Stević et al. (2020) gave the highest importance to the quality criterion among the sub-criteria used in the study. Sustainable supplier selection is one of the most critical issues due to its importance and impact on the environment, economy and society (Ecer and Pamucar, 2020; Jain and Singh, 2020; Tirkolaee et al., 2020; Mahmoudi et al., 2021; Yazdani et al., 2021). The pressure to ensure sustainable development and maintain competitive advantage makes choosing the most suitable green supplier a necessity for manufacturing enterprises (Durmić et al., 2020; Gao et al., 2020; Govindan et al., 2020; Hendiani et al., 2020; Kaur and Singh, 2021). Selection of the most suitable supplier is an integral part of SCM; can be solved effectively by applying different multi-criteria decision-making techniques (Badi and Pamucar, 2020; Chakraborty et al., 2020; Chen et al., 2020; Kumari and Mishra, 2020; Lei et al., 2020; Rouyendegh et al., 2020). The application of MCDM methods for the supplier selection problem is promising for decision makers and practitioners (Baltrunaite et al., 2021; Lu et al., 2021; Mina et al., 2021; Shang et al., 2022; Tong et al., 2022; Kusi-Sarpong et al., 2023).

Conclusion

Supplier selection for the implementation of the right strategies in the agricultural supply chain is a complex task that requires appropriate consideration in business management. The decision for supplier selection, particularly in the agricultural supply chain, requires consideration of various criteria and involves a mix of both quantitative and qualitative criteria. To overcome this problem, a model based on AHP-F was developed considering ARAS-F. Similar studies can be conducted for problems other than fertilizer supplier selection in the agricultural supply chain. In this way, information will be obtained whether the study results can be generalized to other situations. It will be a guide for decision makers and practitioners to solve the problem in choosing fertilizer suppliers in the future. This problem will create a reference point for developing correct strategies in the agricultural supply chain.

This study has various methodological research limitations such as the data set, the methods used, and the criteria used. In addition to the decision makers and practitioners involved in this study, future research may also include other agricultural supply chain members as decision makers to improve results, as other stakeholders of the agricultural supply chain may reveal different preferences. Methodologically, different indicators can be taken as criteria in future studies and new studies can be conducted using different MCDM methods and their integrated versions. From a practical perspective; The application of a combined approach that integrates expert opinion and sustainability-oriented fuzzy multi-criteria decision making is a promising approach to overcome the supplier selection problem characterized by uncertainty.

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