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GREEN SUPPLIER SELECTION USING IMF SWARA AND FUZZY WASPAS TECHNIQUES FOR THE SUPPLY OF AGRICULTURAL PESTICIDES

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Abstract: The concept of sustainability is constantly increasing in importance in all areas of life with its human, social, economic and environmental dimensions. With the impact of global climate change and other environmental factors, concerns about sustainable agriculture and access to sufficient and reliable food are increasing. Reports of the Food and Agriculture Organization of the United Nations (FAO) and other international organizations also confirm this. For this reason, awareness has been created all over the world regarding the United Nations 17 Sustainable Development Goals (SDGs).With the increasing awareness of environmental protection worldwide, green supply chain management (GSCM) has become an important issue for businesses to achieve environmental sustainability. Nowadays, many managers and business owners pay special attention to green supplier selection to gain competitive advantage. Therefore, green supplier selection remains a critical decision for businesses. Businesses need to consider many economic and environmental criteria in the decision process to select the most suitable supplier. The aim of this study is to choose the most suitable green supplier for the supply of agricultural pesticides. Decision makers in selecting the most suitable green supplier for agricultural pesticide supply are business managers and academicians who are experts in the relevant field. In this study, an effective solution based on the combination of IMF SWARA (Improved Fuzzy Stepwise Weight Assessment Ratio Analysis) and fuzzy WASPAS (Weighted Aggregated Sum Product Assessment) methods is proposed to help agricultural enterprises that need to choose the best pesticide supplier. According to the research results, the criteria were determined as cost, quality and green product in order of importance, starting from the most important. In the ranking of the alternatives, alternative 1 ranked first with the highest value. This research proposes a framework to determine the most suitable alternative for green supplier selection through a combined approach of fuzzy multi-criteria decision making involving relevant stakeholders.

Keywords: Green supplier selection, Supply chain, Agricultural marketing, Fuzzy logic, Multi criteria decision making

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1. Introduction

In recent years, with increasing awareness of environmental protection worldwide, GSCM has attracted considerable interest from researchers and practitioners alike. This growing interest has been fueled by a worsening environment, increasing pollution levels, overflowing landfills and dwindling raw material resources. In addition, increased government regulation, stronger public awareness and consumer pressures are making businesses more vigilant about the environmental impacts of their operations. Environmental management is becoming increasingly important as organizational stakeholders such as governments, customers, employees, competitors and communities care about environmental protection. Businesses today should not neglect environmental issues if they want to survive in the global market (Van Hoek, 1999; Hashemi et al., 2015).

In order to sell products in certain countries, businesses need to ensure that their products comply with environmental regulations as well as implement strategies to voluntarily reduce their environmental impact. The integration of environmental, economic and social performance to achieve sustainable development has become an important business challenge for the new century (Verghese and Lewis, 2007). The concept of sustainability is an approach that creates a balance between nature and humans and ensures that existing resources are transferred to future generations without being destroyed (Turna and Solmaz, 2022). Legal and regulatory initiatives have emerged in developed countries, particularly in Europe and Japan. Some pioneering businesses joined the green supply chain trend long before the EU environmental orders came into force. To achieve long-term success in the global market, businesses should not only emphasize financial conditions when evaluating their suppliers, but also consider a variety of criteria, including pro-environmental concerns (Lee et al., 2009).

The green supplier evaluation process is highly complex for a variety of reasons, including the diversity of influencing factors (Kumar et al., 2014), the mix of quantitative and qualitative selection criteria (Sarkis and Talluri, 2002), and the breadth and diversity of suppliers along the supply chain (Bai and Sarkis, 2010). Increased outsourcing, complex and tightening government and regional policies, and conflicting corporate and supply chain objectives have increased the importance and complexity of green supplier selection decisions. Green supplier selection requires the incorporation of environmental criteria into traditional supplier selection practices and approaches (Govindan et al., 2015). While price, quality and service level have been the dominant traditional green supplier selection criteria, carbon footprint and emissions, energy efficiency, water use and recycling initiatives have become more common environmental criteria (Choi, 2013).

Therefore, the objective of this study is to select the most suitable green supplier for the supply of agrochemicals. Since green supplier selection is suitable for the use of methods that can evaluate a large number of criteria together, the study utilized the methods of MCDM. Firstly, the importance levels of the criteria were found by using IMF SWARA, and then the most suitable green supplier was selected by using fuzzy WASPAS method. There are many different studies on green supplier selection in the literature. In this study, both economic and environmental criteria are used for green supplier selection and a comprehensive green supplier selection model is proposed. In addition, it is the first paper in the literature to integrate IMF SWARA and fuzzy WASPAS methods for green supplier selection for the procurement of pesticides. The study is expected to contribute to the literature as it fills the mentioned gaps in the literature.

In the introduction part of the study, which consists of six sections, information about the literature review is presented. In the second section, materials and methods and in the third section, the findings of the analysis are presented. In the fourth section, the findings and similar studies in the literature are interpreted together and a discussion section is included. The study is completed with the fifth and final section, the conclusion section.

1.1. Literature Review

There are many different studies on green supplier selection in the literature.

Table 1. Literature review (Turkish studies)

Author(s) and Year	Method	Sector
Şişman (2016)	fuzzy MOORA (multi-objective optimization by ratio analysis)	White Goods
Denizhan et al. (2017)	AHP (analytic hierarchy process), fuzzy AHP	Machinery Manufacturing
Çelik and Ustasüleyman (2018)	fuzzy AHP, fuzzy TOPSIS (technique for order preference by similarity to ideal solution)	Fitted Kitchen
Daldır and Tosun (2018)	fuzzy AHP, fuzzy WASPAS (weighted aggregated sum product assessment)	Manufacturing
Özkır (2018)	TOPSIS	Automotive
Koca and Behdioğlu (2019)	ENTROPY, Heuristic fuzzy TOPSIS	Automotive
Madenoğlu (2019)	TOPSIS-F, VIKOR-F (multi-criteria optimization and compromise solution), GRA-F, ARAS-F, SWARA-F (step-wise weight assessment ratio analysis)	Furniture
Madenoğlu (2020)	SWARA, GIA (gray relational analysis)	Production
Öztürk and Paksoy (2020)	DEMATEL (the decision making trial and evaluation laboratory) -QFD-AT2 fuzzy AHP	Food
Soyer and Türkay (2020)	ANP (analytic hierarchy process)	White Goods
Akın (2021)	Trapezoidal fuzzy flexible cluster	Food
Çalık (2021)	BWM (best-worst method), CRITIC (criteria importance through intercritera correlation), COPRAS (complex proportional assessment), ENTROPY, MABAC, WASPAS	Food
Erbıyık et al. (2021)	ELECTRE (elemination and choice translating reality english), SWARA	Automotive
Kılınç and Yağmahan (2021)	GIA and AHP	Automotive
Cezlan (2022)	AHP, TOPSIS	Health
Dalay and Sari (2022)	fuzzy DEMATEL	Food
Kara and Yalçın (2022)	SWARA, TOPSIS	Tourism
Karatas and Ozcelik (2022)	EDAS (evaluation based on distance from average solution), VIKOR	Electricity
Uçkun et al. (2023)	fuzzy AHP and fuzzy QFD	Automotive

Table 2. Literature review (English studies)

Author(s) and Year	Method	Sector
Lee et al. (2009)	fuzzy AHP	High Technology
Kuo et al. (2010)	DEA (data envelopment analysis), ANP, ANN (artificial neural network), MADA	Electronics Industry
Bali et al. (2013)	IFS, GRA	Automobile
Kannan et al. (2013)	fuzzy AHP, fuzzy TOPSIS, fuzzy MOLP	Automobile
Yazdani (2014)	AHP, fuzzy TOPSIS	Automotive
Freeman and Chen (2015)	AHP, ENTROPY, TOPSIS	Electronics Industry
Hashemi et al. (2015)	ANP, GRA	Automotive
Kuo et al. (2015)	DANP (analytical hierarchy process), VIKOR	Electronics Industry
Wang Chen et al. (2016)	fuzzy AHP, TOPSIS	Manufacturing Sector
Gupta and Barua (2017)	BWM, fuzzy TOPSIS	Automobile
Yazdani et al. (2017)	DEMATEL, COPRAS, MOORA	Food
Banaeian et al. (2018)	TOPSIS, VIKOR, GRA	Agri-Food
Shi et al. (2018)	GRA, TOPSIS	Agri-Food
Zhu and Li (2018)	H2TL, Choquet Integral	Automobile
Duan et al. (2019)	AQM, SWARA	Paper Industry
Gupta et al. (2019)	AHP, TOPSIS, MABAC, WASPAS	Automotive
Mati´c et al. (2019)	FUCOM (full consistency method), COPRAS	Construction
Miranda-Ackerman et al. (2019)	TOPSIS	Agri-Food
Phochanikorn and Tan (2019)	fuzzy DEMATEL, fuzzy ANP	Food
Ramakrishnan and Chakraborty (2020)	TOPSIS	Automobile
Kazemitash et al. (2021)	RBWM (rough best worst method)	Biofuel Companies
Puška et al. (2021)	PIPRECIA, MABAC	Agriculture
Tirkolaee et al. (2021)	AHP-fuzzy TOPSIS	Food
Ecer (2022)	fuzzy AHP	Home Appliances Manufacturer
Puška et al. (2022)	fuzzy LMAW, fuzzy CRADIS	Agriculture
Wang and Van Thanh (2022)	SF-AHP, CODAS (combinative distance-based assessment)	Agriculture

These studies are given in two different tables in Turkish and English. Table 1 shows the Turkish studies in the literature.

When the studies in Table 1 are examined, it is observed that the studies were conducted between the years 2016-2023 and many different MCDM methods were used and the studies were mostly concentrated in the automotive and food sectors.

Table 2 presents the English studies conducted in the literature. When the studies in Table 2 are examined, it is observed that the studies were conducted between 2008 and 2022 and many different MCDM methods were used and the studies were mostly concentrated in the automotive, food and agriculture sectors.

2. Materials and Methods

In this section, information about the data set used in the study, the analysis methods and the criteria used in the analysis are given.

2.1. Data Set Used in the Study

In order to select the most suitable green supplier for the supply of agricultural pesticides, data were collected from the enterprises using agricultural pesticides and academicians working in the relevant field by survey method. The data of the study belongs to the year 2024.

2.2. Criteria Used in the Study

In order to select the most suitable green supplier for the supply of pesticides, the criteria accepted in the relevant literature and determined comprehensively were determined as decision criteria in accordance with the MCDM methods. The ten criteria are given in Table 3 were used for green supplier selection.

Table 3. Green supplier selection criteria

Criteria	Criteria/ Codes	Author(s) and Year
Green Product	C1	Hashemi et al. (2015), Kazemitash et al. (2021), Puška et al. (2022)
Green Competence	C2	Freeman and Chen (2015), Hashemi et al. (2015), Puška et al. (2022)
Environmental Management System	C3	Hashemi et al. (2015), Puška et al. (2022), Tirkolaee et al. (2021)
Recycling	C4	Puška et al. (2022)
Pollution Control	C5	Gupta et al. (2019), Hashemi et al. (2015), Lee et al. (2009), Puška et al. (2022)
Quality	C6	Freeman and Chen (2015), Gupta et al. (2019), Lee et al. (2009), Puška et al. (2022)
Cost	C7	Freeman and Chen (2015), Gupta et al. (2019), Puška et al. (2022)
Logistics Service	C8	Puška et al. (2022)
Innovativeness	C9	Puška et al. (2022)
Technological Competence	C10	Puška et al. (2022)

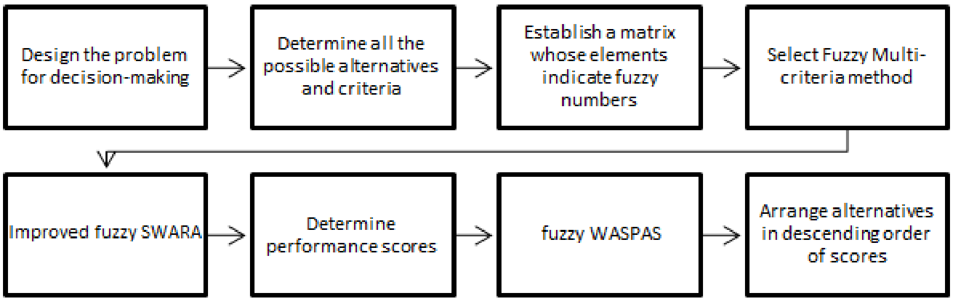

Figure 1. Research flowchart for green supplier selection (Atlı, 2024).

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).

2.3. Analysis Methods Used in the Study

In the study, the MCDM methods were utilized. In order to select the most suitable green supplier for the supply of pesticides, first the importance levels of the criteria were determined with IMF SWARA and then the most suitable one was selected among the alternatives with fuzzy WASPAS. MCDM methods are methods that enable the identification, selection, ranking and classification of multiple alternatives with a large number of criteria (Vassilev et al., 2005).

IMF SWARA and fuzzy WASPAS techniques used in working with fuzzy numbers and application steps are given. Scales used to convert numbers into fuzzy numbers are also presented. The weights of the criteria were calculated with the IMF SWARA method. Then, alternative rankings of green supplier selection in agricultural pesticide supply were obtained by using the fuzzy WASPAS method.

2.4. Fuzzy Logic and Fuzzy Numbers

Fuzzy sets, basic operations, concepts and properties are given in this article. According to Zadeh (2015), one of the main contributions of fuzzy logic is to provide a basis for progress from binarization to gradation, from binary to pluralism, from black and white to shades of grey. Fuzzy logic; It is based on the concepts of fuzzy set and subset (Zadeh, 1965). There are membership functions in different forms that define fuzzy sets analytically and represent their membership degrees, and the most commonly used among the various forms of fuzzy membership functions are triangular, trapezoidal, Gaussian and generalized bell curve membership functions (Sergi, 2021). In this study, triangular fuzzy numbers were used. Triangular fuzzy numbers were created to maximize the accuracy of the evaluations in uncertain evaluations when making decisions (Arslankaya and Göraltay, 2019). Equation 1 is given in (Hudec, 2016), and the graph drawn for the function is given in (Figure 2).

$$\mu_{\tilde{A}}(x) = \begin{Bmatrix} 0, & if\ x \leq l \\ \dfrac{x-l}{m-l}, & if\ l \leq x \leq m \\ \dfrac{u-x}{u-m}, & if\ m \leq x \leq u \\ 0, & if\ u \leq x \end{Bmatrix} \tag{1}$$

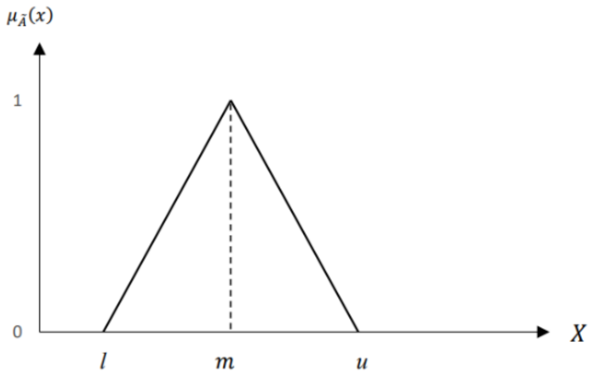

Figure 2. Triangle membership function (Hudec, 2016).

2.5. Calculation of Criterion Weights with the IMF SWARA Method

SWARA technique, introduced by Kersuliene et al. (2010), is an MCDM technique used to calculate the weights of selection criteria. The SWARA technique has an algorithm that can be easily followed by decision makers, and the weights of the criteria can be determined by following these application steps (Zolfani et al., 2021). According to Mardani et al. (2017), SWARA method; unlike the classical MCDM method, it tries to predict the preferences of decision makers and includes these predictions to evaluate the process.

To overcome the many uncertainties that exist in an evaluation process, the fuzzy SWARA technique was developed based on fuzzy sets (Mavi et al., 2017). Fuzzy SWARA is a subjective evaluation technique (Zolfani et al., 2021). Vrtagić et al. (2021) suggested using a new scale by developing the IMF SWARA method, which is a new approach to overcome the shortcomings of the technique for making pairwise comparisons between criteria. The current literature shows that researchers used IMF-SWARA method to analyze different topics. Zolfani et al. (2021) used IMF SWARA and F-MABAC methods to solve the logistics village selection problem with very complex and uncertain conditions based on fuzzy approaches.

Vrtagić et al. (2021) developed an integrated fuzzy model to determine the safety degree of observed road sections. The paper's major contribution is the development of the IMF SWARA method. Vrtagić et al. (2021) applied IMF SWARA to determine the values of the weight coefficients of the criteria and used the fuzzy MARCOS method for the final ranking of the sections. It is crucial to provide a consistent and realistic evaluation tool to reflect the subjective evaluations carried out by decision-makers (Vrtagić et al., 2021). For this purpose, the IMF SWARA (Vrtagić et al., 2021) method will be used to determine the criterion weights and the application steps of the technique as follows.

Step 1. Determine the rank value of the criteria: After determining the criteria, the ranking value of these criteria is determined.

Step 2. Making pairwise comparisons between criteria: Decision makers determine the relative importance of each criterion with the help of the linguistic variables (scale) given in Table 4.

Table 4. The linguistic scale for the IMF SWARA technique and TFNs (Vrtagić et al., 2021)

Linguistic Variable	Abbreviation	TFN Scale		
Absolutely less significant	ALS	1	1	1
Dominantly less significant	DLS	1/2	2/3	1
Much less significant	MLS	2/5	1/2	2/3
Really less significant	RLS	1/3	2/5	1/2
Less significant	LS	2/7	1/3	2/5
Moderately less significant	MDLS	1/4	2/7	1/3
Weakly less significant	WLS	2/9	1/4	2/7
Equally significant	ES	0	0	0

Table 5. Fuzzy linguistic scale for evaluating alternatives (Liang et al., 2021)

(Linguistic Variables)	(Rating)	(TFNs)		
Very poor (VP) / Very low (VL)	1	0.1	0.2	0.3
Poor (P) / Low (L)	2	0.2	0.3	0.4
Slightly poor (SP) / Slightly low (SL)	3	0.3	0.4	0.5
Fair (F) / Medium (M)	4	0.4	0.5	0.6
Slightly good (SG) / Slightly high (SH)	5	0.5	0.6	0.7
Good (G) / High (H)	6	0.6	0.7	0.8
Very good (VG) / Very high (VH)	7	0.7	0.8	0.9

Step 3. Computing the coefficient value: For each fuzzy number, the following steps are followed and kj, qj, wj values are calculated.

: The coefficient value

qj: Weights values of the criteria

wj: Fuzzy weight coefficients values of the criteria

The coefficient $\tilde{k}_j$ value for each fuzzy number is calculated using Equation 2.

$$\tilde{k}_j = \begin{cases} \tilde{1}, & j = 1 \\ \tilde{s}_j, & j > 1 \end{cases} \quad (2)$$

Afterward, weights values of the criteria $\tilde{q}_j$ are calculated by using Equation 3.

$$\tilde{q}_j = \begin{cases} \tilde{1}, & j = 1 \\ \dfrac{\tilde{q}_{j-1}}{k_j}, & j > 1 \end{cases} \quad (3)$$

Finally, fuzzy weight coefficients values of the criteria are calculated with the help of Equation 4.

$$\widetilde{w}_j = \frac{\tilde{q}_j}{\sum_{j=1}^{n} \tilde{q}_j} \quad (4)$$

Step 4. Defuzzying the criteria weights: In the final step of the IMF SWARA technique, fuzzy values are defuzzied by using Equation 5 as follows.

$$w_{Crisp\,Value} = \frac{w^{(l)} + 4w^{(m)} + w^{(u)}}{6} \quad (5)$$

2.6. Ranking of Alternatives with the Fuzzy WASPAS Method

MCDM methods can be effectively applied to determine the value and degree of utility of various fields and prioritize their implementation (Turskis, 2008). WASPAS method is one of these methods. Zavadskas et al. (2012) was developed as a combination of two approaches known as WSM and WPM, which are frequently used in MCDM. Turskis et al. (2015), the fuzzy logic approach and WASPAS method were integrated and introduced into the literature as the fuzzy WASPAS method. The fuzzy WASPAS method is an effective decision-making tool that is widely used due to its ease in complex calculations, simplicity, and high accuracy and consistency in ranking alternatives. The advantageous features of the WASPAS method include its own sensitivity analysis and the ability to check consistency while listing alternatives (Chakraborty, 2014).

Fuzzy WASPAS method was preferred to obtain alternative rankings in green supplier selection. Linguistic variables given by decision makers according to the performance of supplier alternatives in agricultural pesticide supplier selection will be converted

into triangular fuzzy numbers through Table 5.
In the fuzzy WASPAS method proposed by Turskis et al. (2015), the following fuzzy WASPAS steps were used:
Step 1. Creating a fuzzy decision matrix: In Equation 6, m indicates the number of alternatives, while n indicates the number of criteria.

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \dots & \tilde{x}_{1j} & \dots & \tilde{x}_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \tilde{x}_{i1} & \vdots & \tilde{x}_{ij} & \vdots & \tilde{x}_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \dots & \tilde{x}_{mj} & \dots & \tilde{x}_{mn} \end{bmatrix}; i = \overline{1,m}, j = \overline{1,n} \quad (6)$$

Step 2. Creating the normalized decision matrix: The values required to create the normalized decision matrix are calculated using Equation 7.

$$\tilde{\bar{x}}_{ij} = \begin{cases} \dfrac{\tilde{x}_{ij}}{\max_i(\tilde{x}_{ij})} & if\ benefit\ is\ the\ criterion \\ \dfrac{\min_i(\tilde{x}_{ij})}{\tilde{x}_{ij}} & if\ cost\ is\ the\ criterion \end{cases} i = \overline{1,m}, j = \overline{1,n} \quad (7)$$

Step 3. Using Equation 8, the weighted normalized fuzzy decision matrix for WSM is determined. Using Equation 9, the weighted normalized fuzzy decision matrix for WPM is determined.

$$\tilde{\hat{X}}_q = \begin{bmatrix} \tilde{\hat{x}}_{11} & \dots & \tilde{\hat{x}}_{1j} & \dots & \tilde{\hat{x}}_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \tilde{\hat{x}}_{i1} & \vdots & \tilde{\hat{x}}_{ij} & \vdots & \tilde{\hat{x}}_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \tilde{\hat{x}}_{m1} & \dots & \tilde{\hat{x}}_{mj} & \dots & \tilde{\hat{x}}_{mn} \end{bmatrix}; \tilde{\hat{x}}_{ij} = \tilde{\bar{x}}_{ij}\tilde{w}_j \quad i = \overline{1,m}, j = \overline{1,n} \quad (8)$$

$$\tilde{\hat{X}}_p = \begin{bmatrix} \tilde{\bar{\bar{x}}}_{11} & \dots & \tilde{\bar{\bar{x}}}_{1j} & \dots & \tilde{\bar{\bar{x}}}_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \tilde{\bar{\bar{x}}}_{i1} & \vdots & \tilde{\bar{\bar{x}}}_{ij} & \vdots & \tilde{\bar{\bar{x}}}_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \tilde{\bar{\bar{x}}}_{m1} & \dots & \tilde{\bar{\bar{x}}}_{mj} & \dots & \tilde{\bar{\bar{x}}}_{mn} \end{bmatrix}; \tilde{\bar{\bar{x}}}_{ij} = \tilde{\bar{x}}_{ij}^{\tilde{w}_j} \quad i = \overline{1,m}, j = \overline{1,n} \quad (9)$$

Step 4. Calculate values of the optimality function: Values of the optimality function is calculated separately according to WSM and WPM, respectively, using Equation 10 and Equation 11. The fuzzy performance measurement value for each alternative is calculated using Equation 12 and Equation 13.

$$\tilde{Q}_i = \sum_{j=1}^{n} \tilde{\hat{x}}_{ij},\ i = \overline{1,m} \quad (10)$$

$$\tilde{P}_i = \prod_{j=1}^{n} \tilde{\bar{\bar{x}}}_{ij},\quad i = \overline{1,m} \quad (11)$$

$$Q_i = \frac{1}{3}(Q_{i\alpha} + Q_{i\beta} + Q_{i\gamma}) \quad (12)$$

$$P_i = \frac{1}{3}(P_{i\alpha} + P_{i\beta} + P_{i\gamma}) \quad (13)$$

Step 5. The integrated utility function value for an alternative can be determined by Equation 14. In cases where WSM and WPM approaches are considered to have equal impact, the value of λ is taken as 0.5. Otherwise, the λ value is calculated with Equation 15.

$$K_i = \lambda \sum_{j=1}^{m} Q_i + (1-\lambda) \sum_{j=1}^{m} P_i, \lambda = 0, \dots, 1, \quad 0 \le K_i \le 1 \quad (14)$$

$$\lambda = \frac{\sum_{i=1}^{m} P_i}{\sum_{i=1}^{m} Q_i + \sum_{i=1}^{m} P_i} \quad (15)$$

Step 6. Rank preference order. Choose an alternative with maximal K_i value.

3. Results

3.1. Calculation of Criterion Weights with the IMF SWARA Method

The criteria for selecting green suppliers for the supply of agricultural pesticides were evaluated by ten experts. The decision-making expert group that evaluates the criteria; It consists of businesses that use agricultural pesticides and academicians in the related field. As a result of the evaluation, the IMF SWARA method was applied to obtain the weights.
Step 1. The first step in the IMF SWARA method, ranking the criteria from most important to least important, was done by each decision maker one by one. The ranking results were obtained as shown in Table 6.
Step 2. Linguistic evaluations of the importance levels between the criteria determined by the decision makers have been converted into fuzzy numbers through Table 7.
Step 3. In this step, firstly, coefficient kj values were reached by using Equation 2 with the help of sj values. Then, the importance vector qj values of each criterion were calculated using Equation 3. Finally, the weights of the criteria wj were calculated using Equation 4. The kj, qj, wj values calculated for each criterion of the decision makers are shown in Table 7.
Step 4. In the final step of the IMF SWARA technique, fuzzy values was defuzzied by using Equation 5. The geometric mean of the criterion weights was calculated and the final weights of the criteria were obtained as shown in Table 8.
According to Table 8, cost (C7) is the most important criterion for decision makers, with a relative importance score of 0.131. This is followed by quality (C6), green product (C1) and pollution control (C5). Innovativeness (C9) was seen to be a less critical criterion.

Table 6. Ranking of criteria according to decision makers

Code	Criteria	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10
C1	Green Product	1	5	9	10	9	8	1	5	8	3
C2	Green Competence	9	7	8	9	10	6	6	7	7	4
C3	Environmental Management System	7	8	4	3	6	10	4	9	6	2
C4	Recycling	8	4	10	6	8	7	7	4	3	7
C5	Pollution Control	6	6	5	5	7	9	2	1	2	1
C6	Quality	4	3	2	1	1	5	5	2	10	5
C7	Cost	3	1	1	2	2	4	3	3	9	6
C8	Logistics Service	10	2	3	4	3	1	8	6	1	10
C9	Innovativeness	2	9	7	7	4	2	9	8	5	9
C10	Technological Competence	5	10	6	8	5	3	10	10	4	8

Table 7. The weights of criteria were calculated by using the IMF SWARA technique

							DM1						
Code	$\tilde{s}_j$			$\tilde{k}_j$			$\tilde{q}_j$			$\widetilde{w}_j$			Crips Value
C1				1.000	1.000	1.000	1.000	1.000	1.000	0.216	0.232	0.251	0.232
C9	2/9	1/4	2/7	1.222	1.250	1.286	0.818	0.800	0.778	0.177	0.185	0.195	0.186
C7	2/9	1/4	2/7	1.222	1.250	1.286	0.669	0.640	0.605	0.145	0.148	0.152	0.148
C6	2/9	1/4	2/7	1.222	1.250	1.286	0.548	0.512	0.471	0.118	0.119	0.118	0.118
C10	1/4	2/7	1/3	1.250	1.286	1.333	0.438	0.398	0.353	0.095	0.092	0.089	0.092
C5	2/9	1/4	2/7	1.222	1.250	1.286	0.359	0.319	0.274	0.078	0.074	0.069	0.074
C3	2/7	1/3	2/5	1.286	1.333	1.400	0.279	0.239	0.196	0.060	0.055	0.049	0.055
C4	2/9	1/4	2/7	1.222	1.250	1.286	0.228	0.191	0.152	0.049	0.044	0.038	0.044
C2	1/3	2/5	1/2	1.333	1.400	1.500	0.171	0.137	0.102	0.037	0.032	0.026	0.032
C8	1/2	2/3	1	1.500	1.667	2.000	0.114	0.082	0.051	0.025	0.019	0.013	0.019
							DM2						
C7				1.000	1.000	1.000	1.000	1.000	1.000	0.122	0.124	0.128	0.125
C8	2/9	1/4	2/7	1.222	1.250	1.286	0.818	0.800	0.778	0.100	0.100	0.099	0.100
C6	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.122	0.124	0.128	0.125
C4	2/7	1/3	2/5	1.286	1.333	1.400	0.778	0.750	0.714	0.095	0.093	0.091	0.093
C1	2/9	1/4	2/7	1.222	1.250	1.286	0.636	0.600	0.556	0.078	0.075	0.071	0.075
C5	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.122	0.124	0.128	0.125
C2	1/4	2/7	1/3	1.250	1.286	1.333	0.800	0.778	0.750	0.097	0.097	0.096	0.097
C3	2/9	1/4	2/7	1.222	1.250	1.286	0.655	0.622	0.583	0.080	0.077	0.075	0.077
C9	1/4	2/7	1/3	1.250	1.286	1.333	0.524	0.484	0.438	0.064	0.060	0.056	0.060
C10	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.122	0.124	0.128	0.125
							DM3						
C7				1.000	1.000	1.000	1.000	1.000	1.000	0.242	0.264	0.293	0.265
C6	2/9	1/4	2/7	1.222	1.250	1.286	0.818	0.800	0.778	0.198	0.211	0.228	0.212
C8	2/7	1/3	2/5	1.286	1.333	1.400	0.636	0.600	0.556	0.154	0.158	0.163	0.158
C3	2/9	1/4	2/7	1.222	1.250	1.286	0.521	0.480	0.432	0.126	0.127	0.126	0.127
C5	2/5	1/2	2/3	1.400	1.500	1.667	0.372	0.320	0.259	0.090	0.084	0.076	0.084
C10	2/5	1/2	2/3	1.400	1.500	1.667	0.266	0.213	0.156	0.064	0.056	0.046	0.056
C9	2/5	1/2	2/3	1.400	1.500	1.667	0.190	0.142	0.093	0.046	0.038	0.027	0.037

C2	2/7	1/3	2/5	1.286	1.333	1.400	0.148	0.107	0.067	0.036	0.028	0.020	0.028
C1	2/9	1/4	2/7	1.222	1.250	1.286	0.121	0.085	0.052	0.029	0.023	0.015	0.022
C4	1	1	1	2.000	2.000	2.000	0.060	0.043	0.026	0.015	0.011	0.008	0.011
DM4													
C6				1.000	1.000	1.000	1.000	1.000	1.000	0.142	0.147	0.155	0.148
C7	2/5	1/2	2/3	1.400	1.500	1.667	0.714	0.667	0.600	0.101	0.098	0.093	0.098
C3	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.142	0.147	0.155	0.148
C8	1/3	2/5	1/2	1.333	1.400	1.500	0.750	0.714	0.667	0.106	0.105	0.103	0.105
C5	1	1	1	2.000	2.000	2.000	0.375	0.357	0.333	0.053	0.053	0.052	0.053
C4	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.142	0.147	0.155	0.148
C9	1/4	2/7	1/3	1.250	1.286	1.333	0.800	0.778	0.750	0.113	0.114	0.116	0.115
C10	1/4	2/7	1/3	1.250	1.286	1.333	0.640	0.605	0.563	0.091	0.089	0.087	0.089
C2	2/5	1/2	2/3	1.400	1.500	1.667	0.457	0.403	0.338	0.065	0.059	0.052	0.059
C1	2/5	1/2	2/3	1.400	1.500	1.667	0.327	0.269	0.203	0.046	0.040	0.031	0.039
DM5													
C6				1.000	1.000	1.000	1.000	1.000	1.000	0.130	0.134	0.137	0.134
C7	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.130	0.134	0.137	0.134
C8	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.130	0.134	0.137	0.134
C9	2/9	1/4	2/7	1.222	1.250	1.286	0.818	0.800	0.778	0.107	0.107	0.107	0.107
C10	2/9	1/4	2/7	1.222	1.250	1.286	0.669	0.640	0.605	0.087	0.085	0.083	0.085
C3	2/9	1/4	2/7	1.222	1.250	1.286	0.548	0.512	0.471	0.071	0.068	0.065	0.068
C5	2/9	1/4	2/7	1.222	1.250	1.286	0.448	0.410	0.366	0.058	0.055	0.050	0.055
C4	2/9	1/4	2/7	1.222	1.250	1.286	0.367	0.328	0.285	0.048	0.044	0.039	0.044
C1	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.130	0.134	0.137	0.134
C2	2/9	1/4	2/7	1.222	1.250	1.286	0.818	0.800	0.778	0.107	0.107	0.107	0.107
DM6													
C3				1.000	1.000	1.000	1.000	1.000	1.000	0.159	0.165	0.173	0.166
C5	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.159	0.165	0.173	0.166
C1	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.159	0.165	0.173	0.166
C4	2/9	1/4	2/7	1.222	1.250	1.286	0.818	0.800	0.778	0.130	0.132	0.135	0.132
C2	2/9	1/4	2/7	1.222	1.250	1.286	0.669	0.640	0.605	0.106	0.106	0.105	0.106
C6	2/9	1/4	2/7	1.222	1.250	1.286	0.548	0.512	0.471	0.087	0.085	0.082	0.085
C7	1/4	2/7	1/3	1.250	1.286	1.333	0.438	0.398	0.353	0.070	0.066	0.061	0.066
C10	1/4	2/7	1/3	1.250	1.286	1.333	0.351	0.310	0.265	0.056	0.051	0.046	0.051
C9	1/4	2/7	1/3	1.250	1.286	1.333	0.280	0.241	0.198	0.045	0.040	0.034	0.040
C8	1/2	2/3	1	1.500	1.667	2.000	0.187	0.145	0.099	0.030	0.024	0.017	0.024
DM7													
C1				1.000	1.000	1.000	1.000	1.000	1.000	0.227	0.246	0.270	0.247
C5	1/4	2/7	1/3	1.250	1.286	1.333	0.800	0.778	0.750	0.182	0.191	0.203	0.191
C7	2/7	1/3	2/5	1.286	1.333	1.400	0.622	0.583	0.536	0.141	0.143	0.145	0.143
C3	1/4	2/7	1/3	1.250	1.286	1.333	0.498	0.454	0.402	0.113	0.111	0.109	0.111
C6	2/9	1/4	2/7	1.222	1.250	1.286	0.407	0.363	0.313	0.092	0.089	0.084	0.089
C2	2/9	1/4	2/7	1.222	1.250	1.286	0.333	0.290	0.243	0.076	0.071	0.066	0.071
C4	1/4	2/7	1/3	1.250	1.286	1.333	0.267	0.226	0.182	0.060	0.055	0.049	0.055
C8	2/7	1/3	2/5	1.286	1.333	1.400	0.207	0.169	0.130	0.047	0.042	0.035	0.041
C9	1/3	2/5	1/2	1.333	1.400	1.500	0.156	0.121	0.087	0.035	0.030	0.023	0.030
C10	1/3	2/5	1/2	1.333	1.400	1.500	0.117	0.086	0.058	0.026	0.021	0.016	0.021

DM8													
C5				1.000	1.000	1.000	1.000	1.000	1.000	0.160	0.167	0.175	0.167
C6	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.160	0.167	0.175	0.167
C7	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.160	0.167	0.175	0.167
C4	2/9	1/4	2/7	1.222	1.250	1.286	0.818	0.800	0.778	0.131	0.133	0.136	0.133
C1	1/4	2/7	1/3	1.250	1.286	1.333	0.655	0.622	0.583	0.105	0.104	0.102	0.104
C8	1/4	2/7	1/3	1.250	1.286	1.333	0.524	0.484	0.438	0.084	0.081	0.077	0.081
C2	1/4	2/7	1/3	1.250	1.286	1.333	0.419	0.376	0.328	0.067	0.063	0.057	0.063
C9	1/4	2/7	1/3	1.250	1.286	1.333	0.335	0.293	0.246	0.054	0.049	0.043	0.049
C3	2/9	1/4	2/7	1.222	1.250	1.286	0.274	0.234	0.191	0.044	0.039	0.034	0.039
C10	2/9	1/4	2/7	1.222	1.250	1.286	0.224	0.187	0.149	0.036	0.031	0.026	0.031
DM9													
C8				1.000	1.000	1.000	1.000	1.000	1.000	0.162	0.173	0.188	0.174
C5	1/2	2/3	1	1.500	1.667	2.000	0.667	0.600	0.500	0.108	0.104	0.094	0.103
C4	2/5	1/2	2/3	1.400	1.500	1.667	0.476	0.400	0.300	0.077	0.069	0.056	0.068
C10	1/3	2/5	1/2	1.333	1.400	1.500	0.357	0.286	0.200	0.058	0.049	0.038	0.049
C9	1/3	2/5	1/2	1.333	1.400	1.500	0.268	0.204	0.133	0.044	0.035	0.025	0.035
C3	1/4	2/7	1/3	1.250	1.286	1.333	0.214	0.159	0.100	0.035	0.027	0.019	0.027
C2	2/9	1/4	2/7	1.222	1.250	1.286	0.175	0.127	0.078	0.028	0.022	0.015	0.022
C1	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.162	0.173	0.188	0.174
C7	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.162	0.173	0.188	0.174
C6	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.162	0.173	0.188	0.174
DM10													
C5				1.000	1.000	1.000	1.000	1.000	1.000	0.158	0.164	0.172	0.164
C3	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.158	0.164	0.172	0.164
C1	0	0	0	1.000	1.000	1.000	1.000	1.000	1.000	0.158	0.164	0.172	0.164
C2	2/9	1/4	2/7	1.222	1.250	1.286	0.818	0.800	0.778	0.129	0.131	0.134	0.131
C6	2/9	1/4	2/7	1.222	1.250	1.286	0.669	0.640	0.605	0.106	0.105	0.104	0.105
C7	2/9	1/4	2/7	1.222	1.250	1.286	0.548	0.512	0.471	0.087	0.084	0.081	0.084
C4	2/9	1/4	2/7	1.222	1.250	1.286	0.448	0.410	0.366	0.071	0.067	0.063	0.067
C10	1/4	2/7	1/3	1.250	1.286	1.333	0.359	0.319	0.274	0.057	0.052	0.047	0.052
C9	2/7	1/3	2/5	1.286	1.333	1.400	0.279	0.239	0.196	0.044	0.039	0.034	0.039
C8	1/3	2/5	1/2	1.333	1.400	1.500	0.209	0.171	0.131	0.033	0.028	0.022	0.028

Table 8. The final criteria weights

Code	Criteria	Final weights
C7	Cost	0.131
C6	Quality	0.130
C1	Green Product	0.109
C5	Pollution Control	0.107
C3	Environmental Management System	0.084
C8	Logistics Service	0.066
C4	Recycling	0.065
C2	Green Competence	0.061
C10	Technological Competence	0.058
C9	Innovativeness	0.058

3.2. Ranking of Alternatives with the fuzzy WASPAS Method

The agricultural production enterprise where the application was carried out was asked to evaluate its five main suppliers of agricultural pesticides (A1, A2, A3, A4 and A5) according to the determined criteria with linguistic variables (Table 5). For this purpose, fuzzy WASPAS method was used to obtain alternative rankings in green supplier selection. A fuzzy decision matrix was created according to Equation 6. Here, *m* indicates the number of alternatives and *n* indicates the number of criteria.

Depending on whether the selected criterion is a benefit or cost criterion, the initial Decision Matrix is normalized and the normalized decision matrix is shown in Table 10. Finally, according to the criterion weight values determined in Table 8, WSM was calculated as shown in

Table 11 and WPM in Table 12.

The λ value calculated according to Equation 15 was found to be 0.539. Accordingly, in the ranking made using Equation 15, Alternative 1 received the highest value and the highest ranking score with 0.715. Then, the ranking values were determined as Alternative 3 (0.707), Alternative 5 (0.698), Alternative 2 (0.653) and Alternative 4 (0.577).

Table 9. Fuzzy initial decision matrix

	A1	A2	A3	A4	A5
	0.5	0.4	0.4	0.4	0.4
C1	0.6	0.5	0.5	0.5	0.5
	0.7	0.6	0.6	0.6	0.6
	0.7	0.6	0.6	0.4	0.6
C2	0.8	0.7	0.7	0.5	0.7
	0.9	0.8	0.8	0.6	0.8
	0.7	0.6	0.7	0.5	0.6
C3	0.8	0.7	0.8	0.6	0.7
	0.9	0.8	0.9	0.7	0.8
	0.7	0.6	0.6	0.5	0.6
C4	0.8	0.7	0.7	0.6	0.7
	0.9	0.8	0.8	0.7	0.8
	0.7	0.6	0.6	0.5	0.6
C5	0.8	0.7	0.7	0.6	0.7
	0.9	0.8	0.8	0.7	0.8
	0.5	0.6	0.7	0.4	0.7
C6	0.6	0.7	0.8	0.5	0.8
	0.7	0.8	0.9	0.6	0.9
	0.5	0.5	0.7	0.3	0.7
C7	0.6	0.6	0.8	0.4	0.8
	0.7	0.7	0.9	0.5	0.9
	0.5	0.5	0.7	0.2	0.7
C8	0.6	0.6	0.8	0.3	0.8
	0.7	0.7	0.9	0.4	0.9
	0.6	0.4	0.7	0.3	0.7
C9	0.7	0.5	0.8	0.4	0.8
	0.8	0.6	0.9	0.5	0.9
	0.6	0.4	0.7	0.3	0.7
C10	0.7	0.5	0.8	0.4	0.8
	0.8	0.6	0.9	0.5	0.9

Table 10. Normalized fuzzy decision matrix

		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
	l	0.714	0.778	0.778	0.778	0.778	0.556	0.600	0.556	0.667	0.667
A1	*m*	0.857	0.889	0.889	0.889	0.889	0.667	0.500	0.667	0.778	0.778
	u	1.000	1.000	1.000	1.000	1.000	0.778	0.429	0.778	0.889	0.889
	l	0.571	0.667	0.667	0.667	0.667	0.667	0.600	0.556	0.444	0.444
A2	*m*	0.714	0.778	0.778	0.778	0.778	0.778	0.500	0.667	0.556	0.556
	u	0.857	0.889	0.889	0.889	0.889	0.889	0.429	0.778	0.667	0.667
	l	0.571	0.667	0.778	0.667	0.667	0.778	0.429	0.778	0.778	0.778
A3	*m*	0.714	0.778	0.889	0.778	0.778	0.889	0.375	0.889	0.889	0.889
	u	0.857	0.889	1.000	0.889	0.889	1.000	0.333	1.000	1.000	1.000
	l	0.571	0.444	0.556	0.556	0.556	0.444	1.000	0.222	0.333	0.333
A4	*m*	0.714	0.556	0.667	0.667	0.667	0.556	0.750	0.333	0.444	0.444
	u	0.857	0.667	0.778	0.778	0.778	0.667	0.600	0.444	0.556	0.556
	l	0.571	0.667	0.667	0.667	0.667	0.778	0.429	0.778	0.778	0.778
A5	*m*	0.714	0.778	0.778	0.778	0.778	0.889	0.375	0.889	0.889	0.889
	u	0.857	0.889	0.889	0.889	0.889	1.000	0.333	1.000	1.000	1.000

Table 11. The weighted normalised matrix for WSM

		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10		Q(i)
	L	0.078	0.048	0.065	0.051	0.083	0.072	0.078	0.037	0.038	0.039	0.589	
A1	M	0.094	0.054	0.075	0.058	0.095	0.087	0.065	0.044	0.045	0.045	0.662	0.663
	U	0.109	0.061	0.084	0.065	0.107	0.101	0.056	0.051	0.051	0.051	0.738	
	L	0.063	0.041	0.056	0.043	0.071	0.087	0.078	0.037	0.026	0.026	0.527	
A2	M	0.078	0.048	0.065	0.051	0.083	0.101	0.065	0.044	0.032	0.032	0.600	0.601
	U	0.094	0.054	0.075	0.058	0.095	0.116	0.056	0.051	0.038	0.039	0.676	
	L	0.063	0.041	0.065	0.043	0.071	0.101	0.056	0.051	0.045	0.045	0.582	
A3	M	0.078	0.048	0.075	0.051	0.083	0.116	0.049	0.059	0.051	0.051	0.660	0.661
	U	0.094	0.054	0.084	0.058	0.095	0.130	0.044	0.066	0.058	0.058	0.741	
	L	0.063	0.027	0.047	0.036	0.059	0.058	0.131	0.015	0.019	0.019	0.474	
A4	M	0.078	0.034	0.056	0.043	0.071	0.072	0.098	0.022	0.026	0.026	0.527	0.531
	U	0.094	0.041	0.065	0.051	0.083	0.087	0.078	0.029	0.032	0.032	0.593	
	L	0.063	0.041	0.056	0.043	0.071	0.101	0.056	0.051	0.045	0.045	0.573	
A5	M	0.078	0.048	0.065	0.051	0.083	0.116	0.049	0.059	0.051	0.051	0.651	0.652
	U	0.094	0.054	0.075	0.058	0.095	0.130	0.044	0.066	0.058	0.058	0.731	
												$\sum Q_i$	3.108

Table 12. The weighted normalised matrix for WPM

		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10		P(i)
	L	0.964	0.985	0.979	0.984	0.973	0.926	0.935	0.962	0.977	0.977	0.708	0.775
A1	M	0.983	0.993	0.990	0.992	0.987	0.949	0.913	0.974	0.986	0.986	0.776	
	U	1.000	1.000	1.000	1.000	1.000	0.968	0.895	0.984	0.993	0.993	0.840	
	L	0.941	0.976	0.967	0.974	0.958	0.949	0.935	0.962	0.954	0.954	0.643	0.714
A2	M	0.964	0.985	0.979	0.984	0.973	0.968	0.913	0.974	0.967	0.967	0.716	
	U	0.983	0.993	0.990	0.992	0.987	0.985	0.895	0.984	0.977	0.977	0.784	
	L	0.941	0.976	0.979	0.974	0.958	0.968	0.895	0.984	0.986	0.986	0.693	0.762
A3	M	0.964	0.985	0.990	0.984	0.973	0.985	0.880	0.992	0.993	0.993	0.763	
	U	0.983	0.993	1.000	0.992	0.987	1.000	0.866	1.000	1.000	1.000	0.829	
	L	0.941	0.952	0.952	0.963	0.939	0.900	1.000	0.905	0.939	0.938	0.553	0.631
A4	M	0.964	0.965	0.967	0.974	0.958	0.926	0.963	0.930	0.954	0.954	0.633	
	U	0.983	0.976	0.979	0.984	0.973	0.949	0.935	0.948	0.967	0.967	0.707	
	L	0.941	0.976	0.967	0.974	0.958	0.968	0.895	0.984	0.986	0.986	0.685	0.753
A5	M	0.964	0.985	0.979	0.984	0.973	0.985	0.880	0.992	0.993	0.993	0.755	
	U	0.983	0.993	0.990	0.992	0.987	1.000	0.866	1.000	1.000	1.000	0.820	
												$\sum P_i$	3,634

Table 13. Integrated utility function values of the WASPAS-F method

	Q_i	P_i	Λ	K	Rank
A1	0.663	0.775		0.715	1
A2	0.601	0.714		0.653	4
A3	0.661	0.762	0.539	0.707	2
A4	0.531	0.631		0.577	5
A5	0.652	0.753		0.698	3
	3.108	3.634			

4. Discussion

According to the results of the analysis conducted to select the most suitable green supplier for the supply of pesticides, cost, quality and green product were ranked in the first three places in the importance levels of the criteria. In the ranking of alternatives, alternative 1 was determined as the best supplier among five alternative suppliers.

There are many different studies on green supplier selection in the literature. However, among the studies, the study on green supplier selection especially in the agricultural sector and overlapping with this study belongs to Puska et al. Puška et al. (2022) used Z-Numbers, fuzzy LMAW and fuzzy CRADIS Model for green supplier selection using a hybrid fuzzy MCDM model in an uncertain environment in agriculture. According to the results obtained in this study, cost, quality and recycling criteria ranked in the top three in terms of importance levels. When the importance levels of the criteria are compared, it is seen that the first two rankings of the importance levels of the criteria obtained in this study and the study of Puška et al. (2022) are the same. In this direction, it can be said that the important points in selecting the most suitable green supplier are focused on cost and quality, and that price is important as the main economic indicator in the supply of agrochemicals. Therefore, according to the experts' opinion, it can be interpreted that in the selection of green suppliers, it is necessary to obtain raw materials and production materials of excellent quality and at affordable prices. However, in Puška et al. (2022) study, the third most important criterion was found to be recycling. In this study, the third most important criterion is green products. In both studies, in addition to economic criteria, ecological criteria ranked third in the ranking. In this context, it can be interpreted that ecological criteria should also be taken into consideration when selecting green suppliers, and that the raw materials and production materials supplied should not only be of good quality and affordable, but also at an environmentally acceptable level.

On the other hand, in Puška et al. (2022), the best alternatives among the six alternative suppliers were determined as alternative 2 (A2) and alternative 3 (A3). When the ranking of the alternatives is compared, it is seen that the ranking of the alternatives obtained in the Puška et al. (2022) study and this study differ. It can be interpreted that the different persons and institutions where the data were collected had an effect on this result.

5. Conclusion

In this study, the most suitable green supplier for the supply of agricultural pesticides was selected by using the data collected from pesticide-using enterprises and academicians working in the related field. The importance levels of the criteria were determined with the IMF SWARA method and the most suitable green supplier was selected with the fuzzy WASPAS method. It is thought that the results of the study will serve as a guide for both decision makers and other stakeholders and will also be an incentive for agricultural supply chain stakeholders.

Like every study, this study has various methodological limitations such as the data set, the methods used, and the criteria used. In fact, these limitations can shed light on future studies. Methodologically, new studies can be conducted in future studies by using different MCDM methods and their integrated forms. The importance levels of the criteria and green supplier selection can be evaluated by using recent methods that are not included in the literature review table (Tables 1 and 2). Data was collected in 2024 for the ten criteria identified in this study. Different indicators can be taken as criteria in future studies. On the other hand, in this study, both economic and environmental criteria are used for green supplier selection and a comprehensive green supplier selection model is proposed. In the studies to be conducted in this context in the literature, the results obtained by considering the criteria in detail can be compared and the studies to be conducted can fill an important gap.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	H.F.A.	G.S.
C	50	50
D	50	50
S	50	50
DCP	50	50
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	50	50
PM	50	50
FA	50	50

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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