Computers, Materials & Continua
DOI: 10.32604/cmc.2022.026587
Article

Tech Science Press

Optimization Agricultural Supply Chain: A Case Study of Fertilizer Supplier Selection

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Received: 30 December 2021; Accepted: 15 February 2022

Abstract: The 21st century is associated with the Industrial Revolution 4.0 and the organic agriculture trend, making the utilization of high-quality fertilizers, abundant nutritional content, economical, and no affect to environment pollution. According to the new concept, clean agricultural production and organic agricultural products are not allowed to excessively use synthetic chemicals such as chemical fertilizers, and plant protection drugs, but priority is to use manure, organic fertilizers, and natural mineral fertilizers. Fertilizer must meet the balanced nutritional requirements of crops, maintain, and improve the fertility of the ground, protect the surrounding ecosystem, and leave harmful effects in agricultural products, products with high quality, safe for users and high economic efficiency for producers. To achieve the above goal, the selection of a fertilizer supplier is an important decision, supporting the supply chain's sustainable development, fertilizer supplier selection is a multicriteria decision making model, the decision maker must assess all qualitative and quantitative factors. In this paper, the author proposed an integer decision making model including Fuzzy Analytic Hierarchy Process (FAHP) and Complex Proportional Assessment of Alternatives (COPRAS) for fertilizer supplier selection. The weightings of the criteria are calculated by using FAHP, COPRAS is then applied for ranking some potential fertilizer suppliers. The efficiency of the proposed models is proved by a case study conducted in a farm located in the south of Vietnam. This research is the first fertilizer supplier evaluation and se-lection model in Vietnam by interviewing experts and reviewing the literature. Re-search result is to provide a case study on evaluating supplier in agricultural supply chain utilizing the model proposed by the combination of FAHP and COPRAS models.

Keywords: Fertilizer industry; optimization model; fuzzy theory; agricultural supply chain

1 Introduction

Over the years, the agricultural sector of Vietnam has always affirmed its position of contributing to the country's economy. Vietnam's policies have proven to be appropriate and motivated to promote the potentials and advantages of Vietnam's agriculture, turning Vietnam from a food aid recipient to one of food exporter [1]. Vietnam is a developing country; agriculture still plays an important role in the economy today. However, Vietnam's agricultural production is facing many challenges: Due to the increasing population, the demand for food is constantly increasing; agricultural land area is shrinking due to urbanization, so it is necessary to increase agricultural productivity to meet food security; Climate change is taking place strongly, creating great pressure for our country's agriculture; the process of international integration requires higher quality agricultural products [2].

The global supply chain is posing a series of challenges for businesses, including the origin of goods, trade barriers and trade defense mechanisms. Sustainable development requires businesses to form a supply chain of green products and services, and through that change consumer habits [3]. According to the Food and Agriculture Organization of the United Nations FAO, sustainable agricultural development is the process of managing and sustaining organizational, technical and institutional change in agricultural development to meet the growing demand for agricultural products of people in terms of agricultural products and services now and in the future. This development does not harm the environment, does not degrade natural resources in accordance with technology and brings economic efficiency that is acceptable to society [4].

In the context that Vietnamese agriculture is being strongly affected by global climate change today, the issue of synchronous and balanced fertilizer use becomes even more important. However, agricultural production has not paid due attention to environmental protection for a long time. Clean agricultural production, improving the quality of agricultural products to ensure food hygiene and safety and being environmentally friendly are the goals of both the agricultural industry in general and farmers in particular. In agricultural production activities, fertilizer is an important agricultural input and is used quite a lot every year. Fertilizers have contributed significantly to increase crop yield and quality of agricultural products. According to the International Plant Nutrition Institute (IPNI), fertilizers contribute about 30%–35% of total crop production. However, if used incorrectly, it is one of the agents that pollute the agricultural production and living environment [5].

Therefore, choosing the optimal fertilizer supplier is an important task, contributing to ensuring the efficient operation of the agricultural supply chain, and supporting the goal of developing a sustainable supply chain. However, finding proper suppliers involves several variables and it is critically a complex process. This research provides a decision-making tool to solve a fertilizer supplier selection in agricultural supply chain. First, fuzzy analytic hierarchy process (FAHP) is used to calculate the weights to each criterion separately and the final ranking is achieved by Complex Proportional Assessment of Alternatives (COPRAS) for fertilizer supplier selection. This paper has several interrelated objectives. The first aim of this research refers to the development and detailed description of the new fuzzy multicriteria decision making model. The second aim is to improve the efficiency of single MCDM model through hybrid fuzzy MCDM model including fuzzy analytic hierarchy process and Complex Proportional Assessment of Alternatives (COPRAS).

2 Literature Review

The selection of suppliers is a constant process that requires the consideration of a certain number of criteria needed to make a decision on the selection of the most suitable suppliers [6–8]. The supplier selection, according to many authors, is one of the most demanding problems of sustainable supply chain management [9]. Decision-making in the supplier selection domain, as an essential component of the supply chain management, is a complex process since a wide range of diverse criteria, stakeholders and possible solutions are embedded into this process [10].

Liu et al. [11] integrated MCDM model for sustainable supplier selection under interval-valued intuitionistic uncertain linguistic environment. Koganti et al. [12] proposed a MCDM model including Grey Relational Analysis (GRA), Analytical Hierarchy Process (AHP) and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) for supplier evaluation and selection. Wang et al. [13] provide a new MCDM model for decision-makers in evaluating and selecting suppliers in plastic industry, which is formulated based on the supply chain operation reference (SCOR) model, fuzzy analytic network process (FANP), and VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR).

Yazdani et al. [14] showed that supplier evaluation and selection is an important decision for minimizing operational costs and maintaining organizational competitiveness for the purpose of developing business opportunities. Therefore, the author proposed Integrated QFD-MCDM framework for green supplier selection. Jain et al. [15] proposed an integrated fuzzy MCDM techniques for sustainable supplier selection. In this study, they used fuzzy AHP and TOPSIS model. Ghorbani et al. [16] proposes a three-phase approach for supplier selection based on the Kano model and fuzzy MCDM model. Sobhan et al. [17] addressed a critical issue of selection of supplier occurred in supply chain of a manufacturing company. In this project, the authors proposed paper proposes a MCDM method using Decision Making Trial and Evaluation Laboratory (DEMATEL) based on Analytic Network Process (ANP).

Banaeian et al. [18] used fuzzy group decision making methods for green supplier selection for an actual company from the agri-food industry. The incorporation of fuzzy set theory into TOPSIS, VIKOR and GRA methods is thoroughly discussed in this study. Singh et al. [19] applied big data cloud computing framework for a suitable supplier selection in the beef supply chain. The proposed framework would show results in shedding the environmental conduction of beef supply chain as the highest maintainable carbon footprint generated in beef farms.

Cheraghalipour et al. [20] proposed a strong a strong approach, namely best worst method (BWM) along with a well-known MCDM technique with the name of VIKOR for supplier selection in the Iranian agricultural implements industry. Wakeel [21] proposed a hybrid Entropy-Range of Value MCDM Technique for supplier selection in a semiconductor industry.

As literature review, multi-criteria decision-making model is widely applied in many different fields, but there are very few works using the MCDM based on fuzzy sets to develop a decision support system in agricultural supply chain management. Thus, the author proposed fuzzy MCDM model in fuzzy AHP and COPRAS model for fertilizer evaluation and selection in this research.

3 Methodology

This paper introduces a Fuzzy Multi-Criteria Decision-Making (F-MCDM) model for deciding the optimal sustainable supplier in agricultural supply chain using the FAHP and COPRAS methods. This research involves three main steps, as shown in Fig. 1:

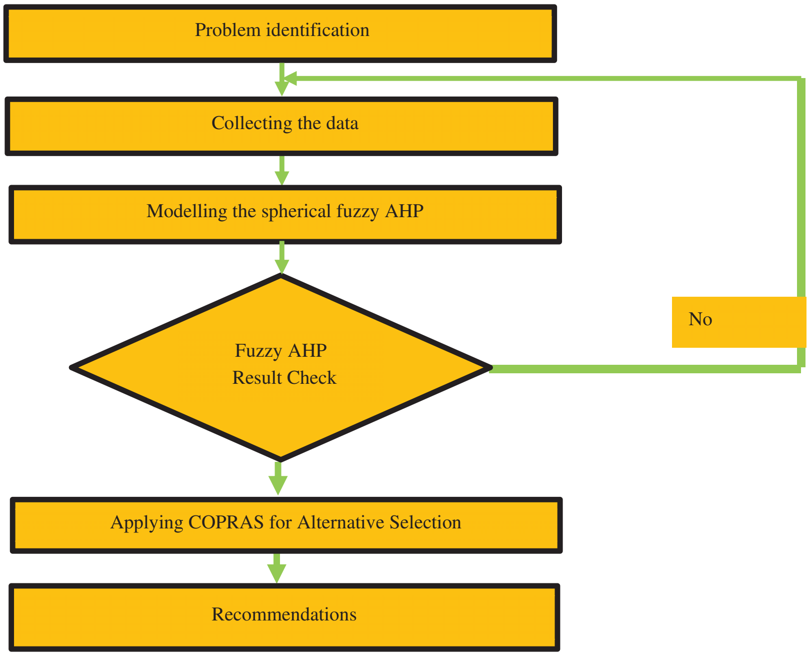

Figure 1: Research processes

Step 1: Identifying all criteria and sub-criteria effecting the fertilizer supplier selection process through interviewing experts and literature review.

Step 2: FAHP is a general form of the decentralized process, which includes the feedback and interdependencies of decision attributes and alternatives. FAHP is employed to determining the weights of the identified criteria.

Step 3: The FAHP can be applied for ranking alternatives, but the of selection several suppliers is practically limited because of the number of pairwise comparisons that need to be made, and a disadvantage of the FAHP model is that input data, expressed in linguistic terms, depend on the experience of decision makers, and thus involve subjectivity. Thus, we proposed the COPRAS model to rank alternatives in the final stage. COPRAS model is applied to rank all the alternatives. The decision maker will use this ranking to support the decision-making process.

3.1 Fuzzy Theory

The Triangular Fuzzy Number (TFN) can be symbolized as (k, h, g), with k, h, and g (k ≤h ≤ g) are parameters that determines the smallest likely value, the most likely value and the highest possible value in TFN. TFN are shown in Fig. 2 and can be described as:

$$\mu\left(\frac{x}{\tilde{M}}\right) = \begin{cases} 0, & x < h, \\ \dfrac{x-\mathrm{k}}{\mathrm{h}-\mathrm{k}} & k \le x \le h, \\ \dfrac{\mathrm{g}-x}{\mathrm{g}-\mathrm{h}} & h \le x \le g, \\ 0, & x > g, \end{cases} \tag{1}$$

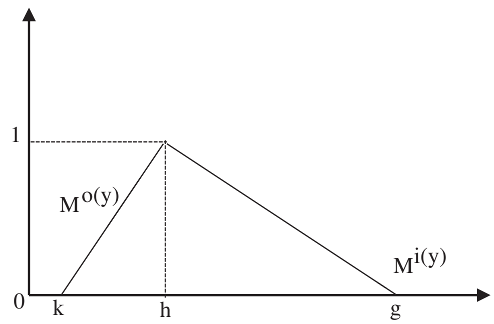

Figure 2: Triangular fuzzy number

A fuzzy number is given as:

$$\tilde{M} = (M^{o(y)}, M^{i(y)}) = [\mathrm{k} + (\mathrm{h} - \mathrm{k})\, y,\ \mathrm{g} + (\mathrm{h} - \mathrm{g})\, y],\, y\ \in [0, 1] \tag{2}$$

With $o(y)$ and $i(y)$ showing the left-hand side and the right-hand side of a fuzzy value, respectively. The below shows basic calculations involve two positive TFN, $(k_1,\ h_1,\ g_1)$ and $(k_2,\ h_2,\ g_2)$.

$$\begin{aligned}
&(k_1,\ h_1,\ g_1) + (k_2,\ h_2,\ g_2) = (k_1 + k_2,\ h_1 + h_2, g_1 + g_2)\\
&(k_1,\ h_1,\ g_1) - (k_2,\ h_2,\ g_2) = (k_1 - k_2,\ h_1 - h_2, g_1 - g_2)\\
&(k_1,\ h_1,\ g_1) \times (k_2,\ h_2,\ g_2) = (k_1 \times k_2,\ h_1 \times h_2, g_1 \times g_2)\\
&\frac{(k_1,\ h_1,\ g_1)}{(k_2,\ h_2,\ g_2)} = (k_1/k_2,\ h_1/h_2, g_1/g_2)
\end{aligned} \tag{3}$$

3.2 Fuzzy Analytic Hierarchy Process (FAHP)

Fuzzy Analytical Hierarchy Process (FAHP) is an extension of AHP that utilizes Fuzzy set theory to calculate its limitation in working with uncertain decision-making environments. Let $X = \{x_1,\ x_2, \ldots, x_n\}$ be the set of objects and $K = \{k_1,\ k_2, \ldots, k_n\}$ be the final suitable set. According to Chang [22] extent analysis method, for each value taken, an extent analysis of its final solution is calculated. Therefore, the l extent analysis values for each object can be obtained. These values are denoted as:

$$L^1_{k_i}, L^2_{k_i}, \ldots, L^m_{k_i},\ i = 1, 2, \ldots, n \tag{4}$$

where $L^j_k\ (j = 1, 2, \ldots, m)$ are the TFNs

Fuzzy synthetic extent value of the i^{th} object is defined as:

$$S_i = \sum_{j=1}^{m} L^j_{k_i} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} L^j_{k_i}\right]^{-1} \tag{5}$$

The possibility that $L_1 \geq\ L_2$ is defined as:

$$V(L_1 \geq L_2) = sup_{y\geq x}\left[min\left(\mu_{L_1}(x),\right), \left(\mu_{L_2}(y)\right)\right] \tag{6}$$

where the pair (x, y) exists with $x \geq y$ and $\mu_{L_1}(x) =\ \mu_{L_2}(y)$, then we have $V(L_1 \geq L_2) = 1$.

Since L_1 and L_2 are convex fuzzy numbers, we have:

$$V(L_1 \geq L_2) = 1,\ if\ l_1 \geq l_2 \tag{7}$$

And

$$V(L_2 \geq L_1) = hgt(L_1 \cap L_2) = \mu_{L_1}(d) \quad (8)$$

where d is the ordinate of the highest intersection point D between μ_{L_1} and μ_{L_2}

With $L_1 = (o_1, p_1, q_1)$ and $L_2 = (o_2, p_2, q_2)$, the ordinate of point D is calculated by (9):

$$V(L_2 \geq L_1) = hgt(L_1 \cap L_2) = \frac{l_1 - q_2}{(p_2 - q_2) - (p_1 - o_1)} \quad (9)$$

In order to compare L_1 and L_2, we need to calculate the values of $V(L_1 \geq L_2)$ and $V(L_2 \geq L_1)$.

The possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $L_i\,(i = 1, 2, \ldots, k)$ is calculated as:

$$V(L \geq L_1, L_2, \ldots, L_k) = V[(L \geq L_1)\ and\ (L \geq L_2)] \quad (10)$$

and, $(L \geq L_k)$= minV$(L \geq L_i),\ i = 1, 2, \ldots,\ k$

Under the assumption that:

$$d'(B_i) = min V(S_i \geq S_k), \quad (11)$$

for $k = 1, 2, \ldots, n$ and $k \# i$, the weight vector is determined as:

$$W' = (d'(B_1), d'(B_2), \ldots, d'(B_n))^T, \quad (12)$$

where B_i are n elements.

The Normalized weight vectors are shown as:

$$W = (d(B_1), d(B_2), \ldots, d(B_n))^T \quad (13)$$

With W is a nonfuzzy number.

An evaluation of a Saaty's matrix is used to test for its consistency.

$$CR = \frac{CI}{RI} = \frac{\bar{\lambda} - n}{(n-1) \times RI} \leq 0.1 \quad (14)$$

where:

- Consistency Ratio (CR);
- Consistency Index (CI);
- Random Index (RI).

3.3 COPRAS Method

The methodology follows of the proposed steps [23]:

Step 1: Determining and selecting contributing criteria (attributes) and the available options

First the attributes which are contributing to the decision in the MCDM problem are determined and the available options are chosen.

Step 2: Prepare the decision matrix between options *vs.* attributes (X)

The gathered data (options and attributes) are layered in matrix formation as shown in Eq. (15)

$$X = \begin{bmatrix} x_{11} & x_{12} & \ldots x_{1m} \\ x_{21} & x_{22} & \ldots x_{2m} \\ \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & x_{nm} \end{bmatrix} \tag{15}$$

where n = number of options; m = number of attributes

Step 3: Normalization of decision matrix ($\bar{X}$)

The normalization of the decision is shown in Eq. (16).

$$\bar{X} = \begin{bmatrix} \bar{x}_{11} & \bar{x}_{12} & \ldots \bar{x}_{1m} \\ \bar{x}_{21} & \bar{x}_{22} & \ldots \bar{x}_{2m} \\ \vdots & \vdots & \vdots \\ \bar{x}_{n1} & \bar{x}_{n2} & \bar{x}_{nm} \end{bmatrix} \tag{16}$$

where $\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}$; I = 1, 2, …, n; and j = 1, 2, …, m

Step 4: Calculation of the weighting of the attributes (W_j)

The attributes' weightings are calculated by using FAHP calculations.

Step 5: Calculation of the overall normalized matrix $(\widehat{X})$

The calculated weights are multiplied across corresponding attribute value of all options to get the overall normalized matrix.

$$\hat{X} = \begin{bmatrix} \hat{x}_{11} & \hat{x}_{12} & \ldots \hat{x}_{1m} \\ \hat{x}_{21} & \hat{x}_{22} & \ldots \hat{x}_{2m} \\ \vdots & \vdots & \vdots \\ \hat{x}_{n1} & \hat{x}_{n2} & \hat{x}_{nm} \end{bmatrix} \tag{17}$$

where $\widehat{X}_{ij} = \bar{x}_{ij} * W_j$

Step 6: Determination of maximizing index (P_j) and minimizing index (R_j)

Based on the qualitative nature of the attribute, the maximizing index (P_j) and minimizing index (R_j) values are determined. Attribute P_j is determined if it is a maximizing index. R_j will be calculated for minimizing index.

$$P_j = \sum_{i=1}^{k} \hat{x}_{ij} \tag{18}$$

$$R_j = \sum_{i=k+1}^{m} \hat{x}_{ij} \tag{19}$$

where k = number of attributes which is to be maximized

Step 7: Calculation of relative weights of each option (Q_j)

Finally, all the attributes overall relative weighting will be determined.

$$Q_j = P_j + \frac{\sum_{j=1}^{n} R_j}{R_j \sum_{j=1}^{n} \frac{1}{R_j}} \tag{20}$$

The alternative with the highest relative weights is considered as the best alternative.

4 Case Study

From a country that has to depend on imported fertilizers, in the past 30 years, Vietnam's fertilizer industry has made strong progress, taking the initiative in supplying and even exporting products to more 20 countries in the world. Although it has met most of the needs of the domestic market, over the past time, many Vietnamese fertilizer factories have only focused on quantity, not really paying attention to improving product quality and environmental factors [24]. In this paper, the author proposed an integer decision making model including Fuzzy Analytic Hierarchy Process (FAHP) and Complex Proportional Assessment of Alternatives (COPRAS) for fertilizer supplier selection in agricultural supply chain.

In the first step of this research, all criteria and sub-criteria effecting the fertilizer supplier selection process are identified through interviewing experts and literature review. A hierarchy of criteria is shown in Tab. 1.

Table 1: List of criteria

No.	Main criteria	Sub criteria	Symbol
1	Cost	Purchase cost	A1
		Logistics cost	A2
2	Green competency	Green material selection	B1
		Cleaner production technologies	B2
		Reduced green packaging	B3
3	Quality	Rejected and returned material ratio	C1
		Quality management capacity	C2
		Product percentage of pass	C3
4	Delivery schedule	Service performance	D1
		On-time delivery rate	D2
		On-time delivery quantity rate	D3
5	Environmental management performance	Waste management	E1
		Remanufacturing/reuse activity	E2
		ISO certification	E3

The Fuzzy Analytic Hierarchy Process (FAHP) is a method for organizing and analyzing complex decisions, using math and psychology. It was developed by Thomas L. Saaty in the 1970s and has been refined since then. The weights of the criteria are calculated by using FAHP in second stage. Results of FAHP is shown in Tab. 2.

Table 2: Weight of criteria are defined by fuzzy AHP

Criteria	Fuzzy sum of each row			Fuzzy synthetic extent			Degree of possibility (Mi)	Weight
A1	12.1851	17.8283	24.4434	0.0375	0.0754	0.1455	0.6541	0.0766
A2	12.7865	18.0290	23.5667	0.0394	0.0762	0.1403	0.6457	0.0757
B1	15.9963	23.7091	32.5221	0.0493	0.1003	0.1936	0.9102	0.1066
B2	12.6212	18.6081	26.1559	0.0389	0.0787	0.1557	0.6891	0.0807
B3	19.7873	26.8057	34.4525	0.0610	0.1134	0.2051	1.0000	0.1172
C1	11.5252	16.5279	23.0055	0.0355	0.0699	0.1370	0.6110	0.0716
C2	10.1926	14.3580	20.2013	0.0314	0.0607	0.1203	0.5274	0.0618
C3	14.2629	20.1416	27.1816	0.0439	0.0852	0.1618	0.7816	0.0916
D1	14.1138	19.6157	26.1531	0.0435	0.0829	0.1557	0.7570	0.0887
D2	9.5429	13.6656	19.6636	0.0294	0.0578	0.1171	0.5024	0.0589
D3	7.5554	10.4612	15.2235	0.0233	0.0442	0.0906	0.3003	0.0352
E1	12.5504	16.9317	23.4373	0.0387	0.0716	0.1395	0.6530	0.0765
E2	7.6862	10.3153	14.8831	0.0237	0.0436	0.0886	0.2839	0.0333
E3	7.1651	9.4853	13.6941	0.0221	0.0401	0.0815	0.2192	0.0257

In the final stage of this study, COPRAS is applied to rank all the alternatives. The decision maker will use this ranking to support the decision-making process. Normalized matrix and Weight normalized matrix of COPRAS are shown Tabs. 3 and 4.

Table 3: Normalized matrix

	OP1	OP2	OP3	OP4	OP5
A1	0.14706	0.17647	0.20588	0.26471	0.20588
A2	0.22857	0.20000	0.25714	0.17143	0.14286
B1	0.24324	0.18919	0.21622	0.16216	0.18919
B2	0.24324	0.16216	0.18919	0.18919	0.21622
B3	0.20000	0.17143	0.25714	0.20000	0.17143
C1	0.25000	0.16667	0.13889	0.25000	0.19444
C2	0.25714	0.17143	0.17143	0.20000	0.20000
C3	0.21951	0.19512	0.17073	0.21951	0.19512
D1	0.21429	0.19048	0.21429	0.16667	0.21429
D2	0.20930	0.16279	0.20930	0.20930	0.20930
D3	0.21951	0.17073	0.21951	0.17073	0.21951
E1	0.24324	0.16216	0.18919	0.21622	0.18919
E2	0.22500	0.17500	0.15000	0.22500	0.22500
E3	0.22500	0.17500	0.20000	0.22500	0.17500

Table 4: Weight normalized matrix

	OP1	OP2	OP3	OP4	OP5
A1	0.0113	0.0135	0.0158	0.0203	0.0158
A2	0.0173	0.0151	0.0195	0.0130	0.0108
B1	0.0259	0.0202	0.0231	0.0173	0.0202
B2	0.0196	0.0131	0.0153	0.0153	0.0175
B3	0.0234	0.0201	0.0301	0.0234	0.0201
C1	0.0179	0.0119	0.0099	0.0179	0.0139
C2	0.0159	0.0106	0.0106	0.0124	0.0124
C3	0.0201	0.0179	0.0156	0.0201	0.0179
D1	0.0190	0.0169	0.0190	0.0148	0.0190
D2	0.0123	0.0096	0.0123	0.0123	0.0123
D3	0.0077	0.0060	0.0077	0.0060	0.0077
E1	0.0186	0.0124	0.0145	0.0165	0.0145
E2	0.0075	0.0058	0.0050	0.0075	0.0075
E3	0.0058	0.0045	0.0051	0.0058	0.0045

The option with the highest relative weighting overall in all aspects is considered as the optimal option for the selection process. As results from Tab. 5, OP1 is optimal supplier in this case study.

Table 5: Final ranking

Alternatives	S+	S-	1/S-	Q	U
OP1	0.2051	0.0173	57.8299	0.2178	100
OP2	0.1625	0.0151	66.0913	0.1770	81.26
OP3	0.1841	0.0195	51.4044	0.1953	89.69
OP4	0.1896	0.0130	77.1066	0.2065	94.81
OP5	0.1831	0.0108	92.5279	0.2034	93.42

5 Conclusion

In the context of the continuously changing economy, agricultural development needs to focus on connecting supply chains, building brands of agricultural products, and locating the value of Vietnamese agricultural products in the agricultural global market. Developing the sustainable agricultural supply chain will help increase the export of goods by easily meeting the technical and phytosanitary standards of the importing country, helping to control export products of enterprises better, especially towards environmental protection. Selecting the optimal fertilizer supplier is an important task, contributing to ensuring the efficient operation of the agricultural supply chain, and supporting the goal of developing a sustainable supply chain. In this research, the author proposed a fuzzy multicriteria decision making model (FMCDM) including Fuzzy Analytic Hierarchy Process (FAHP) and Complex Proportional Assessment of Alternatives (COPRAS) for fertilizer supplier selection. The model was also utilized in a suitable case. It is an important study in the agricultural supply chain, and it can be extended to optimize the supplier selection in other industries.

However, the number of criteria is currently limited in this research. Thus, the authors should consider more criteria in the supplier selection process in the future. Particular attention should be paid to the sustainable development factor, which is evaluating sustainability, which is increasing rapidly with the expansion of the period of industrialization and modernization

Funding Statement: The authors wish to express their gratitude to Van Lang University, Vietnam for financial support for this research.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

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