Journal of Agricultural Science and Technology (JAST), 29(2)
In Press, Pre-Proof Version

Crop Selection Based on Agricultural Enterprises' Preferences in Türkiye's New Production Planning: A Fuzzy Decision-Making Models

Fatma Çiftci[1]

ABSTRACT

The rising uncertainties in agricultural production have led nations to adopt new planning approaches to ensure food security and sustainability of resources. In this regard, the new planned agricultural production approach adopted by Türkiye needs to be empirically assessed, especially in terms of the producers' preferred crops. This research work uses a hybrid approach of Multi-Criteria Decision Making techniques that combine Fuzzy AHP and Fuzzy VIKOR methods based on data collected from 383 agricultural enterprises in Konya province. The findings show that Product Price (23.54%) and Labor Requirements (17.99%) are the most significant criteria in crop selection. Among the alternatives, wheat was found to be the most appropriate crop with the lowest compromise ranking value (Q = 0.000), followed by maize (Q = 0.161) and potatoes (Q = 0.169). The results form an empirical foundation for improving the new production planning approach in Türkiye by enhancing support structures and taking into account resource efficiency.

Keywords: Crop Selection, Fuzzy AHP, Fuzzy VIKOR, New Planned Production Period, MCDM.

1. INTRODUCTION

Recent global pandemics, climate change, economic fluctuations, and geopolitical conflicts have transformed agriculture from merely a production sector into a strategic industry directly linked to food security and national stability. Rising temperatures, prolonged droughts, and disruptions to global supply chains have increased uncertainty in agricultural production systems (UNDP, 2021; EUCRA, 2024; FAO, 2023). These developments have led to a renewed focus on the strategic importance of crop production and prompted countries to restructure their agricultural policies.

On the other hand, the Russia-Ukraine War has had significant and lasting negative impacts on staple agricultural products, particularly cereals, leading to food supply shortages and price increases (Rose et al., 2023). Similar priorities are clearly emphasized in the United Nations Sustainable Development Goals. In this context, SDG-2 (End Hunger) and SDG-12

[1] Department of Industrial Engineering, Faculty of Engineering and Natural Sciences, KTO Karatay University, Türkiye. e-mail: **e-mail:** fatma.ciftci@karatay.edu.tr

(Responsible Production and Consumption) highlight the need for a sustainable restructuring of food systems in all aspects.

In addition to global challenges, a new planned agricultural production model has been implemented in Türkiye as of 2024 to address the restructuring problem in the agricultural sector. This new model is based on water scarcity, mandatory crop rotation, and regional support mechanisms. Of the 52 districts in provinces with water scarcity, 19 are located in Konya province. This situation further highlights the importance of rational product planning in the region.

Product selection is a strategic decision for agricultural businesses, concerning the choice of products to be produced within the framework of the implemented model. Incorrect product selection can lead to both income loss and waste of natural resources. In the agricultural sector, product selection is one of the most critical components of the process. When deciding which product to produce, when, and in what quantity, businesses must consider not only climatic and technical conditions but also economic dynamics, market demands, and policies.

These multifaceted factors complicate the decision-making process, and climate change and environmental conditions directly impact crop yield and quality. Factors such as agricultural income, sustainability goals, natural resource conservation, climate change mitigation measures, market price fluctuations, input costs, and external shocks increase uncertainty and highlight the need for systematic decision-making approaches. The complexity and ambiguity of the criteria highlight the need for systematic decision support tools capable of processing multidimensional and imprecise data.

When economic returns, environmental impacts, and social benefits are considered together in the product selection process, it becomes possible to manage agricultural production both efficiently and sustainably. However, such multidimensional decision problems require comprehensive and systematic evaluation tools. Multi-Criteria Decision Making (MCDM) methods offer producers the opportunity to make more informed and strategic choices in crop selection. These methods structure the decision-making process by holistically considering multiple criteria such as market trends, economic feasibility, yield potential, and policy support (Ragot et al., 2018). However, classical MCDM methods may show limitations in agricultural decision problems dominated by uncertainty and imprecise data. Therefore, the fuzzy logic approach is widely used to increase the accuracy of the decision-making process (Deng, 1999). The literature shows that MCDM methods are effectively used in crop selection and land suitability analyses. Prakash (2003) evaluated land suitability with fuzzy AHP, while Sudha and Jeba (2015) applied the fuzzy TOPSIS method in crop selection. Deepa and Ganesan (2018) used the Entropy–VIKOR approach, while Dokuzlu et al. (2020) preferred the AHP method. In more advanced hybrid models, uncertainty and criterion diversity have been addressed with approaches such as Pythagorean Fuzzy CRITIC-VIKOR (Mishra et al., 2021), MARCOS–VIKOR, and probabilistic ranking methods (Haloui et al., 2025). While these studies demonstrate the effectiveness of multi-criteria methods in crop selection applications, focusing on general suitability analyses, empirical analyses based on producer preferences within the context of newly implemented planned production models at the national level have not been presented.

In the current literature, there is no study that examines the impact of the new planning model for Turkey as of 2024 on producer preferences based on field data. In particular, how producer preferences are shaped within the new planning framework in water-scarce regions, in what direction the criterion weights change, and what kind of consequences this change has for policy design have not been sufficiently analyzed. Studies that empirically evaluate the relationship between producer preferences and the policy framework are limited.

The objectives of this study are: (i) to conduct an empirical product selection analysis at the regional level within the framework of the new planned production system for Turkey, (ii) to model producer preferences in an environment of uncertainty using a fuzzy multi-criteria decision-making approach integrating Fuzzy Analytical Hierarchy Process (AHP) and Fuzzy Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR) methods, and (iii) to generate concrete implications for policymakers regarding data-driven and regionalized support mechanisms for water-scarce regions.

Accordingly, the aim of this study is to determine the product preferences of agricultural enterprises in Konya province, to determine the importance levels of the criteria influencing these preferences, and to develop policy recommendations compatible with the new planned production model in light of the findings.

2. MATERIAL AND METHODS

In this study, primary data collected by the researcher using the survey technique during the 2025 agricultural production season was used. Konya province was selected as the research area due to its pioneering role in agricultural production in Türkiye. The province ranks first in the production of many crops such as wheat, grain corn, barley, and sugar beet. In addition to crop production, it ranks first in the number of cattle, second in the number of sheep, and third in the number of laying hens (TurkStat, 2024). With 92,500 registered agricultural enterprises, the sampling frame was determined by the Ministry of Agriculture and Forestry. The sample size was determined using simple random sampling with finite population proportions (Newbold, 1995).

$$n = \frac{N \times p \times (1-p)}{(N-1) \times \sigma^2_{p^x} + p \times (1-p)} \quad (1)$$

In the formula;

n=Sample volume

N=Number of agricultural enterprises in the main sampling frame

$\sigma^2_{p^x}$ = Variance

p=0.50

q=1-p

Using the formula in Equation (1), the sample size was calculated as 383 with a 5% margin of error and a 95% confidence interval.

This study aims to identify the most appropriate plant product selection and the criteria influencing agricultural enterprises during the transition to a planned production period. Based on the results, policy recommendations are developed to contribute to the new planned production system. In this context, opinions from producers, as well as experts working in universities, public institutions, and other relevant organizations, were utilized. A total of 15 experts were consulted during the criteria identification stage to ensure sectoral and policy relevance. . Experts were not involved in the comparison and evaluation phases. The data used in the Fuzzy AHP and Fuzzy VIKOR analyses were obtained directly from 383 agricultural producers who participated in the survey. For the FAHP, producers performed pairwise comparisons of the criteria, and for the Fuzzy VIKOR phase, they evaluated product alternatives under each criterion using a defined linguistic scale. Individual results were collected using the geometric mean method.

The study identified 11 criteria considered effective in plant product selection: C1;Support, C2;Crop Rotation, C3;Different Climatic Conditions, C4;Yield, C5;Irrigation Opportunities, C6;Product Price, C7;Input Supply, C8;Marketing Opportunities, C9;Labor Requirements, C10;Soil Structure, and C11;Technical Information. The selected criteria reflect economic, environmental, and policy factors for product selection within the framework of the new planned production model. Product price and yield reflect expected income, irrigation possibilities and soil structure reflect production feasibility, support and crop rotation policy compatibility, labor and input supply reflect operational constraints, and marketing opportunities and technical knowledge reflect market access and production capacity. The criteria were established in accordance with the "2025–2027 Plant Production Support Decision" and analyzed using a five-point Likert scale (Very Bad, Bad, Average, Good, Very Good) for wheat, barley, grain corn, dry onion, potato, lentil, chickpea, dry bean, sunflower for oil production, canola, safflower, and forage crops planned for Konya province. Because classical methods do not yield clear results in ambiguous situations, criteria weights were determined using the Fuzzy AHP method; alternatives were ranked and the most suitable product was selected using the Fuzzy VIKOR method. The applied methods support rational and informed decision-making processes in product selection.

Fuzzy logic

Fuzzy logic was first developed by Zadeh(1965) for solving problems in the real world where there is uncertain and ambiguous information. This approach allows for more realistic modeling of uncertain situations based on probabilities rather than certainties in many fields, such as agriculture, and is particularly preferred in the analysis of complex systems. Therefore, fuzzy logic is considered an extended version of classical logic(Wang et al., 1999). Fuzzy sets are defined by membership functions. The membership function of a fuzzy set A is usually denoted by $\mu_A(x)$ and is defined in the range 0 to 1 (Dağdeviren, 2007). Triangular fuzzy numbers are denoted by $\tilde{A}$. $\tilde{A}$ consists of three crisp numbers $(l \le m \le u)$. The membership functions of triangular numbers are as follows;

$$\mu_A(x) = \begin{cases} (x-l)/(m-l) & , \quad l \le x \le m \\ (u-x)/(u-m) & , \quad m \le x \le u \\ 0 & , \quad dy \end{cases} \tag{2}$$

In the equation (2), in the fuzzy number $\tilde{A}$ expressed by $(l \le m \le u)$, m represents the most possible value, l represents the lowest likelihood, and u represents the highest likelihood.

Fuzzy AHP

AHP, first developed by Saaty, is a mathematical decision-making model that allows us to evaluate quantitative and qualitative observations together. This method contributes to obtaining more consistent and systematic results by analyzing the complex structures in decision-making processes. Because the classical AHP method cannot adequately represent uncertainties and flexibility, fuzzy logic-based approaches have been proposed, thus minimizing the margin of error arising from uncertainty and obtaining more reliable results. The triangular membership function, first developed by Van Laarhoven and Pedrycz, has been developed and used using fuzzy numbers. This model has been further developed by Buckley (1985), Chang (1996), and Zhu et al. (1999). In this study, the Fuzzy AHP (FAHP) method developed by Buckley (1985) was used. In the fuzzy AHP method, decision makers' decisions are represented by triangular fuzzy numbers (TFNs). Accordingly, "equally important" is expressed as the reciprocal of (1, 1, 1). "Somewhat important" is defined as the reciprocal of (1/5, 1/3, 1) to (1, 3, 5). "Important" is represented by (3, 5, 7) and its converse is (1/7, 1/5, 1/3). "More important" is represented by (5, 7, 9) and its converse is (1/9, 1/7, 1/5). Finally, "absolutely more important" is defined by (7, 9, 9) and its converse is (1/9, 1/9, 1/7).

Step 1. When k selection criteria and l alternatives are found to create the decision matrix, matrix $\tilde{A}$ is created using the above TFN $(\sim)$ expressions to create the decision-making pairwise comparison matrix.

$$\tilde{A} = \begin{bmatrix} \tilde{a}_{11}^k & \tilde{a}_{12}^k & \dots & \tilde{a}_{1n}^k \\ \tilde{a}_{21}^k & \tilde{a}_{22}^k & \dots & \tilde{a}_{2n}^k \\ \vdots & \vdots & \dots & \vdots \\ \tilde{a}_{m1}^k & \tilde{a}_{m2}^k & \dots & \tilde{a}_{mn}^k \end{bmatrix} \left(i = 1,2,\dots,m; j = 1,2,\dots,n\right) \tag{3}$$

Step 2. In case there is more than one decision maker, they are combined by taking their geometric averages as shown in Equation (4).

$$l_{ij} = \left[\prod_{k=1}^{n} l_{ijk}\right]^{1/n}, m_{ij} = \left[\prod_{k=1}^{n} m_{ijk}\right]^{1/n}, u_{ij} = \left[\prod_{k=1}^{n} u_{ijk}\right]^{1/n} \tag{4}$$

$\tilde{X}_{ijk} = \left(l_{ijk}, m_{ijk}, u_{ijk}\right)$ represents the performance value of the i. criterion with respect to the j. criterion for the k. decision maker.

Step 3. For each row of values in the decision matrix, the geometric mean is calculated using Equation (5).

$$\tilde{r}_i = \left[\prod_{j}^{n} a_{ij}\right]^{1/n}, \ i = 1,2,\dots,n \tag{5}$$

$\tilde{r}_i$, the geometric mean of the comparison values of the *ith* criterion with all fuzzy criteria; n shows the number of criteria.

Step 4. The weights ($\tilde{w}_l$) of the TFN are determined using Equation 6.

$$\tilde{w}_l = \tilde{r}_l \times \left(\tilde{r}_1 + \tilde{r}_2 + \dots + \tilde{r}_n\right)^{-1} = \left(l_i, m_i, u_i\right) \tag{6}$$

Step 5. It is clarified with the Weighted Average Center (COA) using Equality (7). This value represents the net value function D.

$$D_i = \frac{(l_i + m_i + u_i)}{3} \tag{7}$$

Step 6. Net weight values are obtained using Equation (8).

$$w_{D_i} = \frac{D_i}{\sum_{i=1}^{n} D_i} \tag{8}$$

The criterion weights obtained in FAHP are used in the Fuzzy VIKOR method.

Fuzzy VIKOR

The VIKOR method (Opricovic, 1998) is one of the appropriate MCDM approaches for determining alternatives (Opricovic and Tzeng, 2004). Fuzzy VIKOR (FVIKOR), an extension of the VIKOR method used in uncertain environments, evaluates through linguistic expressions. The linguistic expressions are: "Very Poor" (1, 1, 3), "Poor" (1, 3, 5), "Average" (3, 5, 7), "Good" (5, 7, 9), and "Very Good" (7, 9, 9). The basic steps followed in the FVIKOR method are summarized below (Opricovic ve Tzeng, 2007).

Step 1. Considering *m* alternatives, *n* criteria and *k* decision makers, the fuzzy decision matrix $\tilde{A}=\left[\tilde{x}_{ij}\right]$, is obtained by Equality (9):

$$\tilde{A}=\begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad i=1,2,\dots,m,\ \ j=1,2,\dots,n$$

(9)

$$\tilde{x}_{ij}^{k} = (l_{ij}^{k}, m_{ij}^{k}, u_{ij}^{k}),\ W = (w_1, w_2, \dots, w_n),\ (j=1,2,\dots,n)$$

Here, $\tilde{x}_{ij}^{k}$ represents the evaluation of the i^{th} alternative with respect to the j^{th} criterion.

$$l_{ij} = \min_k\left(l_{ij}^{k}\right),\ m_{ij} = \frac{1}{K}\sum_{k=1}^{K} m_{ij}^{k},\ u_{ij} = \max_k\left(u_{ij}^{k}\right) \tag{10}$$

l_{ij} in the fuzzy number represents the minimum value, m_{ij} represents the median value and u_{ij} represents the maximum value.

Step 2. The fuzzy decision matrix is clarified by converting it to crisp values.

$$a = \frac{l + 4m + u}{6} \tag{11}$$

Step 3. Determine the best f_j^* and worst f_j^- values for all criterion functions $j = 1, 2, ..., n$. If criterion j is a benefit criterion:

$$f_j^* = \max_i x_{ij} \quad (12)$$

If criterion j is a cost criterion:

$$f_j^- \min_i x_{ij} \quad (13)$$

In this study, Product Price and Labor Requirement are considered cost criteria, while all other criteria are considered benefit criteria.

Step 4. S_i and R_i values are calculated using Equation (14) and Equation (15):

$$S_i = \sum_{j=1}^{n} w_j \left(f_j^* - x_{ij}\right) / \left(f_j^* - f_j^-\right) \quad (14)$$

$$R_i = \max_j \left[\sum_{j=1}^{n} w_j \left(f_j^* - x_{ij}\right) / \left(f_j^* - f_j^-\right) \right] \quad (15)$$

Here, w_j is the weight values, S_i is the sum of the distance of the ith alternative to the best fuzzy values. R_i is the maximum distance of the worst fuzzy values .

Step 5. Q_i index is calculated using Equation (16):

$$Q_i = q \frac{\left(S_i - S^*\right)}{S^- - S^*} + \left(1 - q\right) \frac{\left(R_i - R^*\right)}{R^- - R^*} \quad (16)$$

Where $S^* = \min_i S_i$, $S^- = \max_i S_i$, $R^* = \min_i R_i$, $R^- = \max_i R_i$ and q express the importance of the strategy. The 1-q value expresses the individual regret value. For the compromising majority, $q \approx 0.5$ is generally taken(Opricovic, 2011).

Step 6. The alternatives are ranked according to their S_i, R_i and Q_i values. In this ranking, the alternative with the lowest Q_i value is considered the most suitable option.

Step 7. Two conditions must be met when determining the compromise solution.

Acceptable Advantage (1): When the Q_i values are ranked, Equation (17) must be satisfied when A^1 is shown as the first alternative and A^2 as the second alternative.

$$Q\left(A^2\right) - Q\left(A^1\right) \geq DQ \quad (17)$$

Stability (2): The top-ranked alternative in Q_i must also rank first in both S_i and R_i. If not, both are considered compromise solutions with the maximum acceptable difference calculated using Equation (18) (Opricovic & Tzeng, 2007).

$$Q\left(A^{m}\right)-Q\left(A^{1}\right)<DQ \tag{18}$$

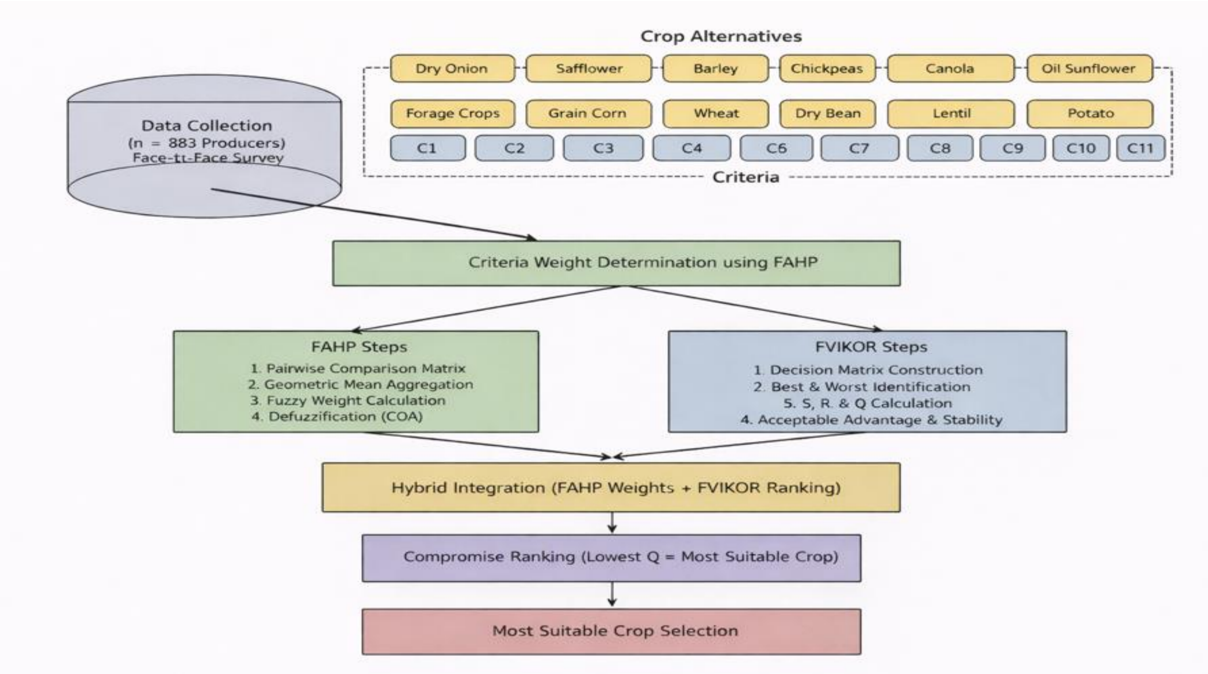

Figure 1. Methodology flowchart (step-by-step).

3. RESEARCH FINDINGS and DISCUSSION

In this section, the results calculated using the FAHP and FVIKOR methods for plant based product alternatives according to the determined criteria are presented and evaluated. The calculations were made in Microsoft Excel.

Obtaining criteria weights with FAHP

Step 1. The fuzzy numbers (Table 1) were obtained.

Table 1. Fuzzy Decision Matrix.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	(1,1,1)	(2.81,4.99,7.06)	(2.98,5.08,7.12)	(0.64,0.9,1.28)	(0.43,0.7,1.32)	(0.15,0.19,0.27)	(2.74,4.51,5.96)	(3.41,5.57,7.48)	(0.54,0.67,0.8)	(1.82,4.01,6.07)	(4.55,6.82,8.07)
C2	(0.14,0.2,0.36)	(1,1,1)	(0.55,0.76,0.85)	(0.13,0.16,0.29)	(0.18,0.23,0.38)	(0.11,0.14,0.2)	(0.74,1.17,1.82)	(1,12,2.31,3.41)	(0.12,0.16,0.24)	(1.1,11,1.21)	(1.93,3.25,4.59)
C3	(0.14,0.2,0.34)	(1,1.32,1.82)	(1,1,1)	(0.13,0.18,0.32)	(0.19,0.26,0.46)	(0.11,0.14,0.19)	(0.85,1.55,2.24)	(1.12,2.83,4.4)	(0.12,0.16,0.25)	(1,1.73,1.9)	(1.93,4.08,6.12)
C4	(0.78,1.11,1.55)	(3.81,5.87,7.74)	(3.47,5.62,7.67)	(1,1,1)	(1.38,2.9,4.36)	(0.43,0.5,0.62)	(2.27,3.62,5.16)	(3.16,4.59,6.16)	(0.74,1.28,1.76)	(2.65,3.78,5.24)	(3.78,4.99,5.95)
C5	(0.76,1.44,2.31)	(2.62,4.29,5.71)	(2.16,3.84,5.39)	(0.24,0.35,0.65)	(1,1,1)	(0.15,0.19,0.28)	(1.55,3.68,5.72)	(1.73,3.87,5.92)	(0.32,0.46,0.72)	(1.54,3.35,4.95)	(4.14,6.22,7.94)
C6	(3.68,5.38,6.64)	(4.91,6.94,8.78)	(5.35,7.3,6.9)	(1.62,1.99,2.85)	(2.45,3.41,4.32)	(1,1,1)	(3.47,4.82,6)	(3.78,5.11,6.15)	(1.12,2.31,3.41)	(2.93,4.15,5.7)	(3.91,5.24,7.82)
C7	(0.17,0.22,0.37)	(0.55,1.06,1.15)	(0.45,0.64,1.17)	(0.2,0.28,0.44)	(0.17,0.27,0.64)	(0.17,0.21,0.29)	(1,1,1)	(1,1.39,1.62)	(0.13,0.18,0.3)	(0.29,0.4,0.72)	(0.85,1.55,2.24)
C8	(0.13,0.18,0.29)	(0.29,0.48,0.9)	(0.23,0.35,0.9)	(0.16,0.21,0.34)	(0.17,0.26,0.58)	(0.16,0.2,0.26)	(0.62,0.72,1)	(1,1,1)	(0.11,0.14,0.19)	(0.18,0.26,0.45)	(0.8,1.12,1.33)
C9	(1.25,1.5,1.84)	(4.44,6.49,8.35)	(4.08,6.12,8.14)	(0.57,0.78,1.69)	(1.39,2.2,3.08)	(0.29,0.43,0.9)	(3.3,5.44,7.67)	(5.35,7.36,9)	(1,1,1)	(3.87,5.72,7.94)	(5.17,7,18,9)
C10	(0.16,0.25,0.55)	(0.82,0.9,1)	(0.53,0.64,1)	(0.19,0.25,0.4)	(0.2,0.3,0.65)	(0.18,0.23,0.34)	(1.39,2.52,3.41)	(2.23,3.84,5.71)	(0.13,0.17,0.26)	(1,1,1)	(1.39,2.79,4.15)
C11	(0.12,0.15,0.22)	(0.22,0.29,0.52)	(0.17,0.25,0.58)	(0.17,0.2,0.26)	(0.13,0.17,0.27)	(0.17,0.2,0.27)	(0.53,0.72,1.17)	(0.75,0.9,1.25)	(0.11,0.14,0.19)	(0.24,0.36,0.72)	(1,1,1)

Step 2-3-4. By calculating the $\tilde{r}_i$ value of each alternative in the decision matrix, the fuzzy weight function $\tilde{w}_l$ for each criterion was determined using equation (6). For $\tilde{w}_l$, the CAO in equation (7) and the net weight values given in equation (8) were calculated and the results are presented in Table 2.

Table 2. $\tilde{r}_i$, $\tilde{w}_l$, and w_{D_i} of values.

Criteria	$\tilde{r}_i$	$\tilde{w}_l$	D_i	w_{D_i}	Arrangement
C1	(1.277, 1.926, 2.622)	(0.059, 0.123, 0.242)	0.141872	0.122114	4
C2	(0.397 ,0.546, 0.769)	(0.018, 0.035, 0.071)	0.041606	0.035812	8
C3	(0.426, 0.646, 0.934)	(0.019, 0.041, 0.086)	0.049274	0.042412	7
C4	(1.691, 2.475, 3.254)	(0.078, 0.158, 0.301)	0.179508	0.154509	3
C5	(0.986, 1.632 ,2.354)	(0.046, 0.104, 0.217)	0.122806	0.105704	5
C6	(2.737, 3.788, 4.866)	(0.127, 0.242, 0.449)	0.273571	0.235473	1
C7	(0.343, 0.487 ,0.731)	(0.016, 0.031, 0,067)	0.038299	0.032966	9
C8	(0.261, 0.348, 0.548)	(0.012, 0.022, 0,051)	0.028433	0.024473	10
C9	(1.981, 2.767, 3.864)	(0.092, 0.177, 0.357)	0.20908	0.179963	2
C10	(0.472, 0.666, 1.002)	(0.022, 0.042, 0.092)	0.052483	0.045174	6
C11	(0.243, 0.306, 0.471)	(0.011, 0.019, 0.043)	0.024861	0.021399	11
			1.161793	1	

The calculated weight values were used as the weights of criteria in the FVIKOR approach for the selection of plant products. As seen in Table 6, "C6" was determined to be the most significant criterion (23.54%). This outcome verifies that profitability is the key factor in farmers' choice-making. This is in line with the results of similar agro-climatic conditions in Türkiye. For example, in study carried out in the Thrace Region, income criteria were found to be the most significant factor in crop selection, which showed that producers give priority to economic return expectations in irrigated production conditions (Gaytancıoğlu & Yılmaz, 2024). Product prices should not only meet production costs but also provide business sustainability.

"C9" came in second (17.99%). The rising average age of producers and the outflow of young labor in the countryside make labor a structural constraint, pushing up production costs. While foreign labor mitigates the problem, it also brings about extra financial burdens. The "C4" criterion ranked third with 15.45%. Increased climate variability has strengthened producers' preference for drought-tolerant crops. This is a result of the increased perception of risk to crop stability in the face of climate change.

The C1 criterion scored the fourth position (12.21%). Although the policy support for planned production and water restriction support mechanisms is highly emphasized, the fact that it is given a relatively lower weight indicates that producers are more interested in actual market returns than in policy support. This result shows that policy support, although institutionally important, may play a less important role in decision-making than actual, tangible profitability considerations. Furthermore, because the analysis is conducted using cross-sectional data that represent the particular economic conditions prevailing during the time of the study, the relative importance of this criterion must be considered in the context of the study period.

The "C5" criterion ranked fifth (10.57%). Given that the long-term average annual precipitation in the Konya region (327.6 mm) is significantly below the national average, irrigation remains structurally critical. Limited rainfall increases production risk and makes access to reliable irrigation infrastructure a key determinant in cultivation decisions. Therefore, irrigation opportunities should be considered a fundamental criterion in crop selection under water-constrained conditions.

Other criteria were determined as follows: "C10" (4.51%), "C3" (4.24%), "C2" (3.58%), "C7" (3.29%), "C8" (2.44%), and "C11" (2.13%). While the analysis reveals that product price and labor requirements are the most important determining criteria, technical knowledge and marketing must be supported for the sustainability of businesses. Indeed, the results demonstrate that production planning should consider all economic, social, and environmental components of agriculture together.

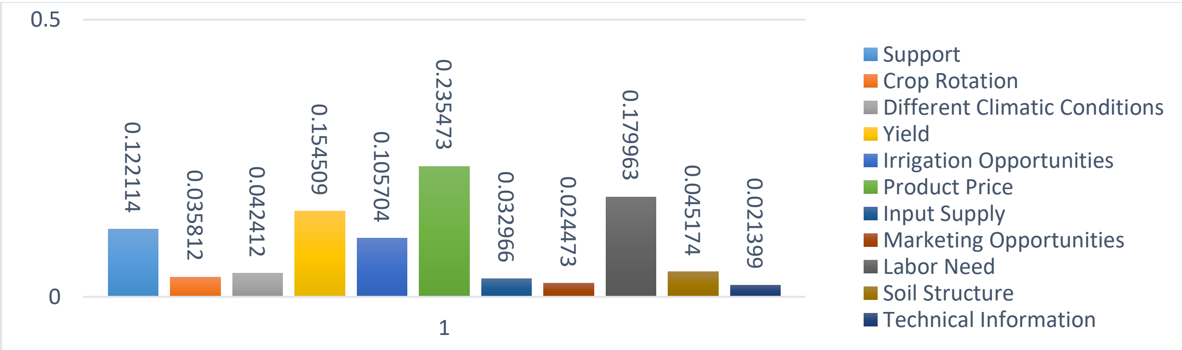

Figure 1. Importance Weights of Criteria and Ranking.

As seen in Figure 1, the importance weights of the 11 criteria are listed as follows: C6 > C9 > C4 > C1 > C5 > C10 > C3 > C2 > C7 > C8 > C11 The sum of the weights equals 1. This ranking indicates the relative importance of the criteria in the crop product selection process and which factors are prioritized by decision-makers.

Product Selection Ranking with FVIKOR Method

Step 1-3. In the FVIKOR procedure, the fuzzy decision matrix was constructed (Eq. 10), defuzzified (Eq. 11), and the best f_j^* and worst f_j^- values were determined (Eqs. 12–13).

Table 3. Defuzzified Decision Matrix and the Best–Worst Values by FVIKOR

	Crop Product Selection											
Criteria	Dry Onion	Safflower	Barley	Chickpeas	Canola	Oil Sunflower	Forage Crops.	Grain Corn	Wheat	Dry Bean	Lentil	Potato
C1	4.266	4.000	3.200	4.266	6.266	6.000	5.866	5.400	6.533	4.600	3.266	5.733
C2	6.400	5.800	3.800	5.733	3.933	4.800	4.600	5.800	3.666	4.733	4.866	5.400
C3	5.733	5.866	5.466	4.866	4.466	6.133	5.666	3.866	6.133	6.133	5.866	4.866
C4	4.533	4.266	4.600	5.800	4.044	5.000	5.000	6.133	6.200	4.666	4.530	5.866
C5	6.133	6.133	4.466	6.133	4.333	5.400	5.533	4.933	6.000	5.666	6.000	5.000
C6	3.466	3.466	6.400	4.800	3.466	4.733	4.533	5.600	4.800	4.266	4.266	5.400
C7	6.533	6.533	5.933	5.133	5.333	5.933	6.000	5.666	5.866	4.866	5.133	6.266
C8	6.666	6.666	6.200	4.333	4.200	5.733	5.600	5.733	3.600	3.733	4.000	6.266
C9	6.400	6.400	4.266	3.466	3.600	5.133	5.133	4.200	6.000	6.000	6.066	4.133
C10	4.866	4.066	6.400	6.133	6.466	4.000	4.133	6.066	5.000	4.266	4.533	6.266
C11	6.933	6.800	6.533	4.866	6.266	5.133	5.333	6.266	6.266	5.133	4.866	6.400
f_j^*	6.533	6.400	6.133	6.200	6.133	6.400	6.533	6.666	6.400	6.466	6.933	6.533
f_j^-	3.200	3.660	3.866	4.044	4.333	3.466	4.866	3.600	3.466	4.000	4.866	3.200

Step 4-5. Using the FAHP-derived criteria weights, the S_i, R_i and Q_i values were calculated (Eqs. 14–16), and the alternatives were ranked in ascending order, where the lowest Q_i value indicates the most suitable option.

Table 4. S_i, R_i and Q_i values..

			Q_i			
Crop Type	S_i	R_i	$q = 0.25$	$q = 0.5$	$q = 0.75$	Rank
Dry Onion	0.474	0.235	0.848	0.697	0.546	10
Safflower	0.525	0.235	0.873	0.745	0.618	11
Barley	0.533	0.131	0.144	0.264	0.386	5
Chickpea	0.526	0.179	0.444	0.487	0.491	8
Canola	0.791	0.235	1.000	1.000	1.000	12
Oil Sunflower	0.464	0.134	0.133	0.212	0.294	4
Forage Crops	0.484	0.149	0.253	0.306	0.359	6
Grain Corn	0.405	0.135	0.112	0.161	0.205	2
Wheat	0.268	0.128	0.000	0.000	0.000	1
Dry Bean	0.541	0.172	0.431	0.461	0.492	7
Lentil	0.569	0.171	0.485	0.488	0.533	9
Potato	0.393	0.139	0.132	0.169	0.211	3
	S^*= 0.268	R^*= 0.128				
	S^-= 0.791	R^-= 0.235				

In this study, rank reversal and sensitivity analysis are clearly distinguished. Rank reversal refers to changes in ranking positions due to variation in the set of alternatives, whereas sensitivity analysis examines the impact of parameter changes on ranking robustness. The VIKOR compromise parameter (0.25, 0.50, 0.75) was varied, and no change in ranking positions was observed.

Step 6. The stability conditions (Eqs. 17–18) were tested to validate the ranking, and the alternative with the minimum Q_i value satisfied both conditions.

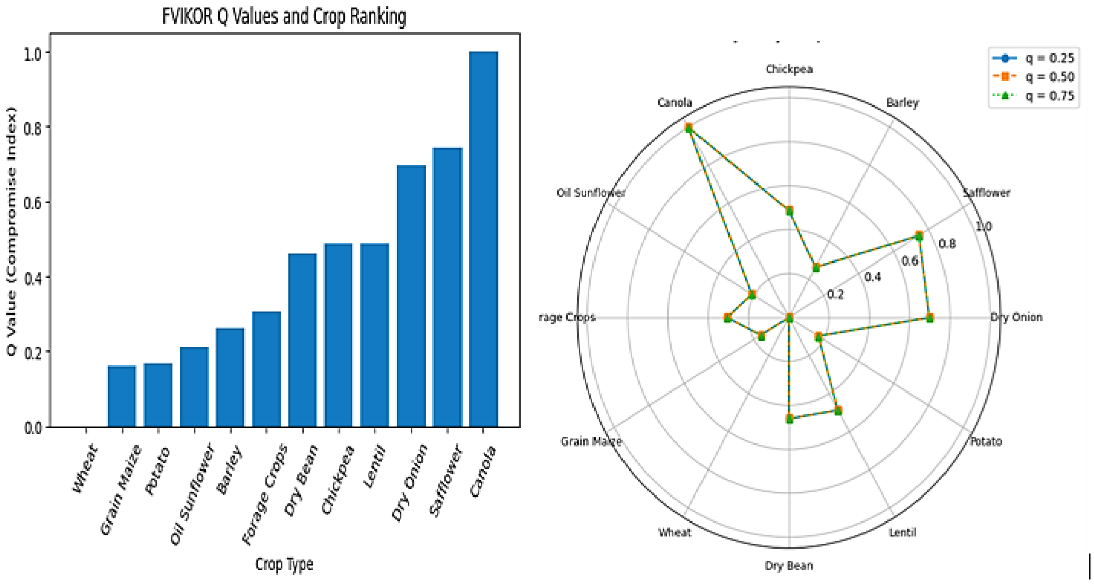

Figure 2. FVIKOR compromise ranking and sensitivity analysis under different *q* parameters.

According to the values obtained in Table 11, Wheat (0.00) ranks first as the most suitable product, followed by Grain Corn (0.161), Potato (0.169), Oil Sunflower (0.212), Barley (0.264), Forage Crops (0.306), Dry Beans (0.461), Chickpeas (0.487), Lentils (0.488), Onion (0.697), Safflower (0.745) and Canola (1.000). Wheat meets approximately 20% of the total calories provided by plant foods worldwide. In Türkiye, this ratio is at the level of 53% (MAF, 2024).

This finding is consistent with various studies in the literature. Sarı and Sarı (2021) in Konya Province, Jamil et al. (2018) in India, Debalke et al. (2023) in Ethiopia, and Cobuloğlu and Büyüktahtakın (2015) emphasized that wheat and corn are preferred over other options in the selection of biomass-based products.

On the other hand, some studies have reported different results. Pant et al. (2021) identified potatoes as the most suitable crop in India, Qureshi et al. (2018) spices, Ali and Khan (2022) tobacco in Pakistan, Sathiyamurthi et al. (2024) maize, peanuts, and pomegranates, Sudha and

Jeba (2015) black lentils, and Gowtham et al. (2023) maize. These differences may be due to changes in the criteria used in the studies, geographical and climatic conditions, agricultural policies and data sets. Elevated wheat prices and temporary import declines may have shaped period-specific preferences.

In this context, the identified high-importance criteria appear to influence producer decisions. High input costs, the need for foreign labor, and drought and water shortages caused by global warming have been observed to force businesses to select certain products. Beyond simply presenting product selection and the criteria that influence this selection, the study will also inform decision-makers in determining production planning, support strategies, and rural development policies.

Notwithstanding the comparatively low ranking of support criteria, in the new system of planned production, which stresses support elements, the rising prices of wheat seem to be compensated to a great extent by the sharp rise in input prices, especially fertilizer, fuel, and energy prices. Thus, the producers appear to give more importance to market forces than policy support. Moreover, the continued preponderance of wheat in water-scarce environments, if diversification is not substantial, may raise economic and environmental risks.

In addition to merely offering information on product choices and the factors that affect such choices, the study will also help decision-makers in planning production, support, and rural development.

In terms of policy implementation, the results indicate that the new planned production system should not only be a regulatory mechanism but also an incentive system that can adjust to changing circumstances. For instance, subsidies could be differentiated based on regional water availability, crop water efficiency, and sustainability. **Taking into account the intensity of water use in formulas for subsidies could improve the steering role of the planning system.**

Conclusions

The growing population of the world and the limited availability of land for agricultural production have made the critical role of food accessibility more apparent every year. However, the growing effects of climate change, pandemics, and economic downturns are adding pressure to the sustainability of agricultural production. In this regard, many nations are formulating new strategies in agricultural production, as well as in food stock management.

Following a shift to a new planning approach in Turkish agriculture, this research aimed to examine crop selection and the relative importance of the criteria influencing this selection.

Wheat was identified as the most suitable crop for the region (0.000%). The strategic value of wheat, its compatibility with climate and soil, its marketing potential, and its technical expertise support this finding.

The most important factor influencing product selection is the price of the product. This is followed, in order, by labor requirements, yield, subsidies, irrigation opportunities, soil structure, climate conditions, crop rotation, input availability, marketing opportunities, and technical knowledge.The increasing elderly population in agriculture and dependence on foreign labor increase production costs and thus affect product selection. Therefore, the government should design programs to encourage young people to participate in agriculture.

Under the new planned production system, rotational cropping became obligatory, and support payments were redesigned. However, support came fourth in the criteria, reflecting limited steering power. Thus, nationally uniform support schemes should be abandoned in favor of regionalized schemes that fit local agro-ecological conditions. In arid regions like Konya, where water is scarce, incentives for low water-demand and key crops should take priority. Environmental indicators such as water-use efficiency, carbon emissions, and regional resource constraints should be integrated into the support formula.

Future studies may extend the framework through comparative regional analyses and the integration ofenvironmental indicators such as water footprint and carbon emissions. Developing data-driven decision support systems that incorporate market data, climate projections, and resource availability could enhance adaptive production planning. Additionally, advanced MCDM approaches, including Pythagorean based methods, may improve methodological robustness and deepen insight into the relationship between producer preferences and policy priorities.

REFERENCES

1. Ali, I. and Khan, N. 2022. Evaluating the impact of climate change on the agriculture sector of Pakistan using Multi Criteria Decision Making (MCDM). *Natural and Applied Sciences International Journal, 3*(**2**), 72–84.
2. Alipour, A., Mosavi, S. H., Khalilian, S., and Mortazavi, S. A. 2020. Land use and agricultural support policies: evidence from Iran’s Irrigated Wheat planting. Journal of Agricultural Science and Technology, **22(1),** 13-26.
3. Buckley, J. J. 1985. Fuzzy hierarchical analysis. *Fuzzy Sets and Systems, 17*(**3**), 233–247.

4. Chang, D. Y. 1996. Applications of the extent analysis method on fuzzy AHP. *European Journal of Operational Research,* ***95*****(3),** 649–655.

5. Cobuloğlu, H. I. and Büyüktahtakın, İ. E. 2015. A stochastic MCDM for sustainable biomass crop selection. *Expert Systems with Applications,* ***42*****(15–16),** 6065–6074.

6. Dağdeviren, M. 2007. Bulanık AHP ile personel seçimi ve bir uygulama. *Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi,* ***22*****(4).**

7. Debalke, D. B., Mengistu, D. A. and Admas, T. E. 2023. Physical land suitability evaluation of rainfed crop production of wheat, barley, and teff in Arsi zone of Ethiopia. *Arabian Journal of Geosciences,* ***16*****(3),** 177.

8. Deepa, N. and Ganesan, K. 2018. Multi-class classification using hybrid soft decision model for agriculture crop selection. *Neural Computing and Applications,* ***30*****,** 1025–1038.

9. Deng, H. 1999. Multicriteria analysis with fuzzy pairwise comparison. *International Journal of Approximate Reasoning,* ***21*****(3),** 215–231.

10. Dokuzlu, S., Pons, J. C., Vandecandelaere, E., Roggia, M., Ricci, M., Erdal, B., Gueye, M., 2020. Food and agricultural product pilot selection for geographical indication projects.

11. EUCRA(European Environment Agency). 2024. European Climate Risk Assessment. https://www.eea.europa.eu/en/analysis/publications/european-climate-risk-assessment (Accessed: 10 May 2025).

12. FAO, 2023. The State of Food and Agriculture 2023 – Revealing the true cost of food to transform agrifood systems. Rome. https://doi.org/10.4060/cc7724en.

13. Gaytancıoğlu, O. and Yılmaz, F. 2024. Agricultural Decision-Making Concerning Crop Selection Using Analytic Hierarchy Process (AHP) in Trakya Region of Türkiye.

14. Gowtham, S., Vedanth, S., Kodipalli, A., Rohini, B. R., Gargi, N. and Soma, B. 2023. Intelligent Crop Selection for Maximizing Agricultural Productivity: A Fuzzy TOPSIS Perspective. *ICRASET.* 1–5.

15. Gunawan, M. I., Sitopu, J. W., Sechan, G. and Gunawan, I. 2024. Optimizing crop selection: A MCDM for sustainable agriculture. *International Journal of Enterprise Modelling,* ***18*****(3),** 113–123.

16. Haloui, D., Oufaska, K., Oudani, M., Yassini, K. E., Belhadi, A. and Kamble, S. 2025. Sustainable urban farming via multi-objective MCDM. *International Transactions in Operational Research, **32***(**2**)**,** 769–801.
17. Jamil, M., Sahana, M. and Sajjad, H. 2018. Crop suitability in Bijnor, UP via AHP. *Agricultural Research, 7*(**4**)**,** 506–522.
18. Ministry of Agriculture and Forestry [MAF], 2024. Buğday Tarımı. https://arastirma.tarimorman.gov.tr/ktae/Belgeler/brosurler/Bu%C4%9Fday%20Tar%C4%B1m%C4%B1.pdf. (Accessed: 24 April 2025).
19. Mishra, A. R., Rani, P. and Bharti, S. 2021. Assessment of agriculture crop selection using Pythagorean fuzzy CRITIC–VIKOR decision-making framework. *Pythagorean fuzzy sets: Theory and applications* .167–191.
20. Newbold, P., 1995. Statistics for Business & Economics. Fourth Edition, Prentice-HallJ.J. Buckley, Fuzzy hierarchical analysis, Fuzzy Sets and Systems **17**, 233–247.
21. Opricovic, S. 1998. *Multicriteria optimization of civil engineering system*. Faculty of Civil Engineering, Belgrade.
22. Opricovic, S. 2011. Fuzzy VIKOR for water resources planning. *Expert Systems with Applications, **38***(**10**)**,** 12983–12990.
23. Opricovic, S. and Tzeng, G. H. 2004. Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European Journal of Operational Research, 156*(2), 445–455.
24. Opricovic, S. and Tzeng, G.H. 2007. Extended VIKOR method in comparison with outrank-ing methods. *European Journal of Operational Research,* **178(2),** 514–529. https://doi.org/10.1016/j.ejor.2006.01.020.
25. Pant, J., Pant, R. P., Singh, M. K., Singh, D. P. and Pant, H. 2021. Analysis of agricultural crop yield prediction using statistical techniques of machine learning. *Materials Today: Proceedings*, **46,** 10922-10926.
26. Prakash, T. N. 2003. Land suitability analysis for agricultural crops: a fuzzy multicriteria decision making approach. ITC.
27. Qureshi, M. R. N., Singh, R. K. and Hasan, M. A. 2018. Decision support model to select crop pattern for sustainable agricultural practices using fuzzy MCDM. *Environment, Development and Sustainability, 20*, 641–659.
28. Ragot, M., Bonierbale, M., Weltzien, E. 2018. From market demand to breeding decisions: a framework. CGIAR gender and breeding initiative working paper, 2.

29. Rose, A., Chen, Z., and Wei, D. 2023. The economic impacts of Russia–Ukraine War export disruptions of grain commodities. Applied Economic Perspectives and Policy, 45(2), 645-665.
30. Saaty, T. L. 1980. *The analytic hierarchy process*. McGraw-Hill.
31. Sarı, F. and Koyuncu, F. 2021. Multi criteria decision analysis to determine the suitability of agricultural crops for land consolidation areas. International Journal of Engineering and Geosciences, **6(2),** 64-73.
32. Sathiyamurthi, S., Sivasakthi, M., Saravanan, S., Gobi, R. and Karuppannan, S. 2024. Assessment of crop suitability analysis using AHP-TOPSIS and geospatial techniques: A case study of Krishnagiri District, India. *Environmental and Sustainability Indicators,* **24,** 100466.
33. Sudha, A. S. and Jeba, J. R. I. 2015. Crop selection via fuzzy TOPSIS with entropy weights. *International Journal of Computer Applications, **124***(**14).**
34. TurkStat. 2024. *Bitkisel üretim istatistikleri*. https://www.tuik.gov.tr(Accessed: 30 April 2025).
35. UNDP. 2021. *COVID-19 rapid impact assessment in Türkiye's agriculture-food sector*. https://www.undp.org.
36. Van Laarhoven, P. J. and Pedrycz, W. 1983. A fuzzy extension of Saaty's priority theory. *Fuzzy Sets and Systems, **11***(**1–3),** 229–241.
37. Wang, L., Langari, R., Yen, J., 1999. Identifying fuzzy rule-based models using orthogonal transformation and backpropagation. In Fuzzy Theory Systems, Academic Press. 187-204.
38. Zadeh, L. A. 1965. Fuzzy sets. *Information and Control, **8***(**3),** 338–353.
39. Zhu, K. J., Jing, Y. and Chang, D. Y. 1999. A discussion on extent analysis method and applications of fuzzy AHP. *European journal of operational research*, ***116***(**2),** 450-456.