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ENHANCING AGRICULTURAL DECISION- MAKING: A TOPSIS- BASED FRAMEWORK FOR CROP SELECTION

Abstract: Multi-Criteria Decision-Making (*MCDM*) is a widely used approach for solving complex decision-making problems. With the help of advanced computational tools, these methods can now be applied efficiently across various fields, including medical sciences, marketing, engineering, and agriculture. *MCDM* methods enable quick problem-solving and detailed analysis to identify optimal solutions. This study focuses on one such method, the *TOPSIS* (Technique for Order Preference by Similarity to Ideal Solution), and explores its theoretical foundations and practical applications in agriculture. Specifically, the research demonstrates how *TOPSIS* can be used to select the most suitable field crop.
Five crops—wheat, corn, sunflower, soybean, and sugar beet—were evaluated and ranked using six key criteria: yield per hectare (in tons), purchase price per kilogram (in dinars), production costs (in dinars per hectare), total domestic consumption (in thousands of tons), exports (in thousands of tons), and adaptability to climatic conditions (drought, frost, floods). The selected crops are widely cultivated in Serbia, making them relevant to the local agricultural context. The criteria were chosen to cover a range of factors, including market dynamics, production efficiency, and economic viability. Using the *TOPSIS* method, the relative closeness of each crop to the ideal solution was calculated. The results showed that corn performed the best, being closest to the ideal solution, followed by sugar beet in second place and soybean in third. Wheat ranked fourth, while sunflower was identified as the least suitable crop under the given conditions.
The *TOPSIS* method provides a systematic way to identify efficient and cost-effective alternatives, making it a useful tool for decision-making in agriculture. This study highlights its potential benefits, such as saving time, reducing costs, and improving energy efficiency, which can be valuable for farmers, managers, agronomists, and other agricultural professionals.

Keywords: Multi-Criteria Decision-Making (MCDM), Agriculture, Crop selection.

1. INTRODUCTION

Decision-making is a process that involves a series of steps and initiatives through which individuals—whether scientists, business professionals, or employees—consciously and actively influence their environment. Decisions can range from choices that primarily impact an individual's personal sphere, such as selecting a vacation destination or

choosing a university, to strategic decisions that affect entire societies and systems, such as determining a target country for exports.
This complexity has led to the need for a systematic approach to decision-making and the development of theoretical frameworks that provide scientific support for this process. Multi-criteria decision-making (MCDM) is a structured method used to identify the most suitable option among a set of alternatives while considering relevant criteria. Due to its universal applicability, MCDM is widely used across various disciplines, making it a valuable tool in diverse research contexts.

2. THEORETICAL BACKGROUND

The terms decision-making and decision are used daily in all aspects of human life. Decision theory is a distinct scientific discipline that has been developing for approximately fifty years. It focuses on defining these concepts and providing support in making optimal decisions.
According to decision theory, decision-making is a process in which the most appropriate solution to a given problem is selected from a set of possible alternatives. The entirety of available alternatives is referred to as a strategy. A decision is defined as the final outcome of the decision-making process and is made to achieve specific objectives set within the given problem context (Čupić, 1987).
Decision theory can be divided into two main approaches. The first approach focuses on improving decision-making by assisting decision-makers in establishing rules and criteria within the decision-making process. This is known as normative decision theory, which emphasizes the question of how decisions should be made.
The second approach is referred to as descriptive decision theory, which examines the actual process of decision-making, analyzing how decisions are made in practice (Suhonen, 2007).
In the decision-making process, mathematical models and optimization methods play a crucial role. A mathematical model is a set of mathematical relationships that define the connections between various physical quantities within a given process (Milinković, 2014). Optimization methods are closely linked to mathematical models, as they facilitate the selection of the best solution from a set of possible alternatives in accordance with predefined objectives.
Formally speaking, optimization involves determining the extrema—either the minimum or maximum—of an objective function using various methods, depending on the types of relationships present within the mathematical model (Kovačić, 2004).
Multi-criteria decision-making (MCDM) has a relatively short history. The foundations of modern MCDM were established in the 1950s and 1960s (Zavadskas, Turskis, & Kildiene, 2014), with significant growth in the field observed since the 1980s (Dyer, Fishburn, Steuer, Wallenius, & Zionts, 1992). MCDM encompasses situations in which a decision-maker must choose one alternative from a set of options, each evaluated based on multiple criteria. It is particularly relevant in cases where multiple criteria—often conflicting—must be considered simultaneously.
This complexity highlights the necessity of various MCDM methods designed to address different types of decision-making problems. MCDM represents one of the most important areas of decision theory, widely applied in solving real-world problems (Bobar, 2014). On the other hand, multi-criteria analysis methods serve as mathematical tools that support decision-makers involved in complex problem-solving processes. These methods are based on scientific principles that enable an efficient selection of the optimal solution.
Since the 1960s, numerous MCDM methods have been developed (Kovačić, 2004). One such method, applied in this study, is the TOPSIS method.

3. METHODOLOGY

The TOPSIS method (*Technique for Order Preference by Similarity to Ideal Solution*) is based on defining an ideal and an anti-ideal solution. The core principle of this method is that the selected alternative should have the shortest distance from the ideal solution and the longest distance from the anti-ideal solution.
The optimal alternative is defined as the one that is geographically closest to the ideal solution while being farthest from the anti-ideal solution. The ranking of alternatives is determined based on their relative similarity to the ideal solution, which prevents situations where an alternative is simultaneously similar to both the ideal and anti-ideal solutions (Chang, Lin, Linc, & Chiang, 2010) .
The **TOPSIS** method consists of six steps:

1. Normalization of the decision matrix $[x_{ij}]_{mxn}$ to obtain the normalized matrix $R=[r_{ij}]_{mxn}$

In the decision matrix, many values x_{ij} have different metrics; therefore, the first step is to normalize the elements to obtain normalized values r_{ij} based on the following relation: .

$$r_{ij} = x_{ij} \,/\, \sqrt{\sum_{i=1}^{m} x_{ij}^2}$$

$i=1,2,\ \dots\ , m;\ j=1,2,\ \dots\ , n$

The normalized matrix in this case contains only dimensionless values.

2. Multiplication of the normalized matrix by weight coefficients

The weighted normalized values v_{ij} are obtained using the following relation:

$$v_{ij}= w_j \cdot r_{ij};\ i = 1, \dots, m, j = 1, \dots, n.$$

In this relation, w_j represents the weight of the j-th criterion, which must be normalized, meaning the following equality holds:

$$\sum_{j=1}^{n} w_j = 1.$$

The weight of a criterion represents a positive number that is independent of the unit of measurement for a given criterion. A higher weight value indicates that the decision-maker assigns greater importance to that particular criterion.

3. Determination of ideal solutions

The ideal solution and the anti-ideal solution are calculated using the following relations:

$$A^{+} = \{(\max v_{ij} \mid j \in J^{max}), (\min v_{ij} \mid j \in J^{min})\} = \{v_1^{+}, v_2^{+}, \dots, v_n^{+}\}$$
$$A^{-} = \{(\min v_{ij} \mid j \in J^{max}), (\max v_{ij} \mid j \in J^{min})\} = \{v_1^{-}, v_2^{-}, \dots, v_n^{-}\} \qquad i=1,2,\ \dots\ , m.$$

J^{max} is associated with revenue-related criteria that are maximized, while J^{min} corresponds to cost-related criteria that are minimized.
The best alternatives are those with the highest v_{ij} values for criteria that are maximized and the lowestv_{ij} values for criteria that are minimized.

4. Determining the distance of alternatives from ideal solutions

The next step involves calculating the distance of all alternatives from both the ideal and anti-ideal solutions. The distances S_i^{+} from the ideal solution and S_i^{-} from the anti-ideal solution are determined using the following relations:

$$S_i^{+} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^{+})^2} \quad ;$$

$$S_i^{-} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^{-})^2}$$

$i=1,2,\ \dots\ , m.$

5. Determining the relative closeness of alternatives to the ideal solution

For each alternative, *the relative distance* to the ideal solution is calculated:

$$RC_1 = \frac{S_i^{-}}{S_i^{+} + S_i^{-}}\ , 0 \le RC_1 \le 1, i = 1,2, \dots\ , m.$$

An alternative is considered closer to the ideal solution RC_1 if its value is closer to 1, or farther if it is S_i^{+}closer to 0.

6. Ranking alternatives in descending order (Srđević B., Srđević Z., & Zoranović, 2002).

4. RESULTS AND DISCUSSION

The selection of crops for planting is a complex and challenging task. Analyzing factors that affect quality, growth rate, and market price fluctuations is of crucial importance. In this section of the paper, we will study the selected criteria from the groups of market, production, and socio-economic indicators for arable crops (wheat, corn, sunflower, soybean, sugar beet) using the TOPSIS method. The aim is to identify the most suitable crop based on multi-criteria analysis. The TOPSIS method allows for ranking alternatives based on their proximity to the ideal solution and distance from the anti-ideal solution, which is particularly useful in complex decision-making processes.
The following section presents an initial table with the selected crops and criteria for selection. The table includes both quantitative and qualitative data, which will serve as the foundation for applying the given method.

Table 1: Initial data for applying the TOPSIS method

Crop Type	Yield per Hectare (tons)	Purchase Price per Kilogram (in dinars)	Production Costs (in dinars per hectare)	Total Domestic Consumption (in thousands of tons)	Exports (in thousands of tons)	Adaptability to Climatic Conditions (drought, frost, floods)
Wheat	5.1	20.74	105.725	1822	1020	Satisfactory
Corn	7.2	17.47	576	4 130	544	Poor
Sunflower	2.9	35.37	101.855	586	80	Satisfactory
Soybean	2.8	49.84	125.141	550	5	Poor
Sugar beet	49.0	6.07	194.954	250	52	Satisfactory

Source: Statistical office of the Republic of Serbia, 2023;
Ministry of Agriculture, Forestry, and Water Management, 2022/23;
Jeločnik, M., Subić, J., & Nastić L. (2021)

The first step is to define the criteria for selecting the crop to plant. Table 2 shows the criteria and their description:

Table 2: Defining the criteria

Criteria (Labels)	Description
C1	Yield per Hectare (tons)
C2	Purchase Price per Kilogram (in dinars)
C3	Production Costs (in dinars per hectare)
C4	Total Domestic Consumption (in thousands of tons)
C5	Exports (in thousands of tons)

Source: Author's Own Calculation

The next step is to transform the initial data into quantitative indicators on a scale from 1 to 5. The decision matrix is formed based on the initial data presented in Table 3:

Table 3: Filled decision matrix in the TOPSIS method

Crop Type	Yield per Hectare (tons)	Purchase Price per Kilogram (in dinars)	Production Costs (in dinars per hectare)	Total Domestic Consumption (in thousands of tons)	Exports (in thousands of tons)	Adaptability to Climatic Conditions (drought, frost, floods)
Wheat	3	4	2	4	5	3
Corn	4	3	5	5	5	2
Sunflower	2	5	2	2	2	3
Soybean	2	5	4	2	1	2
Sugar beet	5	1	5	1	2	3

Source: Author's Own Calculation

Next, the weights (averages) for each criterion are determined (see Table 4).

Table 4: Presentation of criterion weights

Criteria	Weight
C1	0.2
C2	0.2
C3	0.3
C4	0.05
C5	0.1
C6	0.15

Source: Author's Own Calculation

1. Normalization of the decision matrix $[x_{ij}]_{mxn}$ to obtain the normalized matrix $R=[r_{ij}]_{mxn}$

The first step is to normalize the elements to obtain the normalized values r_{ij} based on the following relation:

$$r_{ij} = x_{ij} \Big/ \sqrt{\sum_{i=1}^{m} x_{ij}^2}$$

Table 5: Normalized decision matrix

	C1	C2	C3	C4	C5	C6
A1	0.39	0.46	0.23	0.57	0.65	0.51
A2	0.52	0.34	0.58	0.71	0.65	0.34
A3	0.26	0.57	0.23	0.28	0.26	0.51
A4	0.26	0.57	0.47	0.28	0.13	0.34
A5	0.66	0.11	0.58	0.14	0.26	0.51

Source: Author's Own Calculation

2. Multiplication of the normalized matrix by weight coefficients

The weighted normalized values v_{ij} are obtained using the following relation:

$$v_{ij} = w_j \cdot r_{ij};\ i = 1, ..., m, j = 1, ..., n.$$

Table 6: Weighted normalized decision matrix

	C1	C2	C3	C4	C5	C6
A1	0.078	0.092	0.069	0.0285	0.065	0.0765
A2	0.104	0.068	0.174	0.0355	0.065	0.051
A3	0.052	0.114	0.069	0.014	0.026	0.0765
A4	0.052	0.114	0.141	0.014	0.013	0.051
A5	0.132	0.022	0.174	0.007	0.026	0.0765

Source: Author's Own Calculation

3. Determination of ideal solutions A+ and anti-ideal solution A-

The ideal solutions are determined based on the following table:

Table 7: Ideal solutions

Ideal solution	Calculation
A^+	max ($v_{11}, v_{21}, v_{31}, v_{41}, v_{51}$)
A^+	max ($v_{12}, v_{22}, v_{32}, v_{42}, v_{52}$)
A^+	max($v_{13}, v_{23}, v_{33}, v_{43}, v_{53}$)
A^+	max ($v_{14}, v_{24}, v_{34}, v_{44}, v_{54}$)
A^+	max($v_{15}, v_{25}, v_{35}, v_{45}, v_{55}$)
A^+	max($v_{16}, v_{26}, v_{36}, v_{46}, v_{56}$)

Source: Author's Own Calculation

Table 8: Values of the ideal solutions

Ideal solution	Values
A^+	$V_1^+=0.132$
A^+	$V_2^+=0.114$
A^+	$V_3^+=0.174$
A^+	$V_4^+=0.0355$
A^+	$V_5^+=0.065$
A^+	$V_6^+=0.0765$

Source: Author's Own Calculation

Table 9: Anti-ideal solutions

Ideal solution	Calculation
A^-	$\min(v_{11}, v_{21}, v_{31}, v_{41}, v_{51})$
A^-	$\min(v_{12}, v_{22}, v_{32}, v_{42}, v_{52})$
A^-	$\min(v_{13}, v_{23}, v_{33}, v_{43}, v_{53})$
A^-	$\min(v_{14}, v_{24}, v_{34}, v_{44}, v_{54})$
A^-	$\min(v_{15}, v_{25}, v_{35}, v_{45}, v_{55})$
A^-	$\min(v_{16}, v_{26}, v_{36}, v_{46}, v_{56})$

Source: Author's Own Calculation

Table 10: Values of the anti-ideal solutions

Ideal solution	Values
A^-	$V_1^-=0.052$
A^-	$V_2^-=0.022$
A^-	$V_3^-=0.069$
A^-	$V_4^-=0.007$
A^-	$V_5^-=0.013$
A^-	$V_6^-=0.051$

Source: Author's Own Calculation

4. Calculation of the distance of all alternatives from the ideal and anti-ideal solutions

The distance S_i^+ from the ideal solution is determined as follows:

$$S_i^+=\sqrt{\sum_{j=1}^{6}(v_{ij}-V_j^+)^2},\ i=1,\ldots,5.$$

Table 11: Distances of the ideal solution

Alternative	S^+
Wheat	0.12
Corn	0.06
Sunflower	0.14
Soybean	0.11
Sugar beet	0.10

Source: Author's Own Calculation

The distance S_i^- from the anti-ideal solution is determined as follows:

$$S_i^-=\sqrt{\sum_{j=1}^{6}(v_{ij}-V_j^-)^2},i=1,\ldots,5.$$

Table 12: Distances of the anti-ideal solution

Alternative	S^-
Wheat	0.10
Corn	0.14
Sunflower	0.10
Soybean	0.12
Sugar beet	0.14

Source: Author's Own Calculation

5. Determining the relative closeness of alternatives to the ideal solution

For each alternative, the relative distance to the ideal solution is calculated:

$$RC_1 = \frac{S_i^-}{S_i^+ + S_i^-}, 0 \leq RC_1 \leq 1, i = 1,2, \dots, m.$$

Table 13: Presentation of the relative closeness of each alternative to the ideal solution

Alternative	RC
Wheat	0.45
Corn	0.70
Sunflower	0.42
Soybean	0.52
Sugar beet	0.58

Source: Author's Own Calculation

6. Ranking of alternatives using the TOPSIS method

Based on the calculated values of the relative closeness of alternatives to the ideal solution, the best alternative can be determined. The alternatives are ranked in Table 14:

Table 14: Ranking of alternatives-cereal crops

Alternative	RC	Rank
Corn	0.70	1
Sugar beet	0.58	2
Soybean	0.52	3
Wheat	0.45	4
Sunflower	0.42	5

Source: Author's Own Calculation

Based on the presented table and the performed analysis, the best result was achieved by corn, which is closest to the ideal solution, followed by sugar beet in second place, and soybean in third. Wheat ranked fourth, while sunflower emerged as the least suitable crop to plant.

4. CONCLUSION

Multi-criteria decision-making (MCDM) is a complex process with diverse applications across all sectors of human activity. One of its most significant areas of application is the agricultural sector, as all stakeholders involved in agricultural production systems must make various complex decisions on a daily basis.
By utilizing the TOPSIS method within MCDM, it is possible to determine the most efficient and most profitable solution, that is, the most suitable alternative. This approach serves as a powerful tool that enables farmers, managers, agronomists, and other professionals in the agricultural sector to optimize their decision-making process, saving time, money, and energy.
The analysis revealed that corn ranked as the most efficient and profitable option. This finding further reinforces the importance of corn as a key agricultural commodity, both in terms of economic return and adaptability to market conditions.
Some of the future research directions could include additional criteria such as environmental sustainability, irrigation system efficiency, and the use of artificial fertilizers. This would enable a more comprehensive and suitable analysis. Furthermore, emphasis could be placed on examining the efficiency of corn cultivation relative to soil type. This would focus on the conditions in which corn thrives best, the feasibility of achieving those conditions in our country's territory, and the proposal of the most optimal solutions.

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