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ENHANCING FRUIT ORCHARD ESTABLISHMENT: A MULTICRITERIA APPROACH FOR PLUM VARIETY SELECTION

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Abstract: This research is focused to identifying the most suitable plum variety for establishing a new orchard, aiming to achieve optimal outcomes. To accomplish this goal, multi-criteria decision-making model has been developed striving to support decision-making process. The gained results are based on experience of experts engaged in assessment of certain plum varieties. The analysis of collected expert ratings has involved mutual use of 3 methods, where the FUll COnsistency Method (FUCOM) and CRiteria Importance Through Intercriteria Correlation (CRITIC) methods were applied to determine the weights of selected criteria. The results of applying these methods demonstrated that the Maretability criterion is of highest importance. Besides, the fuzzy MARCOS method (Measurement Alternatives and Ranking according to Compromise Solution) has been applied to rank the plum varieties according to expert ratings. Derived results revealed that the "Čačanska rodna" and "Stanley" varieties were ranked as the most favorable, while the "Prezident" variety was assessed as the most unfavorable. Further, gained research outcomes were corroborated by the sensitivity analysis and results validation. This research contributes to improvement of fruit growing in BiH by previous adequate selection of available plum varieties towards the establishing of new orchards and yielding optimal outcomes.

Keywords: Plums, decision-making model, MARCOS, FUCOM, CRITIC.

MSC: 08A72, 68U35, 90B50, 91B06.

1. INTRODUCTION

Plums belong to the group of drupe fruits [1] and they are globally considered as one of the most significant table fruit species [2]. Plum fruits are well-suited to temperate climates, while it is usually extensively cultivated worldwide [3]. Plums can be consumed fresh or processed (at farms or in processing industry) as brandy, jam or marmalade, dried plums, juices, part of various confectioners, etc. [4-5]. In terms of stone fruit production, plums are globally ranked as second [6]. European plum (Prunus domestica) and Japanese plum (Prunus salicina) are the most notable plum cultivars. First one is commercially grown worldwide for diverse purposes, i.e. production of various products [7], but the most often for the production of alcoholic plum beverage known as "Rakija" or "Šljivovica" [8]. Moreover, the European plum is a vital component of the human diet, offering health benefits such as protection against cardiovascular disease, diabetes, digestive disorders, osteoporosis, etc. [9-10]. Consequently, the plum holds significant importance in the realm of fruit growing.

According to size, plum could grow as the bush or even to 10 m high three [11]. The European plum tree can yield for a period of 30-50 years, or in certain cases even longer [12]. It fits to low maintenance requirements and appliance of modest agro-technics, causing the wide presence in orchards worldwide [4]. Plums have a diverse range of tastes, aroma, texture, colors, size, and other characteristics, contributing to their higher desirability compared to other fruit species [3]. In the Western Balkans, the European plum is considered the leading fruit species [13], usually holding the status of a national fruit (e.g. in BiH, Serbia, Croatia, etc.). While Yugoslavia was one of the biggest producers of European plums at global level in previous century, the plum has gradually lost its significance over the time in ex-Yu countries [12]. One of the factors that have been affecting the decrease in growing areas is plum disease known as Šarka [14-15]. As a result, fruit growers in Western Balkans have turned to cultivation of alternative fruit species. However, in recent time there comes to revival in plum production in mentioned area [16]. Hence, it is crucial to select appropriate plum variety to improve yielding and profitability in plum production.

BiH has extraordinary geographical and climate conditions required for successful plum growing [12], offering the certain level of comparative advantages over the EU countries. According to production area, number of trees, or production volume, plums are the most grown fruit species in BiH [17-18]. Due to huge versatility, resilience, importance, use value and further profitability, plums could represent the highly suitable production alternative for individual agricultural producers, especially small-scale farmers [13-19]. Although the occurred self-sufficiency in plums (as fresh or processed), producers in BiH have been introducing the changes in applied varieties, production technology and used agro-technics, especially encouraging the small producers to enlarge the part of production directed to the market, specifically this that include added value plum products [20]. Besides, considering the constantly increasing regional and global demand for plums, there is a need to expand production areas and volume, thereby enhancing its economic significance [3].

During the variety selection, essential thing is to examine all aspects and implications, making a decision that overlaps the predefined investment goals [16]. In general, the primary objective of investing in new orchard is profitability [21]. Therefore, when choosing an optimal variety for orchard establishment, it has to be synthesized diverse data, while assessed all aspects of planed investment. All in all, selection of appropriate fruit variety stands as the most significant decision in investment process in new plantation establishment [13], as choosing the unsuitable variety will not yield the expected profitability (plantation sustainability is linked to variety that will yield the highest long-term outcomes). Besides, when selecting optimal variety, considerations should go beyond pure profitability, i.e. it has to encompass climate adaptability, level of productivity, fruit quality, potential towards storing and processing, disease resistance, extension in maturity range, etc. [22].

The research in this paper focuses on the wide variety of plum cultivars, and selecting the plum variety that yields the best results is pivotal for investing in new plum plantations. Given the large data quantity, fruit growers strive to summarize and accurately delineate the essential requirements linked to certain variety success [23]. This research tries to identify plum variety that will secure the best production results for fruit growers in BiH after establishing a new orchard. Consequently, the research's objective is to assess plum varieties using expert opinions and multi-criteria analysis methods, and to provide recommendations on which plum variety fruit growers should cultivate to maximize orchard productivity. Therefore, the primary motivation behind this research is to minimize the risks when initiating new orchards, as variety selection is paramount in this endeavor. In practice, selection of adequate variety does not rely just on single criteria, but on predefined group of multiple criteria. Complexity of considering multiple criteria in decision-making process requires application of certain multi-criteria analysis (MCDA) methods [24-27]. These methods are used in evaluation of various available alternatives based on different criteria [28].

Therefore, this paper presents a model designed to assist fruit growers in selecting the plum variety that will yield the best production results after establishment of new orchard. The model engages a group expert decision-making approach, whereby invited specialists assess different plum varieties based on their experiences to predefined criteria. The evaluations are implying the linguistic values, forcing the application of fuzzy methods. Fuzzy approaches align more closely with human reasoning, especially in situations where precise values determination is to challenging. To apply fuzzy methods, linguistic values are shifted to fuzzy numbers using membership functions.

This paper contributes the following:

- The research methodology offers a straightforward solution towards investment issues by applying multi-criteria analysis methods.
- A novel evaluation model for plum varieties selection, specifically for new orchards establishment has been developed.
- Various multi-criteria analysis methods, encompassing both objective and subjective assessment of criteria and alternatives, have been integrated into a unified framework.
- Proposed model and methodology support clear, concise and quick decision-making process for the fruit growing sector.

Besides introduction, paper involves six additional subheadings. The second subheading introduces a unique research methodology, explaining the model used in this study, i.e. applied fuzzy methods. The third section defines elements of practical example. The fourth subheading presents the research results derived from the use of fuzzy methods. The fifth section covers the verification of derived research results, as well as the application of sensitivity analysis. Next, the sixth, subheading discusses the main findings in conducted research. Finally, the seventh section considers conclusions based on the most significant research results, while provides guidelines for some future researches.

2. LITERATURE REVIEW

Orchard (fruit plantation) establishment should be observed as investment [29-30]. Initial financial assets, i.e. investment, is required in moment of fruit plantation establishment, with expectation of achieving high and profitable yields in upcoming future, or rapid return on invested financial assets [31]. However, the main challenges in plum production include noticeable variations in applied growing techniques and used agro-technics, oscillations in gained yields or fruit quality, use of numerous varieties, occurrence of Plum pox virus, etc. [32-33], as well as usual absence of added value, weak marketing, frequent market instability, both national or international, etc. [34]. Therefore, a thorough understanding of suitable fruit varieties for planting is crucial, as it significantly impacts the further fruit plant growing and orchard management [35]. So, achieving the full growing potential and profitability in plum production requires adequate selection of used plum variety in line to available production ambient. Hence, the matter of establishing new orchards has been examined in previous research.

Nedeljković et al. [28] selected apple varieties for the purpose of establishing a new orchard, with the results revealing that the Jonagold apple variety performed the best. Han et al. [36] conducted experiments using various green fertilizers for planting new orchards, using the Korla fragrant pear as a case study. Zhao et al. [37] conducted an evaluation of strawberry varieties to identify the most suitable variety for cultivating new strawberry plants. Todorova et al. [38] investigated different plum cultivars to determine which one exhibited the most favorable characteristics. Mohammadi et al. [39] analyzed the characteristics of various fruit types to select the most suitable fruits for optimal results in Afghanistan. Puška et al. [40] carried out a selection of pear varieties with the best market performance, and this research aims to determine which pear variety should be planted in orchards to achieve the same success.

In addition to these and similar studies focusing on variety selection for new orchards, Multicriteria Decision Making (MCDM) methods have been employed in fruit cultivation research. Rozman et al. [23] utilized the Analytic Hierarchy Process (AHP) method to determine the most suitable apple variety for new orchards. Nedeljković et al. [28], in their apple selection, employed the FUCOM (FUll COnsistency Method), CRITIC (CRiteria Importance Through Intercriteria Correlation), and WASPAS (Weighted Aggregated Sum Product Assessment) methods. Maksimović et al. [16] also chose apple varieties for new orchards, but on that occasion, they used the DEX (Decision EXpert) method. The same method was employed by Rozman et al. [13] to select plum varieties for new orchards. Mohammadi et al. [39] used the AHP and PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) methods in their research. These and similar studies have demonstrated the successful application of MCDM methods in the selection of fruit varieties for establishing new orchards. Therefore, these methods were also employed in this paper.

3. METHODOLOGICAL FRAMEWORK

The methodological framework engaged in this research use three multi-criteria analysis methods: the FUCOM, the CRITIC, and the fuzzy MARCOS (Measurement Alternatives and Ranking according to COmpromise Solution) methods. The FUCOM method is employed to determine the main criteria importance. Then, the CRITIC method determines importance of the sub-criteria, while the fuzzy MARCOS method ranks selected fruit varieties based on expert ratings. Mentioned methods are combined into the hybrid decision-making model used in this research. The integration of these methods is facilitated through a research methodology consisting of 4 phases (Figure 1.).

The inceptive research phase is turned to defining the main problem and research objectives. To address the research problem and achieve the research goals, expert decision-making process is involved. Hence, the next step involves the selection of experts. Six experts were recruited for this research. They initially were selected six plum varieties from the group of available varieties, simultaneously identifying both the main and auxiliary criteria (Figure 2.) in order to evaluate selected varieties. Each main criterion is further subdivided into the same number of auxiliary criteria, supporting its more detailed explanation. By this is ensured that to all main criteria are given the equal importance. The selection of the main and sub-criteria was made based on the following papers: Rozman et al. [13]; Maksimović et al. [16]; Rozman et al. [23]; Nedeljković et al. [28]; Mohammadi et al. [39]. In line to selected criteria and alternative solutions, unique decision-making model is developed for this research.

The next phase involves data collection. According to developed model, adequate two-part questionnaire was created. The role of first part is to define the weights of the main model criteria, so it was tailored in line to FUCOM method, which will be later used in weights defining. In same time, the second part was used to evaluate the selected varieties according to defined auxiliary criteria. Experts have been evaluated each plum variety using linguistic values (Table 1.). Once the experts completed assessment of the main criteria and varieties, the questionnaires were collected. Based on this data, initial decision matrix will be set up, representing the initial step of the MCDA method appliance.

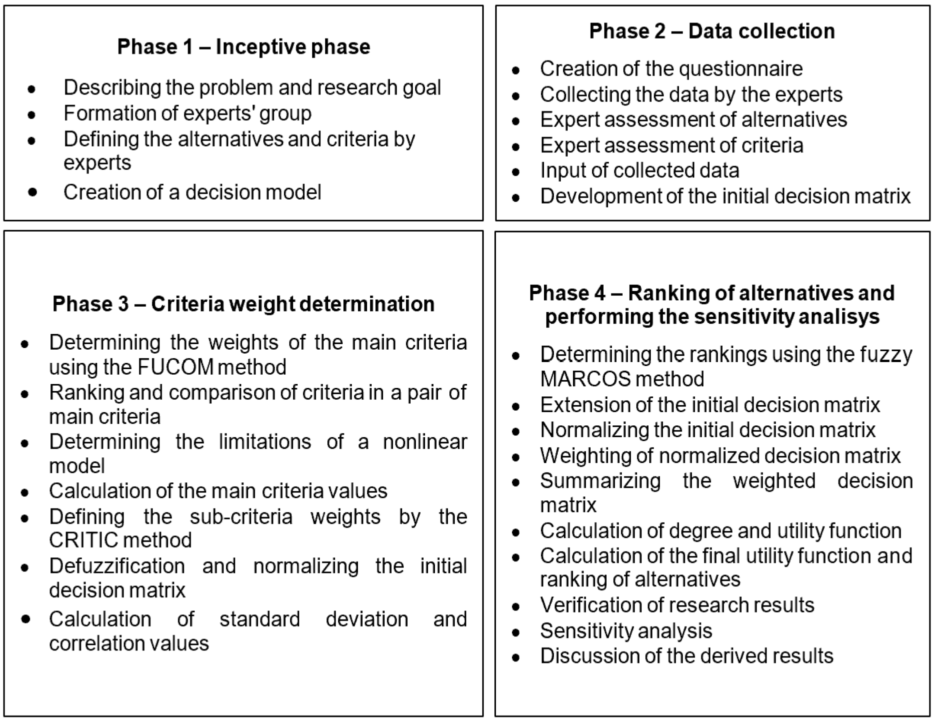

Figure 1: Research methodology

In the third phase, the criteria's weights are defined using the FUCOM and CRITIC methods. These methods will be further explained in following sections. So, based on results from the first part of questionnaire, weights of the main criteria are reckoned using the FUCOM method. Besides, criteria are initially ranked and compared in pairs, followed by the definition of nonlinear model limitations, leading into the calculation of main criteria weights. Calculation of weights of auxiliary criteria are done by the use of linguistic values assigned to the plum variety ratings. These values are transposed in fuzzy numbers by the use of value function, while subsequent defuzzification is done. Then the steps predefined in CRITIC method are engaged in order to calculate the weights of sub-criteria.

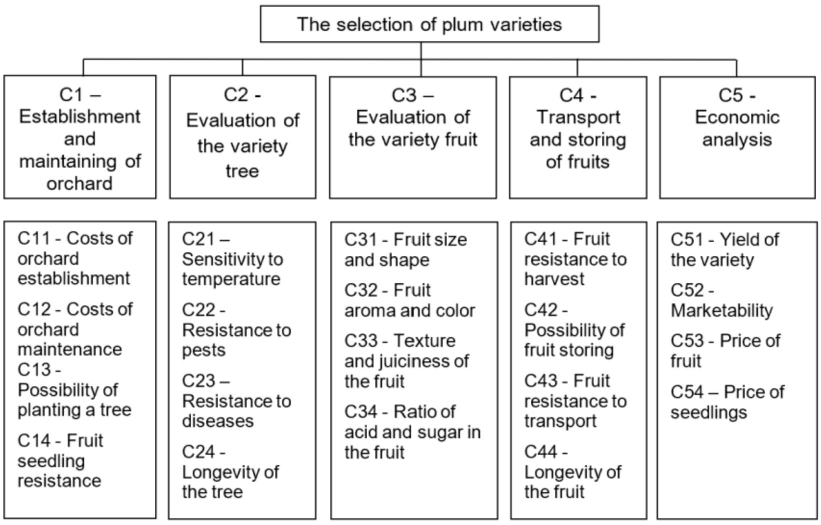

Figure 2: Research model

Ranking alternatives and performing the sensitivity analysis represent the fourth phase of the research. The fuzzy MARCOS method is applied to rank the alternatives. Afterwards, the research results validation is carried out, while other fuzzy methods are applied and derived results are compared to those obtained by fuzzy MARCOS method. This comparison is based on results obtained from the application of other five fuzzy methods. Subsequently, sensitivity analysis is performed, involving the formulation of scenarios which correspond to different variations in weights of the auxiliary criteria. Approach is utilized wherein one auxiliary criterion is assigned a weight six times greater than the weights of other auxiliary criteria. This approach marginalizes other criteria, giving the priority to chosen criterion, evaluating its impact on the final ranking of plum varieties. In this way, a total of 21 scenarios will be formed, according to which the sensitivity analysis will be conducted.

2.1. FUCOM method

FUCOM method was presented for the first time in paper written by [41]. This method is used to describe the weights of criteria in the MCDM environment [42]. It involves pairwise comparison of criteria and validation of results through deviation from maximum consistency [40]. Utilization of mentioned method leads to decrease of subjectivity in the decision-making process [43]. Compared to other methods for defining subjective weights of criteria, the FUCOM method offers several key advantages, such are decreased number of pairwise comparisons, consistency in criterion comparison, and contribution to rational judgment [44-48].

Method is carried out through the next steps [41-45]:

Step 1: Criteria ranking by the use of expert opinions.

Step 2: Defining the assessment vector of comparative criteria importance.

Step 3: Determining the limits of the nonlinear optimization model, where two conditions have to be satisfied:

- Condition 1: There comes to equalization of the ratio of weight coefficients and comparative importance between the reconsidered criteria, expressed as:

$$w_k / w_{k+1} = \varphi_{k/(k+1)}$$

- Condition 2: End values of weighted coefficients are satisfying the requirement of mathematical transitivity, i.e.

$$\varphi_{k/(k+1)} \times \varphi_{(k+1)/(k+2)} = \varphi_{k/(k+2)} \quad (1)$$

Step 4: Developing the model to determine an end values of weighting coefficients for evaluation criteria.

Step 5: Untangling the set model while gaining the end weights for (sub)criteria, $(w_1, w_2, \dots, w_n)^T$.

2.2. CRITIC method

In decision-making process criteria brings information, possessing the weights that reflect the volume of information compressed in each criterion [49]. Development of CRITIC method has been done by Diakoulaki and associates [50]. It is used to define the real values of criteria weights, including the intensity of contrast and conflict present in the structure of decision-making issue [51-53]. In order to ascertain the criteria contrast, there were applied the standard deviations of normalized criterion values, and coefficients of correlation between all pairs set in columns [54]. Method implementation involves next steps [55-56]:

Step 1: Initial decision matrix defuzzification. Ahead the proceeding to other activities within the CRITIC method, all fuzzy numbers are transferred into numerical values [57]. It is carried out by the appliance of next formula [58]:

$$P(\widetilde{m}) = \frac{1}{6}(m_1 \cdot 4x m_2 + m_3) \quad (2)$$

Where m_1, m_2, and m_3 are the first, the second and the third fuzzy number values.

Step 2: Process of normalizing the defuzzified initial decision matrix is done according the following formula:

a) Criteria maximization:

$$r_{ij} = \frac{x_{ij} - x_j^{**}}{x_j^{*} - x_j^{**}} \quad (3)$$

b) Criteria minimization:

$$r_{ij} = 1 - \frac{x_{ij} - x_j^{**}}{x_j^{*} - x_j^{**}} \quad (4)$$

Where, x_j^{*} is the maximal, while x_j^{**} is the minimal value of characteristic of selected criteria.

Step 3: Determining the values for standard deviation and symmetric linear correlation matrix for all pairs of columns.

Step 4: Defining the quantity of information according the next mathematical formula:

$$C_j = \sigma_j \sum_{k=1}^{m}(1 - r_{jk}), j = \overline{1, m} \tag{5}$$

Where σ_j represents the standard deviation, while r_{jk} is the criteria correlation coefficient.

Step 5: Calculation of end values using the next formula:

$$w_j = \frac{C_j}{\sum_{j=1}^{m} C_j} \tag{6}$$

Observed method gives higher weight to criterion, showing the larger standard deviation value, while it is less connected to other criteria [50-59].

2.3. Fuzzy MARCOS method

Mentioned method has been launched by Stević and associates [60]. It relies on predefined relation between selected solutions and their reference values, represented by (anti)ideal points. Use of method in decision-making process is based on a utility function representing a solution in relation to (anti)ideal points [61-62]. The best solution represents one closest to ideal point and farthest from anti-ideal point [44]. It has to be mentioned that a fuzzy version of observed method has been set up by Stanković and associates [61]. It is computed throughout the next steps [63]:

Step 1: Setting the initial fuzzy decision matrix.

Step 2: Extension of the previous matrix, by extending it with (anti)ideal solutions (AAI/AI). AAI represents solution with the worst characteristics towards the criteria type, whether it is a benefit criterion or a cost criterion. Contrary to previous, AI is a solution with the most desired characteristics [44].

Anti-ideal alternative is determined according to next formula:

$$AAI = \min_j x_{ij} \;\; if\; j \in B\; and\; \max_j x_{ij} \;\; if\; j \in C \tag{7}$$

Ideal alternative is determined according to next expression:

$$AI = \max_j x_{ij} \min_j x_{ij} \;\; if\; j \in B\; and\; \min_j x_{ij}\; if\; j \in C \tag{8}$$

With B is described benefit criteria that has to strive to maximal value, while with C is described cost criteria that has to have minimal value.

Step 3: Initial fuzzy decision matrix normalization is done in line to next formula, depending on selected criterion:

$$\tilde{n} = (n_{ij}^l, n_{ij}^m, n_{ij}^u) = \left(\frac{x_{id}^l}{x_{ij}^u}, \frac{x_{id}^l}{x_{ij}^m}, \frac{x_{id}^l}{x_{ij}^l}\right)\; if\; j \in C \tag{9}$$

$$\tilde{n} = (n_{ij}^l, n_{ij}^m, n_{ij}^u) = \left(\frac{x_{ij}^l}{x_{id}^u}, \frac{x_{ij}^m}{x_{id}^u}, \frac{x_{ij}^u}{x_{id}^u}\right)\; if\; j \in B \tag{10}$$

Where, l, m, and u represent the first three fuzzy numbers. Triangular fuzzy numbers were employed in this context, and as such, it is essential to establish the boundaries of these numbers using these three fuzzy values.

Step 4: Weighting the normalized decision matrix by the use of next formula:

$$\tilde{v}_{ij} = \left(v_{ij}^{l}, v_{ij}^{m}, v_{ij}^{u}\right) = \tilde{n}_j \times \tilde{w}_j = v_{ij}^{l} \times w_j^{l}, v_{ij}^{m} \times w_j^{m}; v_{ij}^{u} \times w_j^{u} \tag{11}$$

Step 5: Determining the S_i matrix represents the summing of all values by rows, involving the alternatives for the (anti)ideal solutions, while it is based on next formula:

$$S_i = \sum_{i=1}^{n} v_{ij} \tag{12}$$

Step 6: Defining the utility degree K_i towards the (anti)ideal solutions by applying the following mathematical expression:

$$\tilde{K}_i^{-} = \left(\frac{\tilde{s}_i}{\tilde{s}_{ai}}\right) = \left(\frac{s_i^l}{s_{ai}^u}, \frac{s_i^m}{s_{ai}^u}, \frac{s_i^u}{s_{ai}^u}\right) \tag{13}$$

$$\tilde{K}_i^{+} = \left(\frac{\tilde{s}_i}{\tilde{s}_{id}}\right) = \left(\frac{s_i^l}{s_{id}^u}, \frac{s_i^m}{s_{id}^u}, \frac{s_i^u}{s_{id}^u}\right) \tag{14}$$

Step 7: Determining the fuzzy matrix $\tilde{T}_i$ with next formula:

$$\tilde{T}_i = \tilde{t}_i = \left(t_i^l, t_i^m, t_i^u\right) = \tilde{K}_i^{-} \oplus \tilde{K}_i^{+} = (\tilde{k}_i^{-l} + \tilde{k}_i^{+l}, \tilde{k}_i^{-m} + \tilde{k}_i^{+m}, \tilde{k}_i^{-u} + \tilde{k}_i^{+u}) \tag{15}$$

Then, a new fuzzy number $\tilde{D}$ is determined using the expression:

$$\tilde{D} = (d^l, d^m, d^u) = \max_i \tilde{t}_{ij} \tag{16}$$

Step 8: Fuzzy numbers defuzzification is done with the next formula:

$$df_{def} = \frac{l+4m+u}{6} \tag{17}$$

Step 9: Determination of utility function $f(K_i)$ throughout aggregation of utility functions towards (anti)ideal solutions.

a) Utility function towards AAI:

$$f(\tilde{K}_i^{+}) = \frac{\tilde{K}_i^{-}}{df_{def}} \tag{18}$$

b) Utility function towards AI:

$$f(\tilde{K}_i^{-}) = \frac{\tilde{K}_i^{+}}{df_{def}} \tag{19}$$

Step 10: Determination of final utility function:

$$f(K_i) = \frac{K_i^{+} + K_i^{-}}{1 + \frac{1-f\left(K_i^{+}\right)}{f\left(K_i^{+}\right)} + \frac{1-f\left(K_i^{-}\right)}{f\left(K_i^{-}\right)}} \tag{20}$$

Step 11: Ranking the solutions, while the best one has the maximal value, or the worst one has the minimal value.

3. CASE STUDY AND RESULTS

The research was conducted by the use of expert decision-making. Experts were asked to provide ratings for specific plum varieties grown in BiH with main goal to improve plum production sector. Since plum production in BiH has stagnant or decreasing trend, there was a need to obtain expert opinions from competent professionals. Experts were selected from neighboring country – Serbia (six experts), specifically professors for fruit growing from agricultural faculties in Novi Sad and Niš, as well as researchers from the Fruit Research Institute in Čačak. The reasons for choosing Serbian experts lies in:

- Plums are the most widely grown fruit species in BiH and Serbia.
- Globally, Serbia ranks as third in plum production.
- Many regionally used plum varieties have been selected and branded in Serbia.
- Serbia and BiH share similar geographical and climate conditions.

Mainly due to mentioned reasons, experts from Serbia have been chosen to share their experience with Bosnian fruit growers, as Serbia is globally positioned among the top three plum producers.

Since there are numerous different plum varieties locally available for establishing the new plum orchards in BiH, initially it has to be selected the most significant varieties in collaboration with the experts. Selected fruit varieties, predominantly grown in the Southeastern Balkan region, are: Čačanska lepotica (A1), Čačanska rodna (A2), Stanley (A3), Požegača (A4), Šumadinka (A5), and Prezident (A6). These varieties have a growing tradition within the region, showing the best results according to expert opinion. To evaluate mentioned varieties, adequate decision-making model was created, consisting of five main criteria divided into four sub-criteria (Figure 2.). The main criteria in developed model are: orchard establishment and maintenance (C1), evaluation of varieties' three (C2), evaluation of varieties' fruit (C3), fruit transportation and storing (C4), and economic analysis (C5). Defined criteria aimed to examine the plum varieties based on following aspects:

- "Orchard establishment and maintenance" (C1): criterion focuses on the costs associated with establishing and maintaining orchards, suitable planting and agro-technic methods applied for specific varieties, required growing conditions of selected varieties.
- "Evaluation of varieties' tree" (C2): criterion assesses the sensitivity of individual varieties to low and high temperatures, resistance to pests and diseases, as well as longevity of the trees.
- "Evaluation of varieties' fruit" (C3): criterion aims to evaluate the size and shape of fruits, as well as their aroma, color, texture, juiciness, and the ratio of acidity to sugar.
- "Fruit transportation and storing" (C4): criterion examines the fruit's resistance during and after harvest, its suitability for storing, as well as its durability and resistance during transportation.
- "Economic analysis" (C5): criterion investigates the yield and marketability of individual varieties, including their selling prices and the cost of seedlings.

Once the specific plum varieties and criteria for their analysis were determined, adequate two-parts questionnaire was developed. The first part is focused to determining the characteristics of individual plum varieties based on the predefined sub-criteria. To assess these characteristics, experts are used linguistic values, which ranged from "very bad" to "very good", encompassing 7 levels of (dis)agreement with each sub-criterion (Figure 2.). Every linguistic value was added to the best responding fuzzy number using a membership function (Table 1.).

Table 1: Fuzzy number's membership function

Linguistic values	Fuzzy numbers
Very bad (VB)	(0, 0, 1)
Bad (B)	(0, 1, 3)
Moderately bad (MB)	(1, 3, 5)
Medium (M)	(3, 5, 7)
Moderately good (MG)	(5, 7, 9)
Good (G)	(7, 9, 10)
Very good (VG)	(9, 10, 10)

Source: [35]

After evaluating plum varieties, engaged experts filled out a second part of questionnaire focused on the significance of the main criteria. In this part of questionnaire, each expert ranked the criteria according to their significance in solving the decision-making issue. They are marking for them the most significant criterion and assigned to it the value one (1). Then to remaining criteria were assigning the values relative to the most significant criterion, with maximum value of nine (9). The less significant criterion considered by the experts receives the higher value. The initial results of performed research were obtained by completing mentioned questionnaire.

Before determining the rank order of assessed solutions, it is required to establish the weights of each criteria. To define the weights of main criteria, the FUCOM method was used. The parameters required for determining the weights of main criteria were gained from experts after they completed the second part of questionnaire (Table 2.). Four experts think that criterion C3 is the most important, while two of them stated that C5 is the most important criterion. Based on these answers, it is visible that there are different opinions that have to be harmonized. In order to reconcile the expert opinions, the geometric mean was applied. The geometric mean ensures that each participating expert has an equal influence on the final results, giving all experts an equal role in the process. If one expert were given more weight, their opinion would carry greater importance, potentially diminishing the influence of other experts. Therefore, it was decided that each expert's opinion should be equally considered.

Table 2: Experts rating of main criteria

Expert 1	C3	C5	C1	C4	C2
C3 (most important criterion)	1	3.5	4.5	5	7
Expert 2	C3	C5	C1	C4	C2
C3 (most important criterion)	1	1.5	2	2.5	5
Expert 3	C5	C4	C1	C3	C2

C5 (most important criterion)	1	1.5	3	5	8
Expert 4	C5	C1	C4	C3	C2
C5 (most important criterion)	1	1.5	2	2.5	7
Expert 5	C3	C1	C5	C4	C2
C3 (most important criterion)	1	2	4	5	9
Expert 6	C3	C5	C1	C4	C2
C3 (most important criterion)	1	2.5	3	4	7

Source: Own calculation based on expert's opinion

After following the FUCOM method steps, model was defined, while all main criteria weights were defined by each expert individually. Later, based on the geometric mean, the aggregate weights of the main criteria were defined (Table 3.).

Table 3: Main criteria weights

Expert 1	C1	C2	C3	C4	C5
	0.1780	0.1438	0.3115	0.1699	0.1968
Expert 2	C1	C2	C3	C4	C5
	0.1973	0.1435	0.2631	0.1857	0.2105
Expert 3	C1	C2	C3	C4	C5
	0.1938	0.1246	0.1585	0.2325	0.2906
Expert 4	C1	C2	C3	C4	C5
	0.2152	0.1242	0.1899	0.2018	0.2690
Expert 5	C1	C2	C3	C4	C5
	0.2276	0.1214	0.3034	0.1655	0.1821
Expert 6	C1	C2	C3	C4	C5
	0.1941	0.1344	0.2912	0.1747	0.2056
Final weights	C1	C2	C3	C4	C5
	0.2030	0.1334	0.2486	0.1895	0.2254

Source: Own calculation based on expert's opinion

Determining the weights of all sub-criteria follows the determination of the main criteria weights. They will be defined using the CRITIC method. Since the initial steps for FMARCOS and CRITIC methods are the same, they will be explained together. Firstly, it will be determined the rank order of alternatives as the expert evaluation. The engaged experts are assessing the selected solutions with the linguistic values, which are then transposed in fuzzy numbers. Along the membership function of fuzzy numbers (Table 1.), the linguistic responses were transformed into fuzzy numbers. For instance, the linguistic value "Moderately good" is transformed into a fuzzy number (5, 7, 9) using the membership function provided in Table 1. Based on these membership functions, other linguistic values are similarly transformed. In line to that, six fuzzy decision matrices were formed, one for each expert (Table 4.). In order to proceed with sub-criteria's ranks and weights determination, these tables were consolidated using the arithmetic mean. This resulted in joint fuzzy decision matrix.

Table 4: Initial decision matrix

Exp. 1	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{41}	C_{42}	C_{43}	C_{44}	C_{51}	C_{52}	C_{53}	C_{54}
A1	MG	MG	MG	G	MG	MB	M	MG	MG	MG	G	G	MG	M	M	MG	VG	MG	MG	G

A2	MG	G	VG	G	G	G	MG	G	M	MG	M	M	G	G	VG	G	G	G	M	MG
A3	MG	G	M	G	G	MG	MG	MG	VG	G	MG	MG	MG	MG	MG	G	MG	M	MG	MG
A4	G	G	MG	G	M	MB	MB	MG	MB	MB	M	MG	MG	MG	MG	MG	MG	MG	M	G
A5	MB	MG	M	MG	MB	MG	M	M	B	MB	MG	M	MB	M	MB	MB	MB	B	M	MG
A6	MG	MG	MB	M	MB	MB	M	M	MB	M	MG	M	MB	MG	M	M	MB	MB	B	MB
Exp. 2	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{41}	C_{42}	C_{43}	C_{44}	C_{51}	C_{52}	C_{53}	C_{54}
A1	MG	MG	MG	VG	MG	MB	M	MG	G	G	G	G	MG	M	M	MG	VG	MG	MG	G
A2	MG	G	VG	G	G	G	MG	G	M	G	M	M	G	G	VG	G	G	G	MG	G
A3	VG	G	G	G	G	MG	MG	MG	VG	G	G	MG	MG	M	G	VG	MG	MG	MG	MG
A4	G	VG	MG	VG	MG	MB	MG	G	MG	MB	M	MG	MG	MG	MG	MG	G	G	M	G
A5	MB	MG	M	MG	MB	MG	MG	M	B	MG	MG	MG	MB	M	MB	MB	MG	B	M	MG
A6	MG	MG	MB	M	MB	MB	M	M	MB	M	G	M	MB	MG	M	M	M	MB	B	MB
Exp. 3	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{41}	C_{42}	C_{43}	C_{44}	C_{51}	C_{52}	C_{53}	C_{54}
A1	MG	MG	MG	VG	MG	MB	M	MG	VG	G	G	G	MG	M	M	MG	VG	MG	MG	G
A2	MG	G	VG	G	G	G	MG	G	M	G	M	M	G	G	VG	MG	G	MG	MG	G
A3	MG	MG	MG	MG	G	G	MG	MG	VG	G	MG	M	MG	M	G	VG	VG	G	G	MG
A4	G	G	MG	G	MG	MB	MG	G	MG	MB	MG	MG	G	G	G	MG	G	G	M	G
A5	MB	MG	M	MG	M	MG	MG	M	B	MG	MG	G	MB	M	MB	MG	MG	B	M	MG
A6	MG	MG	MB	MG	M	M	MG	M	MB	M	G	MG	MB	MG	M	MG	M	MB	B	MB
Exp. 4	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{41}	C_{42}	C_{43}	C_{44}	C_{51}	C_{52}	C_{53}	C_{54}
A1	MG	MG	MG	VG	MG	MB	M	MG	MG	G	MG	G	MG	M	M	MG	VG	MG	MG	G
A2	MG	G	VG	G	G	G	M	G	M	G	MG	M	G	G	VG	G	G	VG	MG	G
A3	VG	G	MG	G	G	MG	MG	M	VG	VG	G	G	MG	M	G	VG	MG	MG	MG	MG
A4	G	VG	MG	VG	MG	MG	M	M	MG	MG	M	MG	G	G	MG	MG	G	VG	MG	G
A5	MG	MG	MG	G	MB	MG	MG	M	B	MG	MG	MG	MB	M	MB	MB	G	B	M	MG
A6	MG	MG	M	M	MB	MB	MG	MG	MB	M	G	M	MB	MG	M	M	M	MB	B	MB
Exp. 5	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{41}	C_{42}	C_{43}	C_{44}	C_{51}	C_{52}	C_{53}	C_{54}
A1	MG	MG	MG	VG	MG	MB	M	MG	VG	MG	MG	G	MG	M	M	MG	VG	MG	MG	G
A2	MG	G	VG	G	G	G	G	G	M	G	MG	M	G	G	VG	G	G	G	MG	G
A3	VG	MG	G	MG	G	MG	MG	MG	G	G	G	M	G	M	G	G	MG	MG	MG	G
A4	MG	VG	MG	VG	MG	M	MG	MG	MG	MB	M	MG	G	MG	G	MG	G	G	M	G
A5	MB	MG	M	MG	M	MG	MG	M	MB	MG	MG	MG	MB	M	MB	MB	MG	MB	M	MG
A6	MG	MG	B	M	MB	MB	MG	MG	MB	MG	G	MG	MB	MG	M	M	M	B	B	MB
Exp. 6	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{41}	C_{42}	C_{43}	C_{44}	C_{51}	C_{52}	C_{53}	C_{54}
A1	MG	G	G	VG	MG	MB	M	MG	G	G	G	G	MG	M	M	MG	VG	MG	MG	G
A2	MG	G	VG	G	G	VG	G	G	MG	G	M	MG	G	G	G	G	G	G	MG	MG
A3	VG	VG	G	G	G	MG	MG	MG	VG	MG	G	G	MG	MG	G	VG	MG	MG	MG	MG
A4	G	VG	G	VG	MG	MB	MG	G	MG	MG	M	G	MG	G	MG	MG	G	G	M	G
A5	MB	G	M	MG	M	MG	MG	MG	B	MG	MG	MG	MB	M	MB	M	G	B	M	M
A6	MG	MG	MB	M	MB	MB	M	M	MB	M	G	MG	MB	MG	M	M	M	M	B	MB

Source: Own calculation based on survey data

Determining the rank order of alternatives firstly requires reckoning of weights of sub-criteria by the use of CRITIC method. After forming the joint fuzzy decision matrix, CRITIC method defuzzifies the fuzzy numbers and converts them into crisp numbers (Equation 2.). For instance, considering the fuzzy number (5, 7, 9), derived from the linguistic value "Moderately good", the defuzzified value is calculated as follows: $P(m) = \frac{5+4\cdot 7+9}{6} = 7$. Similarly, other fuzzy numbers are converted into crisp values. Further, the defuzzified decision matrix is normalized. For instance, for the first alternative and the first criterion, the normalization is performed as follows: $n_{11} = \frac{7-3.67}{8.89-3.67} = 0.64$. This normalization process is applied uniformly to all elements of the crisp decision matrix. It involves subtracting the normalized data from the smallest value among all alternatives for that criterion and dividing by the difference between the highest value among the alternatives for that criterion and the smallest value for that criterion. Based on the values of the normalized decision matrix, standard deviation and correlation coefficient values are computed. These values can be calculated using corresponding functions in Excel, involving the use of a symmetric matrix of linear correlation. The sum of values for each sub-criterion is multiplied by the standard deviation (Equation 5.). According to these values there come to calculation of the weights of individual criteria (Equation 6.). To calculate the final weights of the sub-criteria, the weights obtained from the CRITIC method are multiplied by weights obtained from the FUCOM method.

Table 5: Exercising the CRITIC method

Standard deviation																			
C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{41}	C_{42}	C_{43}	C_{44}	C_{51}	C_{52}	C_{53}	C_{54}
0.35	0.40	0.34	0.38	0.43	0.41	0.36	0.37	0.38	0.42	0.44	0.34	0.44	0.42	0.38	0.37	0.35	0.42	0.37	0.38
Correlation																			
C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{41}	C_{42}	C_{43}	C_{44}	C_{51}	C_{52}	C_{53}	C_{54}
1.00	0.58	0.34	0.33	1.00	0.48	0.33	0.79	1.00	0.53	0.16	0.46	1.00	0.47	0.85	0.85	1.00	0.72	0.85	0.96
0.58	1.00	0.69	0.61	0.48	1.00	0.93	0.34	0.53	1.00	0.27	0.04	0.47	1.00	0.69	0.32	0.72	1.00	0.61	0.71
0.34	0.69	1.00	0.82	0.33	0.93	1.00	0.22	0.16	0.27	1.00	0.29	0.85	0.69	1.00	0.90	0.85	0.61	1.00	0.88
0.33	0.61	0.82	1.00	0.79	0.34	0.22	1.00	0.46	0.04	0.29	1.00	0.85	0.32	0.90	1.00	0.96	0.71	0.88	1.00
$\sum_{k=1}^{m}\left(1-r_{jk}\right)$																			
C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{41}	C_{42}	C_{43}	C_{44}	C_{51}	C_{52}	C_{53}	C_{54}
0.00	0.42	0.66	0.67	0.00	0.52	0.67	0.21	0.00	0.47	0.84	0.54	0.00	0.53	0.15	0.15	0.00	0.28	0.15	0.04
0.42	0.00	0.31	0.39	0.52	0.00	0.07	0.66	0.47	0.00	0.73	0.96	0.53	0.00	0.31	0.68	0.28	0.00	0.39	0.29
0.66	0.31	0.00	0.18	0.67	0.07	0.00	0.78	0.84	0.73	0.00	0.71	0.15	0.31	0.00	0.10	0.15	0.39	0.00	0.12
0.67	0.39	0.18	0.00	0.21	0.66	0.78	0.00	0.54	0.96	0.71	0.00	0.15	0.68	0.10	0.00	0.04	0.29	0.12	0.00
$C_j = \sigma_j \sum_{k=1}^{m}\left(1-r_{jk}\right)$																			
C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{41}	C_{42}	C_{43}	C_{44}	C_{51}	C_{52}	C_{53}	C_{54}
0.62	0.45	0.39	0.46	0.59	0.52	0.55	0.60	0.71	0.91	0.99	0.76	0.36	0.63	0.21	0.34	0.17	0.40	0.24	0.17
W																			
C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{41}	C_{42}	C_{43}	C_{44}	C_{51}	C_{52}	C_{53}	C_{54}
0.32	0.23	0.20	0.24	0.26	0.23	0.24	0.27	0.21	0.27	0.29	0.22	0.23	0.41	0.14	0.22	0.17	0.41	0.25	0.17
Final criteria weights																			
C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{41}	C_{42}	C_{43}	C_{44}	C_{51}	C_{52}	C_{53}	C_{54}
0.07	0.05	0.04	0.05	0.03	0.03	0.03	0.04	0.05	0.07	0.07	0.06	0.04	0.08	0.03	0.04	0.04	0.09	0.06	0.04

Source: Own calculation based on survey data

After establishment of the joint fuzzy decision matrix, following step in fuzzy MARCOS method represents expanding the matrix by defining the (anti)ideal points (Equations 7. and 8.). Taking criterion C11 as an example, the ideal value is as follows: (7.67, 9.00, 9.83), and the anti-ideal value is: (1.67, 3.67, 5.67). Then, data normalization will be performed (Equation 9.). For instance, for alternative A1 and criterion C11, this process appears as follows: $n_{11} = \left(\frac{5.00}{9.83} = 0.51,\ \frac{7.00}{9.83} = 0.71, \frac{9.00}{9.83} = \ 0.92\right)$. Normalization values for all elements of the extended decision matrix are computed similarly, with the maximum criterion value varying based on the specific criterion. The expanded and normalized fuzzy decision matrix is multiplied by the weights of the criteria. In the given example, weighting is performed as follows: (0.51, 0.71, 0.92) x (0.07, 0.07, 0.07) = (0.03, 0.05, 0.06). Further activity in fuzzy MARCOS method is defining the Si matrix, which involves summing the values by rows for all solutions, involving the (anti)ideal solutions (Equation 11.). Subsequent step is to define the utility degree respecting the (anti)ideal alternatives (Equations 12. and 13.). For alternative A1, it is computed as follows: $K_1^- = \left(\frac{0.55}{1.00} = 0.55,\ \frac{0.74}{0.92} = \ 0.81,\ \frac{0.90}{0.75} = 1.21\right), K_1^+ = \left(\frac{0.55}{0.59} = 0.94, \frac{0.74}{0.38} = 1.94, \frac{0.90}{0.20} = 4.51\right)$. In a similar manner, utility degree values for other alternatives are calculated. Finnaly, values obtained from summation and utility degree are presented in Table 6.

Table 6: Summation and calculation of utility degree

Element	S_i	K_i^-	K_i^+
Ideal	(0.75, 0.92, 1.00)	(0.75, 1.00, 1.34)	(1.27, 2.38, 3.29)
A1	(0.55, 0.74, 0.90)	(0.55, 0.81, 1.21)	(0.94, 1.94, 4.51)
A2	(0.62, 0.81, 0.94)	(0.62, 0.89, 1.27)	(1.05, 2.12, 4.70)
A3	(0.61, 0.80, 0.94)	(0.61, 0.87, 1.26)	(1.03, 2.07, 4.67)
A4	(0.54, 0.74, 0.89)	(0.54, 0.81, 1.20)	(0.93, 1.92, 4.45)
A5	(0.32, 0.51, 0.71)	(0.32, 0.56, 0.95)	(0.54, 1.32, 3.53)
A6	(0.30, 0.50, 0.70)	(0.30, 0.54, 0.93)	(0.52, 1.30, 3.46)
Anti-ideal	(0.20, 0.38, 0.59)	(0.20, 0.42, 0.79)	(0.34, 1.00, 1.93)

Source: Own calculation based on survey data

Next step that has be done in fuzzy MARCOS method is to determine the fuzzy matrix $\tilde{T}_i$ (Equation 15.). The utility values with respect to (anti)ideal solutions are added for each alternative, while the maximal values of the fuzzy numbers are calculated. Then, the defuzzification of maximal numbers is performed (Equation 17.), while the value of df_{crisp} is calculated.

Table 7: Fuzzy matrix $\tilde{T}_i$

Alternative	$\tilde{T}_i$
A1	(1.49, 2.75, 5.72)
A2	(1.67, 3.00, 5.97)
A3	(1.64, 2.94, 5.93)
A4	(1.47, 2.73, 5.65)
A5	(0.86, 1.88, 4.48)
A6	(0.82, 1.84, 4.39)
Max	(1.67, 3.00, 5.97)

Source: Own calculation based on survey data

In this case, the df_{crips} has next value: $df_{crips} = \frac{1.67+4\cdot 3.00+5.97}{6} = 3.28$. Gained value served for calculation of the function with respect to (anti)ideal solutions. Mentioned values are obtained by dividing the utility degree values with respect to anti-ideal solution (K_i^-) with df_{crisp} value, while the utility function for ideal solution is calculated accordingly. To calculate the utility function for anti-ideal solution, the utility degree values with respect to the ideal solution (K_i^+) are divided by the df_{crips} value. For alternative A1, it is computed as follows: $\boldsymbol{f(\tilde{K}_i^-)} = \left(\frac{0.94}{3.28} = 0.32, \frac{1.94}{3.28} = 0.59, \frac{4.51}{3.28} = 1.38\right) \boldsymbol{f(\tilde{K}_i^+)} = (\frac{0.55}{3.28} = 0.17, \frac{0.81}{3.28} = 0.25, \frac{1.21}{3.28} = 0.37$. In a similar manner, other elements of Utility functions are calculated.

Table 8: Utility functions

Alternative	$f(\tilde{K}_i^-)$	$f(\tilde{K}_i^+)$
A1	(0.29, 0.59, 1.38)	(0.17, 0.25, 0.37)
A2	(0.32, 0.65, 1.44)	(0.19, 0.27, 0.39)
A3	(0.32, 0.63, 1.43)	(0.19, 0.27, 0.38)

A4	(0.28, 0.59, 1.36)	(0.17, 0.25, 0.37)
A5	(0.17, 0.40, 1.08)	(0.10, 0.17, 0.29)
A6	(0.16, 0.40, 1.06)	(0.09, 0.17, 0.28)

Source: Own calculation based on survey data

Once the utility degree and utility functions are calculated, before ranking the alternatives, these values has to be defuzzified towards determining the final utility function (Equation 20.). Calculation of defuzzification is done in the same manner as in the previous cases.

Table 9: Defuzzified utility degree and utility functions

Alternatives	$d\widetilde{K}_i^-$	$d\widetilde{K}_i^+$	$df(\widetilde{K}_i^-)$	$df(\widetilde{K}_i^+)$
A1	0.836	2.198	0.671	0.255
A2	0.906	2.370	0.723	0.277
A3	0.890	2.330	0.711	0.272
A4	0.828	2.177	0.665	0.253
A5	0.582	1.561	0.476	0.178
A6	0.569	1.528	0.466	0.174

Source: Own calculation based on survey data

So, after calculating the defuzzified utility degree and utility functions, the final utility function is determining (Equation 20.). Obtained results are showing alternative A2 (Čačanska rodna) as the best-ranked, while the next one is A3 (Stanley). As the last ranked alternative is marked A6 (Prezident), (Table 10.). Further confirmation of derived results requires performing of sensitivity analysis.

Table 10: Ranking of alternatives

Alternatives	K_i	Rank
A1	0.688	3
A2	0.820	1
A3	0.788	2
A4	0.674	4
A5	0.319	5
A6	0.304	6

Source: Own calculation based on survey data

4. RESULTS VALIDATION AND SENSITIVITY ANALYSIS

Comparison of gained results by other methods becomes a standard in scientific research, so it could be found in many papers [64-68]. During the results validation, the ranking of alternatives was tested using the other fuzzy methods. For validation of derived research results, following methods were used: fuzzy SAW, fuzzy MABAC, fuzzy ARAS, fuzzy TOPSIS, and fuzzy WASPAS.

After applying mentioned methods, derived results show that only in fuzzy TOPSIS method comes to different ranking of alternatives compared to other methods, specifically alternatives A5 and A6 (Figure 3.). Observing the results of fuzzy MARCOS method, it's visible that the difference for these 2 alternatives is minimal, so it was expected that one of mentioned methods might change the ranking process for selected alternatives. Based on performed analysis, there is conclusion that gained results in primary research are confirmed by other applied fuzzy methods.

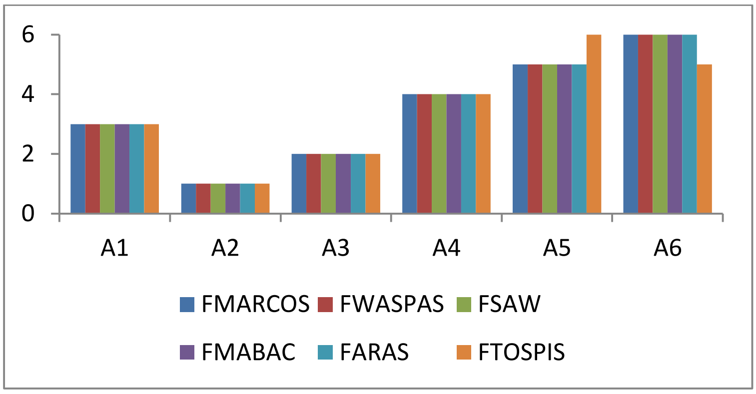

Figure 3: Ranking of alternatives based on various fuzzy methods

As in step of results validation, throughout the comparing of derived results by other methods, the sensitivity analysis of the model is most often used in scientific articles as the main part of a defined model [69-71]. The main goal of sensitivity analysis is confirmation or refuting the ranking of alternatives gained by the fuzzy MARCOS method. Analysis was done to examine (dis)advantages of certain plum varieties at which secondary criteria caused a change in alternative's rank, as well as the impact of each secondary criterion on alternative's rank.

Sensitivity analysis covers 21 scenarios. Firstly, the weight of one specific criterion is increased by four times, while the weight of the other criteria is reduced in proportion to that increase. This procedure is carried out for all criteria, of which there are twenty. Adhering to this principle, a single criterion per scenario can be increased to four times its original weight, while the remaining criteria are adjusted accordingly. This approach allows us to evaluate the impact of an individual criterion when its importance outweighs that of the others in determining the ranking list. Based on this, twenty scenarios are formed. The twenty-first scenario gives equal importance to all criteria (Table 11.).

Table 11: Sensitivity analysis scenarios

Scenario	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	…	C_{41}	C_{42}	C_{43}	C_{44}	C_{51}	C_{52}	C_{53}	C_{54}
Scen. 1	0.26	0.04	0.03	0.04	0.03	0.03	…	0.04	0.06	0.02	0.03	0.03	0.08	0.05	0.03
Scen. 2	0.05	0.19	0.03	0.04	0.03	0.03	…	0.04	0.06	0.02	0.03	0.03	0.08	0.05	0.03
Scen. 3	0.05	0.04	0.16	0.04	0.03	0.03	…	0.04	0.06	0.02	0.03	0.03	0.08	0.05	0.03
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Scen. 19	0.05	0.04	0.03	0.04	0.03	0.03	…	0.04	0.06	0.02	0.03	0.03	0.08	0.22	0.03
Scen. 20	0.05	0.04	0.03	0.04	0.03	0.03	…	0.04	0.06	0.02	0.03	0.03	0.08	0.05	0.16
Scen. 21	0.05	0.05	0.05	0.05	0.05	0.05	…	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

Source: Own calculation based on survey data

Derived results from analysis showed that the alternatives were grouped in certain pairs: alternatives A2 and A3 as the best-ranked, alternatives A1 and A4 as moderately ranked, and alternatives A5 and A6 as the worst-ranked alternatives (Figure 4.). Ranking of the alternatives is changing in line to used scenario. Alternative A2 is ranked as the first in 17 scenarios, while alternative A3 is ranked as the first in remaining four scenarios. This suggests that alternative A3 has better characteristics in terms of maintaining costs of plantation, fruit aroma and color, fruit acidity and sugar ratio, and fruit resistance during harvesting. Therefore, in these scenarios, alternative A3 had better results compared to alternative A2. During the sensitivity analysis, when adjusting the weights of the primary criterion C3, the results indicated that plum variety A1 outperforms plum variety A4.

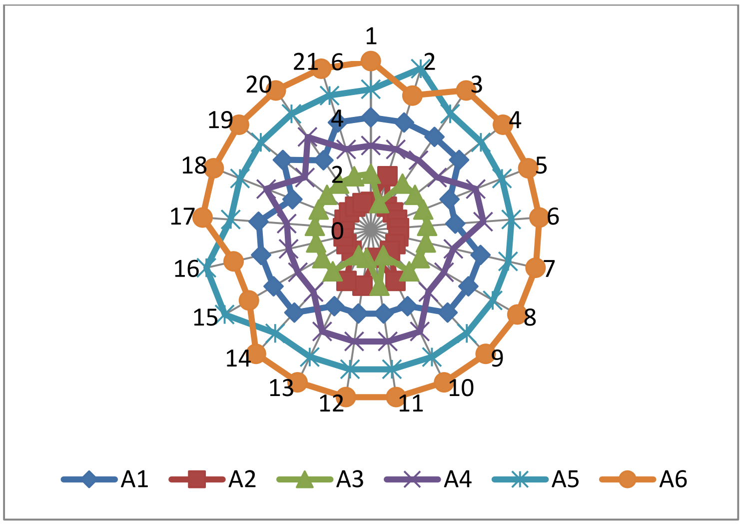

Figure 4: Ranking alternatives within the sensitivity analysis

So, if for example, a plum grower wants to reduce costs of orchard maintenance while satisfying other sub-criteria, logical choice for him would be plum variety A3. However, accepting the overall analysis and all obtained results, the logical choice for establishment of plantation would be plum variety A2. Additionally, derived results showed that alternatives A5 and A6 are not so good choices for plum growing as they performed weak features compared to other observed varieties. Alternative A5 showed the weakest results in three scenarios. In same time alternative A6 has the poorest results in 18 scenarios.

Ultimately, sensitivity analysis confirmed the results derived after appliance of the fuzzy MARCOS method in relation to other criteria and change in sub-criteria weights.

5. DISCUSSION

In process of choosing optimal plum varieties for establishing new plantations in BiH five main criteria were used. They were later subdivided in the certain sub-criteria. In total, the created model operates with 20 secondary criteria. When experts evaluated the main criteria, the most significant criteria for decision-making were C3 - Evaluation of fruit quality for individual varieties, and C5 - Economic analysis. In same time, experts assigned less importance to other observed criteria. However, when making a final decision, there is a need to consider all predefined criteria to ensure its comprehensiveness [16]. Based on the expert's weight assessment of the main criteria and objective determination of sub-criteria weights with the CRITIC method, weights were obtained for the all sub-criteria, indicating that sub-criteria C52 (Marketability) and C42 (Fruit storing potential) particularly stood out compared to other criteria. This could be explained by facts that all plum varieties are planted in a similar manner and conditions, as well as that their trees are similar, while their taste and aroma do not differ significantly [15].

Results derived from the analysis of plum varieties most commonly grown in BiH have been showed that the best results were achieved by plum varieties A2 - Čačanska rodna and A3 - Stanley. Similar results were gained in research done by Rozman and associates [13], when the Stanley plum variety achieved the best results in integrated plum production. So, these two varieties exhibited the best characteristics according to expert evaluation, while they should dominate in the establishment of new plum plantations in BiH. Mentioned will increase the economic significance that plums already have in BiH fruit sector [12], as the demand for plums worldwide constantly increases [3]. With planned and systematic approach, plum production in BiH can be pushed up at higher level, simultaneously with full utilization of available geographical and climate conditions.

The strengthening of fruit sector in BiH should not be limited only to plum production, as there are huge potentials for the production of other fruit species. As was previously mentioned, during establishment of new orchards, it is required to reconsider a group of factors that have effects on production of certain fruit species. Additionally, it is required to boost overall food (fruit) processing capacities in BiH, since the majority of plum exports to EU markets currently is in the form of fresh plums without added value. This is essential to produce other plum-based products [7] and thereby strengthen not only the primary agriculture, but also the entire food industry in BiH. Meanwhile, it is particularly important to work on further tech-tech development and branding of certain food products based on plum regionally well recognized, e.g. alcoholic beverages known as "Rakija" or "Šljivovica" [72-73].

The formed and later applied model based on combination of different MCDA methods have shown good analytical results in performed research. The use of mentioned methods based on experts' opinions facilitated decision-making process, as they only have to assess the values of alternatives in line to specific secondary criteria and determine the importance of the main criteria. This made it much easier to gather data from the experts. Involvement of experts from Serbia enables transfer of knowledge and experience related to plum growing in BiH, what is highly recommended for further improvement of plum sector in BiH.

6. CONCLUSION

Selection of optimal fruit variety is among the most important steps in the process of new orchard establishment. Planting the wrong variety can result in weak orchard outcomes endangering the previously made investment. Therefore, adjusting the good agricultural practice requires selection of variety that will deeply justify the planned investment in fruit plantation establishment. The main goal of this study is facilitation of decision-making process towards the selection of optimal plum variety that will secure the best production results to fruit growers in BiH. To achieve this goal, a multi-criteria decision-making model based on multi-criteria analysis, expert assessment, fuzzy approach, and group decision-making were designed and carried out.

The FUCOM and CRITIC methods were used to define the weights of criteria. Besides, the fuzzy MARCOS method was applied to rank the assessed solutions. Based on experts' experience and knowledge, the most commonly grown plum varieties in BiH and wider region were evaluated, while there were identified those that demonstrate the best production results. Engaged experts are the representatives of scientific-research sector in Serbia, focused to plum growing. The main reason for their involvement was in enabling the knowledge transfer towards the specific varieties to fruit growers in BiH, as the Serbian plum sector is globally recognized.

Derived results from performed complex analysis show that the Čačanska rodna plum variety provides the best production results, while the use of Prezident plum variety could not fully satisfy the grower's expectations. Gained results were furtherly confirmed throughout the sensitivity analysis. At the end, gained research results provide strong recommendation regarding the plum varieties that should be favorited in BiH, supporting the decision-making process at the level of fruit growers, and simultaneously contributing the advancement of BiH plum production sector.

The limitations of this research primarily pertain to the selection of plum varieties. While the reasons behind choosing these specific varieties are well-founded, it is important to address why these varieties were favored over others. An analysis of the market in BiH reveals that these varieties are the most widely available. In future research, it is imperative to expand the scope by considering alternative plum varieties and comparing their performance with those in this study. It is possible that newer varieties could potentially deliver better results. Furthermore, it is vital to incorporate plum varieties from other countries, ensuring the broader applicability of the research findings beyond the Western Balkans. By including international perspectives, the decision-making process for planting plum orchards can be enhanced not only in the Western Balkan nations but also in a global context. In terms of methodology, an apparent limitation lies in the application of these methods. However, it's worth noting that validation of the results has demonstrated that the outcomes obtained using the WASPAS method closely align with those generated by other fuzzy methods employed. Future research should explore alternative methods for determining criteria weights, further enhancing the robustness and reliability of the research outcomes..

The utilized model demonstrates high flexibility and yields the reliable results and conclusions towards the selection of optimal plum variety. In future research, the presented model could be additionally modified and fine-tuned in line to predefined decision-making issues (also, some other criteria should be included). Or, set decision-making model could be advanced and applied on certain new issues that are not reconsidered in performed research, or it could be applied on another fruit production sectors, or other sectors of the economy. All in all, performed research has laid a solid foundation for the future development of presented model (methodology).

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