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A model for supporting the decision of plum variety selection based on fuzzy logic

Model za podršku odlučivanju izbora sorte šljive zasnovan na fuzzy logici

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ABSTRACT

The choice of the appropriate variety of fruit is one of the most important factors in establishing new orchards. It is necessary to choose the variety that will give the best results in meeting the investment goals. This paper offered an innovative decision support model for plum variety selection, based on expert decision making and fuzzy logic. The fuzzy MARCOS (Measurement Alternatives and Ranking according to COmpromise Solution) method was used. The research was conducted with the aim of improving plum production in Bosnia and Herzegovina (BiH). To achieve this, the knowledge of experts from the Republic of Serbia was used, because this country is currently the third in the world in plum production and have branded many plum varieties. The results obtained using this model showed that two plum varieties stand out - Čačanska rodna and Stanley. These results were also confirmed by the performed sensitivity analysis. The worst results were obtained by the Šumadijka variety. These results will help in the selection of plum varieties when establishing new orchards in BiH to achieve the best results in Bosnian plum production.

Keywords: decision support model, fuzzy logic, MARCOS method, plum variety

SAŽETAK

Izbor odgovarajuće sorte voća je jedan od najvažnijih čimbenika kod podizanja novih voćnjaka. Potrebno je odabrati sortu koja će dati najbolje rezultate da bi se ispunili ciljevi ulaganja. Ovaj rad je ponudio inovativni model za podršku odlučivanju pri izboru sorti šljiva zasnovan na ekspertnom odlučivanju i fuzzy logici. Pri tome je korištena fuzzy MARCOS (Measurement Alternatives and Ranking according to COmpromise Solution) metoda. Istraživanje je provedeno s ciljem poboljšanja proizvodnje šljive u Bosni i Hercegovini (BiH). Za postizanje ovog cilja korištena su znanja stručnjaka iz Republike Srbije, jer je to trenutno treća zemlja u svijetu po proizvodnji šljive i brendirali su brojne sorte šljiva. Rezultati dobiveni korištenjem ovog modela pokazali su da se dvije sorte šljiva naročito izdvajaju od drugih, a to su sorte Čačanska rodna i Stanley. Rezultati su potvrđeni i provedenom analizom osjetljivosti. Najlošije rezultate je ostvarila sorta Šumadijka. Dobiveni rezultati će pomoći pri odabiru sorti šljiva za podizanje novih voćnjaka u BiH kojima bi se ostvarili najbolji nacionalni rezultati u proizvodnji šljive.

Ključne riječi: fuzzy logika, MARCOS metoda, model potpore odlučivanju, sorte šljiva

INTRODUCTION

Plum is produced worldwide as the second stone fruit (Petri et al., 2018). The plum fruit is adapted to a temperate climate (Maglakelidze et al., 2017). Based on that, plums are grown all over the world. The two most important plum subspecies are: European (Prunus domestica) and Japanese plum (Prunus salicina). The European plum is the subject of this research. The plum fruit can be used for various purposes: plums can be consumed fresh, dried in the form of various jams and sweet, but plums also can be processed into alcoholic and non-alcoholic beverages. The most famous alcoholic drink made of plums is "Rakija" or "Šljivovica" (Milošević et al., 2013).

In the last century, the former Yugoslavia was the largest producer of plums in Europe (Salkić et al., 2019), and in Bosnia and Herzegovina (BiH) plums are the national fruit and the most represented in fruit production. However, plum production in BiH stagnated and declined as fruit growers opted to produce other types of fruit. However, due to the constant demand for plums, fruit growers in BiH are increasingly raising new plum orchards. The reason for this should be sought in the fact that many products can be made from plum fruits, so this fruit is profitable and suitable for production (Rozman et al., 2017). In addition, BiH has excellent agroecological conditions for plum cultivation (Salkić et al., 2019).

To increase production in BiH it is needed to look at many factors, the most important of which are: site selection, agrochemical soil analysis, soil preparation and variety selection (Maksimović et al., 2016).

The choice of variety that will give the best results when establishing new orchards is certainly one of the most important factors (Vávra et al., 2018). Therefore, it is necessary to examine which varieties shows the best characteristics. When choosing the appropriate variety, it is necessary to consider various factors and make decisions based on several criteria. Sometimes the alternative may not be the best by all criteria, and the decision is made based on compromise solutions. In addition, fruit growers are often found with large amounts of data being considered in a range of multiple methods (Rozman et al., 2015).

Fuzzy logic is closer to human thinking especially when it is difficult to determine precise values (Puška et al., 2018). In addition, this logic is used when it is necessary to transform human thinking into a mathematical model that is solved by applying the fuzzy method. These methods are used when it is necessary to analyze several different alternatives that are available, and all these alternatives are evaluated using different criteria (Rozman et al., 2017).

The use of methods and models based on fuzzy logic in fruit growing is very widespread. Berk et al. (2019) used fuzzy logic to determine the doses of plant protection products in apple orchards. Papageorgiou et al (2018) used a fuzzy inference system (FIS) and an adaptive neuro-fuzzy inference system (ANFIS) to determine the apple quality classification. Paunović et al. (2018) used FIS to select cherry varieties when establishing orchards. Prabakaran et al. (2018) used fuzzy logic to reduce fertilizer consumption and increase productivity in orchards. Teoh et al. (2013) applied fuzzy logic for mango fruit sorting. Based on these and similar papers conclusion is that the application of fuzzy logic is represented in all segments of fruit production. Therefore, it is necessary to create a model and methodology that will facilitate decision making in fruit growing using linguistic values based on fuzzy logic. This paper, unlike similar fuzzy models and approaches used in agriculture, attempts to offer a simple and flexible approach based only on linguistic values. Closer to human thinking are the notion of values as little-big, long-short, good-bad, than giving numerical ratings (Rozman et al, 2017). Therefore, it is necessary to use linguistic values to facilitate a decision-making process. Another reason for creating this approach is to solve the problem and decide without too much mathematization. The reason for this should be sought in the excessive mathematization and performance of complicated calculations when applying fuzzy logic. In agricultural practice, it is necessary to decide easily and quickly, and this work helps farmers with it. This paper aims to help the fruit growers in the form of decision support models in the selection of plum varieties based on fuzzy logic.

To realize the research objective the decision model is formed based on usage of fuzzy MARCOS (Measurement Alternatives and Ranking according to COmpromise Solution) method. Fuzzy MARCOS is only one of the methods that use the fuzzy logic and can be used in this example. To confirm the results and the model, a comparison with other fuzzy methods will be performed. In this way, it will be shown that other methods can be used in solving decision-making problems in fruit growing based on the use of fuzzy logic.

When decision making, it is necessary to gather all the necessary information to obtain a decision. Information can be obtained in various ways, and this paper will use the knowledge of an expert who will provide the necessary information. Expert decision-making is applied when it is necessary to systematize the determinations of expert knowledge to evaluate certain alternatives. Since four experts were involved in this research, the model will be based on group decision making. The contribution of this approach is as follows:

- Facilitate decision-making in fruit growing on the example of choosing plum varieties when establishing orchards
- Considering different criteria in decision making
- Create a simple methodology based on linguistic values that are more adapted to human thinking
- Provide a model to help fruit growers make decisions.

MATERIALS AND METHODS

In this research, decision-making through a decision support model will be based on the use of fuzzy logic and the application of the fuzzy MARCOS (Measurement Alternatives and Ranking according to COmpromise Solution) method. The research methodology was as follows:

- Defining research problems and research goals
- Selection of experts
- Selection of criteria and alternatives by experts
- Creating a model to support decision-making
- Creating a model-based questionnaire
- Completion of questionnaires by experts
- Forming a decision matrix
- Implementing the steps of the fuzzy MARCOS method
- Ranking the alternatives
- Conducting sensitivity analysis.

After the problem and goals of the research, research directions are defined. Since the problem here is decision-making with multiple criteria, it was necessary to apply an appropriate method and the fuzzy MARCOS method was chosen. Then it was necessary to create a decision model. To create a model, it was necessary to select experts on whose knowledge this decision-making will be based. These experts were selected from the neighbouring Republic of Serbia, namely professors of fruit growing at the faculties of agronomy in Novi Sad, Niš and experts from the Institute of fruit growing in Čačak. The reason why these experts were taken is to transfer their huge experience to fruit growers in BiH.

These experts first selected the criteria by which the alternatives in the form of plum varieties would be evaluated. These criteria are: C1 - Possibility of planting, C2 - Resistance of seedlings, C3 - Resistance to pests, C4 - Resistance to diseases, C5 - Size and shape of fruit, C6 - Ratio of acid and sugar, C7 - Quality of fruit, C8 - Possibility of storage, C9 - Possibility of sale and C10 - Costs of establishing orchards. In selecting these criteria, the experts used the following studies: Farag et al. (2012), Rozman et al. (2015), Milovanović and Stojanović (2016), Maksimović et al. (2017), Rozman et al. (2017), Paunović et al. (2018), Maksimović et al. (2018). Then they chose the alternatives that are mostly grown in these areas and which showed the best results, namely: A1 - Čačanska lepotica, A2 - Čačanska rodna, A3 - Stanley, A4 - Požegača, A5 - Šumadinka and A6 - President. Based on these criteria and alternatives, a decision support model was formed. The model consists of the elements that make up the decision matrix. Each of the elements is marked with the designation xij, where the designation “i” indicates the value of the alternative (in this case of the plum variety), while the designation “j” indicates the criterion by which a particular alternative is observed. Take as an example the element x_{24}, it denotes the value of alternative A2 (Čačanska rodna) according to the observed criterion C4 (Resistance to diseases). Using this approach, a decision matrix is formed. Using this model, a questionnaire was created and sent to experts. The experts first had to determine the importance of each criteria and the importance of each alternative in the observed criterion (Table 1). The experts selected the appropriate value for the criterion and the appropriate value for the alternatives of the selected criterion.

Based on the collected data, an initial decision matrix was formed, which is the first step in implementing the fuzzy MARCOS method. After that, using the steps of this method, the ranking order of alternatives of this research was determined. The steps in implementing the fuzzy MARCOS method will be presented below. Finally, a sensitivity analysis was performed to confirm the results obtained. Before explaining the steps in implementing the fuzzy MARCOS method, it is necessary to first explain the fuzzy logic.

Fuzzy logic

Zadeh (1965) set the foundations of fuzzy logic. In his work, he said: in order to deal with very complex problems, we do not have to move towards rigor, greater accuracy of description and thinking about phenomena, but we can go in the opposite direction and allow descriptions to be inaccurate in the spirit of natural language (Zadeh, 1965). Fuzzy sets have two different meanings, a narrower approach in which fuzzy logic is an extension of classical logic and a broader approach where fuzzy logic is used for sets that have no clear boundaries. When using fuzzy logic, it is necessary to determine the membership function $\mu_{\tilde{A}}(x)$. It shows how much an individual element meets the condition of belonging to set A. The membership function can have any value in the interval from zero to one. If the statement has "more truth", it will to a greater extent meet the conditions of belonging to the set A, respectively $0 \leq \mu_{\tilde{A}}(x) \leq 1$ is valid for each element from the set A. This research will use a triangular fuzzy number whose membership function is defined as:

$$\mu_A(x) = \begin{cases} 0, x < a \\ \frac{(x-a)}{(b-a)}, \ a \leq x \leq b \\ \frac{(c-x)}{(c-b)}, \ b \leq x \leq c \\ 0, \ x > c \end{cases} \quad (1)$$

These belong to triangular fuzzy numbers (Figure 1).

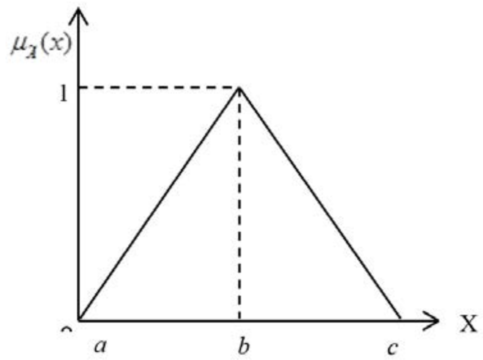

Figure 1. Membership functions for triangular fuzzy numbers

Based on this, it is concluded that each fuzzy set is completely and uniquely determined by the membership function. According to fuzzy theory, the choice of the affiliation function, the form of the function and the width of the confidence interval, is most often made based on subjective assessment or experience (Božanić and Pamučar, 2010). The operations that can be done when we have two fuzzy sets $\tilde{A}_1 = (m_1, m_2, m_3)$ and $\tilde{A}_2 = (n_1, n_2, n_3)$ are:

Addition of fuzzy numbers: (2)

$\tilde{A}_1 + \tilde{A}_2 = (m_1, m_2, m_3) + (n_1, n_2, n_3) = (m_1 + n_1, m_2 + n_2, m_3 + n_3)$

Subtracting fuzzy numbers: (3)

$\tilde{A}_1 - \tilde{A}_2 = (m_1, m_2, m_3) - (n_1, n_2, n_3) = (m_1 - n_1, m_2 - n_2, m_3 - n_3)v$

Multiplication of fuzzy numbers: (4)

$\tilde{A}_1 \times \tilde{A}_2 = (m_1, m_2, m_3) \times (n_1, n_2, n_3) = (m_1 \times n_1, m_2 \times n_2, m_3 \times n_3)$

Division of fuzzy numbers: (5)

$\tilde{A}_1 \div \tilde{A}_2 = (m_1, m_2, m_3) \div (n_1, n_2, n_3) = (m_1 \div n_1, m_2 \div n_2, m_3 \div n_3)$

Linguistic values will be used to apply fuzzy logic. The concept of linguistic values is useful in resolving situations that are too complex or not well defined to be valued in quantitative terms. In these cases, linguistic values are used.

When determining the degree of a linguistic value importance, they can be unimportant, moderately important, important, and very important. The following linguistic values can be set to determine the weight of the criteria: very low, low, medium, high, and very high.

To use linguistic values, it is necessary to transform these values into appropriate fuzzy numbers and for that the affiliation function is used. By applying the affiliation function, linguistic values are transformed into quantitative values in the form of fuzzy numbers. By applying fuzzy numbers, it is possible to apply appropriate fuzzy methods when evaluating alternatives that may be different in fruit growing. In this paper, the function shown in Table 1 will be used.

Fuzzy MARCOS method

The MARCOS (Measurement Alternatives and Ranking according to COmpromise Solution) method was developed by the authors Stević et al. (2020) and it represents a new method of multicriteria analysis. The MARCOS method is based on a defined relationship between alternatives and the reference values of those alternatives that represent ideal and anti-ideal points. Decision making using the MARCOS method is based on the utility function (Puška et al., 2020). The utility function represents an alternative to the ideal and anti-ideal solution (Stanković et al., 2020). The best alternative is the one that is closest to the ideal and at the same time the furthest from the anti-ideal reference point (Stević and Brković, 2020). A fuzzy version of the MARCOS method was developed by Stanković et al. (2020). This method is calculated using the following steps:

Step 1. Forming an initial fuzzy decision matrix. When forming the initial decision matrix, a value is formed for each alternative i = (1, 2, 3..., n) according to defined criteria j = (1, 2, 3..., m), and the value is determined x_{ij} for all elements of the decision matrix giving the value of alternatives for individual criteria.

Step 2. Expand the initial fuzzy decision matrix. In this step, the initial matrix is expanded with anti-ideal (AAI) and ideal solution (AI). Anti-ideal solution (AAI) is an alternative with the worst characteristics, ideal solution (AI) is an alternative with the best characteristics (Stević and Brković, 2020).

The anti-ideal solution (AAI) is obtained by applying the following expression:

$$AAI = \min_j x_{ij} \quad \text{if } j \in B \quad \text{and} \quad \max_j x_{ij} \quad \text{if } j \in C \tag{6}$$

The ideal solution (AI) is obtained using the following expression:

$$AI = \max_j x_{ij} \quad \text{if } j \in B \quad \text{and} \quad \min_j x_{ij} \quad \text{if } j \in C \tag{7}$$

B represents the benefit criteria that need to be maximized, while C represents the cost criteria that need to be minimized.

Step 3. Normalize the initial fuzzy decision matrix. Normalization is performed using the following expressions depending on the criterion in question:

Table 1. Fuzzy number correlation function for criterion values and for evaluating alternatives

Linguistic values	Fuzzy numbers	Linguistic values	Fuzzy numbers
Very low (VL)	(0, 0, 0.1)	Very bad (VB)	(0,0,1)
Low (L)	(0, 0.1, 0.3)	Bad (B)	(0,1,3)
Medium low (ML)	(0.1, 0.3, 0.5)	Medium bad (MB)	(1,3,5)
Medium (M)	(0.3, 0.5, 0.7)	Medium (M)	(3,5,7)
Medium High (MH)	(0.5, 0.7, 0.9)	Medium good (MG)	(5,7,9)
High (H)	(0.7, 0.9, 1)	Good (G)	(7,9,10)
Very High (VH)	(0.9, 0.9, 1)	Very Good (VG)	(9,10,10)

$$\tilde{n} = \left(n_{ij}^{l}, n_{ij}^{m}, n_{ij}^{u}\right) = \left(\frac{x_{id}^{l}}{x_{ij}^{u}}, \frac{x_{id}^{l}}{x_{ij}^{m}}, \frac{x_{id}^{l}}{x_{ij}^{l}}\right) \ if\ j \in C \tag{8}$$

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

where *l* is the first fuzzy number, *m* is the second fuzzy number and *u* is the third fuzzy number.

Step 4. Complicate the normalized decision matrix with the following expression:

$$\tilde{v}_{ij} = \left(v_{ij}^{l}, v_{ij}^{m}, v_{ij}^{u}\right) = \tilde{n}_j \times \tilde{w}_j \tag{10}$$

Step 5. The calculation of the *Si* matrix implies the sum of values by rows (alternatives) including the anti-ideal and ideal solution by the following expression:

$$S_i = \sum_{i=1}^{n} v_{ij} \tag{11}$$

Step 6. Calculation of the degree of usefulness of *Ki* in relation to the anti-ideal and ideal solution using the following terms:

$$\tilde{K}_i^- = \left(\frac{\tilde{S}_i}{\tilde{S}_{ai}}\right) = \left(\frac{s_i^l}{s_{ai}^u}, \frac{s_i^m}{s_{ai}^u}, \frac{s_i^u}{s_{ai}^u}\right) \tag{12}$$

$$\tilde{K}_i^+ = \left(\frac{\tilde{S}_i}{\tilde{S}_{id}}\right) = \left(\frac{s_i^l}{s_{id}^u}, \frac{s_i^m}{s_{id}^u}, \frac{s_i^u}{s_{id}^u}\right) \tag{13}$$

Step 7. Calculate the fuzzy matrix $\tilde{T}_i$ using the expression:

$$\tilde{T}_i = \tilde{t}_i = \left(t_i^l, t_i^m, t_i^u\right) = \tilde{K}_i^- + \tilde{K}_i^+ = \left(\tilde{k}_i^{-l} + \tilde{k}_i^{+l}, \tilde{k}_i^{-m} + \tilde{k}_i^{+m}, \tilde{k}_i^{-u} + \tilde{k}_i^{+u}\right) \tag{14}$$

Determining the fuzzy number $\tilde{D}$ using the expression:

$$\tilde{D} = \left(d^l, d^m, d^u\right) = \max_i \tilde{t}_{ij} \tag{15}$$

Step 8. Rephase fuzzy numbers using the following expression:

$$df_{def} = \frac{l+4m+u}{6} \tag{16}$$

Step 9. Determining the utility function *f(Ki)* through the aggregation of the utility functions according to the anti-ideal solution a) and the ideal solution b).

a) Utility function according to the anti-ideal solution

$$f\left(\tilde{K}_i^+\right) = \frac{\tilde{K}_i^-}{df_{def}} \tag{17}$$

b) Utility function according to the ideal solution

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

Step 10. Calculate the final utility function:

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1-f(K_i^+)}{f(K_i^+)} + \frac{1-f(K_i^-)}{f(K_i^-)}}; \tag{19}$$

Step 11. Ranking alternatives. The best alternative is the one with the highest value, while the worst is the alternative with the lowest value.

RESULTS

When collecting data from the expert, the experts first had to determine the weight of the criteria used in this model. The weights of the criteria ranged from "medium" to "very high". Expert 1 gave the highest weight to criterion C7, while the lowest weight was given to criterion C1. Expert 2 gave the highest weights to criteria C3, C5, C7, C9 and C10, while assigning the lowest weight to criteria C1 and C8. Expert 3 gave the highest weights to criteria C1, C4, C7 and C10, while the lowest weight was given to criterion C6. Expert 4 gave the highest weights to criteria C9 and C10, while the lowest weights were given to criteria C2 and C6.

After the experts have given the linguistic values of the weight criteria, it is necessary to transform these weights using the membership function (Table 1). In order to take into account the opinion of all experts, these weights were harmonized by an arithmetic mean (Pamučar et al. 2018). In this way, the mean value of these weights obtained by the experts was calculated. The results show that the highest weight was given to criterion C9, while the lowest weight was given to criterion C6.

To determine the values of the alternatives, the experts evaluated all the alternatives through linguistic values according to the selected criteria. In that way, the initial decision matrix was formed, which needs to be transformed through the membership function (Table 1). For this initial decision matrix to be applied, it is necessary to form a collective fuzzy decision matrix. This matrix is obtained by calculating the average values for the observed varieties. This transformed decision matrix is the basis for calculating the values of selected varieties by experts and is the first step in the fuzzy MARCOS method.

The 2nd step of the fuzzy MARCOS method is to extend this matrix by determining the ideal and anti-ideal point (expressions 6 and 7). The 3rd step is data normalization (expression 8). The 4th step is to multiply the extended normalized fuzzy decision matrix by the criterion weights. The 5th step is the calculation of the Si matrix which implies the sum of the values of the alternatives by rows. This sum is made for both the anti-ideal and the ideal solution (expression 10). The 6th step is to calculate the degree of utility according to the anti-ideal and ideal solution (expressions 11 and 12) (Table 5). The sum of the alternative values, ideal and anti-ideal solutions, is formed by adding the values that make it difficult to normalize the decision matrix. These values are used to calculate the utility value. Utility function values K_i^- are formed based on the sum of the ideal solution, while the value K_i^+ is formed based on anti-ideal solutions. The reason for this is that a certain alternative should be as close as possible to the ideal solution, and as far as possible from the anti-ideal solution.

The 7th step is to calculate the fuzzy matrix $\tilde{T}_i$ (expression 14). The utility values of the anti-ideal and ideal solution are summed for the alternatives and the maximum values of the individual fuzzy numbers are determined. The 8th step is to phase out these maximum values of fuzzy numbers (expression 16) and calculate the df_{crisp} values. df_{crisp} values is the basis for determining the utility function. The utility function is obtained by placing the corresponding utility function in relation to the value df_{crisp}.

Calculating the value of df_{crisp} is done as follows: df_{crisp} = (1.16 + 3.84 + 5.53) / 6 = 3.67. This value is used to calculate the utility function according to anti-ideal and ideal solutions. The 9th step is to calculate the value of the utility function. The first utility function is calculated by dividing the utility efficiency values according to the anti-ideal solution (K_i^-) by the df_{crisp} value.

Table 2. Evaluation of criteria by experts

Expert	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Expert 1	M	H	MH	MH	H	MH	VH	MH	H	MH
Expert 2	M	MH	H	MH	H	MH	H	M	H	H
Expert 3	H	MH	MH	H	MH	M	H	MH	VH	H
Expert 4	MH	M	MH	MH	MH	M	MH	MH	H	H

Table 3. Weights of the main criteria

Expert	Expert 1	Expert 2	Expert 3	Expert 4	Average
C1	0.3 0.5 0.7	0.3 0.5 0.7	0.7 0.9 1.0	0.5 0.7 0.9	0.45 0.65 0.83
C2	0.7 0.9 1.0	0.5 0.7 0.9	0.5 0.7 0.9	0.3 0.5 0.7	0.50 0.70 0.88
C3	0.5 0.7 0.9	0.7 0.9 1.0	0.5 0.7 0.9	0.5 0.7 0.9	0.55 0.75 0.93
C4	0.5 0.7 0.9	0.3 0.5 0.7	0.7 0.9 1.0	0.5 0.7 0.9	0.55 0.75 0.93
C5	0.7 0.9 1.0	0.5 0.7 0.9	0.5 0.7 0.9	0.5 0.7 0.9	0.60 0.80 0.95
C6	0.5 0.7 0.9	0.7 0.9 1.0	0.3 0.5 0.7	0.3 0.5 0.7	0.40 0.60 0.80
C7	0.9 1.0 1.0	0.5 0.7 0.9	0.7 0.9 1.0	0.5 0.7 0.9	0.70 0.88 0.98
C8	0.5 0.7 0.9	0.7 0.9 1.0	0.5 0.7 0.9	0.5 0.7 0.9	0.45 0.65 0.85
C9	0.7 0.9 1.0	0.7 0.9 1.0	0.9 1.0 1.0	0.7 0.9 1.0	0.75 0.93 1.00
C10	0.5 0.7 0.9	0.7 0.9 1.0	0.7 0.9 1.0	0.7 0.9 1.0	0.65 0.85 0.98

Table 4. Initial decision matrix

Expert 1	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	M	MG	M	MG	G	VG	M	MG	M	MG
A2	G	VG	VG	G	MB	MG	G	G	MG	MB
A3	VG	MG	G	M	G	M	M	MG	MB	G
A4	VG	VG	B	B	MG	M	MG	M	M	B
A5	B	MG	MG	VG	MG	MG	B	MB	VB	MB
A6	B	MG	MG	VG	MG	MG	B	MB	M	M
Expert 2	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	MG	MG	M	M	VG	G	MB	MG	M	VG
A2	G	G	VG	VG	M	M	MG	VG	G	MB
A3	G	G	MG	M	G	M	MG	MG	M	VG
A4	MG	VG	B	MB	MG	MB	G	M	MG	B
A5	MG	M	MG	B	M	VG	MB	B	B	B
A6	B	MG	G	G	G	MG	B	VB	M	M
Expert 3	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	VG	G	MG	VG	VG	G	MG	G	MG	VG
A2	VG	VG	VG	VG	MG	MG	G	VG	VG	M
A3	VG	VG	G	G	VG	MG	G	MG	G	VG
A4	G	VG	MB	MG	G	M	VG	MG	MG	M
A5	G	MG	G	MB	MG	VG	M	MB	MB	M
A6	MB	MG	VG	VG	VG	G	MG	MB	G	G
Expert 4	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	M	MB	B	B	MG	MG	B	MB	B	G
A2	MG	MG	MG	MG	B	B	MB	M	MG	M
A3	MG	MG	M	B	MB	M	M	MB	MB	VG
A4	M	G	VB	B	M	B	MG	B	M	VB
A5	MB	B	M	VB	MB	MG	B	VB	VB	B
A6	VB	MB	G	MG	M	MB	VB	VB	B	MB

Table 5. Summarizing, calculating the degree of utility and Fuzzy matrix $\tilde{T}_i$

	Si	K_i^-	K_i^+		
Ideal	4.28 6.95 9.10	0.47 1.00 2.13	1.09 3.73 4.17		$\tilde{T}_i$
A1	2.69 5.00 7.48	0.30 0.72 1.75	0.68 2.68 3.43		0.98 3.40 5.18
A2	3.20 5.64 7.99	0.35 0.81 1.87	0.81 3.03 3.66		1.16 3.84 5.53
A3	2.99 5.45 7.89	0.33 0.78 1.84	0.76 2.93 3.61		1.09 3.71 5.45
A4	2.16 4.12 6.46	0.24 0.59 1.51	0.55 2.21 2.96		0.79 2.81 4.46
A5	1.42 3.13 5.46	0.16 0.45 1.28	0.36 1.68 2.50		0.52 2.13 3.78
A6	2.18 4.17 6.46	0.24 0.60 1.51	0.56 2.24 2.96		0.80 2.84 4.47
Anti-ideal	0.65 1.86 3.93	0.07 0.27 0.92	0.17 1.00 1.80	Max	1.16 3.84 5.53

Table 6. Utility functions and rephased values of utility level and utility function

Alternative	$f(\tilde{K}_i^-)$	$f(\tilde{K}_i^+)$	$d\tilde{K}_i^-$	$d\tilde{K}_i^+$	$df(\tilde{K}_i^-)$	$df(\tilde{K}_i^+)$
A1	0.19 0.73 0.93	0.08 0.20 0.48	0.820	2.474	0.673	0.223
A2	0.22 0.82 1.00	0.10 0.22 0.51	0.911	2.764	0.752	0.248
A3	0.21 0.80 0.98	0.09 0.21 0.50	0.884	2.679	0.729	0.241
A4	0.15 0.60 0.80	0.06 0.16 0.41	0.686	2.061	0.561	0.187
A5	0.10 0.46 0.68	0.04 0.12 0.35	0.539	1.597	0.435	0.147
A6	0.15 0.61 0.81	0.07 0.16 0.41	0.692	2.079	0.566	0.188

Table 7. Final rank of alternatives

Alternative	K_i	Rank
A1	0.663	3
A2	0.842	1
A3	0.787	2
A4	0.448	5
A5	0.263	6
A6	0.456	4

The second utility function is calculated by dividing the utility degree values according to the ideal solution (K_i^+) by the df_{crisp} value. After calculating the degree of utility and utility function it is necessary to transform these values which are in the form of fuzzy numbers into crips numbers. This is achieved by applying the expression 16.

Then it is necessary to rephase all utility values and utility functions, to be able to calculate the final utility function - the rank order based on the fuzzy MARCOS method. The 10th step is to calculate the utility function (expression 19). The obtained results of group expert decision-making showed that the best ranked alternative is A2-Čačanska rodna, followed by A3-Stanley, while the worst ranked alternative is A5-Šumadinka. A sensitivity analysis will be performed to confirm these results.

Sensitivity analysis and validation of results

Sensitivity analysis and validation of results was performed in two ways. First, the obtained results were examined using other fuzzy methods. The aim of this is to confirm or reject the results obtained using the fuzzy MARCOS method. Second, the sensitivity of the ranked alternatives to the change of weight criteria was examined. The aim of this analysis is to examine the dependence of certain varieties on individual criteria and how they cause a change in the rank of alternatives.

To confirm the results obtained by fuzzy MARCOS, it is necessary to compare these results with the results obtained by applying other fuzzy methods (Stević et al., 2020). The following methods were used to test the results obtained by the fuzzy MARCOS method: fuzzy SAW (Simple Additive Weighting technique), fuzzy MABAC (Multi-Attributive Border Approximation area Comparison), fuzzy ARAS (Additive Ratio ASsessment), fuzzy TOPSIS (Technique for Order Performance by Similarity to Ideal Solution), fuzzy WASPAS (Weighted Aggregated Sum Product ASsessment).

The results of the analysis of these methods showed that only the fuzzy WASPAS method has a different order of alternatives. The alternatives A4 and A6 have replaced the ranking order compared to other fuzzy methods (Figure 3). The reason for this should be sought in the fact that there is small difference between the results of these alternatives and therefore it was to be expected that some of the methods would give a different ranking order. The results of the fuzzy MARCOS method are the same as results of other fuzzy methods. Based on this, it can be concluded that the results obtained by the fuzzy MARCOS method were confirmed.

The second step of this analysis is the application of sensitivity analysis. Sensitivity analysis was performed by changing the weights of the criteria (Božanić et al., 2019) and observe how changing one of the criteria has an impact on the overall ranking of plum varieties. In addition, the task of sensitivity analysis is not only to consider the impact of different criteria on the change in the value of alternatives, but also the impact of these changes on the overall assessment of alternatives (Puška et al., 2019). When examining the influences that the weights of the sub-criteria have, 11 scenarios were formed. The first scenario gave the same importance to all criteria, namely

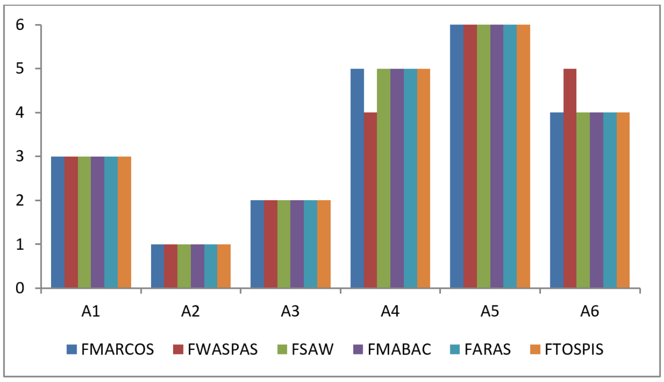

Figure 2. Rank of alternatives with different fuzzy methods

Table 8. Scenarios in sensitivity analysis

Scenario	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Scenario 1	M	M	M	M	M	M	M	M	M	M
Scenario 2	VH	M	M	M	M	M	M	M	M	M
Scenario 3	M	VH	M	M	M	M	M	M	M	M
Scenario 4	M	M	VH	M	M	M	M	M	M	M
Scenario 5	M	M	M	VH	M	M	M	M	M	M
Scenario 6	M	M	M	M	VH	M	M	M	M	M
Scenario 7	M	M	M	M	M	VH	M	M	M	M
Scenario 8	M	M	M	M	M	M	VH	M	M	M
Scenario 9	M	M	M	M	M	M	M	VH	M	M
Scenario 10	M	M	M	M	M	M	M	M	VH	M
Scenario 11	M	M	M	M	M	M	M	M	M	VH

the value "medium". In the other 10 scenarios, a certain criterion was assigned a value of "very high" while the other criteria were assigned a value of "medium" (Table 8).

The results of this sensitivity analysis show that alternative A2 has the best ranking in 9 scenarios while in 2 scenarios alternative A3 has the best ranking. These results point to the fact that alternative A3 has better indicators in criterion C5 which shows what the size and shape of the fruit is, and in criterion C10 which shows what the costs of establishing orchards are. Alternative A1 took 3rd place in all scenarios, alternative A6 took 4th place in the ranking in 6 scenarios, while Alternative A4 took 4th place in 5 scenarios. In all implemented scenarios, the A5 alternative has the worst ranking compared to the other alternatives.

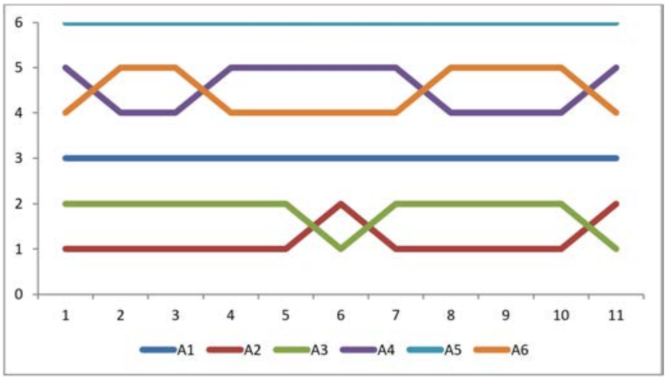

Figure 3. Ranking during sensitivity analysis

Based on the obtained results of the performed sensitivity analysis, it can be concluded that the results obtained by the fuzzy MARCOS method can be confirmed.

CONCLUSION

An innovative decision support model was used in this paper. To obtain results using this model, group expert decision-making based on linguistic values was used. Linguistic values are much closer to human thinking and it is used when it is necessary to nuance the values of certain alternatives. In addition, fuzzy logic and the fuzzy MARCOS method were used to obtain results based on linguistic values. Professors of fruit growing at the faculties of agronomy in the Republic of Serbia were taken as experts. These professors were taken to impart knowledge about plum cultivation and selection of plum varieties that should achieve the best results of all plum varieties used. Four decision-making experts were used. The use of more experts in decision-making leads to a greater possibility of creating conflict situations since more experts involved entail the problem of harmonizing their opinions, which can be very different. The experts selected the criteria and alternatives used in this study. The results showed that two varieties of plums stand out from the others, namely the varieties Čačanska rodna and Stanly. These results were confirmed by the performed sensitivity analysis.

In future research, it is necessary to take more varieties of plums that could be planted in BiH and include other criteria for multi-criteria analysis. It is also necessary to upgrade the model used because it has shown great flexibility in use and facilitates decision-making in fruit growing. This model should be used in future research in other decision-making problems in fruit growing, but it is necessary to adapt it to this problem. Adapting this model would be in the use of other criteria that would best solve this decision-making problem. Also, through sensitivity analysis it has been shown that other fuzzy methods can be used, not only the fuzzy MARCOS method. The choice of the method to be used is left to the discretion of future researchers because it has been proven that there are no large differences in the results obtained when using different fuzzy methods.

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