Rankıng Districts of Çanakkale in Terms of Rangeland Quality by Fuzzy MCDM Methods

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Due diligence of rangelands, which are among the renewable energy sources, is very important for improvement projects. In this study, it is proposed to use fuzzy multi-criteria decision-making (MCDM) methods as a supportive statistical approach in examining rangeland conditions. Among these methods, fuzzy AHP, TOPSIS and VIKOR are explained. Vegetation data of a rangeland condition determination project were examined by these methods. According to the results, the fuzzy MCDM methods provide effective support in determining the rangeland conditions numerically. For this reason, it is recommended to be used in similar studies.

Key Words: Rangeland condition; Fuzzy sets; MCDM; AHP; TOPSIS; VIKOR.

1. INTRODUCTION

Turkey's one of the most important renewable natural resources is rangelands (Altın et al. 2011). Many studies have been carried out under the coordination of TAGEM to classify the rangelands through vegetation studies to reveal the social, economic and environmental benefits of rangelands and to create breeding and management models suitable for rangeland condition (Avağ et al. 2012; Aydoğdu et al. 2020).

In the study on rangeland vegetation, first of all, key areas reflecting the situation as a result of rangeland management were discussed. In addition, the general structures of the vegetation developing depending on the environment and usage factors have also been one of the criteria taken into consideration in the selection of rangeland areas (Altın et al. 2011). In addition to soil and climate factors, grazing management is the determining factor in the formation and development of rangeland vegetation (Holechek et al. 2011). For this reason,

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soil and land characteristics and the effects of grazing were the criteria taken into account in the selection of rangeland parcels.

There are several methods used when determining rangeland conditions. One of them is to classify rangelands by calculating climax according to vegetation data. In this method, the climax is determined by summing the decreasers' and increasers' ratios (not the observed grass number, but the number of species) in the botanical composition (if the increasers' ratio is more than 20%, it is included in the calculation as 20%). The rangeland condition is said to be weak if the climax is less than 25%, moderate if it is between 26–50%, good if it is between 51–75%, and very good if it is between 76–100% (Altın et al. 2011). However, this classification may not reflect the amount of production per unit area of rangelands. In other words, the rangeland condition may not reflect the rangeland quality. For example, if the rate of decreasers is low, but the grass yield of the unit area is high, more animals can graze in the rangeland, which can increase the quality of the rangeland.

In this study, it was aimed to rank the rangelands in terms of quality by taking the factors that affect the vegetation of the rangelands (altitude, slope, erosion, stony and soil depth) and the families (grasses, legumes and other families), including grass species into account. It was aimed to determine the best rangeland. For this purpose, vegetation data were analyzed with fuzzy multi-criteria decision-making (MCDM) methods. The criteria considered in the study were altitude, slope, erosion, stony, soil depth, grasses ratio, legumes ratio, other families ratio, decreasers' ratio, increasers' ratio and invaders ratio. The alternatives that are districts of Çanakkale intended to be ranked are Central district, Ezine, Lapseki, Gökçeada, Ayvacık, Bayramiç, Gelibolu, Eceabat, Biga, Yenice and Çan districts.

Fuzzy MCDM methods have been developed to eliminate uncertainty and indecision in selection and ranking problems (Ilbahar et al. 2022). The purpose of these methods is to rank the alternatives or choose the best alternative in terms of certain criteria. During this selection, the opinions of the decision makers are also taken into account (Atalik and Şentürk 2019).

In this study, first of all, fuzzy MCDM methods AHP, TOPSIS and VIKOR are briefly explained. Then, the vegetation data obtained from the research carried out to determine the rangeland conditions of Çanakkale districts are examined with these three methods, and the districts are ranked in terms of rangeland quality and the best district is selected.

Fuzzy MCDM methods are generally applied for observational data, scales or scores. In this study, fuzzy MCDM methods are applied to an experimental data. In addition, with this study, the rangeland conditions are evaluated and ranked for the first time with fuzzy MCDM methods.

2. MATERIAL AND STATISTICAL METHOD

In this study, fuzzy AHP, TOPSIS and VIKOR methods, which are suitable for the structure of the application problem in Chapter 3, are mentioned. In solving the application problem, these methods are preferred; fuzzy AHP because the problem has a hierarchical structure, fuzzy VIKOR because the conflicting sub-criteria are under the same main cri-

Table 1. Significance scale for fuzzy AHP (Van Laarhoven and Pedrycz 1983)

Linguistic term	Fuzzy AHP (for triangular fuzzy number)	
	Scale	Reciprocal scale
Equally importance	(1, 1, 1)	(1, 1, 1)
Moderate importance of one over another	(2, 3, 4)	(1/4, 1/3, 1/2)
Essential or strong importance	(4, 5, 6)	(1/6, 1/5, 1/4)
Demonstrated importance	(6, 7, 8)	(1/8, 1/7, 1/6)
Extreme importance	(9, 9, 9)	(1/9, 1/9, 1/9)
Intermediate values between two adjacent judgements	(1, 2, 3)	(1/3, 1/2, 1)
	(3, 4, 5)	(1/5, 1/4, 1/3)
	(5, 6, 7)	(1/7, 1/6, 1/5)
	(7, 8, 9)	(1/9, 1/8, 1/7)

terion, and fuzzy TOPSIS because it gives satisfactory results, has a wide application area and has common processing steps with the fuzzy VIKOR.

While applying these methods, criteria and alternatives are initially evaluated by decision makers. In the literature, there are integrated fuzzy TOPSIS and/or VIKOR methods weighted with fuzzy AHP (Aktan and Samut 2013; Babashamsi et al. 2016; Dincer and Hacioglu 2015; Kahraman et al. 2020; Perçin and Aldalou 2018; Ramavandi et al. 2021; Rezaie et al. 2014; Stević et al. 2016; Suganthi 2018; Sun 2010; Taylan et al. 2020). This type of integrated weighting was not used in this study. Because, as can be seen in Table 13, the weight of 8 criteria of the problem was calculated as 0 (zero) in the fuzzy AHP application. Therefore, in the fuzzy TOPSIS and VIKOR methods, the criteria were weighted by scales not fuzzy AHP.

There are FAHP, FTOPSIS and FVIKOR techniques that are frequently used for different fuzzy number types (Han and Trimi 2018; Kahraman et al. 2017; Kutlu Gündoğdu and Kahraman 2019a,b; Rouyendegh et al. 2020). However, in this study, it was decided to use triangular fuzzy numbers due to its simplicity and popularity (Kizielewicz and Bączkiewicz 2021).

The methods are given in subsections, respectively.

2.1. FUZZY AHP

Fuzzy AHP method is the most preferred MCDM method in the presence of hierarchical criteria (Kubler et al. 2016). Thus, it is easier to overcome uncertainty in the decision-making process.

The main criteria, sub-criteria and alternatives related to the decision-making problem are evaluated by the decision makers and paired comparisons are made (Bakır and Atalık 2021). For these comparisons, AHP importance scale suggested by Saaty (1980) was used by adapting it to triangular fuzzy numbers. This scale is given in Table 1.

Extension analysis is applied to each object for each objective (g_i), $X = \{x_1, x_2, \ldots, x_n\}$ set of objects and $U = \{u_1, u_2, \ldots, u_m\}$ set of objectives. With the extension expression, it is stated how much this object fulfills the purpose. As a result, m-grain extension

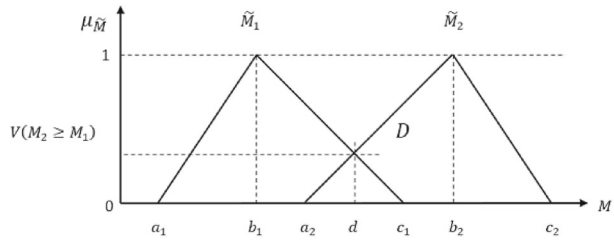


Figure 1. Intersection of $\tilde{M}_1$ and $\tilde{M}_2$.

analysis values, $M_{g_i}^1, M_{g_i}^2, \ldots, M_{g_i}^m$, $i = 1, 2, \ldots, n$ are obtained for each object. The $M_{g_i}^j$, $j = 1, 2, \ldots, m$ values are all triangular fuzzy numbers and are represented as $M_{g_i} = (a_i, b_i, c_i)$. Chang (1996)'s extension analysis method is performed with the following steps.

Step 1 According to the i.th objective, the fuzzy synthetic extended value is obtained by Eq. 1.

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} \tag{1}$$

To find the value of $\sum_{j=1}^{m} M_{g_i}^j$, the operations given by Eqs. 2, 3 and 4 are performed, respectively.

$$\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{j=1}^{m} a_j, \sum_{j=1}^{m} b_j, \sum_{j=1}^{m} c_j\right) \tag{2}$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{j=1}^{n} a_j, \sum_{j=1}^{n} b_j, \sum_{j=1}^{n} c_j\right) \tag{3}$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} = \left(\frac{1}{\sum_{j=1}^{n} c_j}, \frac{1}{\sum_{j=1}^{n} b_j}, \frac{1}{\sum_{j=1}^{n} a_j}\right) \tag{4}$$

For the comparison of fuzzy numbers, the weight vectors of the elements at each level of the hierarchy are obtained by using fuzzy synthetic values (Paksoy et al. 2013).

Step 2 The likelihood degree of $M_2 = (a_2, b_2, c_2) \geq M_1 = (a_1, b_1, c_1)$ is obtained by Eq. 5.

$$\begin{aligned} V(M_2 \geq M_1) &= \sup_{y \geq x} \left[\min\left(\mu_{M_1(x)}, \mu_{M_2(y)}\right)\right] \\ &= hgt(M_1 \cap M_2) = \mu_{M_2(d)} = \begin{cases} 1, & b_2 \geq b_1 \\ 0, & a_1 \geq c_2 \\ \frac{(a_1 - c_2)}{(b_2 - c_2) - (b_1 - a_1)}, & \text{others.} \end{cases} \end{aligned} \tag{5}$$

Here d is the ordinate of D, which is the highest intersection point between μ_{M_1} and μ_{M_2}. To compare M_1 and M_2, both $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$ must be calculated. The operations for this step are shown in Fig. 1 (Chang 1996).

Step 3 The degree of likelihood of a convex M fuzzy number greater than k-grain M_i ($i = 1, 2, \ldots, k$) fuzzy numbers is calculated by Eq. 6.

$$V\left(M \geq M_1, M_2, \ldots, M_k\right) = \min V\left(M \geq M_i\right), \; i = 1, 2, \ldots, k. \tag{6}$$

Here, the non-fuzzy weight vector given in Eq. 7 is obtained by making the assumption $d^{'}\left(A_i\right) = \min V\left(S_i \geq S_k\right)$ with $k = 1, 2, \ldots, n; i \neq k$.

$$W^{'} = \left(d^{'}\left(A_1\right), d^{'}\left(A_2\right), \ldots, d^{'}\left(A_n\right)\right)^T \tag{7}$$

Equation 8 is obtained by normalizing the weight vector (Karakiş 2019).

$$W = \left(d\left(A_1\right), d\left(A_2\right), \ldots, d\left(A_n\right)\right)^T \tag{8}$$

Step 4 The first three steps are repeated for pairwise comparisons of all (main and sub) criteria and each alternative under each sub-criterion. Finally, the preference weights of the alternatives are determined. When these preference values are sorted in descending order, the target ranking is obtained.

2.2. FUZZY TOPSIS

TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) is a multi-criteria decision-making method developed by Hwang and Yoon (1981) to select the alternative closest to the positive ideal solution and the farthest to the negative ideal solution. Its main idea is to rank the alternatives according to the distance between the positive and negative ideal solutions. In the fuzzy TOPSIS method, linguistically expressed evaluations are fuzzyficated, and uncertainty and indecision situations are overcome more easily. There are TOPSIS methods that work on uncertain data for different types of fuzzy numbers. These methods have gained popularity due to their ease of application and expression of preferences using fuzzy numbers, and are also used in many decision-making problems with uncertain data.

The operation steps of the fuzzy TOPSIS method for triangular fuzzy numbers are listed below (Chen 2000; Kutlu Gündoğdu and Kahraman 2019b).

Step 1 A decision-maker group consisting of "n" experts is formed.

Step 2 Determine "k" criteria and "m" alternatives.

Step 3 Appropriate linguistic terms are identified for evaluation of the criteria and alternatives.

While applying fuzzy TOPSIS on triangular fuzzy numbers, one of the scales used by decision makers to evaluate the criterion and alternatives is a seven-point scale, which is given in Table 2a, b, and c represent the lower, middle, and upper values for the triangular fuzzy number, respectively.

Table 2. Seven fuzzy scale and triangular fuzzy number equivalents used by decision makers to evaluate criteria and alternatives (Chen 2000)

Criteria				Alternatives			
Linguistic term	*a*	*b*	*c*	Linguistic term	*a*	*b*	*c*
Very low (V.L)	0	0	0.1	Very poor (V.P)	0	0	1
Low (L)	0	0.1	0.3	Poor (P)	0	1	3
Medium low (M.L)	0.1	0.3	0.5	Medium poor (M.P)	1	3	5
Medium (M)	0.3	0.5	0.7	Medium (M)	3	5	7
Medium high (M.H)	0.5	0.7	0.9	Medium good (M.G)	5	7	9
High (H)	0.7	0.9	1	Good (G)	7	9	10
Very high (V.H)	0.9	1	1	Very good (V.G)	9	10	10

Step 4 The fuzzy weights of each criterion and alternative are determined by the equations (9) and (10).

$$\tilde{w}_j = \frac{1}{n}\left[\sum_{y=1}^{n} \bar{w}_j^y\right], \quad j = 1, \ldots, k \tag{9}$$

$$\tilde{x}_{ij} = \frac{1}{n}\left[\sum_{y=1}^{n} \bar{x}_{ij}^y\right], \quad i = 1, \ldots, m. \tag{10}$$

Here, $\tilde{x}_{ij}$ is the degree of the ith alternative according to the jth criterion and $\tilde{w}_j$, j. represents the importance weight of the criterion.

Step 5 Using Eqs. (11) and (12), fuzzy decision matrix is created.

$$\tilde{D} = \begin{bmatrix} \bar{x}_{11} & \bar{x}_{12} & \cdots & \bar{x}_{1j} \\ \bar{x}_{21} & \bar{x}_{22} & \cdots & \bar{x}_{2j} \\ \vdots & \vdots & \vdots & \vdots \\ \bar{x}_{i1} & \bar{x}_{i2} & \cdots & \bar{x}_{ij} \end{bmatrix}, \quad i = 1, 2, \ldots, m; j = 1, 2, \ldots, k \tag{11}$$

$$\tilde{w} = \left[\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n\right]. \tag{12}$$

Here again, $\tilde{x}_{ij}$ represents the degree of the ith alternative according to the jth criterion, $\tilde{w}_j$ represents the importance weight of the jth criterion and $\tilde{D}$ the fuzzy decision matrix.

Step 6 By normalizing the fuzzy decision matrix, the standardized fuzzy decision matrix given by Eq. (13) is obtained.

$$R = \left[r_{ij}\right]_{mxn}, \quad i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \tag{13}$$

$$\left.\begin{aligned} \tilde{r}_{ij} &= \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), \quad j \in B,\ c_j^* = \max_i c_{ij},\ \text{if } j \in B \\ \tilde{r}_{ij} &= \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), \quad j \in B,\ a_j^- = \min_i a_{ij},\ \text{if } j \in C \end{aligned}\right\} \tag{14}$$

Here, R represents the standardized fuzzy decision matrix, c_j^* and a_j^-, respectively, the maximum and minimum values of the third components in a column in the fuzzy decision

matrix, and $\tilde{r}_{ij}$ the normalized values obtained by dividing each value in the fuzzy decision matrix by c_j^*. In addition, B is the benefit criterion and C is the cost criterion.

Step 7 Considering the weight of each criterion, the weighted standardized fuzzy decision matrix given by Eq. (15) is obtained.

$$\tilde{V} = \left[\tilde{v}_{ij}\right]_{mxn}, \quad i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \tag{15}$$

$$\tilde{v}_{ij} = \tilde{r}_{ij}\,(.)\,\tilde{w}_j. \tag{16}$$

Here, $\tilde{V}$ represents the weighted standardized fuzzy decision matrix.

Step 8 The distances of each alternative from the fuzzy positive ideal solution (FPIS, A*) and the fuzzy negative ideal solution (FNIS, A^-) are calculated by Eqs. (17) and (18), respectively

$$A^* = \left(\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*\right), \tag{17}$$

$$A^- = \left(\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-\right),$$

$$\tilde{v}_j^* = \max_i v_{ij}, \text{ if } j \in B,$$

$$\tilde{v}_j^- = \min_i v_{ij}, \text{ if } j \in B. \tag{18}$$

The distance of each alternative from FPIS and FNIS is calculated by Eqs. (19) and (20), respectively.

$$d_j^* = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^*\right), \quad i = 1, 2, \ldots, m \tag{19}$$

$$d_j^- = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^-\right), \quad i = 1, 2, \ldots, m. \tag{20}$$

Here $d(.,.)$ represents the distance between two triangular fuzzy numbers. This distance is calculated by the vertex method. Equation (21) is used when finding the distance between "m" and "n" with this method.

$$\tilde{m} = (m_1, m_2, m_3) \text{ and } \tilde{n} = (n_1, n_2, n_3)$$

$$d(\tilde{m}, \tilde{n}) = \sqrt{\frac{1}{3}\left[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2\right]}. \tag{21}$$

Step 9 After finding the distances, the closeness coefficients of the alternatives are obtained by Eq. (22).

$$\mathrm{CC}_i = \frac{d_i^-}{d_i^* - d_i^-}, \quad i = 1, 2, \ldots, m. \tag{22}$$

Here, as the closeness coefficient (CC_i) approaches 1, A_i moves away from FNIS and approaches FPIS. In other words, the closest alternative to 1 is determined as the best alternative and all alternatives are ranked according to the closeness coefficient (Yavuz and Deveci 2014).

2.3. FUZZY VIKOR

VIKOR (Vlsekriterijumska Optimizacija I Kompromisno Resenje) method is developed for solving a problem with conflicting criteria (Opricovic 1998; Opricovic and Tzeng 2002). The aim of the method is to reach a compromise solution that will provide maximum group utility and minimum individual regret during the ranking and selection phase of alternatives (Opricovic and Tzeng 2004). The fuzzy VIKOR method is also an adaptation of the VIKOR method to a fuzzy environment (Opricovic 2011).

While applying fuzzy VIKOR on triangular fuzzy numbers, one of the fuzzy scales used by decision makers to evaluate criteria and alternatives is the scale given in Table 2.

The first five steps of the fuzzy TOPSIS and fuzzy VIKOR methods are same. Other process steps are listed below (Kutlu Gündoğdu and Kahraman 2019a; Opricovic and Tzeng 2007).

Step 6 The fuzzy best and worst values of all criterion functions are determined by Eq. (23).

$$\tilde{f}_j^* = \max_i \tilde{x}_{ij} \text{ and } \tilde{f}_j^- = \min_i \tilde{x}_{ij}. \tag{23}$$

Step 7 $\tilde{S}_i$ and $\tilde{R}_i$ values are calculated by Eqs. (24) and (25), respectively.

$$\tilde{S}_i = \sum_{j=1}^{k} \tilde{w}_j \left(\tilde{f}_j^* - \tilde{x}_{ij}\right) / \left(\tilde{f}_j^* - \tilde{f}_j^-\right), \tag{24}$$

$$\tilde{R}_i = \max_j \left[\tilde{w}_j \left(\tilde{f}_j^* - \tilde{x}_{ij}\right) / \left(\tilde{f}_j^* - \tilde{f}_j^-\right)\right]. \tag{25}$$

Here, $\tilde{S}_i$ and $\tilde{R}_i$ represent the mean and worst scores of A_i, respectively (AKYÜZ 2012).

Step 8 $\tilde{S}^*$, $\tilde{S}^-$, $\tilde{R}^*$, $\tilde{R}^-$, $\tilde{Q}_i$ and v are calculated.

$$\tilde{S}^* = \min_i \tilde{S}_i \text{ and } \tilde{S}^- = \max_i \tilde{S}_i, \tag{26}$$

$$\tilde{R}^* = \min_i \tilde{R}_i \text{ and } \tilde{R}^- = \max_i \tilde{R}_i, \tag{27}$$

$$\tilde{Q}_i = v\left(\tilde{S}_i - \tilde{S}^*\right) / \left(\tilde{S}^- - \tilde{S}^*\right) + (1-v)\left(\tilde{R}_i - \tilde{R}^*\right) / \left(\tilde{R}^- - \tilde{R}^*\right),\ v = (m+1)/2m \tag{28}$$

Here $\tilde{S}$ represents the maximum group utility, $\tilde{R}^*$ the minimum regret of the opponents, $\tilde{Q}_i$ is the index in which group utility and minimum regret are evaluated together, and m is the number of alternatives. The v value represents the maximum group utility (or the majority of criteria) and the weight of the strategy that yields $1 - v$ individual regret (or the maximum group utility) (Opricovic 2011). Compromise can be achieved by "majority vote" ($v > 0,5$), "consensus" ($v = 0,5$) and "veto" ($v < 0,5$) (Kizielewicz and Bączkiewicz 2021).

Step 9 The triangular fuzzy number $\tilde{Q}_i$ is defuzzyficated, and the index Q_i is obtained. In this study, the second weighted average method (second weighted mean), shown by Eq. 29, was used for the defuzzyfication (Opricovic 2011). In defuzzification, a, b, and c represent

the lower, middle, and upper values for the triangular fuzzy number, respectively.

$$\mathrm{SWM}_i = (2b + a + c)/4, \quad i = 1, 2, \ldots, m \tag{29}$$

When the Q_i index is sorted of ascending, the alternatives are also ranked from best to worst. Two more rankings are obtained by calculating the S_i and R_i indices with similar operations.

Step 10 If the following two conditions are met, the ranking obtained by the Q_i index is the best ranking and "$a^{'}$ is the compromise solution".

Condition 1 (C1). Acceptable advantage. Let $a^{'}$ and $a^{''}$ represent the best and second best alternatives in Q_i, respectively. Accordingly, C1 is checked with Inequality 30 as $DQ = \frac{1}{1-m}$ ($DQ = 0.25 \, if \, m \leq 5$).

$$Q\left(a^{''}\right) - Q\left(a^{'}\right) \geq DQ \tag{30}$$

Condition 2 (C2). Acceptable Stability in decision making. The best alternative of the Q_i rank, $a^{'}$ must also be the best alternative of the order S_i and R_i ranks.

$$(Q\left(a^{'}\right) = S\left(a^{'}\right) = R\left(a^{'}\right)) \tag{31}$$

If $Q\left(a^{m}\right) - Q\left(a^{'}\right) < DQ$ and C1 is not provided, then all m alternatives are compromise solutions. If C2 is not provided, although $a^{'}$ has a relative advantage, there is no stability in decision making and both $a^{'}$ and $a^{''}$ are the compromise solution.

Step 11 The smallest value in the Q_i rank is determined as the best alternative. The final ranking result is the compromise solution with the compromise ranking list of the alternatives and the "advantage rate" (Opricovic and Tzeng 2007).

3. RESULTS

3.1. STUDY DATA

The application was carried out with the data of the Çanakkale part of the project named "Determination of Rangeland Existence and Rangeland Conditions" (Aydoğdu et al. 2020). Four different vegetation samples were taken from each district, and tables were created by taking the arithmetic mean of the proportional sizes of the sampling points for all sub-criteria (Gökkuş et al. 2023).

Table 3. Çanakkale districts and their rangeland condition (Gökkuş et al. 2023)

District	Climax	Rangeland condition
Central d.	31.41925	Medium
Ezine	27.748	Medium
Lapseki	14.633	Poor
Gökçeada	14.849	Poor
Ayvacık	26.402	Medium
Bayramiç	19.59075	Poor
Gelibolu	26.5305	Medium
Eceabat	15.479	Poor
Biga	35.17125	Medium
Yenice	22.3145	Poor
Çan	18.2465	Poor

Table 4. Criteria used in Fuzzy AHP, TOPSIS and VIKOR applications

Main criteria	Vegetation	Familia	Grazing
Sub-criteria	Altitude	Grasses	Decreasers
	Slope	Legumes	Increasers
	Erosion	Other familia	Invaders
	Stony		
	Soil depth		

Three main criteria were determined in order to rank the rangelands with the fuzzy AHP, TOPSIS and VIKOR. These main criteria and the sub-criteria of each main criterion are shown in Table 6.

The slope, erosion, stony and Invaders sub-criteria given in Table 6 have a negative effect on the rangeland quality, while the other criteria have a positive effect (Altın et al. 2011; Alatürk and Gökkuş 2019; Aydoğdu et al. 2020; Gökkuş and Oral 2022). The hierarchical structure of the MCDM methods applied in this study is shown in Fig. 2.

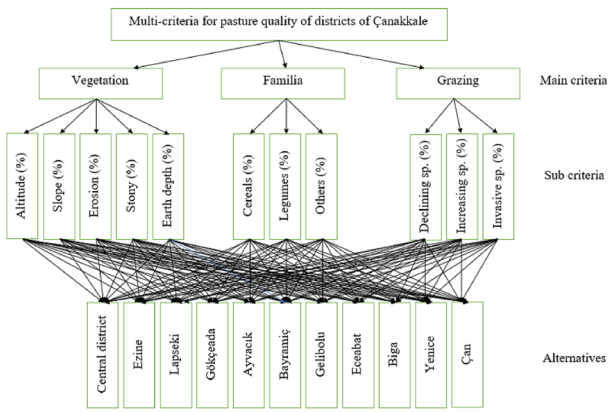


Figure 2. Hierarchy structure of the MCDM problem (Gökkuş et al. 2023) .

Only one expert opinion was obtained for the main criteria by the research team that carried out this study. The scaling of the sub-criteria for the alternatives was done in accordance with the experimental data. Experimental data were obtained from each alternative (district) in four replicates. Initially, these repetitions were treated as four experts (decision makers), but it was understood that the repetitions were very close to each other; therefore, the same scale values should be given to all four repetitions. As a result, it was decided to evaluate the scale values of the alternatives for the sub-criteria according to the average of four repetitions (single expert opinion). In fact, these scalings reflect the performances of the alternatives on the criteria and do not contain a personal opinion (Deng et al. 2000; Opricovic and Tzeng 2004). Studies conducted with a single expert opinion are available in the literature (Kizielewicz and Bączkiewicz 2021; Opricovic and Tzeng 2007) (Tables 3, 4).

3.2. FUZZY AHP

Aydogdu et al. (2020)'s measurement data regarding the criteria of alternatives were obtained. The criteria weights determined in Table 6 were determined by the same study team to the significance scale given in Table 1. The fuzzy pairwise comparison matrix of the main criteria is given in Table 5, and the pairwise comparison matrices of the sub-criteria are given in Tables 6 and 7. While the pairwise comparison matrices were created for slope, erosion, stony and invaders criteria, the evaluation was made according to the opposite scale values and for the other criteria, the scale values were evaluated.

The primary criterion is Grazing and the Familia will not have an impact on the ranking. Therefore, there is no need for pairwise comparisons of the Familia.

Slope, erosion and stony sub-criteria have no effect on the solution of this problem, since their weights are zero (0).

Table 5. Pairwise comparison matrix of main criteria

Main criterion	Vegetation	Familia	Grazing	*W*
Vegetation	(1, 1, 1)	(3, 4, 5)	(1/4, 1/3, 1/2)	0.28
Familia	(1/5, 1/4, 1/3)	(1, 1, 1)	(1/6, 1/5, 1/4)	0
Grazing	(2, 3, 4)	(4, 5, 6)	(1, 1, 1)	0.72

Table 6. Pairwise comparison matrix of vegetation sub-criteria

Sub-criterion of Vegetation	Altitude	Slope	Erosion	Stony	Soil depth	*W*
Altitude	(1, 1, 1)	(4, 5, 6)	(4, 5, 6)	(2, 3, 4)	(1/4, 1/3, 1/2)	0.348
Slope	(1/6, 1/5, 1/4)	(1, 1, 1)	(1, 1, 1)	(1/4, 1/3, 1/2)	(1/7, 1/6, 1/5)	0
Erosion	(1/6, 1/5, 1/4)	(1, 1, 1)	(1, 1, 1)	(1/4, 1/3, 1/2)	(1/7, 1/6, 1/5)	0
Stony	(1/4, 1/3, 1/2)	(2, 3, 4)	(2, 3, 4)	(1, 1, 1)	(1/6, 1/5, 1/4)	0
Soil depth	(2, 3, 4)	(5, 6, 7)	(5, 6, 7)	(4, 5, 6)	(1, 1, 1)	0.652

Table 7. Pairwise comparison matrix of grazing sub-criteria

Sub-criterion of Grazing	Decreasers	Increasers	Invaders	*W*
Decreasers	(1, 1, 1)	(2, 3, 4)	(4, 5, 6)	1
Increasers	(1/4, 1/3, 1/2)	(1, 1, 1)	(1, 2, 3)	0
Invaders	(1/6, 1/5, 1/4)	(1/3, 1/2, 1)	(1, 1, 1)	0

Since their weights are zero (0), the sub-criteria of reproductive species and invaders have no effect on the solution of the problem.

For the main and sub-criteria with zero (0) weight in Tables 5, 6 and 7, it is not necessary to make a pairwise comparison of the alternatives.

The fuzzy pairwise comparison matrices of the alternatives for each criterion with weights different from zero were obtained by adapting the experimental founds given in Tables 3, 4 and 5 to the scale given in Table 1. The fuzzy pairwise comparison matrix of the alternatives for the decreasers' criterion is given in Table 8; other matrices are not included for simplicity.

Chang (1996)'s extension analysis was applied to fuzzy pairwise comparison matrices, and S_i synthetic values were calculated. The S_i synthetic values of the alternatives for the decreasing species criterion are calculated with Eq. 1, and d'(Ai) values were obtained as a result of the clarified probabilities calculated according to Eq. 6 as seen in Table 11. Then, by dividing the d'(Ai) values in the last column of Table 9 by their sums, the weights of the decreasers' sub-criterion were calculated for the alternatives. Similar procedures were performed for the altitude and soil depth sub-criteria and the weights were calculated. The weights calculated for the three criteria in the fuzzy AHP method are given in Table 10.

Here, the weights obtained for each district were first multiplied by the sub-criteria weight, and then, by the main criterion weight and the final weights were determined. For example, the overall weight for the Center is calculated as $0.186 * 0.348 * 0.28 + 0 * 0.652 * 0.28 + 0.315 * 1 * 0.72 = 0.2442$. The overall weights (priority values) obtained for all alternatives according to the fuzzy AHP method and the ranking of the districts according to rangeland quality are given in Table 25.

3.3. FUZZY TOPSIS

By using the scale given in Table 2, the weights of the criteria were determined and the performances of the alternatives were evaluated according to the criteria. The weight matrix created for the main criteria is given in Table 11.

The fuzzy numbers given in Table 11 also represent the main criterion weights, since a single expert opinion evaluates the main criteria. The fuzzy weight matrices created for the sub-criteria are given in Table 12. These values are multiplied with the weights of the main criteria in Table 16, and general criteria weights are calculated.

The data in Tables 3, 4 and 5 are evaluated according to Table 2 as in Table 13.

With the normalization process, the standardized decision matrix given in Table 14 was created. According to Eq. 14, the normalization process was carried out by taking the min

Table 8. Fuzzy pairwise comparison matrix of alternatives for the decreasers' sub-criterion

	Central d.	Ezine	Lapseki	Gökçeada	Ayvacık	Bayramiç	Gelibolu	Eceabat	Biga	Yenice	Çan
Central d.	(1, 1, 1)	(3, 4, 5)	(3, 4, 5)	(4, 5, 6)	(3, 4, 5)	(2, 3, 4)	(4, 5, 6)	(4, 5, 6)	(1, 1, 1)	(3, 4, 5)	(1, 2, 3)
Ezine	(1/5, 1/4, 1/3)	(1, 1, 1)	(1, 1, 1)	(1, 2, 3)	(1, 1, 1)	(1/3, 1/2, 1)	(1, 2, 3)	(1, 2, 3)	(1/5, 1/4, 1/3)	(1, 1, 1)	(1/4, 1/3, 1/2)
Lapseki	(1/5, 1/4, 1/3)	(1, 1, 1)	(1, 1, 1)	(1, 2, 3)	(1, 1, 1)	(1/3, 1/2, 1)	(1, 2, 3)	(1, 2, 3)	(1/5, 1/4, 1/3)	(1, 1, 1)	(1/4, 1/3, 1/2)
Gökçeada	(1/6, 1/5, 1/4)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1, 1, 1)	(1/3, 1/2, 1)	(1/4, 1/3, 1/2)	(1, 1, 1)	(1, 1, 1)	(1/6, 1/5, 1/4)	(1/3, 1/2, 1)	(1/5, 1/4, 1/3)
Ayvacık	(1/5, 1/4, 1/3)	(1, 1, 1)	(1, 1, 1)	(1, 2, 3)	(1, 1, 1)	(1/3, 1/2, 1)	(1, 2, 3)	(1, 2, 3)	(1/5, 1/4, 1/3)	(1, 1, 1)	(1/4, 1/3, 1/2)
Bayramiç	(1/4, 1/3, 1/2)	(1, 2, 3)	(1, 2, 3)	(2, 3, 4)	(1, 2, 3)	(1, 1, 1)	(2, 3, 4)	(2, 3, 4)	(1/4, 1/3, 1/2)	(1, 2, 3)	(1/3, 1/2, 1)
Gelibolu	(1/6, 1/5, 1/4)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1, 1, 1)	(1/3, 1/2, 1)	(1/4, 1/3, 1/2)	(1, 1, 1)	(1, 1, 1)	(1/6, 1/5, 1/4)	(1/3, 1/2, 1)	(1/5, 1/4, 1/3)
Eceabat	(1/6, 1/5, 1/4)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1, 1, 1)	(1/3, 1/2, 1)	(1/4, 1/3, 1/2)	(1, 1, 1)	(1, 1, 1)	(1/6, 1/5, 1/4)	(1/3, 1/2, 1)	(1/5, 1/4, 1/3)
Biga	(1, 1, 1)	(3, 4, 5)	(3, 4, 5)	(4, 5, 6)	(3, 4, 5)	(2, 3, 4)	(4, 5, 6)	(4, 5, 6)	(1, 1, 1)	(3, 4, 5)	(1, 2, 3)
Yenice	(1/5, 1/4, 1/3)	(1, 1, 1)	(1, 1, 1)	(1, 2, 3)	(1, 1, 1)	(1/3, 1/2, 1)	(1, 2, 3)	(1, 2, 3)	(1/5, 1/4, 1/3)	(1, 1, 1)	(1/4, 1/3, 1/2)
Çan	(1/3, 1/2, 1)	(2, 3, 4)	(2, 3, 4)	(3, 4, 5)	(2, 3, 4)	(1, 2, 3)	(3, 4, 5)	(3, 4, 5)	(1/3, 1/2, 1)	(2, 3, 4)	(1, 1, 1)

Table 9. Sum and synthetic values obtained from fuzzy pairwise comparison matrix of alternatives and unfuzzy probabilities for the decreasers' sub-criterion

	Sum (j)			Fuzzy synthetic values (Si)			Unfuzzy probabilities	
	a	b	c	a	b	c	$d'(Ai)$	P
Central d.	29	38	47	0.119	0.204	0.344	$\min V(S1 > S2, S3, S4, S5, S6, S7, S8, S9, S10, S11)$	1
Ezine	7.983	11.333	15.167	0.033	0.061	0.111	$\min V(S2 > S1, S3, S4, S5, S6, S7, S8, S9, S10, S11)$	0
Lapseki	7.983	11.333	15.167	0.033	0.061	0.111	$\min V(S3 > S1, S2, S4, S5, S6, S7, S8, S9, S10, S11)$	0
Gökçeada	5.117	5.983	8.333	0.021	0.032	0.061	$\min V(S4 > S1, S2, S3, S5, S6, S7, S8, S9, S10, S11)$	0
Ayvacık	7.983	11.333	15.167	0.033	0.061	0.111	$\min V(S5 > S1, S2, S3, S4, S6, S7, S8, S9, S10, S11)$	0
Bayramiç	11.833	19.167	27.000	0.049	0.103	0.197	$\min V(S6 > S1, S2, S3, S4, S5, S7, S8, S9, S10, S11)$	0.437
Gelibolu	5.117	5.983	8.333	0.021	0.032	0.061	$\min V(S7 > S1, S2, S3, S4, S5, S6, S8, S9, S10, S11)$	0
Eceabat	5.117	5.983	8.333	0.021	0.032	0.061	$\min V(S8 > S1, S2, S3, S4, S5, S6, S7, S9, S10, S11)$	0
Biga	29	38	47	0.119	0.204	0.344	$\min V(S9 > S1, S2, S3, S4, S5, S6, S7, S8, S10, S11)$	1
Yenice	7.983	11.333	15.167	0.033	0.061	0.111	$\min V(S10 > S1, S2, S3, S4, S5, S6, S7, S8, S9, S11)$	0
Çan	19.667	28	37	0.081	0.150	0.271	$\min V(S11 > S1, S2, S3, S4, S5, S6, S7, S8, S9, S10)$	0.739
$\sum$	136.783	186.45	243.667					3.175

Table 10. Weights (W) obtained from pairwise comparisons of sub-criteria

	Altitude	Soil depth	Decreasers
Central d.	0.186	0	0.315
Ezine	0	0	0
Lapseki	0.186	0.013	0
Gökçeada	0	0	0
Ayvacık	0	0.013	0
Bayramiç	0	0.196	0.138
Gelibolu	0	0.196	0
Eceabat	0.276	0.105	0
Biga	0.276	0.266	0.315
Yenice	0	0.105	0
Çan	0.076	0.105	0.233

Table 11. Fuzzy weight matrix for the main criteria

Main criterion	Linguistic term	Fuzzy scale
Vegetation	M	(0,3, 0,5, 0,7)
Familia	L	(0, 0,1, 0,3)
Grazing	V.H	(9, 1, 1)

Table 12. Fuzzy weight matrices for sub-criteria

	Sub-criteria	Linguistic term	Fuzzy scale	General weight (W)
Vegetation	Altitude	M.L	(0,1, 0,3, 0,5)	(0,03, 0,15, 0,35)
	Slope	V.L	(0, 0, 0,1)	(0, 0, 0,07)
	Erosion	V.L	(0, 0, 0,1)	(0, 0, 0,07)
	Stony	L	(0, 0,1, 0,3)	(0, 0,05, 0,21)
	Soil depth	M	(0,3, 0,5, 0,7)	(0,09, 0,25, 0,49)
Familia	Grasses	V.L	(0, 0, 0,1)	(0, 0, 0,03)
	Legumes	V.L	(0, 0, 0,1)	(0, 0, 0,03)
	Other F.	L	(0, 0,1, 0,3)	(0, 0,1, 0,3)
Grazing	Decreasers	V.H	(0,9, 1, 1)	(0,81, 1, 1)
	Increasers	H	(0,7, 0,9, 1)	(0,63, 0,9, 1)
	Invaders	M.L	(0,1, 0,3, 0,5)	(0,09, 0,3, 0,5)

value of the relevant columns for slope, erosion, stony and invaders criteria, and the max value for other criteria.

Table 15 includes a weighted standardized decision matrix.

The positive and negative separation measures ((Dij*) and (Dij^{-}), respectively) were calculated by clarification according to Eqs. 19 and 20.

The fuzzy ideal positive and negative solutions and the closeness coefficients (CCi) of the alternatives are calculated by Eq. 22 (Tables 16, 17, 18, 19).

Table 13. Fuzzy decision matrix for sub-criteria of alternatives

	Altitude				Slope				Erosion				Stony				Soil depth			
	a	b	c	L.T	a	b	c	L.T	a	b	c	L.T	a	b	c	L.T	a	b	c	L.T
Central d.	0	1	3	P	3	5	7	M	9	10	10	V.G	5	7	9	M.G	5	7	9	M.G
Ezine	3	5	7	M	7	9	10	G	7	9	10	G	9	10	10	V.G	5	7	9	M.G
Lapseki	0	1	3	P	7	9	10	G	7	9	10	G	9	10	10	V.G	5	7	9	M.G
Gökçeada	5	7	9	M.G	9	10	10	V.G	7	9	10	G	7	9	10	G	5	7	9	M.G
Ayvacık	9	10	10	V.G	3	5	7	M	7	9	10	G	5	7	9	M.G	5	7	9	M.G
Bayramiç	1	3	5	M.P	3	5	7	M	5	7	9	M.G	5	7	9	M.G	9	10	10	V.G
Gelibolu	1	3	5	M.P	7	9	10	G	5	7	9	M.G	5	7	9	M.G	9	10	10	V.G
Eceabat	0	1	3	P	7	9	10	G	5	7	9	M.G	7	9	10	G	7	9	10	G
Biga	0	1	3	P	3	5	7	M	5	7	9	M.G	5	7	9	M.G	9	10	10	V.G
Yenice	9	10	10	V.G	3	5	7	M	5	7	9	M.G	5	7	9	M.G	7	9	10	G
Çan	1	3	5	M.P	3	5	7	M	5	7	9	M.G	5	7	9	M.G	7	9	10	G

	Grasses				Legumes				Other familia				Decreasers				Increasers				Invaders			
	a	*b*	*c*	L.T	*a*	*b*	*c*	L.T	*a*	*b*	*c*	L.T	*a*	*b*	*c*	L.T	*a*	*b*	*c*	L.T	a	*b*	*c*	L.T
Central d.	7	9	10	G	3	5	7	M	3	5	7	M	9	10	10	V.G	0	1	3	P	7	9	10	G
Ezine	3	5	7	M	9	10	10	V.G	3	5	7	M	1	3	5	M.P	7	9	10	G	7	9	10	G
Lapseki	3	5	7	M	3	5	7	M	7	9	10	G	1	3	5	M.P	0	1	3	P	9	10	10	V.G
Gökçeada	1	3	5	M.P	5	7	9	M.G	9	10	10	V.G	0	1	3	P	1	3	5	M.P	9	10	10	V.G
Ayvacık	3	5	7	M	9	10	10	V.G	3	5	7	M	1	3	5	M.P	5	7	9	M.G	7	9	10	G
Bayramiç	3	5	7	M	9	10	10	V.G	5	7	9	M.G	1	3	5	M.P	1	3	5	M.P	9	10	10	V.G
Gelibolu	9	10	10	V.G	7	9	10	G	0	0	1	V.P	0	1	3	P	7	9	10	G	7	9	10	G
Eceabat	3	5	7	M	5	7	9	M.G	5	7	9	M.G	1	3	5	M.P	1	3	5	M.P	9	10	10	V.G
Biga	7	9	10	G	5	7	9	M.G	1	3	5	M.P	5	7	9	M.G	5	7	9	M.G	7	9	10	G
Yenice	5	7	9	M.G	3	5	7	M	5	7	9	M.G	1	3	5	M.P	3	5	7	M	9	10	10	V.G
Çan	9	10	10	V.G	0	1	3	P	1	3	5	M.P	3	5	7	M	0	1	3	P	9	10	10	V.G

Table 14. Standardized fuzzy decision matrix for alternatives

	Altitude			Slope			Erosion			Stony			Soil depth		
	a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
Central d.	0	0.1	0.3	0.429	0.6	1	0.5	0.5	0.556	0.556	0.714	1	0.5	0.7	0.9
Ezine	0.3	0.5	0.7	0.3	0.333	0.429	0.5	0.556	0.714	0.5	0.5	0.556	0.5	0.7	0.9
Lapseki	0	0.1	0.3	0.3	0.333	0.429	0.5	0.556	0.714	0.5	0.5	0.556	0.5	0.7	0.9
Gökçeada	0.5	0.7	0.9	0.3	0.3	0.333	0.5	0.556	0.714	0.5	0.556	0.714	0.5	0.7	0.9
Ayvacık	0.9	1	1	0.429	0.6	1	0.5	0.556	0.714	0.556	0.714	1	0.5	0.7	0.9
Bayramiç	0.1	0.3	0.5	0.429	0.6	1	0.556	0.714	1	0.556	0.714	1	0.9	1	1
Gelibolu	0.1	0.3	0.5	0.3	0.333	0.429	0.556	0.714	1	0.556	0.714	1	0.9	1	1
Eceabat	0	0.1	0.3	0.3	0.333	0.429	0.556	0.714	1	0.5	0.556	0.714	0.7	0.9	1
Biga	0	0.1	0.3	0.429	0.6	1	0.556	0.714	1	0.556	0.714	1	0.9	1	1
Yenice	0.9	1	1	0.429	0.6	1	0.556	0.714	1	0.556	0.714	1	0.7	0.9	1
Çan	0.1	0.3	0.5	0.429	0.6	1	0.556	0.714	1	0.556	0.714	1	0.7	0.9	1

	Grasses			Legumes			Other familia			Decreasers			Increasers			Invaders		
	a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
Central d.	0.7	0.9	1	0.3	0.5	0.7	0.3	0.5	0.7	0.9	1	1	0	0.1	0.3	0.7	0.778	1
Ezine	0.3	0.5	0.7	0.9	1	1	0.3	0.5	0.7	0.1	0.3	0.5	0.7	0.9	1	0.7	0.778	1
Lapseki	0.3	0.5	0.7	0.3	0.5	0.7	0.7	0.9	1	0.1	0.3	0.5	0	0.1	0.3	0.7	0.7	0.778
Gökçeada	0.1	0.3	0.5	0.5	0.7	0.9	0.9	1.0	1	0	0.1	0.3	0.1	0.3	0.5	0.7	0.7	0.778
Ayvacık	0.3	0.5	0.7	0.9	1	1	0.3	0.5	0.7	0.1	0.3	0.5	0.5	0.7	0.9	0.7	0.778	1
Bayramiç	0.3	0.5	0.7	0.9	1	1	0.5	0.7	0.9	0.1	0.3	0.5	0.1	0.3	0.5	0.7	0.7	0.778
Gelibolu	0.9	1	1	0.7	0.9	1	0	0	0.1	0	0.1	0.3	0.7	0.9	1	0.7	0.778	1
Eceabat	0.3	0.5	0.7	0.5	0.7	0.9	0.5	0.7	0.9	0.1	0.3	0.5	0.1	0.3	0.5	0.7	0.7	0.778
Biga	0.7	0.9	1	0.5	0.7	0.9	0.1	0.3	0.5	0.5	0.7	0.9	0.5	0.7	0.9	0.7	0.778	1
Yenice	0.5	0.7	0.9	0.3	0.5	0.7	0.5	0.7	0.9	0.1	0.3	0.5	0.3	0.5	0.7	0.7	0.7	0.778
Çan	0.9	1	1	0	0.1	0.3	0.1	0.3	0.5	0.3	0.5	0.7	0	0.1	0.3	0.7	0.7	0.778

Table 15. Weighted standardized fuzzy decision matrix for alternatives

	Altitude			Slope			Erosion			Stony			Soil depth		
	a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
Central d.	0	0.015	0.105	0	0	0.07	0	0	0.039	0	0.036	0.21	0.045	0.175	0.441
Ezine	0.009	0.075	0.245	0	0	0.03	0	0	0.05	0	0.025	0.117	0.045	0.175	0.441
Lapseki	0	0.015	0.105	0	0	0.03	0	0	0.05	0	0.025	0.117	0.045	0.175	0.441
Gökçeada	0.015	0.105	0.315	0	0	0.023	0	0	0.05	0	0.028	0.15	0.045	0.175	0.441
Ayvacık	0.027	0.15	0.35	0	0	0.07	0	0	0.05	0	0.036	0.21	0.045	0.175	0.441
Bayramiç	0.003	0.045	0.175	0	0	0.07	0	0	0.07	0	0.036	0.21	0.081	0.25	0.49
Gelibolu	0.003	0.045	0.175	0	0	0.03	0	0	0.07	0	0.036	0.21	0.081	0.25	0.49
Eceabat	0	0.015	0.105	0	0	0.03	0	0	0.07	0	0.028	0.15	0.063	0.225	0.49
Biga	0	0.015	0.105	0	0	0.07	0	0	0.07	0	0.036	0.21	0.081	0.25	0.49
Yenice	0.027	0.15	0.35	0	0	0.07	0	0	0.07	0	0.036	0.21	0.063	0.225	0.49
Çan	0.003	0.045	0.175	0	0	0.07	0	0	0.07	0	0.036	0.21	0.063	0.225	0.49

	Grasses			Legumes			Other familia			Decreasers			Increasers			Invaders		
	a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
Central d.	0	0	0.03	0	0	0	0	0.1	0.2	0.7	1	1	0	0.1	0.3	0.1	0.233	0.5
Ezine	0	0	0.021	0	0	0	0	0.1	0.2	0.1	0.3	0.5	0.4	0.8	1	0.1	0.233	0.5
Lapseki	0	0	0.021	0	0	0	0	0.1	0	0.1	0.3	0.5	0	0.1	0.3	0.1	0.21	0.389
Gökçeada	0	0	0.015	0	0	0	0	0.1	0	0	0.1	0.3	0.1	0.3	0.5	0.1	0.21	0.389
Ayvacık	0	0	0.021	0	0	0	0	0.1	0.2	0.1	0.3	0.5	0.3	0.6	0.9	0.1	0.233	0.5
Bayramiç	0	0	0.021	0	0	0	0	0.1	0.3	0.1	0.3	0.5	0.1	0.3	0.5	0.1	0.21	0.389
Gelibolu	0	0	0.03	0	0	0	0	0	0	0	0.1	0.3	0.4	0.8	1	0.1	0.233	0.5
Eceabat	0	0	0.021	0	0	0	0	0.1	0.3	0.1	0.3	0.5	0.1	0.3	0.5	0.1	0.21	0.389
Biga	0	0	0.03	0	0	0	0	0.0	0.2	0.4	0.7	0.9	0.3	0.6	0.9	0.1	0.233	0.5
Yenice	0	0	0.027	0	0	0	0	0.1	0.3	0.1	0.3	0.5	0.2	0.5	0.7	0.1	0.21	0.389
Çan	0	0	0.03	0	0	0	0	0.0	0.2	0.2	0.5	0.7	0	0.1	0.3	0.1	0.21	0.389

Table 16. Positive separation measures (Dij*)

	Altitude	Slope	Erosion	Stony	Soil depth	Grasses	Legumes	Other f.	Decreasers	Increasers	Invaders
Central d.	0.961119	0.977224	0.987207	0.922668	0.796896	0.990101	0.993049	0.917715	0.156	0.879034	0.530
Ezine	0.895867	0.990101	0.983616	0.954097	0.796896	0.993049	0.990101	0.917715	0.726765	0.340872	0.530
Lapseki	0.961119	0.990101	0.983616	0.954097	0.796896	0.993049	0.993049	0.879034	0.726765	0.879034	0.578
Gökçeada	0.86419	0.992283	0.983616	0.942995	0.796896	0.995	0.991082	0.875595	0.875595	0.744058	0.578
Ayvacık	0.835011	0.977224	0.983616	0.922668	0.796896	0.993049	0.990101	0.917715	0.726765	0.453183	0.530
Bayramiç	0.928558	0.977224	0.977224	0.922668	0.745467	0.993049	0.990101	0.894017	0.726765	0.744058	0.578
Gelibolu	0.928558	0.990101	0.977224	0.922668	0.745467	0.990101	0.990101	0.990101	0.875595	0.340872	0.530
Eceabat	0.961119	0.990101	0.977224	0.942995	0.761291	0.993049	0.991082	0.894017	0.726765	0.744058	0.578
Biga	0.961119	0.977224	0.977224	0.922668	0.745467	0.990101	0.991082	0.942231	0.389027	0.453183	0.530
Yenice	0.835011	0.977224	0.977224	0.922668	0.761291	0.991082	0.993049	0.894017	0.726765	0.59167	0.578
Çan	0.928558	0.977224	0.977224	0.922668	0.761291	0.990101	0.997009	0.942231	0.551679	0.879034	0.578

Table 17. Negative separation measures (Dij^-)

	Altitude	Slope	Erosion	Stony	Soil depth	Grasses	Legumes	Other f.	Decreasers	Increasers	Invaders
Central d.	0.061237	0.040415	0.022453	0.122984	0.275155	0.017321	0.012124	0.124633	0.919	0.180831	0.321
Ezine	0.148021	0.017321	0.028868	0.068887	0.275155	0.012124	0.017321	0.124633	0.339883	0.785405	0.321
Lapseki	0.061237	0.017321	0.028868	0.068887	0.275155	0.012124	0.012124	0.180831	0.339883	0.180831	0.258
Gökçeada	0.191898	0.013472	0.028868	0.088075	0.275155	0.009	0.015588	0.182574	0.182574	0.330085	0.258
Ayvacık	0.2204	0.040415	0.028868	0.122984	0.275155	0.012124	0.017321	0.124633	0.339883	0.65983	0.321
Bayramiç	0.104338	0.040415	0.040415	0.122984	0.32102	0.012124	0.017321	0.161038	0.339883	0.330085	0.258
Gelibolu	0.104338	0.017321	0.040415	0.122984	0.32102	0.017321	0.017321	0.017321	0.182574	0.785405	0.321
Eceabat	0.061237	0.017321	0.040415	0.088075	0.313419	0.012124	0.015588	0.161038	0.339883	0.330085	0.258
Biga	0.061237	0.040415	0.040415	0.122984	0.32102	0.017321	0.015588	0.088318	0.698576	0.65983	0.321
Yenice	0.2204	0.040415	0.040415	0.122984	0.313419	0.015588	0.012124	0.161038	0.339883	0.492687	0.258
Çan	0.104338	0.040415	0.040415	0.122984	0.313419	0.017321	0.005196	0.088318	0.516091	0.180831	0.258

Table 18. Fuzzy ideal positive, negative solutions and closeness coefficients (preference values of alternatives)

Alternative	di*	di$^-$	CCi
Central d.	9.111	2.096	0.187
Ezine	9.119	2.138	0.190
Lapseki	9.735	1.435	0.128
Gökçeada	9.639	1.575	0.140
Ayvacık	9.126	2.162	0.192
Bayramiç	9.477	1.747	0.156
Gelibolu	9.280	1.947	0.173
Eceabat	9.559	1.637	0.146
Biga	8.879	2.386	0.212
Yenice	9.248	2.017	0.179
Çan	9.505	1.687	0.151

According to the fuzzy TOPSIS method, the normalized CCi values and the ranking of the alternatives are given in Table 25.

3.4. FUZZY VIKOR

The VIKOR method is an effective tool in solving decision-making problems with conflicting criteria (Opricovic and Tzeng 2007). In this study, the sum of decreaser and increaser' rates in the direction of benefit and invaders rates in the direction of cost, which are the sub-criteria of grazing, is equal to 1 (100%). However, in order to scale up the quality of rangeland, the ratio of both decreasers and increasers must ascend together. This co-increase expectation was considered as a contradiction and it was found appropriate to use the fuzzy VIKOR method in this study.

Similar application steps with the fuzzy TOPSIS method were applied as given in Tables 11, 12 and 13.

Table 19. Fuzzy best and worst performances for criteria

	fi*			fi$^-$		
Criterion	*a*	*b*	*c*	*a*	*b*	*c*
Altitude	9	10	10	0	1	3
Slope	3	5	7	0	0	1
Erosion	1	3	5	0	0	1
Stony	1	3	5	0	1	3
Soil depth	9	10	10	5	7	9
Grasses	9	10	10	3	5	7
Legumes	9	10	10	0	1	3
Other familia	9	10	10	0	1	3
Decreasers	9	10	10	3	5	7
Increasers	7	9	10	0	1	3
Invaders	3	5	7	0	0	1

Table 20. Standardized fuzzy distance matrix

	Central d.			Ezine			Lapseki			Gökçeada			Ayvacık			Bayramiç		
Crieterion	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
Altitude	0.03	0.15	0.35	0.02	0.083	0.15	0.03	0.15	0.35	0.013	0.05	0.05	0	0	0	0.027	0.117	0.25
Slope	0	0	0	0	0	0.047	0	0	0.047	0	0	0.07	0	0	0	0	0	0
Erosion	0	0	0.07	0	0	0.035	0	0	0.035	0	0	0.035	0	0	0.035	0	0	0
Stony	0	0	0	0	0.075	0.42	0	0.075	0.42	0	0.05	0.21	0	0	0	0	0	0
Soil depth	0.09	0.25	0.49	0.09	0.25	0.49	0.09	0.25	0.49	0.09	0.25	0.49	0.09	0.25	0.49	0	0	0
Grasses	0	0	0	0	0	0.03	0	0	0.03	0	0	0.05	0	0	0.03	0	0	0.03
Legumes	0	0	0.013	0	0	0	0	0	0.013	0	0	0.004	0	0	0	0	0	0
Other f.	0	0.056	0.129	0	0.056	0.129	0	0.011	0	0	0	0	0	0.056	0.129	0	0.033	0.043
Decreasers	0	0	0	0.81	1	1	0.81	1	1	0.81	1	1	0.81	1	1	0.81	1	1
Increasers	0.63	0.9	1	0	0	0	0.63	0.9	1	0.54	0.675	0.714	0	0	0	0.54	0.675	0.714
Invaders	0.09	0.24	0.333	0.09	0.24	0.333	0.09	0.3	0.5	0.09	0.3	0.5	0.09	0.24	0.333	0.09	0.3	0.5
$\sum$ Si	0.84	1.596	2.385	1.01	1.704	2.634	1.65	2.686	3.885	1.543	2.325	3.124	0.99	1.546	2.017	1.467	2.125	2.537

	Gelibolu			Eceabat			Biga			Yenice			Çan		
Criterion	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
Altitude	0.027	0.117	0.25	0.03	0.15	0.35	0.03	0.15	0.35	0	0	0	0.027	0.117	0.25
Slope	0	0	0.047	0	0	0.047	0	0	0	0	0	0	0	0	0
Erosion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stony	0	0	0	0	0.05	0.21	0	0	0	0	0	0	0	0	0
Soil depth	0	0	0	0.045	0.083	0	0	0	0	0.045	0.083	0	0.045	0.083	0
Grasses	0	0	0	0	0	0.03	0	0	0	0	0	0.004	0	0	0
Legumes	0	0	0	0	0	0.004	0	0	0.004	0	0	0.013	0	0	0.03
Other f.	0	0.1	0.3	0	0.033	0.043	0	0.078	0.214	0	0.06	0.1	0	0.078	0.214
Decreasers	0.81	1	1	0.81	1	1	0.27	0.2	0	0.81	1	1	0.54	0.6	0.333
Increasers	0	0	0	0.54	0.675	0.714	0	0	0	0.36	0.45	0.429	0.63	0.9	1
Invaders	0.09	0.24	0.333	0.09	0.3	0.5	0	0	0	0.09	0.3	0.5	0.09	0.3	0.5
$\sum$ Si	0.927	1.457	1.93	1.515	2.292	2.898	0.3	0.428	0.569	1.305	1.893	2.046	1.332	2.078	2.328

Table 21. Testing the Q_i rank for conditions C1 and C2

C1	DQ = 0.100	$Q'' - Q' = 0.659$	$Q'' - Q' >= \text{DQ}$	True	Rank
C2	Biga is in the 1st place			True	Q_i

Table 22. Fuzzy S_i and R_i values for alternatives

	S_i			R_i		
Alternative	*a*	*b*	*c*	*a*	*b*	*c*
Central d.	0.84	1.596	2.385	0.63	0.9	1
Ezine	1.01	1.704	2.634	0.81	1	1
Lapseki	1.65	2.686	3.885	0.81	1	1
Gökçeada	1.543	2.325	3	0.81	1	1
Ayvacık	0.99	2	2	0.81	1	1
Bayramiç	1.467	2.125	2.537	0.81	1	1
Gelibolu	0.927	1.457	1.93	0.81	1	1
Eceabat	1.515	2.292	3	0.81	1	1
Biga	0.3	0	1	0.27	0.2	0.35
Yenice	1.305	1.893	2.046	0.81	1	1
Çan	1.332	2.078	2.328	0.63	0.9	1

Table 23. Fuzzy S*, S^-, R*, R^- and v values

	a	*b*	*c*
$S*$ (min)	0.3	0.428	0.569
S^- (Max)	1.65	2.686	3.885
$R*$ (Min)	0.27	0.200	0.350
R^- (Max)	0.81	1	1
$v = (n+1)/2n$	0.545		

At this stage, the best (fi*) and worst (fi^-) performances of the alternatives for each criterion were determined from the fuzzy decision matrix in Table 13.

The standardized fuzzy distance matrix was calculated as given in Table 20.

By using the normalized fuzzy weights in Table 20, the sum of fuzzy weights (S_i) and fuzzy weighted max operator (R_i) values are calculated according to Eqs. 23 and 24 for the alternatives (Tables 22, 23).

The max and min values and v values for the fuzzy S_i and R_i values were calculated with the help of Eqs. 26, 27 and 28.

The fuzzy Q_i, S_i and R_i values were clarified and the rankings in Table 24 were obtained for each.

For the validity of the Q_i ranking, Eqs. 30 and 31 and C1 and C2 were tested and the best alternative and ranking were determined.

Table 24. Ranking of alternatives by fuzzy Qi index

Alternative	Q_i			Q_i		S_i		R_i	
	a	*b*	*c*	Index	Rank	Index	Rank	Index	Rank
Central d.	0.521	0.680	0.753	0.659	2	1.604	4	0.858	2
Ezine	0.741	0.763	0.794	0.765	6	1.763	5	0.953	4
Lapseki	1	1	1	1	11	2.727	11	0.953	4
Gökçeada	0.957	0.913	0.875	0.914	10	2.329	10	0.953	4
Ayvacık	0.733	0.725	0.693	0.719	4	1.525	3	0.953	4
Bayramiç	0.926	0.864	0.778	0.858	8	2.063	8	0.953	4
Gelibolu	0.708	0.703	0.678	0.698	3	1.443	2	0.953	4
Eceabat	0.945	0.905	0.838	0.898	9	2.249	9	0.953	4
Biga	0	0	0	0	1	0.431	1	0.255	1
Yenice	0.861	0.809	0.698	0.794	7	1.784	6	0.953	4
Çan	0.720	0.796	0.744	0.764	5	1.954	7	0.858	3

Both C1 (acceptable advantage) and C2 (acceptable stability in decision making) conditions were met, and Biga was found to be the best alternative in terms of rangeland quality compared to fuzzy VIKOR method (Table 21).

4. DISCUSSION AND CONCLUSION

In this study, eleven districts of Çanakkale were evaluated in terms of rangeland quality with fuzzy AHP, TOPSIS and VIKOR methods, taking 11 vegetation factors into account. Priority values and rankings of alternatives for three methods are in Table 25.

Comparison of rankings obtained from the three methods is presented in Fig. 3 (Kizielewicz and Bączkiewicz 2021).

When the rankings obtained by all three fuzzy multi-criteria decision-making methods are examined, it is seen that Biga is the district with the best rangeland quality. The expert team that carried out the experiment stated that it was an expected result that Biga was in

Table 25. Preference values (P.V.) and rankings obtained from FAHP, FTOPSIS and FVIKOR

Alternative	FAHP		FTOPSIS		FVIKOR	
	P.V.	*Rank*	P.V.	Rank	P.V.	Rank
Central d.	0.2442	2	0.094	4	0.659	2
Ezine	0.0000	11	0.095	3	0.765	6
Lapseki	0.0210	7	0.064	11	1	11
Gökçeada	0.0004	10	0.070	10	0.914	10
Ayvacık	0.0024	9	0.096	2	0.719	4
Bayramiç	0.1347	4	0.078	7	0.858	8
Gelibolu	0.0357	6	0.087	6	0.698	3
Eceabat	0.0467	5	0.073	9	0.898	9
Biga	0.3017	1	0.106	1	0	1
Yenice	0.0193	8	0.090	5	0.794	7
Çan	0.1939	3	0.075	8	0.764	5

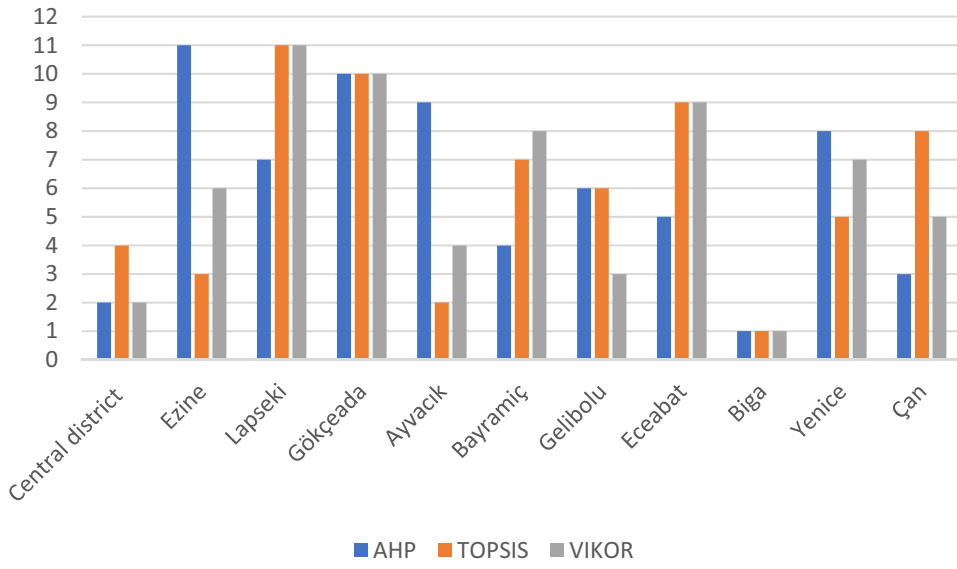


Figure 3. Comparison of rankings for fuzzy AHP, TOPSIS and VIKOR .

the first place and preferred to use the FAHP ranking (Altın et al. 2011; Aydoğdu et al. 2020). The study was carried out in Çanakkale, which is located in the Southwest Marmara Region and generally has Mediterranean vegetation. Therefore, in terms of its results, it will be able to reflect the changes that occur depending on the soil (depth, etc.) and land structures (slope, altitude, stony, erosion) and vegetation status (functional species) and use of rangelands in similar ecologies.

Therefore, all three methods performed well in identifying the district with the best rangeland quality (Kumar and Barman 2021).

When the priority values in the table are examined, it is noteworthy that Biga is in better condition than other districts, but the values of some of the districts are close to each other and poor (Aydoğdu et al. 2020). Therefore, it is normal for the rankings obtained by the three methods to differ. However, as the number of sampling stations increases, the rankings are predicted to become somewhat more similar.

When the rangeland conditions given in Table 5 and the rankings obtained in this study are examined, it is seen that the rangeland conditions of some districts should be handled in more detail. When the rangeland conditions determined by the number of observed species, not the grass yield per unit area, were evaluated alone, the rangeland condition of Çan is determined as *poor*. However, according to fuzzy AHP ranking, Altın et al. (2011) and Aydoğdu et al. (2020), Çan should be at the top of the ranking. In other words, the rangeland condition of Çan is better than some of the districts specified as *medium*. This study was very effective in determining the rangeland condition of Çan statistically. Therefore, this study has proven that fuzzy MCDM methods can be a good support in the examination of rangeland conditions. As a result, it is recommended to be used in similar studies.

In this study, FMCDM methods are studied for triangular fuzzy numbers. The study data were obtained by experimentation, not by the personal evaluations of the decision makers. In

future studies, it is planned to study FMCDM methods for different types of fuzzy numbers with experimental data.

Declarations

Conflict of interest No other authors declared a potential conflict of interest regarding this article.

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