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ASSESSMENT OF DROUGHT PROCESS WITH INTEGRATED MULTI-CRITERIA DECISION-MAKING METHODS

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Abstract

This study aimed to prioritize the factors affecting the drought, which is an important issue for the sustainability of agricultural production, and classify the factors by the severity of dry periods. An integrated decision model based on multi-criteria decision making (MCDM) techniques, Entropy, TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and MAUT (Multi Attribute Utility Theory) methods, was presented in the study. The proposed decision model was applied on a numerical case study to determine the drought periods, considering some climatic parameters between 1971 and 2019 in Kırşehir province. The Entropy-weighted results relative to TOPSIS and MAUT methods indicated 17 drought years within the last 49 years, and the drought severity in 17 years was classified in three different levels as weak, moderate and severe. Ten out of 17 years were weakly drought (20.41%), 6 of them were moderate drought (12.24%), and 1 year was serious drought (2.04%). The results of MAUT method showed that 11 of 17 years were weak drought (22.45%), 5 were moderate drought (10.20%) and 1 was serious drought (2.04%). The results revealed that the use of multi-criteria decision making models such as Entropy, TOPSIS and MAUT can support the decision analysis for combating agricultural drought in fruit growing by using long-term climatic factors.

Keywords: Agriculture, Drought, Entropy, Maut, Topsis

KURAKLIK SÜRECİNİN BÜTÜNLEŞİK ÇOK KRİTERLİ KARAR VERME YÖNTEMLERİ İLE DEĞERLENDİRİLMESİ

Özet

Bu çalışma, tarımsal üretimin sürdürülebilirliği açısından önemli bir konu olan kuraklık üzerinde etkili olan faktörlerin önceliklendirilmesini ve kurak dönemlerin şiddetine göre sınıflandırılmasını hedeflemektedir. Bu amaçla çalışmada, çok kriterli karar verme tekniklerinden (ÇKVV) Entropi, TOPSIS ve MAUT yöntemlerine dayalı entegre bir karar modeli sunulmaktadır. Önerilen karar modeli, Kırşehir ili 1971-2019 yılları arası bazı iklim parametreleri dikkate alınarak kurak dönemlerin belirlenmesine yönelik sayısal bir vaka çalışması üzerine uygulanmaktadır. Uygulama sonucunda, Entropi ağırlıklandırmalı TOPSIS ve MAUT yöntemine göre geçen 49 yıl boyunca 17 yılın kurak geçtiği, bu yıllara ait kuraklık şiddetinin zayıf, orta ve ciddi olmak üzere üç farklı seviyede sınıflandırılabileceği gözlemlenmiştir. Bunların 10 tanesinin zayıf kurak (%20.41), 6 tanesinin orta kurak (%12.24) olduğu belirlenirken, 1 yılın ise ciddi kurak (%2.04) olduğu gözlemlenmiştir. MAUT yöntemine göre 11 adet zayıf kurak (%22.45), 5'i orta kurak (%10.20) ve 1'de ciddi kurak (%2.04) yıl olarak geçtiği belirlenmiştir. Sonuç olarak, uzun yıllık iklimsel faktörlerden yararlanılarak meyve yetiştiriciliği açısından tarımsal kuraklıkla mücadeleye yönelik karar analizinin yapılmasında Entropi, TOPSIS ve MAUT gibi çok kriterli karar verme modellerinin kullanılması destekleyici bir yol gösterebilir.

Anahtar Kelimeler: Tarım, Kuraklık, Entropy, Maut, Topsis

Cite

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1. Introduction

Living organisms are in a close relationship with the environment in which they live [1]. The plants have a variety of interactions with the growth environment. The processes controlling the growth and development of plants are affected by the genetic structure and environmental conditions. Diversity of plant production in a region is determined by the environmental factors [2].

Drought is defined as "the natural event that adversely affects the land and water resources and hydrology due to the significant decrease in precipitation compared to the long term averages recorded" [3,4]. The definition of the drought in agricultural science is different from other disciplines. The amount of water available in the plant root zone during the growth period is more important than the total precipitation during the year. Therefore, the lack of water that plants need during the emergence and development period is defined as agricultural drought. The drought is a recurring phenomenon of climate, whereas it is still unpredictable. The time of occurrence, duration, severity and impact area of drought varies from year to year; thus, causes economic, social and environmental impacts which sometimes pose great threat for humanity. The long-term average of the equilibrium between precipitation and evapotranspiration in a region should be taken into account in drought analyses. Therefore, drought should be considered as a time-dependent parameter [5].

The amount of newly formed fruit buds on fruit trees (eg apple pear) will significantly increase in a dry or moderately dry year, and therefore more flowering will occur in the following spring [6]. In addition, the drought, which causes periodicity in apples, can be reduced by planning a regular and adequate irrigation program. The responses of different fruit species to drought vary depends on the period in which drought occurs. This can be attributed to the differences in the growth and development of fruits in different plant species. Apple and pear fruits grow almost at the same rate until maturity when soil contains adequate available water in the root zone. The fruit growth in stone fruits during the beginning of endocarp hardening is slow or may not occur at all. However, growth continues very rapidly from endocarp hardening to maturity. There is no final growth period in stone seed fruits. The stone fruits reach the final fruit sizes when inside the seed starts to fill in the middle of summer. The fruits never reach the size of a desired juicy fruits when the fruit growth is retarded due to the drought.

Possible decreases in precipitation along with a decrease in irrigation water to be used will adversely affect the sustainability of agricultural production. Therefore, drought analysis is very important for agricultural production and preliminary activities for the drought action plans. On the other hand, drought represents a complex process in which a large number of time-dependent factors (criteria) play an effective role in the time of drought occurrence, and the duration and severity. In this context, drought analysis can be expressed as a multi-criteria decision problem. The multi-criteria decision making techniques are widely used as an effective and useful tool in solving such decision problems. Assessment of water quality [7], determining the location of agricultural farm [8], drought analysis [9, 10] and agricultural land quality index application [11,12] are the examples of multi-criteria decision making techniques.

"Turkey (2017-2023) National Drought Management Strategy Document and Action Plan" on the measures to be taken; the work to be done before the drought, the work to be done during the drought, the work to be done after the drought are evaluated under 3 headings. Among these measures, estimating the course of the drought and making warnings were also included [13].

This study proposes a decision model for drought assessment by the integration of Entropy, TOPSIS and MAUT methods. The study with the proposed decision model was aimed to determine the drought periods between 1971 and 2019 based on some climatic parameters, and recommend some solutions for fruit growing during drought periods by classifying the severity of drought.

2. Materials and methods

2.1. Materials

The annual average highest and lowest temperature, total precipitation and evaporation values measured between 1971 and 2019, obtained from the Kırşehir province Directorate of Meteorology (Latitude 39.1639, Longitude: 34.1561 and Altitude: 1007.0 m) were used in the study.

Kırşehir province has a typical continental climate defined with cold and snowy in winter, hot and dry in summer, rainy in autumn and spring. The average annual precipitation in Kırşehir varies between 350 and 500 mm. The highest precipitation occurs in spring and minimum precipitation in summer. Long term annual average precipitation of the Kırşehir is 383.3 mm. The distribution of rainfall is irregular and the lowest rainfall occurs in the summer months when the water is most needed.

2.2. Methods

Schematic representation of the implementation stages of the decision model proposed for the drought assessment process was shown in Figure 1. The first step of the proposed model is the data preliminary process, which includes the determining the goals and criteria and the arrangement of relevant data from the database [14]. In the second step, the weight values of the criteria are calculated by the Entropy method. The third step involves the application of MCDM (Multi-criteria decision making) methods, ranking the drought status by years and obtaining the classification results.

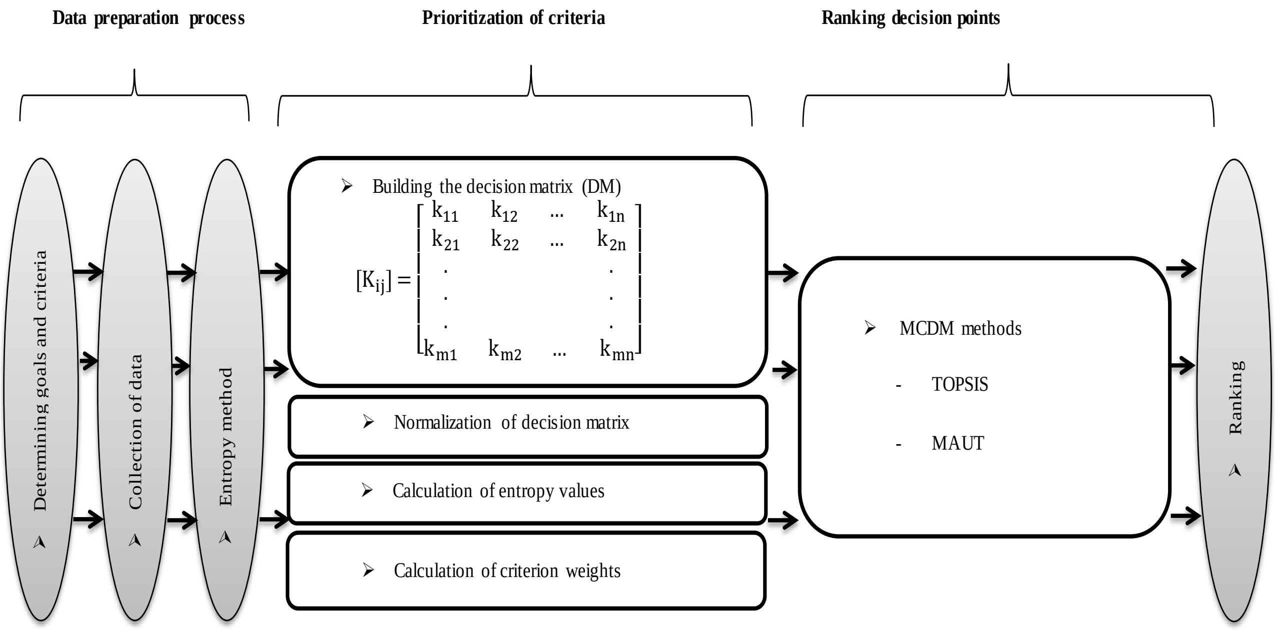

Figure 1. Schematic illustration of the proposed decision model for the drought evaluation process

2.2.1. ENTROPY, TOPSIS and MAUT methods

Entropy method, which is preferred for weighting the criteria [15, 16], application steps of TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) [17-21] and MAUT (Multi Attribute Utility Theory) [22, 23], methods used in evaluating the periodic (annual) drought process and the equations used are given below.

2.2.2. Calculation of weight values of criteria with ENTROPY method

The application steps of the entropy weight method are as follows [15, 16]:

Step 1. *In this step, [Kij] decision matrix was obtained as given in Equation 1 to show n criteria and m alternatives. The matrix created also expresses the decision matrix used in MCDM methods applied in other steps.*

$$[K_{ij}] = \begin{bmatrix} k_{11} & k_{12} & \cdots & k_{1n} \\ k_{21} & k_{22} & \cdots & k_{2n} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ k_{m1} & k_{m2} & \cdots & k_{mn} \end{bmatrix} \qquad (1)$$

Step 2. *Normalization of the decision matrix*

$$n_{ij} = \frac{k_{ij}}{\sum_{i=1}^{j} k_{ij}} \qquad (2)$$

Step 3. *Calculation of Entropy Values*

$$c_j = -k\sum_{j=1}^{n} n_{ij} \,.\, \ln(n_j) \quad (i=1,2,3, ..m; j=1,2,3, ...n) \qquad (3)$$

$$k = \frac{1}{\ln(m)} \qquad (4)$$

$$b_j = 1 - c_j \quad (i=1, 2, 3, m; j=1, 2, 3, ..., n) \qquad (5)$$

Step 4. *Calculation of the Criteria Weight Values*

$$a_j = \frac{1-c_j}{\sum_{i=1}^{n}(1-c_j)} \quad , a_1 + a_2 + \cdots + a_n = 1 \qquad (6)$$

2.2.3. Application of multi-criteria decision making (MCDM) methods

a) TOPSIS (Technique for Order Preference by Similarity to Ideal Solution)

The application steps of the TOPSIS method are as follows [17-21]:

Step 1. *Building the decision matrix:* The decision matrix used in this step of the TOPSIS method is the same as the matrix presented in the Equation 1 for the operation steps of the entropy method.

Step 2. *Normalization of the decision matrix*

$$N_{ij} = \frac{k_{ij}}{\sqrt{\sum_{i=1}^{m} k_{ij}^2}} \quad i= 1, ..., m, j= 1,....., n \qquad (7)$$

Step 3. *Establishing weighted standardized decision matrix*

$$b_{ij} = a_j * N_{ij} \qquad (8)$$

Step 4. *Calculation of positive and negative ideal solution values*

$$I^* = \{(\max_i b_{ij} \,|j \in J), (\min_i b_{ij} \,|j \in J') \; i = 1, \dots, m)\,, \quad I^* = \{b_1^*, b_2^*, \dots, b_n^*\} \qquad (9)$$

$$AI^- = \{(\min_i b_{ij} \,|j \in J), (\max_i b_{ij} \,|j \in J') \; i = 1, \dots, m) \qquad (10)$$

$$I^- = \{b_1^-, b_2^-, \dots, b_n^-\} \; J = \{j = 1,2, \dots, n|\,\} \; J' = \{j = 1,2, \dots, n|\}$$

J: benefit; J': Cost value.

Step 5. *Calculation of distance values*

$$U_i^* = \sqrt{\sum_{j=1}^{n}(b_{ij} - b_j^*)^2} \quad i=1,2, ..., m \qquad (11)$$

$$U_i^- = \sqrt{\sum_{j=1}^{n}(b_{ij} - b_j^-)^2} \quad i=1,2, ..., n \qquad (12)$$

Step 6. *Calculation of proximity for decision points to positive ideal solution and distance from negative ideal solution:*

$$G_i^* = \frac{U_i^-}{U_i^- + U_i^*} \qquad i=1,2,\ldots, m \qquad (13)$$

In the equation; G_i^* value ranges in $0 \le G_i^* \le 1$ and $G_i^* = 1$ represents the absolute proximity of decision point to the ideal solution point. The $G_i^* = 0$ shows the absolute proximity decision point to the negative ideal solution. The G_i values obtained with the TOPSIS method in the range of [0-1] considering the range values given in Table 1 were divided into 9 different classes. The drought class values were determined between 0 and 0.4 [10]. The value ranges of drought classes created using the TOPSIS (Gi*) value given in Table 1 were used in the classification with the MAUT method.

Table 1. Range values for drought level classification with TOPSIS method [10]

Drought Class	Drought Values		
Extreme Wet	0.9	$< G_i^* <$	1
Serious Wet	0.8	$< G_i^* <$	0.9
Moderate wet	0.7	$< G_i^* <$	0.8
Weak Wet	0.6	$< G_i^* <$	0.7
Normal	0.4	$< G_i^* <$	0.6
Weak Drought	0.3	$< G_i^* <$	0.4
Moderate Drought	0.2	$< G_i^* <$	0.3
Serious Drought	0.1	$< G_i^* <$	0.2
Extreme Drought		$G_i^* <$	0

b) MAUT (Multi Attribute Utility Theory) Method
The application steps of the MAUT method are as follows [22, 23]:
Step 1. *Determination of the weight values of the criteria*

Step 2. *Building the Decision Matrix:* Similar to the decision matrix consisting of criteria and alternatives as in the TOPSIS method, the matrix expressed by Equation 1 was used in the application of the MAUT method [22, 23].

Step 3. *Normalization of the decision matrix*

$$f_i(e_i) = \frac{kij - e_i^-}{e_i^+ - e_i^-} \text{ (benefit)}, \; f_i(e_i) = \frac{e_i^+ - kij}{e_i^+ - e_i^-} \text{ (cost)} \qquad (14)$$

In the equation; (e_i^+) represents the best value ($e_i^+ = \max k_{ij}$), (e_i^-) is the worst value ($e_i^- = \min k_{ij}$), fi(e): shows the utility value in the calculated line.

Step 4. *Calculation of total benefit values*

$$F_{(e)} = \sum_1^m f_i(e_i) * a_j \qquad (15)$$

The $F_{(e)}$ in the equation is the utility value of the alternatives, $f_i(e_i)$ is the normalized utility value, and a_j is the weight value shows the utility value in the calculated line.

Step 5. *Ranking the Alternatives (Decision Points):* The alternatives in the last step of the MAUT method were ranked from the most useful criterion to the least useful criterion.

3. Results

3.1. Climatic condition of Kırşehir Province

Long term annual average monthly temperature values of Kırşehir province between 1950 and 2019, average monthly temperature values and relative humidity values for the last 10 years covering between 2010 and 2019 were given in Table 2, Table 3 and Figure 2.

Table 2. Differences between long-year (1950-2019) and last ten-year (2010-2019) temperature values of Kırşehir province

Period	1950-2019	2010-2019	Difference
January	-0.1	0.6	0.7
February	1.4	3.4	2.0
March	5.4	6.7	1.3
April	10.8	11.5	0.7
May	15.3	16.1	0.8
June	19.6	20.5	0.9
July	23.0	24.3	1.3
August	23.0	24.6	1.6
September	18.5	20.2	1.7
October	12.6	13.2	0.6
November	6.4	6.9	0.5
December	2.0	2.4	0.4
Annual	11.5	12.5	1.0

Table 3. Differences between long-year (1950-2019) and last ten-year (2010-2019) relative humidity values of Kırşehir province

Period	1950-2019	2010-2019	Difference
January	78.5	82.2	3.7
February	74.1	72.4	-1.7
March	67.7	65.3	-2.4
April	63.0	58.3	-4.7
May	61.3	59.8	-1.5
June	55.1	54.6	-0.5
July	48.3	43.1	-5.2
August	48.2	42.7	-5.5
September	52.6	44.3	-8.3
October	62.7	60.2	-2.4
November	71.9	67.2	-4.8
December	78.9	79.8	0.9
Annual	63.5	60.8	-2.7

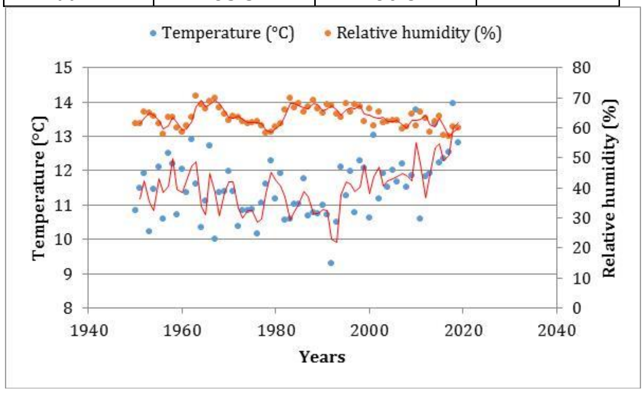

Figure 2. Long term annual (1950-2019) average temperature and relative humidity values of Kırşehir province

The highest temperature difference between the long-term and the last 10-year average temperature values in Kırsehir province was determined in February with 2 °C. The average annual temperature in the last 10-year was 1 °C higher than the long-term values (Table 2). The annual average temperature values between 1950 and 2019 showed that the variation in the annual average temperature was in an increasing trend.

The difference between the long-term annual relative humidity values for Kırşehir and the average relative humidity values of the last 10-year tends to decrease and the difference reached the highest value in September with 8.3% (Table 3).

3.2. Calculation of weight values of criteria

Entropy weight values of four different criteria used in drought assessment were calculated by the application of equations between (1) and (5), respectively, and the results were shown in Figure 3.

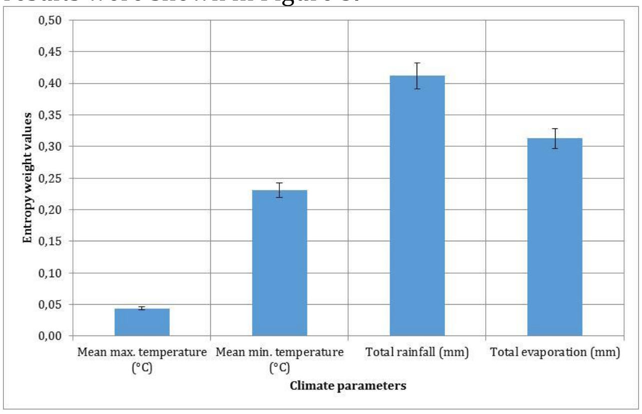

Figure 3. Entropy weight values

The ranking of the criteria with the importance level showed that the most important climate parameter in the occurrence of drought was the total rainfall with 41.21%, followed by the total evaporation (31.28%), average minimum temperature (23.11%) and average maximum temperature (4.40%) (Figure 3).

3.3. The results for drought assessment and ranking using the proposed decision model

In the application of the proposed decision model based on the integration of Entropy, TOPSIS and MAUT methods, the criterion weights were calculated using the entropy method, then the implementation steps of TOPSIS and MAUT methods were begun. The decision matrix of 49x4 was obtained by placing the years in rows and the climate parameters in the columns. The results for TOPSIS method were obtained by the application of decision matrix to equations between (7) and (13) and the results for MAUT method were obtained by the help of the equation (14) and (15). The results obtained by TOPSIS and MAUT methods were given in Table 4.

Table 4. TOPSIS and MAUT method application results

	TOPSİS			**MAUT**
YEARS	**U***	**U-**	G_i*	$F_{(e)}$
1971	0.0367	0.0439	0.5446	0.52
1972	0.0360	0.0372	0.5076	0.45
1973	0.0491	0.0294	0.3746	0.29
1974	0.0422	0.0319	0.4307	0.38
1975	0.0280	0.0380	0.5758	0.57
1976	0.0280	0.0391	0.5822	0.56
1977	0.0326	0.0332	0.5048	0.49
1978	0.0340	0.0317	0.4827	0.48
1979	0.0317	0.0341	0.5183	0.53
1980	0.0234	0.0436	0.6505	0.65
1981	0.0285	0.0364	0.5611	0.56
1982	0.0451	0.0268	0.3727	0.33
1983	0.0346	0.0314	0.4757	0.47
1984	0.0502	0.0205	0.2900	0.27
1985	0.0291	0.0429	0.5958	0.61
1986	0.0419	0.0251	0.3742	0.38
1987	0.0275	0.0484	0.6374	0.67
1988	0.0306	0.0351	0.5342	0.53
1989	0.0452	0.0202	0.3086	0.31
1990	0.0434	0.0225	0.3419	0.34
1991	0.0329	0.0325	0.4970	0.49
1992	0.0376	0.0325	0.4634	0.42
1993	0.0413	0.0272	0.3973	0.37
1994	0.0480	0.0210	0.3043	0.31
1995	0.0283	0.0393	0.5817	0.59
1996	0.0224	0.0446	0.6657	0.66
1997	0.0300	0.0372	0.5540	0.54
1998	0.0241	0.0427	0.6397	0.65
1999	0.0388	0.0267	0.4077	0.42
2000	0.0339	0.0333	0.4954	0.48
2001	0.0412	0.0267	0.3932	0.43
2002	0.0441	0.0221	0.3341	0.33
2003	0.0494	0.0191	0.2791	0.31
2004	0.0504	0.0164	0.2452	0.26
2005	0.0385	0.0274	0.4156	0.45
2006	0.0477	0.0192	0.2870	0.32
2007	0.0537	0.0175	0.2456	0.25
2008	0.0591	0.0105	0.1505	0.16
2009	0.0355	0.0351	0.4977	0.52
2010	0.0278	0.0495	0.6406	0.72
2011	0.0369	0.0295	0.4438	0.43
2012	0.0308	0.0416	0.5745	0.60
2013	0.0513	0.0210	0.2907	0.26
2014	0.0313	0.0362	0.5364	0.56
2015	0.0228	0.0432	0.6542	0.65
2016	0.0268	0.0393	0.5949	0.58
2017	0.0435	0.0255	0.3693	0.36
2018	0.0253	0.0433	0.6316	0.67
2019	0.0295	0.0360	0.5495	0.55

U*: Positive ideal values. U-: Negative ideal values G_i*: Relative proximity values to the ideal solution. $F_{(e)}$: Multiple Utility Function Value.

The ranking of drought status in Kırşehir province, determined by the application of TOPSIS and MAUT methods, between 1971 and 2019 was shown in Figure 4.

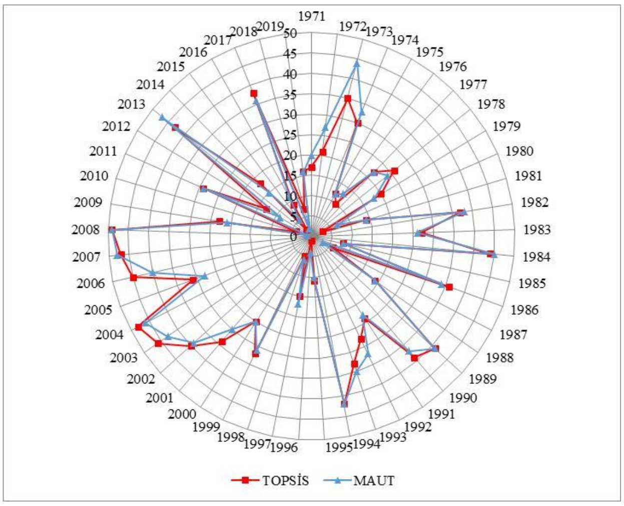

Figure 4. TOPSIS and MAUT method ranking values

The relationship between the ranking for last 49 years of drought with the years (Figure 4) was examined by Spearman rank correlation analysis and the concurrence between the rankings was recorded as 98% ($\rho = 0.98$; $p<0.01$).

The classification using the TOPSIS method, considering the class intervals of drought severity (Table 1), indicated that 17 drought years occurred in the 49 years examined. Ten of the drought years were classified as weak drought (20.41%), 6 of the drought years were determined as moderate drought (12.24%), and 1 year was serious drought (2.04%). The number of years without drought (normal year) was 25 (51.02%) and the number of years with weak wetness was 7 (14.29%). Similar to the TOPSIS method, the MAUT method revealed that 17 out of 49 years were drought. Eleven out of 17 years were classified as weak drought (22.45%), 5 years were moderate drought (10.20%) and 1 was severe drought (2.04%) year. The number of normal years was 24 (48.98%), the number of weak wet years was 7 (14.29%), and the number of years with moderate wetness was 1 (2.04%).

4. Discussion

Studies carried out on global climate change indicated that extremely high temperatures and widespread and severe drought events may occur throughout the world. Fifth assessment report in the intergovernmental climate change panel stated that the temperature during the summer period will increase by 2 to 3 °C between 2013 and 2040 in north-west part of Turkey, and by 1 to 1.5 °C in south-east region [23].

The responses of plants to increasing temperatures differ depending on the type of fruit species. The fruits cannot meet the cooling requirements during winter period under increasing temperatures; thus, the blooming of flower and leaf buds are delayed and the yield and quality are adversely affected. The disruption of balance between photosynthesis and respiration in the summer slows down the growth of plants. The plants turn into yellow, fade, dry and finally die when the rapidly increasing water loss in the soil is not met [2]. [24] reported that irrigation programs based on the drought stress in plants gained importance due to the decrease in irrigation water resources in the world. The use of high temperature tolerant varieties and rootstocks is one of the most effective approaches to solve the drought problem [25].

The decreasing relative humidity during the periods of increasing temperatures is a negative situation for orchards. Humidity has a great influence on the growth and productivity of fruit trees. The temperature particularly has an impact on the size, shape, color and quality of fruits [2]. [26] studied the long-term (1960-2015) and last 10-year temperature and relative humidity changes in Kırşehir, and reported that the average temperature in the last 10-year was 0.68 ° C higher than in long term temperature value, while the relative humidity was 2.96% lower compared to the long-term value. Similarly, the results of this study also indicated that average temperature values tend to increase in general, relative humidity tends to decrease, and this will have a negative impact on the quality and yield of fruits (Figure 2). [2] stated that drought, depending on the frequency and duration, will negatively affect the cultivation of horticultural crops especially in spring and summer, when vegetative growth of plants is intense. Therefore, they reported that fruit growing and viticulture cannot be carried out economically without irrigation under insufficient total annual precipitation (300-500 mm). In addition, fruits cannot even develop in a region with sufficient total annual precipitation (800-900 mm), if most precipitation occurs outside the fruit development period.

The decision model proposed in the drought assessment of Kırşehir province between 1971 and 2019 revealed that total amount of precipitation (41.21%) was more effective than other criteria (evaporation, the highest and lowest temperatures) in drought occurrence. In addition, the results indicated that drought occurred in 17 out of 49 years, and drought severity could be classified in three different levels as weak, moderate and severe. The agreement between the rankings of drought obtained with TOPSIS and MAUT methods was 98%. [9] determined the drought or rainy years by using the long term annual, the lowest and the highest average temperatures, average the lowest and the highest relative humidity, average annual precipitation, and total annual precipitation of Kahramanmaraş province between 1995 and 2014 using the TOPSIS method. The researchers reported the possibility of meteorological droughts in 2002, 2008 and 2011 and a gradual droughts in 2015, 2016 and 2017. The results suggested that droughts will occur due to climate change in the future and will become a recurring natural event in the long term. Therefore, new generation drought prediction models should be developed.

[10] created a decision model using the TOPSIS method to calculate the drought or rainy years using annual evaporation, maximum and minimum temperature and total precipitation data between 1963 and 2016 in Adana. The longest rainfall, temperature and evaporation records in the region indicated the occurrence of 10 moderate, 15 weak and 7 serious drought in 54 years. The researchers stated the importance of monitoring the months and years with a drought trend and taking the necessary precautions for a possible drought by water resources planners.

[27] analyzed the drought occurrence in Seyfe Lake during 1975–1991 (the 1st period) and 1992–2008 (2nd period) using the Standardized Precipitation Index (SPI) method in Kırşehir. The occurrence of weak, moderate, severe, very severe and extraordinary drought were reported in Kırşehir and Seyfe Lake between 1975 and 2008. The weak drought values in all dry periods (3, 6, 12 and 24 months) of the second period increased compared to the drought values in the first period. In contrast, the intensity of normal humidity decreased from the first to the second period. The results revealed that the water stress will increase in the Kırşehir Province in the coming years, therefore, necessary drought measures should be taken.

The findings and the suggestions of the researchers showed the importance of monitoring the periods of drought trend by the authorized institutions and taking the necessary measures for possible drought to minimize the adverse effects that may be experienced during dry years in Kırşehir. Some of these measures are creating drought prediction models, selecting drought-resistant rootstocks and varieties, arranging irrigation programs suitable for fruit species and varieties, and using pressurized irrigation systems for effective irrigation.

The results revealed that the use of multi-criteria decision-making models such as Entropy, TOPSIS and MAUT can provide supportive information to make decision analysis by using the advantage of long-term climatic factors to combat agricultural drought.

5. References

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