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Drought Analysis Using the Entropy Weight-based TOPSIS Method: A Case Study of Kars, Turkey

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Abstract—The aim of this study is to conduct a drought analysis at Kars station in the northeast of Turkey using six different meteorological parameters by utilizing The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method based on the entropy weight method. As of the input parameters of the study, the mean monthly rainfall, mean monthly maximum and minimum temperature, mean monthly relative humidity, mean monthly wind speed, mean monthly sunshine duration, obtained by the Kars meteorology station for 1990 and 2018 period are used. In the second section of the study, Mann–Kendall trend analysis was applied to TOPSIS results. The findings of this study indicated that the drought tends to increase in January, May and October. In the final section of the study, multivariate regression analysis, which accepts six different parameters as independent variables and TOPSIS drought index results as dependent variables, was performed. According to the findings of this study, there were no cases of extreme wet, severe wet, medium wet, severe drought and extreme drought at the Kars station. The driest months are May and June. The wettest months are March and November.

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1. INTRODUCTION

On a global scale, droughts are natural disasters of a recurrent scale due to sub-normal precipitation. They are sometimes associated with high temperatures and adversely affect human health, social, economic, and cultural activities [15]. Since the dawn of civilization, drought has had extreme and sometimes disastrous effects on people livelihoods. On the contrary, in the 21st century droughts have been intensified by massive agricultural production losses affecting global food security, depletion of water resources and increasing devastating wildfires [9].

The common definition of drought is still missing due to numerous problems, both physical and completely methodical [10]. However, we can define drought as a negative climatic phenomenon that occurs as a result of unpredictable changes in the parameters that make up the hydrological cycle, especially precipitation, temperature, relative humidity and sunshine duration. Precipitation is less than the normal or does not fall at all in the region where it occurs. A drought can be induced by deficiency in precipitation relative to what is expected (i.e., “normal”) and which is usually extended over a season or longer period of time with adverse effects on human activities, crop production, livestock, and the environment [5].

Recent worldwide efforts are put in investigating the causes of drought formations, defining this phenomenon and determining feedforward and feedback mechanisms [3]. In the past decades, recurring drought events along with global warming caused drastic changes in the natural landscape of many species [4]. Therefore, early warning and monitoring of drought is crucial in reducing potential adverse effects on society and the environment. For this purpose, several experimental methods for drought calculation have been put forward, but these are almost completely made up of precipitation alone.

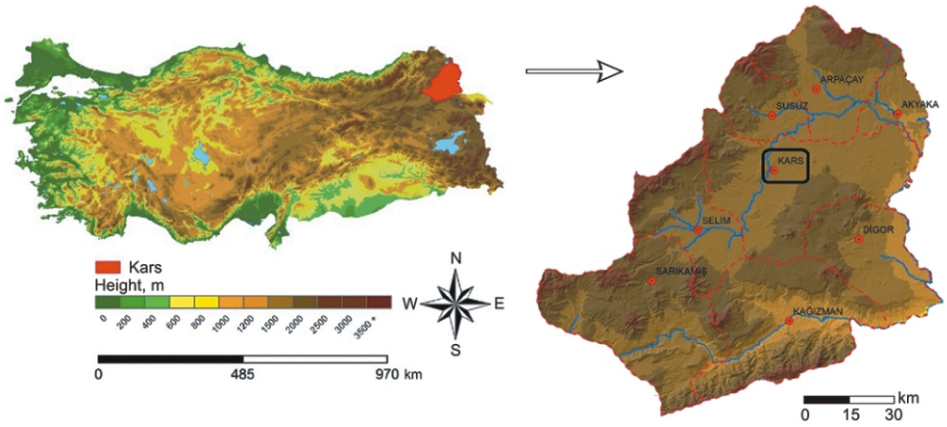


Fig. 1. Location of Kars province and Kars meteorological station.

The authors of [12] developed the Standardized Precipitation Index (SPI) which is the most widely used drought determination method in the world. This index is a very common method in practice due to its ease of calculation and considering only precipitation as a meteorological parameter [20, 21]. In this study, unlike other conventional drought indices, The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) [8] method was selected for drought analysis. This TOPSIS method is widely used in industrial engineering [1]. TOPSIS is a method used in many areas such as organizational and financial performance evaluation, product and service quality evaluation, customer-oriented product design process, multi-purpose inventory planning, risk assessment and data mining, facility location selection, supplier selection, and production method selection [6]. However, it can also be used in hydrological studies. Research papers of [2, 7, 13–15, 17–19, 23] are examples of drought-related hydrological studies using the TOPSIS method.

The aim of this study is to conduct the drought analysis at Kars station (situated at the city center) which is located within the Aras Basin in the northeast of Turkey. The analysis is performed with the TOPSIS method using obtained data for 1990 and 2018 period, i.e., mean monthly rainfall, mean monthly maximum and minimum temperature, mean monthly relative humidity, mean monthly wind speed, and mean monthly sunshine duration. Kars city is less developed economically due to its climatic and geographical features and its distance to other developed regions. Due to the cold climate of Kars and its vicinity, the city is often overlooked in hydrological studies of droughts. Meteorological stations established in some provinces and districts around Kars station do not have meteorological parameters such as long-year wind speed and sunshine duration used in the TOPSIS method. For this reason, only the meteorological station data in the center of Kars could be used in the present study. Many water resources planning projects have come to the fore in the region, especially in recent years, due to the increasing population, livestock activities and irrigation water need. For this reason, it has become necessary to carry out studies on drought in this region. The main purpose of this study is to make a drought analysis that will be effecient in water resources planning in the study area.

2. MATERIALS AND METHODS

The meteorological parameters used in this study were obtained from the Turkish State Meteorological Service. In Turkey, in water resources planning, flood and drought analyses, meteorological and hydrological studies, analyzes are generally carried out on monthly values of meteorological data. In other words, monthly average and monthly total values of climatic data are used. In addition, as can be seen from the studies on TOPSIS mentioned in the introduction part of the present paper, monthly average values of climatic parameters were used in hydrological studies. For this reason, it was preferred to analyze the monthly average values of meteorological data in this study. The location of the meteorological study station is shown in Fig. 1. The geographical characteristics of Kars station are as follows: 40.6042 N and 43.1073 E, sea level height is 1777 m. The following parameters calculated for the period 1990–2018 are used:

—X_1: mean monthly rainfall is 44.9 mm;
—X_2: mean monthly maximum temperature, 19.4 C;
—X_3: mean monthly minimum temperature, –8.6 C;
—X_4: mean monthly relative humidity, 70.2%;
—X_5: mean monthly wind speed, 2.4 m/s;
—X_6: mean monthly sunshine duration, 198.9 hours.

The TOPSIS is one of the multicriteria decision making methods that facilitates making the optimal choice among many alternatives. TOPSIS method is widely used in multicriteria decision making techniques. The TOPSIS is preferred due to its easily explained and understood application stages and easy to interpret results. While making a decision in this method, the alternative that is closest to the positive ideal solution and the furthest to the negative ideal solution is preferred. Proximity to a positive ideal solution (PIS) refers to the maximization of return and minimization of cost (loss) (in this study, for example, maximum temperature, wind speed and sunshine duration have cost attributes in terms of increasing drought) if the criterion has a benefit attribute (in this study, for example, precipitation, minimum temperature and relative humidity have benefit attributes in terms of drought reduction). In short, the alternative is expected to be close to the ideal solution and far from the negative ideal solution [11]. Since the optimal choice in TOPSIS method is determined according to the one that is far from the negative ideal solution and close to the positive ideal solution, it is a very suitable method for pessimistic (risk-avoiding) decision makers.

The TOPSIS method has a widespread use in many areas from the private sector to the public sector and from financial analysis to engineering research. As it has such a wide range of uses, there are some incomplete interpretations in the literature, especially in terms of the TOPSIS calculation steps. While there is only one methodology for TOPSIS, each scientific field has tried to modify the TOPSIS method in accordance with its own. For example, when TOPSIS, which is applied in the financial field, is tried to be applied to hydrological studies, some crucial parts are overlooked. In order to eliminate these deficiencies, in this study, TOPSIS calculation steps are included in a detailed and updated way, which can be a resource especially in drought research. In the present paper, the calculation procedure of the TOPSIS method has been tried to be explained step by step in terms of drought analysis.

In the TOPSIS method, alternatives are listed according to defined criteria. In the first step of the method, the decision (data) matrix is created. The normalized matrix is obtained from the decision matrix. Afterwards, the normalized decision matrix is weighed and the ideal solution and negative ideal solution values are determined. Following this, the ideal and negative ideal distances as well as the alternatives are calculated [22].

In the final results table, the alternative with the highest score value is determined as the optimal choice. The application steps mentioned for the TOPSIS method are as follows.

A. Scoring. At first, invite relevant experts to score the evaluation index (qualitative and quantitative indicators). Scoring results are then expressed in the mathematical matrix format, and the generated value matrix is demonstrated in equation (1):

$$D \quad \begin{matrix} x_{11} & \dots & x_{1j} & \dots & x_{1n} & D_1(x_1) \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{i1} & \dots & x_{ij} & \dots & x_{in} & D_i(x_j) \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{m1} & \dots & x_{mj} & \dots & x_{mn} & D_m(x_n) \end{matrix} . \tag{1}$$

B. Standard Matrix Calculation. The feature matrix is normalized to obtain the normalized vector r_{ij}, and build standardized matrix about normalized vector r_{ij}. Normalized vector r_{ij} is calculated as in equation (2). Critically, the logarithmic calculation of negative values and zero is not significant. However, some climatic data values, such as temperature, might experience negative values, or in the case of rainfall, zero values. Therefore, it is suggested applying equation (2) to take this into account.

$$r_{ij} \quad \frac{x_{ij} \quad \min(x_{ij})}{\max(x_{ij}) \quad \min(x_{ij})}, \quad i = 1, 2,..., m; \quad j = 1, 2,..., n. \tag{2}$$

C. Index Weight Determining. The process of determination and calculation of the weight of each index by means of entropy weight method is as follows.

1. Calculating the proportion p_{ij} of index value of project i under index j: p_{ij} is calculated as in equation (3):

$$p_{ij} \quad \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}}. \tag{3}$$

2. Calculating the entropy e_j of index j, e_j is identified in equation (4):

$$e_j \quad k \sum_{i=1}^{m} [p_{ij} \ln p_{ij}]. \tag{4}$$

The k in equation (4) can be calculated in equation (5):

$$k \quad 1/\ln m. \tag{5}$$

3. Calculating the entropy weight w_j of index j, w_j is calculated as in equation (6):

$$w_j \quad \frac{1 \quad e_j}{\sum_{j=1}^{n} (1 \quad e_j)}, \quad \sum_{j=1}^{n} w_j \quad 1. \tag{6}$$

4. Building standardized matrix of weight: calculate standardized value v_{ij} of weight and build standardized matrix of weight, v_{ij} is measured as in equation (7):

$$v_{ij} \quad w_j r_{ij}, \quad i = 1, 2,..., m; \quad j = 1, 2,..., n. \tag{7}$$

5. Determining the ideal solution and the anti-ideal solution: determine the ideal solution A^* and the anti-ideal solution A^- according to standardized value v_{ij} of weight. A^* and A^- are identified in equation (8) and equation (9):

$$A^* \quad \{(\max_i x_{ij}, \ j \quad J_1), (\min_i v_{ij}, \ j \quad J_2), \ i \quad 1, 2,\ldots, m\} \quad v_1^*, v_2^*,\ldots, v_n^*, \tag{8}$$

$$A^- \quad \{(\min_i x_{ij}, \ j \quad J_1), (\max_i v_{ij}, \ j \quad J_2), \ i \quad 1, 2,\ldots, m\} \quad v_1^-, v_2^-,\ldots, v_n^-. \tag{9}$$

J_1 in equation (8) and equation (9) which reveals the optimum value of index j is a profitability index set; J_2 in equation (8) and equation (9) which shows the worst value of index j is a loss index set. v_j^* is the distance between index j and the optimum objective while v^- is the distance between index j and the worst objective. The larger the profitability index value is or the smaller the loss index is, the better the performance is of the evaluation result and vice versa.

6. Calculating distance scale: the distance between each objective and ideal solution or anti-ideal solution is defined as distance scale and calculated by Euclidean distance. S^* constitutes the distance between the objective and ideal solution A^*, and S^- shows the distance between the objective and anti-ideal solution A^-. The calculation formula is identified in the following way in (10) and (11):

$$S^* \quad \sqrt{\sum_{j=1}^{n} (v_{ij} \quad v_j^*)^2}, \tag{10}$$

$$S^- \quad \sqrt{\sum_{j=1}^{n} (v_{ij} \quad v_j^-)^2}. \tag{11}$$

In (10) and (11), $i = 1, 2,..., m$, and S^* represents the closeness between each evaluation and the ideal objective. The smaller the value of S^* is, the shortest the distance from objective to ideal solution is, and the most preferred the program is.

7. Calculating closeness degree of ideal solution C^*, C^* is calculated as in (12):

$$C_i^* \quad \frac{S_i^-}{S_i^* \quad S_i^-}. \tag{12}$$

In equation (12), C_i^* is in the range of 0 to 1. When $C_i^* = 0$, then $A_i = A^*$, which means A_i is the most optimal evaluation objective. From small to large scale, all of the evaluation objectives are categorized based on the value of C_i^*. The larger the value of C_i^* is, the better the evaluation objective is.

Table 1. Drought category according to TOPSIS value

Drought category	Interval
Extremely Wet	0.9 < TOPSIS <1
Severe Wet	0.8 < TOPSIS < 0.9
Medium Wet	0.7 < TOPSIS < 0.8
Weak Wet	0.6 < TOPSIS < 0.7
Normal	0.4 < TOPSIS < 0.6
Weak Drought	0.3 < TOPSIS < 0.4
Medium Drought	0.2 < TOPSIS <0.3
Severe Drought	0.1 < TOPSIS < 0.2
Extremely Drought	0 < TOPSIS < 0.1

Table 2. Weights calculated for desired climatic parameters using entropy methods for Kars station

Parameter	Entropy weights
X_1: Mean monthly rainfall (mm)	0.327
X_2: Mean monthly maximum temperature (°C)	0.186
X_3: Mean monthly minimum temperature (°C)	0.186
X_4: Mean monthly relative humidity (%)	0.050
X_5: Mean monthly wind speed (m/s)	0.136
X_6: Mean monthly sunshine duration (hours)	0.116
Total entropy weights	1

When output varies from zero to one, high ratio is an indicator of wet conditions, and lower values indicate drought conditions. Quantitative and qualitative classifications of the TOPSIS drought index is seen in Table 1. In the second section of the study, the Mann–Kendall trend analysis was conducted by utilizing MAKESENS Excel macro [16]. The trend analysis is defined as a process of estimating change in future outcomes using historical past data based on their trend. Historical data set for this study were analyzed to acquire patterns by using non-parametric analysis, i.e., the Mann–Kendall trend test. The increase or decrease in the trend is controlled by the normalized test statistics (Z) value. Its positive and negative values show the increasing and decreasing trend, respectively. In the third analysis of the study, the first step involves calculating values of drought/wet years using the TOPSIS model for Kars meteorological station. The second step of analysis uses multivariate regression, with the TOPSIS drought index identified as the dependent variable (Y), and six climate parameters used for model input as the independent variable (X) for the period 1990–2018. Based on the extracted regression model outputs, for each of the independent variables coefficients were determined. Afterwards, in order to test accuracy of model, the TOPSIS values were applied to a variety of statistical tests, such as Mean Squared Error (MSE), Root Mean Square Error (RMSE), and Mean Absolute Percentage Error (MAPE), the Mean Absolute Error (MAE) and coefficient of determination (R^2). The formulas of these statistical tests are common.

3. RESULTS AND DISCUSSION

In this study, drought analysis was conducted for Kars meteorological station by using six different climatic parameters as input parameters in the TOPSIS method. From January to December, between 1990–2018, the monthly drought situation was tried to be determined. By using the Entropy method used in TOPSIS method, the weights of the parameters used in the study were identified. According to the results, mean monthly rainfall is the most weight effect, while mean monthly relative humidity is the least weight effect. The entropy weights of climatic parameters are listed in Table 2.

When the Kars station TOPSIS results are considered as the whole series, it is determined as 127 months weak wet, 195 months normal, 21 months weak drought and 5 months medium drought. Extreme drought and extreme wet situations have not been observed. The drought conditions by months for the years

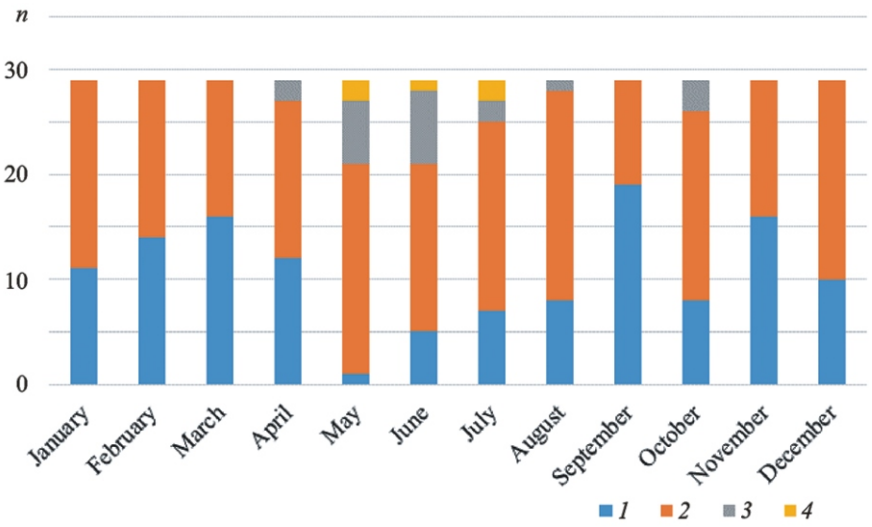


Fig 2. Number of drought events according to drought category observed in Kars station. *n* is number of dry months; (*1*) is weak wet; (*2*) is normal; (*3*) is weak drought; (*4*) is medium drought.

1990–2018 are demonstrated in Table 2. As illustrated in Table 2, 2002 and 2006 April periods are weak drought, 2004 and 2018 May periods are medium drought, 2005, 2010–2013 and 2016 May periods are weak drought, 1992 June period is medium drought, 2002, 2008, 2009, 2013, 2016 and 2018 June periods were identified as weak drought. Weak drought is observed in July 2001 and 2010, medium drought is observed in 2002 and 2009 July period, weak drought observed in 2014 August, weak drought is observed in 2003, 2006 and 2015 October period. The other months were reported to be normal.

The number of dry months from January to December has been determined. According to the monthly analysis results, only weak wet, normal, weak drought and medium drought events were observed. Drought events at Kars station are the most common in May and the least common in March and September. The results are graphed in Fig. 2.

The results of the Mann–Kendall trend analysis performed in the second step of the study showed that the 29-year period, between 1990 and 2018, according to the test *Z* results, an increase in drought was detected in January, May, and October, while there was no statistical trend in terms of increase or decrease in the other months.

At the final section of the study, regression analysis was conducted using six different climatic parameters. TOPSIS drought values as the dependent variable and six climatic parameters as independent variables were utilized in the regression analysis. Linear regression coefficients of each climatic parameter were identified. The coefficients of each climatic parameter were obtained and the following regression equation was composed using these coefficients:

$$Y \quad 0.037 \quad 0.019X_1 \quad 0.01X_2 \quad 0.923X_3 \quad 0.002X_4 \quad 0.002X_5 \quad 0.002X_6. \tag{13}$$

Error rates between the actual TOPSIS values and the TOPSIS values obtained from linear regression analysis are as following: MAE = 0.008; RMSE = 0.010; R^2 = 0.998; MSE = 0.0001; MAPE = 2.052. While the R^2 value was almost 1, the values were very low in other error statistics.

As a result, TOPSIS method has successfully managed to detect drought events in Kars meteorological station. The best known and commonly used indices such as SPI, only requires precipitation parameter. However, the TOPSIS can be calculated using as many different climatic parameters as desired. This outlines an advantage in drought calculation with the TOPSIS. Nevertheless, according to entropy weight results, precipitation is the most effective in drought formation, followed by temperature parameter. The characteristics, numbers, and types of climatic parameters used will definitely affect the result. As the value ranges representing the TOPSIS drought categories change, so the defined dry months do. However, in this study it was preferred to use the interval in the authors of [19].

The present drought analysis carried out in the study area can help to reduce the negative effects of drought, because the results obtained according to years and months reveal the degrees of droughts

experienced. The frequency of the drought and especially the months and years when it is observed may recur in the future. When drought occurs, the stockbreeding (common in the study area) and agricultural plants growth will be adversely affected. Water management projects that do not take into account the hydrological studies related to drought will not reach their goals and the creatures living in the region will be deprived of the basic amount of water. People will be affected by the negative events caused drought, especially due to the lack of clean drinking water.

4. CONCLUSION

Drought is a natural climatic event that can be seen in all climatic conditions. While short-term drought-induced events can be managed and mitigated by taken measures preventing harm, long-term droughts might leave permanent negative and detrimental effects on the society and the environment. For this reason, drought analysis and used indices have an important and highlighted place for hydrological studies.

In this study, drought analysis was carried out at Kars meteorological station (situated in one of the highest city centers) located in the northeast of Turkey by utilizing Entropy Weight method based on the TOPSIS model. By using six different climatic parameters, drought information for 1990–2018 was tried to be explored. In Kars station, winters are very cold and snowy, and summers are cool and rainy. These continental climate characteristics are also reflected in TOPSIS drought values. According to the results of the analysis, May was the most common month of drought situations. Also, according to the Mann–Kendall trend analysis results, May was determined to be the month in which drought intensity tended to increase the most. While normal conditions prevail throughout the Kars station, weak drought and medium drought incidents are frequently observed. As a result of the linear regression, a single equation was developed to obtain the TOPSIS results using climatic parameters. Error rates were found to be perfectly low in the regression analysis.

There are many dams and hydroelectric power plants in the study area. Due to the increasing population and irrigation needs, water use is gradually increasing. Therefore, various projects related to water planning continue to be carried out in the study area. It is asserted that the remarkable findings of this study might be used in the future water resources projects for reference and a valuable contribution to the literature.

REFERENCES

1. Z. F. Antmen and P. Mic, “Selection of Mechanical Ventilator in Pediatric Intensive Care Unit by Multicriteria Decision Making and a Case Study,” Cukurova University Journal of the Faculty of Engineering and Architecture, No. 4, **33** (2018).
2. H. Babaei, S. Araghinejad, and A. Hoorfar, “Developing a New Method for Spatial Assessment of Drought Vulnerability (Case Study: Zayandeh-Rood River Basin in Iran),” Water and Environ. J., **27** (2013).
3. E. A. Cherenkova, M. Yu. Bardin, and A. N. Zolotokrylin, “The Statistics of Precipitation and Droughts during Opposite Phases of the Quasi-Biennial Oscillation of Atmospheric Processes and Its Relation to the Yield in the European Part of Russia,” Meteorol. Gidrol., No. 3 (2015) [Russ. Meteorol. Hydrol., No. 3, **40** (2015)].
4. E. Sh. Elizbarashvili, R. Sh. Meskhiya, M. E. Elizbarashvili, L. D. Megrelidze, and V. E. Gorgisheli, “Frequency of Occurrence and Dynamics of Droughts in Eastern Georgia in the 20th Century,” Meteorol. Gidrol., No. 6 (2009) [Russ. Meteorol. Hydrol., No. 6, **34** (2009)].
5. Ghanghermeh, G. R. Roshan, and S. Al-Yahyai, “The Influence of Atlantic-Eurasian Teleconnection Patterns on Temperature Regimes in South Caspian Sea Coastal Areas: A Study of Golestan Province, North Iran,” Pollut., No. 1, **1** (2015).
6. H. Gokkaya and T. Kellegoz, “Decision Support Model Based on Ahp, TOPSIS and Hungarian Algorithms for Personnel Assignment Processes,” J. Industrial Eng., No. 1, **28** (2017) [in Turkish].
7. S. Hadisuwito, and F. H. Hassan, “Selection Drought Index Calculation Methods Using Electre, Topsis, and Analytic Hierarchy Process,” Int. J. Eng. and Technol., **7** (4.36) (2018).
8. C. L. Hwang, and K. Yoon, *Multiple Attribute Decision Making* (Springer-Verlag, Berlin, 1981).
9. K. Kogan, and W. Guo, “Early Twenty-first-century Droughts during the Warmest Climate,” Geomatics, Nat. Hazards and Risk, No. 1, **7** (2016).
10. I. A. Kulikova, E. N. Kruglova, D. B. Kiktev, and V. G. Sal’nikov,“Practical Predictability of the Standardized Precipitation Index on Monthly and Seasonal Timescales,” Meteorol. Gidrol., No. 9 (2017) [Russ. Meteorol. Hydrol., No. 9, **42** (2017)].
11. Y. J. Lai, T. Y. Liu, and C. L. Hwang, “TOPSIS for MODM,” Europ. J. Operational Res., **76** (1994).

12. T. B. McKee, N. J. Doesken, and J. Kleist, "The Relationship of Drought Frequency and Duration to Time Scales," in *Proceedings of the 8th Conference on Applied Climatology*, **17** (1993).
13. M. Ozfidaner, E. Gonen, and S. Kartal, "Drought Analysis by TOPSIS Method in Adana," Mediterranean Agr. Sci., No. 1, **33** (2020).
14. G. Roshan, G. Mirkatouli, and A. Shakoor, "A New Approach to Technique for Order-preference by Similarity to Ideal Solution (TOPSIS) Method for Determining and Ranking Drought: A Case Study of Shiraz Station," Int. J. Phys. Sci., No. 23, **7** (2012).
15. G. Roshan, A. Ghanghermeh, and S. W. Grab, "Testing a New Application for TOPSIS: Monitoring Drought and Wet Periods in Iran," Theor. Appl. Climatol., **131** (2018).
16. T. Salmi, A. Maata, P. Antilla, T. Ruoho-Airola, and T. Amnell, *Detecting Giddiss of Annual Values of Atmospheric Pollutants by the Mann–Kendall Test and Sen's Slope Estimates—the Excel Template Application Makesens* (Finnish Meteorological Institute, Helsinki, Finland, 2002).
17. A. Sepehr and C. Zucca, "Ranking Desertification Indicators Using TOPSIS Algorithm," Springer, **62** (2012).
18. B. Sobhani and V. Safarianzengir, "Monitoring and Prediction of Drought Using TIBI Fuzzy Index in Iran," Caspian J. Environ. Sci., No. 3, **18** (2020).
19. C. Tanriverdi, H. Depirmenci, M. Tekinerdopan, E. Gonen, F. Arslan, and A. Atilgan, "Precision of Drought Based on the TOPSIS Method," Scientific Papers. Series A. Agronomy, No. 1, **61** (2018).
20. E. Topcu and N. Seckin, "Drought Analysis of the Seyhan Basin by Using Standardized Precipitation Index (SPI) and L-moments," J. Agr. Sci., **22** (2016).
21. A. Vishwakarma, M. K. Choudhary, and M. S. Chauhan, "Trend Analysis of Meteorological Variables and Drought Indices in the Bundelkhand Region Using the Non-Parametric Approach," Meteorol. Gidrol., No. 12 (2020) [Russ. Meteorol. Hydrol., No. 12, **45** (2020)].
22. F. Yildirim and E. Onder, *Multi-criteria Decision Making Methods in Solving Operational, Managerial, and Strategic Problems* (Dora Publishing, 2015) [in Turkish].
23. S. Zeyaeyan, E. Fattahi, A. Ranjbar, and M. Vazifedoust, "Classification of Rainfall Warnings Based on the TOPSIS Method," Climate, No. 5, **33** (2017).