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SIMULATION AND ANALYSIS OF NATURAL HAZARD PHENOMENON, DROUGHT IN SOUTHWEST OF THE CASPIAN SEA, IRAN

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Abstract: As a result of atmospheric anomalies and lack of rainfall occur Droughts. Drought occurs in arid and semi-arid regions of the world. no place in the world is protected from drought. Everywhere in different regions of the world there is a shortage of precipitation and rising temperatures they appear as drought. One of these areas is southwest of the Caspian Sea, which suffered from this phenomenon in recent years. The purpose of this study is to model, analyze and predict the drought in Northwest of Iran. To do this, climatic parameters (precipitation, temperature, sunshine, minimum relative humidity and wind speed) of 21 stations were used in the period of 31 years (1988-2018). For modelling of the TIBI fuzzy index, first, four indices of Standardized Evapotranspiration Torrent White Index (SET), Standardized Precipitation Index (SPI), Standardized Evapotranspiration Blanney Creedal FAO Index (SEB) and Modified CZI Index (MCZI) have been fuzzy in Matlab software. Then the indices were compared and the Topsis model was used for prioritizing areas involved with drought. Results showed that the new fuzzy index of T.I.B.I for classifying drought reflected four above indicators with high accuracy. Of these five climatic parameters used in this study, the temperature parameter had the most effect on the fluctuation of drought severity. The severity of the drought was more based on a 12-months scale modelling than 6-months. The longest drought persistence in the study area occurred in Urmia Station in the 12-month period from July 2003 to December 2004. The highest percentage of drought occurrence was at Urmia station on a 12-month scale and the lowest was in Sanandaj station on a six-month scale. According to the results of the present study, areas and stations that will be affected by drought in the future. This problem can be overcome by careful planning.

Keywords: Drought, simulation, Fuzzy logic, monitoring, Predict.

1. INTRODUCTION

In recent decades, there has been a shortage of rainfall due to climate change and climate anomaly it was more intense (Sobhani & Safarianzengir, 2019). Drought is one of the natural hazards that during the period of its occurrence results in damage in various sectors of agriculture, economy, etc. Drought is not limited to arid areas, different parts of the world are subject to drought (Sobhanizengir et al., 2019b). In recent years, there has been a severe drought in different parts of the world. Also, drought is one of the most important natural disasters affecting water resources, which is abundant especially in arid and semi-arid regions of Iran. Drought analysis and monitoring are one of the most important principles in managing drought and risk. Drought is a natural phenomenon that has a complex process due to the interactions of various meteorological factors and occurs in all climatic conditions and in all parts of the planet. Drought is a clear indication of climate fluctuations and has a major impact on human societies. The study of drought condition is very important for planning and management of water resources (Ronald & Péter, 2018; Mirzaei et al., 2015; Shamsniya et al, 2008; Alizadeh et al., 2017; Zeinali & Safarianzengir, 2017; Zeinali et al., 2017; Samadian Fard & Asadi, 2018; Fathizadeh et al., 2017; Jafari et al., 2018; Parsamehr & Khosravani, 2017; Sobhani et al., 2018). Drought is the result of atmospheric anomalies and increasing temperature and evapotranspiration in different areas Earth is happening (Sobhani et al., 2019a).

The results of Alizadeh et al., (2017) in research named at the modelling of dispersion of drought caused by climate change in Iran using dynamic system conclude that at all stations, the values of evapotranspiration of the reference plant) increased from January to July, then fell to December, and all stations reached their maximum levels in July. Kamasi et al., (2016) conducted a drought prediction with SPI and EDI indexes using ANFIS modelling method in Kohgiluyeh and Boyer-Ahmad province. They concluded that clustering increases the accuracy of modelling at the stage of calibration. Zeinali et al., (2017) studied the drought and its prediction in the stations of Lake Urmia basin. The highest percentage of drought occurred in Urmia station and the lowest in Mahabad. Bayazidi (2018) evaluated the drought of synoptic stations in the west of the country using HERBST method and comparative neuro-fuzzy model. They concluded that the coefficient of determination and the error rate of the model were not better than those of Kermanshah, Mianeh and Piranshahr stations. Torabipoudeh et al., (2018) estimated droughts using smart grids and showed that the use of wavelet neural network model could be effective in drought estimation.

Akhtari khajeh & Dinpazhoh (2018) applied the Effective Drought Index (EDI) to study drought periods. The results showed that the years of 2002-2003, 2004-2005 and 2006-2007 are the driest year for Tabriz, Bandar Anzali and Zahedan stations respectively during the 60-year statistical period. Moradi et al., (2008) simulated and analyzed the relationship between aquatic and climatic droughts using probabilistic models in Babol plain and concluded that the occurrence of droughts and wet-years in the Babol River is affected more by wet-years and drought of Ghaemshahr station. Liu et al., (2017) examined drought changes in southwest China and showed that the dangers and severity of droughts in the past decades have increased dramatically throughout the studied region. Hao et al., (2016) presented a drought theory method for multivariate drought index based on a linear hybrid index. Based on the standard index of drought, theoretical distribution of linear combination index (LDI) is derived which can be used for drought classification using per cent method. The results of comparing this method with experimental methods show its satisfactory performance for drought classification. Huanga et al., (2016) investigate the relationship between hydrological drought, climate indicators and human activity in the Columbia River basin. The results show that the use of maximum and minimum annual are not a suitable way to check Characteristics of volume and duration of flood and drought and in order to assess drought, other methods, such as the standard index, should be widely used. Quesada et al., (2018) have studied hydrological changes in a consistent approach to assessing flood and drought changes and concluded that most of the methods used to detect extreme hydrologic trends are not suitable for trend detection and cannot be used in decision making. Therefore, they proposed a method based on the theory of implementation and threshold level. Modaresirad et al., (2017) studied the drought of meteorological and hydrological in the west of Iran. The results showed that the SPI index can show two main characteristics of meteorological and hydrological droughts and also provide accurate estimation for recurrence of a severe drought. Zelekei et al., (2017) have used the Standard Precipitation Index (SPI) and Palmer Drought Index (PDSI) and satellite data to investigate the drought in Ethiopia. The results showed that the observed dry and wet periods in the north of the study area mainly depend on the change of the ENSO in the spring and summer season, while the drying trend in the south and southwest is associated with the warming of the Atlantic and the surface water temperature in the western Pacific Ocean. Kis et al., (2017), in their research, analyzed the dry and wet conditions using RCM and concluded that uncertainty exists in weather forecasts. However, according to their results, probably dryer summers will occur in the southern regions and more severe precipitation will occur in the winter and autumn in the northern regions of the study area in the future. Jinum & Jeonbin (2017), in an attempt to investigate the regional climate models (RCMS), examined the observed drought characteristics based on SPEL in Central Asia, and the results showed that RCM in wet areas, they are accurate, but in irregular areas, and this model cannot produce drought events for large spatial scales. Other internal and external researchers have investigated various models in the field of drought, including: Zahiri et al., 2014; Shokrikouchak & Behnia, 2013; Yarahmadi, 2014; Haddadi & Heidari, 2015; Montaseri & Amirataee, 2015; Sobhani et al., 2015; Salahi & Mojtabapour, 2016; Zolfaghari & Nourizamara, 2016; Damavandi et al., 2016; Fanni et al., 2016; Gholamali et al., 2011; Kheshtkarisani, 2015; Jan Darmian et al., 2015; Touma et al., 2015 and Spinoni et al., 2015. According to the studies done inside and outside the country, this study was conducted to model and monitor the drought phenomenon in the southwest of the Caspian Sea using the new fuzzy index TIBI.

2. MATERIALS AND METHODS

The present study conducts modelling, monitoring and prediction of drought in southwest of the Caspian Sea using climatic data including precipitation, temperature, sunshine, relative humidity and wind speed (as monthly and yearly and in 6 and 12 months' scale) for the time period The 31-year (1988-2018) in five provinces of Ardabil, East Azerbaijan, West Azerbaijan, Zanjan and Kurdistan for 21 stations by implication of TIBI new index (that calculated by four valid indicators of WMO including SET, SPI, SEB and MCZI). The position of the study area was presented in Figure 1.

For modelling of the new TIBI index, the climatic data were first normalized, then four indices of SET, SPI, SEB, and MCZI were calculated separately and the fuzzy modelling of the four indices was performed in the Matlab software and eventually to prioritize the drought-affected areas, Topsis model was used. For the standardization of the SET, SPI indicators, it was used the equation 1 and SEB and MCZI indices were used from equation 2.

Equation (1) $$x_{ij} = \frac{x_j max - x_j}{x_j max - x_j min}$$

Equation (2) $$x_{ij} = \frac{x_j - x_j min}{x_j max - x_j min}$$

In these relationships, xij represents the standardized value, xj the desired index value, xjmax the maximum value in the number series, and xjmin represents the lowest value in the numeric series (Mulchsfaki, 2006). One of the ways in which linguistic expressions in regular words can be converted to their corresponding fuzzy numbers is to use membership functions in the Matlab software, with the range of four inputs between ±2 (Table 1) and the output index domain is between 0 and 1 (Table 2).

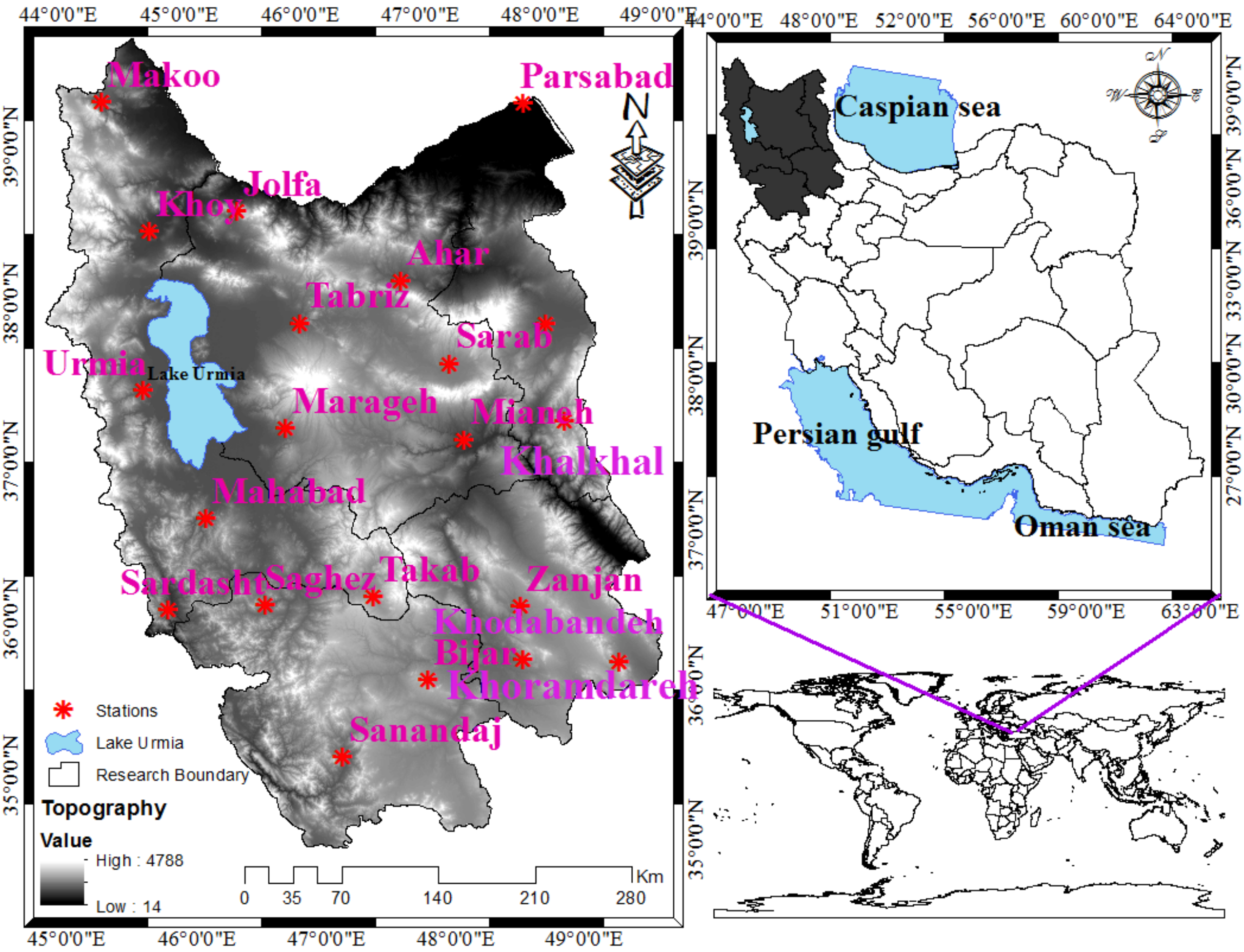

Figure 1. The geographical location of the study area in the southwest of the Caspian Sea, (21 Station studied in the southwest of the Caspian Sea: Ardabil, Khalkhal, Parsabad, Tabriz, Ahar, Jolfa, Sarab, Maraghe, Miane, Urmia, Khoy, Mahabad, Mako, Sardasht, Takab, Sanandaj, Bijar, Saghghez, Zanjan, Khoramdareh & Khodabandeh).

Table 1. Linguistic variables and fuzzy values of input indices (SET, SPI, SEB, and MCZI)

Language variables	Fuzzy value
WVH	2 ≥
WH	1.5 - 1.99
WA	0.99 - 1.39
WS	0.5 - 0.99
N	-0.39 - 0.39
DS	-0.99 - -0.5
DA	-1 - -1.39
DH	-1.5 - -1.99
DVH	-2 ≤

Table 2. Linguistic variables and fuzzy values of the new index derived from the modelling of TIBI, Safarianzengir, et al., 2019

Language variables	Fuzzy value
WVH	0, 0, 0, 0.1
WH	0, 0.1, 0.1, 0.2
WA	0, 0.2, 0.2, 0.4
WS	0.2, 0.35, 0.35, 0.5
N	0.3, 0.5, 0.5, 0.7
DS	0.5, 0.65, 0.65, 0.8
DA	0.6, 0.8, 0.8, 1
DH	0.8, 0.9, 0.9, 1
DVH	0.9, 1, 1 , 1

After the modelling of the TIBI fuzzy index, the effect of climate parameters on the drought of the studied stations was investigated. Then drought was monitored. In drought monitoring based on T.I.B.I, trend, the severity of persistence and frequency of drought occurrence were studied and the trend of the indices was determined by linear trend method. Frequency relationship was used to obtain the percentage of drought occurrence in different classes.

3. RESULTS AND DISCUSSION

3.1 Monitoring of drought fluctuations based on four integrated indices in TIBI

In order to investigate the effect of indices drought fluctuations in drought conditions of stations, it is possible to analyze the changes in the indicators (SET, SPI, SEB, and MCZI) as appeared in the TIBI index. Considering the large number of stations, for the sake of better understanding, only the drought series graph of Tabriz station was presented in both 6- and 12-month scale (Figs. 2 and 3) in these figures, the cross-sectional red line shows drought margin on a 6-month and more scale with the amount of 0.74 and on a 12-month and more scale with the amount of 0.74.

The analysis of these figures shows that at the 6 and 12-month scale at Tabriz station, the amount of evapotranspiration was similar in drought conditions, which decreased from Mars 1994 to July 1998, and after this month an increase was observed, while the impact of rainfall on a 6-month scale is weaker than the 12-month scale. It means that from April 1996 to December 2004, an increasing trend occurred and after that followed by the same pattern. The indicators (SET, SPI, SEB, and MCZI) affect the TIBI index and show somehow a trend, indicating that the new TIBI fuzzy index reflects the four indicators well. The scale of its drought classes was presented in (Table 3). The T.I.B.I index at the 12-month scale shows a sharper shape than the 6-month scale.

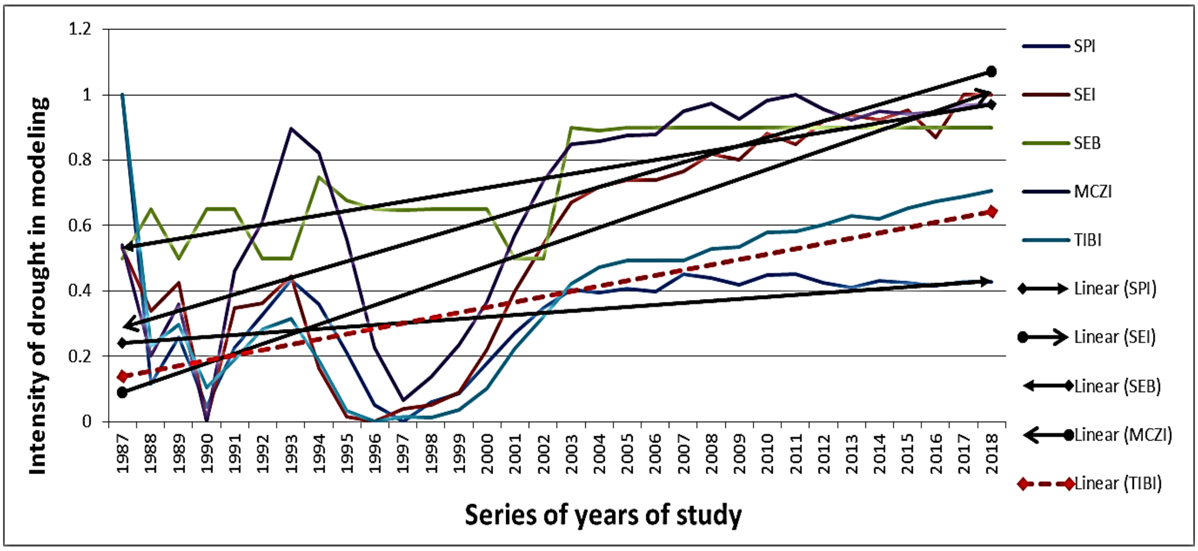

Figure 2. The fluctuation of the indices at Tabriz Station in the 6-month scale and statistical period of 1987-2018.

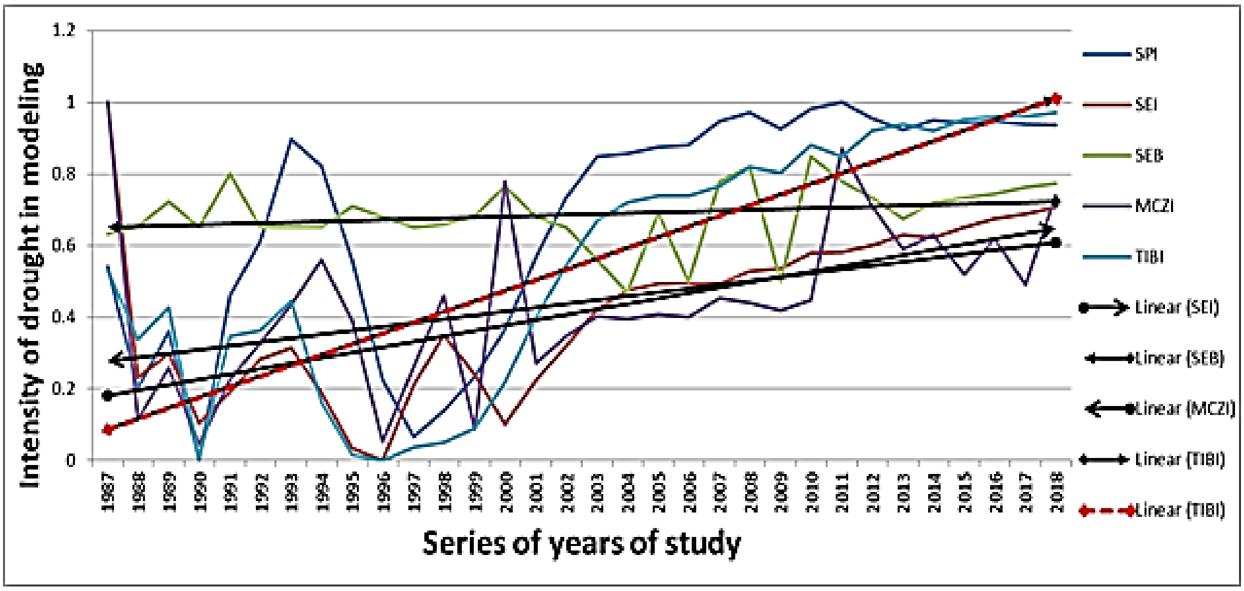

Figure 3. The fluctuation of the indices at Tabriz station in the 12-month scale and statistical period of 1987-2018.

Table 3. Classification of drought and wet year severity based on fuzzy modelling of T.I.B.I index, Safarianzengir, et al., 2019.

Drought classes	The index value of T.I.B.I
Very severe drought	0.96 - 1
severe drought	0.87 - 0.96
moderate drought	0.74 - 0.87
mild drought	0.59 - 0.74
Normal drought	0.44 - 0.59
Mild wet season	0.29 - 0.44
Moderate wet season	0.15 - 0.29
Severe wet season	0.06 - 0.15
The very severe wet season	0 - 0.06

According to the results obtained from the frequency of drought in the 6 and 12-month scale, the total percentages of drought were at 6-months of West and Northwest stations were more than 12-months scale. The stations of Urmia, Jolfa and Mako had most percentages of droughts (15.26, 9.10 and 10.70 respectively). Stations with a lower percentage of drought severity were more frequently in East parts of the region including the stations of Sanandaj, Maraghe and Tabriz with frequency percentage of 1.39, 2.01 and 2.20 (Table 4) and (Fig. 4). At the 12-month scale, west of the study area was most exposed to drought, with the most drought-affected stations in Urmia, Jolfa and Maku with drought frequency obtained (13.90, 11.82 and 12.18 respectively) from four integrated indices (SET, SPI, SEB and MCZI) in the new TIBI fuzzy model. Central and southern stations of the study area were less exposed to drought, including Khorramdareh, Tabriz and Maragheh with drought frequency percentages (4.15, 4.34 and 4.19, respectively) (Table 5) and (Fig. 5).

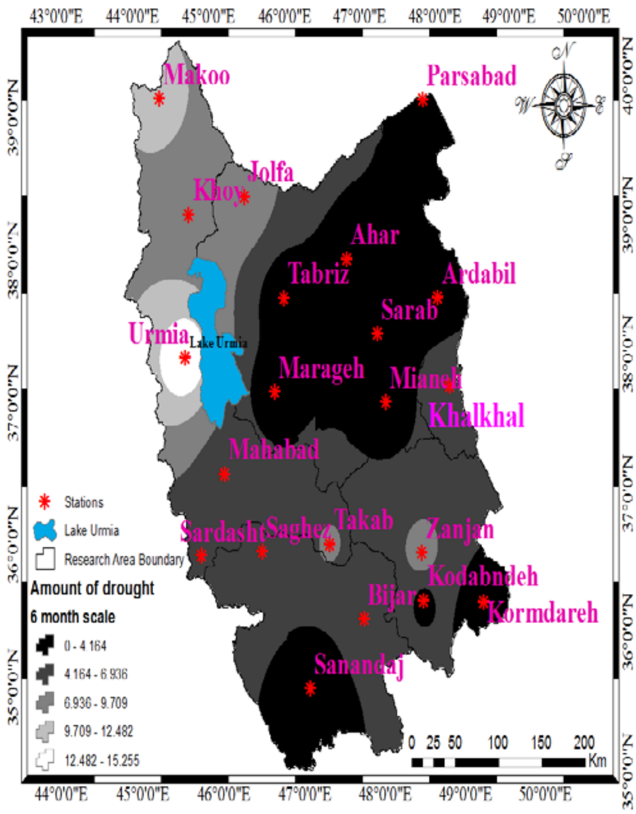

Figure 4. Mapping of frequency per cent of drought occurrence in studied stations in a 6-month scale and statistical period of 1988-2018, (21 Station studied in the southwest of the Caspian Sea: Ardabil, Khalkhal, Parsabad, Tabriz, Ahar, Jolfa, Sarab, Maraghe, Miane, Urmia, Khoy, Mahabad, Mako, Sardasht, Takab, Sanandaj, Bijar, Saghghez, Zanjan, Khoramdareh & Khodabandeh).

Table 4. Frequency percentage of drought incidence in different classes in the 6-month time scale and statistical period of 1988-2018.

Station names	Normal	Mild drought	Mediocre drought	Severe drought	Very severe drought	Total
Ardabil	1.2	4	0.99	0.92	0.63	2.54
Khalkhal	5.3	6	4.15	2.12	0	6.27
Parsabad	4.4	8	2.40	1.30	0	3.70
Tabriz	2.9	9.1	1.47	0.21	0.52	2.20
Ahar	2.36	14.12	3.5	0.11	0	3.61
Jolfa	1.96	13	5	4.10	0	9.10
Sarab	4.85	7.74	2	1.41	0	3.41
Maraghe	6	9.36	1.20	0.69	0.12	2.01
Miane	3	6.11	1.60	0.96	0	2.56
Urmia	5	7.1	8	6.47	0.79	15.26
Khoy	4	10	5.5	3.32	0	8.82
Mahabad	2	10.52	3.5	2.78	0	6.28
Mako	1.25	11.10	6.5	4.2	0	10.70
Sardasht	6.89	12.14	4.3	0.96	0	5.26
Takab	4.63	4.4	3.2	4.1	0	7.30
Sanandaj	3	6.9	1	0.25	0.14	1.39
Bijar	1	16.18	3.10	1.87	0	4.97
Saghghez	2.29	14.15	2.18	3.86	0	6.04
Zanjan	3	12.59	4	4.47	0	8.47
Khoramdareh	2	13.25	2	0.88	0	2.88
Khodabandeh	1.5	14.69	1.85	1.79	0	3.64

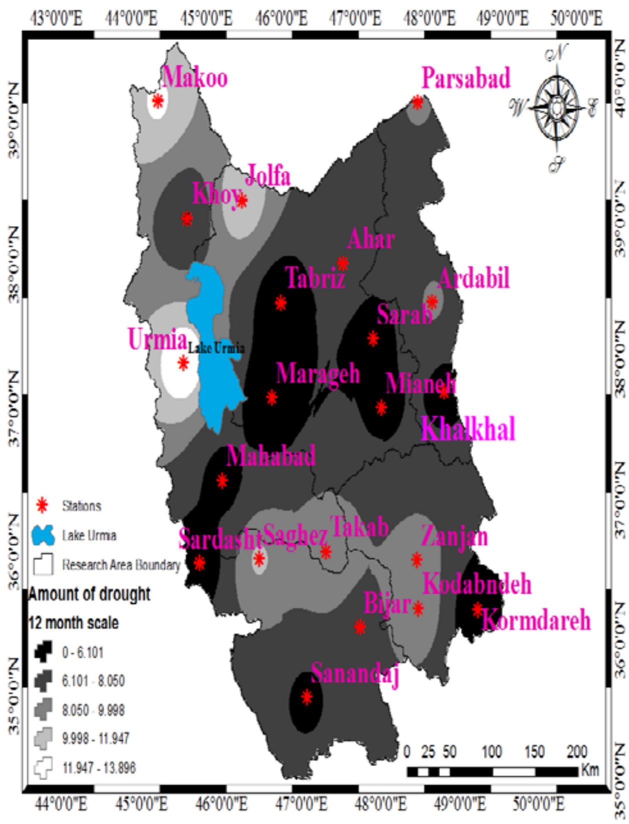

Figure 5. Mapping of frequency per cent of drought occurrence in studied stations on a 12-month scale, in the statistical period of 1988-2018, (21 Station studied in the southwest of the Caspian Sea: Ardabil, Khalkhal, Parsabad, Tabriz, Ahar, Jolfa, Sarab, Maraghe, Miane, Urmia, Khoy, Mahabad, Mako, Sardasht, Takab, Sanandaj, Bijar, Saghghez, Zanjan, Khoramdareh & Khodabandeh).

According to the definition of drought based on the T.I.B.I index, values of 0.74 or higher or mild to higher drought are considered as arid conditions. Accordingly, in the modelling of the new TIBI fuzzy index, the drought intensity at the 12-month scale was higher than the 6-month scale. Based on the results of the present study, the annual drought intensity at the 6-month scale started in 1998 and at the 12-month scale since 1996 began mildly and continued upward.

3.2. Assessment of drought-affected areas based on the TOPSIS model

Prioritization of the stations involved in drought in Iran was analyzed using TOPSIS model. To calculate and analyze the statistical data, each of the parameters took a weight and then the desirability and the lack of desirability of each of the studied stations was investigated in terms of climatic indices and, finally, an appropriate option was selected from an approximate approach to ideal proportions (Sobhani & Safarianzengir, 2018). The results of the implementation of the TOPSIS model using the degree of importance of the criteria derived from the entropy method indicate that, in terms of drought,

Table 5. Frequency percentage of drought incidence in different classes in the 12-month time scale and statistical period of 1988-2018.

Station names	Normal	Mild drought	Mediocre drought	Severe drought	Very severe drought	Total
Ardabil	2.47	6.39	6.09	1.10	1.12	8.31
Khalkhal	4.52	9.05	2.12	3.19	0.32	5.63
Parsabad	3.85	10	6.02	2.12	0	8.14
Tabriz	3.29	8.03	2.36	1.09	0.89	4.34
Ahar	1.87	13.74	4.85	2.21	0	7.06
Jolfa	2.74	12	6	5.11	0.71	11.82
Sarab	3.32	5.36	3	2.26	0	5.26
Maraghe	5	4.12	2.68	1.15	0.36	4.19
Miane	4	5.06	3.60	2.09	0	5.69
Urmia	4	4.83	7	5.96	0.94	13.9
Khoy	3	14	4.75	1.30	0	6.05
Mahabad	3	12.11	1.32	3.36	0.65	5.33
Mako	0.87	13.45	7.12	5.6	0	12.18
Sardasht	4.89	14.63	3.08	0.98	0.73	4.79
Takab	3.08	7.56	6.87	3.09	0	9.96
Sanandaj	2	9.86	4	0.92	0.76	5.68
Bijar	3	15.10	4.18	2.49	0.98	7.65
Saghghez	1.08	13.87	5.86	4.28	0.16	10.30
Zanjan	4	8.65	7	1.89	0	8.89
Khoramdareh	6	9.68	3	0.86	0.29	4.15
Khodabandeh	2.8	13.55	6.12	2.98	0	9.10

more and fewer places are involved with drought by combining the two 6 and 12-month scale were identified according to the TOPSIS model. The three stations of Urmia, Mako and Jolfa with priority values of 1, 0.67, and 0.56 were most affected respectively by the drought, and three stations of Sanandaj, Maraghe and Tabriz were rated as 0.03, 0.04, and 0.05, respectively had less priority for drought occurrence (Table 6) and (Fig. 6).

Table 6. Prioritization of stations involved with drought based on the Topsis model during the statistical period of 1988-2018

Station names	Topsis values	Station names	Topsis values
Ardabil	0.11	**Mahabad**	0.34
Khalkhal	0.34	**Mako**	0.67
Parsabad	0.18	**Sardasht**	0.27
Tabriz	0.05	**Takab**	0.43
Ahar	0.16	**Sanandaj**	0.03
Jolfa	0.56	**Bijar**	0.36
Sarab	0.14	**Saghghez**	0.35
Maraghe	0.04	**Zanjan**	0.50
Miane	0.08	**Khoramdareh**	0.10
Urmia	1	**Khodabandeh**	0.18
Khoy	0.51		

3.3. Comparison of research results with findings of other researchers

In this research, we studied modelling, monitoring and prediction of drought phenomenon in

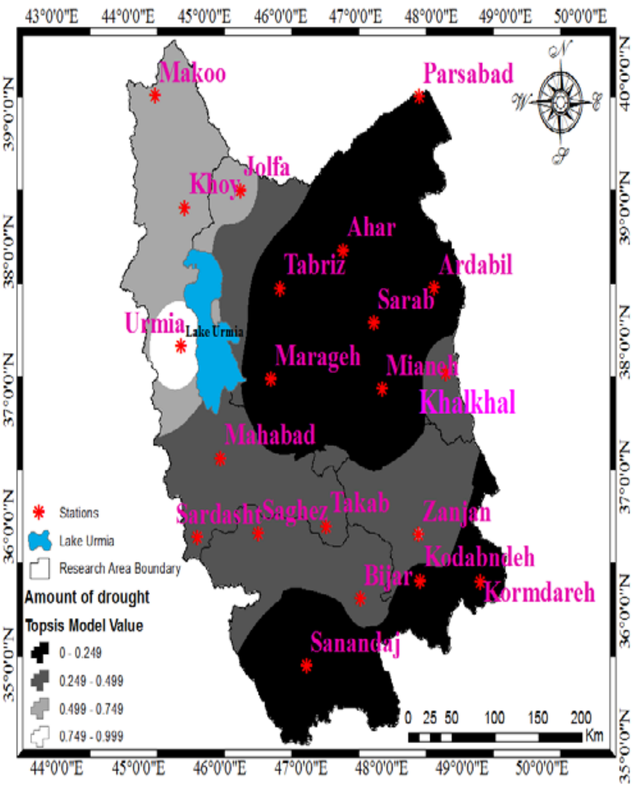

Figure 6. The final map of areas affected by drought in the southwest of the Caspian Sea based on Topsis model during the statistical period of 1988-2018, (21 Station studied in the southwest of the Caspian Sea: Ardabil, Khalkhal, Parsabad, Tabriz, Ahar, Jolfa, Sarab, Maraghe, Miane, Urmia, Khoy, Mahabad, Mako, Sardasht, Takab, Sanandaj, Bijar, Saghghez, Zanjan, Khoramdareh & Khodabandeh).

the southwest of the Caspian Sea. This method has been used in many studies and it has been considered as a suitable method for monitoring, analysis and comparison, for example: Drought characterization from a multivariate perspective (Hao & Singh, 2015); The impracticality of a universal drought definition (Lloyd-Hughes, 2014); Comparison of drought indicators derived from multiple data sets over Africa (Naumann et al., 2014); drought index for Rainfed agriculture: The Standardized Precipitation Crop Evapotranspiration Index (SPCEI) (Pei et al., 2019); Candidate Distributions for Climatological Drought Indices (SPI and SPEI) (Stagge et al., 2015); Handbook of Drought Indicators and Indices (Svoboda & Fuchs, 2016); Evaluation of six indices for monitoring agricultural drought in the south-central United States (Tian et al., 2018); Performance of Drought Indices for Ecological, Agricultural, and Hydrological Applications (Vicente-Serrano et al., 2012). However, models in the present study were useful in modelling, monitoring and predicting the drought phenomenon in the southwest of the Caspian Sea.

4. CONCLUSION

In recent years, drought has been one of the most important issues in causing damages in various sectors such as agriculture, economy and so on in different regions of Iran including southwest of the Caspian Sea. Researchers have done a lot of research on drought monitoring with different models, but not enough on the issue. The purpose of the present study is to model and investigate the drought phenomenon in northwestern Iran at 6 and 12 months' scale. The results of the study showed that the drought severity, drought repetitions and its continuity were more at 12- months than those of at 6-months. The drought was less continuous in short-run time scale and affected by temperature parameter, while the severity of drought in the long periods of time was less responsive to rainfall variations. Drought trend in northwestern Iran showed an increase and temperature trend was mildly upward.

The highest percentage of drought incidence in 6 and 12-months scale was for Urmia station and the lowest was for Sanandaj. The frequency percentage of drought in the Jolfa, Mako and Urmia stations in 12 months' scale was higher than the 6 months. According to the results, modelling was highly reliable and new TIBI fuzzy index outperformed the SPEI fuzzy index. Also, according to the results of the new TIBI index modelling, drought was more intense at the 12-month scale than the 6-month scale. Based on the results of the 6-month modelling, the highest per cent of droughts occurred in the northwest of the study area (Mako, west of Urmia Lake and the Urmia stations) and in the 12-month scale, the semi-western scale of the study area (south and west of Urmia Lake). Finally, based on TOPSIS multivariate decision-making model, Urmia station with a score of 1 was given the highest priority by drought conflict and Sanandaj station with a score of 0.03% was the last priority with a drought conflict.

Conflicts of interest

There are no conflicts to declare

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