Monitoring and prediction of drought using TIBI fuzzy index in Iran

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ABSTRACT
The drought phenomenon is not specific to the region, affecting different parts of the world. One of these areas is Iran in Southwest Asia, suffering from this phenomenon in recent years. The purpose of this study was to model, analyze and predict the drought in Iran. So that, climatic parameters (precipitation, temperature, sunshine, minimum relative humidity and wind speed) were used at 30 stations during 29 years (1990-2018). For modelling the TIBI fuzzy index, at first, four indicators (SET, SPI, SEB, and MCZI) were been fuzzy in MATLAB software. Then the indices were compared and the TOPSIS model was used for prioritizing areas involved drought, followed by employing ANFIS adaptive artificial neural network model for predicting drought. Results showed that the new fuzzy index TIBI for classifying drought reflected four above indicators with high accuracy. Of these five climatic parameters used in this study, the temperature and precipitation exhibited the most impact on the fluctuation of drought severity. The severity of drought was more based on 6-month scale modelling than on 12-month one. The highest rate of drought occurrence was found at the Bandar Abbas station with 24.30% on a 12-month scale, and while the lowest was at the Shahrekord station with 0.36% on a six-month scale. Based on ANFIS model and TIBI fuzzy index, Bandar Abbas, Bushehr and Zahedan stations were more encountered ones to drought due to the TIBI index of 0.62, 0.96 and 0.97 respectively. According to the results in both 6- and 12-month scales, the southern regions of Iran were more severely affected by drought, which requires suitable water management in these areas.

Key words: Statistical evaluation, TIBI index, Fuzzy, Drought, ANFIS.

INTRODUCTION
Drought is one of the natural hazards that is dominated by climate change. Drought is also one of the most important natural disasters affecting agriculture and water resources (Shamsniya et al. 2008; Sobhani & Safarianzengir 2020; Sobhani et al. 2020a; Amazzal et al. 2020; Azizi et al. 2020). In recent years, different regions of the world have experienced more severe drought (Mirzaee et al. 2015). Also, drought is a natural phenomenon that occurs in all climatic conditions and all parts of the planet (Samidianfard & Asadi 2018; Safarianzengir et al. 2019; Mdehheb et al. 2020; Safarianzengir & Sobhani 2020; Zolfagharpour et al. 2020). Moreover, drought as a climatic phenomenon greatly affects all aspects of human activity (Zeinali & Safarianzengir 2017). Other authors have investigated various models in the field of droughts (Haddadi & Heidari 2015; Montaseri & Amir Ataee 2015; Sobhani et al. 2015; Huanga et al. 2015; John Jan Darmian et al. 2015; Spinoni et al. 2015; Salahi & Mojtabapour 2016; Zolfaghari & Nouri Zamara 2016; Damavandi et al. 2016; Fanni et al. 2016; Alizadeh 2017; Zeinali et al. 2017; Jafari et al. 2018; Sobhani et al. 2018; Sobhani & Safarianzengir 2019a; Sobhani et al. 2019b; Sobhani et al. 2019a). Alizadeh et al. (2017) in a study about the modelling of dispersion of drought caused by climate change in Iran using dynamic system concluded that at all stations, the evapotranspiration rates of the reference plant increased from January through July, then decreased through December, and all stations reached their maximum levels in July. Kamasi et al. (2016) predicted drought with SPI...
MATERIALS AND METHODS

The present study conducts modelling, monitoring and prediction of drought in Iran using climatic data including precipitation, temperature, sunshine, relative humidity and wind speed (as monthly and yearly in 6- and 12-month scales) for a 29-year period (1990-2018) at 30 stations by implication of TIBI new index (that calculated by four valid indicators of WMO including SET, SPI, SEB, MCZI). The location of the study area was presented in Fig. 1.

For modelling the new TIBI index, the climatic data were first normalized, then four indices including SET, SPI, SEB, MCZI were calculated separately. Moreover, the fuzzy modelling of the four indices was performed in the MATLAB software and eventually to prioritize the drought-affected areas, TOPSIS model was employed (Sobhani et al., 2020b). The Equation 1 was used for the standardization of the SET and SPI indicators, while SEB and MCZI indices were calculated using Equation 2.

\[
x_{ij} = \frac{x_{j \text{max}} - x_j}{x_{j \text{max}} - x_{j \text{min}}} \\
x_{ij} = \frac{x_j - x_{j \text{min}}}{x_{j \text{max}} - x_{j \text{min}}}
\]

In these equations, \( x_{ij} \) represents the standardized value, \( x_j \) the desired index value, \( x_{j \text{max}} \) the maximum value in the number series, and \( x_{j \text{min}} \) the lowest value in the numeric series (Malchovsky 2007; Sobhani et al., 2019c; Sobhani & Safarianzengir, 2019b). For converting the corresponding fuzzy numbers to linguistic expressions in regular words, we used 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).
Fig. 1. Geographic location of the study area.

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

<table>
<thead>
<tr>
<th>Language variables</th>
<th>Fuzzy value</th>
</tr>
</thead>
<tbody>
<tr>
<td>WH</td>
<td>1.5 - 1.99</td>
</tr>
<tr>
<td>WA</td>
<td>0.99 - 1.39</td>
</tr>
<tr>
<td>WS</td>
<td>0.5 - 0.99</td>
</tr>
<tr>
<td>N</td>
<td>-0.39 - 0.39</td>
</tr>
<tr>
<td>DS</td>
<td>-0.99 - 0.5</td>
</tr>
<tr>
<td>DA</td>
<td>-1 - 1.39</td>
</tr>
<tr>
<td>DH</td>
<td>-1.5 - 1.99</td>
</tr>
<tr>
<td>DVH</td>
<td>≥ 2</td>
</tr>
</tbody>
</table>

Table 2. Linguistic variables and fuzzy values of the new index derived from the modelling of TIBI.

<table>
<thead>
<tr>
<th>Language variables</th>
<th>Fuzzy value</th>
</tr>
</thead>
<tbody>
<tr>
<td>WVH</td>
<td>0, 0, 0, 0.1</td>
</tr>
<tr>
<td>WH</td>
<td>0, 0.1, 0.1, 0.2</td>
</tr>
<tr>
<td>WA</td>
<td>0, 0.2, 0.2, 0.4</td>
</tr>
<tr>
<td>WS</td>
<td>0.2, 0.35, 0.35, 0.5</td>
</tr>
<tr>
<td>N</td>
<td>0.3, 0.5, 0.5, 0.7</td>
</tr>
<tr>
<td>DS</td>
<td>0.5, 0.65, 0.65, 0.8</td>
</tr>
<tr>
<td>DA</td>
<td>0.6, 0.8, 0.8, 1</td>
</tr>
<tr>
<td>DH</td>
<td>0.8, 0.9, 0.9, 1</td>
</tr>
<tr>
<td>DVH</td>
<td>0.9, 1, 1, 1</td>
</tr>
</tbody>
</table>

After the modelling of the TIBI fuzzy index, the effects of climate parameters on the drought in the studied stations were investigated, followed by drought monitoring. In the monitoring based on TIBI, we studied trend, the severity of persistence and frequency of drought occurrence. Then, the indices trends were determined using linear trend method. Frequency relationship was used to obtain the rate (%) of drought occurrence in different classes.
TOPSIS model
The steps of TOPSIS Model are as follows:

Step 1: Formation of the data matrix, matrix 1 based on m option and n index
\[
X_{ij} = \begin{bmatrix}
X_{11} & X_{22} & X_{1n} \\
X_{21} & X_{22} & X_{2n} \\
... & ... & ... \\
X_{m1} & X_{m2} & X_{mn}
\end{bmatrix} \quad \text{Matrix (1)}
\]

Step 2: Unsealing data and the formation of an unscaled matrix, equation 3.
\[
r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \quad (3)
\]

Step 3: Calculation of a weighted unscaled matrix: Indeed, the matrix (v), the matrix 2 is the multiplication of the unscaled matrix in the weighted matrix.
\[
V_{ij} = \begin{bmatrix}
v_{11} & v_{22} & v_{1n} \\
v_{21} & v_{22} & v_{2n} \\
... & ... & ... \\
v_{m1} & v_{m2} & v_{mn}
\end{bmatrix} \quad \text{Matrix (2)}
\]

Step 4: Determining the positive ideals (the best function of each index), which are indicated by \((A^+)^i\). Equations 4 and 5.
\[
A^+ = \left\{ (\max_{i} v_{ij} | j \in J), (\min_{i} v_{ij} | j \in J') \right\} \quad (4)
\]
\[
A^+ = \{ v_1^+, v_2^+, ... v_n^+ \} \quad (5)
\]

Step 5: Determining the negative ideals (the worst function of each indicator), which are represented by \((A^-)^i\). Equations 6 and 7.
\[
A^- = \left\{ (\min_{i} v_{ij} | j \in J), (\max_{i} v_{ij} | j \in J') \right\} \quad (6)
\]
\[
A^- = \{ v_1^-, v_2^-, ... v_n^- \} \quad (7)
\]

Step 6: Determining the distance of each option from negative and positive ideals (\(S_{i}^+, S_{i}^-\)), Equations 8 and 9.
\[
d_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2} \quad (8)
\]
\[
d_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \quad (9)
\]

Step 7: Determining the relative closeness of the options, which is calculated from equation 10.
\[
C_i = \frac{d^-}{d_i^+ + d_i^-} \quad (10)
\]

Step 8: Ranking options by \((C_i^+)^i\) value. So that 0 < \(C_i^+ < 1\). Accordingly, if as much as one option approaches the ideal point, \(C_i^+\) trends to 1.

Hence, it will be the best option (Malchovsky 2007).
ANFIS Neural Network Model
In this step, the possibility of modelling and prediction of dust was studied in the studied area using the ANFIS model, (Ansari 2010). In this study, the drought phenomenon in a series of time (276 months) was considered in two models of ANFIS and RBF neural networks in each station. The fuzzy system is a system based on the "conditional-result" logical rules that, using the concept of linguistic variables and fuzzy decision-making process, depicts the space of input variables on the space of the output variables. Fig. 2 presents a SOGNO fuzzy system with four inputs, one output and two laws as well as an equivalent ANFIS system. This system has two inputs including x and y and one output (Ahmadzade et al. 2010). At the end, the error rates of the resulting models were compared together and the function obtaining the lowest error rate at the lowest analyzing time, was selected as a membership function (Konarkuhi 2010).

RESULTS
Monitoring of drought fluctuations based on four integrated indicators in TIBI
In order to investigate the effects of drought fluctuation indices in drought conditions of stations, it is possible to analyze the alterations in the indicators (SET, SPI, SEB, and MCZI) as appeared in the TIBI index. Given a large number of stations, for the sake of better understanding, only the drought series graph of Bojnord station was presented in both 6- and 12-month scales (Figs. 3 and 4). In these Figs., the cross-sectional red line shows drought margin on a 6-month and more scales with 0.74 as well as a 12-month and more scales with 0.76. The analyses of these figs. exhibit that at the 6- and 12-month scales in Bojnourd station, the amount of evapotranspiration was similar in drought conditions, decreasing from April 1994 through February 1999, though elevated after this month. However, the impact of rainfall at a 6-month scale was weaker than at a 12-month one. It means that from May 1993 through November 1997, an increasing trend occurred, there after followed by the same pattern. The indicators such as SET, SPI, SEB, and MCZI affected the TIBI index and displayed 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 TIBI index at the 6-month scale revealed a sharper figure than at the 12-month one. According to the results obtained from the frequency of drought in the 6- and 12-month scales, the total drought rate (%) at 12-month scale was higher than at 6-month one. However, drought severity at 6-month scale was higher than at 12-month scale. In the study area at 6-month scale, the drought severity in Iran was more pronounced in the south, west and center than in the other parts. Bandar Abbas and Bushehr in the south, Ahwaz in the southwest and Zahedan in the south-east of the study area exhibited the most drought rate (16.62%, 11.24%, 14.13% and 6.62% respectively).
Monitoring and prediction of...

Stations with a lower drought severity were located more frequently in the north-west, north and west parts of the region including Urmia and Ardebil with 1.10% and 1.88%; in the west including Ilam and Yasuj with 1.61% and 2.01%; and finally in the north including Rasht and Gorgan with 1.26% and 0.87% respectively (Table 4). According to the model, in the 12-month scale, semi-southern regions of Iran were more exposed to drought. Bandar Abbas and Bushehr in the south of Iran with drought frequency of 24.30% and 14.83%, Ahvaz with 18.47% in the southwest, Kerman with 6.74% in southeast exhibited the highest drought occurrence in the 12-month scale, while Birjand (1.70%) and Bojnurd (3.66%) in the northeast, Urmia (1.17) and Tabriz (2.66%) in northwest, Rasht (0.58%) and Sari 0.78%) in the north displayed the lowest drought frequency (Table 5).

Depending on the definition of drought based on the TIBI index, values of 0.74 and higher, or from a mild drought class to higher, are raised as dry conditions. Accordingly, in the modeling of the TIBI fuzzy index, the drought

Table 3. Drought severity classification based on fuzzy modelling of TIBI.

<table>
<thead>
<tr>
<th>Drought classes</th>
<th>The index value of T.I.B.I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very severe drought</td>
<td>0.96-1</td>
</tr>
<tr>
<td>severe drought</td>
<td>0.87-0.96</td>
</tr>
<tr>
<td>moderate drought</td>
<td>0.74-0.87</td>
</tr>
<tr>
<td>mild drought</td>
<td>0.59-0.74</td>
</tr>
<tr>
<td>Normal drought</td>
<td>0.44-0.59</td>
</tr>
<tr>
<td>Mild wet season</td>
<td>0.29-0.44</td>
</tr>
<tr>
<td>Moderate wet season</td>
<td>0.15-0.29</td>
</tr>
<tr>
<td>Severe wet season</td>
<td>0.06-0.15</td>
</tr>
<tr>
<td>The very severe wet season</td>
<td>0.06-0.06</td>
</tr>
</tbody>
</table>

Fig. 3. The fluctuation of the indices at the Bojnourd station at a 6-month scale and period of 1990-2018.

Fig. 4. The fluctuation of the indices at the Bojnourd station at the 12-month scale and period of 1990-2018.
investigated in terms of climatic indices for predicting drought phenomena. Drought index data of TIBI was.

After modelling drought indices and reassurance, TIBI index was predicted for the next 16 years using the ANFIS network model. Implementation of the TOPSIS model using the degree of importance of places affected with drought. Based on the TOPSIS model, Bandar Abbas, Ahvaz and Bushehr in the south and southwest of Iran with priority values of 1, 0.78, and 0.62 were the most affected stations by the drought respectively, while Gorgan, Shahre-Kord and Urmia in the north and west regions with 0.026, 0.033, 0.03 and 0.035, respectively had less priority for drought occurrence (Table 6) (Fig. 5).

Table 4. The frequency (%) of drought incidence in different classes in the 6-month time scale and study period (1990-2018).

<table>
<thead>
<tr>
<th>No.</th>
<th>Station</th>
<th>Normal drought</th>
<th>Mild drought</th>
<th>Moderate drought</th>
<th>Severe drought</th>
<th>Very severe drought</th>
<th>Very severe wet season</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ormia</td>
<td>0.03</td>
<td>1.19</td>
<td>0.15</td>
<td>0.82</td>
<td>0.13</td>
<td>0</td>
<td>1.10</td>
</tr>
<tr>
<td>0</td>
<td>Tabriz</td>
<td>1.41</td>
<td>0.47</td>
<td>1.04</td>
<td>1.09</td>
<td>0.07</td>
<td>0.01</td>
<td>2.20</td>
</tr>
<tr>
<td>3</td>
<td>Ardelb</td>
<td>3.25</td>
<td>0.36</td>
<td>1.21</td>
<td>0.58</td>
<td>0.09</td>
<td>0.03</td>
<td>1.88</td>
</tr>
<tr>
<td>4</td>
<td>Esfahan</td>
<td>0.56</td>
<td>1.25</td>
<td>0.26</td>
<td>0.19</td>
<td>0.47</td>
<td>0</td>
<td>0.92</td>
</tr>
<tr>
<td>5</td>
<td>Ilam</td>
<td>1.64</td>
<td>0.08</td>
<td>1.5</td>
<td>0.11</td>
<td>0</td>
<td>0</td>
<td>1.61</td>
</tr>
<tr>
<td>6</td>
<td>Boushehr</td>
<td>3.99</td>
<td>7.89</td>
<td>4.54</td>
<td>6.11</td>
<td>0.59</td>
<td>0</td>
<td>11.24</td>
</tr>
<tr>
<td>7</td>
<td>Tehran</td>
<td>1.74</td>
<td>2.41</td>
<td>1.3</td>
<td>2.23</td>
<td>0.02</td>
<td>0</td>
<td>3.55</td>
</tr>
<tr>
<td>8</td>
<td>Shahrekord</td>
<td>1.21</td>
<td>1.54</td>
<td>0.23</td>
<td>0.11</td>
<td>0.02</td>
<td>0</td>
<td>0.36</td>
</tr>
<tr>
<td>9</td>
<td>Birjand</td>
<td>2.34</td>
<td>3.87</td>
<td>0.45</td>
<td>0.02</td>
<td>0</td>
<td>0</td>
<td>0.47</td>
</tr>
<tr>
<td>10</td>
<td>Mashhad</td>
<td>1.4</td>
<td>4.41</td>
<td>1</td>
<td>1.57</td>
<td>0.11</td>
<td>0</td>
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</tr>
<tr>
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<td>Bojnord</td>
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<td>1.15</td>
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<td>0.04</td>
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<tr>
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<td>Ahvaz</td>
<td>4.54</td>
<td>9.12</td>
<td>6.47</td>
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<td>4.12</td>
<td>2.74</td>
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<td>Ghom</td>
<td>1.45</td>
<td>1.17</td>
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<td>0.87</td>
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<td>1.14</td>
<td>0</td>
<td>0</td>
<td>1.26</td>
</tr>
<tr>
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<td>2.28</td>
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<td>0.09</td>
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<tr>
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<td>Sari</td>
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<td>0</td>
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</tr>
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</table>

Drought prediction based on ANFIS model
After modelling drought indices and reassurance, TIBI index was predicted for the next 16 years using the ANFIS adaptive neural network model. After verifying the validity of neural network models in modelling, ANFIS neural network model revealed more precision for predicting drought phenomena. Drought index data of TIBI was estimated for the period of 2019-2033. Based on the results of predictions, Bandar Abbas, Bushehr and Zahedan, with the TIBI index of 0.62, 0.96 and 0.97 in southern Iran, were more exposed to drought for the coming years while the Urmia, Tabriz and Shahre-Kord displayed the lowest rate of drought based on the TIBI index with 0.17, 0.15 and 0.12 respectively (Fig. 6). In this study, we performed modelling, monitoring and prediction of drought phenomenon in Iran.

Table 5. The frequency percent of drought incidence in different classes in the 12-month scale and statistical period (1990-2018).
Table 6. Prioritization of drought-influenced stations based on the TOPSIS model during the study period (1990-2018).

<table>
<thead>
<tr>
<th>Station</th>
<th>TOPSIS value</th>
<th>Station</th>
<th>TOPSIS value</th>
<th>Station</th>
<th>TOPSIS value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kermanshah</td>
<td>0.203</td>
<td>Bojnord</td>
<td>0.2147</td>
<td>Ormia</td>
<td>0.0351</td>
</tr>
<tr>
<td>Yasouj</td>
<td>0.1495</td>
<td>Ahvaz</td>
<td>0.7898</td>
<td>Tabriz</td>
<td>0.0992</td>
</tr>
<tr>
<td>Gorgan</td>
<td>0.0263</td>
<td>Zanjan</td>
<td>0.2976</td>
<td>Ardebil</td>
<td>0.0931</td>
</tr>
<tr>
<td>Rasht</td>
<td>0.0356</td>
<td>Semnan</td>
<td>0.1795</td>
<td>Esfahan</td>
<td>0.0466</td>
</tr>
<tr>
<td>Khorrramabad</td>
<td>0.1611</td>
<td>Zahedan</td>
<td>0.2982</td>
<td>Ilam</td>
<td>0.0969</td>
</tr>
<tr>
<td>Sari</td>
<td>0.0537</td>
<td>Shiraz</td>
<td>0.0855</td>
<td>Boushehr</td>
<td>0.6291</td>
</tr>
<tr>
<td>Arak</td>
<td>0.205</td>
<td>Ghazvin</td>
<td>0.2122</td>
<td>Tehran</td>
<td>0.1805</td>
</tr>
<tr>
<td>Bandarabas</td>
<td>1</td>
<td>Ghom</td>
<td>0.2973</td>
<td>Shahrekord</td>
<td>0.0333</td>
</tr>
<tr>
<td>Hamedan</td>
<td>0.1578</td>
<td>Sanandaj</td>
<td>0.2724</td>
<td>Birjand</td>
<td>0.0359</td>
</tr>
<tr>
<td>Yazd</td>
<td>0.1072</td>
<td>Kerman</td>
<td>0.2509</td>
<td>Mashhad</td>
<td>0.1624</td>
</tr>
</tbody>
</table>

Fig. 5. The final map of areas affected by drought in Iran based on the TOPSIS model during the study period (1990-2018).
This method has been used in a few studies and considered as a suitable method for monitoring, analysis and comparison. Alizadeh et al. (2017), e.g. once working on the modelling dispersion of droughts due to climate change in Iran using a dynamical system and also Zeinali & Safarianzengir (2017) on drought monitoring in the Lake Urmia Basin using the fuzzy index concluded that this method exhibits acceptable performance. Fathi-Zadeh et al. (2017) once working on the relationship between meteorological drought and solar variables in some of interconnection stations in Iran, and finally, Parsamehr & Khosravani (2017) used TOPSIS model and verified the efficiency of the models. Models presented in the current study are also useful in modelling, monitoring and predicting the drought phenomenon in Iran.

**DISCUSSION**

Drought is a natural disaster that is gradually evolving under the influence of climatic abnormalities over a long period. In recent years, various parts of the Middle East have faced drought, including Iran in Southwest Asia. Drought is one of the natural hazards that has been gradually evolving over the years through the climatic fluctuations and has its effects on the different parts of the environment. One of these areas is in Iran, which in recent years has been encountered drought in its different parts, especially the southern regions with high intensity.

In this study, the drought phenomenon was predicted in two 6- and 12-month scales using the TIBI new fuzzy index. The results of the study revealed that the total frequencies of drought were higher at 12-month scale than at 6-month one. However, the severity of the 6-month drought was higher than that of 12-month one. At a 12-months scale, drought repetitions and its continuity were higher than at 6-month one. The drought was less continuous in short-run time scale and affected by temperature, while the severity of drought in the long periods was less responsive to rainfall variations. The highest rates (%) of drought incidence in a 6-month scale were found in Bandar Abbas, Bushehr, Ahvaz and Zahedan in the southern part of the study area with the frequency of drought of 16.62%, 11.24%, 14.13% and 6.62% respectively, while the lowest at 6-month scale were in Urmia, Ardebil, Iam and Yasuj with frequency of 1.10%, 1.88%, 1.61% and 2.01% respectively. Moreover, Rasht and Gorgan exhibited a drought severity of 1.26 and 0.87 in the north and west of Iran. The highest frequency of drought incidence in a 12-months scale were predicted in two 6- and 12-month scales using the TIBI new fuzzy index. The lowest frequencies at the 6-month scale were found in Birjand (1.70%), Bojnurd (3.66%), Urmia (1.17%) and Tabriz (2.66%) in the northwest as well as Rasht (0.58%) and Sari (0.78%) in the northern part of Iran. Also, based on TOPSIS model, Bandar Abbas, Ahvaz and Bushehr in the south and southwest of Iran were prioritized with high drought severity (1. 0.78, and 0.62 respectively). The prediction of drought based on the ANFIS comparative neural network model indicate that Bandar Abbas, Bushehr and Zahedan with the TIBI index of 0.62, 0.96 and 0.97 respectively in southern parts of Iran will be mostly encountered to drought for the coming years.
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پایش و پیش بینی خشکسالی با استفاده از شاخص فازی TIBI در ایران

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چکیده
پدیده خشکسالی مختص ناحیه‌های خاص نیست و مناطق مختلف جهان از آن متأثر است. یکی از این مناطق ایران در جنوب غرب آسیا است که در سال‌های اخیر از این پدیده رنج می‌برد. هدف پژوهش حاصل مدل‌سازی، تحلیل و پیش‌بینی خشکسالی در ایران است. برای این کار ابتدا فرآیندهای اقلیمی: بارش، دما، ساعت‌های آفتابی، کم‌وبیش رطوبت نسبی و سرعت باد در بانه زمینی 29 ساله (1991-2019) در 30 ایستگاه ایران استفاده شد. برای مدل‌سازی، شاخص فازی TIBI ابتدا جهار شاخص ANFIS (SET, SPI, SEB, MCZI) با استفاده از منطق فازی در نرم‌افزار MATLAB شاخص‌های زندانی و در نهایت برای تحقیق TIBI پیش‌بینی از مدل شکوهی مصنوعی تطبیقی در مشابهات خشکسالی، جهار شاخص مذکور را با دقت بالا در خود متعکس کرد. از بین 5 فرآیندهای اقلیمی مورد استفاده در TIBI این پژوهش، دما و بارش در نویسنده شاخص خشکسالی بیشترین تأثیر را داشت. شاخص خشکسالی براساس مدل مدل‌سازی انجم شده در مقیاس 6 ماهه بیشتر از 12 ماهه بیشتر درصد خشکسالی در ایستگاه‌های بندرسازی با مقدار (0/42) در مقیاس 12 ماهه و کم‌ترین آن در ایستگاه شهرکرد با مقدار درصد فراوانی خشکسالی 46/3% در مقیاس 6 ماهه انفک افتاد. خاک‌پوشانی، بارش تابستان به وسیله اختلاف TIBI براساس مدل ANFIS شاخص فازی TIBI بیشتر بوده و در زمینه‌های بخش‌های اقلیم‌های بندرسازی بیشتر و زاهدان به ترتیب با مقدار TIBI (1/061/6) در نیمه جنوبی ایران بیشتر در معرض خشکسالی قرار گرفتند. براساس نتایج کلی پژوهش در دوره متمایز 6 و 12 ماهه مناطق نیمه جنوبی ایران از شدت بیشتر خشکسالی برخوردار بود که نیازمند مدیریت دقیق و کارآمد در مدیریت منابع آبی در این مناطق است.

مؤلف مسئول

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