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ORIGINAL PAPER

A comparative study of precipitation-based drought indices with the aim of selecting the best index for drought monitoring in Iran

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Abstract

Drought is a natural disaster that occurs frequently or intermittently and affects all economic, social, and environmental aspects of a society. The present study is an attempt to compare different drought indices and select the best drought index for drought monitoring in Iran. To this end, seven drought indices including SPI, PN, ZSI, DI, CZI, EDI, and MCZI were used for 1-, 3-, 6-, 12-, and 24-month timescales. The monthly precipitation data of 41 synoptic stations in Iran over a period of 28 years (1985–2013) were used in order to achieve the research objectives. After the required databases were obtained, the effective drought index (EDI) was used as a basic indicator and as the basis of calculations in order to choose the best index for drought monitoring. The results showed that the EDI index indicates the general drought classes better than other indices. Of the indices used in the study, three indices namely ZSI, SPI, and CZI showed the highest consistency in their behavior. In addition, the 6-, 12-, and 24-month timescales showed very similar drought results in the abovementioned indices. Moreover, the behavior of DI and PN indices proved to be inconsistent with the behavior of other indices, and these indices proved to be unsuitable for drought monitoring in Iran. The MCZI index, as compared to the EDI index, showed no acceptable performance in drought monitoring. Finally, SPI and EDI indices were detected as the first and second best indices for drought monitoring in Iran.

1 Introduction

Drought is prolonged period of water scarcity in which the conventional course of growth, product development, and the conventional relationship between humans and the environment is disrupted. Therefore, drought is not peculiar to arid zones and is likely to happen in every type of climate. This phenomenon can happen even in zones where annual precipitation is over 1500 mm.

This climate phenomena has incurred great economic, social, and environmental costs, and the damages attributed to it are rising at an unexpected rate. Although, determination of drought costs and damages is very difficult due to lack of valid historical evaluations, it is clear that in countries located in arid regions of the world, including Iran, this figure is more than several billion dollars per year. For example, two extensive droughts occurred in Iran during 1970–1971 and 1988–1989 and covered 82.21 and 92.05% of the country respectively. During these periods, the country sustained a lot of damage (Bazrafshan 2011). Countries like America that generally offer exact figures for damages and losses, the losses sustained during moderate droughts (as in 1975) was equal to 700 million dollars, while this figure has been reported as approximately $7 billion during extensive droughts (e.g., 1995) (Ansari 2004). As another example, in 1970 and 1984, Australia spent 925 million dollars to compensate for the losses caused by drought or the South African government spent $5.2 billion to compensate the losses caused by drought in the mid-1970s to mid-1980s (Wilhite 1987).

Therefore, preparation and planning for dealing with the adverse effects of this event depend on the information on the extent, severity, and duration of drought. This information can be obtained by drought indices that provide decision makers with quantitative information on the drought features. Such quantitative information is very useful in drought monitoring.

Early works on drought monitoring mainly began with small scale regional frequency analysis by Whipple (1966). These works were then pursued by other researchers like Eder and Davis (1987), Oladipo (1986), and Sen (1980) across

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some states of America and in some cases for the whole country. In some studies such as Palmer (1965) design and development of drought monitoring systems, to deal with drought is strongly recommended. Drought monitoring is done using some indices. The preparation and application of drought indices is an attempt to perform a simple and quantitative assessment of the drought characteristics such as severity, duration, and extent (Hayes et al. 1999). In the drought monitoring and assessing process, determination of a set of appropriate and accurate indices is of particular importance. Various indices are used to assess drought. These indices include the Palmer Drought Severity Index (PDSI; Palmer 1965), Deciles Index (DI; Gibbs and Maher 1967), Crop Moisture Index (CMI; Palmer 1968), the Bhalme–Mooley Drought Index (BMDI; Bhalme and Mooley 1980), Surface Water Supply Index (SWSI; Shafer and Dezman 1982), Standardized Precipitation Index (SPI; McKee et al. 1993), Effective Drought Index (EDI; Byun and Wilhite 1999), and Reclamation Drought Index (RDI; Tsakiris et al. 2007). Although none of the indices is superior to the others, some of them only work in certain zones. For example, the Palmer Severity Drought Index (PDSI) is widely used in America, while DI index is used in Australia, and the Chinese Z index (CZI) is used by the National Center for Meteorology in China (Wu et al. 2001).

So far, several studies have been conducted for the purpose of drought assessment using drought indices in different zones. These studies include Khalili et al. (2010) studies in the assessment of CMI index, Ameziane et al. (2003) in the evaluation of SWSI index, Tsakiris (2004), and Pashiardis and Michaelides (2008) in the evaluation of RDI index, as well as studies conducted by Ntale and Gan (2003) and Mavromatis (2010) in the assessment of PDSI index.

The drought monitoring studies in which attempts are made to compare different drought indices in a given region include Moghadasi et al. (2005) in which Tehran's drought monitoring using DI, SPI, and EDI indices over 1998–1999 to 2001–2002 was investigated. The results showed that the EDI index provides a generally acceptable reaction to droughts. In addition, logical consistency as observed in the results, Morid et al. (2006) compared DI, PN, SPI, CZI, MCZI, and EDI drought indexes in their attempt to design a drought monitoring system for Tehran province in Iran. The results indicated that SPI and EDI outperform other indices. Akhtari et al. (2007) performed a spatial analysis on the effective drought index and standardized precipitation in the same province. The results indicate that effective drought index has a higher spatial autocorrelation compared to the Standardized Precipitation Index. Wu et al. (2001) used precipitation data to assess the Standardized Precipitation Index (SPI), Chinese Z, and Z score in different time scales for dry and wet climates. The researchers showed that all three indices provide similar results for all time scales. Other studies in this field include Ntale and Gan (2003) in West Africa, Morid and Paymozd (2008) in Iran, Dogan et al. (2012) in a river basins in Turkey, and Jain et al. (2015) in Ken river basin in India.

The present study is an attempt to compare different drought indices for monitoring the entire country. In this study, drought monitoring is conducted by different drought indices such as DI, PN, SPI, CZI, MCZI, and EDI. These indices are precipitation-based, because precipitation is a major factor that contributes to the creation, development, and persistence of droughts. However, other parameters such as evapotranspiration may also reflect the behavior of drought in any region, but due to problems in calculation of these parameters, precipitation is regarded as the best and most accessible climatic parameter for development and calculation of drought indices. On the other hand, the indices that are only based on this variable are more readily accepted by the scientific community and users. Therefore, in the present study, drought monitoring is conducted using drought indices that are based on the element of precipitation. A brief description of the indices studied in the present research is provided below.

1.1 Percent of Normal Index (PNI)

This index was first developed by Willeke et al. (1994). The Percent of Normal Index is the ratio of normal precipitation to normal amount of precipitation in a specified period that is expressed in percentage. This index is suitable for public awareness of drought conditions at the local and seasonal scale. That is why many researchers use it in their studies (Barua et al. 2011; Hayes 2000; Morid et al. 2006; and Smakhtin and Hughes 2007).

1.2 Deciles Index (DI)

The Deciles Index was first selected and used in 1967 by Gibbs and Maher in Australia. The index was developed to prevent the problems in application of Percent of Normal Index. This index was also used for drought monitoring purposes in Mpelasoka et al. (2008), Keyantash and Dracup (2002), and Pandey et al. (2008). In this index, the monthly precipitation data arranged in ascending order and divided into ten sections in a longer period.

1.3 Effective Drought Index (EDI)

This index was first developed by Byun and Wilhite (1999) for detection and identification of drought starting and ending time. Unlike other drought indices, the original Effective Drought Index (EDI) is calculated based on daily data (Akhtari et al. 2009; Kalamaras et al. 2010; Kim and Byun 2009; Kim et al. 2009; Morid et al. 2006; and Roudier and Mahe 2010); however, its principles can be extended to monthly precipitation data as well (Morid et al. 2007 and Pandey et al. 2008).

1.4 Standardized Precipitation Index (SPI)

The index was first developed in 1993 by researchers at Colorado State University to improve the operational status of water supply monitoring in the state of Colorado. Standardized Precipitation Index is a powerful tool in the analysis of precipitation data. SPI mainly aims to assign a numerical value to precipitation in order to provide the ground for comparison of completely different climatic zones. The advantages of SPI include simple calculations, utilization of accessible recipitation data, and calculability for any arbitrary time scale. According to the features mentioned above, the index has attracted the attention of many researchers, and is widely used to monitor and zoning local and regional droughts around the world. McKee et al. (1993) were the first ones who used this index to monitor the state of Colorado. After that, several researchers, including Hayes et al. (1999), Seiler et al. (2002), Loukas and Vasiliades (2004), and Smakhtin and Hughes 2007) used this index to monitor drought in their countries.

1.5 Z-Score Index

ZSI is very easy to calculate. This index is used in many drought studies such as Tsakiris and Vangelis (2004), Patel et al. (2007), and Morid et al. (2006). ZSI does not need any transformation of index data such as gamma distributions or Type III Pearson distribution that is done in SPI and CZI.

1.6 CZI index

The CZI index was first widely used in 1995 by the National Meteorological Center of China. This index is based on the cube root transformation of Wilson-Hilferty with the assumption that the data comply with the Pearson Type III distribution (Kendall and Stuart 1977). The calculations made by this index are available in Wu et al. (2001) and Morid et al. (2006). Modified CZI index (MCZI) is calculated in the same way CZI is calculated except that, instead of mean, we use median in calculation of this index.

2 Materials and methods

The monthly precipitation data of 41 synoptic stations over a period of 28 years (2013–1985) were used for comparison of different monthly drought indices. It was observed in a preliminary investigation of the precipitation data acquired from Iran's Meteorology Organization that we have complete data for all of the studied stations, except for four of them, namely Khorram Abad, Arak, Isfahan, and Bushehr. There were some missing data for meteorological stations in Khorram Abad stations for February 1985, for Arak in August, for Isfahan in February and March 1997, and for Bushehr in June, July, August, and September 2013. These missing data were reconstructed for the intended stations using Pierson product-moment correlation coefficient and classic linear regression models. After reconstructing the missing data and perfection of the data related to all the studied stations, their randomness was verified using Run Test, and it was observed that all the precipitation time series of the studied stations feature randomness in statistical terms. The homogeneity test of the studied stations' precipitation data, as well, was examined using double mass test. It was found out that all of the studied stations, except Gorgan, are homogeneous in their time series data. Thus, the precipitation data of Gorgan station was revised using the adjacent stations' precipitation data and its homogeneity was evaluated. Distribution of stations under study in this research is presented in Fig. 1.

Seven indices including present normal drought index (PN), Standardized Precipitation (SPI), Deciles Index (DI), China-Z Index (CZI), Modified China-Z Index (MCZI), Z-Score Index, and Effective Drought Index (EDI) were selected in this study. A common feature of all these indices is that the monthly precipitation parameter is used to calculate all of them.

2.1 Percent of Normal Index (PNI)

Percent of Normal Index is one of the simplest indices used to assess drought and is calculated by dividing the occurred precipitation amount (Pi) by the amount of normal precipitation (average long-term) ($\overline{P}$) and is usually expressed in percentage. The index is calculated at monthly, quarterly and yearly scales through the following equation:

$$\mathrm{PNI} = \frac{P_i}{\overline{P}} \tag{1}$$

2.2 Deciles Index (DI)

As mentioned before, in this index, the precipitation data are arranged in ascending order and divided into ten sections in a longer period. Each of these sections is called a docile. The first docile is the precipitation rate that is lower than 10% of the precipitation. The second docile represents the amount of precipitation, which is lower than 20% of the precipitation. The fifth docile or median represents the precipitation amount that does not exceed 50% of precipitation. These deciles will continue until the tenth docile. Just like the PN index, this index is calculated at monthly, quarterly, and annually time scales.

Fig. 1 Geographical position and spatial distribution of the studied stations inside Iran

2.3 Effective Drought Index (EDI)

Calculation of EDI includes several stages that are briefly described below. The basic concept in this index is effective precipitation or EP. EP is the total daily rainfall rate at a time-based decreasing function that is calculated using the following equation:

$$\mathrm{EP} = \sum_{n=1}^{i} \left[\left(\sum_{m=1}^{n} P_m \right) / n \right] \tag{2}$$

where i is assumed continuity and P_m indicates precipitation up to $m-1$ days before.

Table 1 Classification of numerical values of drought indices

	Extreme drought (− 3)	Severe drought (− 2)	Moderate drought (− 1)	Normal (0)
DI	40 ≥	10–20	20–30	30–70
PN	10≥	40–50	55–80	80–100
SPI	− 2 ≥	− 1.99 to − 1.5	− 1.49 to − 1.00	− 0.99 to 0.99
CZI	− 2 ≥	− 1.99 to − 1.5	− 1.49 to − 1.00	− 0.99 to 0.99
MCZI	− 2 ≥	− 1.99 to − 1.5	− 1.49 to − 1.00	− 0.99 to 0.99
ZSI	− 2 ≥	− 1.99 to − 1.5	− 1.49 to − 1.00	− 0.99 to 0.99
EDI	− 2.5 ≥	− 1.5 to − 2.49	− 0.7 to − 1.49	− 0.69 to 0.69

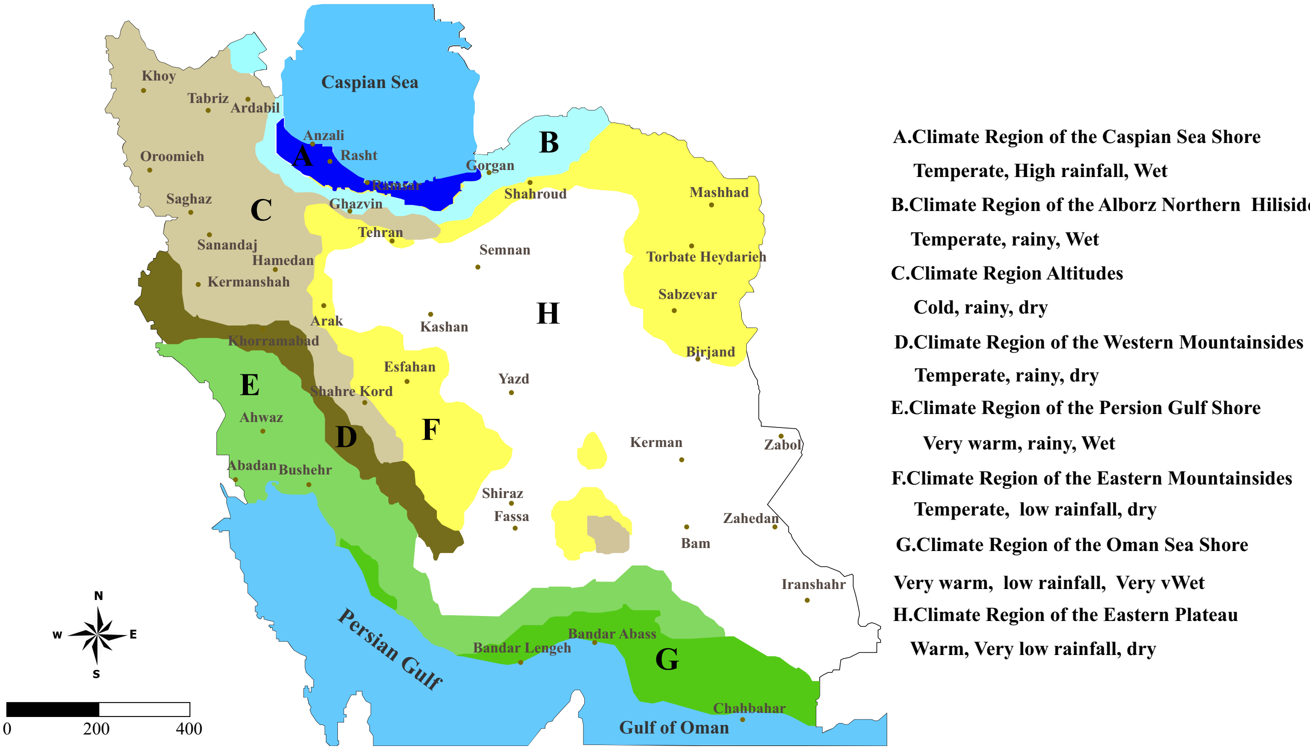

Fig. 2 Climatic classification of Iran and the assigning of the studied stations to each climatic class

Estimation of EP deviation from MEP is the next in calculation of this index. This deviation is calculated through the following equation (DEP). In fact, MEP is the mean or normal EP for each calendar day that is one of the climatic characteristics at a specific place and time.

$$\mathrm{DEP} = \mathrm{EP}-\mathrm{MEP} \quad (3)$$

Calculation of precipitation needed for a return to normal conditions (PRN) is another step in this calculation that is calculated by the following equation:

$$\mathrm{PRn} = \mathrm{DEP}/\sum_{n=1}^{j}\frac{1}{N} \quad (4)$$

and finally, EDI that is actually standardized form of PRN is calculated in accordance with the following equation:

$$\mathrm{EDI} = \mathrm{PRN}/\mathrm{ST(PRN)} \quad (5)$$

In this equation, ST (PRN) represents the standard deviation from PRN.

2.4 Standardized Precipitation Index (SPI)

The index is based only on the precipitation variable and is a proper tool to identify the phenomenon of drought in various regions. In this index, the precipitation data in each station at the pre-determined time scale is first fitted to a probability

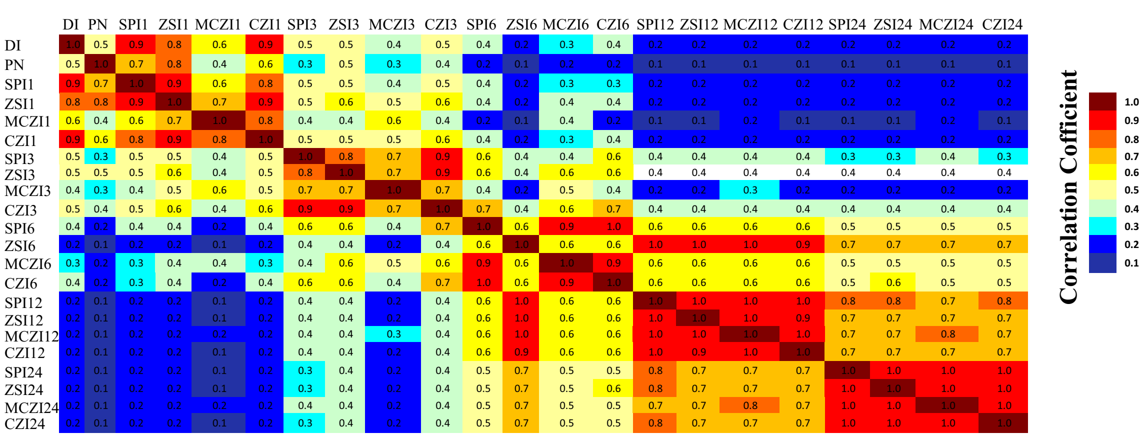

Fig. 3 The mean correlation coefficient between various drought indices at different time scales

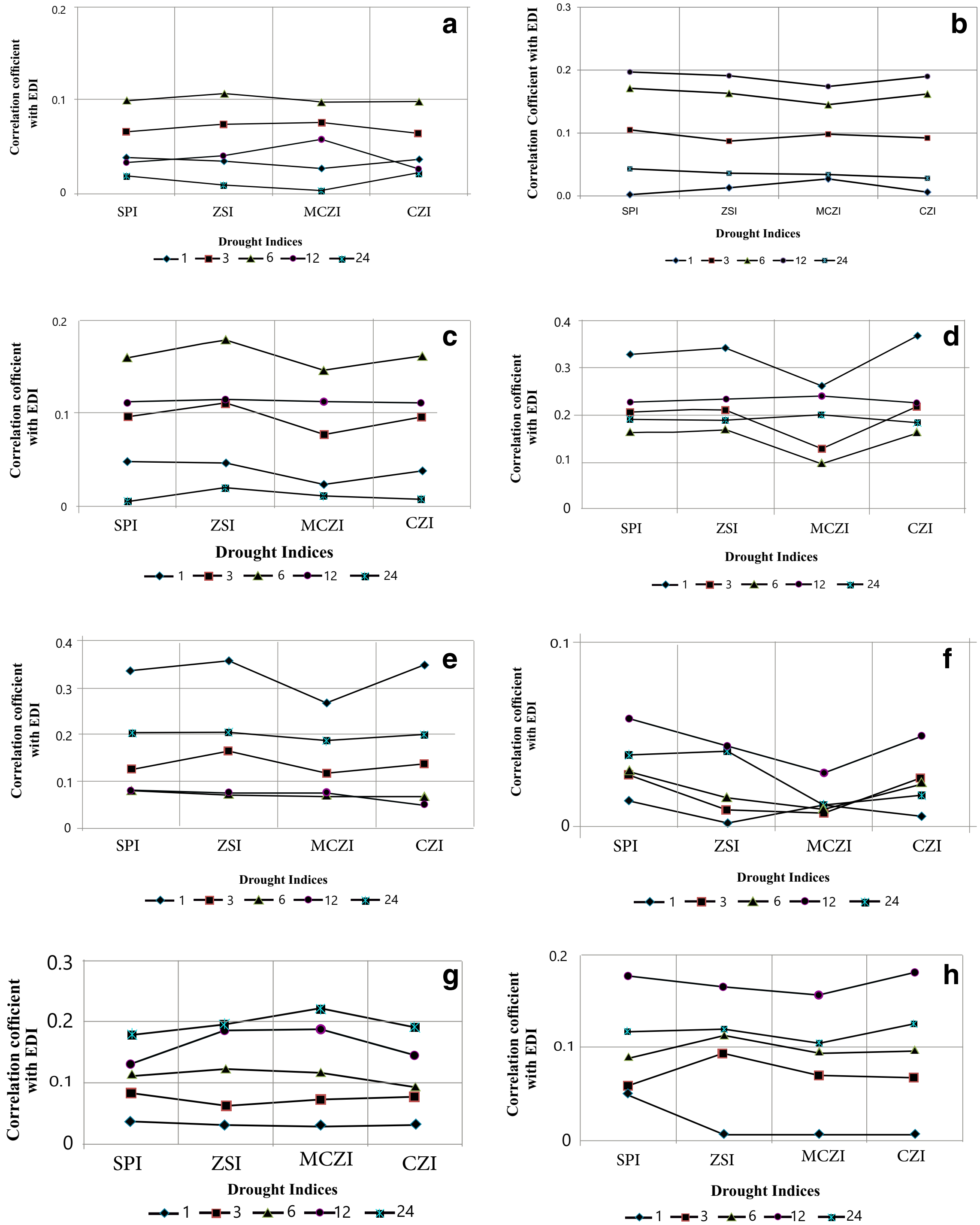

Fig. 4 Mean correlation coefficient between EDI and other indices in different timescales

function (usually gamma distribution), then transformed to a normal distribution, so that the mean value for that given location and time becomes equal to zero. Positive SPI indicates long-term precipitation greater than the mean value, and negative SPI suggests long-term precipitation lower than the mean value. Negative SPI is a sign of drought and positive SPI promises an end to the drought.

2.5 The Z-Score Index

ZSI is very easy to calculate. In this index, there is no need to transform the fit data into distributions such as gamma distributions or Pearson Type III (what is done in SPI and CZI). The index is derived from the following equation:

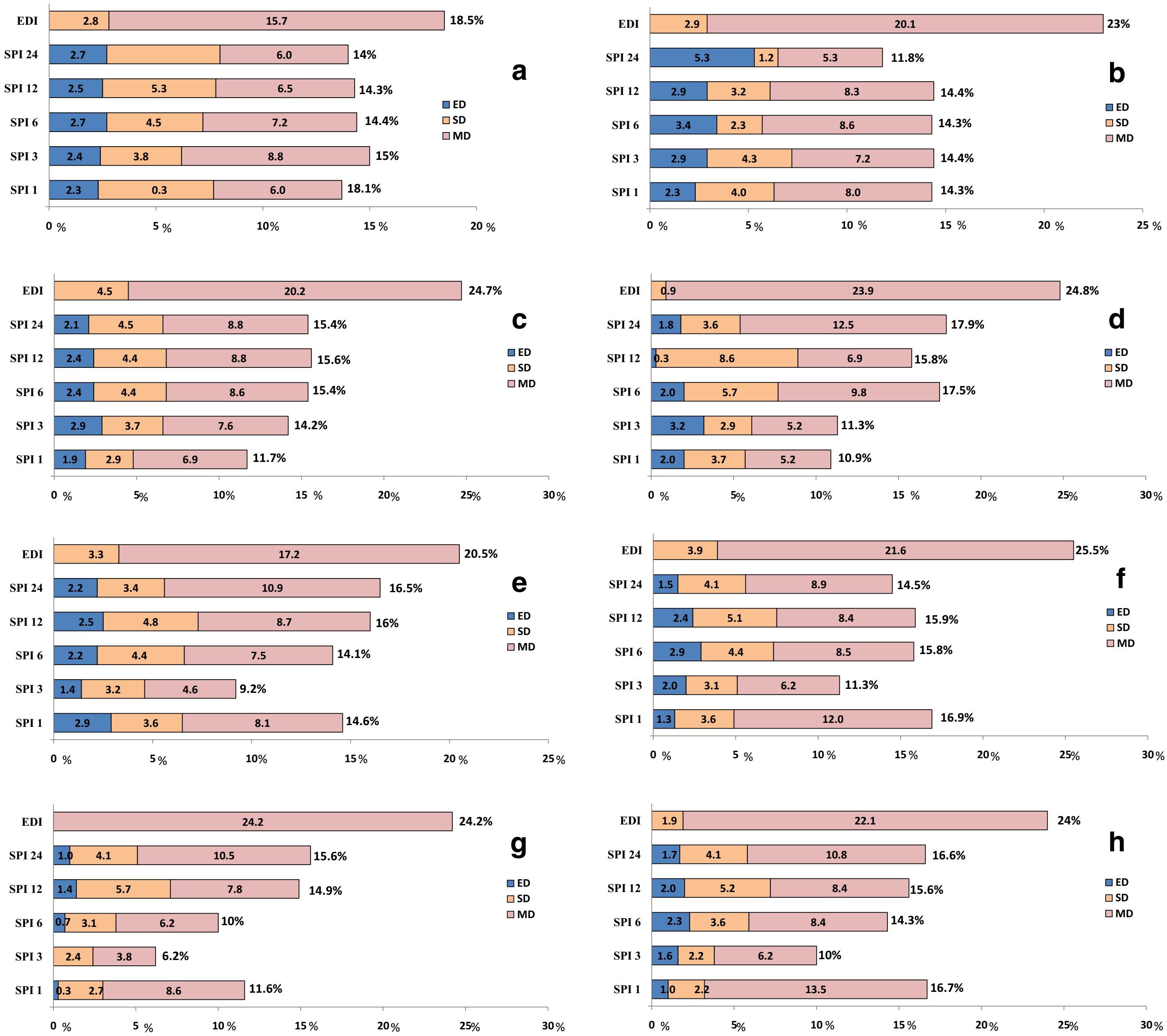

Fig. 5 Comparison of drought severity classes in SPI and EDI indices within different times scales

$$\mathrm{ZSI} = \frac{\left(X_{ij} - \overline{X}\right)}{\sigma_i} \tag{6}$$

In the above equation, X_{ij} is the precipitation for the period i, while σ_i and $\overline{X}$ indicate the standard deviation and mean precipitation at each time scale respectively.

2.6 CZI index

CZI index is based on the cube root transformation of Wilson - Hilferty with the assumption that the data comply with the Pearson Type III distribution. This index is calculated as below:

$$\mathrm{CZI} = \frac{6}{C_s}\left(\frac{C_s}{2}\,\text{Z-Score} + 1\right)^{1/3} - \frac{6}{C_s} + \frac{C_s}{6} \tag{7}$$

In the above equation, C_s is the coefficient of skewness and $Z-$Score is the same as Eq. (6).

Modified CZI index (MCZI) is calculated in the same way as CZI except that, we use median, rather than mean, in calculation of this index.

3 Results and discussion

DI, SPI, PN, ZSI, CZI, EDI, and MCZI indices were used on 1-, 3-, 6-, 12-, and 24-month time scales in order to compare different drought indices in Iran. Given that EDI index has been considered as a benchmark index in many studies, this index was considered as a benchmark index in this study. Comparison of various drought indices calls for consideration of the same numerical range for them. As the numerical range of CZI, ZSI, MCZI, and SPI indices is somewhat similar to the EDI index, it was possible to draw a direct analogy between these indices and the EDI, but this was not feasible for PN and DI indices, because the numerical range of these indices was quite different from the numerical range of EDI index. Therefore, some modifications were made in the classification of these indices in order to pave the path for comparison of them (Table 1).

First, different classes of drought for 41 stations at the abovementioned time scales were extracted for all the indices. Since the results indicated the extensiveness of this study, the climatic zoning of Iran provided by Masoodian (2012) was used to regulate the presentation of the final results of the study and avoid any burble. This zoning is presented in Fig. 2 in the form of a map for eight zones.

3.1 Investigation of the relationship between drought indices

The relationship between various drought indices in five time scales plus DI and PN indices for all climatic classifications was achieved in a 22 × 22 matrix (Fig. 2). Since the results are almost the same for all regions, the correlation table was included in the study for the sake of brevity (Fig. 3). The results showed that the median timescales (12 and 6 months) have a better relationship with the timescales before and after themselves, such that at the 12-month time scale no correlation coefficient of less than 0.6 was observed in the preceding (6 months) and following time scales (24 months). The results also showed that the 1-month and 3-month time scales have a stronger relationship with their close time scales. For example, the 3-month time scale had the greatest correlation with itself

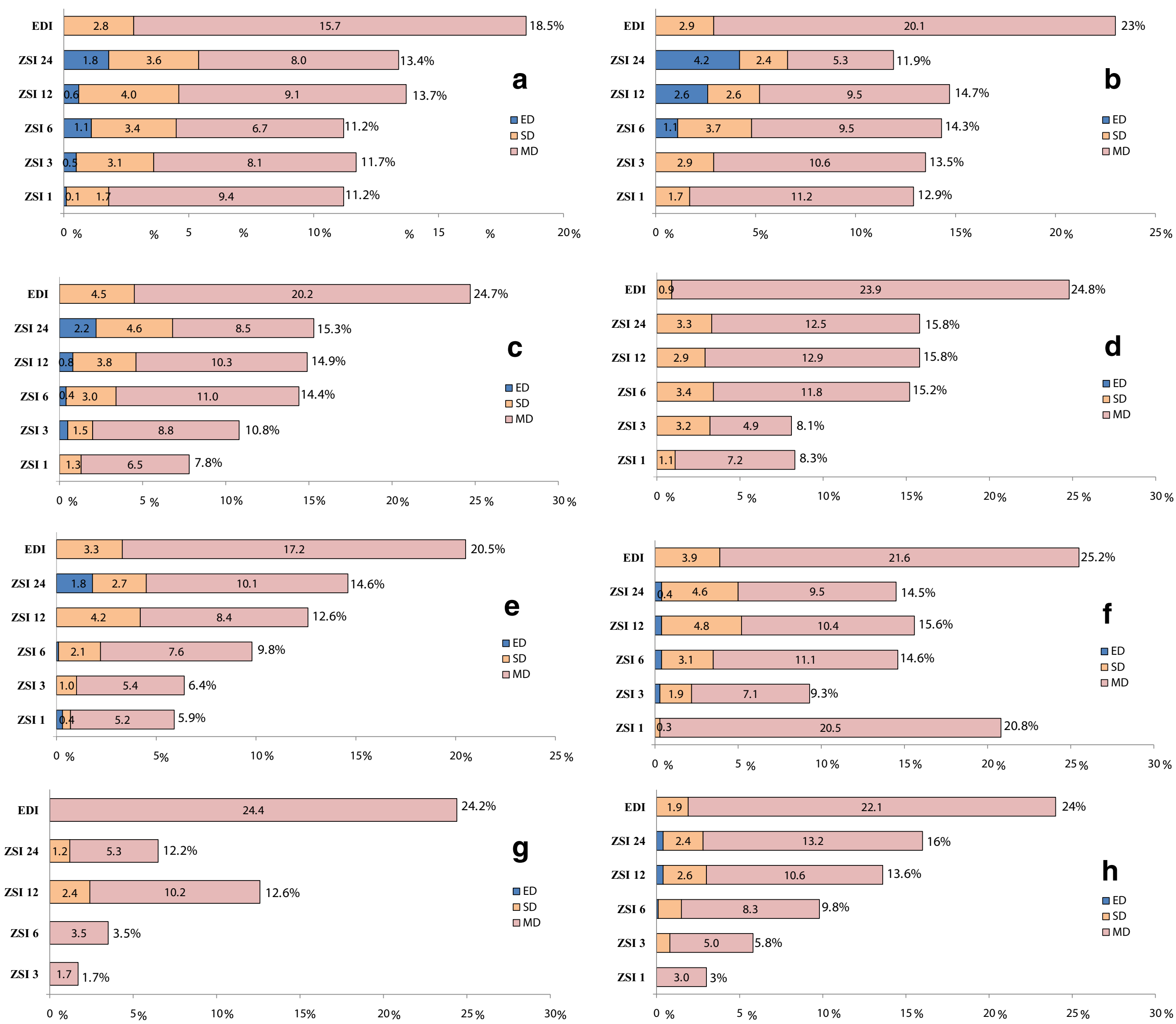

Fig. 6 Comparison of drought severity classes in ZSI and EDI indices within different timescales

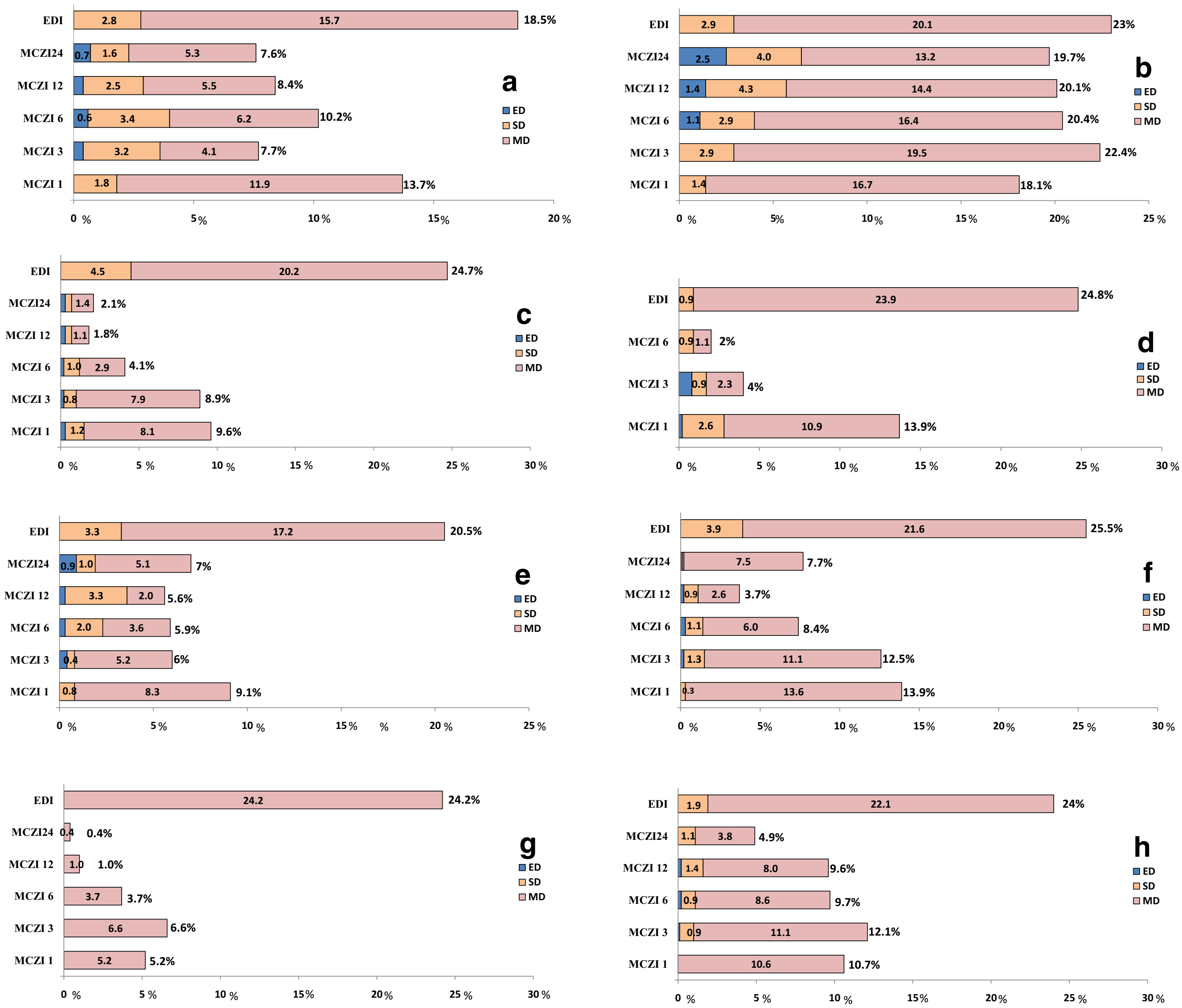

Fig. 7 Comparison of drought severity classes in MCZI and EDI indices within different timescales

and with any increase in the timescale; the correlation between the 1-month time scale and other time scales declines.

Figure 4 shows the mean correlation between EDI and other indices at various timescales. It is clear that the EDI index has a poor correlation with other indices in different zones. In other words, the index has had the highest correlation with CZI, ZSI, and SPI indices (respectively) in D and E zones (close to 0.4) in the 1-month timescale. In addition, in zone F, no correlation was observed between the EDI index and other indices (close to zero).

3.2 Comparison of EDI drought index with other indices

The EDI drought index can only be calculated at daily and monthly time scales. In the present study, the monthly time scale has been used. Comparison of this index with other indices at different time scales calls for the percentage of wet and drought classes in indices under study. Therefore, in this study, three classes of drought namely moderate drought (MD), severe drought (SD), and extreme drought (ED) were selected for comparison purposes, and then the percentage of each class was obtained for the timescales.

Figure 5 draws an analogy between severity of different classes of drought in the SPI and EDI drought indices. This figure shows that the EDI drought index has had higher overall drought percentage (MD + SD + ED) compared to other SPI-time scales in all zones of study. In addition, the percentage of moderate drought (MD) shown by this index is higher than what is shown by the SPI index. In other words, the highest percentage of moderate drought class in the EDI index within zone G, is equal to 24.2%, while the highest percentage of moderate drought class obtained in the SPI index (in the 24-month timescale) is equal to 12.5% in zone H according to the

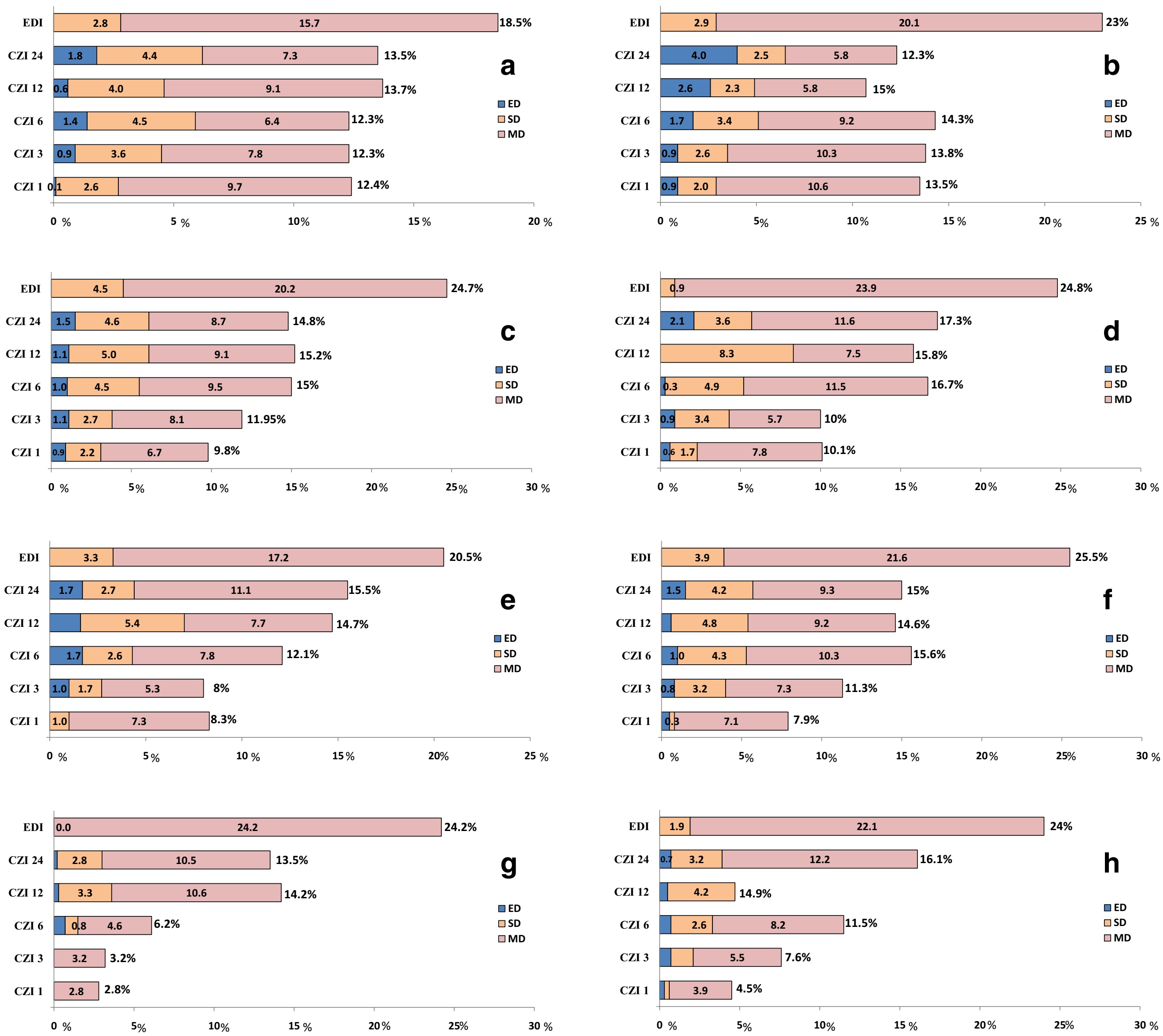

Fig. 8 Comparison of drought severity classes in CZI and EDI indices within different timescales

results. EDI estimations of severe drought in some zones (A, D, and H) are lower than SPI estimations in all timescales. EDI estimations of severe drought were only higher than SPI estimations in a few zones in F and C zones and within 1 and 3 timescales). The noteworthy point about the EDI index is that this index has never experienced extreme drought.

Comparison of the two drought indices (EDI and ZSI) is shown in Fig. 6. In all timescales, the overall percentage of drought in EDI is more than the overall drought percentage obtained in ZSI. In the 1-month timescale in zone F, the value of ZSI index is 20.8% that is close to the overall percentage of EDI index, (25.2%) in this zone. In addition, the percentage of moderate drought obtained in the EDI index is higher than the percentage obtained in the ZSI in all zones. The severe drought estimated by the EDI drought index is lower than the severe drought estimated by the ZSI index in several zones. For example, in the zone A, severe drought estimated by the ZSI index is higher than the severe drought estimated by the EDI index within all timescales (except for the 1-month timescale). The noteworthy point about ZSI index is that the numerical values of this index are very close in the 12- and 24-month timescales in all zones (except for zone B). In addition, the ZSI value increased from the 1-month timescale to the 24-month timescale (in zones C, D, E, and H).

The MCZI drought index is in fact the modified version of CZI index that, in comparison with the EDI drought index, shows the drought classes very low in all zones. According to the results, the moderate and severe drought classes estimated by this index are lower than the moderate and severe drought classes obtained by the EDI index in all zones (with the exception of zone B). The noteworthy point about the MCZI index is that in this index (as opposed to the ZSI index), any increase in the timescale leads to decreased drought percentage (C, G, D zones) (Fig. 7).

Figure 8 shows the comparison of CZI and EDI indices. Like the other indices, the incidence percentage of total classes in the EDI index is higher than that in the CZI index. In CZI, the total incidence percentage of classes in zones A and B is very close within all timescales while the percentage of drought classes is only close in some zones (C D E F) within the 6-, 12-, and 24-month timescales. The incidence percentage of moderate drought class in CZI is much lower than its incidence percentage in the EDI index. But, in most timescales, the incidence percentage of severe drought in CZI is more than the percentage obtained in the EDI index. In addition, the incidence percentage of extreme drought in CZI index is negligible. In other words, the highest incidence percentage of severe drought classes in this index was achieved in zone B, (4%) within the 24-month timescale, while the incidence percentage of this class is equal to zero in the EDI index.

Figure 9 draws an analogy between the drought classes obtained in the PN and DI indices and the drought classes obtained in the EDI index in the monthly timescales. The findings indicate that the overall draught classes in the PN and DI indices are greater than the drought classes obtained in the EDI index in all zones. The moderate drought percentage obtained in the EDI index is higher than the moderate drought percentage obtained in the PN and DI indices in all zones. However, the incidence percentage of severe drought

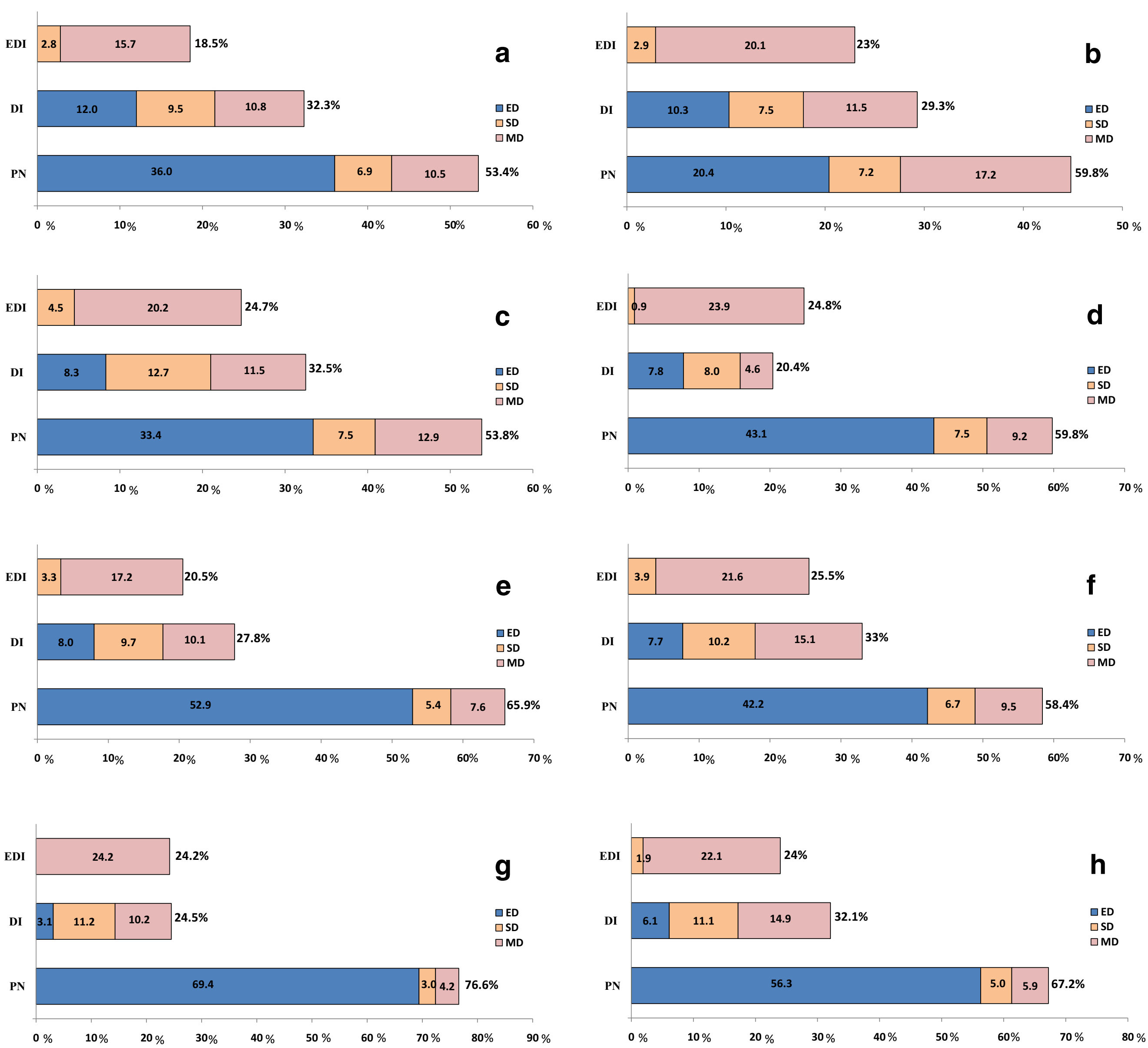

Fig. 9 Comparison of drought severity classes in PN and DI indices and EDI index within different timescales

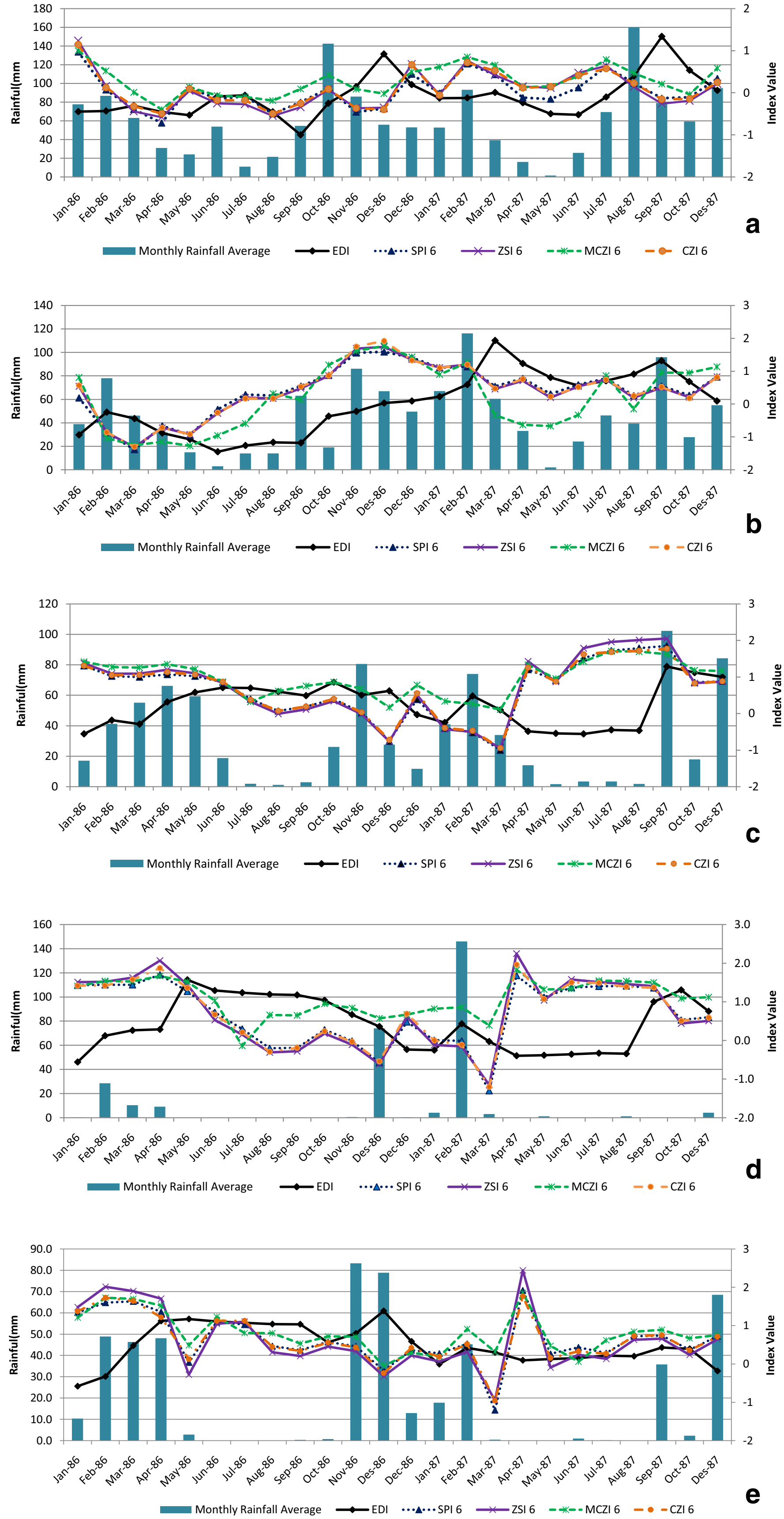

Fig. 10 Fluctuations between the EDI and some other drought indices such as CZI, ZSI, MCZI, and SPI within the 6-month timescale during 1987 and 1986

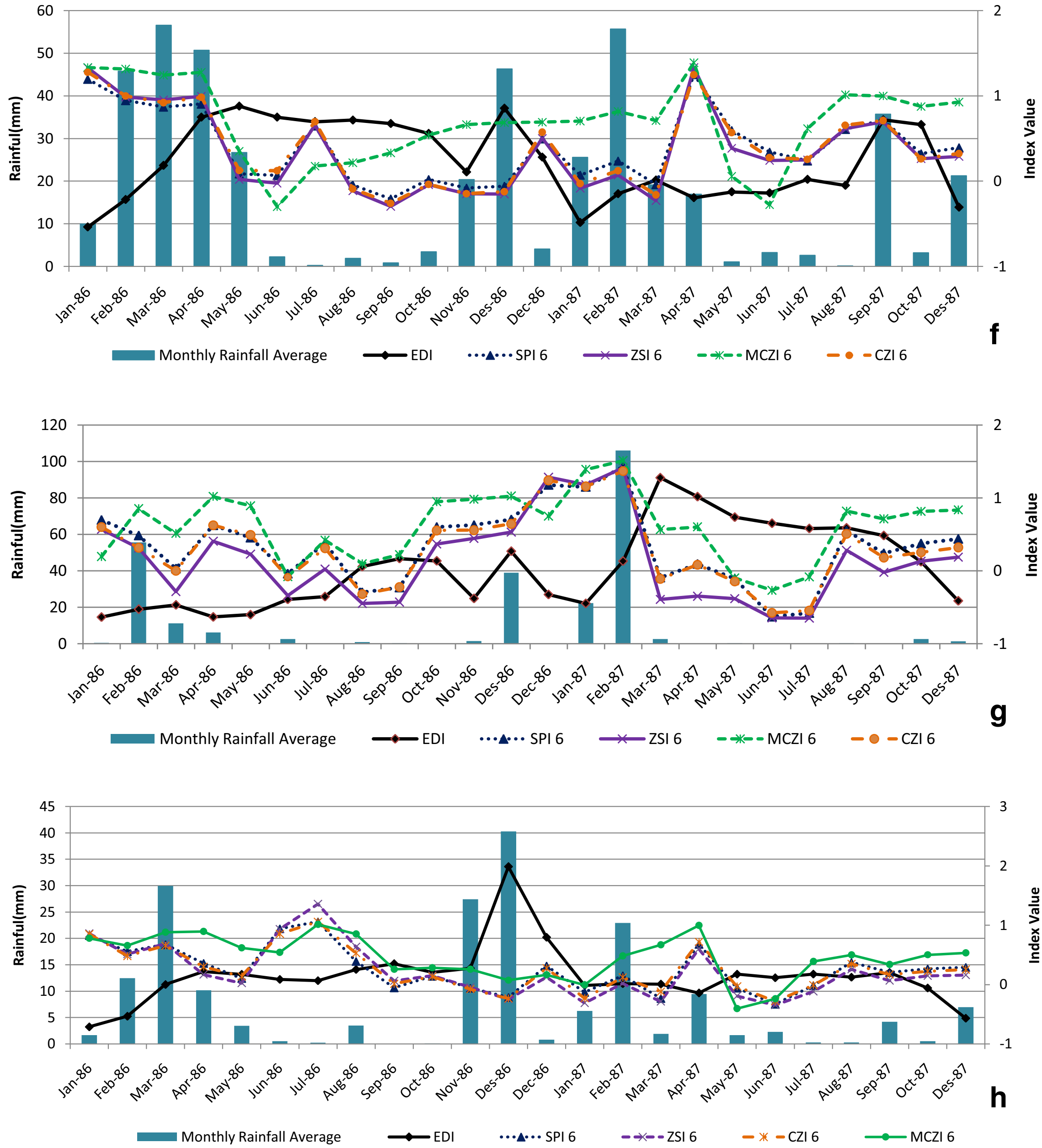

Fig. 10 (continued)

class in the PN and DI indices is higher than the incidence percentage of this drought obtained in the EDI index. The obvious point about DI index and PN index in particular is that the overall drought incidence percentage shown by these indices is much higher than the overall drought incidence percentage shown by other indices.

3.3 Investigation of fluctuations between the EDI and other drought indices

Figure 10 shows the fluctuations between the EDI and some other drought indices such as CZI, ZSI, MCZI, and SPI within the 6-month timescale during 1987 and 1986. The results show consistency in the behavior of three indices namely CZI, ZSI, and the SPI. In some zones, the MCZI index results were in contrast to the behavior of other indices. In December 1986, the SPI, ZSI, and CZI indices showed signs of moderate drought in zone C, while the MCZI index was in wet conditions. Just like MCZI, the EDI index showed very little consistency with other indices, and this inconsistency can be seen in most zones. For example, in January 1986, the EDI index reacted to the lack of precipitation, while other indices have shown no reaction to the lack of precipitation. However, in some

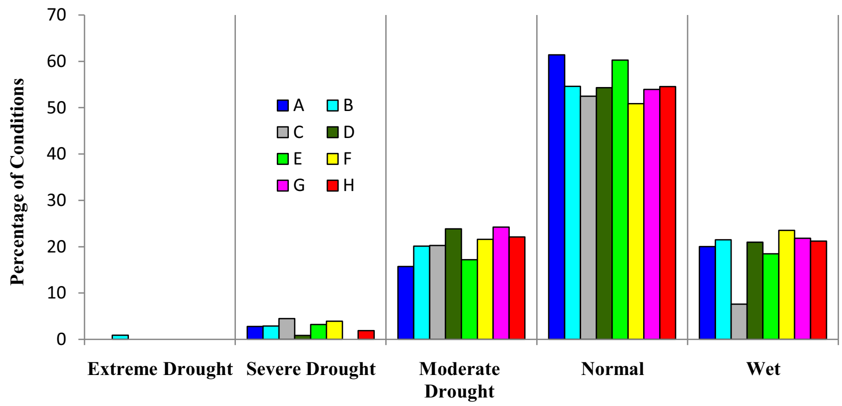

Fig. 11 Spatial variability of drought in various parts of the country (climatic classification), according to the EDI index

zones (H), the EDI index indicates more reasonable differences with the other indices.

3.4 Spatial variability of the droughts detected by EDI

Figure 11 shows the spatial distribution of drought severities in different zones of the country. F and H are among the most arid zones of Iran. According to the EDI index, the moderate drought in zones H and F is equal to 22.1% and 21.6% respectively. In addition, according to this index, the severe drought in the H and F zones is equal to 0.9 and 3.9% respectively. Based on the EDI drought index, extreme drought can only be seen in zone G (0.9). In general, the most frequent droughts in the country (MD + SD + ED) have occurred in zones F (25.5%) and D (24.8%) respectively, while the least frequent ones have occurred in zone A (the zone with the highest precipitation levels) (18.5%) and in zone E (20.4%). The normal class has had the highest incidence level among the drought and wet period classes.

4 Conclusion

In this study, seven drought indices namely SPI, PN, ZSI, DI, CZI, EDI, and MCZI were used at various timescales to compare various drought indices. Of these indices, EDI—according to the literature—was regarded as the benchmark index. The most important results of this research are as follows:

- The PN and DI indices showed no consistency and uniformity with other indices. In this study, the PN index showed droughts very high and unreasonable. This index proved to be rather non-useful for comparative studies, unless the purpose of its utilization is prespecified. In addition, the DI index results were proved to be more suitable than the PN index results. The severe droughts classes showed by this index are much higher than the ones presented by the EDI index, but this drought class can be observed in all zones. Severe drought indicated by DI in rainy zones such as A and B is very high and unreasonable, as a result, this index, just like the PN index, proved to be inadequate.
- The CZI, SPI, and ZSI indices had the highest consistency with one another. The consistency in the behavior of these indices can particularly be seen in investigations of their differences. The overall drought percentage obtained by these three indices is less than the overall drought percentage obtained by the EDI and the EDI index outperformed these three indices.
- The SPI index showed droughts much better than the ZSI and CZI indices. In this index, the results of 6-, 12-, and 24-month timescales were close to one another. Of the three timescales, the 12- and 24-month timescales showed better drought results.
- The CZI index results were almost the same as SPI index results. In this index as well, the 6-, 12-, and 24-month timescales showed drought better and closer drought results.
- The 12- and 24-month timescales in the ZSI index showed better and closer results. It can be said that, in this index, any increase in the timescale leads to increasing incidence percentage of droughts.
- No significant consistency was observed between the behavior of MCZI and EDI indices, and the MCZI index proved to be unsuitable for comparative studies. In this index, any increase in the timescale leads to reduced incidence percentage of droughts.
- The EDI index showed the highest overall drought percentage compared to the SPI, ZSI, CZI, and MCZI indices in all timescales.

In final, according to the results of this study, it can be said that the EDI and then SPI indices have had the best performance in drought monitoring respectively, and these indices are recommended for monitoring droughts in Iran.

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