Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Spatial analysis of drought severity, duration and frequency using different drought indices (Case study: Fars Province, Iran)

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ABSTRACT
The present drought is a phenomenon that can occur in any climate, hence, due to its creeping and mysterious nature, economic losses, social effects as well as crises in agricultural, natural resources and ecosystems, its study is of great importance. Therefore, in this study, by using 9 drought indices including SPEI, SIAP, DI, SPI, PN, MCZI, CZI, RDI and ZSI, the drought was analyzed using 40 meteorological and synoptic stations in Fars Province, Iran during the last half century. In order to select the best drought index, three methods including minimum amount of precipitation, normal distribution, and correlation were used. Also, the severity, duration and frequency of droughts and their return period were determined using Run Theory (RT) method and SDF curves. Finally, after determining the best index, the drought events of the region were interpolated using ArcGIS techniques along with the simple and conventional kriging methods with spherical, exponential, and Gaussian models as well as the inverse weighted distance (IDW) method. In order to determine the most appropriate interpolation method, Cross-Validation method and MAE and MBE indices were used. The results showed that the SPI index performed as the best indicator to describe the drought. The results of RT method and SDF curves showed that by increasing time scale and return period, drought continuity and magnitude increase and as drought persisted, the severity of drought not increase at a constant rate. According to the results, the most severe and widespread droughts in the province occurred in 1970, 1993, 1999, 2007, 2014 and 2016. Also, Gaussian conventional Kriging method was the best method of drought interpolation in the study area due to its lower error rate. Therefore, by spatial monitoring and distribution of droughts, necessary measures can be taken to better deal with and manage water and natural resources.

Keywords: Biodiversity, Run theory, Interpolation, Drought, SDF, GIS.
Article type: Research Article.

INTRODUCTION
Drought is one of the environmental events, an integral part of climate change and one of the causes of environmental crises, which depends on different factors and parameters. Among these, the analysis of precipitation is of special importance. Since rainfall is the most important variable, its alterations are directly reflected in soil moisture, surface flows, changes in groundwater table in reservoirs and so on. On the other hand, among climatic variables, rainfall (especially in arid and semi-arid regions) is one of the most unstable parameters (Lashanizand 2004). Unlike floods and rainfall, drought is often described as a creeping phenomenon that is very difficult to describe temporally and spatially (Alizadeh 2006). Lack of rainfall and subsequent drought exhibits many impacts on the natural and human environment including an increase in mean air temperature, EC rates,

Caspian Journal of Environmental Sciences, Vol. 21 No. 2 pp. 259-276 Received: Oct. 26, 2022 Revised: Jan. 14, 2023 Accepted: Feb. 23, 2023
DOI: 10.22124/CJES.2023.6475

Publisher: University of Guilan,

water shortage crisis and its effects on health, welfare, forest fires, spread of pests and diseases. Meanwhile, drop in groundwater level and food security also lead to a decline in surface water and finally mal effects on economic and social problems (Jamali 2013). In fact, drought would have direct and indirect effects on all aspects of the life and various sections of societies, especially the change in natural environment. So, lack of understanding of its meaning causes doubts and stagnation in various sectors of economics, management and policy-making (Arbabi Sabzevari 2010). In addition, drought causes less structural damage than other natural hazards, while assistance in the event of this phenomenon is more complex and difficult than other phenomena such as floods (Shahani 2009). Since Iran is located on the arid and semi-arid belt of the world, dryness is an ecological characteristic in most parts of the country. Drought conditions somehow intensifies this situation or durations. It may extend severity in some years which in some cases can even turn into a crisis at the national level) Hosseini *et al.* 2014). Therefore, due to its dependence on the time scale, monitoring and evaluation of drought require the determination of this scale. Spatial monitoring and analysis of drought is necessary to predict drought-prone areas and compare it at different times. In this regard, Jun *et al.* (2012) analyzed drought using the SIAP index in the Huaihe River Basin. The results showed that the frequency of drought in this basin declined, however, the severity of drought was increased. Naumann *et al.* (2014) compared different indicators of drought in Africa. Their results showed that the analyzed indicators were consistent in showing the time of drought, however, performed differently in determining the extent of drought. Homdee *et al.* (2016) examined the performance of drought indicators in the Chi River Basin in Thailand, reporting that SPEI and SPAEI multivariate indices are more accurate in detecting variability in drought severity than SPI index. Gaucin *et al.* (2018) studied the spatial distribution of drought in Mexico, reporting that 38.9% of the total population in Mexico live in the cities with a very high degree of vulnerability to drought. Chou *et al.* (2019) assessed the spatial distribution of drought in China based on climate change. Hosseini *et al.* (2012) monitored droughts in Saqez, Iran using percentage of normal (PN), deciles (DI), standard distribution (Z), moving average (MA) and rainfall anomalies (RAI). The results of their study indicated that severe and very severe droughts did not occur in the area. However, mild drought by 63% and moderate drought by 37% exhibited the highest frequency. Ghanavati *et al.* (2013) monitored and compared drought in Omidieh, Southern Iran based on Z, SIAP, RAI and SPI indices, pointing out that the most appropriate indicators for determining the rate of drought are RAI, SPI and SIAP, respectively. Alipour *et al.* (2017) evaluated and compared 8 meteorological drought indices in the central part of Iran, reporting that on a monthly scale only SPI index is able to monitor drought in this part of the country. Nasabpour *et al.* (2018) assessed drought vulnerability in Iran using five climatic indicators, topography, steam density, land use and groundwater resources, revealing that the central, southern and southeastern regions of Iran are mainly in two classes of very low or very high vulnerability. Fars Province as one of the southern provinces in Iran, has always been faced with the phenomenon of drought and due to its special demographic, industrial and agricultural characteristics, it has always been affected by drought stresses. Population growth, along with a relative decrease in rainfall and rising temperatures, has increased the province's susceptibility to drought. Therefore, the objective of this study was to spatial analysis of drought severity, duration and frequency in Fars Province using drought indicators and GIS techniques, to study this phenomenon scientifically and accurately.

MATERIALS AND METHODS

Study area and data gathering

The study area, Fars Province, Iran with an area of 122,608 km^2 in the southern part of Iran, covers 8.1% of the country. In terms of geographical coordinates, the study area is located between 27º 03′ to 31º 42′ north latitude and 50º 36′ to 55º 35′ east longitude (Fig. 1). The average annual rainfall in the study area is 388.5 mm. The highest and lowest rainfall during the statistical period is related to Ben Rood and Monj stations with 1013 and 120 mm, respectively. In order to monitor and distribute the drought spatially, temperature, precipitation and evaporation data of 40 meteorological stations during the statistical period of the last half century (1966-2016) were used. The meteorological stations under study include 8 synoptic stations, 13 rain gauge stations and 19 evaporation stations. Necessary data were gathered from the Iran Water Resources Management Company and the Iran Meteorological Organization. The stations were selected in such a way that they have long-term data and can be a good indicator for all regions of Fars Province. The spatial distribution of precipitation in the study area shows that by moving from the northwest to the southeast, the amount of rainfall in the study area declines (Fig. 2).

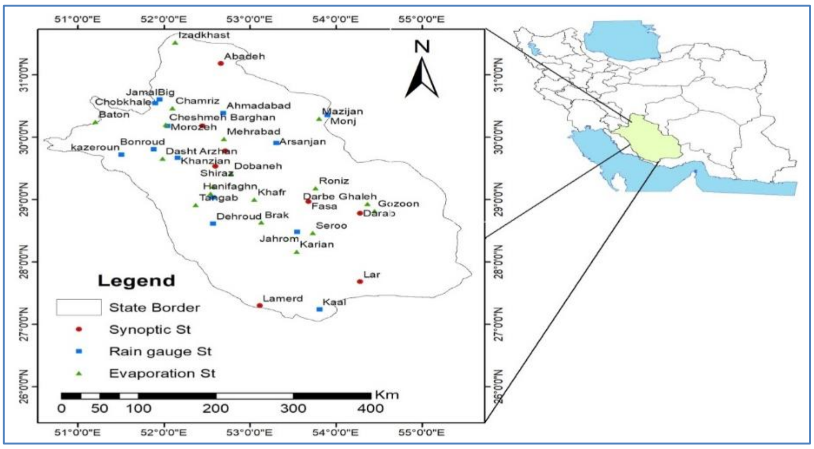


Fig. 1. Geographic location of the study area and the different stations used in the study.

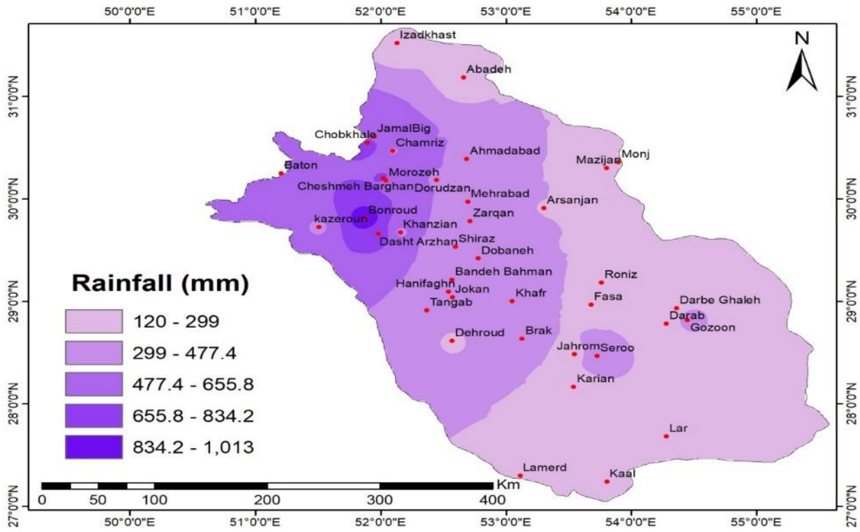


Fig. 2. Spatial distribution of annual rainfall in the study area during (1966-2016).

After collecting the data using the Run test, Double mass and Kolmogorov-Smirnov tests, the data were confirmed to be random, homogeneous and normal, respectively. Drought was then monitored. To analyze and monitor drought, various indicators were used in different countries among which the analysis of rainfall data is one of the most common methods of drought analysis. This is due to the easy access to all types of rainfall data. On the other hand, rainfall is one of the most unstable climatic variables and therefore it can be a good indicator for studying drought. Precipitation is also the most important variable of the atmosphere, the changes of which are directly reflected in soil moisture, underground reservoirs, surface currents, etc. Therefore, it is the first variable that can be considered in the study of any drought situation (Wilhite 1994). In the present study, in order to monitor the drought in Fars Province, 9 meteorological drought indicators were used, the list of their characteristics is given in Table 1. The accuracy of drought monitoring indicators in accordance with the specific conditions of different regions and basins is questionable. For this reason, one of the most important issues is to select an index appropriate to the conditions of the region in order to achieve reliable results. In this study, three methods including minimum amount of precipitation, normal distribution and cross validation were used to determine the best drought monitoring index in the study area (Khalili & Bazrafshan 2003). One of the most common methods of analyzing the characteristics of drought is the Run Theory (RT) method, which was developed in 1967 by Yevjevich. This theory leads to the separation of dry and wet spells (Yevejevich 1967). Also, by employing this method, some characteristics of drought such as intensity, magnitude and duration of dry events can be determined. Negative sequence length determines the duration of a dry period (Drought Duration). The sum of negative deviations in each sequence measures the drought severity, while drought intensity expresses the average amount of rainfall deficit in a particular period of drought. As shown in Fig. 3, the selection of the surface profile X_0 leads to the production of negative (drought) and positive (wet) sequences (Khalili & Bazrafshan 2007). In this study, the intensity, duration and frequency of droughts were analyzed in the study area. In order to derive the curves of drought severity, duration and frequency (SDF) using Run Theory (RT), the drought of the studied stations was first determined on a monthly basis. Then the severity and magnitude of droughts with a duration of one to 11 months were calculated and arranged, then for each continuity for the return periods of 2, 5, 10, 20, 50 and 100 years were calculated using the Minitab and Hyfran$^+$ software through data frequency analysis.

Table 1. Meteorological drought indices studied in the present research.

Index	Abbrev	Equation	References
Standard Index of Annual Precipitation	SIAP	$SIAP = \frac{Pi - \overline{P}}{SP} * 100$	Khalili 1991
Percent of Normal	PN	$PN = \frac{Pi}{\overline{P}} \times 100$	Hayes 2006
Deciles	DI	$P_i = \frac{i}{N+1} \times 100$	Gibbs & Maher 1967
Reconnaissance Drought Index	RDI	$RDI_{st}^{(i)} = \frac{y^{(i)} - \bar{y}}{\hat{\sigma}_y}$	Tsakiris *et al.* 2007
Z-Score	ZSI	$ZSI = \frac{(X - \mu)}{\sigma}$	Triola 1995
Standardized Precipitation Index	SPI	$SPI = \frac{Pi - \overline{P}}{S}$	McKee *et al.* 1993
Standardized Precipitation Evapotranspiration Index	SPEI	$SPEI = W - \frac{C_0 + C_1 W + C_2 W^2}{1 + d_1 W + d_2 W^2 + d_3 W^3}$	Vicente –Serrano *et al.* 2010
China Z Index	CZI MCZI	$Z_{ij} = \frac{6}{C_{si}} \left(\frac{C_{si}}{g} \varphi_{ij} + 1 \right)^{1/3} - \frac{6}{C_{si}} + \frac{C_{si}}{6}$	Kendall & Stuart 1977

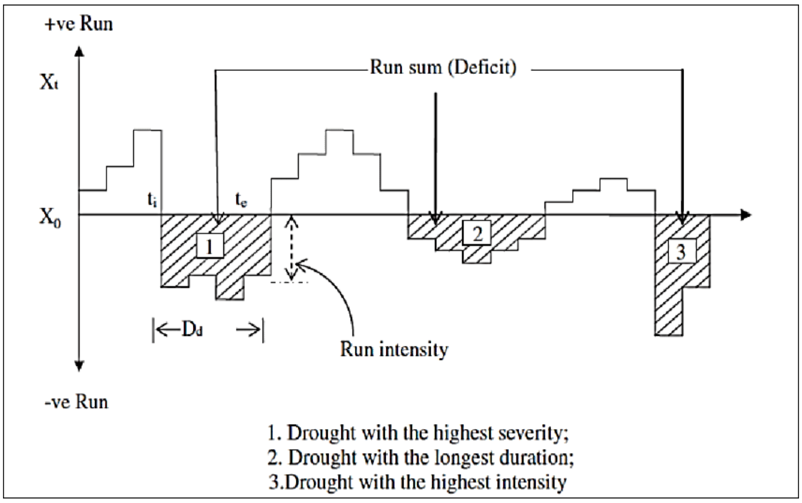


Fig. 3. Determination of drought characteristics using the RT method (Khalili *et al.* 2007)

Due to the fact that precipitation is measured on a point scale and information at the area level is needed for planning, drought zonation is necessary to show the drought situation. In fact, drought mapping is one of the main tools in a drought monitoring system and the spatial zoning of dry periods, so that, its regional distribution is one of the important features leading to a better understanding of this phenomenon and a more detailed study of its effects (Moghaddasi *et al.* 2005) . So, by employing the GIS and simple and conventional Kriging methods, as well as the IDW method, the driest years during the statistical period, were interpolated in the study area. To calculate the Kriging coefficients, it is necessary to calculate the variogram, which uses a variety of spherical, exponential and Gaussian models (Zabihi *et al.* 2011). In this study, the above-mentioned models were examined. Interpolation methods are also evaluated based on the mutual evaluation method, for which two indicators, MAE and MBE, were used. The MAE index indicates the error of the results, while MBE reveals the deviation of the results of the methods used. When these two are zero, it shows that the method used simulates really well and by moving away from zero, the accuracy also declines or in other words, the deviation elevates. These indicators are calculated based on Equations 1 and 2 (Zabihi *et al.* 2011):

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n}\left|Z^{*}(x_i) - Z(x_j)\right| \quad \mathbf{1}$$

$$\mathrm{MBE} = \frac{1}{n}\sum_{i=1}^{n}\left(Z^{*}(x_i) - Z(x_j)\right) \quad \mathbf{2}$$

where Z* is the estimated value, Z: the measured value, and N: the number of data. Finally, the drought situation in the study area was presented as a drought map using the best drought index and the best interpolation method in ArcGIS10.6.

RESULTS AND DISCUSSION

In this study, in different stations of the study area, by selecting 9 drought indices, three methods of selecting suitable indices including minimum amount of precipitation, normal distribution and correlation were evaluated. Due to the large number of stations in the tables and figures, only the results of some stations were presented as examples. The results of selecting the appropriate index, based on the minimum amount of precipitation method, showed that simultaneously with the occurrence of minimum precipitation, all indicators exhibit very severe and severe drought. While at Monj, ChubKhale, Fasa, Lar and Abadeh stations in the year of minimum rainfall, some indices showed moderate drought, while some other revealed normal conditions (Table 2). Therefore, selecting the appropriate index using this method causes unrealistic results, since the least rainy year does not always coincide with the most severe drought and the role of other factors will be effective. In addition, a year with minimal rainfall but with a uniform distribution throughout the year may not cause drought, while a year with a lot of rain, but concentrated in a short period of time may lead to. Therefore, selecting the appropriate index from the minimum amount of precipitation can cause unrealistic results in a number of years.

Table 2. Results of selecting the best index based on the method of minimum rainfall in the studied stations.

Station	Year of occurrence	Minimum of precipitation	CZI	MCZI	RAI	ZSI	PN	DI	SIAP	SPEI	SPI
Shiraz	2007-2008	119.4	ED	SD	ED	SD	ED	ED	SD	ED	ED
Bonroud	1993-1994	430.5	SD	SD	ED	SD	SD	ED	SD	SD	ED
Monj	2007-2008	64.4	MD	MD	SD	MD	SD	ED	SD	N	ED
Chubkhaleh	1993-1994	391.5	SD	N	ED	SD	SD	ED	SD	SD	SD
Abadeh	2007-2008	58.4	ED	SD	SD	MD	SD	ED	SD	MD	SD
Eqlid	2007-2008	84.8	ED	ED	ED	ED	ED	ED	SD	ED	ED
Fasa	2007-2008	113.7	SD	MD	SD	MD	ED	ED	SD	N	SD
Darab	2007-2008	94.1	ED	ED	ED	SD	ED	ED	SD	SD	ED
Lar	2007-2008	80.0	ED	SD	SD	MD	N	ED	SD	N	SD
Dorudzan	2007-2008	136.9	ED	MD	ED	ED	ED	ED	SD	ED	ED

ED: Extremely dry; **SD**: Severely dry; **MD**: Moderately dry; **N**: Normal

According to Steinmann (2003), drought severity events follow a normal distribution. Therefore, the results obtained from drought indices display a higher capability, if they are close to normal distribution. In this method, in order to select the appropriate index, the frequency percentage of each drought situation in different indicators was calculated. Then, the difference between the frequency (%) of each drought situation and the similar situation with normal distribution in the studied stations was calculated, hence the index with the lowest total difference in all situations was selected as the best one (Table 3).

Table 3. Selecting the best index based on the normal distribution method

Class of drought	Probability(%)	Class of drought	Probability(%)
Extremely wet	2.275	Extremely dry	9.185
Severely wet	4.406	Severely dry	4.406
Moderately wet	9.185	Moderately dry	2.275
	Normal		69.268

Based on this method, the percentage difference of each drought index with the percentage of normal distribution in the 7 class drought was calculated. The results are presented as an example for Shiraz synoptic Station in Table 4. Based on these results, SPEI index with a total difference of 10.9% in total classes was selected as the most appropriate drought index. MCZI, SPI and CZI were placed in the next ranks with a total difference of 14.43, 17.10 and 18.43, respectively. In addition, DI and SIAP were introduced with low values of total differences, as the lower reliability indices for drought monitoring and drought detection in this station. Based on the results in other studied stations, SPEI with the lowest total differences of each class of normal distribution was introduced as the best drought index, while ZSI, SPI and MCZI were placed in the next ranks. In the method of selecting the best drought index based on normal distribution, in fact, drought follows a normal phenomenon based on a series of error statistics that in some extents, can determine the appropriate index by comparing these statistics in different indicators. Statistically, the distribution of rainfall due to infimum from below cannot be completely normal. Also, in the series of rainfall amounts, some days and even some months experienced zero rainfall. Therefore, they exhibited positive skewness which raised in short-term scales values of zero which can be effective on the assumption that the drought phenomenon is normal. On the other hand, in areas where drought is more prevalent, the assumption that it is normal may not be so accurate, since based on the normal distribution, the frequency of drought classes in these areas would become equal to the other areas having fewer drought events.

Table 4. Selecting the best index based on compliance with the normal distribution in Shiraz Station.

Class of drought	SIAP	SPEI	RDI	DI	ZSI	MCZI	CZI	SPI
Extremely dry	0.1	0.6	1.1	4.6	2.3	2.3	2.3	1.3
Severely dry	3.1	0.9	3.7	1.3	3.4	2.7	1.4	2.6
Moderately dry	5.8	2.0	5.4	18.6	4.0	1.7	4.7	4.7
Normal	12.9	3.6	9.4	33.1	13.2	6.6	8.4	0.9
Extremely wet	3.9	2.5	1.0	4.7	4.5	0.6	0.2	8.3
Severely wet	0.1	0.4	0.2	2.8	1.4	0.1	0.1	0.2
Moderately wet	7.7	0.9	0.1	10.6	2.4	0.4	0.1	0.4
Sum of the differences	33.57	10.9	20.88	75.57	31.25	14.43	17.1	18.43
Maximum differences	12.93	3.60	9.4	33.1	13.23	6.57	8.40	8.32
Sum of the differences (wet)	11.67	3.85	1.28	18	8.32	1.16	0.34	9
Sum of the differences (normal)	12.93	3.6	9.40	33.10	13.23	6.57	8.40	0.9
Sum of the differences (dry)	8.97	3.45	10.20	24.47	9.7	6.70	8.37	8.53

As different scientists (in the different parts of the world) have suggested SPI as a suitable indicator due to its comprehensiveness, acceptability and more benefits. In the present study, SPI was selected as the basis, while its behavioral similarity and correlation with other indicators were evaluated. According to the results, SPI exhibited a strong correlation with CZI, MCZI, ZSI, SIAP and RDI, especially in the wet and normal months. Weak correlations were also more pronounced in dry months, since SPI values tend to be negative in these months and displayed higher negative values compared to other indices. It was true for the most studied meteorological stations. Pearson correlation coefficient for Shiraz Synoptic Station ranged from 0.44 to 0.94. In general, it can be said that using correlation method, CZI and RDI indices due to correlation and more behavioural similarity with SPI can be used as a suitable indicator to monitor and identify meteorological drought in Fars Province (Figs. 4-14). In addition, PN and DI which exhibited the lowest correlation and behavioural similarity with SPI in all stations and in all dry and wet spells, could not be used for identifying or monitoring drought in the study area.

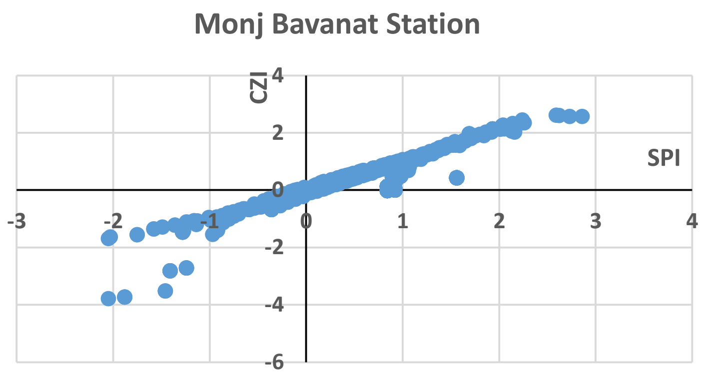


Fig. 4. Scatter diagram of SPI and CZI indices for Monj Bavanat station.

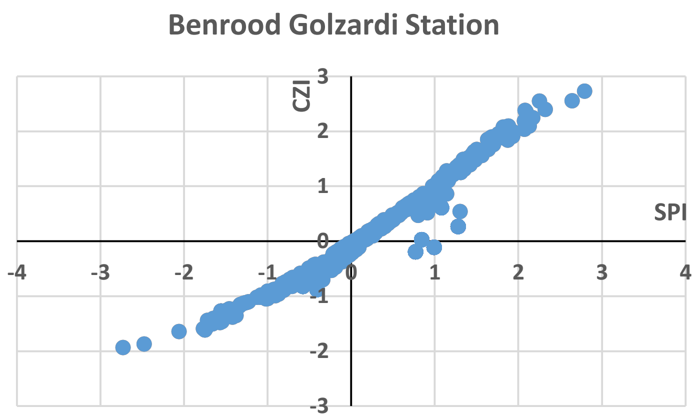


Fig. 5. Scatter diagram of SPI and CZI indices for Benrood Golzardi station.

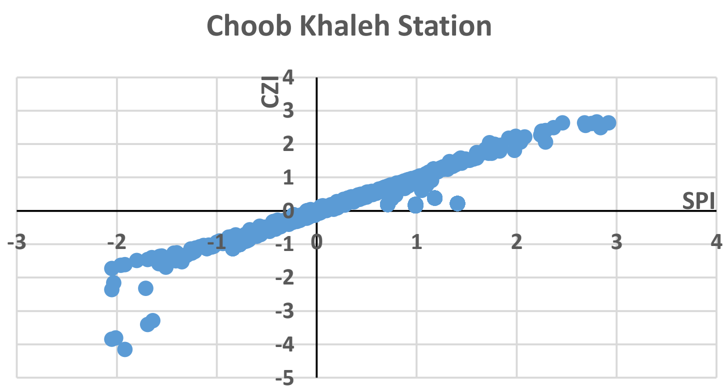


Fig. 6. Scatter diagram of SPI and CZI indices for Choob Khaleh station.

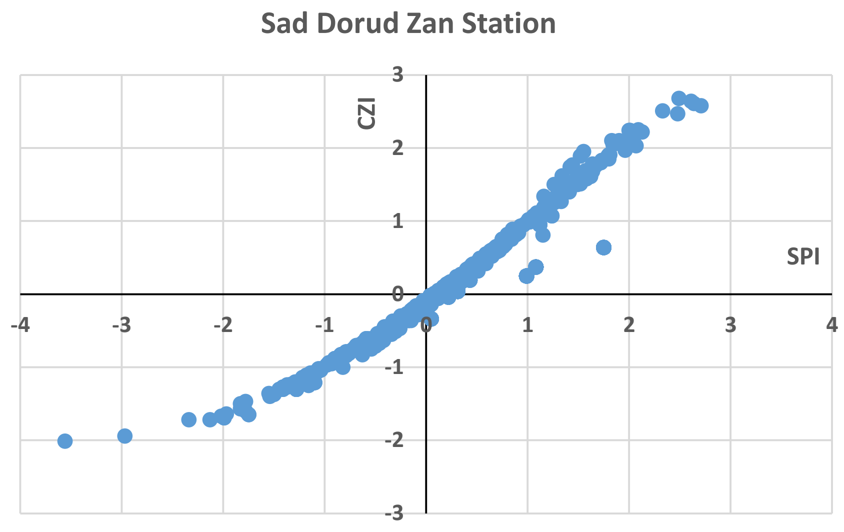


Fig. 7. Scatter diagram of SPI and CZI indices for Sad Darudzan station.

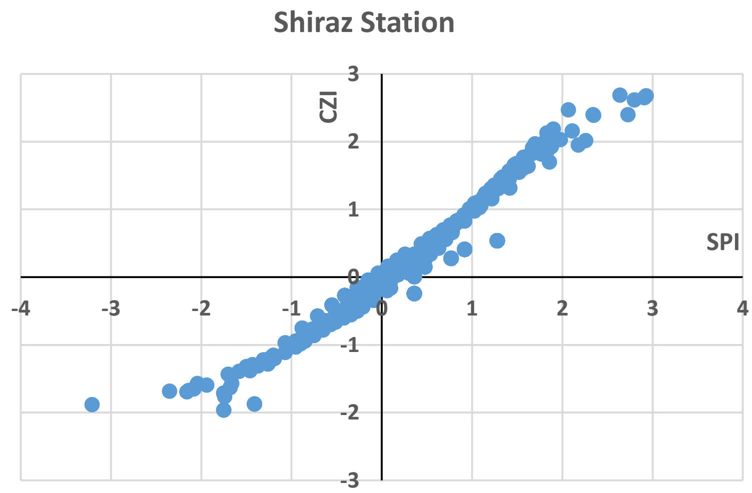


Fig. 8. Scatter diagram of SPI and CZI indices for Shiraz station.

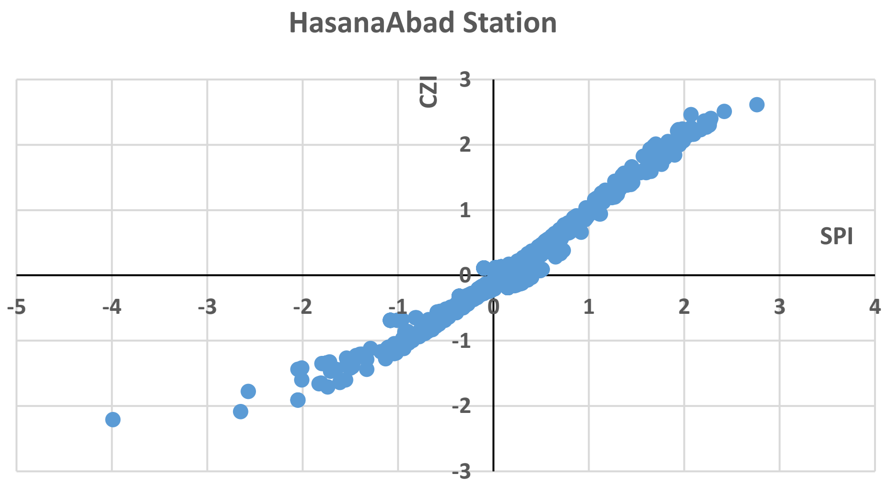


Fig. 9. Scatter diagram of SPI and CZI indices for Hassanabad station.

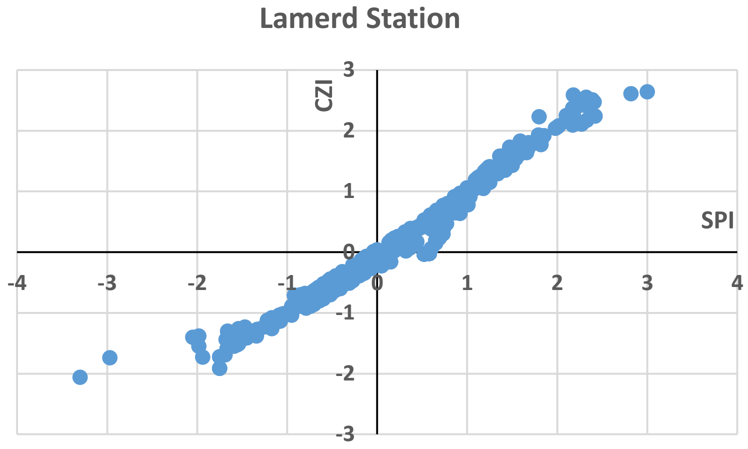


Fig. 10. Scatter diagram of SPI and CZI indices for Lamerd Station.

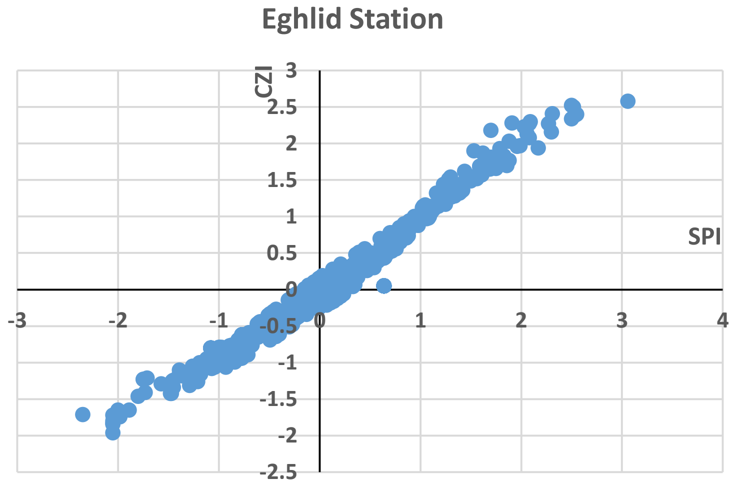


Fig. 11. Scatter diagram of SPI and CZI indices for Eghlid station.

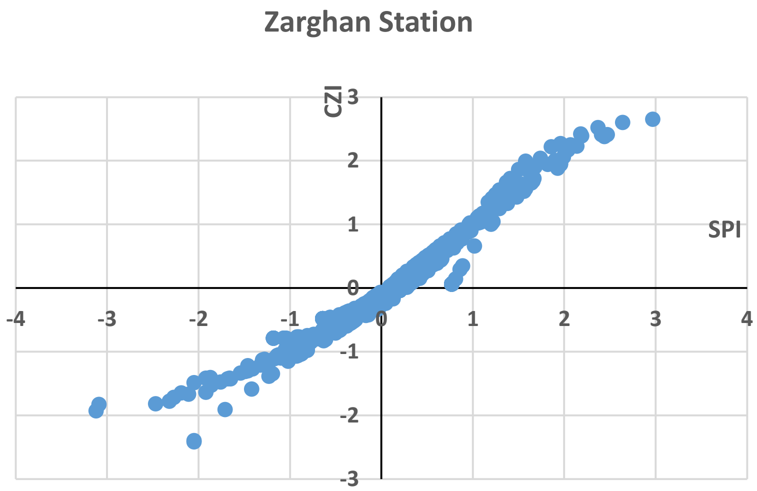


Fig. 12. Scatter diagram of SPI and CZI indices for Zarghan station.

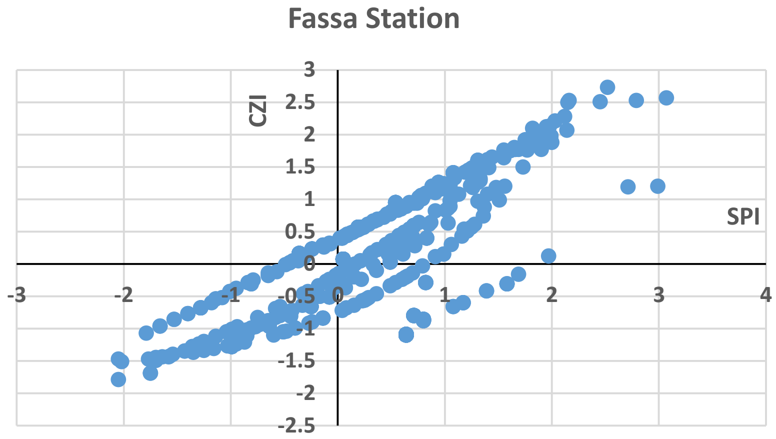


Fig. 13. Scatter diagram of SPI and CZI indices for Fassa station.

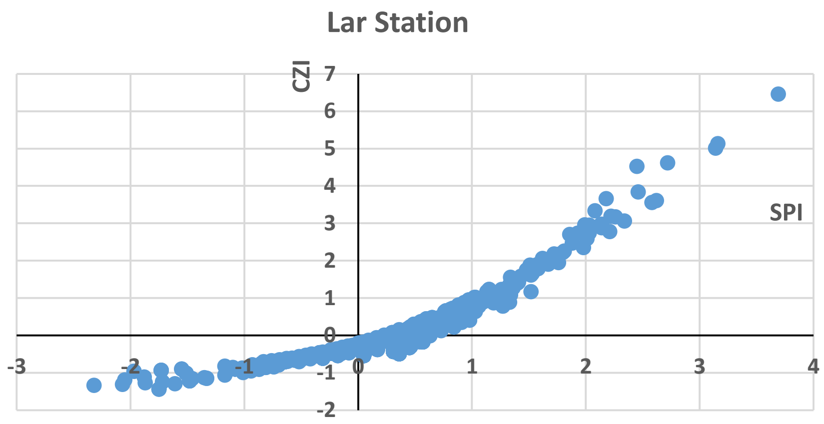


Fig. 14. Scatter diagram of SPI and CZI indices for Lar station.

The relative frequencies of different dry and wet spells for the indices used in the selected stations in Fars Province are presented by details in Fig. 5. Based on the results, most of the used indices exhibit a bell-shaped histogram. However, only in the case of DI index, the relative frequency of different dry and wet spell was different from other indices. In DI index, the relative frequency of very severe drought, severe drought and very severe wetness classes were higher than in the other indices. In the latter indices, the normal and moderate class droughts displayed the highest frequency in the study area (Figs. 15-23).

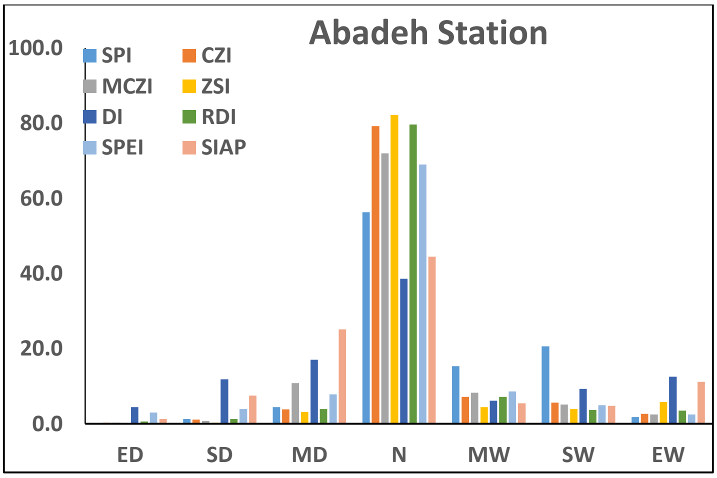


Fig. 15. Relative frequency distribution of different drought classes for the indices in Abadeh station.

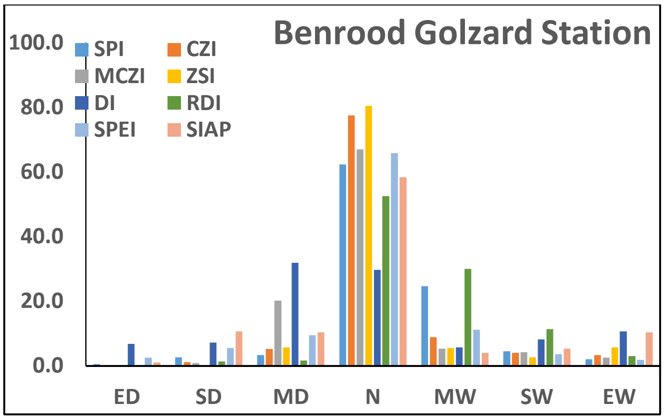


Fig. 16. Relative frequency distribution of different drought classes for the indices in Benrood Golzard station.

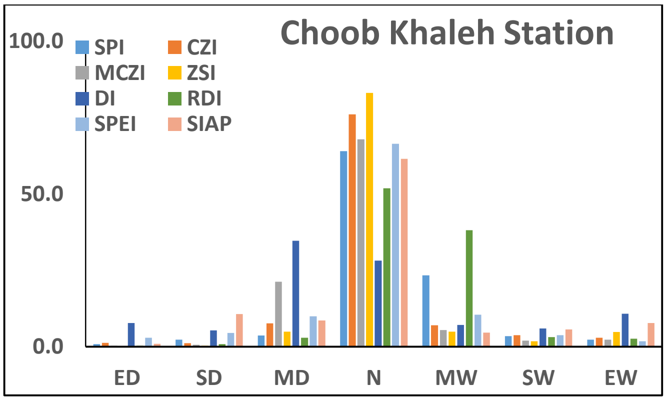


Fig. 17. Relative frequency distribution of different drought classes for the indices in Choob Khaleh station.

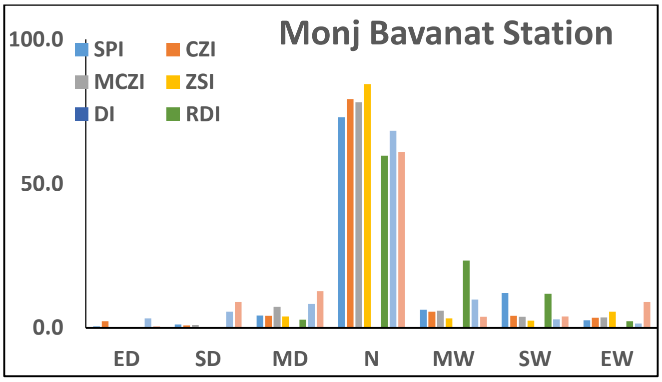


Fig. 18. Relative frequency distribution of different drought classes for the indices in Monj Bavanat station.

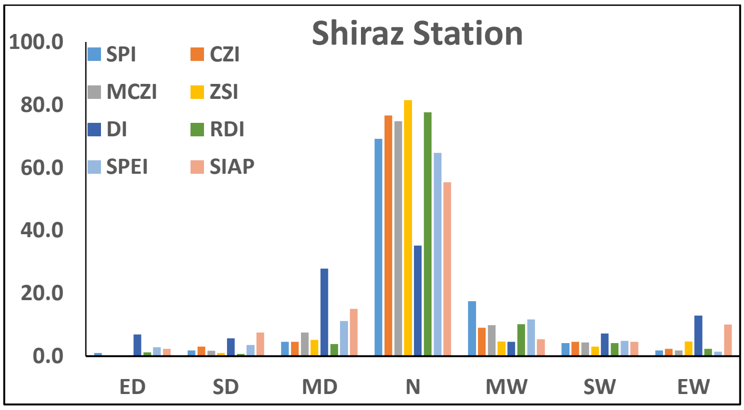


Fig. 19. Relative frequency distribution of different drought classes for the indices in Shiraz station.

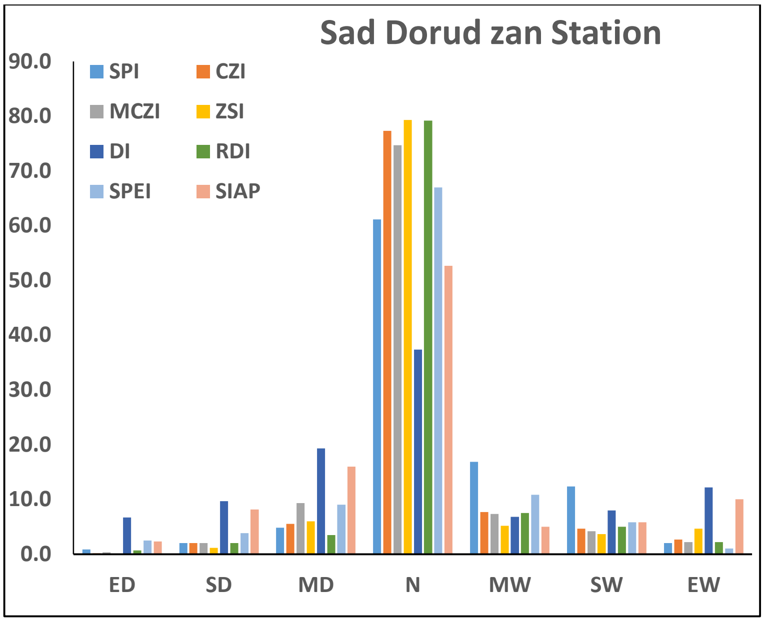


Fig. 20. Relative frequency distribution of different drought classes for the indices in Sad Dorudzan station.

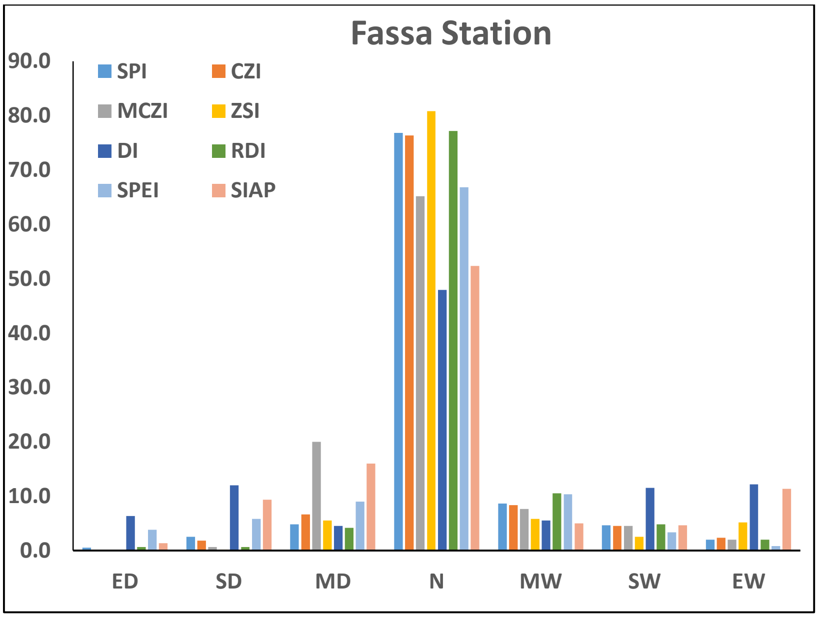


Fig. 21. Relative frequency distribution of different drought classes for the indices in Fassa station.

The results of data fitting on statistical distributions showed that the Pearson type III distribution is the best one for evaluating droughts in the study area. Assessing SDF curves in the selected stations exhibited that by elevating in the time scale and return period in the stations, drought duration and magnitude upraised. This means that the longer durations and higher magnitudes are less likely to occur with longer return periods. Studies also showed that by elevating in drought duration, drought intensity does not rise at a constant rate (Fig. 24).

In general, based on the results, the most severe and longest drought period in the last half century (1966-2016) in the study area have been related to 1970, 1993, 1999, 2007, 2014 and 2015. Therefore, in order to investigate the spatial distribution of drought, severity in the study area, those affected by the drought phenomenon were drawn with different intensities and classes for SPI in the last three drought events, since SPI was selected as the best index to determine the droughts in the study area based on the abovementioned methods. Fig. 25 illustrates the experimental variogram for the last three droughts. These variograms have found the best fit according to the specifications of different interpolation models with the Gaussian model. Based on the results, the lowest value related to the distance factor in relation to the Gaussian model in the year 2007 was obtained and strength of spatial structure in Gaussian model has been very strong for this year.

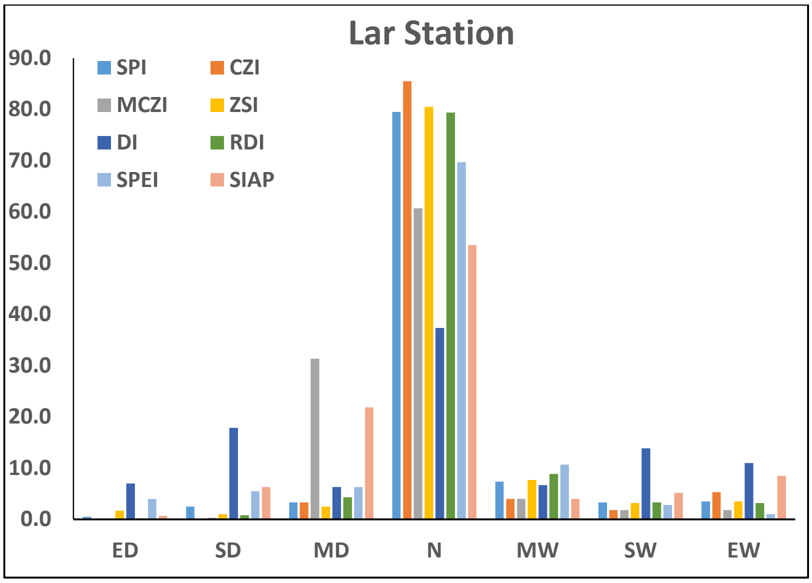


Fig. 22. Relative frequency distribution of different drought classes for the indices in Lar station.

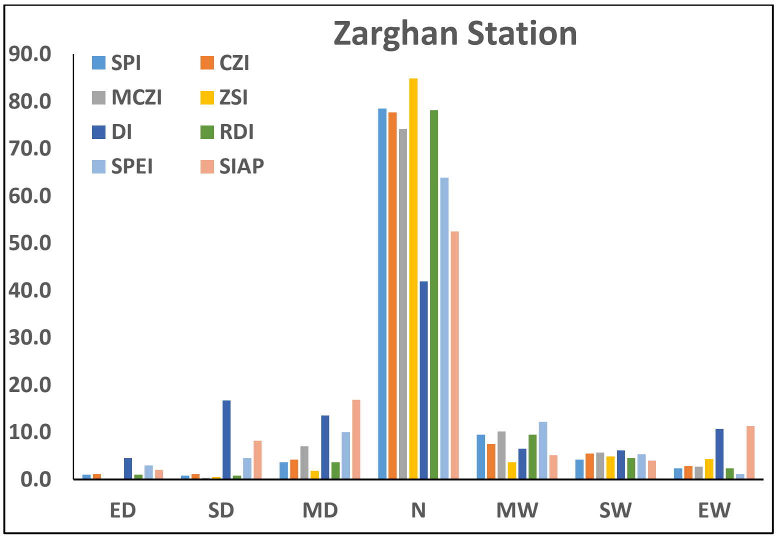


Fig. 23. Relative frequency distribution of different drought classes for the indices in Zarghan station.

Then, in order to find the best interpolation method for drawing the drought of the abovementioned years, the error of Kriging method with Gaussian, exponential and spherical models as well as IDW method with powers of 1 to 5 were calculated (Table 5). Based on the results obtained in 2007, the simple Gaussian Kriging interpolation method exhibited the lowest computational error, while in 1994, the Gaussian conventional kriging interpolation method displayed the same. Overall, a comparison of the interpolation methods shows that the inverse weighted distance method reveals a higher error in most of the prepared maps than the kriging method. Kriging method uses a more complex mathematical parameters and pattern in determining the value of an unknown point, hence it is a more appropriate method for interpolation in the study area. Shabani (2009) and Alipour *et al.* (2017) pointed out the superiority of Kriging method over inverse distance method in their studies, similar to the present study. As mentioned above, the extent of drought in Fars Province based on SPI and Kriging interpolation method for the last recent three drought events was presented. The results showed that in 2007 about two thirds of the area of Fars Province according to this criterion has experienced severe and very severe drought. The drought intensity varied in different cities of the province, so that the cities located in the north and northeast of the province experienced very severe drought in comparison with other cities. In contrast, the cities located in the southwest of the province, such as Larestan, Gerash and Zarrindasht, experienced a moderate impact of drought this year (Fig. 26).

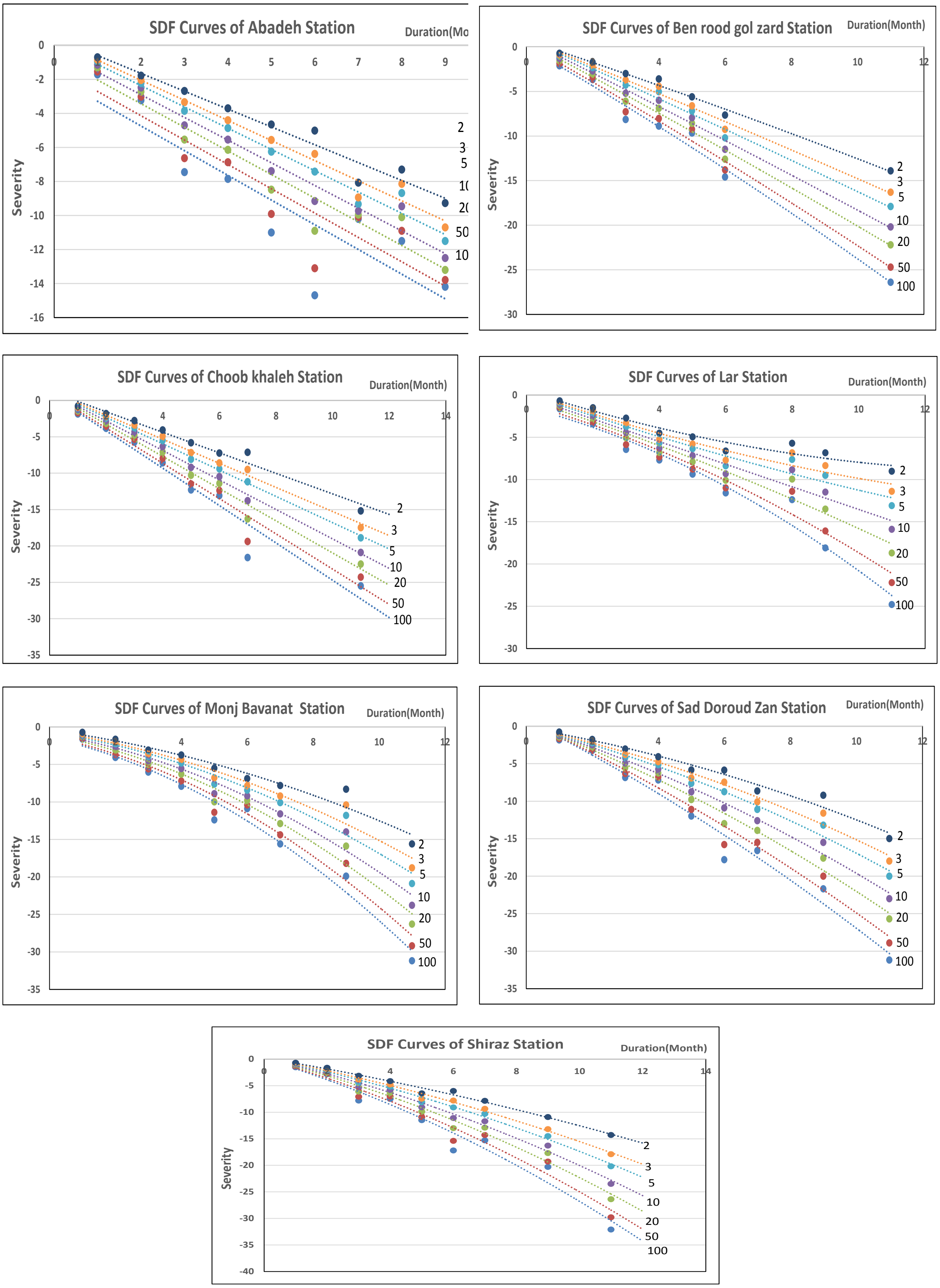
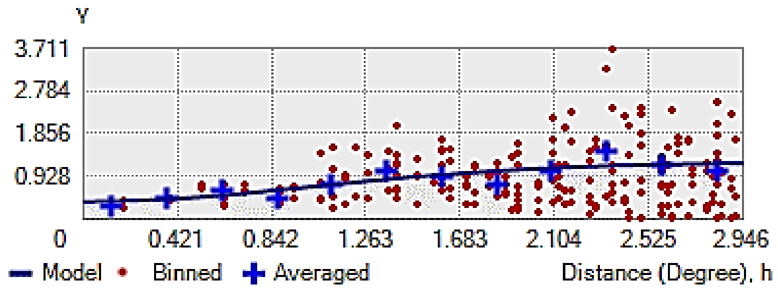
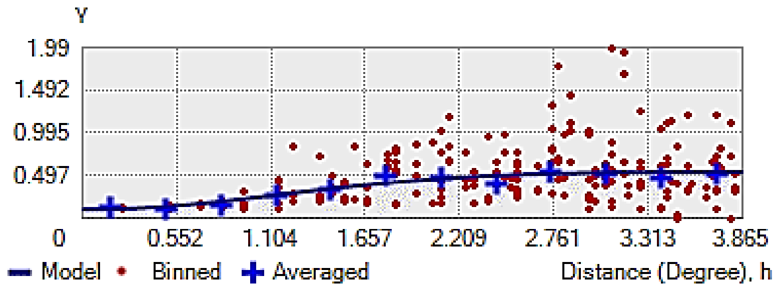


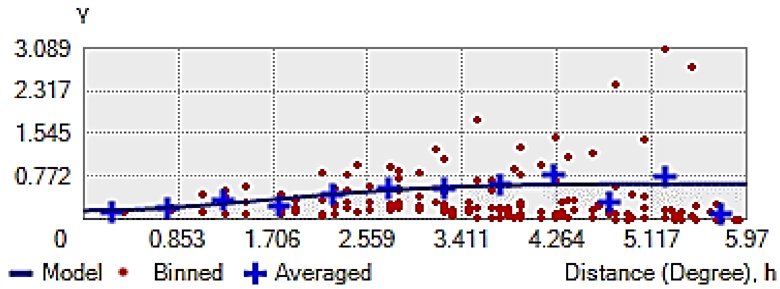
Fig. 24. SDF curves for different return periods at selected meteorological stations in the study area.



2007



2014



2016

Fig. 25. Experimental variogram of Gaussian model related to three recent drought periods.

Table 5. Error resulting from cross-validation for different interpolation methods in the last three droughts.

Interpolation method	**Type**	**Model**	**2007-2008**		**2014-2015**		**2015-2016**	
			MAE	MBE	MAE	MBE	MAE	MBE
Kriging	Simple	Gaussian	**0.566**	**-0.066**	0.4427	-0.05	0.745	0.096
		Exponential	0.5749	-0.075	0.471	-0.054	0.613	-0.076
		Spherical	0.5723	-0.737	0.4589	-0.0533	0.614	-0.078
	Ordinary	Gaussian	0.587	-0.084	**0.439**	**-0.0361**	**0.609**	**-0.011**
		Exponential	0.595	-0.086	0.4662	-0.0398	0.633	-0.038
		Spherical	0.593	-0.087	0.455	-0.04158	0.613	-0.012
IDW	1st Power		0.616	-0.1	0.487	-0.07149	0.644	0.0098
	2nd Power		0.61	-0.08	0.494	-0.0396	0.694	0.017
	3rd Power		0.6	-0.06	0.51	-0.0259	0.702	0.021
	4th Power		0.604	-0.042	0.52	-0.01479	0.708	0.0279
	5th Power		0.606	-0.028	0.53	-0.00491	0.713	0.032

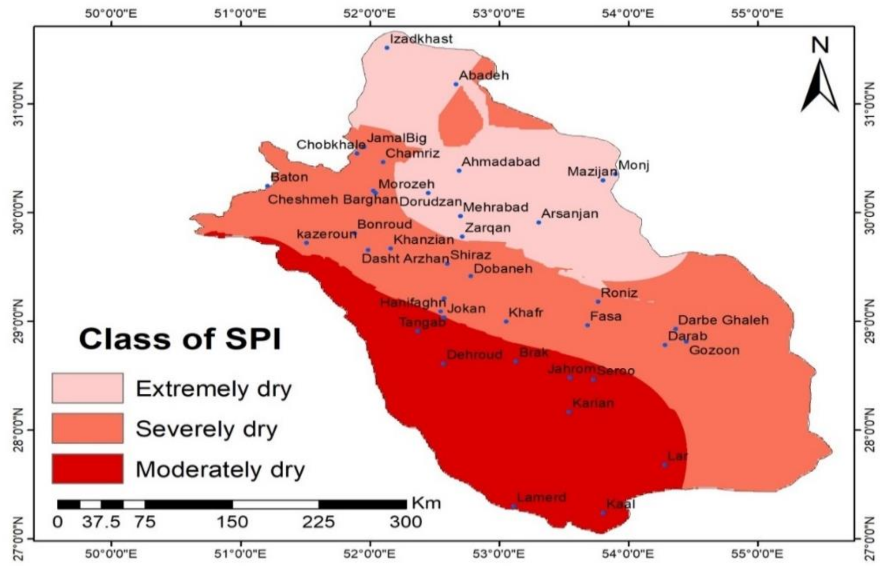


Fig. 26. Drought distribution based on SPI index in the year 2007 in the study area.

As shown in Fig. 27, in 2014, the western and north-western parts of the study area were affected by moderate drought, while the southern areas and small parts of the northern and eastern regions, according to the SPI index, were in a normal or wet status.

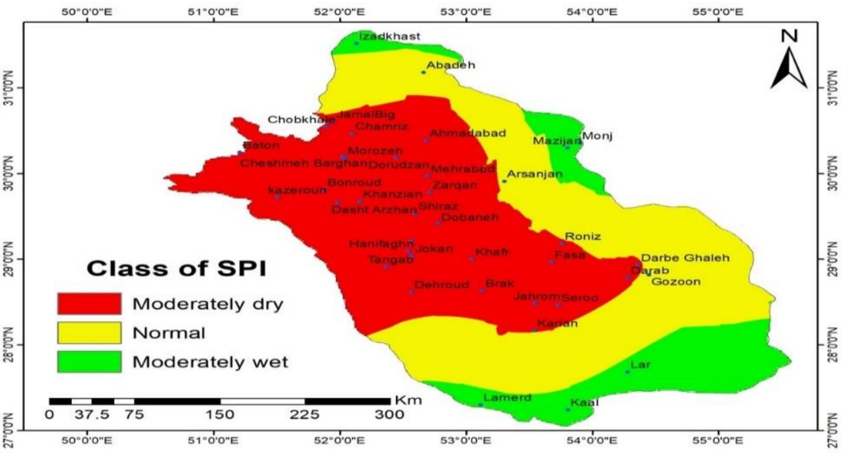


Fig. 27. Drought distribution based on SPI index in the year 2014 in the study area.

In 2016, most of the study area was affected by moderate drought and only the southern areas, while Zarrindasht and Larestan were in a relatively normal and wet state in terms of humidity (Fig. 28).

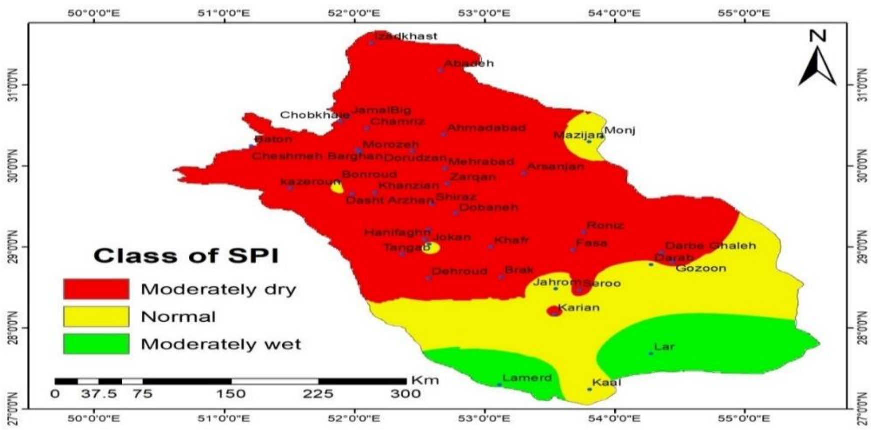


Fig. 28. Drought distribution based on SPI index in the year 2016

Overall, the results showed that drought in the southern regions was less continuous and dry periods were quickly replaced by wet ones. Drought in the northwestern, northern and central regions was more persistent and severe, which caused the drought in these areas to exhibit more adverse effects, in accordance with results obtained by Hosseini *et al.* (2012), Qanavati *et al.* (2013), Alipour *et al.* (2017) and Nasabpour *et al.* (2015).

CONCLUSION

Preservation of valuable water resources is considered as a unique treasure in the livelihood of the people of an area. Also, in order to preserve it for future generations, the need for proper knowledge and management requires comprehensive studies on the phenomenon of drought. Drought monitoring using rainfall data is one of the most common methods due to the variability of this climatic variable and at the same time, easy access to its data. By monitoring drought, the effects and consequences can be reduced to some extent or we can prepare ourselves to deal with it. In this study, monthly and annual precipitation data of the last half century 1966 -2016 at 40 meteorological stations in Fars Province were assessed in order to monitor and zoning droughts using different indices. The results showed that SPI index is the best indicator for assessing the severity of drought in the study area. In addition, SPI was able to introduce over 90% of the annual minimum rainfall as the driest years in all stations and therefore is introduced as the best indicator in the region. According to the drought assessments and monitoring in Fars Province, in most of the studied stations, a severe drought occurred in the wet years including 1970, 1993, 1999, 2007, 2014 and 2016. Almost all indicators have described these few years as very dry. Drought zoning using Kriging method in recent periods also showed that the moderate and severe drought has spread in most areas of the province. The highest continuity of drought has been attributed to the last decade, i.e. 2007. According to the results, the severity and frequency of drought in the 70s and 80s was higher than the 90s and the highest frequency of drought in the study area, based on most drought indicators, was attributed to the normal and moderate drought.

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Bibliographic information of this paper for citing:

Massoudi, M, Goodarzi, M, Moeini, A, Motamedvaziri, B 2023, Spatial analysis of drought severity, duration and frequency using different drought indices (Case study: Fars Province, Iran). Caspian Journal of Environmental Sciences, 21: 259-276.