



# Analysis of changes trend in spatial and temporal pattern of drought over south of Iran using standardized precipitation index (SPI)

Abdol Rassoul Zarei<sup>1</sup>

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## Abstract

In this research, the precipitation data of 16 synoptic stations from 1980 to 2014 in the south of Iran were used to evaluate the changes of the spatial and temporal pattern of drought based on the SPI index. Results of changes trend analysis in the temporal pattern based on linear regression (LR) showed that the most droughts occurred in the annual time scale (at 37.5% of stations). Based on Mann–Kendall (MK) and Spearman's Rho (SR) tests, the most drought trends occurred in winter and annual time scales. Analysis of spatial pattern changes of drought showed that percent of areas in all classes of drought and all-time scales had non-significant changes (based on MK test), according to SR test, only the areas in moderate wet class of drought had a significant decreasing trend at 5% level. Analysis of LR test showed that the percent of areas in all classes of drought in seasonal time scales had non-significant changes, in annual time scale severe dry and extreme dry classes had a significant decreasing trend at 5% level. Generally, results showed that area percentage with dry classes had an increasing trend, therefore the study area is going to be drier and it's effective on agricultural activities, natural resources management, surface water resources and underground water resources planning and other activities.

**Keywords** SPI index · Drought · Spatial changes · Temporal changes · Parametric · Non-parametric tests

## 1 Introduction

Drought is a natural disaster that could be occurred in all regions with different climate conditions. Drought can be affected on the surface water resources, underground water resources, agriculture water demand, water consumption in natural resources, industry, humans and wildlife sections [6, 10, 21, 26, 28, 36, 37, 40, 43]. Drought develops slowly, is difficult to detect and can present a range of diverse aspects in different regions [1, 39].

The drought has been categorized into 4 types [13, 14]: meteorological, agricultural, hydrological and socio-economic. Meteorological drought is defined as the lack of precipitation over a region in a specific time period (in this paper the changes trend in the spatial and temporal pattern of meteorological drought were assessed). If the meteorological drought continues, it can cause other

types of drought [8]. Drought indices that are based on climatic parameters (such as precipitation, evapotranspiration, temperature and etc.), soil properties and others, were used to evaluate drought severity [15, 44]. Drought indices can help the scientists and managers to assess the characteristics of droughts for reducing the impacts of it [2, 27].

Many different drought indices have been introduced to assess drought conditions in the world. One of the popular indices in recognizing and monitoring of drought is the standardized precipitation index (SPI) that was introduced by McKee et al. [17]. In this study, the SPI index was used to evaluate drought because of the following reasons: (1) only precipitation data are needed for the calculation of this index. (2) The SPI index is a standardized measure of precipitation in different climatic regions and different time-scales [35, 38].

✉ Abdol Rassoul Zarei, Ar\_Zareiee@Fasau.ac.ir; Ar\_Zareiee@Yahoo.com | <sup>1</sup>Department of Range and Watershed Management (Nature Engineering), College of Agricultural Science, Fasa University, Fasa, Iran.



Many researchers from different regions of the world have used SPI index to assess drought conditions in recent years: [3, 4, 7, 22, 25, 30–33, 42].

Mahmoudi et al. [16] compared seven (precipitation-based) drought indices in Iran using meteorological data series of 41 stations from 1985 to 2013. Results of this research indicated SPI index is the best drought index to assess drought conditions in Iran. Kavianpour et al. [11] used the SPI index and two other drought indices for spatial and temporal analysis of drought in three provinces of Iran using meteorological data series of during 1982–2012. Nasrollahi et al. [20] used SPI index to assess the spatial and temporal patterns of drought hazard and risk in Semnan province, Iran. In this research data series of meteorological stations from 1985 to 2011 in 3-months and 12-months time scales were used. Results of this paper showed Shahroud and Damghan at 3-months and Shahroud, Damghan, and Semnan at 12-months timescale were the most susceptible regions to drought.

Zarei et al. [41] evaluated the spatial pattern of drought in the south of Iran based on Reconnaissance Drought Index (RDI). According to the results of this paper, in a 3-months time scale, the area percentage with dry classes had an increasing trend and areas with the wet condition had a decreasing trend. In the annual time scale, the area percentage with wet classes and the normal class had a decreasing trend, and the area percentage with near-normal class and dry classes had an increasing trend. Hanafi et al. [9] to evaluate drought characteristic in Tehran province were used the SPI index and Markov Chain model. Results of this paper showed that the equilibrium probability of dry, wet and normal periods in the stations of this province is 29, 30 and 41% respectively. Results of drought assessment in Golestan province based on SPI index with Bazrafshan et al. [5] showed that the most severe drought in 6-months time scale was observed in Saliantapeh station while the highest severity in 9, 12 and 24-time scales was observed in Polejadeh station. Rostamian et al. [23] used the SPI index for predicting meteorological drought intensity in Beheshtabad watershed. Results of this research showed that an increase in duration and magnitude of droughts in the third future period is more than the second and initial future periods. Saadati et al. [24] used the SPI index for drought frequency analysis in Isfahan province. According to the results, a severe drought has occurred in the west of the province and an extreme drought has occurred in the east and northeast of the province.

The objectives of this study are: (a) assessment of temporal monotonic trends at the time scale of seasonal and annual drought based on SPI index using parametric and nonparametric trend analysis techniques, such as LR, MK and SR testes in South of Iran from 1980 to 2014. (b) Evaluation of the spatial pattern trend changes of drought (trend

of changes in areas percentage with different classes of drought) based on standardized precipitation index (SPI) in seasonal and annual time scales.

## 2 Methods and material

### 2.1 Study area

The study area is located in the south of Iran with an area of 594,996.54 km<sup>2</sup>. The climate of this area varies between hyper-arid and semi-arid. In this study the precipitation data of 16 synoptic stations from the study area (Fig. 1) for the period 1980–2014 were used, the selected synoptic stations and their meteorological characteristics are presented in Table 1. Statistical parameters of monthly precipitation time series at 16 synoptic stations during the period 1980–2014 showed that the mean monthly precipitation varies from 4.25 to 26.05 mm. Besides, it is evident that Zabol station in the southeast of the area had the lowest mean monthly precipitation. The highest coefficient of variation (CV) of the annual precipitation value was observed at Jask station (located in the south of area) at the rate of 298.84%, while the lowest CV of 163.56% was found in Kerman. The main amount of precipitation fell in western regions of the area, such as Bushehr, Fasa and Shiraz.

### 2.2 Estimation of standardized precipitation index (SPI)

SPI computation involves two stages that at the first stage, a probability distribution (e.g. gamma distribution) fitted to a long-term precipitation record at the desired station. Transformation of gamma distribution into normal distribution is the second stage resulted in zero mean SPI. Both dry and wet conditions can be monitored using SPI drought index and this index may be computed with different time steps (e.g. 1-month, 3-months and 24-months). The use of different time scales allows the effects of a precipitation deficit on different water resource components (groundwater, reservoir storage, soil moisture and streamflow) to be assessed [19]. SPI drought index was expressed below [17]:

$$SPI = \mp \left[ t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3} \right] \quad (1)$$

$$t = \sqrt{\ln \left[ \frac{1}{(G(x))^2} \right]} \quad (2)$$

where  $c_0$ ,  $c_1$ ,  $c_2$ ,  $d_0$ ,  $d_1$  and  $d_3$  are calculation parameters and  $G(x)$  is gamma function:

$$g(x) = \frac{1}{\beta^\alpha \cdot \Gamma(\alpha)} x^{\alpha-1} \cdot e^{-\frac{x}{\beta}}, \quad x > 0 \quad (3)$$

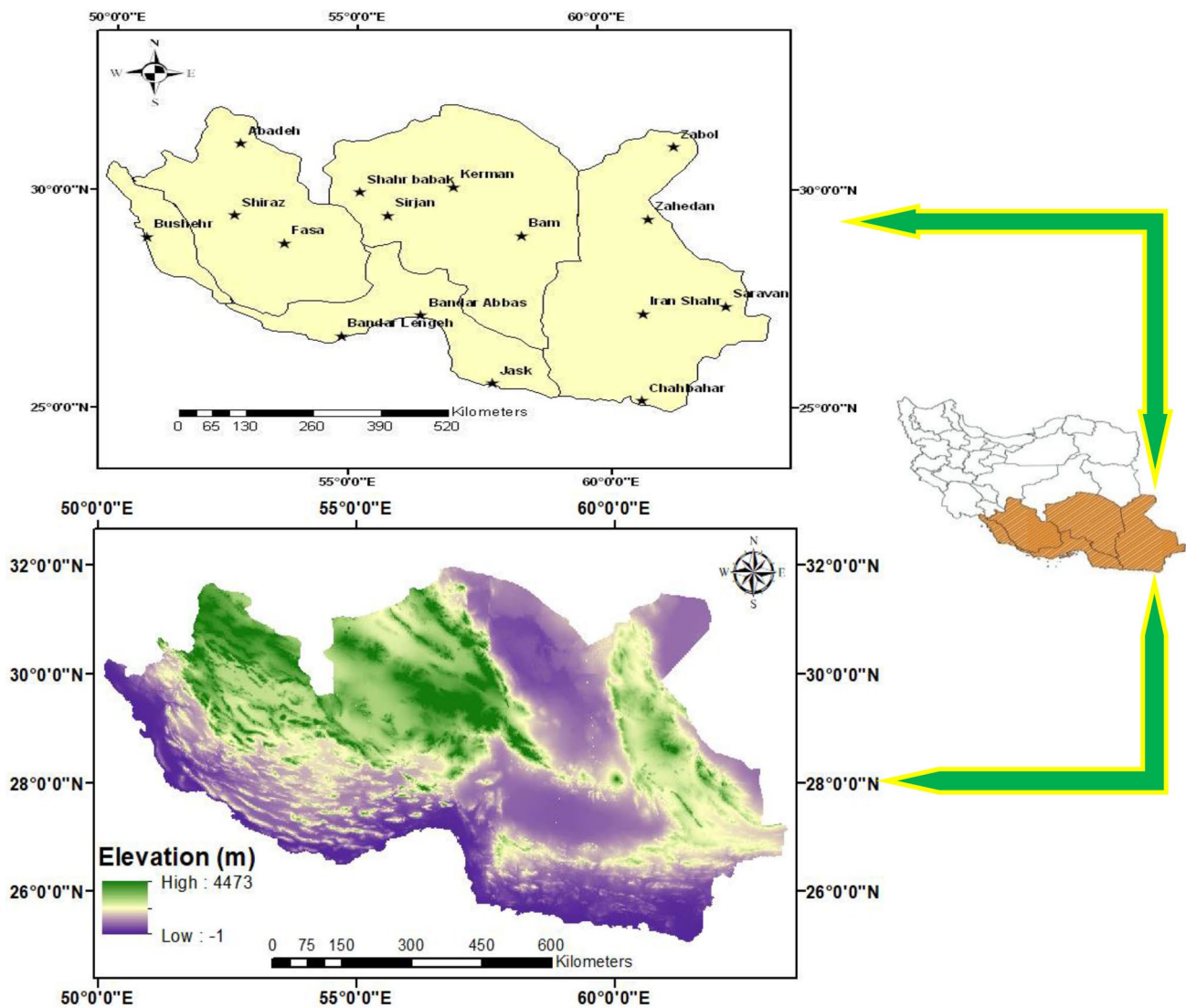


Fig. 1 Geographical position and digital elevation map (DEM) of the study area and spatial distribution of selected stations

where  $\alpha$  = form parameter;  $\beta$  = scale parameter;  $x$  = precipitation quantity;  $\Gamma(\alpha)$  = gamma function. The SPI drought classification showed in Table 2.

In this study using the monthly precipitation data of 16 meteorological stations in the south of Iran, SPI values were calculated for the time scales of 3-months (seasonal) and 12-months (annual) for the period of 1980 to 2014 (Figs. 2, 3 and 4). In the next stage, LR, MK and SR tests at 5% significance level were used to evaluate the changes in the temporal pattern of drought.

The spatial maps of drought that were prepared based on geostatistical analysis and interpolation techniques using ArcGIS 10.2 software were used in the study area in 3-months and 12-months time scales for each year to assess the changes trend in the spatial pattern of drought (Figs. 5, 6, 7, 8, 9). In order to provide interpolation maps

the inverse distance weighting (IDW) method were used because calculated SPI data series in all stations for each year (at each time scales) were not normal. Then, the surface percent of the study area that is located in each drought classes were calculated for each year. Finally, the changes trend in the surface percent in each class of drought in the study area were evaluated based on LR, MK and SR tests at 5% significance level.

### 2.3 Statistical methods

In this study, after assessing the normality of seasonal and annual SPI data series using Shapiro–Wilk test (Table 3), Because of the large variation in the results of the normality test of data series, the trend of calculated SPI data series was evaluated based on non-parametric statistical

**Table 1** selected synoptic stations and climatic properties of them

Stations	Longitude (degree, decimal)	Latitude (degree, decimal)	Elevation (m a.s.l)	Precipitation (mm year <sup>-1</sup> )	ET <sub>0</sub> (mm year <sup>-1</sup> )	Aridity index	Climate condition
Abadeh	52.671	31.181	2030.11	131.98	1647.59	0.080	Arid
Bam	58.352	29.102	1066.80	55.56	2340.59	0.024	Hyper-arid
Bandar Abbas	56.370	27.221	9.81	171.31	1894.01	0.090	Arid
Bandar Lengeh	54.831	26.531	22.90	126.27	2051.90	0.062	Arid
Bushehr	50.824	28.971	7.10	251.66	1845.69	0.136	Arid
Chahbahar	60.323	25.310	7.81	120.7	1746.39	0.069	Arid
Fassa	53.683	28.970	1287.80	285.71	1631.62	0.175	Arid
Jask	57.773	25.633	4.91	124.74	1881.06	0.066	Arid
Iran Shahr	60.670	27.094	590.31	101.12	2839.72	0.035	Hyper-arid
Kerman	56.971	30.251	1753.73	135.23	1911.98	0.071	Arid
Saravan	62.331	27.332	1194.21	106.23	2606.13	0.041	Hyper-arid
Shahr Babak	55.130	30.102	1833.91	148.09	1903.53	0.078	Arid
Shiraz	52.602	29.533	1483.80	312.60	1794.19	0.174	Arid
Sirjan	55.683	29.470	1738.70	144.86	1869.43	0.077	Arid
Zabol	61.494	31.011	488.32	51.09	2584.21	0.019	Hyper-arid
Zahedan	60.930	29.470	1369.73	76.21	1788.52	0.043	Hyper-arid

ET<sub>0</sub> calculated based on FAO-56 Penman–Monteith equation. Aridity index show the degree of dryness of the climate [34]

**Table 2** Categorized of SPI drought index [3, 18]

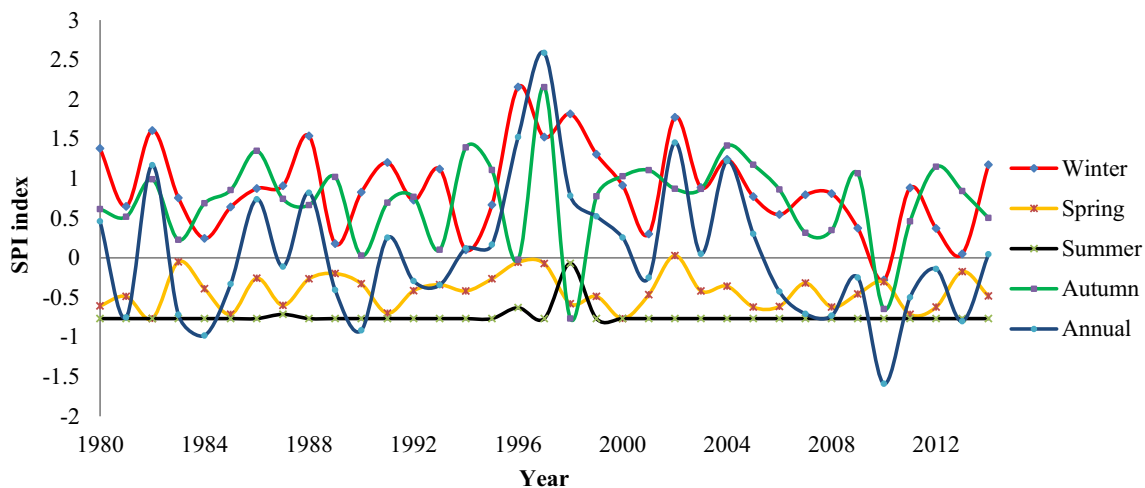
Class number	Category	Values of SPI index	Symbol
1	Extremely dry	$SPI \leq -2$	ED
2	Severely dry	$-1.99 < SPI < -1.5$	SD
3	Moderately dry	$-1.49 < SPI < -1$	MD
4	Near normal	$-0.99 < SPI < 0$	NN
5	Normal	$0 < SPI < 0.99$	N
6	Moderately wet	$1 < SPI < 1.49$	MW
7	Very wet	$1.5 < SPI < 1.99$	VW
8	Extremely wet	$SPI \geq 2$	EW

(Mann–Kendall (MK) and Spearman’s Rho (SR) tests) and parametric test (linear regression (LR) test).

### 2.3.1 Mann–Kendall (MK) trend test

MK trend tests were commonly used to evaluate of trends in series of environmental data, climate data or hydrological data [41]. The MK test statistic  $S$  [12] is calculated by using:

$$s = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sgn}(x_j - x_i) \tag{4}$$



**Fig. 2** Annual and seasonal SPI time series in Bushehr synoptic station (with semi-arid climate condition)

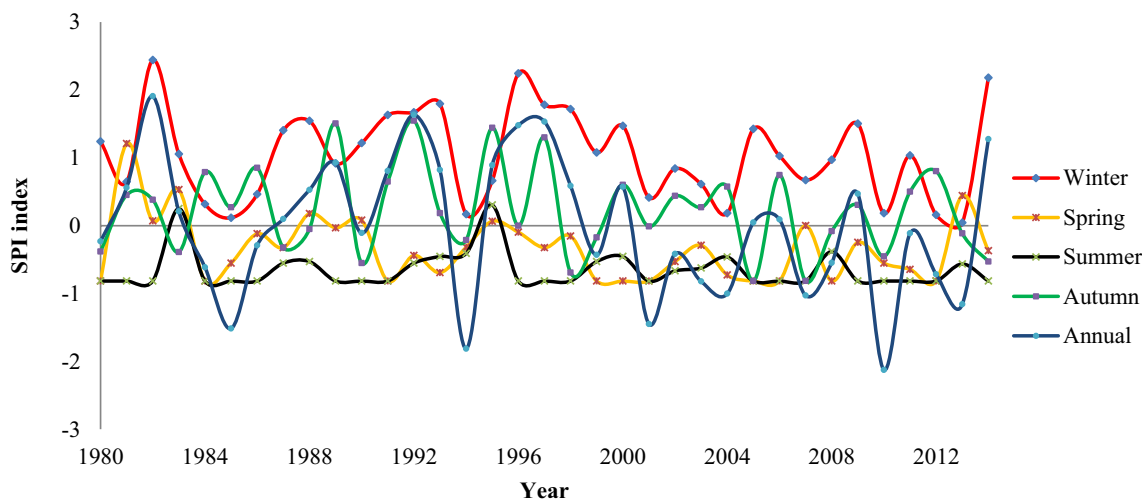


Fig. 3 Annual and seasonal SPI time series in Bandar Abass synoptic station (with arid climate condition)

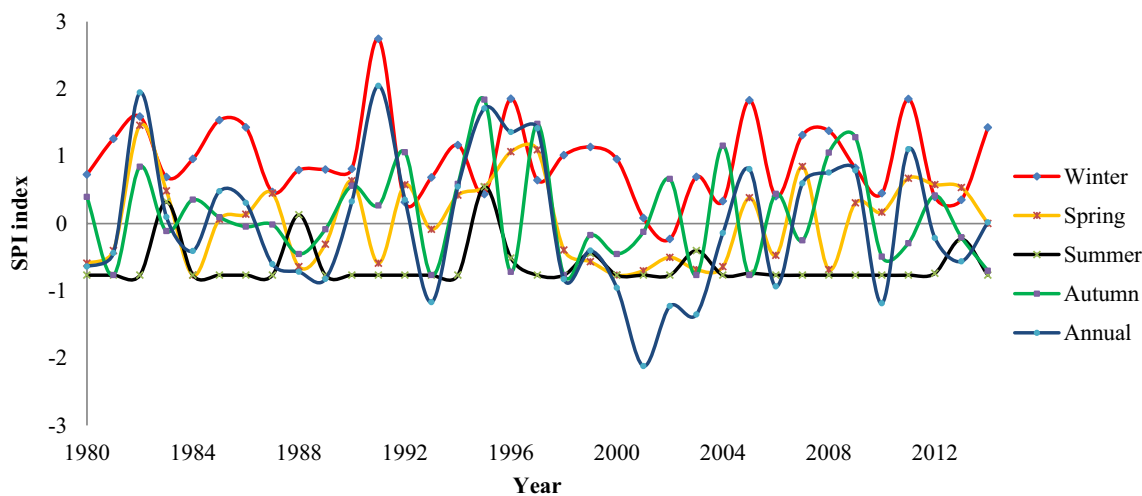


Fig. 4 Annual and seasonal SPI time series in Zahedan synoptic station (with hyper-arid climate condition)

The standardized normal test statistic  $Z_s$  is computed as:

$$Z_s = \begin{cases} \frac{s-1}{\sqrt{\sigma^2(s)}}, & \text{if } S > 0 \\ 0, & \text{if } S = 0 \\ \frac{s-1}{\sqrt{\sigma^2(s)}}, & \text{if } S < 0 \end{cases} \quad (5)$$

If  $Z_s$  was more than 1.96 trend of changes is increasing and If  $Z_s$  was less than  $-1.96$  trend of changes is decreasing (At the 5% significance level).

### 2.3.2 Spearman's Rho (SR) test

The standardized test statistic ( $Z_D$ ) based on SR test was expressed as follows [29]:

$$Z_D = D \sqrt{\frac{n-2}{1-D^2}} \quad (6)$$

$$D = 1 - \frac{6 \sum_{i=1}^n (R(X_i) - i)^2}{n(n^2 - 1)} \quad (7)$$

where  $R(X_i)$ : is the rank of the observation data,  $X_i$ ; in the time series and  $n$  is the length of the time series. If  $Z_D$  was more than 2.08 trend of changes is increasing and If  $Z_D$  was less than  $-2.08$  trend of changes is decreasing (at the 5% significance level).

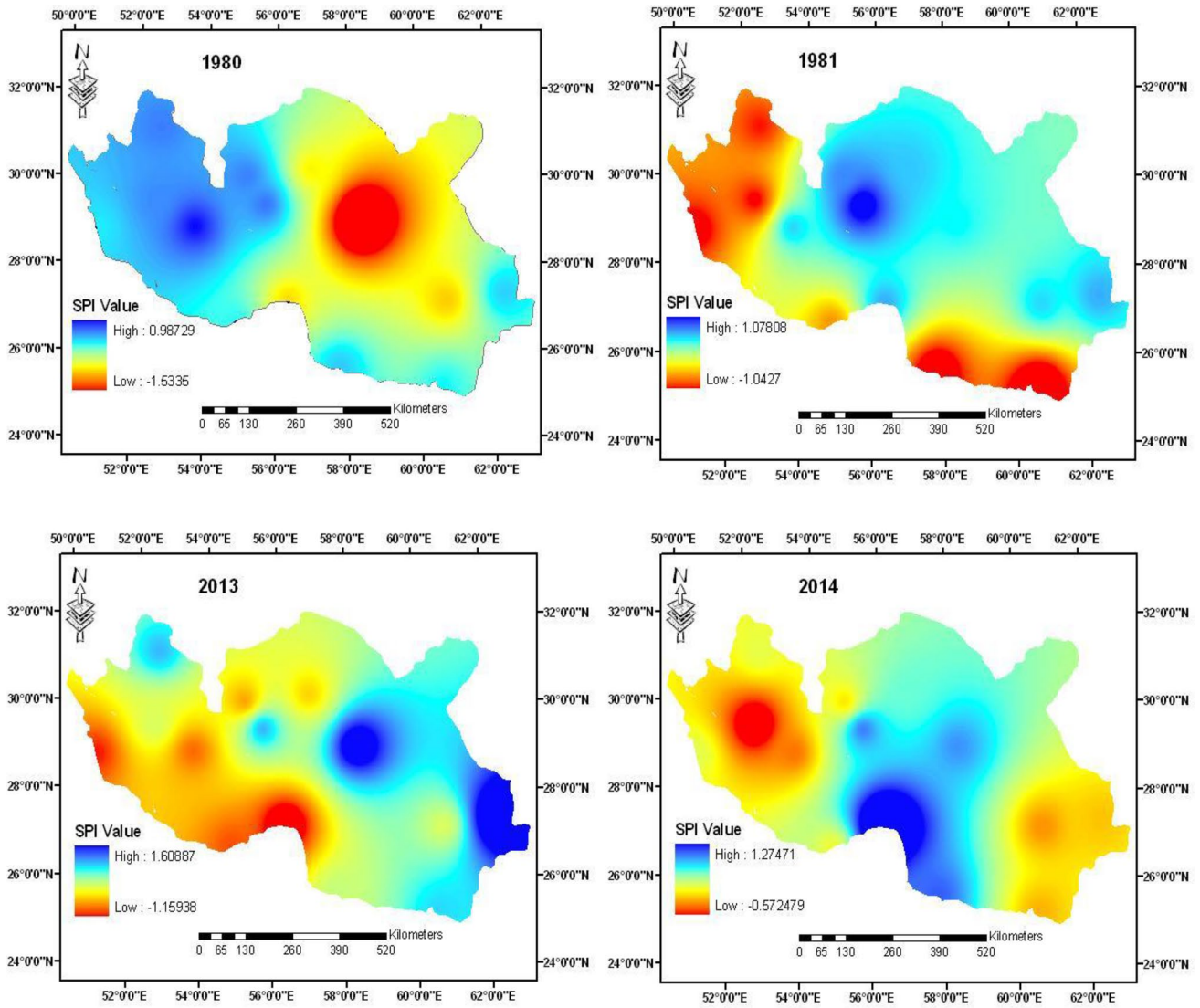


Fig. 5 Spatial Pattern drought based on SPI index in annual time scale (for example)

### 2.3.3 Linear regression (LR) method

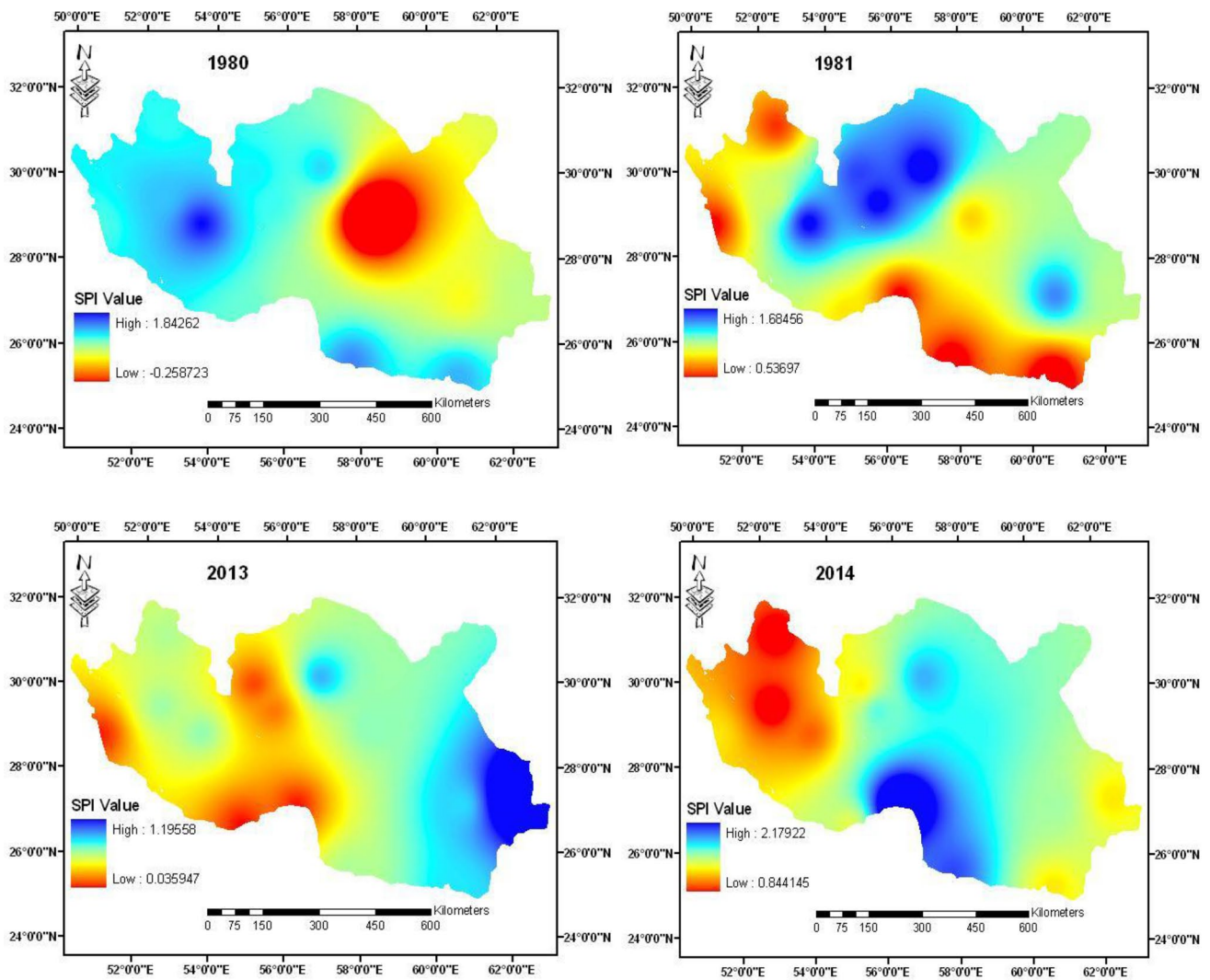
An LR method is one of the parametric methods that is used to indicate the mean temporal change of the studied variables (slope). If the slope of mean temporal change of the studied variables was positive, data series will have an increasing trend, while negative values of the slope of the studied variables indicate decreasing trends.

## 3 Results and discussion

### 3.1 Analysis of trend of changes in temporal pattern of drought

#### 3.1.1 Analysis of trend of changes in seasonal (3-months) SPI index

Analysis of 3-months SPI trend showed that: In spring time scale there is a general negative trend in 10 stations out of 16



**Fig. 6** Spatial Pattern of drought based on SPI index in 3-months time scale (winter) (for example)

and is a general positive trend in 6 stations out of 16 (trend of changes at all stations were non-significant based on all statistical tests). In summer time scale there is a general negative trend in 6 stations out of 16 which is significant in only Bandar Lengeh station (Based on Spearman's Rho test) and is a general positive trend in 10 stations out of 16 which is significant in only Shiraz station (Based on Spearman's Rho test). In autumn time scale there is a general negative trend in 14 stations out of 16 and is a general positive trend in 2 stations out of 16 (trend of changes at all stations were non-significant based on all statistical tests). In winter time scale there is a general negative trend in 15 stations out of 16

which is significant in only two stations (Based on all statistical tests) (Table 4).

### 3.1.2 Analysis of annual (12-months) changes trend SPI index

Result of Analysis of 12-months (annual) SPI trend showed that there is a general negative trend in 14 stations out of 16 which is significant in only four stations based on linear regression test (Bandar Abbas, Bandar Lengeh, Jask and Saravan stations) and is significant in only two stations (Sirjan and Zabol stations) based on all statistical tests (Table 5).

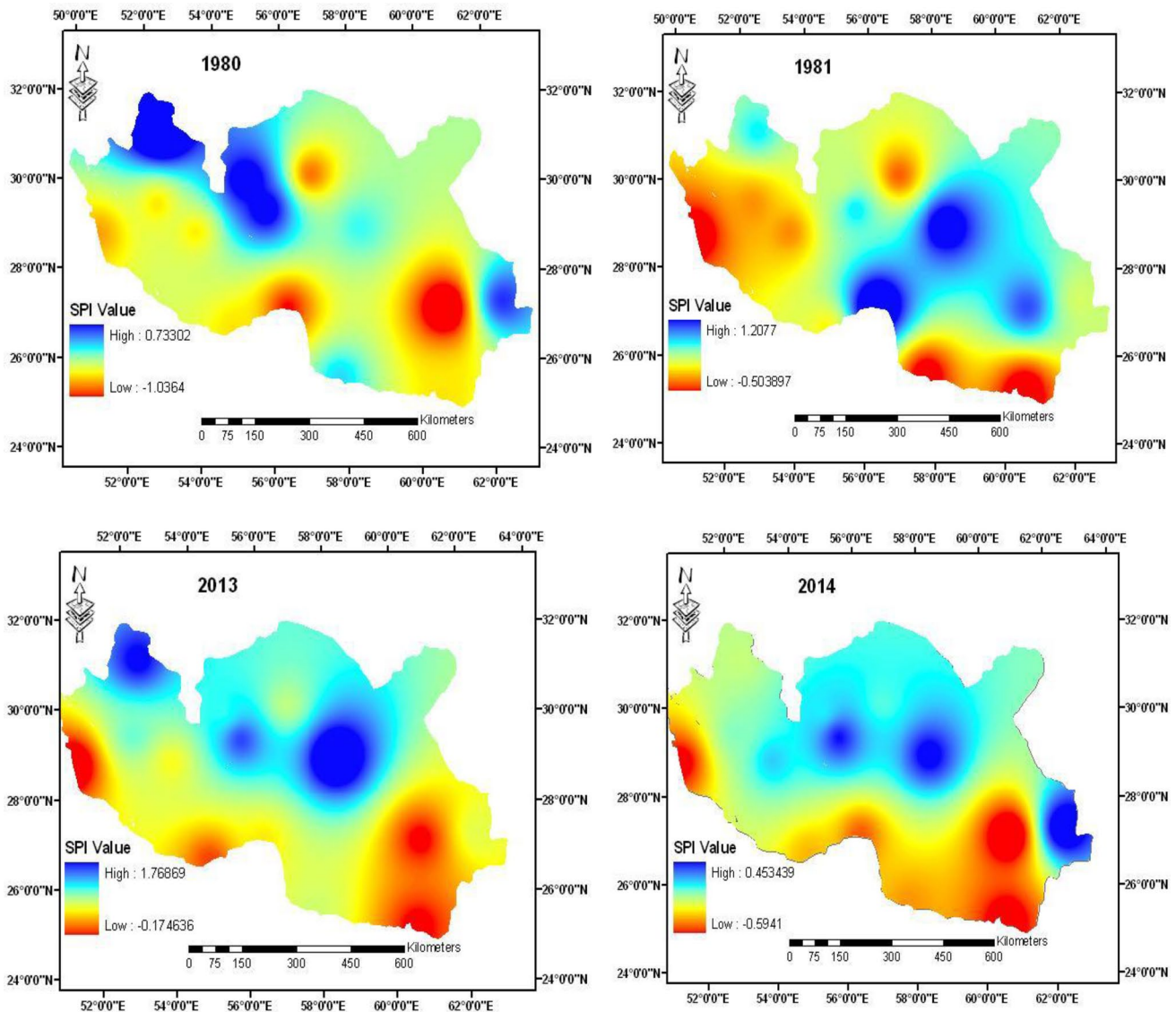


Fig. 7 Spatial Pattern of drought based on SPI index in 3-months time scale (spring) (for example)

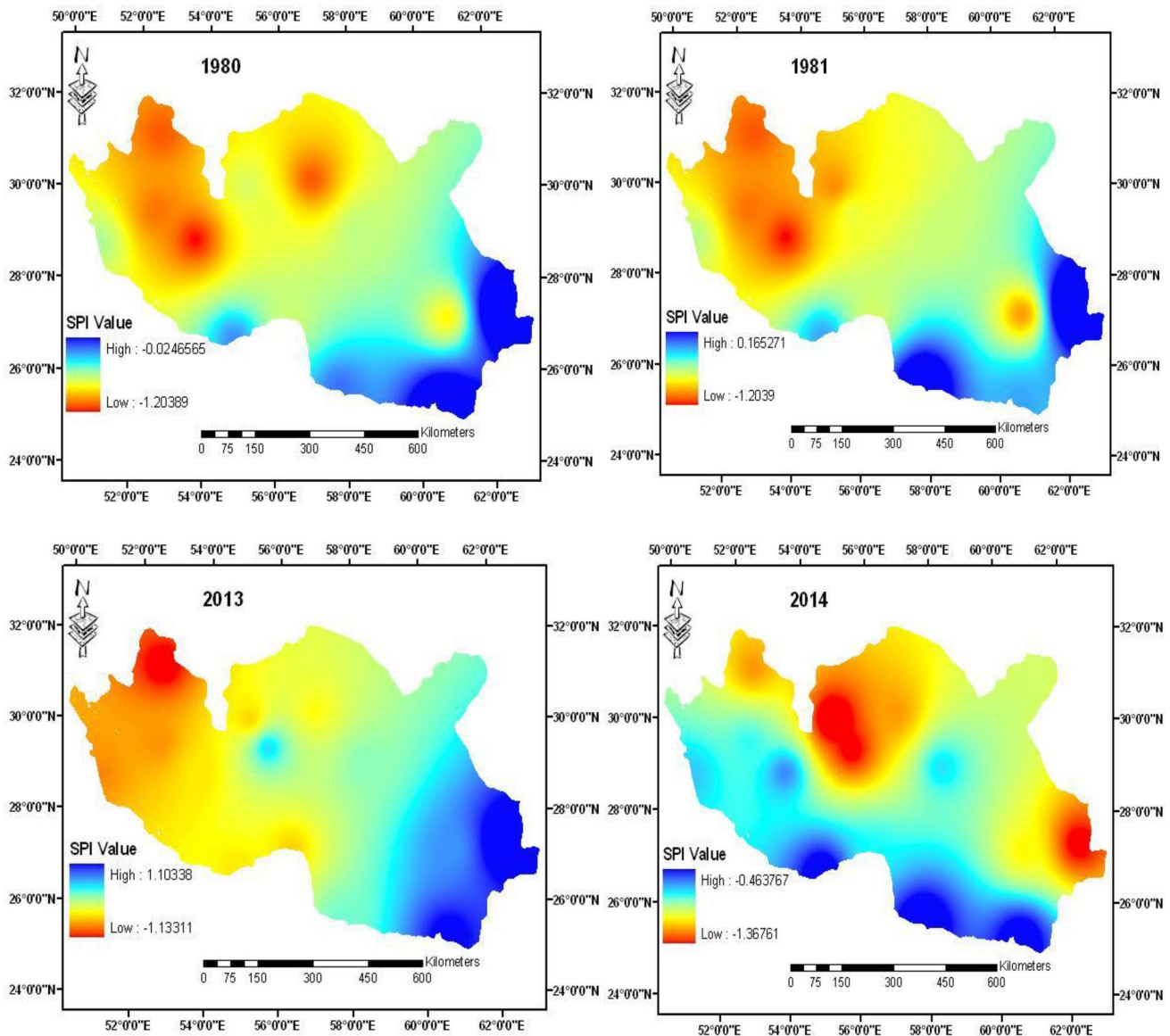
### 3.2 Analysis of changes trend in spatial pattern of drought

#### 3.2.1 Analysis of seasonal (3-months) changes trend in SPI index

According to the results, analysis of changes trend in spatial pattern of drought in seasonal time scale that is presented in Table 6 based on MK and SR tests, the area percentage of study area in classes with normal and wet

condition (Extremely Wet (EW), Very Wet (VW), Moderately Wet (MW) and Normal (N) classes) almost in all seasonal time scales (winter, spring, summer and autumn) had decreasing trend and in classes with dry condition (Extremely Dry (ED), Severe Dry (SD), Moderately Dry (MD) and Near Normal (NN) classes) almost in all time scales had increasing trend but these trends of changes are not significant. Only decreasing trend of changes in the area percentage of moderate wet class in summer time scale was significant at 5% level based on the SR





**Fig. 8** Spatial Pattern of drought based on SPI index in 3-months time scale (summer) (for example)

test with  $Z_D = -2.323$ . Analysis of changes trend in the spatial pattern of drought based on LR method showed that in winter time scale, the surface percent of the study area in EW, VW and MW classes had decreasing trend and trend of changes in N and NN classes was increasing. Changes trend in all classes in this time scale was not significant. MD, SD and ED classes were not observed in winter time scale. In spring time scale the area percentage in VW, MW and N classes had decreasing trend and trend of changes in NN and MD classes were increasing.

Changes trend in all classes in the spring was non-significant. EW, SD and ED classes were not observed in this time scale. In summer time scale classes with MW, N, NN and MD condition were observed, almost all classes had not significant trend, other classes of drought were not observed in summer time scale. In autumn time scale the area percentage with VW, MW and N classes had a decreasing trend. The area percentage with NN and MD classes had an increasing trend. Change trend in all classes was not significant (Table 6).

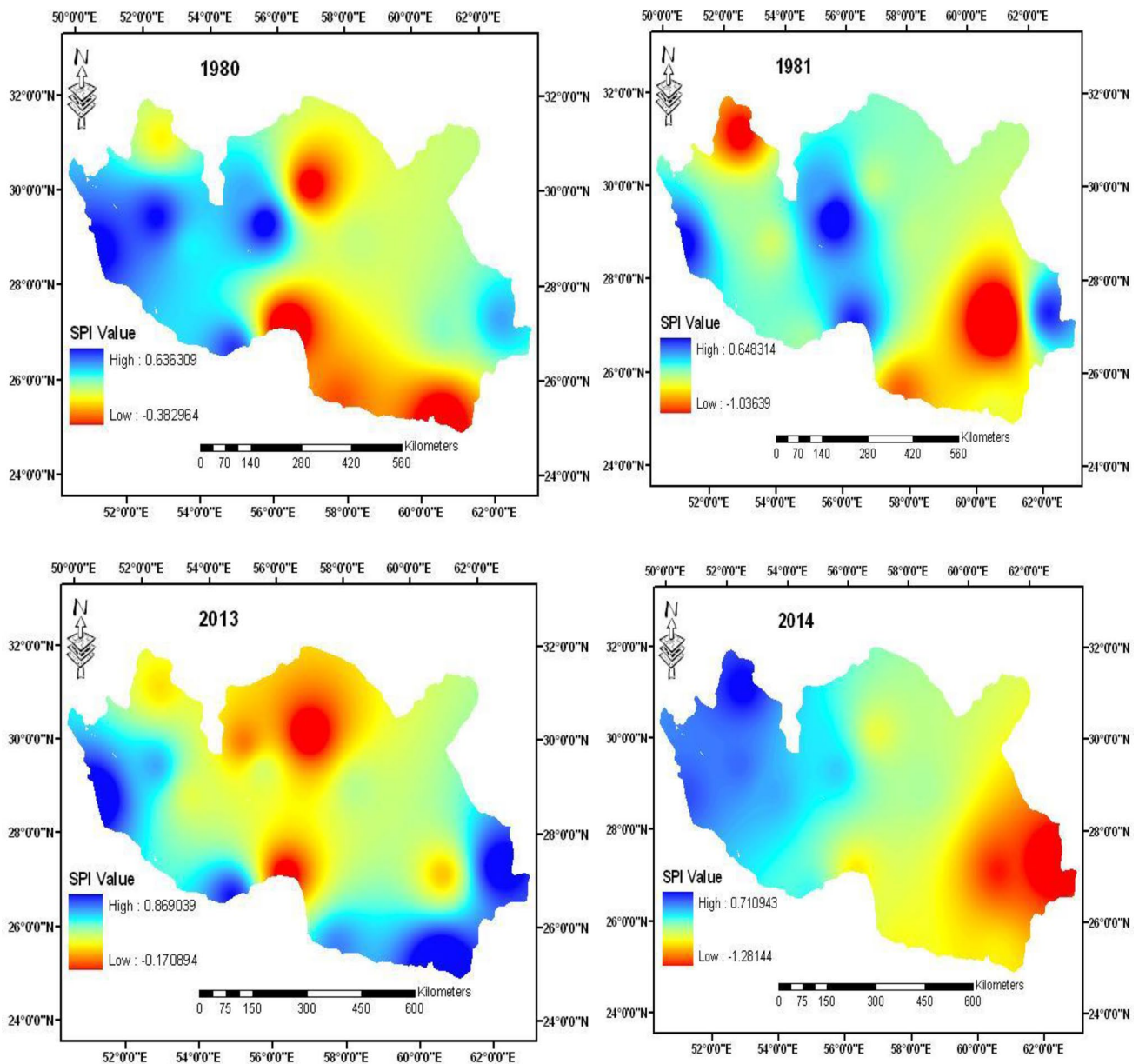


Fig. 9 Spatial Pattern of drought based on SPI index in 3-months time scale (autumn) (for example)

### 3.2.2 Analysis of annual (12-months) changes trend in SPI index

In the annual time scale, the area percentage of VW, MW and N classes had a decreasing trend. The area percentage with NN, SD and ED classes had an increasing trend. Change trend in SD and ED classes were significant at 5% level (Table 6).

## 4 Conclusions

In this research, the changes trend of the spatial and temporal pattern of drought in the south of Iran in annual and seasonal time scales using SPI was evaluated. According to the meteorological data of 16 synoptic stations during the period of 1980–2014 in the south of Iran the most

**Table 3** Results of normality test of calculated SPI index in different time scales (based on Shapiro–Wilk test)

Station name	Winter	Spring	Summer	Autumn	Annual
Abadeh	0.582*	0.208*	0.000	0.502*	0.704*
Bam	0.182*	0.008	0.000	0.024	0.585*
Bandar Abbas	0.257*	0.001	0.000	0.301*	0.936*
Bandar Lengeh	0.280*	0.000	0.000	0.048	0.991*
Bushehr	0.935*	0.327*	0.000	0.119*	0.185*
Chahbahar	0.965*	0.000	0.000	0.001	0.057*
Fassa	0.303*	0.471*	0.000	0.575*	0.670*
Jask	0.673*	0.000	0.000	0.002	0.255*
Iran Shahr	0.817*	0.018	0.001	0.011	0.364*
Kerman	0.679*	0.822*	0.000	0.573*	0.412*
Saravan	0.004	0.133*	0.002	0.034	0.008
Shahr Babak	0.122*	0.993*	0.001	0.103*	0.076*
Shiraz	0.323*	0.353*	0.000	0.644*	0.518*
Sirjan	0.507*	0.546*	0.001	0.119*	0.008
Zabol	0.662*	0.000	0.000	0.052*	0.300*
Zahedan	0.250*	0.018	0.000	0.051*	0.632*

\*Data series is normal at 5% level

percent area of the study region has arid and semi-arid climate conditions. Results of analysis of changes trend in the temporal pattern of drought indicated that, in spring time scale about 56.2%, in summer 43.75%, in autumn 87.5% and in winter time scale 93.7% of station had decreasing trend in SPI index based on all statistical methods (LR, MK and SR tests). In annual time scale 87.5% of the stations had a decreasing trend. According to the results of the analysis of changes trend in the temporal pattern of drought based on parametric and non-parametric statistical tests indicated that the study area is becoming drier. Therefore, it is imperative that managers in their planning, especially for water affiliated sectors, pay special attention to this issue. Considering the upward trend of drought can reduce its negative effects. Results of analysis of changes trend in the spatial pattern of drought revealed that almost in all seasonal and annual time scales the surface percent with dry classes (ED, SD and MD classes) had increasing trend and areas with a wet condition (EW, VW and MW) had a decreasing trend. According to the spatial pattern maps of drought in the study area, it seems, the increase in the surface percent of areas with dry classes has mainly occurred in the western, southern and southeastern regions of the study area. Finally, given that the main source of income of the residents of southern Iran is agriculture and animal husbandry, therefore, it is suggested that managers using the results of this paper try to reduce the negative impacts of drought in these sections.

**Table 4** Statistical tests of seasonal (3-months) standardized precipitation index (SPI) from 1980–2014 period

Station name	Test	Spring	Summer	Autumn	Winter
Abadeh	$Z_s$	-0.014	0.741	0.809	-0.469
	$Z_D$	-0.036	1.524	0.922	-0.510
	$b$	0.000	0.001	0.008	-0.005
Bam	$Z_s$	-1.236	0.000	-0.057	-0.682
	$Z_D$	-1.181	0.683	-0.440	-0.544
	$b$	-0.012	0.003	-0.004	-0.004
Bandar Abass	$Z_s$	-1.726	-0.064	-0.810	-0.881
	$Z_D$	-0.644	-1.066	-0.823	-0.862
	$b$	-0.015	-0.003	-0.010	-0.010
Bandar Lengeh	$Z_s$	-0.044	-1.448	-1.023	-1.463
	$Z_D$	-0.968	-2.421*	-0.823	-1.477
	$b$	-0.002	-0.002	-0.009	-0.016
Bushehr	$Z_s$	-0.327	-0.500	-0.497	-1.094
	$Z_D$	-0.185	-1.219	-0.402	-1.011
	$b$	-0.001	0.000	-0.002	-0.011
Chahbahar	$Z_s$	0.326	0.575	1.032	-1.236
	$Z_D$	1.834	1.537	1.873	-1.314
	$b$	0.009	0.003	0.014	-0.017
Fassa	$Z_s$	0.696	1.177	-0.597	-1.264
	$Z_D$	0.819	1.797	-0.560	-1.198
	$b$	0.005	0.005	-0.008	-0.009
Iran Shahr	$Z_s$	-0.699	-0.331	-0.827	-0.312
	$Z_D$	-0.206	-0.538	-0.189	-0.202
	$b$	-0.004	-0.008	-0.009	-0.007
Jask	$Z_s$	0.484	-1.360	-0.157	-2.386*
	$Z_D$	1.763	-0.180	-0.127	-2.556*
	$b$	0.005	-0.003	-0.005	-0.027*
Kerman	$Z_s$	-0.526	0.424	-0.951	-1.719
	$Z_D$	-0.381	1.856	-0.958	-1.677
	$b$	-0.005	0.004	-0.012	-0.011
Saravan	$Z_s$	-0.895	-1.892	-1.667	0.241
	$Z_D$	-0.695	-0.652	-0.887	0.480
	$b$	-0.006	-0.018	-0.017	0.004
Shahr Babak	$Z_s$	-0.398	0.000	-0.682	-2.173*
	$Z_D$	-0.450	1.026	-0.982	-2.288*
	$b$	-0.005	0.003	-0.012	-0.021*
Shiraz	$Z_s$	0.099	1.533	-0.071	-1.406
	$Z_D$	0.145	2.398*	-0.056	-1.345
	$b$	0.000	0.006	-0.002	-0.010
Sirjan	$Z_s$	-1.207	0.014	-1.193	-1.548
	$Z_D$	-1.001	0.981	-1.400	-1.356
	$b$	-0.009	0.005	-0.014	-0.013
Zabol	$Z_s$	0.688	0.000	-0.839	-1.818
	$Z_D$	1.049	-1.106	-0.723	-1.954
	$b$	0.000	0.000	-0.015	-0.019
Zahedan	$Z_s$	0.355	0.501	-0.484	-0.923
	$Z_D$	0.400	0.221	-0.296	-0.934
	$b$	0.002	-0.004	-0.003	-0.008

$Z_s$  Mann–Kendall test,  $Z_d$  Spearman's Rho test,  $b$  slope of linear regression

\* Significantly trend at 5% level

**Table 5** Statistical tests of annual standardized precipitation index (SPI) from 1980 to 2014

Station name	Test	Annual	Station name	Test	Annual
Abadeh	$Z_s$	0.568	Jask	$Z_s$	-1.576
	$Z_D$	0.484		$Z_D$	-1.674
	$b$	0.000		$b$	-0.026*
Bam	$Z_s$	-0.937	Kerman	$Z_s$	-1.633
	$Z_D$	-0.757		$Z_D$	-1.760
	$b$	-0.016		$b$	-0.006
Bandar Abass	$Z_s$	-1.633	Saravan	$Z_s$	-0.625
	$Z_D$	-1.753		$Z_D$	-0.640
	$b$	-0.028*		$b$	-0.032*
Bandar Lengeh	$Z_s$	-1.520	Shahr Babak	$Z_s$	-1.889
	$Z_D$	-1.834		$Z_D$	-1.976
	$b$	-0.029*		$b$	-0.047
Bushehr	$Z_s$	-0.639	Shiraz	$Z_s$	-0.923
	$Z_D$	-0.644		$Z_D$	-0.842
	$b$	-0.017		$b$	-0.017
Chahbahar	$Z_s$	0.497	Sirjan	$Z_s$	-2.002*
	$Z_D$	0.476		$Z_D$	-2.173*
	$b$	0.003		$b$	-0.023*
Fassa	$Z_s$	-1.605	Zabol	$Z_s$	-2.059*
	$Z_D$	-1.481		$Z_D$	-2.357*
	$b$	-0.022		$b$	-0.035*
Iran Shahr	$Z_s$	-0.667	Zahedan	$Z_s$	-0.327
	$Z_D$	-0.811		$Z_D$	-0.334
	$b$	-0.013		$b$	-0.009

$Z_s$  Mann–Kendall test,  $Z_d$  Spearman's Rho test,  $b$  Slope of linear regression

\*Significantly trend at 5% level

**Table 6** Statistical tests of the trend of changes in area percent of different classes of drought based on standardized precipitation index in different time scales from 1980 to 2014 period

SPI Classes	Test	Annual	Spring	Summer	Autumn	Winter
Extremely dry	$Z_s$	0.610	×	×	×	×
	$Z_D$	1.455	×	×	×	×
	$b$	0.430*	×	×	×	×
Severely dry	$Z_s$	0.053	×	×	×	×
	$Z_D$	0.733	×	×	×	×
	$b$	0.429*	×	×	×	×
Moderately dry	$Z_s$	0.014	0.745	-0.326	1.448	×
	$Z_D$	1.181	1.316	-0.419	1.737	×
	$b$	0.212	0.060	-0.028	0.147	×
Near normal	$Z_s$	0.568	0.326	0.156	0.057	0.881
	$Z_D$	0.671	0.234	0.138	0.221	0.988
	$b$	0.223	0.221	0.029	0.122	0.079
Normal	$Z_s$	-0.326	-0.598	0.048	0.057	1.434
	$Z_D$	-0.306	-0.333	1.267	0.189	1.088
	$b$	-0.062	-0.161	0.006	0.029	0.267
Moderately wet	$Z_s$	-0.763	0.089	-1.465	-0.136	-0.805
	$Z_D$	-0.881	0.646	-2.323*	-1.442	-1.321
	$b$	-0.245	0.056	-0.007	-0.154	-0.210
Very wet	$Z_s$	-1.299	0.239	×	-0.304	-1.270
	$Z_D$	-0.367	0.914	×	-0.366	-0.344
	$b$	-0.066	0.023	×	-0.086	-0.176
Extremely wet	$Z_s$	0.020	×	×	×	-0.404
	$Z_D$	0.497	×	×	×	-0.822
	$b$	0.006	×	×	×	-0.059

$Z_s$  Mann–Kendall test,  $Z_d$  Spearman's Rho test,  $b$  slope of linear regression and × class with this condition was not observed in this time scale

\*Significantly trend at 5% level

**Acknowledgments** Authors would like to thank national meteorological organization of Iran for provide the meteorological data.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest

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