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The Relationship of Drought Intensity, Duration and Frequency in the Southern Coast of Caspian Sea

[1]Mehrdad Ramazanipour and [1]Mahmoud Roshani and [2]Jafar Ghomi Aveily

[1]Department of Geography, Chalous Branch Islamic Azad University, Chalous, Iran
[2]Department of Geology, Chalous Branch, Islamic Azad University, Chalous, Iran

Abstract: Present study investigated the drought in the southern coast of Caspian Sea, Iran. The rainfall data were obtained from five meteorological stations (Anazali, Rasht, Ramsar, Babolsar and Gorgan) for the past 48 years (1956-2003) in order to study of droughts. In the first, the drought coefficients are calculated on the basis of SPI and then characteristics of drought (intensity, duration and frequency) were analyzed. The results suggested that the high frequency of wet is one of the main distinguishing elements of the area. This included about 62-83 percent of droughts, which occurred between 1-3 months. Therefore, the long-term drought has had the least frequency. In addition, the drought coefficient had high correlation in the western stations rather than eastern stations that were revealed droughts no occur concurrently. The relationships between duration and intensity of drought indicated that increasing of intensity and duration is relevant the decrease of frequency. Meanwhile, it was seen in the sub-periods, too.

Key words: Drought · SPI · Monitoring · Frequency · Probability · Caspian Sea

INTRODUCTION

The human has still been vulnerable against natural phenomena with regard to technical and scientific progresses, including droughts and is seeking for methods which to recognize the occurrence of this phenomenon. This phenomenon has had multidimensional effects and has attracted most enthusiasts. Therefore, its recognition can be present practical strategies. The extensive worldwide studies have been carried out with regard to the importance of drought. [1] Nikbakht shahbazi *et al.* have shown that the SPI values can be predicted by proposed model with 2 to 5 months lead-time with enough accuracy to be used in long-term water resources planning and management in four reservoir basins supplying the water demands of Tehran. [2] Khayatnezhad *et al.* studied the ability of several selection indices to identify drought resistance cultivars under a variety of environmental conditions. The results of calculated gain from indirect selection from moisture stress environment would improve yield in moisture stress environment better than selection from non moisture stress environment. [3] Masoudi *et al.* presented a model to assess hazard of ground water resource degradation related to drought using the Geographical Information System (GIS). They believed that the entire land of Southern Iran faces problems arising out of land degradation and also the hazard indicator maps take into account the hydro geological and climatologically characteristics and those anthropogenic activities related to irrigation farming. [4] Yildiz calculated the drought intensity, surface extent and frequency curve for various return periods, then, investigated old drought return periods and drought intensity in Turkey. [5] Sirdas and Sen (2003) investigated many of the direct connection between duration and extent of drought by Run and Z- Score methods and Kriging interpolating in Trakya area of Turkey. [6] Lloyd-Hughes and Saunders (2002) believed that the Gamma distribution is the best model for describing monthly precipitation over the Europe. They have also compared the characteristics of the SPI with the PDSI. In this paper we used the standardized precipitation index for recognition, monitoring and determination of drought components (intensity, duration and frequency) in the Caspian Sea coastal area.

Data and Methods: The southern coast of Caspian Sea is the area of greatest source of rainfall in north of Iran that located between 48°32′48" to 54°25′45"E and 35° 47′00" to 38° 27′02"N. We have received the monthly precipitation data for five Synoptic stations for our research from the Iran Meteorological Organization for the

Corresponding Author: Mehrdad Ramazanipour, Department of Geography, Chalous Branch, Islamic Azad University, Chalous, Iran. Mob: +98-9111370065.

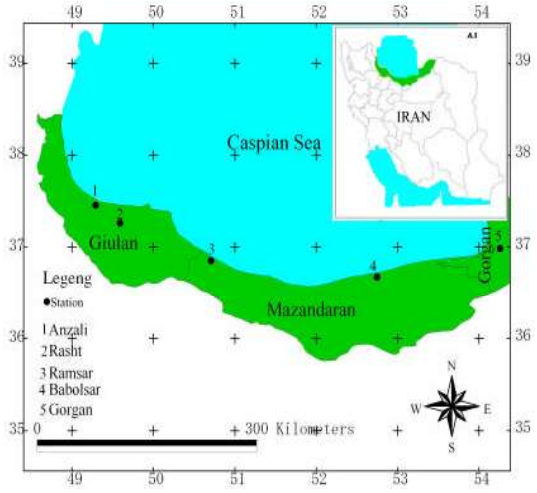

Fig. 1: Geographic location of the rain gauge stations

Table 1: Drought classification based on SPI value and corresponding event probabilities

Class	SPI value	% Probability
Extremely Wet	<2	2.3
Severe Wet	(1.5) - (1.99)	4.4
Moderately Wet	(1) - (1.49)	9.2
Slight Wet	0 - (0.99)	34.1
Slight Drought	0 - (- 0.99)	34.1
Moderately Drought	(-1) - (-1.49)	9.2
Severe Drought	(-1.5) - (-1.99)	4.4
Extremely Drought	> -2	2.3

period 1956-2003 (Figure 1). Also, we have used mathematical SPI model in this study. Firstly, this model was presented by climatologists. In terms of mathematic, SPI is based on probability of accumulative precipitation. Therefore, the data has been fitted with gamma probability distribution, then, transformed into the standard normal distribution to yield the SPI (Table 1). Based on the basic idea of [7] Edwards and McKee (1997) the first is the gamma distribution, whose probability density function is defined as

$$G(x)=\frac{1}{\alpha^{\beta}\Gamma\beta}\int_{0}^{X}X^{\beta-1}e^{-x/\alpha}dx \qquad (1)$$

Where α > '0' is a shape parameter, β > '0' is a scale parameter and x > '0' is the amount of precipitation. 'Γ' (α) is the gamma function. The gamma distribution is undefined for x = '0' and q = P(x = 0) > '0' where P(x = 0) is the probability of zero precipitation, the cumulative probability becomes

$$H(x)=q+(1-q)G \qquad (2)$$

The simplest method for calculation of SPI amounts is acquired from approximate conversion of Abramowitz and Stegun. The SPI amount for '0' < H (x) = 0.5 will be equal to

$$SPI=-\left[t-\frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right] \qquad (3)$$

For 0.5 < H(x) < '1' is calculated by equation 4:

$$SPI=+\left[t-\frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right] \qquad (4)$$

According to the magnitude of the displaced amounts of the gamma, SPI values are obtained from't' displacement with various formulas that are used in the determination of 3, 6, 12, 18, 24 and 48- month drought.

RESULTS

Research has shown the impact of drought on region based on SPI. As noted in Table 2, the necessary component is presented for calculating SPI. The results showed that there is a good correlation for SPI values in western region such as the correlation for the SPI values in Anzali and Rasht is 0.90 (in the west of region) and in Babolsar and Gorgan are 0.61(in the east of region) and also the correlation between Anzali and Gorgan calculated at the rate of 0.44. In Table 3 is seen that the simultaneous occurrence of drought has decreased from west to east at adjacent stations. Likewise, the probability of moderate drought increases in relation to extremely drought from west to east. In conclusion, there is more frequency of moderate drought (SPI, '0' - (- 0.99)) in relation to extremely drought (SPI>-2) in the stations. The frequency of wetness for 576 months is 286, 302, 280, 299 and 321, as drought is seen more than wetness in Rasht, Babolsar and Gorgan and Anzali and Ramsar is less than it. The ratio of drought - wetness show that the probability of severe and extreme drought/wetness (-1.5 > SPI > 1.5) is changed out of certain limits at the rate of 1-7 to 1-9 (Table 4 and Figure 2). This means that in every 7 or 8 months the drought or wetness is presumably occurred for 1 month in Southern Coast of Caspian Sea. At first the SPI coefficient is accounted for 5 stations with regard to their duration and then it is presented for the evaluation of the droughts frequency. These results showed that 1-3- month draught has more frequency and 6, 7, 8 and 9- month draught has less frequency at the stations. In other words, 1 - 9- month drought is not the same and do not follow linear trend. Rather, 1- month drought in Gorgan has more frequency

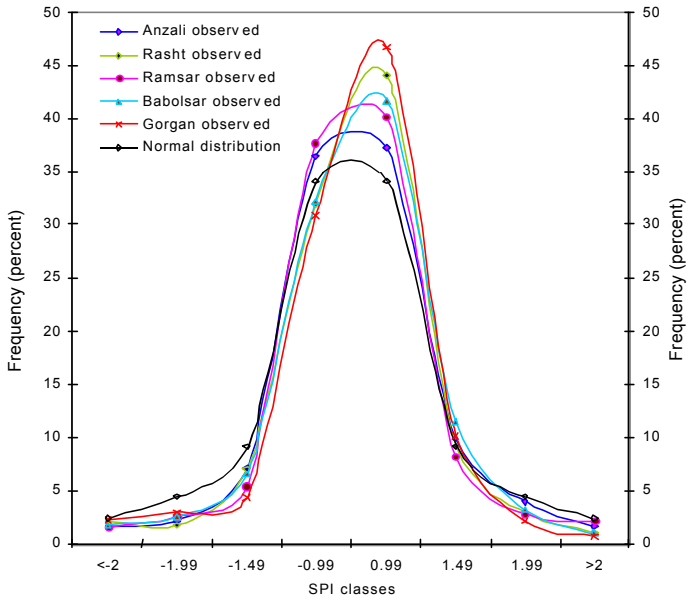

Fig. 2: Comparing of observed drought/ wetness frequency with SPI values

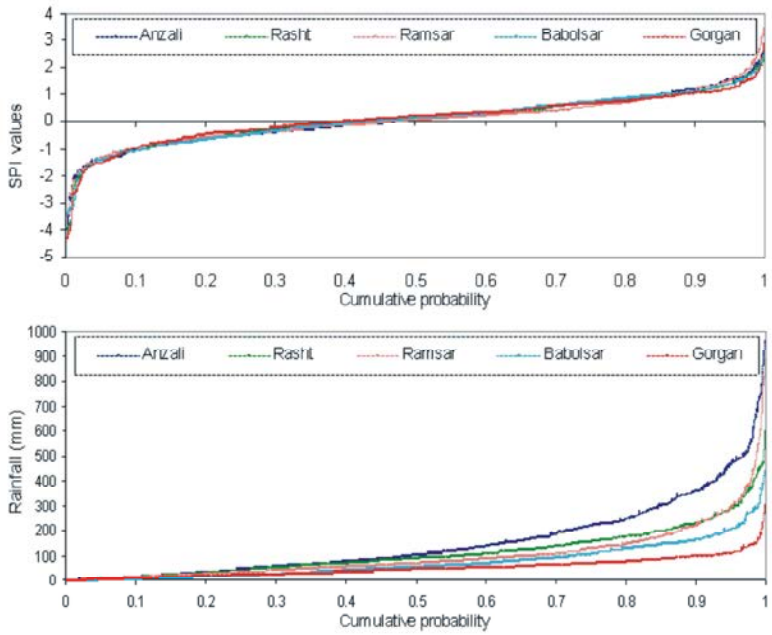

Fig. 3: Final climatic model of transformation from a fitted gamma distribution to standard normal distribution

at the rate of 68 frequencies and Anzali station with 34 frequencies has less frequency and the frequency of 1- month drought decrease from west to east (Table 5). The relationship between the duration and frequency indicated that trend of the type of nonlinear decreased in all stations because of the existence of decrease in the frequency from 1 to 9-month drought such as the secondary peak is seen in 5, 6 and 7- month drought frequency. The rate of R_2, from Anzali to Gorgan is equal to 0.91, 0.86, 0.95, 0.93 and 0.88 and it follows the exponential function. The most important change is seen in 1- month drought frequency as it has increased from 21 to 13 in Anzali, from 16 to 24 in Ramsar, from 29 to 39 in Gorgan from the first half (1956- 1979) to second half of the period (1979 - 2003) and there is no change in Rasht and decreased from 22 to 24 in Babolsar. But, the frequency of 2- month drought is decreased in the second half of the period (except of Gorgan). The frequency of 3 and 4-month drought has significant trend during two sub period. As a result, the value of SPI can be estimated by

Table 2: Coefficient of Gamma distribution for calculating SPI coefficient

Station	μ Precipitation	Ln x	Ln μ	U	α	β
Anzali	154.9	4.45	5.04	0.59	0.798	194.04
Rasht	112.6	4.24	4.72	0.48	0.93	120.19
Ramsar	102.23	4.11	4.63	0.51	0.89	114.58
Babolsar	75.32	3.68	4.32	0.64	0.75	99.93
Gorgan	51.81	3.55	3.95	0.39	1.08	47.77

Table 3. Coefficient of correlation of SPI values in adjacent stations

Station	Anzali	Rasht	Ramsar	Babolsar	Gorgan
Anzali	1				
Rasht	0.90	1			
Ramsar	0.77	0.77	1		
Babolsar	0.77	0.79	0.64	1	
Gorgan	0.44	0.52	0.44	0.61	1

Table 4: Comparison of observed probability distribution with normal distribution

Class	Anzali	Rasht	Ramsar	Babolsar	Gorgan
Extremely Wet	1.91	1.21	2.95	1.72	1.22
Severe Wet	4.86	2.77	3.29	3.298	2.43
Moderately Wet	9.55	8.51	7.98	12.15	11.28
Slight Wet	32.81	39.75	34.2	34.55	40.62
Slight Drought	35.41	33.68	37.15	30.90	30.21
Moderately Drought	7.46	7.29	8.33	9.89	6.25
Severe Drought	5.55	4.16	3.47	4.51	3.99
Extremely Drought	2.43	2.60	2.60	2.95	3.99

Table 5: Relation between drought frequency and occurred durations

Duration (month)										
Station	Period	1	2	3	4	5	6	7	8	9
Anzali	1956-2003	34	18	7	8	11	9	4	3	1
	1956-1979	13	12	3	2	5	6	1	2	1
	1979-2003	21	6	4	6	6	3	3	1	0
Rasht	1956-2003	42	14	11	11	15	0	5	1	1
	1956-1979	21	10	5	4	9	0	2	0	1
	1979-2003	21	4	6	7	6	0	3	1	0
Ramsar	1956-2003	42	32	12	9	9	9	2	1	0
	1956-1979	16	18	7	5	6	4	0	0	0
	1979-2003	26	14	5	4	3	5	2	1	0
Babolsar	1956-2003	46	13	7	13	11	8	2	2	0
	1956-1979	24	8	4	6	7	5	0	0	0
	1979-2003	22	5	3	7	4	3	2	2	0
Gorgan	1956-2003	68	28	10	11	6	3	1	0	0
	1956-1979	29	13	5	7	1	2	0	0	0
	1979-2003	39	15	5	4	5	1	1	0	0

the monthly rainfall. Certainly, rainfall data should be the long- term and normal. The final climatic model of SPI is presented in Figure 3, for all stations.

CONCLUSIONS

The results of the analysis of this study illustrate the short-term drought (1-3-month) has more than frequency in relation to long- term and decreased its frequency from west to east. A similar effect is seen in the sub period and 1- month drought in the second half have more than frequency in relation to the first half of the period in many of the stations. In other hands, 2-month drought decreased in relation to the first half of the period. The value of standard precipitation index show that there are also statistically significant correlations at adjacent stations (Anzali and Rasht) but, its correlation decreased when the distance of stations is increased. The lacks of drought simultaneous is clearly seen in all stations and there is not linear relationship between duration-frequency and follow exponential function. Likewise, there is the inverse linear relationship between intensity-frequency but generally the probability of severe and extreme droughts is less. In the investigation of drought indicated that this phenomenon has been repeatedly occurred in the area. Accordingly, in this research, the all drought characteristics are recognized in area. As a main point of drought investigation by SPI method is ignoring daily time scale for precipitation which in the EP method, this defect has been removed.

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