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EVALUATION OF DROUGHT CHANGES OF ISFAHAN CITY BASED ON THE BEST FITTED PROBABILITY DISTRIBUTION FUNCTION

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ABSTRACT

Generally, in arid and semi-arid region due to climatic conditions, a good match between conventional agriculture, soil and water conditions as well. Personal experiences of rural and old traditions teaches them how to avoid minor changes in environmental conditions of drought risks. In this study, the monthly rainfall statistical period 1951 to 2005 for Isfahan synoptic stations were used. Climate of the mentioned area is dry, according to climate Domarten Climagram. By choosing the best fitted distribution function basis of statistics Kolmogrov-Smirnov, the cumulative probability values were calculated and SPI values were corrected accordingly. The monthly scale results showed that in the months of June, July, August and September can be used Gamma function, but for the other months, the greatest difference between the results of the Gamma distribution with the best distribution in the frequency of droughts classes, can be seen in December. Also, the results showed that in addition to the frequency, the intensity values of drought is significant difference. It is often recommended that the default SPI index (Gamma) is not used. It should be noted that in the years studied, 1955 and 2000, respectively, the year was as wet and dry.

KEYWORDS: Drought, SPI, Arid and Semi-Arid Climate, Gamma, Standardized precipitation index.

INTRODUCTION

Changes in rainfall patterns has serious effects on the quantity and quality water supply [1]. Moreover, asymmetrical distribution of rain time and location in most countries has caused that the water resources management and especially drought management be considered [2]. Drought is a global phenomenon that it can occur almost in every region and lead to losses and major economic, social and environmental costs. Drought can be considered as an effect of a period of abnormally and dry weather conditions that have to be durable enough to imbalance the hydrological conditions of a region. Since droughts also have negative social and economic impact directly or indirectly, its effects can be generally divided into environmental, economic and social effects [3].

In recent years, a lot of research have been carried out regarding the impact of drought with different aspects such as environmental changes [4], economic impact [5], social experience [6], food crisis [7, 8], Political issues [9] and climate change impact [10]. In the meantime, agriculture, by considering its dependence on water, is usually the first part that gets damage from drought.

Drought has different types. But the most important of them are drought atmospheric, hydrological and agricultural. Atmospheric drought is mainly due to the situation resulting from shortage of precipitation. Regarding this matter, various indicators such as Palmer drought index (PDSI) [11], Rainfall Abnormal index (RAI) [12], Deciles Index (DI) [13], Standardized Precipitation Index (SPI) [12], and the Effective Drought Index (EDI) [14] can be used which these indicators will be useful if they are able to determine drought characteristics such as intensity, duration and locative extension [15].

Research carried out by Palmer [11] is one of the first studies in the field of drought. For example, one of the things that have been done in the field of meteorological drought is the Research of Herbst, Bredenkamp [16] that their method was modified later by Mohan and Rangacharya [17]. Dupigny-Giroux [18] believes that the SPI drought index

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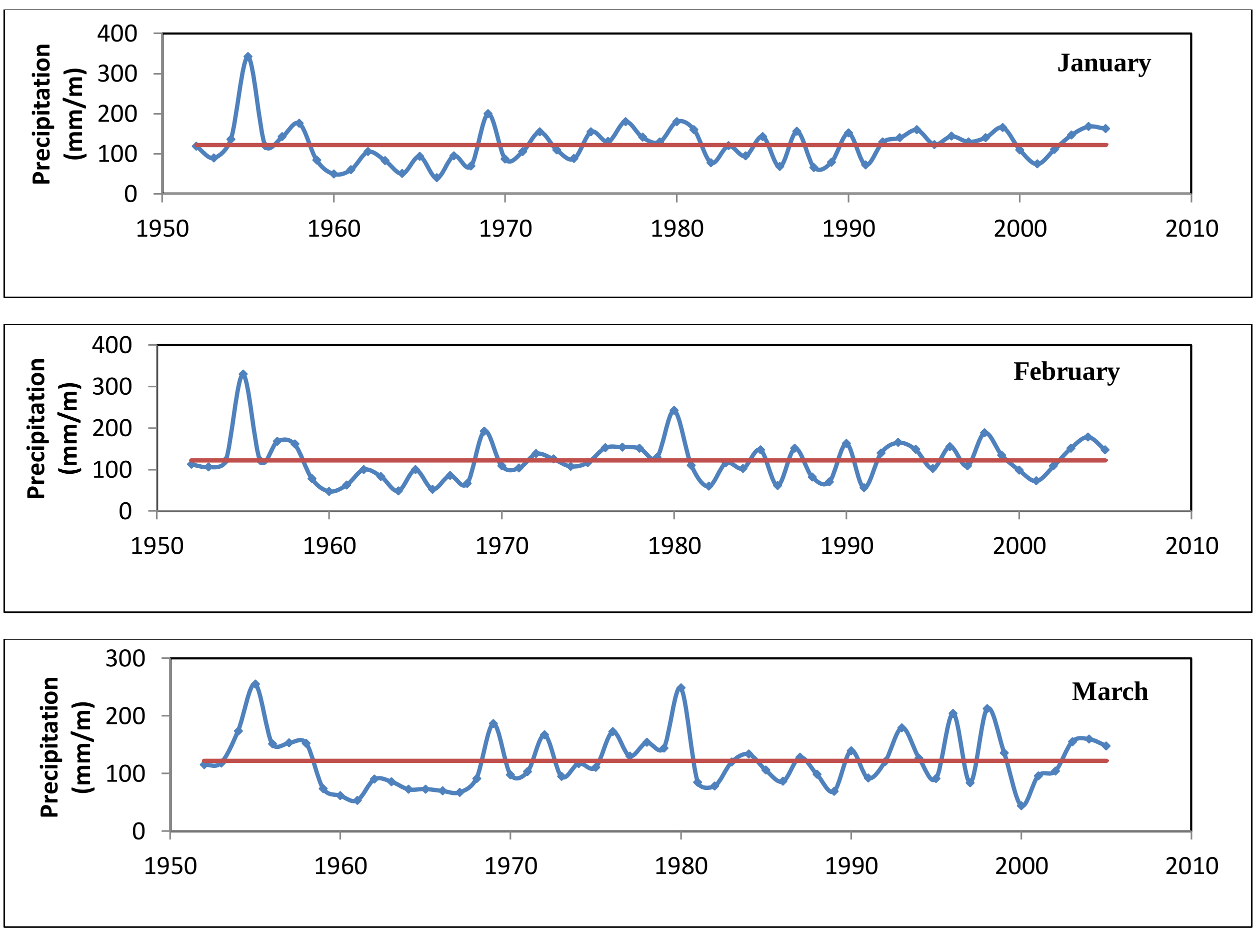
acts better than profile moisture and modified Palmer indexes in small to medium timescales. Also, ENSAFI [19] conducted a study on 34 Meteorology stations of salt basin which in this study, he showed that Standardized Precipitation Index (SPI) and Decile Index (DI) are in the first place and Z score index is in the second place and normal percentage index is in third place. The fallow drought of Tehran Provinces was conducted by using DI, PN, SPI, CZI, MCZI and EDI indices by Morid, Smakhtin [20] and they concluded that SPI and EDI indicators are better than other indices.

Iran is located in arid and semi-arid regions of the world and also, it has access to synoptic stations [21]. Therefore, Study the phenomenon of drought in Iran is a valuable and effective research. The aim of this study is to determine meteorology drought events by using the SPI index by using monthly precipitation data in the period from 1951 to 2005 in the city of Isfahan.

MATERIALS AND METHODS

Case Study

Isfahan city is located in 32.61 east latitude, 51.66 longitude and 1550.4 meters in height above sea level. For doing the present study, Monthly precipitation statistics for the period 195-2005 was taken from the Meteorological Organization in Isfahan province. Due to the drought in annual scale per month is also associated with the precipitation amount in the months before the considered month, precipitation changes are presented in the figure 1 according to the months by considering this reason, according, for example, it is necessary to consider total precipitation in last 11 months to study precipitation changes.



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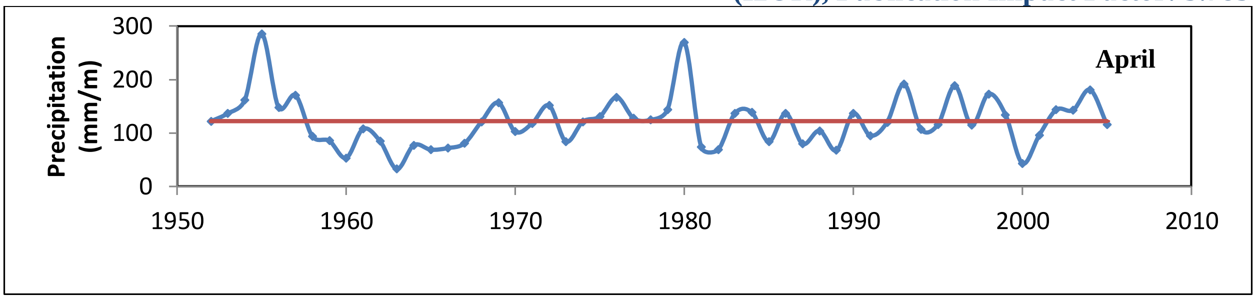
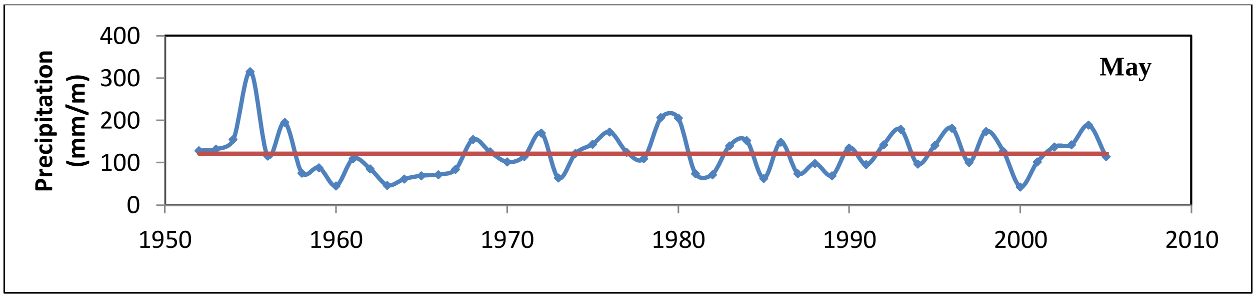
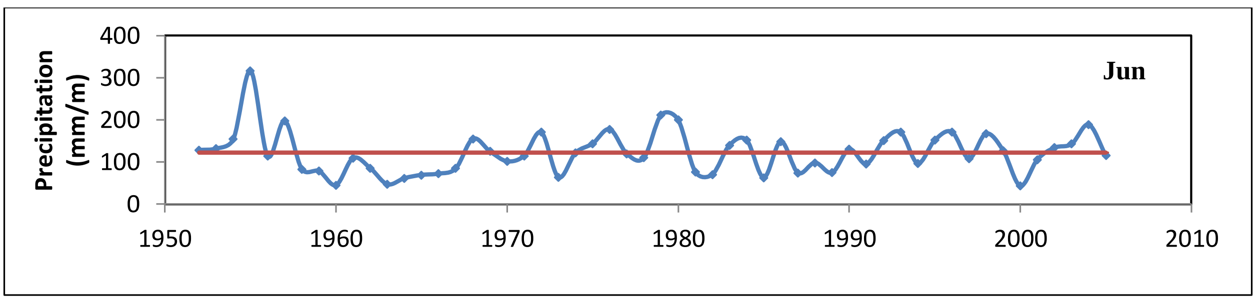
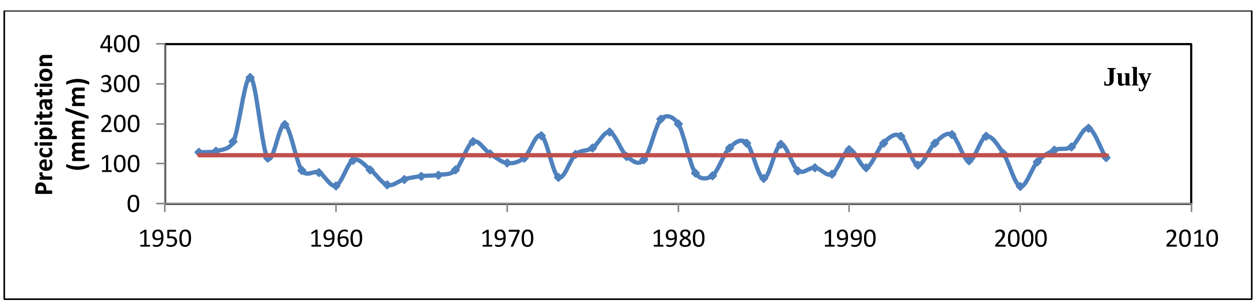
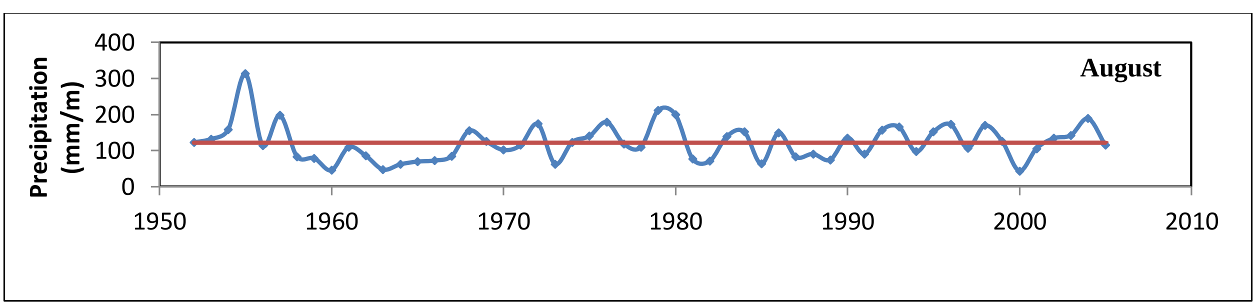










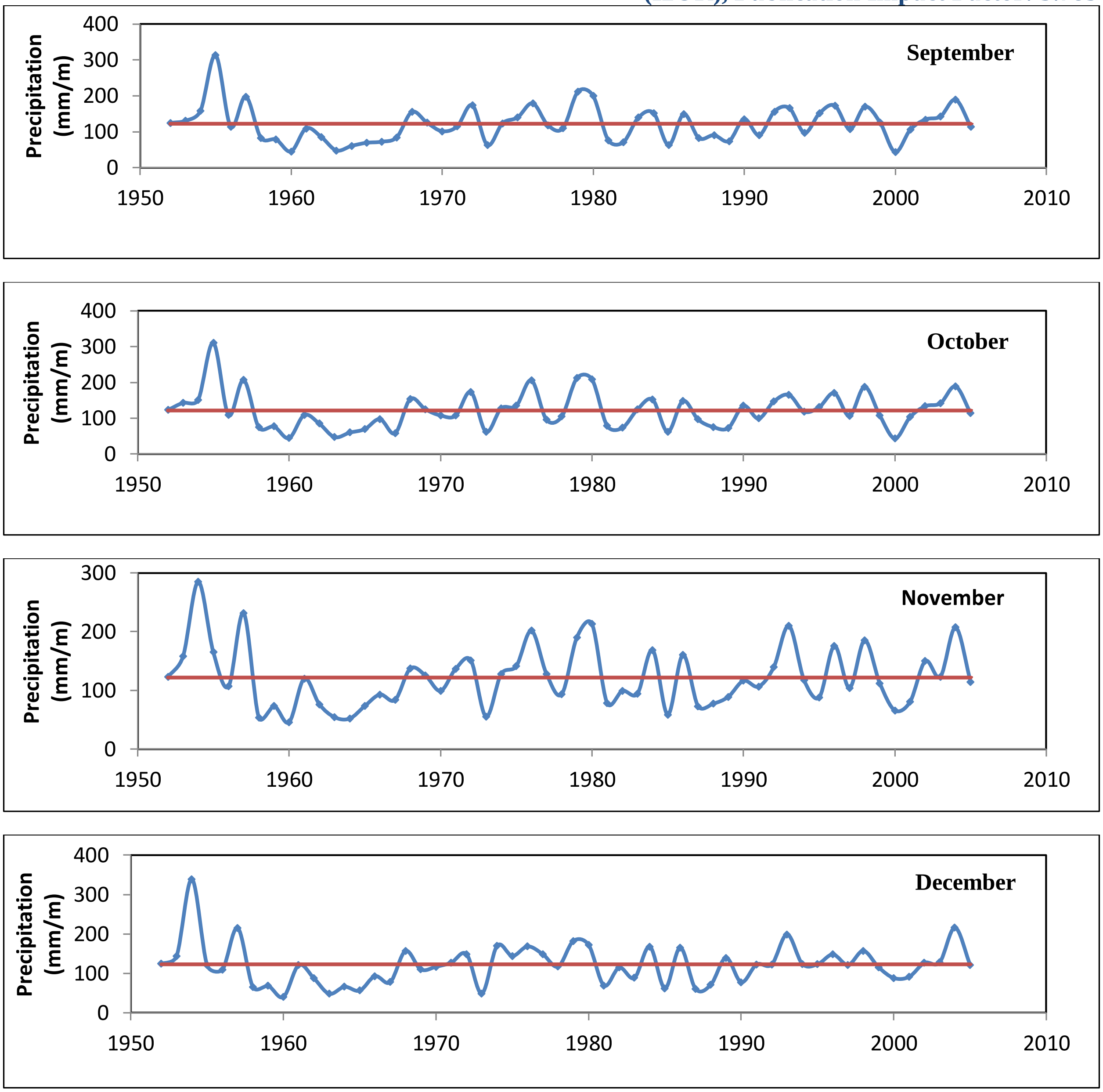


Fig 1. Monthly precipitation changes during the period (1951-2005)

Comparing precipitation change charts (with effect of total precipitation of 11 months ago in each of the months of the study) show that the most fluctuations occur in the months whose contribution in precipitation has been considerable in the last months. That is the highest volatility to average precipitation starts from February and reduced in January.

Methodology

Then, the procedure of conducting the present research consists of two following stages:

1-Calculating the values of Standardized Precipitation Index (SPI)

The SPI index was created in 1993 by McKee and colleagues for drought monitoring climate of Colorado in America that its relationship is straight [22].

$$\mathbf{Zs} = +\left[\left(-\pi/2 \ \mathrm{Ln}\left(1-(2PU-1)^2\right)\right)\right]^{0.5} \quad \text{if} \quad PU \geq 0.5 \qquad (1)$$

$$\mathbf{Zs} = -\left[\left(-\pi/2 \ \mathrm{Ln}\left(1-(2PU-1)^2\right)\right)\right]^{0.5} \quad \text{if} \quad PU < 0.5 \qquad (2)$$

In this relationship, PU is cumulative probability value and Zs is standard normal distribution value (natural). The calculation of this indicator requires fitting suitable probable distribution over long series of precipitation data at any desired time performance in the station that for this indicator Gamma distribution was suggested by McKee et al. (1993) McKee, Doesken [22] that by considering of following precipitation from the Gamma distribution, obtained cumulative probability distribution of Gamma should be converted to cumulative standard normal distribution with zero mean and variance 1 after calculating the index SPI which by considering the different classes of drought, drought periods can be determined (Table 1).

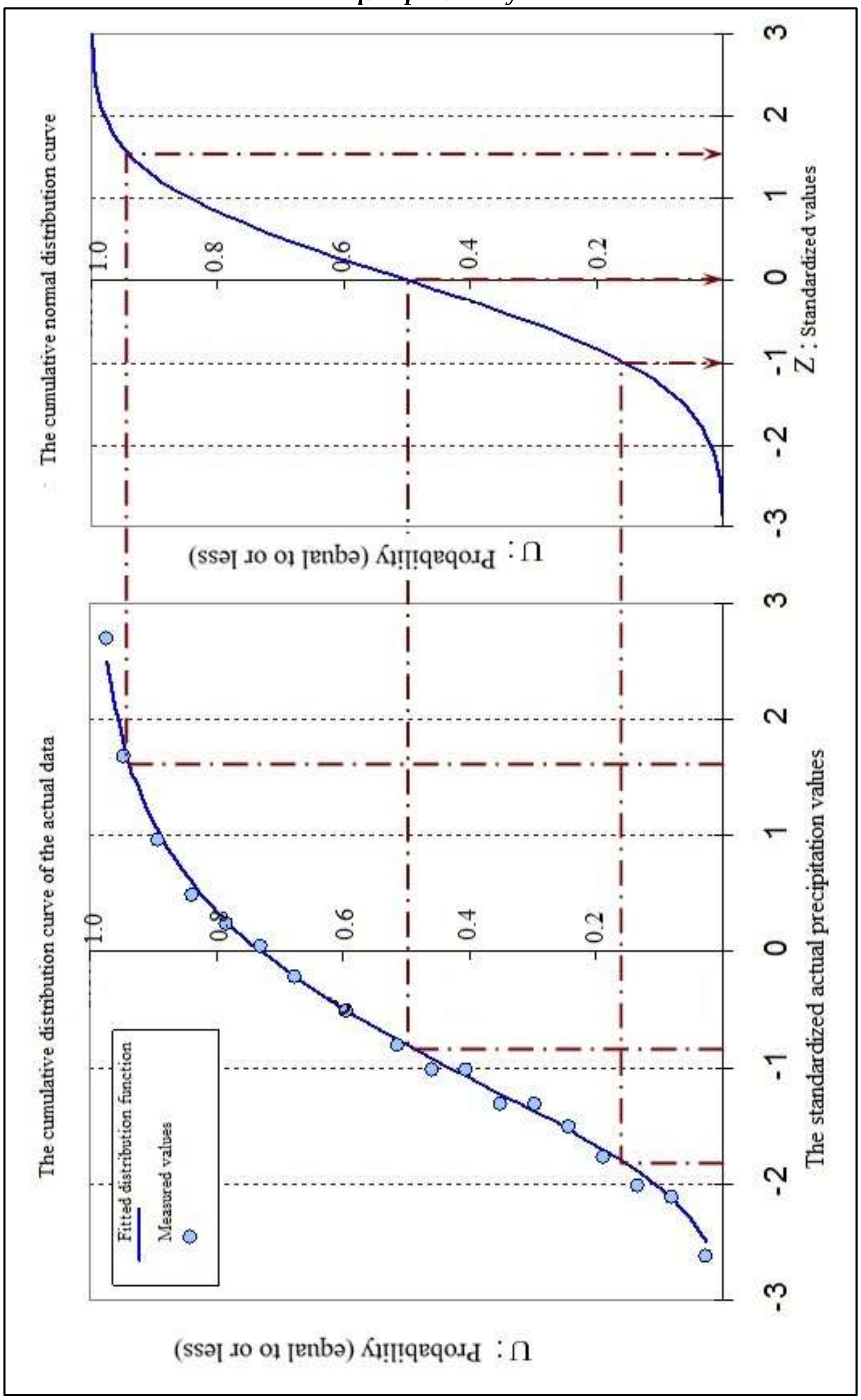
Table 1. Different classes of SPI drought index

Classification of drought	SPI index
Extremely wet	More than +2
Sever wet	Between 1.5 to 2
Mean wet	Between 1 to 1.5
Moderate wet	Between 0.5 to 1
Normal	Between -0.5 to 0.5
Moderate drought	Between -0.5 to -1
Mean drought	Between -1 to -1.5
Severe drought	Between -1.5 to -2
Extremely drought	Less than -2

2. Selecting the most appropriate probability distribution function for the SPI index

The default distribution for the index is Gamma SPI which Easy fit 5.4 software was used to assess the default in this study. Thus, in this study, this index was calculated monthly and taking into account the total effect of last 11 month precipitation on the drought occurrence in the desired month during the desired statistics period. After calculating the effective cumulative precipitation each month (adding precipitation of the month under studying and last 11 month precipitation which is 12 months totally) and sorting the data in ascending order and choosing the most suitable distribution functions and extraction parameters of the distribution, the probable cumulative values were calculated. Then, by using the principle of co-probable transfer, the corresponding values with precipitation amounts in normal distribution are standardized (Figure 2).

Figure 2. The method of transfer and conversion of a statistical distribution into normal distribution through equal probability



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RESULTS AND DISCUSSION

According to this method, drought period occurs when the SPI gets consistently to negative and the value of -1 or less and when it will end that the SPI value gets positive. Results of the number of occurred drought is presented in the Table (2) below.

Table 2. Frequency of different classes of drought in the SPI index for the station (1951-2005)

	January	February	March	April	May	June	July	August	September	October	November	December
Extremely wet	1	2	2	2	0	1	1	1	1	1	1	1
Sever wet	1	0	2	0	3	1	1	1	1	2	2	3
Mean wet	3	3	4	6	5	5	5	6	6	5	6	5
Moderate wet	10	13	9	8	8	11	10	9	9	8	7	8
Normal	20	22	19	20	22	20	19	19	19	23	21	19
Moderate drought	10	4	9	10	8	7	9	9	9	5	10	7
Mean drought	6	8	6	5	5	6	6	6	6	7	3	8
Severe drought	3	2	2	2	2	3	3	3	3	3	4	3
Extremely drought	0	0	1	1	1	0	0	0	0	0	0	0

The most appropriate probability distribution function based on the division of the months under studying with their parameters are presented in Table 3.

Table 3. Results of the bet distribution function fitted to monthly precipitation data in the statistical period (1951-2005)

Months	The most appropriate distribution	Parameters	The number of differences	The driest year	The wettest year
April	Dagum	0.39; 5.66; 126.68; 21.15; 6.43; 18.92	5	1963	1955
May	Pert	93.161 ;34.4; 315.4 ;5.8 ;20.97	8	2000	1955
June	Gama	5.85 ; 20.81	0	2000	1955
July	Gama	5.86 ; 20.77	0	2000	1955
August	Gama	5.86 ; 20.74	0	2000	1955
September	Gama	5.86 ; 20.73	0	2000	1955
October	Gen Gama	1.01; 5.73; 21.83; 5.57; 21.83	3	2000	1955
November	Gen ex val	-0.00014; 42.031; 97.78; 5.47; 22.29	2	1960	1954
December	Dagum	0.48; 5.93; 143.43; 5.5; 22.23	6	1960	1954
January	Chi	1108;-986.63 ;6.12;19.92	9	1966	1955
February	Chi	1172;-1051.1;5.79;20.99	2	1960	1955
March	Jonson Sb	1.86;1.46 ;400.11; 26.41 ;6.7; 18.13	1	2000	1955

As the comparisons in above table show only for warm months like June, July, August and September when precipitation is low, the Gamma distribution can be used to monitor drought, but in other months, it is recommended that the best probable distribution function is adopted for standard Precipitation Index. It should also be noted that the greatest differences in the type of drought classification values equals with 9times, can be seen in January. Also among the statistical years, basically, year of 2000 and 1955 have been known as the driest and wettest year.

CONCLUSION

Meteorological drought which is cited as Drought Climatology in many sources is created by lack of or reduction in the amount of precipitation over a period of time. In this study, which aim is to select the most suitable distribution for drought monitoring more closely based on SPI index and the impact of the adoption of the most appropriate distribution function instead of the default Gamma distribution function on the frequency change of the drought classes and numerical values index SPI, was evaluated, the results showed that in the warm months like June, July, August and September when precipitation is low, the Gamma distribution can be used to monitor drought, but in other months, it is recommended that the best probable distribution function is adopted for the Standardized Precipitation Index. Also among the statistical years, primarily 1955 and 2000 year were known as, the wettest and the driest years, respectively.

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