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Comparison the Suitability of SPI, PNI and DI Drought Index in Kahurestan Watershed (Hormozgan Province/South of Iran)

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Abstract
Drought is a climatic anomaly, characterized by shortage (lack) of rainfall, high evaporation and unsuitable distribution of rainfall. This study investigated and compared the Standardized Precipitation Index (SPI),Percent Normal Precipitation Index(PNPI) and Deciles Index (DI) indices for drought monitoring in Kahurestan watershed in Hormozgan province in south of Iran. In this study, rainfall data of five stations including Kahurestan ,Tedrouye, Dezhgan, Ghalat and Shahgeyb were selected from 1985 to 2010 (26 years). The SPI, PNPI and DI are compared in different stations. Then, Assessment of the suitability of drought index was performed with rainfall minimal symmetry test in the study area**.** Results shows that PNI index due to determine the frequency of droughts and also, accurate showing of drought years with different severities, it is categorized in the first place and DI and SPI are categorized in next place, respectively.
Keywords: Drought, Standardized Precipitation Index (SPI), Percent Normal Precipitation Index (PNPI), Deciles Index (DI), Kahurestan, Hormozgan, Iran

1. Introduction

Drought is a temporary feature resulting from prolonged absence, or deficiency or poor distribution, of precipitation (Ogallo, 1994). Drought is a complex physical and social process of widespread significance. It is not usually a vast phenomenon, with differing conditions in the state often making drought a regional issue. However, the widely accepted classification of drought is meteorological, agricultural, hydrological and socio-economical droughts (Wilhite and Glantz, 1985; Hayes et al., 2010). Meteorological drought is associated with a precipitation shortage and it dependents upon its duration, which can result in agricultural (related to soil moisture) or hydrological drought (related to e.g. stream flow, ground water level, reservoir storage). Socio-economic drought addresses the monetary effects of drought. There are different types of drought classification based on the duration, severity and continuous of that, such as Standardized Precipitation Index (SPI), Aggregate Drought Index (ADI), Percent Normal Precipitation Index (PNPI) and Deciles Index (DI).This is essential that drought indices measured for forecasting and recognizing of the years of drought. Recognizing of drought in the past years helps that water resources are used reasonably in future. It is common in our time the idea that water resources have been decreasing in consequence of several causes, mainly due to less precipitation in certain regions of the planet like the Mediterranean basin, as a result of climatic changes. In fact, it is often said that drought events are becoming more frequent and/or more severe due to climate change (Brunetti et al., 2004; Huntington, 2006).This idea could be supported by several studies using data from the last fifty years such as through the use of trend analysis and principal component analysis in precipitation and SPI time series (Bordi and Sutera, 2001; Bordi and Sutera,2002; Bonaccorso et al., 2003).The numerous studies have performed concern with drought indices. For example, a comparison has performed among the SPI, PNPI and DI in the Khorasan province in Iran. They showed that the most severity of drought years were 1991 and 2001 (Mohammadiyan et al; 2010).The purpose of this study is using of index suitability for assessment of drought phenomena. Finally, it was decided to analyze and monitored SPI, PNPI and DI drought indices in the study area.

1.1. Standardized Precipitation Index (SPI)

Mckee et al. (1993) developed the Standardized Precipitation Index (SPI) for monitoring drought condition based on rainfall. The SPI is computed by dividing the difference between the normalized seasonal precipitation and its long-term seasonal mean by the standard deviation. Thus,

$$SPI=\frac{x_{ij}-\bar{x}}{\sigma} \quad (1)$$

Where, x is the seasonal precipitation at the i^{th} rain gauge and j^{th} observation, $\bar{x}$ the long-term seasonal mean and σ is its standard deviation.

1.2. Percent Normal Precipitation Index (PNPI)

Percent Normal Precipitation Index (PNPI) is one of the simplest indices that it is used in assessment of drought indices. Analysis of the PNPI is effective in the drought and wet time series and during a particular season (Willke et al., 1994).The equation is following as:

$$PN = \frac{Pi}{\bar{P}} \times 100 \quad (2)$$

Where, Pi is annual rainfall and $\bar{P}$is long time rainfall mean.

1.3. Deciles Index (DI)

In this method, originally suggested by Gibbs and Maher (1967), monthly precipitation totals from a long-term record are first ranked from highest to lowest to construct a cumulative frequency distribution. The distribution is then split into 10 parts (deciles). The first decile is the precipitation value not exceeded by the lowest 10% of all precipitation values in a record; the second is between the lowest 10 and 20%, etc. Any precipitation value (e.g. from the current or past month) can be compared with and interpreted in terms of these deciles. Formula for drought calculation is:

$$Pi = \frac{i}{n+1} \times 100 \quad (3)$$

Where, Pi is probability of rain in number ith,$n$is number of rainfall data.
Table 1 shows the Categorization of SPI, DI and PNI values.

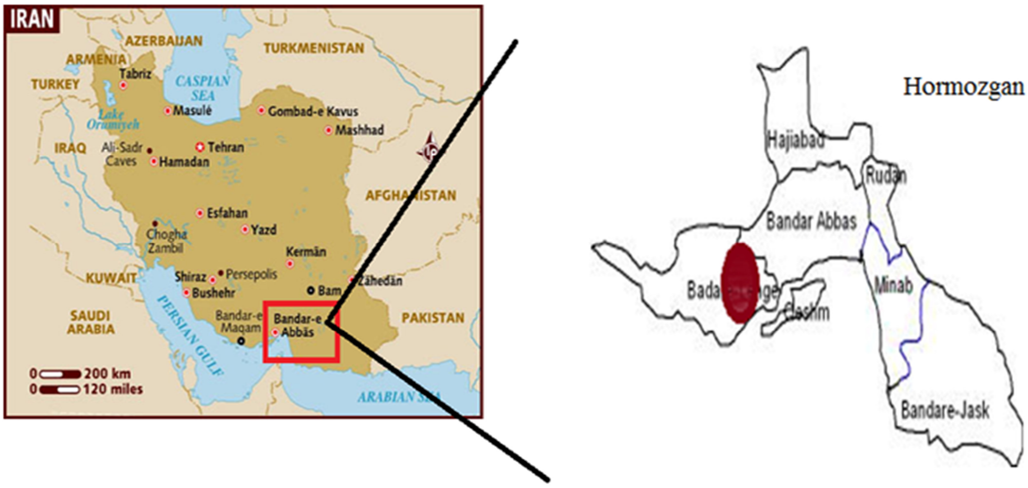
Table I. Categorization of SPI, PNI and DI values into classes

Drought classes	SPI	PNI (%)	DI (%)	Class
Extremely wet	≥2		≥90	7
Very wet	1.5 to 1.99		80 to 90	6
Moderately wet	1 to 1.49	≥ 110	70 to 80	5
Near normal	-0.99 to 0.99	80 to 110	30 to 70	4
Moderately drought	-1 to -1.49	55 to 80	20 to 30	3
Severely drought	-1.5 to -1.99	40 to 55	10 to 20	2
Extremely drought	≤ -2	≤ 40	≤ 10	1

2. Materials and Methods

2.1. Study Area

The Kahourestan watershed is located in 55° 35' 59" E and 27° 10' 33" N in Hormozgan province with171.45 km^2 in about 75 km northwest of Bandar Abbas city, the capital city of Hormozgan province (Fig1).Mean elevation is about 354 m (varies from 100 to 1283). Most of the rainfall (66%) is in winter, and 12.03%, 17.34% and 4.5% in spring, autumn and summer respectively. Temperature varies from 5.72°C to 47.72°C and climate is arid to semi-arid. Geological formations are part of Zagros fold and the Makran mountains string, which is located in the southeast of Iran (Barkhordari, 2003). Based on the FAO international classification method (Dewan and Famouri, 1964) Soils in the study area have been classified in five major groups. These include (Barkhordari, 2003): Leptosoils, Fluvisoil, Solonchaks, Arenosoils, Regosoils and Cambisoils. Main vegetation types are *Prosopis Cineraria ,ZiziphusSpina-hrisi*, and AccaciaTotilis. The main land uses are agriculture and low elevated hills.



Figuer 1. The study area in Iran, Hormozgan Province, Kahourestan Watershed

Table 2. The name of the selected stations over the study area

Stations	Longitude	Latitude	Mean of rainfall (mm)
Kahurestan	55° 35' 59"	27° 10' 33"	155.9
Tedrouye	54°42' 34"	27°17'28"	196.2
Dezhgan	55°16' 46"	26° 53' 00"	142.3
Ghalat	56°04' 03"	27° 17' 30"	142.9
Shahgeyb	55° 01' 03"	27° 54' 06"	163.4

2.2. Data Sources

In this study, rainfall data of five stations including Kahurestan ,Tedrouye, Dezhgan, Ghalat and Shahgeyb were selected from 1985 to 2010 (26 years). All of the rainfall data of rain gauge stations were collected the Regional Water Corporation of Hormozgan province, and used for the selected indices calculation.

3. Result and Discussions

Drought indices are representing of normal limits of droughts occurrences to allow their assessments are possible in the different temporal and spatial scales. In this part is expressed the comparison of suitable among SPI, PNI and DI indices.

Figures of SPI, PNI and DI are show in the26 years period (1985-1986 to 2009-2010), respectively. Rainfall is only required data for the study of drought in SPI, which the result of that is shown in Figure 2.As Figure 2 shows, highest SPI levels is concerned (in five selected stations in the area)in 1991-1992 and 1995-1994 years(with values 2.79 and 2.68), which is very wet conditions in field. Overall, by considering to Table 1, the drought is near normal in the watershed with the SPI index.

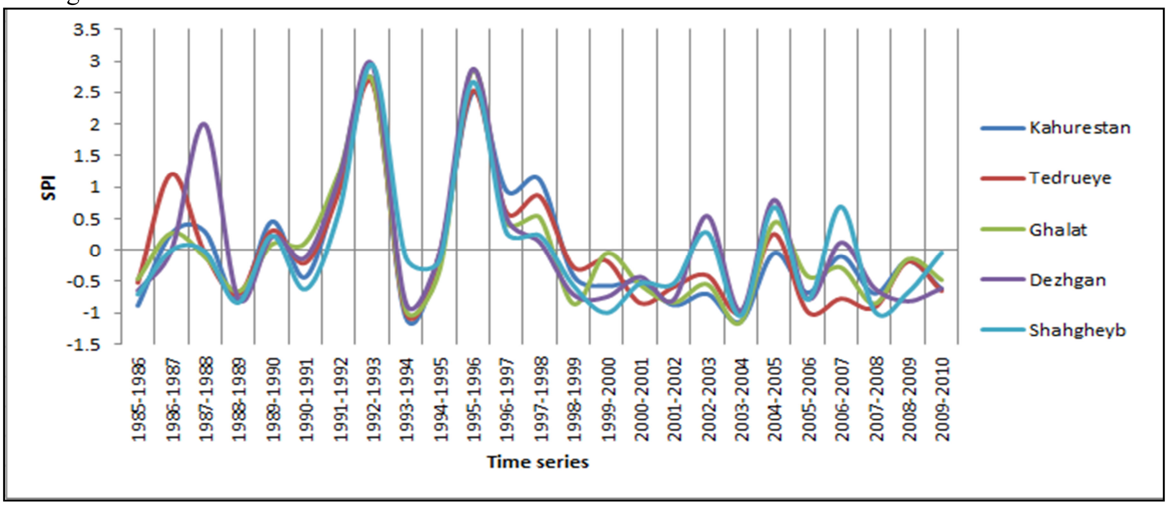


Figure 2. The SPI index for stations of study area (1985-2010)

As figure 3shows, along two-year period from 1992- 1993 years, the highest PNPI value is concerned in the five station with value of 302.37 and 300.02 percent and the lowest PNI value is concerned in the five station with value of 20.75 percent in 2003-2004 years. Thus, the index takes the extremely wet and moderately drought range from 1992 - 1993 and 2003-2004, respectively.

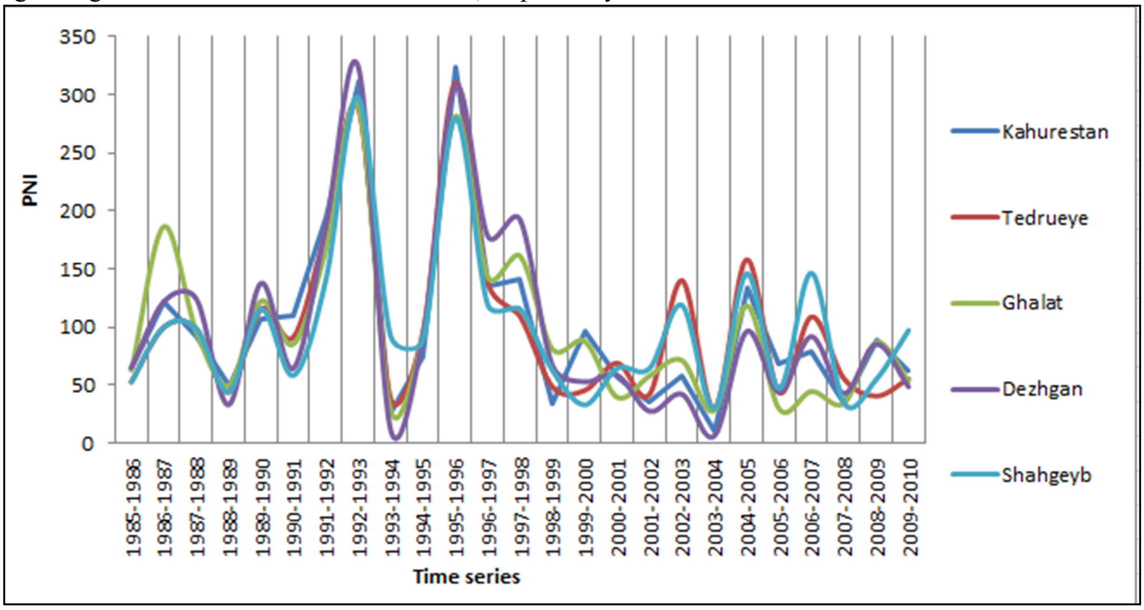


Figure 3. The PNI time series for stations of study area (1985-2010)

Figure4 shows the DI time series for stations of study area. In this figure, the highest DI is concerned (in the five selected stations in the area) with value of 10 percent in 1992-1993 and 1995-1996, respectively, and the lowest DI is concerned with value of 1percentin 1993-1994 and 2003-2004(Boundary between wet and dry years is third decile).Thus, the index takes the severely drought and extremely drought range, respectively.

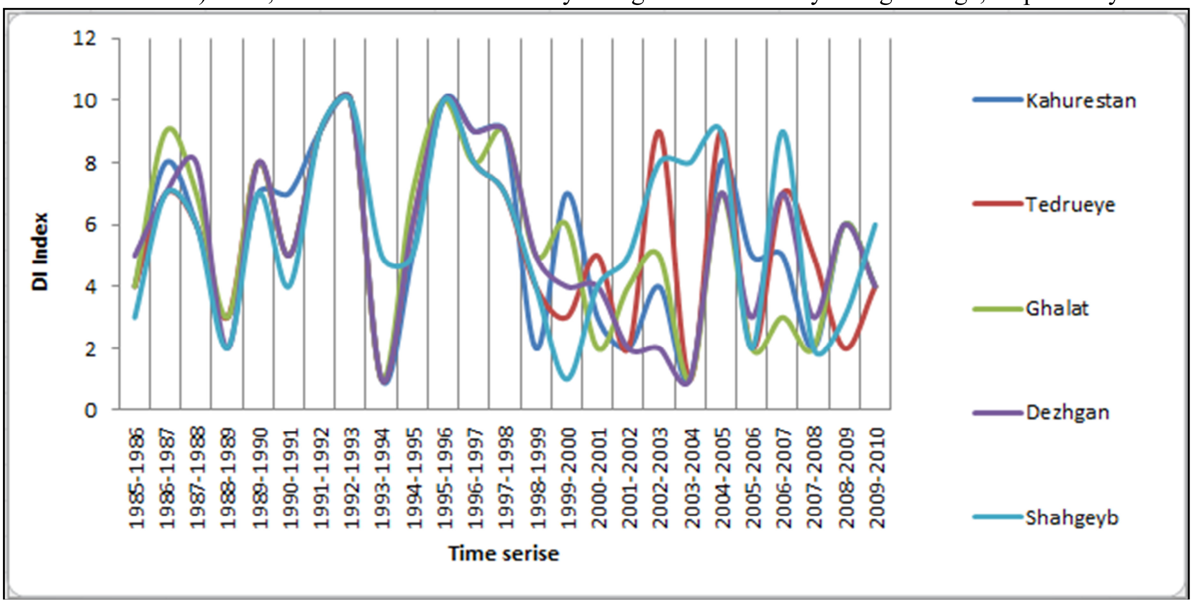


Figure 4. The DI time series for stations of study area (1985-2010)

3.1. Assessment of the suitability of drought index in study area

In order to, assessment of drought indices in this research and the select of the best index were used the rainfall minimal symmetry test. According to this test, the minimum of rainfall collected from each station then each of the drought indices has been assessed. Therefore, accurate assessment and quantify of drought severity were used of three indices (SPI, PNI and DI) to determine the suitable index for stations of study area.

Table 2. Rainfall minimum occurrence (event) test for suitability of drought index at selected stations

Stations	minimum of rainfall(mm)	Year	SPI	PNI	DI
Kahourestan	16.1	2003-2004	3	1	1
Tedrouyeh	49	2003-2004	4	1	1
Dezhgan	8.5	2003-2004	3	1	1
Ghalat	41.5	2003-2004	3	1	1
Shahgeyb	57.5	2003-2004	3	1	6

In this table (2) the numbers is representing the classes of drought in table 1. In above table the class of 1, 3, 4 and 5 is representing extremely drought, moderately drought, near normal and moderately wet. Here by, three indices are analyzed by Rainfall minimum occurrence test. Rainfall minimum occurrence test shows which PNI index presents the drought event of severe in all of the stations and higher performance than the standardized precipitation index in extremely drought present. Decile index of rainfall minimum occurrence test is shown which an extremely drought occurred in all stations except a station.

Table 3. Comparison of the drought characteristics in Kahurestan(1985-2010)

Year	SPI	PNI	DI
1985	Near normal	Moderately drought	Near normal
1986	Near normal	Moderately wet	Moderately wet
1987	Near normal	Near normal	Near normal
1988	Near normal	Severely drought	Severely drought
1989	Near normal	Moderately wet	Near normal
1990	Near normal	Near normal	Near normal
1991	Near normal	Moderately wet	Very wet
1992	Extremely wet	Moderately wet	Extremely wet
1993	Near normal	Extremely drought	Extremely drought
1994	Moderately drought	Near normal	Near normal
1995	Extremely wet	Moderately wet	Extremely wet
1996	Near normal	Moderately wet	Very wet
1997	Near normal	Moderately wet	Very wet
1998	Near normal	Moderately drought	Moderately wet
1999	Near normal	Moderately drought	Near normal
2000	Near normal	Moderately drought	Near normal
2001	Near normal	Severely drought	Severely drought
2002	Near normal	Near normal	Near normal
2003	Moderately drought	Extremely drought	Extremely drought
2004	Near normal	Moderately wet	Moderately wet
2005	Near normal	Severely drought	Moderately drought
2006	Near normal	Severely drought	Near normal
2007	Near normal	Severely drought	Severely drought
2008	Near normal	Moderately drought	Near normal
2009	Near normal	Moderately drought	Near normal
2010	Near normal	Moderately drought	Near normal

As table (3) shows, all of the drought classification are analyzed in seven classes that it is discussed in table (1). Above table determines the value of the classes such as extremely wet, very wet, moderately wet, near normal, moderately drought, severely drought and extremely drought based on available data in the study area. Finally, finding results is showed in table (4).

Table 4. Result of frequency of SPI, PNI and DI index in Kahurestan area

Classification	Frequency of SPI Index	Frequency of PNI Index	Frequency of DI Index
Drought	8%	54%	23%
Near normal	84%	15%	50%
Wet	8%	31%	27%

As table 4 shows, drought frequency values in PNI and DI have the similar situation and the suitable output. According to select of the most suitable index in drought analysis, the PNI index due to determining of the frequency of droughts in Kahurestan watershed and also, accurate showing of drought year with different severities, it categorizes in the first place and the DI index due to more compliance with PNI index , it categorizes in the second place. The SPI index due to the distinguishing characteristics in identify and earlier drought periods appearance than droughts others, it categorizes in the third place.

Conclusion

To sum up, among three used indices, it can be concluded that the suitability of index is PNI index in study region. Because of determining the frequency of droughts and also, accurate showing of drought years with different severities, it categorizes in the first place and DI and SPI are categorized in next place, respectively.

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