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Index of drought and wet years using the percentage of normal (PNPI) and Nietzsche Semnan

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Abstract

Hazards such as drought, which is affecting all aspects of life and the environment, so understanding the sources and across different environments, can be an important step in resource management. In this study the province's rainfall, annual rainfall data for stations of Semnan, Shahrood, Damqan, Garmsar and Biarjmand, for calculation of wet and dry years were used for statistical analysis. There are different indicators for quantifying drought phenomenon. Indicators used in this study measures the Percent of Normal Precipitation Index (PNPI) and Nietzsche Index . The findings lead to the precipitation and the frequency of wet years and drought conditions in the stations was studied. The overall results indicate that in both Nietzsche and PNPI all stations during the study period with normal conditions have been met. However, the frequency of occurrence in normal years Nietzsche's approach is far more of PNPI.

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Introduction

Among the climate elements, rainfall has the most fluctuations. This is more important particularly in a country like Iran, where the average annual precipitation is about 250 mm. therefore, it is common and natural to observe drought with different intensities and destructive wet years in Iran (Azizi, 2003). Iran is located in arid or desert areas that naturally years with below average rainfall in it are more than years with more than average Long-term annual rainfall. Drought is one of the most persistent natural disasters. In recent decades, among the natural disasters that have affected human population, the frequency of this phenomenon is more than other events (Alijani, 2009).

Drought cause low crop production, loss of livestock, pastures destruction, soil erosion and falling groundwater levels. Drought diagnosis before it become serious is very difficult due to its slow growing nature. Nevertheless, if the exact pattern of drought is identified in the early stages of its development, there is sufficient time to prepare for the worst situation. Thus, drought indices have been developed to quantify the drought situation. Lack of a clear and precise definition of drought is one of the main obstacles in effective investigation of this phenomenon. Because of different variables that are involved directly or indirectly in drought, definition of this term is difficult to define and there is no comprehensive definition of drought.

Palmer's (1965) researches about the drought are of the early researches that has considered drought as lack of continued and abnormal (mean deviation from the normal conditions or long term mean of meteorological parameters). Many profiles have been proposed to determine the characteristics of meteorological drought. Drought profiles are calculated based on one or more climatic variables. Percent of Normal Precipitation Index (PNPI), Rainfall Anomaly Index (RAI), Deciles of precipitation Index (DPI), Standardized Precipitation Index (SPI) and Bahlme and Mooley Drought Index (BMDI) profiles are based solely on the use of rainfall variable. Many studies have been done in Iran regarding drought history and its problems. Below are a few examples of studies conducted by the researchers. Nahavi *et al*., using annual precipitation data of synoptic station in Rasht, Babolsar, Anzali, Gorgan and Ramsar in a period of 45 years and PNPI, RAI ,SPI, SLPA and Nietzsche indicators calculated intensity and frequency of drought in three periods 15 years. Different indicators of drought years relate to 1991 and 1955. Zare' abyane *et al*. (2009), in comparative study of four profiles of metrological drought concluded that RAI, Z and SPI profiles in seasonal and annual scales and PNPI in seasonal scale present good estimates of intensity and persistence of drought. Bourdi *et al*. (2001), has used spi factors to study drought conditions in Italy. Uojoich (2004), studied drought patterns in Valencia during 1951-2009 using 95 set of annual precipitation and SPI index. KhalighiSigaroudi *et al*. (2009), studied evaluation profiles of wet years and drought in Mazandran and concluded that among SPI and PNPI profiles which are used in research, SPI have higher accuracy in separating wet and dry periods because of higher capacities like accurate differentiation of classes and higher sensitivity to rainfall changes and it is the best model for determining rainfall statistical characteristics (intensity and frequency) and differentiating wet years and drought. One of important action in predicting drought in each area is quantifying different climate phenomena and using profiles in order to analyze amount, intensity and persistence of these phenomena. Purpose of this study in measuring capabilities of two profiles of meteorological drought (Nietzsche and PNPI) in studying intensity and duration in Semnan province.

Material and methods

In this study, annual rainfall data from Semnan stations were selected in statistical period 26 years (1986 – 2011). Geographical and statistical characteristics of study stations are presented in table (1). In order to reconstruct statistical defects and data

homogeneity analysis using normal ration, data were completed and their accuracy were measured and finally wet years and droughts were studied. In order to determine and classify wet years and droughts of study stations, two methods PNPI and Nietzsche index were used. Geographical coordinate system and statistical period of study stations were shown in table (1).

Table 1. Geographical coordinate and statistical period of study stations.

station	Semnan	Shahrood	Damqan	Garmsar	Biarjmand
Longitude	53	54	54	52	55
Latitude	35	36	36	35	36
AMSL	1130/85	1380	1154/5	825/2	1106/2
Period of study	1986 – 2011	1986 – 2011	1986 – 2011	1986 – 2011	1992 – 2011

Percent of Normal Precpitation Index (PNPI)

PNPI is a simple drought index. This has caused many researchers especially Australian researches apply it. This index is calculated by following formula:

$$PN = \frac{P_i}{\bar{P}} 100$$

where P_i is year I rainfall and P is mean rainfall in statistical years. This index is always positive and is limited to zero from below and in upper part it has no theoretical limitation. Different classes of this index are presented in this table(2).

Table 2. Compared to classify the severity of the drought based PNPI method.

Index	Normal threshold	Drought weak	Drought Moderate	Drought Severe	drought
PNPI	80-120	70-80	55-70	40-55	< 40

Index Nietzsche

Nietzsche used table (3) equation for studying wet years, drought and normal years applying annual rainfall data I that p_I is year i rainfall and SD is standard deviation of rainfall during statistical period and p is mean long term rainfall. Regarding above equations, this method has a limitation for normal rainfall (equation 1) and two threshold value for beginning wet year (equation 2) and drought year (equation 3). Table (3) shows different classes of studied indices for all drought indices.

Table 3. Drought classification based on Nietzsche.

Index Nietzche	$\bar{p} - SD \leq p_i \leq \bar{p} + SD$	$p_i \geq \bar{p} + SD$	$p_i \leq \bar{p} - SD$
Classes drought	Normal	wet	drought

Results

Annual rainfall statistical parameters of Semnan stations are presented in table (4). The most important results of rainfall statistical analysis are as followed: Shahrood has the highest and Damqan has the least mean rainfall and long-term standard deviation between studied stations. Rainfall change factors indicate stability of rainfall in Semnan station and instability in other station especially Biarjmand. Skew of Shahrood, Biarjmand and Damqan stations have highest and skew of Garmsar and Semnan have lower values that indicates symmetry of annual precipitation in Garmsar and Semnan stations and severe asymmetry of Shahrood, Biarjmand and Damqan.

Table 4. Statistical properties of station under drought in Semnan Province.

Statistics \ station	Semnan	Shahrood	Damqan	Garmsar	Biarjmand
Average	143/9	158/7	104/6	119/2	127/3
Median	149/6	157/7	103/9	120	122/7
Minimum	67/8	90/2	46/1	38/8	61/3
Maximum	209/9	312/8	168/2	176/4	225/3
Range	142/1	222/6	122/1	137/6	164
Skewness	-0/26	1/4	0/01	-0/47	0/54
Kurtosis	-1/07	2/3	-1/22	-0/17	-0/42
Standard deviation	43/0	53/4	34/8	38/4	44/9
Coefficient of Variation (CV)	29/9	33/6	33/2	32/2	35/3

Percent of Normal Precpitation Index (PNPI)

Results of calculated model output by PNPI in 5 rainfall measuring stations in Semnan: results show that all studied stations except Damqan station have normal rainfall trend. In 26 statistical years, Shahrood and Damqan have highest and lowest normal periods, respectively. Regarding number of dry years Damqan and Biarjmand have highest dry years with 9 years and other stations have least dry years. The longest drought period in Biarjmand stations is a consecutive drought period from 1999 to 2001. Regarding wet years, Semnan station during 1986 to 1987 and Damqan and Garmsar during 2002-2004 have highest wet year.

Table 5. Classification status of annual precipitation, based on PNPI (1986- 2011).

Year	Semnan	Shahrood	Damqan	Garmsar	Biarjmand
1986	Wet	Normal	Wet	Wet	Wet
1987	Wet	Wet	Normal	Normal	Normal
1988	Wet	Normal	Normal	Normal	Normal
1989	Drought	Normal	Drought	Normal	Drought
1990	Drought	Drought	Drought	Drought	Drought
1991	Wet	Wet	Wet	Wet	Wet
1992	Normal	Wet	Wet	Wet	Wet
1993	Drought	Normal	Drought	Drought	Drought
1994	Normal	Drought	Normal	Normal	Normal
1995	Wet	Wet	Wet	Wet	Wet
1996	Normal	Drought	Drought	Drought	Drought
1997	Normal	Normal	Normal	Normal	Normal
1998	Normal	Normal	Drought	Normal	Normal
1999	Normal	Normal	Wet	Drought	Drought
2000	Normal	Normal	Drought	Normal	Drought
2001	Drought	Drought	Drought	Drought	Drought
2002	Wet	Normal	Wet	Wet	Wet
2003	Normal	Normal	Wet	Wet	Normal
2004	Wet	Normal	Wet	Wet	Wet
2005	Wet	Drought	Drought	Normal	Drought
2006	Wet	Normal	Normal	Normal	Wet
2007	Normal	Normal	Wet	Normal	Drought
2008	Drought	Drought	Drought	Drought	Normal
2009	Normal	Normal	Wet	Normal	Normal
2010	Drought	Normal	Normal	Normal	Normal
2011	Wet	Normal	Wet	Normal	Normal

Fig. (1), show drought Frequency based on PNPI index. The main results of this calculation are as follows:

Based on this index, normal years had highest frequency and Damqan and Biarjmand have highest dry year.

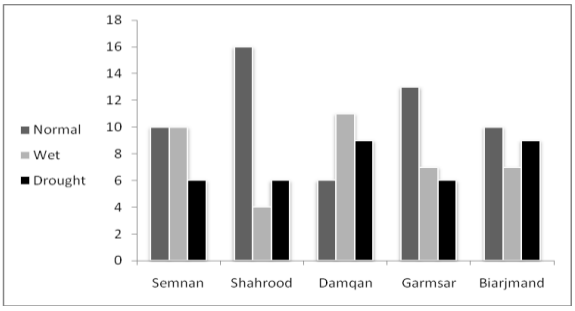

Fig. 1. drought Frequency based on PNPI index

Index Nietzsche

Using Nietzsche equation and rainfall threshold value in study stations in table (6), we determined and classified normal, wet and dry years in Semnan. In table (7), we can observe annual rainfall classification. Results show that Shahrood and Garmsar with 3 dry years have least drought and Semnan, Damqan and Biarjmand stations with 5 dry years have highest drought. The longest drought period can be observed by two-year drought period in Semnan and Biarjmand that this drought has occurred in 1989 to 1990. Semnan and Garmsar had 5 wet years and Damqan with 3 years had least years. Results of Nietzsche method and rainfall analysis showed that all stations in most statistical period rainfall are in normal condition. It is worth mention that years with normal rainfall are equally divided between stations and all of them have experienced wet year and drought.

Table 6. Using Nietzsche equation and rainfall threshold value in study stations.

	Semnan	Shahrood	Damqan	Garmsar	Biarjmand
Drought threshold	< 100/9	< 105/3	< 69/8	< 80/8	< 82/4
The normal range	100/9-186/9	105/3-212/1	69/8- 139/4	80/8- 157/6	82/4- 172/2
Wet threshold	> 186/9	> 212/1	> 139/4	> 157/6	> 172/2

Table 7. Classification status of annual precipitation, based on Nietzsche (1986- 2011).

Year	Semnan	Shahrood	Damqan	Garmsar	Biarjmand
1986	Wet	Normal	Normal	Wet	Normal
1987	Normal	Wet	Normal	Normal	Normal
1988	Normal	Normal	Normal	Normal	Normal
1989	Drought	Normal	Normal	Normal	Normal
1990	Drought	Normal	Drought	Drought	Drought
1991	Wet	Wet	Normal	Normal	Wet
1992	Normal	Wet	Wet	Wet	Wet
1993	Drought	Normal	Normal	Normal	Normal
1994	Normal	Normal	Normal	Normal	Normal
1995	Wet	Wet	Normal	Wet	Wet
1996	Normal	Drought	Drought	Drought	Drought
1997	Normal	Normal	Normal	Normal	Normal
1998	Normal	Normal	Normal	Normal	Normal
1999	Drought	Normal	Normal	Normal	Normal
2000	Drought	Normal	Normal	Normal	Normal
2001	Drought	Drought	Drought	Normal	Normal
2002	Wet	Normal	Wet	Wet	Wet
2003	Normal	Normal	Normal	Normal	Normal
2004	Wet	Normal	Wet	Wet	Normal
2005	Normal	Drought	Drought	Normal	Drought
2006	Normal	Normal	Normal	Normal	Normal
2007	Normal	Normal	Normal	Normal	Normal
2008	Drought	Normal	Drought	Drought	Normal
2009	Normal	Normal	Normal	Normal	Normal
2010	Normal	Normal	Normal	Normal	Normal
2011	Normal	Normal	Normal	Normal	Normal

Fig. (2), show drought Frequency based on Nietzsche index. The main results of this calculation are as follows:

Based on this index, normal years had highest frequency and Damqan, Semnan and Biarjmand have highest dry year.

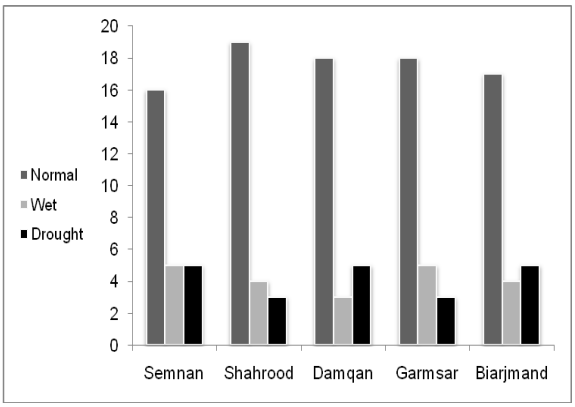

Fig. 2. drought Frequency based on Nietzsche index

Application of profiles based on rainfall in this research indicates used thresholds in computational methods. Each of PNPI and Nietzsche methods has specified wet years and drought with minor differences. In both methods, all stations faced normal condition during statistical period. But regarding frequency, normal years in Nietzsche method is higher than PNPI method. Based on Nietzsche from 26 statistical years, 18 years had normal conditions. On the contrary, in PNPI drought and wet years had higher frequencies. Drought years have negative effects on quantity and quality of water resources and ranges. Because droughts like other climatic phenomena have return period, predicting drought in each stations can help us in confronting and overcoming droughts and crisis caused by rainfall shortage. But shortage of statistical period related to climatic elements especially rainfall does not prevent prediction based on Marcov chains (which needs at least 75 years statistical period). Regarding climatic nature of Iran and area which drought is part of it, it is necessary to create optimal water consumption culture, to develop pre-alarming systems, correct management and accurate planning of water resources especially water storage in high rainfall years (including artificial feeding of aquifers) to pass drought.

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