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# Investigate the relationship between hydrological and meteorological droughts in Karaj dam Basin

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**ABSTRACT**

*Drought is a deficiency in precipitation over an extended period, usually a season or more, resulting in a water shortage causing adverse impacts on vegetation, animals and people. It is a normal, recurrent feature of climate that occurs in virtually all climate zones, from very wet to very dry. In this study for assessment and analysis the occurrence of droughts use from Standardized Precipitation Index (SPI) and Standardized Discharge Index (SDI). For this purpose, used from fifteen monthly meteorological stations statistics as well as five stations in Karaj Dam basin and indices were evaluated in six time periods (3, 6, 9, 12, 24, 48 monthly). To study the effect of drought on surface water resources the first were examined relationship between rainfall and discharge and a time lag of rain fall rate was calculated. Then Standardized Precipitation Index and Standardized Discharge Index evaluated on different timescales with using Pearson correlation in the whole area was compared by separation in the sub-basin. The results shows that time relationship occurrence of Meteorological drought and hydrological with together in99% level is significant as well as in the range of 3months was maximum. Occurrence of drought in the area their effect showed on the same month on the same month and one month delay on surface water sources. The highest correlation is related to the following areas of the Sira station which can be attributed to the geographic location of the studied watershed.*

**Keywords:** SPI, SDI, Pearson correlation, Karaj Dam basin

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## INTRODUCTION

Drought has been identified as one of the environmental phenomena and in fact is an integral part of climate change that can happen in any geographic area. The drought phenomenon has the various types of drought that divides to meteorological, hydrological, and agricultural as well as socio-economic[16]. The first meteorological drought occurs that refers to lack of rainfall. Meteorological drought led to a lack of soil moisture and agricultural production as well as increases the risk of forest fires (agricultural drought).With its development hydrological drought occurs when surface water flow scarcity and ground water relative to the normal condition.

Drought is a complex term that has various definitions, depending on individual perceptions e.g. in farmer's language "a shortage of rainfall or a long period of time without any rainfall", or a period of below average rainfall

or a prolonged period of dryness that can cause damage to plants. It may be categorized into different types e.g. Meteorological, Hydrological, Agricultural and Socio-economic drought. The glossary of Meteorology defines drought as a period of abnormally dry weather sufficiently prolonged for the lack of water to cause serious hydrological imbalance in the affected area, on the degree of dryness and the duration of dry spell [8].

Although, many erroneously consider it a rare and random event but drought is a normal, recurrent feature of climate. It can occur in virtually all climatic zones, with its characteristics varying significantly from one region to another. It is an insidious hazard of nature. Drought is a reoccurring phenomenon in the northwestern part of Bangladesh. Though the drought has attracted less scientific attraction than flood or cyclone, several authors found that the impact of drought can be more defenseless than flood and cyclone [1].

Moradi and et al.[13] with use SPI and SDI study assessment of Meteorological and hydrological drought in Khoram Abad basin. The results of the statistical analysis and comparison between SPI and SDI indices showed that the dominant mode in this area is almost normal. Kashefi[10] to evaluate the temporal and spatial risk of drought occurred in Semnan province used from SPI. The results showed that occurrence of drought in the region reveals their effect immediate or one month delayed on surface water sources. Hedari[7] study Meteorological and hydrological drought in the southwest of Iran. Their results showed that hydrological drought in the Urmia city with a one-month delay and in Khoy city with a time lag of 2months, than meteorological drought has been occurrence. Stability of Hydrological drought respectively three months and five months was determined after the event. Serrano and Lopez study SPI drought in Spain to compare different time-scale with surface hydrologic variables. Their research results showed that the overall surface flows with short periods of 1 to 3 month SPI and ground water resources with longer periods of 7 to10 months are most correlated. This study aimed to investigate the relationship between drought in different period to determine relationship between meteorological drought and hydrological drought is done with using SPI and SDI in Karaj Dam basin.

## MATERIALS AND METHODS

Case study

Karaj Dam basin is partial of southern slopes of the Alborz Mountain in Northwest of Tehran province and located between 51˚ 5′ 38″ until 51˚ 30′ 57″ east longitude and 35˚ 52′ 56″ until 36˚11′ 49″ north latitude. This basin in divided is a part of Salt Lake basin its areais778 square kilometers. The highest point in the area with an altitude of 4368meters in Dizin and the average height of basin is 2827 meters above sea level and drainage density equal to 7.1 $km^2$.km. The lowest annual rainfall is for Karaj Dam station with 418.33 mm and the maximum is for Nesa station with 667.43 mm. The climate of region is wet as well as precipitation regime in the region is Mediterranean type. Average slope of the study area is about 43.84 percent. Most of the soils are litho soil and rego soil and soil depth in more than half are shallow as well as pebbles. Soil texture in the study area is mainly sandy loam. The most land use that can see in region is rangeland and forest.

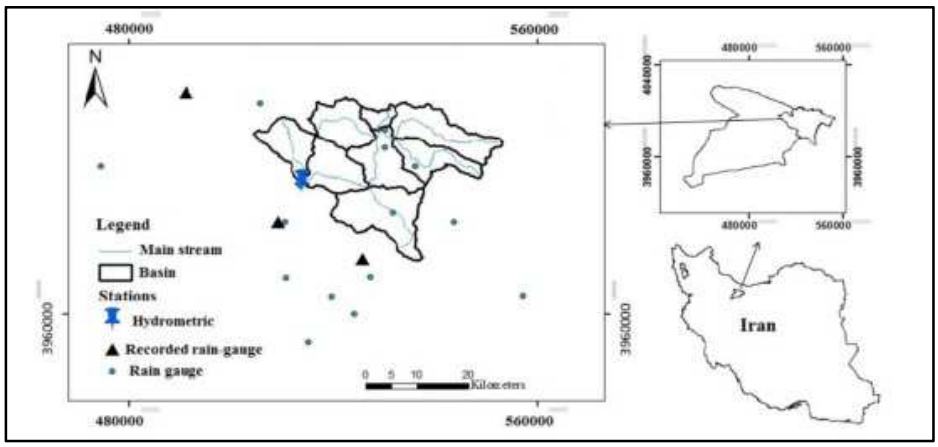


**Fig 1. Case of study**

Standardized Precipitation Index (SPI)

If the monthly rainfall time series of stations in area are referred to $P_{ij}$ in this i is hydrological year and j is months of the hydrological year. Rainfall time series with different periods can be obtained using the following equation.

$$R_{ik} = \sum_{j=1} P_{ij}$$

$i = 1,2, \ldots \quad j = 1,2, \ldots ,12 \quad k = 1,2,3,4,5,6$

SPI based on high cumulative rainfall ( $R_{ik}$ ) for the basis period (k) Relating to(i) hydrological year is obtained as following equation.

$$SPI_{ik} = \frac{R_{ik} - \overline{R_k}}{S_k}$$

$i = 1,2, \ldots \quad k = 1,2,3,4,5,6$

$\overline{R_k}$ and $S_k$ is the mean height of cumulative rainfall and standard deviation cumulative rainfall for the based on k. Table1showed the various modes of drought in SPI.

**Tab 1. Classes of SPI**

| Description | Range |
|---|---|
| Extremely Wet | $+2 \leq SPI$ |
| Moderately Wet | $1.5 \leq SPI < 2$ |
| Wet | $1 \leq SPI < 1.5$ |
| Neutral | $-1 \leq SPI < +1$ |
| Dry | $-1.5 \leq SPI \leq -1$ |
| Moderately Dry | $-2 \leq SPI < -1.5$ |
| Extremely Dry | $SPI < -2$ |

Standardized Discharge Index

In this study SDI is quite similar with SPI. In this method, assumed that the time series of monthly stream flow volumes i is as that is hydrological year and j is months of the hydrological year. This series is based on the following equation.

$$V_{ik} = \sum_{j=1} Q_{ij}$$

$i = 1,2, \ldots \quad j = 1,2, \ldots ,12 \quad k = 1,2,3,4,5,6$

k is based on monthly. K values against 1, 2, 3, 4, 5, and 6 as well as respectively represent time periods 3, 6, 9, 12, 24 and 48 monthly. Standardized Discharge Index based on the cumulative volume of river flows $V_{ik}$ under for the period k About I hydrological year is obtained following equation.

$$SDI_{ik} = \frac{V_{ik} - \bar{V}_k}{S_k}$$

$i = 1,2, \ldots \quad k = 1,2,3,4,5,6$

Respectively $\overline{V_k}$ and $S_k$ is mean total volume flow and standard deviation of cumulative flow volume for under period k. Table2 showed the various modes of drought in SDI.

**Tab 2. Classes of SDI**

| Description | Range |
|---|---|
| Non-drought | SDI ≥ 0.0 |
| Mild drought | -1.0 ≤SDI<0.0 |
| Moderate drought | -1.5 ≤SDI<-1.0 |
| Severe drought | -2.0 ≤SDI< -1.5 |
| Extreme drought | SDI< -2.0 |

To investigate the effects of drought on surface flow initially the relationship between rainfall and discharge were studied in the area and calculated latency effect of rainfall on discharge. Then SPI and SDI in the sixth period (3,6,9,12,24 and 48 monthly) study by pearson correlation method and separately was compared to the same sub basin.

## RESULTS AND DISCUSSION

Initially to study the effect of drought on surface water resources determined deficient precipitation and then time delay surface flow reduce than it was estimated. In order to investigate the relationship between precipitation and surface water flow in Karaj dam basin of two methods Comparison rainfall weighted average with Sierra station (Located in the basin output) and rainfall weighted mean comparison with discharge weighted average were used. Results showed a significant relationship in the level of 99% there are between precipitation and surface water flow and the highest correlation occurs between them in the same month or a one-month lag (tab 3).

**Tab 3.Pearson correlation coefficients with different time delays**

| Sierra Station | 48 | 24 | 12 | 9 | 6 | 3 |
|---|---|---|---|---|---|---|
| Same time | $0.541^{**}$ | $0.642^{**}$ | $0.688^{**}$ | $0.736^{**}$ | $0.794^{**}$ | $0.821^{**}$ |
| One month lag | $0.509^{**}$ | $0.622^{**}$ | $0.667^{**}$ | $0.735^{**}$ | $0.787^{**}$ | $0.813^{**}$ |
| Two month lag | $0.465^{**}$ | $0.549^{**}$ | $0.619^{**}$ | $0.709^{**}$ | $0.774^{**}$ | $0.795^{**}$ |

95%*
99% **

Comparison of the two methods showed no significant difference between the m and so the Sierra discharge station at the outlet of the study area can be used as representative of the whole field (tab 4).

**Tab 4.F-test for comparison between the two methods of rainfall and discharge**

| Condition Test | P | Freedom degree | F |
|---|---|---|---|
| The lack significant differences | 0.5 | 2 | 1.3 |

To investigate the relationship between meteorological and hydrological drought, weighted average of SPI and SDI in the whole basin and the breakdown basin were compared with sixth time scale and was calculated pearson correlation coefficient. Results showed that the highest correlation between SPI and SDI scale is in 3monthsso the correlation is significant even at the 99%confidence level (tab 5). Also, the results of Pearson correlation between SPI and SDI shows that the highest correlation is related to Sierra station which can be attributed to the location of the domain (tab6).

**Tab 5.Pearson correlation coefficient between SPI and SDI**

| $SPI_{48}$ | $SPI_{24}$ | $SPI_{12}$ | $SPI_9$ | $SPI_6$ | $SPI_3$ | Index / period |
|---|---|---|---|---|---|---|
| $0.471^{**}$ | $0.515^{**}$ | $0.685^{**}$ | 0.728 | $0.731^{**}$ | $0.745^{**}$ | $SDI_3$ |
| $0.250^{**}$ | $0.532^{**}$ | $0.553^{**}$ | 0.702 | $0.720^{**}$ | $0.736^{**}$ | $SDI_6$ |
| $0.244^{**}$ | $0.416^{**}$ | $0.540^{**}$ | 0.621 | $0.719^{**}$ | $0.730^{**}$ | $SDI_9$ |
| $0.228^{**}$ | $0.383^{**}$ | $0.542^{**}$ | 0.593 | $0.718^{**}$ | $0.721^{**}$ | $SDI_{12}$ |
| $0.226^{**}$ | $0.348^{**}$ | $0.465^{**}$ | 0.549 | $0.708^{**}$ | $0.713^{**}$ | $SDI_{24}$ |
| $0.123^{**}$ | $0.179^{**}$ | $0.246^{**}$ | 0.347 | $0.531^{**}$ | $0.692^{**}$ | $SDI_{48}$ |

*95%**
*99% ***

**Tab 6.Pearson correlation coefficient between in sub basin**

| $SPI_{48}$ | $SPI_{24}$ | $SPI_{12}$ | $SPI1_{9}$ | $SPI_{6}$ | $SPI_{3}$ | Sub basin |
|---|---|---|---|---|---|---|
| 0.289v | 0.318** | 0.487** | 0.528** | 0.629** | 0.676** | Ksyl Nesa |
| 0.362** | 0.428** | 0.542** | 0.619** | 0.638** | 0.708** | Shahrestanak |
| 0.439** | 0.502** | 0.638** | 0.665** | 0.731** | 0.742** | Tekye Sepahsalar |
| 0.472** | 0.524** | 0.675** | 0.752** | 0.773** | 0.793** | Sierra |
| 0.187** | 0.329** | 0.453** | 0.542** | 0.607** | 0.619** | Varangeh Rood |
| 0.207** | 0.371** | 0.429** | 0.576** | 0.624** | 0.637** | Velayat Rood |
| 0.117** | 0.228** | 0.329** | 0.472** | 0.503** | 0.518** | Kandovan |
| 0.102** | 0.182** | 0.284** | 0.376** | 0.428** | 0.520** | Azadbar |

*95%**
*99% ***

## CONCLUSION

The results of this review is similar with the results of the research Moradi et al. (2009), Hedari et al. (2009) and Mofidi et al. (2010). Review temporal discipline Meteorological and hydrological drought in region shows the highest correlation occurs at 3-month intervals. So even at the 99% level is significant and with increasing time scale the correlations of SPI and SDI decreased in region that results Conform with Mofidi et al. (2010). Correlation is weak $SPI_{48}$ which indicates that this time scale can't describe hydrological drought as well as the surface flow. The review showed that there is the highest correlation between the spatial discipline meteorological and hydrological droughts in Sierra sub basin. The correlation between meteorological and hydrological drought in the Sierra station can be linked to the location of rainfall and hydrometric stations.

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