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Effect of drought on groundwater levels drop in Kermanshah Province

Jaber Soltani, Fariba Khodabakhshi, Mohammad Dadashi

Abstract—Drought is a natural disastrous phenomenon that occurs due to the continuous reduction of rainfall over a short or a long period of time. A deficit in precipitation (meteorological drought) can result in a recharge deficit, which in turn causes lowered groundwater heads and a deficit in groundwater discharge. Given the importance of water in human life, it is necessary to determine the relationship between drought and groundwater levels. This paper related to a drop in groundwater levels in the plains of Kermanshah in a 13-year period (1998-2011) using data on precipitation and groundwater, and DIP and SPSS software has been examined. First by using SPI indices and other derived parameters such as the number of months in the face of drought and drought magnitude (DM), long-term drought conditions in the study area have been investigated. Then correlation coefficient between the time scales of SPI index of 1, 3, 6, 9, 12, 18, 24, 48 months with groundwater level with time lag 1, 2, 3, 4, 5, 6, 9, 12, 18, 24, and 48 monthswere calculated, for the plain, And a time scale and the optimal time lag that highest correlation is introduced, then linear regression between groundwater level fluctuations on time scales of SPI Index and the optimal time delay is obtained for each region.

Index Terms—DIP software, Drought, Groundwater Level Decline, Kermanshah, SPI index

INTRODUCTION

Drought is a slow-onset disaster that has economic, social, and environmental consequences and it is one of the most important hazards. Over the last decade, Iran has experienced its most prolonged, extensive and severe drought in over 30 years. This drought of 2003–2011 (as it is still ongoing) has affected many farm families and rural communities across most of the central, eastern and southern parts of Iran. Although Iran has a history of drought, critical features of the current drought are not only their widespread natures and severity, but the fact that the impacts of the current drought have been exacerbated by its proximity to the previous drought (1998–2001) [1]. Drought can therefore be regarded as a normal part of the Iranian farmers' environment. Drought is the most complex of all natural hazards, and more farmers are affected by it than any other hazard. There is few studies have identified the complexity of these impacts at varying indicators, and databases to document impacts and track trends by region or sector are virtually nonexistent [2].

With the increased population pressure and excessive human expansion into drier areas an increasing number of people have become vulnerable and exposed to more frequent weather calamities. The consumption of the critical production elements such as water, alternative uses of dry season grazing land through introduction of irrigated and non-irrigated crops, and the industrial and urban uses of land and water at the expense of rural agricultural producers have broken the links in traditional production chains and, where not compensated, have led to a breakdown of the entire production system. Due to its geographical location, Iran has an arid and semi-arid environment covering 90% of the country. Only the Caspian Plain in the northern parts of Iran receives more than 1000 mm of rainfall annually. Zagros mountain chains in the western parts of the country and Alborz in the northern parts prevent clouds to enter central, eastern and southern parts of the country. Therefore, central and southern low lands along with eastern parts of the country receive very little precipitation. Due to shortage of precipitation and its uneven distribution in these areas, most rivers are seasonal and their flows depend heavily on the amount of rainfall. If there is more rainfall than the average, flush flood is a common phenomenon. Otherwise, it is drought. The distribution of precipitation is also very important. For the growth of vegetation and replenishment of water resources, if throughout the hydrological year the distribution of precipitation is even, the outcome is normally good. If not, all resources will be negatively affected. [3].

Groundwater is a vital natural resource. It is estimated that approximately one third of the world's population use groundwater for drinking [4]. In some parts of the worlds such as large areas of the Middle East, groundwater is the unique source of water. In general, the Middle East is characterized by scarcity of water and rapid growth in population. Water is therefore the most important constraint for future development in this region [5], [6], [7]. However, it is anticipated that the process of development will continue, resulting in greater demands for fresh water and declining groundwater level. Iran as a country in the Middle East is confronted by multiple water-related problems, such as drought and environmental degradation from overexploitation of aquifers in the central and eastern parts of the country. Iran is considered as a semi-arid to arid zone. It has gained substantial importance because of agricultural prosperity. Almost all water consumption needs are met from groundwater resources. In the last decades, rapid population growth coupled with agricultural expansion has significantly increased demand on groundwater resources. Large increases in water demand with

- *Jaber Soltani, Assistant Professor of Irrigation and Drianage Engineering Department, Aboureyhan Compus, University of Tehran,.E-mail: Jsoltani@ut.ac.ir*
- *Fariba Khodabakhshi masters degree in Water Resources Management engineering in Zabol University, Iran. E-mail: Fariba.khodabakhshi@Gmail.com*
- *Mohammad Dadashi masters degree in Irrigation Drainage engineering in Zabol University, Iran. E-mail: mohammaddadashi65@Gmail.com*

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little recharge have strained groundwater resources resulting in declines in water levels and deterioration of groundwater quality in the major parts of the plain. It's worth mentioning that the paramount cause of sharp drop in the groundwater table in recent years is conclusively attributed to pumping out of well water which confirmedly exceeds the level of the natural recharge.

First, it is necessary a appropriate index of meteorological drought and its impact on the water resources of the region is determined. Among the various indices Standardized Precipitation Index (SPI) is used most by McKee et al [8]. were presented. Peters and et al [9]. the propagation of a drought from groundwater recharge to discharge and the influence of aquifer characteristics on the propagation was analysed by tracking a drought in recharge through a linear reservoir. The results showed that the delay in the groundwater system caused a shift of the main part of the decrease in recharge from the high-flow to the low-flow period. This resulted in an increase in drought deficit for discharge compared with the drought deficit for recharge. Also the development of multiyear droughts caused an increase in drought deficit. The attenuation in the groundwater system caused a decrease in drought deficit. In most cases the net effect of these processes was an increase of drought deficit as a result of the propagation through groundwater. Only for small droughts the deficit decreased from recharge to discharge. The amount of increase or decrease depends on the reservoir coefficient and the severity of the drought. Under most conditions a maximum in the drought deficit occurred for a reservoir coefficient of around 200 days. Khan and et al [10]. examined the relationship between drought and groundwater level in one of the regions of Australia began. And concluded that the standardized precipitation index and the shallow groundwater level, there is a strong correlation. Tweed and et al [11]. examined the interaction between surface water and groundwater and the impact of multi-year drought on lakes conditions in South-East Australia using data from four years of drought (1992- 1996) and drought (1997- 2006) The Great Lakes Basin Durgmaynt examined. And concluded that the drought causes a loss of 60% of the lake area and 80% reduction in the volume of water in the two lake.

MATERIALS AND METHODS

The Kermanshah Province as one of the main cereal-growing region is located in the western part of iran, with total area of 24,890 km2. Its annual precipitation varies from 375 to 500mm. The province includes 11 provincial cities(PC). Table 1 and Figure 1 indicates the geographical location of cities.

Table 1 - Characteristics of the study in Kermanshah province.

Row Name	station	longitude	latitude	altitude (m)
1	Songhor	47°35′	34°47′	1700
2	Ravansar	46°39′	34°43′	1379.7
3	Kermanshah	47°09′	34°21′	1318.6
4	Kangavar	47°59′	34°30′	1468.2
5	Sahneh	45°87′	34°45′	1395.2
6	Harsin	47°59′	34°27′	1426.9
7	Aslamabadghrb	46°28′	34°07′	1348.8

Fig1 - Location of the studied provinces.

In the present study monthly rainfall data from rain gauge stations and synoptic weather station in Kermanshah province in the period 1367 to 1390 and groundwater level data from 236 wells during the period 1998 to 2011 is used Piezometric. Position and Piezometric rain gauge stations in the region (2) is shown. The data from the Regional Water Board and Kermanshah Province Kermanshah Province Meteorological were prepared.

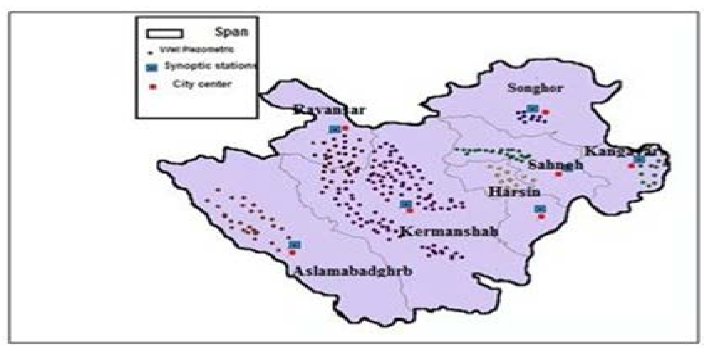

Fig 2 - Location of meteorological stations and Piezometric Kermanshah Province

Meteorological stations selected by considering several cases such as long-term statistics (minimum 23 years) and the low statistical errors are selected. Initially monthly rainfall data stations in terms of homogeneity by two doubly Mass were investigated and test drive, all the data were homogeneous. The statistical errors of the data using the ratio of the difference was renovated. In the next step values of the standardized precipitation (SPI), using rainfall data and application deployment DIP, on time scales of 1, 3, 6, 9, 12, 18, 24, and 48 months during the period 1998 to 2011 calculated. The correlation coefficient between groundwater level fluctuations and SPI index using equation (1) is calculated.

$$P_{x,y} = \frac{\mathrm{cov}(x,y)}{\sigma_x \ \sigma_y} \quad (1)$$

Where $P_{x,y}$: The correlation between the volatility index and the standardized precipitation, groundwater, X: Standardized Precipitation Index, Y: groundwater level fluctuations, σ_x: Standardized Precipitation Index, σ_y: groundwater level fluctuations.

The SPI calculated in this way has the following desirable traits: The SPI is uniquely related to probability.

1. The precipitation used in SPI can be used to calculate the precipitation deficit for the current period.
2. The precipitation used in SPI can be used to calculate the current percent of average precipitation for time period of i months.
3. The SPI is normally distributed so it can be used to monitor wet as well as dry periods.
4. SPI can be calculated for the other water variables of snowpack, reservoir, stream flow, soil moisture, and ground water.

The SPI is normalized so that wetter and drier climates will be represented in a similar way. Using the SPI as the indicator, a functional and quantitative definition of drought can be established for each time scale. A drought event for time scale i is defined here as a period in which the SPI is continuously negative and the SPI reaches a value of -1.0 or less. The drought begins when the SPI first falls below zero and ends with the positive value of SPI following a value of -1.0 or less. Drought intensity is arbitrarily defined for values of the SPI with the following categories:

Table2- Drought classification based on SPI value

Class	SPI value
Extremely Wet	<2
Severe Wet	(1.5) - (1.99)
Moderately Wet	(1) - (1.49)
Slight Wet	0 - (0.99)
Slight Drought	0 - (- 0.99)
Moderately Drought	(-1) - (-1.49)
Severe Drought	(-1.5) - (-1.99)
Extremely Drought	> -2

The definition of drought thus far has included a beginning date, ending date, and a current drought intensity. Duration of drought can be either a current duration since the beginning or the duration of a historic drought event from beginning to ending. Peak intensity can easily be determined from the SPI. A measure of the accumulated magnitude of the drought can be included. Drought M,agnitude (DM) is defined as:

$$DM = -\left(\sum_{j=1}^{x} SPI_{ij}\right) \quad (2)$$

where j starts with the first month of a drought and continues to increase until the end of the drought (x) for any of the i time scales. The DM has units of months and would be numerically equivalent to drought duration if each month of the drought has SPI = -1.0. In fact, many droughts will have a DM very similar to the duration in months since most of the SPI values are between 0 and -2.0. Other benchmarks that help assess the vulnerability of each station on SPI drought appears to be an important measure of the longest duration period (number of months in the face of drought.) In order to determine the time delay caused by drought and the Standardized Precipitation Index (SPI) on the groundwater level, the correlation coefficient between this index and fluctuations in groundwater level plains with a time lag of 1, 2, 3, 4, 5, 6, 9, 12, 18, 24, and 48 months were studied. The groundwater level fluctuations during the period 1998-2011 SPI index by software spss, was calculated.

Results and Discussion:

As mentioned before In this study, the criteria for assessing vulnerability to drought faced many months of drought, And a large assembly of drought (DM) was calculated for each The results in Table 3 and Figure 3 is presented.

Table 3 - Standards drought in each of the stations

Row Name	station	Total DM	Faced with months of drought
1	Songhor	482.83	311
2	Ravansar	508.52	314
3	Kermanshah	482.76	304
4	Kangavar	460.48	298
5	Sahneh	435.13	308
6	Harsin	465.81	296
7	Aslamabadghrb	506.23	318

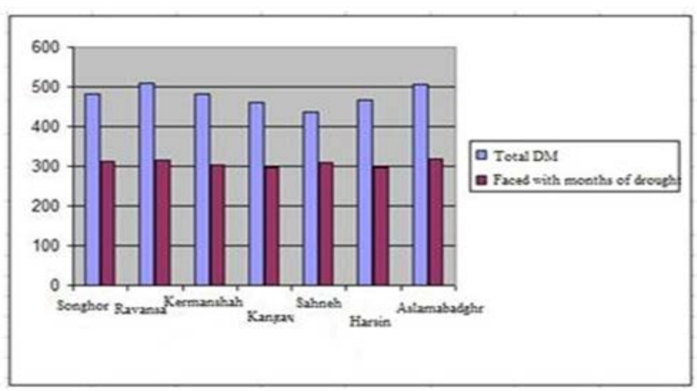

Fig 3 - Standards Evaluation of drought in each of the stations

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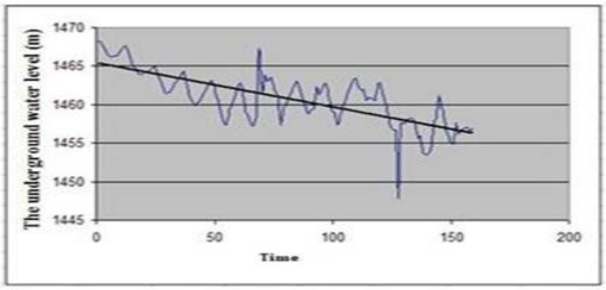
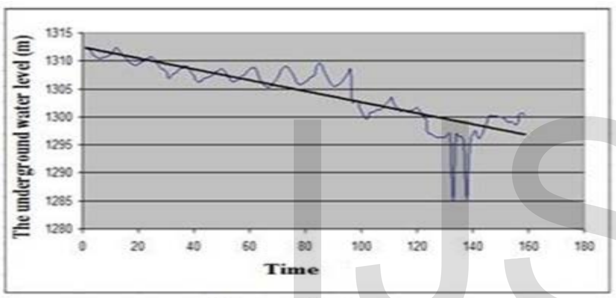
As shown in Table (3) also appears Ravansar stations with a total of 508.52 Maximum of Sahneh stations with the lowest total DM has a total of 435.13. In terms of the time scale of months 1, 3, 6, 9, 12, 18, 24 and 48 months with a total of 318 months in the face of drought, Maximum station in Islamabad and with the Harsin station is 298 minimum.

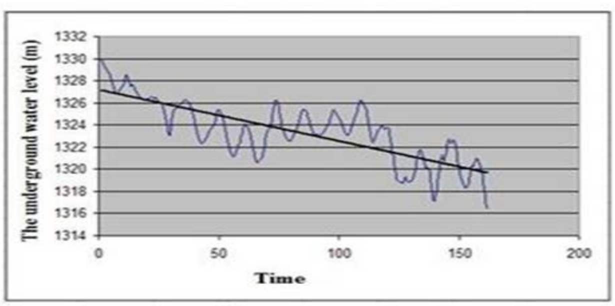
Groundwater level fluctuations in Kermanshah province during the period 1998-2011 is depicted in Figure 3. The groundwater level in the form of Kermanshah in most cities is generally declining.



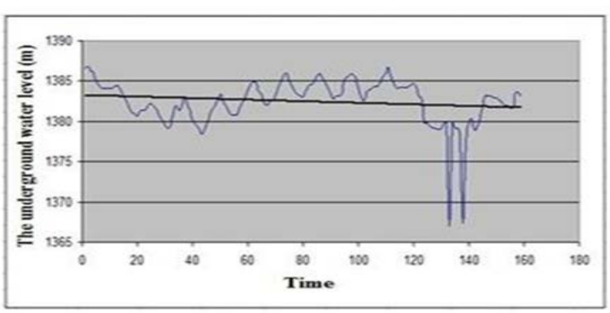
Kangavar



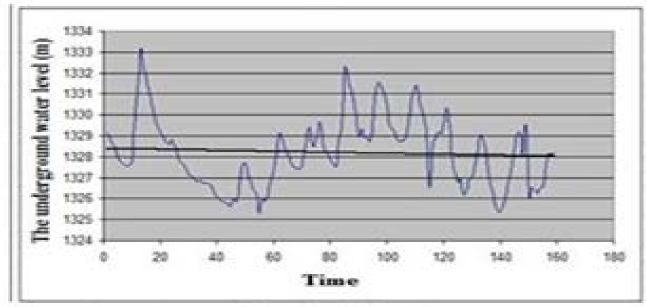
Kermanshah



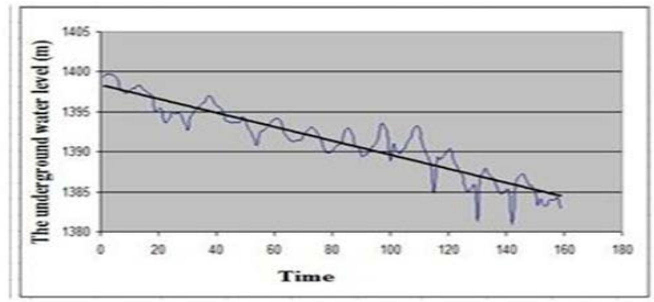
Ravansar



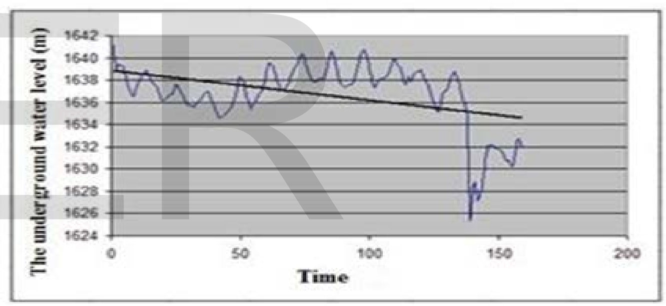
Sahneh



Aslamabadghrb



Harsin



Songor

Fig 4 - groundwater level fluctuations during the period of 1998-2011 regions of Kermanshah province.

The index values of SPI, during the period 1998-2011 was marked by the 2007-2008 and 2010-2 periods of drought occurred. Table 4 Correlation coefficients between SPI index and the average groundwater level in the regions of Kermanshah province during the period 1998-2011 shows.

Table 4 - Correlation coefficients between standardized precipitation index and the average groundwater level in different regions of Kermanshah province during the period 1390-1377.

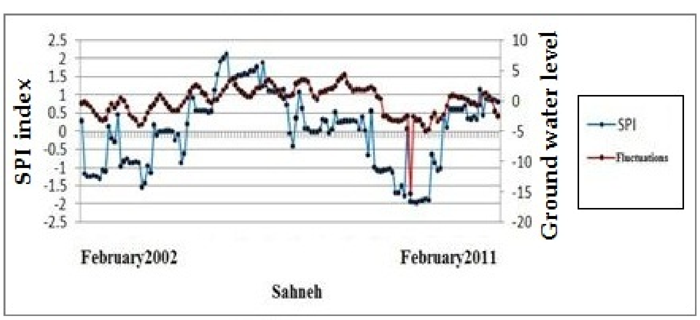
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Kangavar
0.261	0.213	0.098	0.075	0.014	-0.039	0.009	-0.068	Kermanshah
0.499	0.176	-0.023	0.025	-0.071	-0.106	-0.042	-0.065	Ravansar
0.743	0.518	0.316	0.306	0.189	0.059	0.076	-0.07	Songhor
0.32	-0.064	-0.128	-0.079	-0.142	-0.153	-0.065	-0.038	Harsin
0.64	0.664	0.497	0.42	0.292	0.13	0.083	-0.009	Sahneh
0.479	0.4	0.269	0.235	0.135	0.036	0.061	-0.072	Aslamabadghr

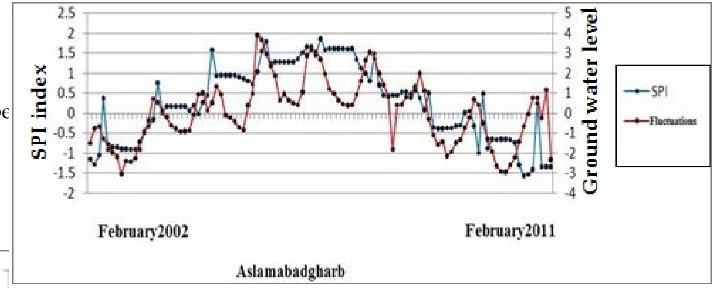
According to Table 4, Maximum correlation is found in every city., To determine the effect of time delay on the SPI index groundwater level, the correlation between the standardized precipitation index option with the highest correlation coefficients in Table 4 had a mean groundwater levels at 1, 2, 3, 4, 5, 6, 9, 12, 18, 24, 48 months, of which the results are presented in table 3.

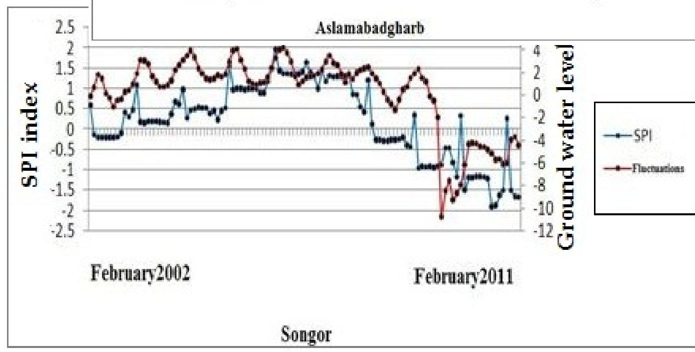
Table 5 - Correlation coefficients between the standardized precipitation index and the average groundwater level plains of the province with the exercise of choice latency period

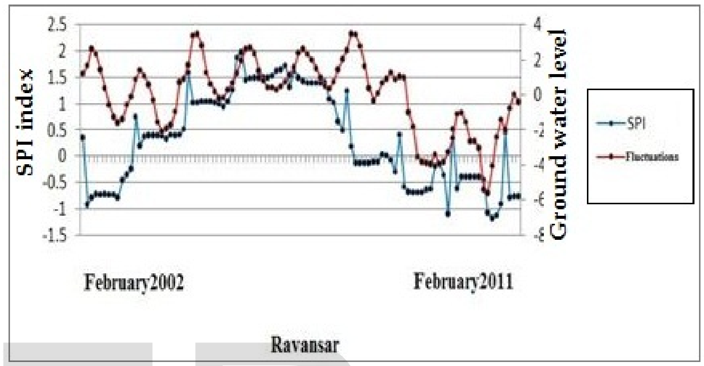
Station	Lag0	Lag1	Lag2	Lag3	Lag4	Lag5	Lag6	Lag9	Lag1	Lag1	Lag2	Lag4
Kangavar	0.583	0.580	0.545	0.53	0.454	0.446	0.406	0.429	0.389	0.274	0.257	-0.079
Kermansha	0.261	0.25	0.245	0.255	0.274	0.295	0.284	0.4	0.5	0.624	0.814	0.46
Ravansar	0.499	0.481	0.471	0.448	0.427	0.414	0.427	0.535	0.559	0.396	0.377	-0.429
Songhor	0.743	0.714	0.7	0.705	0.695	0.679	0.712	0.722	0.647	0.501	0.327	-0.442
Harsin	0.32	0.321	0.294	0.339	0.356	0.35	0.375	0.473	0.559	0.516	0.602	0.493
Sahneh	0.664	0.631	0.556	0.516	0.48	0.428	0.35	0.261	0.109	-0.246	-0.356	-0449
Aslamabadghr	0.479	0.462	0.595	0.592	0.597	0.591	0.62	0.71	0.639	0.559	0.327	-0.659

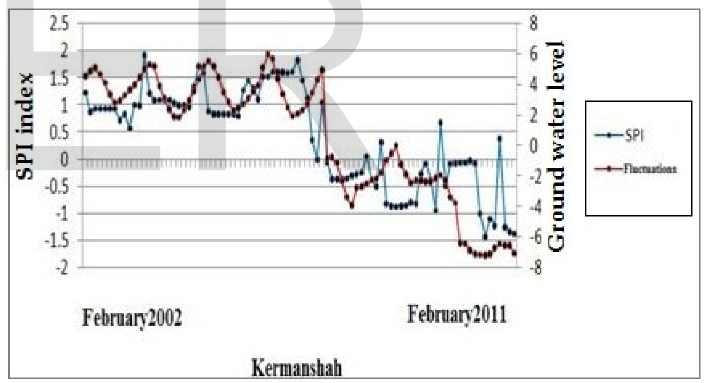
Numbers Table (5) shows the correlation between mean groundwater level in the scale of 48-month SPI index without delay to the city Kangavar and SPI-scale 48-month and 24-month time lag for the city of Kermanshah, SPI-scale 48-month and 12-month delay for station Ravansar SPI 48 months and the falcon station without delay, SPI time scale with a time lag of 48 months and 24 months for the station Harsin , SPI 24-month scale and without delay to the station and SPI-scale 48-month and 9-month time lag. Figure (5) changes with time scales of SPI index of the selected choice and latency than the monthly average groundwater level fluctuations during the period 1998-2011, the total area of the study shows.











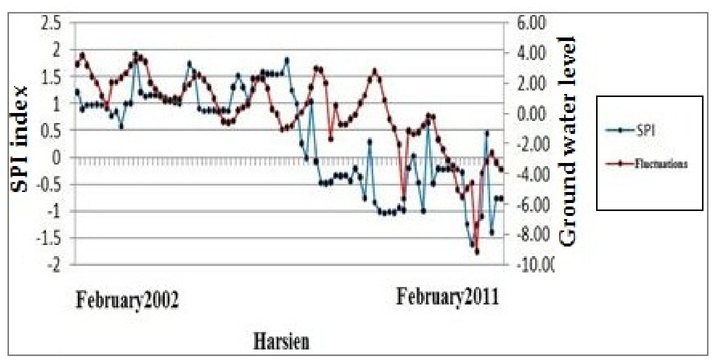
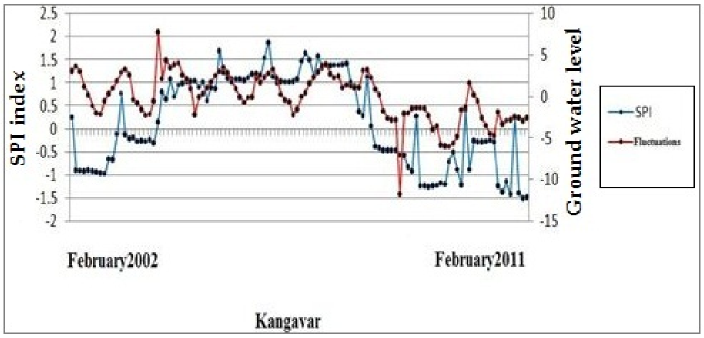


Fig (5) - Standardized Precipitation Index variations with time scale and time delay selection and groundwater level fluctuations than the monthly average for the study area.



province, in order to determine the impact of drought on groundwater level fluctuations, regression equations between SPI and the amount of groundwater level fluctuations during the period (1390-1377), was determined the high correlation indicates that the groundwater level decline was directly affected by the drought index was confirmed in the plains. DM or a drought directly related to the number of months in the face of drought and famine of each month (value SPI). because the number of months in the face of increasing drought the total value DM and DM drought event in a 23-year period, for example, will increase and this is also true for each month in relation to the severity of the drought. Therefore this feature is to evaluate an area's vulnerability to drought index, the index number of the months were faced with drought

Figure 5 shows the monthly average groundwater level fluctuations that follow, the SPI index is changed. In other words, whenever the Standardized Precipitation Index in the form (5) has a value of -1 or Less (droughts) is to show a further decline in groundwater levels. In order to determine the impact of drought on groundwater levels decline, Simple linear regression relationship between groundwater level fluctuations (the dependent variable, WT) with SPI index in the selected time scale (the independent variable, SPI) determines the period 1 has been the results in Table 5 are shown. This relationship suggests a direct effect of drought on groundwater level fluctuations in the study area.

Table 6 - Results of simple linear regression between the standardized precipitation index in the selected time scale. Fluctuations in groundwater levels in the study area during the period 1390-1377

Equation of the regression line	R^2	Dependent variable	Independent variable	Station
$y = -3.02 + 1.72x$	0.58	WT	SPI48	Kangavar
$y = -1.24 + 3.96x$	0.82	WT	SPI48	Kermanshah
$y = -3.70 + 1.29x$	0.588	WT	SPI48	Ravansar
$y = -3.88 + 2.64x$	0.74	WT	SPI48	Songhor
$y = -5.73 + 1.66x$	0.60	WT	SPI48	Harsin
$y = -2.83 + 1.69x$	0.68	WT	SPI24	Sahneh
$y = -2.60 + 1.18x$	0.71	WT	SPI48	Aslamabadghr

Equations are given in Table 6 it can be concluded that for a given unit of SPI index for each area of a few meters of groundwater levels will occur in Kermanshah and vice versa.

Conclusion

Kermanshah plain aquifer of drought on groundwater resources has a negative impact, So that the relationship between the standardized precipitation index (SPI) scale and the ground water level and there is a time lag. The time delay and time scale of the plains is different, because of these differences, the depth of ground water, soil and aquifer hydraulic properties in each region is concerned. Due to declining groundwater levels in the regions of Kermanshah

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