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Evaluation of the effects of meteorological drought on ground water table fluctuations (Case study: Hormozgan Province, Iran)

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Abstract
Drought as a natural but temporary imbalance of water availability is the interaction between natural environment and human life resulting in diminished water resources availability and reduced carrying capacity of the ecosystems. Drought indices are essential elements for an efficient drought monitoring system. These indices make the transforming information of climatic anomalies easier and allow the scientists to quantitatively assess the climatic anomalies. In this research drought condition in Hormozgan province, Iran based on RDI and SPI was studied and the effects of drought on groundwater resources have been studied as well. The highest correlation in almost all plains is related to long term periods (24 months) which show that drought becomes more important and hazardous in long term periods. However higher correlation of some plains like Minab plain with RDI&SPI 3 month shows the quick response of this plain to the meteorological droughts. The results are very useful tool for planners and decision makers to monitor the region based on its susceptibility to drought.

Keywords
drought, groundwater, index, standardized precipitation index.

1. Introduction
Drought is a recurring natural phenomenon associated with a deficit availability of water resources over a large geographical area and extending along a significant period of time (Rossi, 2000). The effects of drought often accumulate slowly over a considerable period of time that may linger for several years even after the termination of drought. Therefore, some authors have called it a creeping phenomenon (Wilhite, 2000). Drought is considered as the most complex, but the least understandable phenomenon of all the natural hazards affecting more people than any other hazards (Mishra & Desai 2005). Approximately 85% of the natural disasters are related to extreme meteorological events (Obasi, 1994) with drought being the one that causes most damages (CRDE, 2003). Drought is a global phenomenon that is caused by the lack of precipitation and occurs virtually in all landscapes causing significant damage both in natural environment and in human lives. It causes huge losses in agriculture and has many negative effects on natural ecosystems. Drought causes degradation of soils, desert formation (Nicholson et al, 1990; Pickup, 1998), famine and impoverishment. The identification of drought was realized by using drought indices. Spatial and temporal extent and severity of drought could be determined using these indices (Guttmann, 1998; Hayes, 2000). Drought indices are essential elements for an efficient drought monitoring system, aimed at providing its overall concise

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picture (Mendicino et al., 2008). These indices make the transforming information of climatic anomalies easier and allow the scientists to quantitatively assess the climatic anomalies in terms of their intensity, duration, frequency and spatial extent (Wilhite et al., 2000). It allows the analysis of historical occurrence of droughts and the estimation of recurrence probability. This information is extremely useful for the management and application of water resource development schemes for the environment and human use as well (Tsakiris et al., 2007).The Reconnaissance Drought Index (RDI) is based on the ratio between two aggregated quantities of precipitation and potential evapotranspiration. It is advisable to use the periods of 3, 6, 9 and 12 months if RDI has to be calculated as a general index of meteorological drought. In its initial formulation, RDI, for a 12 months’ time period can be directly compared with the Aridity Index produced for the area under study. If, for a certain year, α12 is lower than the Aridity Index calculated according to UNEP (1992), the area is said to be suffering from drought during that specific year. The interpretation of Standardized RDI (RDIst) and SPI (Standardized Precipitation Index) is the same because same threshold levels can be used in both techniques. Severity and affected area are two basic characteristics of the meteorological drought analysis, especially in Iran. Severity is represented by two general indices, i.e., the SPI and RDI (Asadi Zarch et al., 2010).The objective of this research is the analysis of drought condition in Hormozgan province, Iran based on RDI and SPI. Meanwhile, the effects of drought ongroundwater resources have been studied as well.

2. Study area

The Hormozgan province is located between 52041’ E and 59015’E longitudes and 25034’ N and 28057’N latitudes in southern part of Iran and in the northern coast of the Persian Gulf (Fig.1). The total area of the province is 71139 km^2 and climate is predominantly dry and wet. In this study, the monthly rainfall, temperature, wind, relative humidity and sunshine data of 25 years period were taken from 12 meteorological synoptic stations, distributed over the province and neighboring areas as well.

Table 1 shows the main characteristics in the studied stations. Precipitation and potential evapotranspiration were used for classifying the bioclimatic aridity in a globally comparable way. In mathematical terms, UNESCO (1979) used an aridity/humidity classification system based on average annual precipitation (P) divided by the average annual potential evapotranspiration (PET).

During the present analysis, RDI calculations were performed by MATLAB. As the Standardized RDI and SPI perform in a similar manner (McKee et al., 1993), they have the similar interpretation of results. Therefore, the RDI_{st} values could be compared to the same thresholds as that of the SPI technique (Table 2).

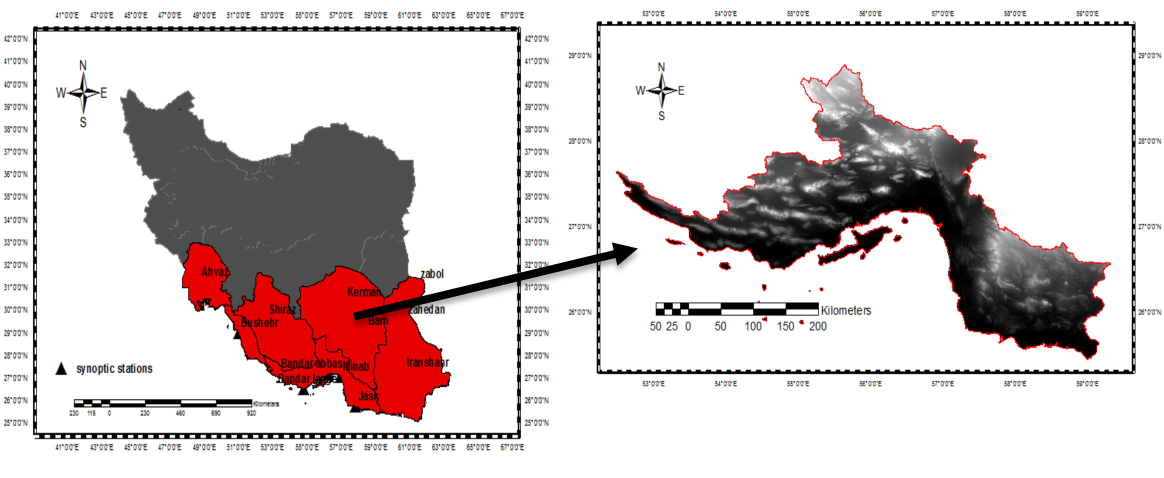

Fig. 1. Location Hormozgan province of Iran

Table 1. General characteristics studied synoptic stations

Station	X coordinate m	Y coordinate m	Elevationa.s.l. (m)	P (mm)
Ahwaz	321231	3492096	22.5	240.9
Bam	625967	6495690	66.9	59.3
Bandar abbas	522503	6274776	9.8	152.9
Bandar lengeh	492608	6137456	22.7	205.6
Bushehr	683239	5695746	19.6	277.2
Iranshahr	517934	6781397	591.1	112.4
Jask	444292	6460648	5.2	139.0
Kerman	345695	6388972	1753	142.1
Shiraz	693140	3307538	484	348.0
Zabol	397206	6853442	489.2	62.6
Zahedan	648294	6817934	1370	75.3
Minab	509911	2999361	27	214

Table 2. Classification of drought according to the SPI and RDI_{st} values

SPI and RDI_{st} range of drought classes	
2 or more	Extremely wet
1.5 to 1.99	Very wet
1 to 1.49	Moderately wet
0.99 to 0.0	Normal
0.0 to −0.99	Near normal
−1 to −1.49	Moderately dry
−1.5 to −1.99	Severely dry
−2 and less	Extremely dry

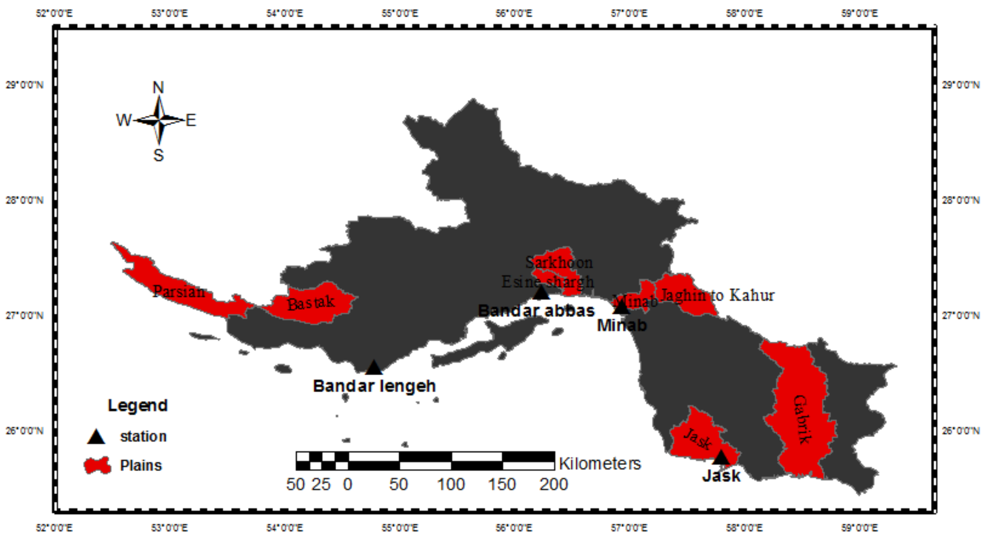

Fig. 2. Location of selected meteorological stations and nearest plains

Occurring droughts have considerable effects on natural environments and human life of the region, then study of climatic parameters does not provide reliable results. In this study the effects of meteorological drought on groundwater resources was studied in different time scales (3, 6, 9, 12, 18 and 24 months). Based on geographical location of each synoptic station, some plains in the province were selected and their groundwater piezometric level was monitored over the same period. Location of the selected plains and the nearest synoptic stations have been shown in Figure 2.

3. Material and Methods

3.1. Drought Indices

The Standardized Precipitation Index (SPI), which is one of the most widely used drought indices, was designed by McKee et al. (1993). The SPI has the following favorable characteristics: (a) It is uniquely related to probability; (b) the precipitation used in the SPI can be used to calculate the precipitation deficit for the current period and the current percent of average precipitation for a time period of i months and (c) the SPI is normally distributed so it can be used to monitor wet as well as dry periods (Asadi Zarch et al., 2010). Another widely used meteorological index is the rainfall declines?, which was developed by Gibbs and Maher (1967). A new reconnaissance drought identification and assessment index was first presented in the coordinating meeting of MEDROPLAN (Tsakiris, 2004), while, a more comprehensive description was presented in other publications (Tsakiris & Vangelis, 2005; Tsakiris et al., 2006).The index, which is referred to as the Reconnaissance Drought Index (RDI) may be calculated by the following expressions, for illustrative purposes the yearly expressions are presented first. The first expression, called the initial value of RDI (a_o). Is presented in aggregated form using a monthly time step and may be calculated for each month of the hydrological year or a complete year. The a_o is usually calculated for the i_{th} year in an annual basis using the following equation:

$$a_0^{(i)} = \frac{\sum_{j=1}^{12} Pij}{\sum_{j=1}^{12} PETij}, \ i = 1 to\, N \ and \ j = 1 to\, 12 \tag{1}$$

in which P_{ij} and PET_{ij} are the precipitation and potential evapotranspiration of the j^{th} month of the i^{th} year, starting usually from October as it is customary for Mediterranean countries and N is the total number of years of the available data. During the present study, the PET rates were estimated with the Penman-Monteith equation (Monteith, 1965), which is the most reliable way to estimate PET under various climatic conditions (Jensen et al., 1990). The Penman-Monteith method reflects changes in all meteorological factors affecting the evaporation and transpiration in the plants. Jensen et al. (1990) have proposed the term 'reference evapotranspiration' instead of PET to describe the same phenomenon. PET does not directly provide an indication of actual evapotranspiration rate, governed by the characteristics of soil (soil type and infiltration capacity), relief (slope, exposition and relief form), plant (vegetation type, soil cover, LAI, rooting depth) and climate (precipitation amount and intensity, PET and the temporal distribution of both variables). One main advantage of the concept of PET was that it provides a standardized value that allows the comparison of evaporative environments under different climatic conditions. This concept was developed by the Food and Agriculture Organization (FAO) of the United Nations during the last decade (Allen et al., 1998; Doorenbos & Kassam, 1986; Doorenbos & Pruitt, 1977; Smith, 1992) and was applied globally for the land use studies (Fischer et al., 2000).

$$ET_0 = \frac{0.408\Delta\left(R_n - G\right) + \gamma\left[\frac{900}{T + 273}\right]U\,2\left(e_s - a_a\right)}{\Delta + \gamma\left(1 + 0.34U_2\right)} \tag{2}$$

A second expression, the Normalized RDI (RDI_n) is computed using the following equation for each year, in which it is evident that the parameter a_o is the arithmetic mean of a_o values calculated for the N years of data (Tsakiris et al., 2007).

$$RDI_n = \frac{a_0^{(i)}}{\bar{\alpha}} - 1 \tag{3}$$

The third expression, the Standardized RDI (RDI_{st}), is computed following a similar procedure to the one that is used for the calculation of the SPI: The expression for the Standardized RDI is:

$$RDI_{st(k)}^{(i)} = \frac{y_k^{(i)} - \bar{y}}{\hat{\partial}_{yk}} \tag{4}$$

in which y_i is the $\ln(a_0^{(i)})$; $\bar{y}_k$ is its arithmetic mean and $\hat{\partial}_{yk}$ is its standard deviation. It is noted that the above expression is based on the assumption that the a_o values follow a lognormal distribution. The Standardized RDI behaves similar to the SPI and so is the interpretation of results. Therefore, the RDI_{st} can be compared to the same thresholds as the SPI (Tsakiris et al., 2007).The choice of the lognormal distribution is not constraining but it assists in devising a unique procedure instead of various procedures depending on the probability distribution function, which best fits the data. However, the hypothesis that the data of the RDI_n follow a lognormal distribution seems to be the most appropriate. In all examples analyzed during the establishment of the RDI, the goodness-of-fit tests confirmed that the lognormal distribution fits the data satisfactorily. It should be emphasized that the RDI is based both on precipitation and on potential evapotranspiration. The mean initial index $\bar{\alpha}$ represents the normal climatic conditions of the area and is equal to the Aridity Index as was proposed by the FAO (Tsakiris et al., 2007). Like SPI computation by Gamma approach, this method tends to solve the problem of calculating RDI_{st} for the small time scales, such as monthly, which may include zero-precipitation values (α_k=0), for which Equation (3) could not be applied (Tsakiris et al., 2008). The gamma distribution is defined by its frequency or probability density function (Asadi Zarch et al., 2010).

$$g(X) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta} \quad for: x > 0 \tag{5}$$

where α >0 is a shape factor; β>0, a scale factor and x>0 is the amount of precipitation (Tsakiris et al., 2008). Γ (α) is the gamma function, defined as:

$$\Gamma(\alpha) = \int_0^{\infty} y^{\alpha-1} e^{-y}\, dy \tag{6}$$

Fitting of distribution to data requires the estimation of α and β. Maximum likelihood estimations of α and β are:

$$\alpha = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right) \tag{7}$$

$$\beta = \frac{\bar{X}}{\alpha} \tag{8}$$

Where

$$A = \ln(\bar{x}) - \frac{1}{n}\sum_{i=1}^{n} \ln(x_i) \tag{9}$$

For n observations the resulting parameters were then used to find the cumulative probability of an observed precipitation event for the given month or any other time scale:

$$G(X) = \int_0^{x} g(x)dx = \frac{1}{\beta^{\alpha}\Gamma(\alpha)}\int_0^{x} x^{\alpha-1} e^{-x/\beta} dx \tag{10}$$

Substituting t for $\frac{x}{\beta}$ reduces the Eq. 6 to incomplete gamma function

$$G(X) = \frac{1}{\Gamma(\alpha)}\int_0^{x} t^{\alpha-1} e^{-t}\, dt \tag{11}$$

Since, the gamma function is undefined for x=0 and a precipitation distribution may contain zeros, where the cumulative probability becomes:

$$H(x) = q + (1-q)G(x) \tag{12}$$

where q is the probability of zero precipitation and G(x) is the cumulative probability of the incomplete gamma function. If m is the number of zeros in a αk time scales, then q drought Monitoring by Reconnaissance Drought Index (RDI) in area could be estimated by m/n. The cumulative probability H(x) is then transformed to the standard normal random variable z with mean zero and the variance of one (Abramowitz & Stegun, 1965), which is the value of RDI_{st} (Tsakiris et al., 2008).

4. Results and Discussion

Table 3 shows the results of Reconnaissance Drought Index (RDI) in the studied stations. According to UNESCO, the potential evapotranspiration was calculated according to the Penman formula. Based on this classification, Table 3 demonstrates the type of climatic condition, introduced for each experimental station.

In order to better understand the response of the region to drought characteristics; it is necessary to look for the correlation of both indices in different time scales. The correlation coefficients of SPI and RDI for each station and each time scale are described in Table 4.

The primary impact of drought is usually apparent in agriculture through a decrease in soil moisture and high evapotranspiration. Soil water is rapidly depleted during the extended dry periods. Surface and subsurface water resources are usually the last ones to be affected by an extended period of dryness (Sönmez et al., 2005). So, the soil moisture is more influenced during the three months time periods and agricultural studies are needed to be carried out with more caution. The main advantage of SPI is that it is calculated for several time scales (McKee et al., 1995). RDI quantifies the precipitation deficit during multiple time scales, which reflects the impact of precipitation deficiency on the availability of different water suppliers. Groundwater level fluctuations also were monitored at the end of recharge period (August) and end of discharge (February) and the correlation of groundwater level with RDI and SPI was calculated for different short and long term time scales (Tables 5 -8).

According to Table 5, correlation coefficient between groundwater level and RDI & SPI in Esinshargh plain has some fluctuations in August; however Sarkhoon and Esinshargh have the highest correlation with the indices in 24 months period.

Table 3. General characteristics and RDI results of the studied synoptic stations

Station	P (mm)	ETP (mm)	P/ETP	Climatic classification
Ahwaz	240.9	1989.7	0.121	Arid
Bam	59.3	2040.3	0.029	Hyper- arid
Bandar abbas	152.9	1865.5	0.082	Arid
Bandar lengeh	205.6	1737.7	0.118	Arid
Bushehr	277.2	1690.8	0.164	Arid
Iranshahr	112.4	2073.4	0.054	Arid
Jask	139.0	1768.4	0.079	Arid
Kerman	142.1	1667.7	0.085	Arid
Shiraz	348.0	1640.5	0.212	Semi-arid
Zabol	62.6	2813.5	0.022	Hyper-arid
Zahedan	75.3	1870.2	0.040	Arid
Minab	214	39512.2	0.010	Arid

Table 4. Correlation coefficient of SPI and RDI in the stations for different time scales

	Station	Time scales					
		3 month	6 month	9 month	12 month	18 month	24 month
1	Ahwaz	0.98	0.98	0.95	0.91	0.93	0.88
2	Bam	0.95	0.94	0.90	0.90	0.89	0.88
3	Bandar abbes	0.99	0.99	0.98	0.97	0.97	0.96
4	Bandar lengeh	0.99	0.99	0.99	0.99	0.99	0.99
5	Bushehr	0.99	0.99	0.99	0.98	0.98	0.98
6	Iranshahr	0.96	0.95	0.94	0.95	0.95	0.96
7	Jask	0.99	0.99	0.99	0.99	0.99	0.99
8	Kerman	0.97	0.96	0.91	0.88	0.89	0.86
9	Shiraz	0.99	0.98	0.96	0.96	0.95	0.93
10	Zabol	0.97	0.97	0.95	0.95	0.95	0.96
11	Zahedan	0.97	0.97	0.96	0.96	0.97	0.98
12	Minab	0.996	0.995	0.99	0.99	0.992	0.99

Table 5. Pearson correlation coefficient of SPI and RDI with water level in August and February for Bandar Abbas and neighboring plains

Bandar abbas	RDI				SPI			
	AUG		FEB		AUG		FEB	
	Esinshargh	Sarkhoon	Esinshargh	sarkhoon	Esinshargh	Sarkhoon	Esinshargh	Sarkhoon
3	0.75	0.70	0.50	0.71	0.57	0.62	0.45	0.60
6	0.66	0.70	0.50	0.72	0.50	0.53	0.33	.050
9	0.44	0.55	0.30	0.50	0.43	0.50	0.30	0.50
12	0.40	0.50	0.30	0.50	0.80	0.52	0.33	0.50
18	0.55	0.70	0.51	0.64	0.62	0.60	0.40	0.60
24	0.63	0.80	0.70	0.76	0.60	0.71	0.66	0.70

Table 6. Pearson correlation coefficient of SPI and RDI with water level in August and February for Bandar Lengeh and neighboring plains

Bandar lengeh	RDI				SPI			
	AUG		FEB		AUG		FEB	
	Parsian	Bastak	Parsian	Bastak	Parsian	Bastak	Parsian	Bastak
3	0.13	-0.1	0.26	0.33	0.46	0.11	0.43	0.45
6	0.53	0.12	0.43	0.53	0.60	0.11	0.43	0.53
9	0.55	0.12	0.44	0.60	0.60	0.11	0.64	0.61
12	0.60	0.14	0.43	0.61	0.60	0.14	0.45	0.64
18	0.67	0.12	0.50	0.67	0.52	0.24	0.40	0.60
24	0.70	0.1	0.57	0.68	0.73	0.10	0.62	0.71

Table 7. Pearson correlation coefficient of SPI and RDI with water level in August and February for Jask station and neighboring plains

Jask	RDI				SPI			
	AUG		FEB		AUG		FEB	
	Jask	Gabrik	Jask	Gabrik	Jask	Gabrik	Jask	Gabrik
3	0.1	0.66	0.10	0.72	0.21	0.63	0.21	0.70
6	0.30	0.67	0.30	0.72	0.30	0.60	0.30	0.60
9	0.40	0.55	0.35	0.52	0.36	0.54	0.35	0.50
12	0.40	0.52	0.40	0.45	0.41	0.61	0.40	0.55
18	0.50	0.61	0.45	0.55	0.27	0.70	0.26	0.71
24	0.62	0.62	0.60	0.60	0.64	0.55	0.57	0.50

As shown in Table 6, the highest correlation coefficient is related to 24 months period for Parsian plain but in Bastak plain the correlation was too low.

Highest correlation for Jask plain is related to 24 months period for both indices. However for Gabrik plain the highest correlation for RDI is 6 months while for SPI occurs in 18 months period.

Jaghin to kahur plain, there is a relatively regular condition showing the highest correlation in 3 months period while in Minab it is correlated with 24 months period.

Table 9 shows the average groundwater level depletion of the studied plains. Fluctuations of groundwater table and drought indices are shown in Figures 3 to 6.

When rain fails, or is low, soil moisture and surface streams dry up and groundwater storage is reduced to very low levels. This does not apply to deeper ground waters, which are independent of even a few years of drought. Hence, groundwater still remains available for man's use when all other sources of water fail. The quality as well as the quantity of groundwater must always be borne in mind. Shallow, or phreatic, groundwater is replenished each year by the annual rainfall; its level rises after rain and infiltration, but falls in dry periods. It is the groundwater tapped by most open wells; when groundwater levels fall, such wells often go dry.

Table 8. Pearson correlation coefficient of SPI and RDI with water level in August and February for Minab station and neighboring plains

Minab	RDI				SPI			
	AUG		FEB		AUG		FEB	
	Minab	Jaghin to kahur	Minab	Jaghin to kahur	Minab	Jaghin to kahur	Minab	Jaghin to kahur
3	0.37	0.70	0.40	0.71	0.44	0.68	0.46	0.70
6	0.35	0.63	0.37	0.64	0.42	0.62	0.44	0.62
9	0.32	0.56	0.34	0.57	0.40	0.55	0.40	0.56
12	0.35	0.41	0.35	0.53	0.42	0.51	0.42	0.52
18	0.50	0.60	0.51	0.60	0.60	0.60	0.60	0.55
24	0.60	0.61	0.61	0.56	0.66	0.60	0.66	0.53

Table 9. Average depletion (m) of water level in AUG and FEB over the study period

Station	Plain	AUG	FEB
Bandar Abbas	Esinsargh	5.19	5.93
	Sarkhoon	5.37	6
Bandar lengeh	Parsiyan	1.22	1.8
	Bastak	3.41	3.11
Jask	Jask	0.27	0.40
	Gabrik	0.41	0.47
Minab	Minab	5.02	5.60
	Jaghin to kahur	8.05	9.95

Table 10. Annual discharge and number wells (1991-2009)

	Annual yield (MCM)		Number of wells			
			1991		2009	
	1991	2009	deep	shallow	deep	shallow
Sarkhoon	23.848	35.93	26	301	38	464
Esinsharghi	12.921	7.02	17	137	17	209
Minab	40.061	67.42	109	967	112	548
Jaghin to kahur	104.729	177.7	31	1202	116	2220
Bastak	3.382	11.95	4	55	7	566
Parsiyan	16.757	39.33	12	689	3	1445
Jask	1.681	2.74	1	87	14	126
Gabrik	1.141	1.53	0	14	0	29

Increasing agricultural productivity with groundwater irrigation, and lessening reliance on surface water sources, can reduce the impacts of predicted declines in rainfall. The key to understanding the effect of a groundwater system on droughts is to understand how the delay and attenuation caused by the storage in an aquifer affect the discharge droughts (Table 10). An analysis of droughts in the simulated recharge and groundwater discharge shows a much stronger tendency for multi-year droughts for the semiarid regime than for the sub-humid regime.

This is caused by the relatively strong, regular seasonal component in the Pang as compared to the Hormozgan province. This seasonal cycle has two effects on the discharge droughts. First, it prevents pooling of the droughts and thus the forming of multi-year droughts. Second, it causes a large influence of the recharge in winter (or high flow season) on the discharge drought in the following summer (low flow season), because the effect of the decrease in recharge is delayed.

So, the major processes influencing the discharge droughts for the semiarid regime are pooling of the droughts and attenuation, and for the sub-humid regime is delay from winter to summer and attenuation.

Ground-water recharge in the arid and semiarid parts in the south of Iran results from the complex interplay of climate, geology, and vegetation across widely ranging spatial and temporal scales. Present-day recharge tends to be narrowly focused on time and space.

The paper stresses the potential of deep groundwater to provide reliable supplies of good water when surface supplies and shallow groundwater dry up during a drought.

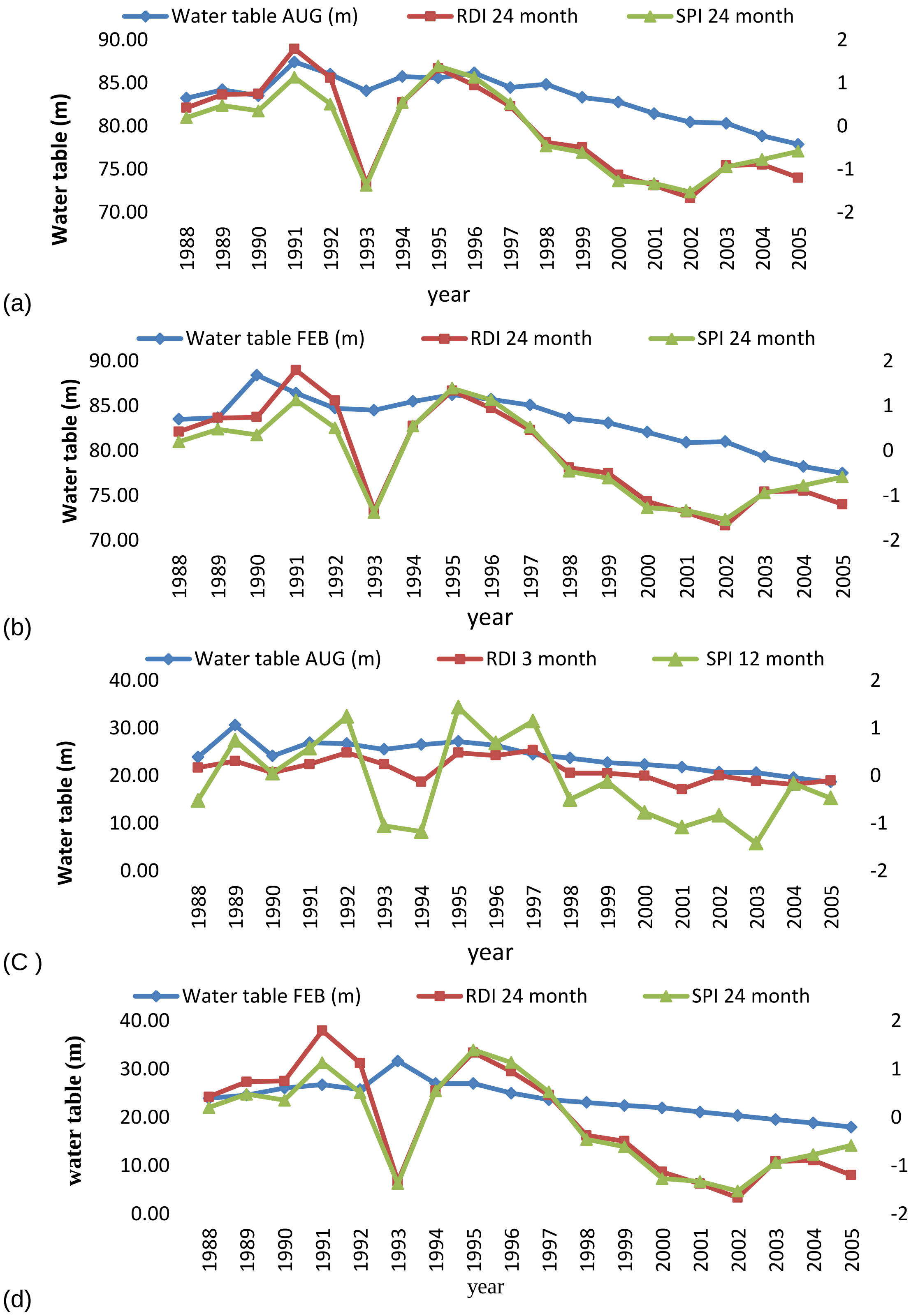

Fig. 3. a= Water table of Sarkhoon and RDI & SPI on AUG, b= water table of Sarkhoon and RDI & SPI on FEB,c= water table of Esinshargh and RDI & SPI on AUG, d= water table of Esinshargh and RDI & SPI on FEB

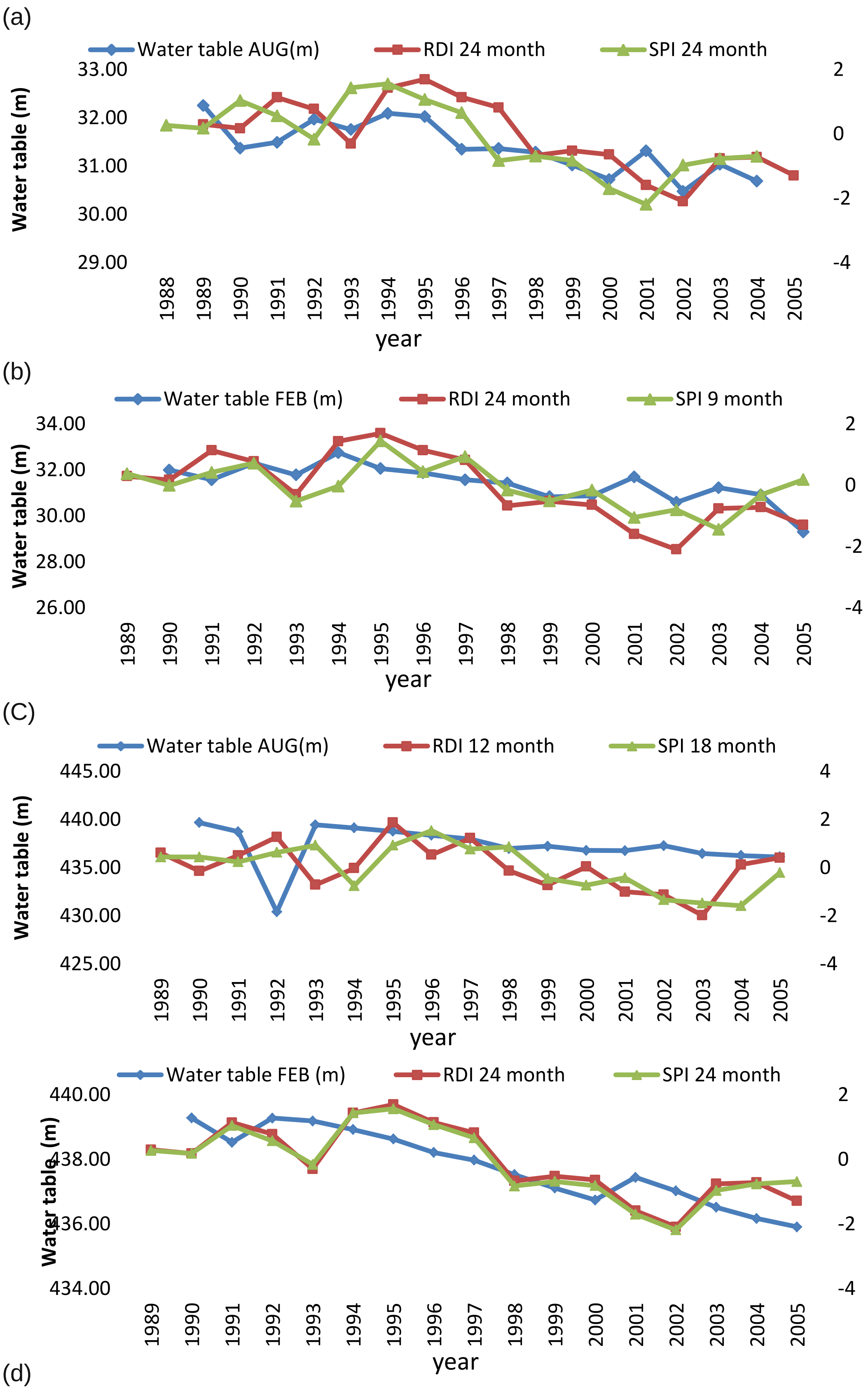

Fig. 4. a= Water table of Parsian and RDI & SPI on AUG, b= Water table Parsian and RDI & SPI on FEB,c= Water table of Bastak and RDI & SPI on AUG, d= Water table of Bastak and RDI & SPI on FEB

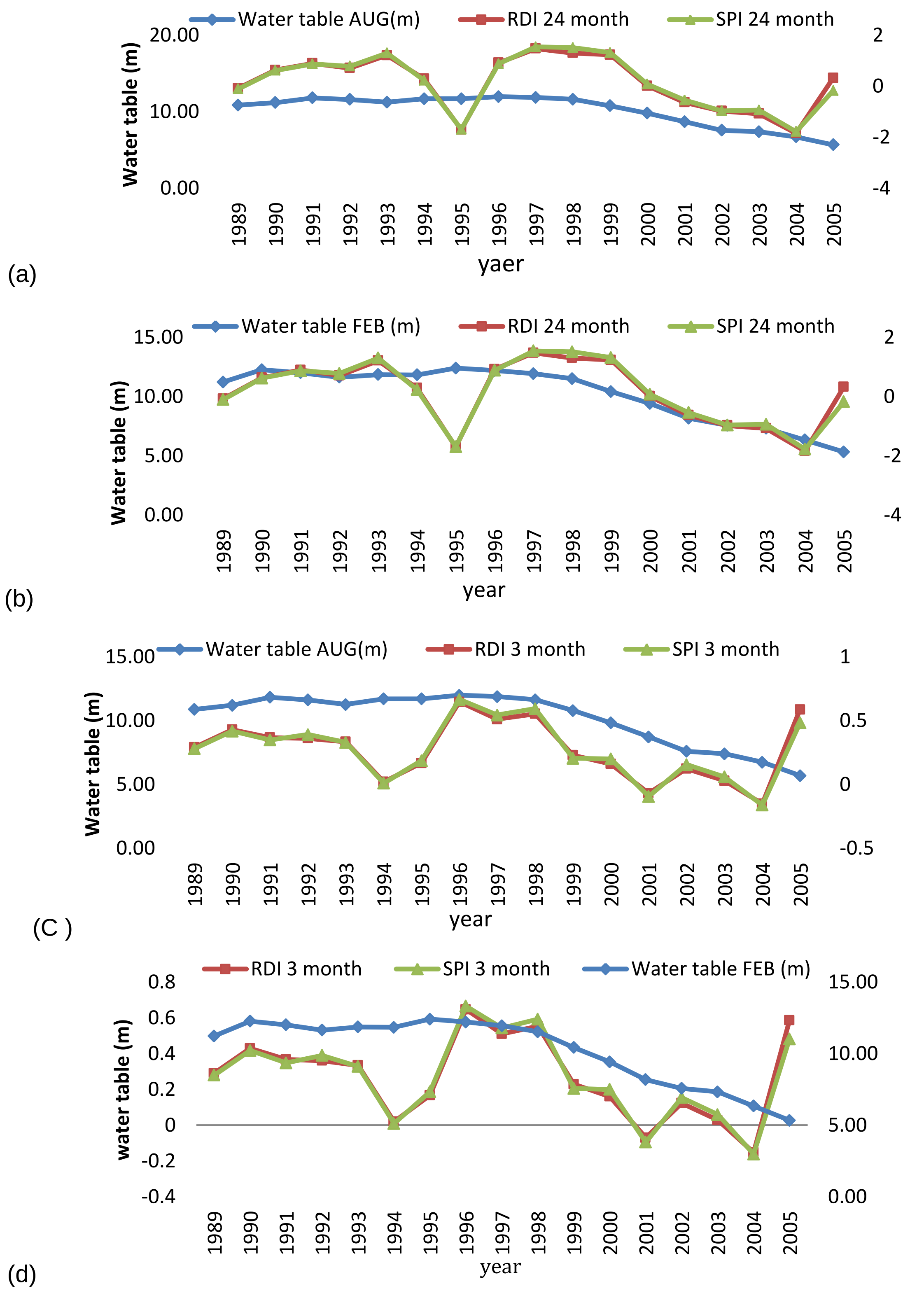

Fig. 5. a=Water table of Minab and RDI & SPI on AUG, b= Water table of Minab and RDI & SPI on FEB,c= Water table of Jaghin to kahur and RDI & SPI on AUG, d= Water table of Jaghin to kahur and RDI & SPI on FEB

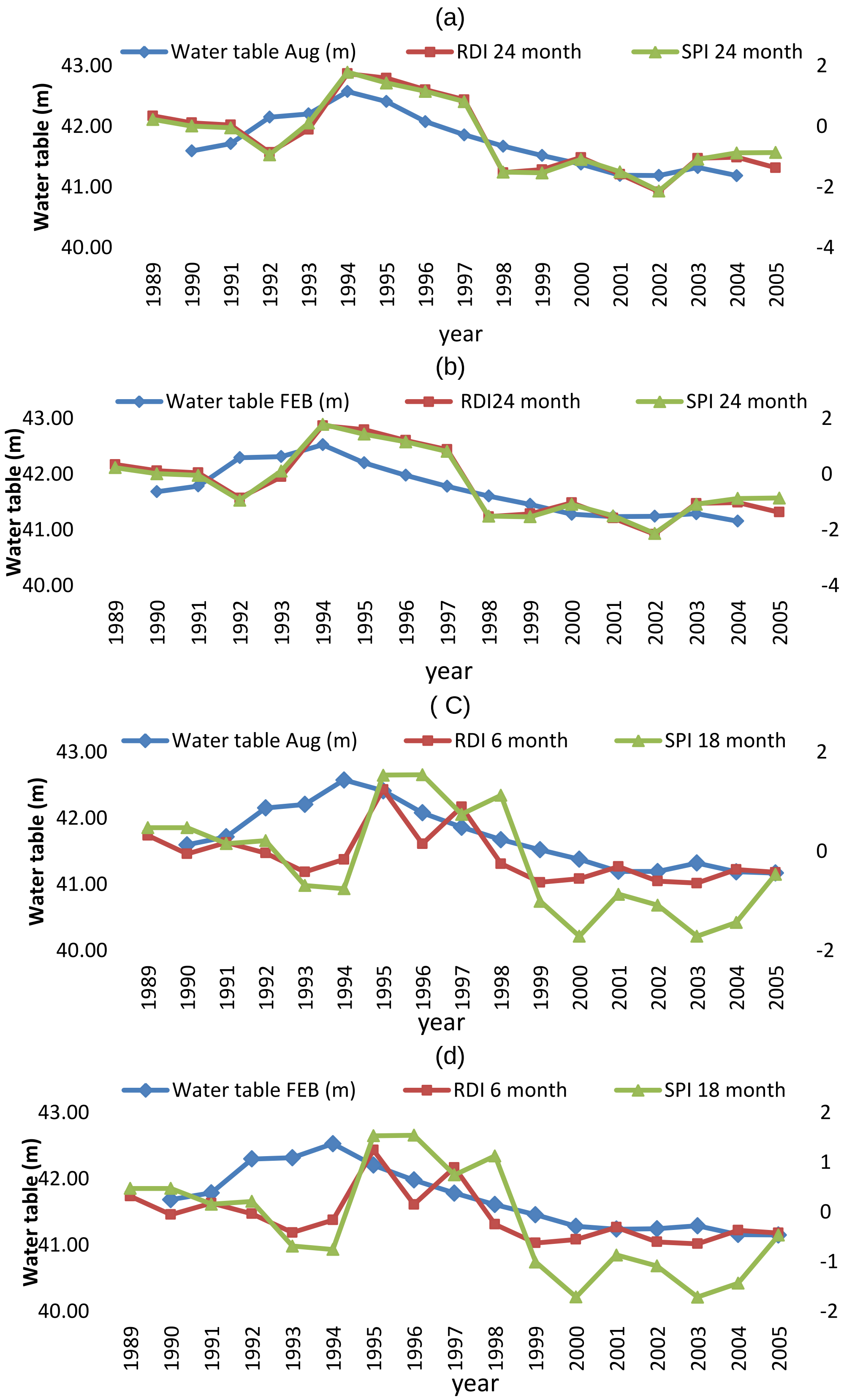

Fig. 6. a=Water table of Jask and RDI & SPI on AUG, b= Water table of Jask and RDI & SPI on FEB, c= Water table of Gabrik and RDI & SPI on AUG, d= Water table of Gabrik and RDI & SPI on FEB

As shown in Figure 3a and b, RDI and SPI follow slightly similar behavior in Sarkhoon. Also RDI behavior is in accordance with groundwater table of summer period from 1988 to 1992 and 1995.In other years, RDI and SPI are below zero line in which groundwater table depletion has occurred. The most severe drought has occurred in 1993 and 2002. However the correlation between indices and groundwater table is the lowest for winter time (February) in Esinshargh plain (Fig. 3d and Table 5). As a general conclusion, the highest correlation in almost all plains is related to long term period (24 months) which shows that drought becomes more important and prevalent in long term periods. However higher correlation of Minab plain and RDI&SPI three months shows the quick response of this plain to the meteorological droughts.

Esinshargh plain shows drought period changes in the range in August. One reason may be the affection of the wells in this plain by precipitation in Genu Mountain. In other conditions, Groundwater levels Esinshargh and Sarkhoon plains have shown good correlation (Respectively 0.66- 0.8; 0.7-0.8) correlation with the indices in 24 month period.

Jaghin to kahur is located at an altitude above sea level. According to plain topographic conditions, the majority of wells feeding is provided by rainfall in mountainous areas. According to the meteorological, total annual precipitation Jaghin to kahur plain is greater than Minab plain. Hence, the three months drought indices inthis plain have good correlation (0.68-0.71) with the water level. Minab plain is located on a coastline of beaches. The drought of recent years in the area accompanied with a decrease in atmospheric precipitation. So the best correlation drought (0.6- 0.66) with groundwater levels happens in a period of 24 months.

Bastak plain Rainfall amount is more because this plain is located at highlands. This plain weather conditions is influenced by the masses of the South West. Hence, groundwater resources in this plain show more variability to drought indices. Parsian plain is located in the coastal plain. Changes in groundwater levels show a high correlation (0.57-0.73) with the drought period of 24 months.

Gabric plain is affected by the Bashagard mountains. With monsoon rains, the water comes from upstream to the plain. Due to the monsoon and shortage of rainfalls, drought trend indicators RDI and SPI are different from groundwater level changes. Jask plain is located in the coastal strip like Minab and Parsian plains. Changes in groundwater levels are highly correlated (0.64-0.57) with drought period of 24 months.

5. Conclusions

Groundwater resources and their long-term replenishment are controlled by long-term climate conditions. Climate change will therefore have a great impact on groundwater resources. Groundwater has to be used and managed in a sustainable way in order to maintain its buffer and contingency supply capabilities as well as adequate water quality for human consumption, also under predicted climate changes. Land use planning has to consider groundwater resources as a precious and finite resource, and take all possible measures to protect groundwater resources and their recharge mechanisms in the long run.

Groundwater is the intricate, but often overlooked, link between surface waters and many freshwater and terrestrial ecosystems. As many groundwater systems both discharge into and are recharged from surface water, impacts on surface water flow regimes are expected to affect groundwater. Thus neglecting the consideration of groundwater in the process of IWRM can result in the mismanagement of surface water with severe effects on the population and the environment. Safeguarding and enhancing the benefits from groundwater under climate change will only be possible through dedicated efforts and intelligent development and management strategies.

By studying and implementing flood spreading and artificial recharge, in order to strengthen balance part of aquifers can avoid the risk of decline in groundwater levels. These risks include reducing the volume of underground water reservoirs, the influx of saltwater, reduce the discharge of dry wells and aqueducts, meeting the destruction of the earth's surface and underground water reservoirs and underground water resources is fresh water quality degradation and destruction. Reducing groundwater levels in areas near the sea, underground aquifers can be replaced with sea water. Due to the proximity of Minab, Bandar Abbas, Bandar Lengeh and Parsian plains can lead to destructive consequences. The level of groundwater in the long term can be reduced to such an extent that precipitation is not able to replace it. As a result, rivers and wetlands will dry and groundwater pumping to the surface also becomes impossible. According to drought of the past 17 years ignoring and disregarding the consequences caused irreparable damage to groundwater and as a result of agriculture, livestock and even industry activity.

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