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International Journal of Pharmaceutical Research & Allied Sciences, 2016, 5(3):437-447

Research Article

ISSN : 2277-3657
CODEN(USA) : IJPRPM

Studying the effects of drought on groundwater aquifers of Zarand, Kerman

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ABSTRACT

Today, considering the important role of groundwater and due to the severe loss in its level, predicting the changes in the level of groundwater is an important issue in the management of water resources, particularly in arid and semi-arid areas. In the present age, population growth and factors related to it on the one hand, and the occurrence of drought on the other hand have always caused more efforts on the part of human to find appropriate solutions for supplying and water and its optimized consumption. Therefore, in this study it was tried to study the effect of drought on groundwater and pistachio products in Zarand.
In doing so, the precipitation of a 32-year period was studied and 36 piezometric wells were considered to assess the effect of drought. According to data analysis with the help of SPI indices, and GIS and SPSS software, it was found that during the study period, a weak drought prevailed. The worst drought in terms of intensity and continuity was in 1999-2000 and 2005-2006, and the highest wet period was in 1992-1993, which have been examined during the period under study. According the main objective of the study, there is a weak correlation between fluctuations in rainfall and groundwater level. Therefore, one cannot have an absolute verdict, considering the direct impact of rainfall fluctuations on groundwater level fluctuations. In the next step, correlation analyses were performed on the fluctuations and pistachio production, and the results showed no significant correlation between these two factors.
Keywords: *drought, groundwater, Zarand, SPI index*

INTRODUCTION

The occurrence of drought in an area is closely connected to water supply in that area, and as supplying water in any area is connected to the region's climate regime, the definition of drought changes according to the conditions of each area. Thus, the definition of drought should be expressed in sectional and regional forms [5]. In fact, the absence of a general definition of drought, taking into account the severity, duration, and scope of its effect, has differentiated this phenomenon from other natural disasters [6]. In defining drought, it should be stated that human being has always struggled with natural disasters such as droughts, floods, earthquakes, etc., and many studies and projects have been conducted for predicting, controlling, and planning to prevent the damage of these phenomena. Drought is a phenomenon different from other natural disasters in that it does not occur at random and suddenly, and the damage it may cause in case of occurrence during a period is irretrievable. In their studies, [2] have defined drought as a phenomenon that occurs in any kind of weather and climatic conditions and as a part of the climatic characteristics of each climate that occurs from time to time. Moreover, in the definition of drought, [4] stated that drought is the unexpected reduction of atmospheric precipitations in a certain period in an area that is not necessarily dry. This phenomenon is not the constant feature of the climate of a region, but if it continues, it turns to drought and is often associated with other climatic factors such as high temperatures, high-speed winds and low relative humidity.

Groundwater has always been considered as one of the major sources of supplying drinking water and agriculture, especially in arid and semi-arid areas. Uncontrolled exploitation of groundwater in many parts of the world has brought about a sharp drop in groundwater level that has aggravated the effects of drought in turn. Statistics presented at the World Resources show the annual loss of groundwater. Fluctuation in groundwater levels is an appropriate indicator to calculate the rate of changes in water table storage. Many factors such as precipitation, evapotranspiration, river flow, perspiration, etc., are the cause of these fluctuations [7]. Fluctuations in groundwater level can be in three ways:

1) Short-term fluctuations: If the water table is high, we may have short-term daily, weekly, or monthly fluctuation.

2) Seasonal-annual fluctuations: These fluctuations mostly happen due to rainfall and the resulting effective penetration and pumping of groundwater for irrigation.

3) Long-term fluctuations: alternating wet and dry periods cause long-term fluctuations in groundwater levels.

For more information on the status of groundwater resources and their optimal management, it is necessary to have an exact examination of groundwater level fluctuations. In a study entitled "The management and development of water resources in Kadapa, India," [10] states that the continuous decline in groundwater levels, wells drying up, and water quality issues are as the result of the indiscriminate exploitation of groundwater resources for agriculture, industry, and livestock uses. [1] used panel data models in three joint, fixed, and random effects to predict the behavior of groundwater level in Neyshabur plain and showed that the joint-effects panel data model has the best results in predicting groundwater level. By scrutinizing the underground water level fluctuations, one can use them in reliable water supply planning and management of water resources [1]. For this purpose, finding rainfall effects and studying its significant effects on groundwater levels are necessary [9]. From among the quantitative indices in analyzing drought, SPI has global acceptance as an appropriate index to analyze drought due to simplicity of calculations, using available data on rainfall, and the ability to be calculated for different periods of time and different location scales [8]. Using the standardized precipitation index, [3] studied drought and its impact on groundwater resources in the East of Kermanshah. Their results showed that SPI is almost an appropriate index to examine the effects of drought on groundwater resources and a high correlation between SPI value and underground water depth is a suitable reason to confirm this issue.

Due to the special geographical and climatic conditions, Kerman has not been immune from this phenomenon, and there is always the possibility of several destructive droughts. Therefore, it is necessary to develop and provide scientific projects to identify the characteristics of drought in the region, so that with the help of them, a step can be taken towards better recognition of this phenomenon and to minimize the social and economic losses due to its occurrence.

The main objective of this study is to investigate the effect of drought on water resources in Zarand as well as the reasons and causes of drought in this city and to find ways to prevent drying of groundwater resources, so that by providing functional projects, the reduction of these valuable resources can be prevented to some extent.

Materials and Methods

Area under study

Zarand plain with an area of 5870 square kilometers is located between the mountains of edge of Lut (in northeast) and Badamu mountains (in the southwest). This plain has a longitude of 56 degrees and 34 minutes east, latitude of 30 minutes and 49 minutes north, and medium altitude of 1500 meters above sea level and has two parts: Central and Yazdan Abad (Figure 1).

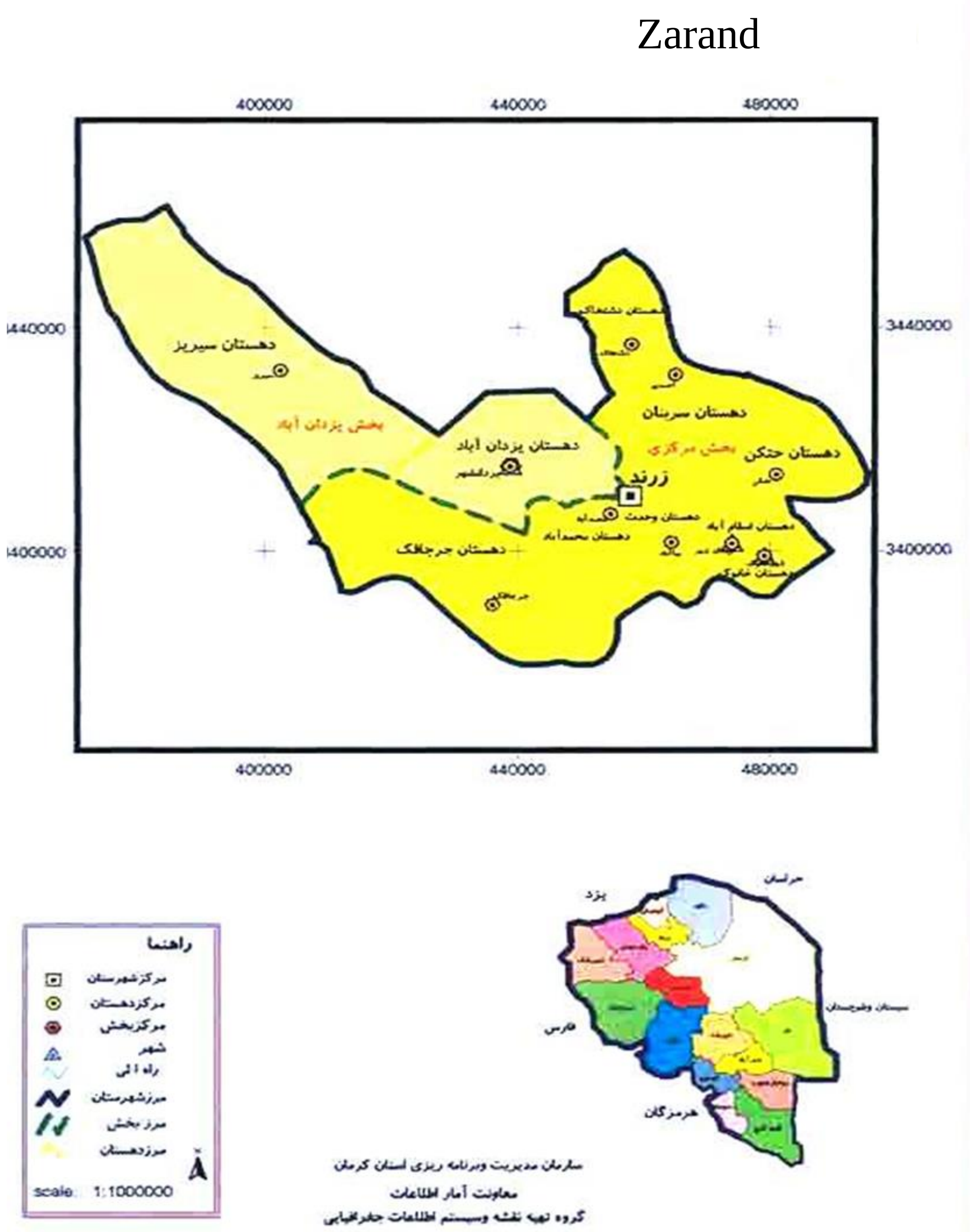

Figure 1: Geographical location of Zarand

The required data

As to calculate SPI index, a minimum of 30-year period is required, in the studied area, the monthly rainfall data of 13 pluviometry stations in Zarand plain during a 32-year period (1982-2013) with regular statistics and low defects has been used. Defects in statistics have been fixed using SPSS software (Table 1).

Table 1: Stations used in SPI drought index

In this study, the statistical database and synoptic data for the amount, duration, and intensity of rainfall in the city

Station name	Longitude	Latitude	Altitude	Record period length	Type of stations
Kerman	58-56	48-30	1753	1982-2013	Pluviometry
Zarand	34-56	48-30	1680	1982-2013	Pluviometry
Siriz	58-55	57-30	1405	1982-2013	Pluviometry
Bibi Hayat	36-56	28-30	2210	1982-2013	Pluviometry
Kuhban	17-56	21-31	2010	1982-2013	Pluviometry
Jorjafak	19-56	39-30	1090	1982-2013	Pluviometry
Aliabad	30-56	51-30	1658	1982-2013	Pluviometry
Simak (Bidouiyeh)	32-57	22-30	962	1982-2013	Pluviometry
Dahouiyeh	42-56	46-30	1950	1982-2013	Pluviometry
Sarasiab	15-56	22-30	1840	1982-2013	Pluviometry
Arjas	31-56	25-20	2230	1982-2013	Pluviometry
Bilabad	23-56	36-30	2220	1982-2013	Pluviometry
Dashtkhak	33-56	04-31	2290	1982-2013	Pluviometry

are used, and the other is environmental data of the research. Geographic area studied in this research is 13 pluviometry stations (Kerman, Zarand, Siriz, Bibi Hayat, Kuhban, Jorjafak, Aliabad, Simak (Bidouiyeh), Dahouiyeh, Sarasiab, Arjas, Bilabad, Dashtkhak) for a 31-year period of peak discharge and rainfall, and the days with extreme precipitation are determined.

Statistics and information have been provided from meteorological organization and hydrometric data from the Regional Water of Kerman during a period of 12 years. Data analysis has been done through tables and using GIS and SPSS software, and the zoning map of the area has been plotted by GIS software. To determine the correlation coefficient, Pearson's statistical methods have been used. SPSS software is used for statistical analysis, and GIS software for zoning area.

Data analysis

The results of SPI

This index is based on monthly and annual precipitation of the studied region. Due to the abundance of tables and analyses, the results of applying the index on data from Zarand station are sufficed as samples that are given below (Table 2).

Table 2: The results of applying SPI index on annual data of rainfall in Zarand

SPI index	rainfall	Year	SPI index	rainfall	Year
0.74	139	1998-1999	0.47	124.5	1982-1983
-2.03	368	1999-2000	0.82	143	1983-1984
-0.55	80.1	2000-2001	0.22	112.5	1984-1985
0.3	116.5	2001-2002	0.45	123.5	1985-1986
-0.42	85	2002-2003	1.16	163	1986-1987
0.23	113	2003-2004	1.55	187.5	1987-1988
1.26	169	2004-2005	-0.69	75	1988-1989
-2.24	32.5	2005-2006	0.28	115.5	1989-1990
0.24	113.5	2006-2007	0.69	136.18	1990-1991
-0.74	73	2007-2008	0.05	104.77	1991-1992
-1.19	58.5	2008-2009	2.16	230	1992-1993
-0.34	88	2009-2010	-0.05	100.2	1994-1995
-0.86	69	2010-2011	-0.41	85.2	1994-1995
-1.19	58.5	2011-2012	1.27	169.5	1995-1996
-0.63	77	2012-2103	-0.03	101.2	1996-1997
-1.47	50.5	2013-2014	0.97	151.5	1997-1998

To determine the severity and frequency of wet and dry years of the area studied using SPI, rainfall fluctuations on time scales of Autumn, Winter, Spring, Summer, 6 months (March to August), 6 month (September to February), 6-month winter and spring, 9 farming months (from January to August) and annual time scale have been studied.

The reason for selecting these indices in short-term and long-term forms is the process of effects that rainfall has in a shorter time-scale on soil moisture and farming issues have on water resources in long-term. The analyses of fluctuations in rainfall according to classification related to criteria SPI index are given in Tables 3 and 4 in the relevant time scales.

Table 3: Values set for drought using SPI indices

SPI classification			
Status	**SPI**	**Status**	**SPI**
Extremely wet	Greater than or equal to 2	A little dry	-1 to 1.49

Very wet	1.5 to 1.99	Very dry	-1.5 to -1.99
Mildly wet	1 to 1.49	Extremely dry	Smaller than or equal to -2
Close to normal	-0.99 to 0.99		

Table 4: Frequency of the intensity of wet and dry years in the studied region in different time scales

Intensity of dry and wet year / Period	Extremely wet	Very wet	Mildly wet	Close to normal	A little dry	Very dry	Extremely dry	Total
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency
Fall	3	4	6	77	5	0	0	96
Winter	2	6	6	65	10	7	0	96
Spring	2	4	10	74	4	0	2	96
Summer	3	34	30	29	0	0	0	96
6 months (March to August)	5	10	0	143	15	7	1	192
6 month (September to February)	5	38	40	103	4	2	0	192
6-month winter and spring	4	10	16	139	14	0	0	192
9 farming months	7	44	46	168	14	9	0	288
Annual	1	1	3	22	3	0	2	32

As specified in the table, the results of applying SPI index indicate that the most highly wet and dry years are in near-normal class and after that, there are very wet and mildly wet classes with equal frequency.

Index years of wet and dry years

Calculations of the SPI were used to determine dry and wet years. According to the calculations, years 1999-2000 and 2005-2006 were determined as an indicator of drought years and 1992-1993 were determined as wet year indicator (Figure 2).

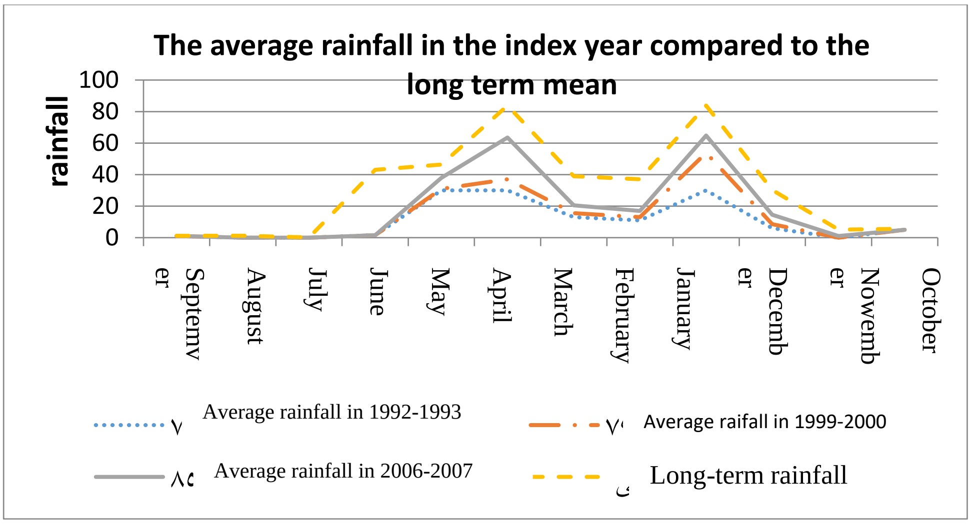

Figure 2: The average rainfall in the index years compared to long term mean

As can be seen in Figure 2, the most severe drought occurred in the area in 1999-200 and 2005-2006, so these years are considered as index dry years. Moreover, the diagram shows that the years 1992-1993 are as wet year index in the period studied.

Examining piezometer wells

In order to study fluctuations in groundwater level, 36 piezometric wells are studied. It should be noted that these wells are chosen from among the ones in Zarand and around the city. Below the map of these wells in the study area are examined (Figure 3).

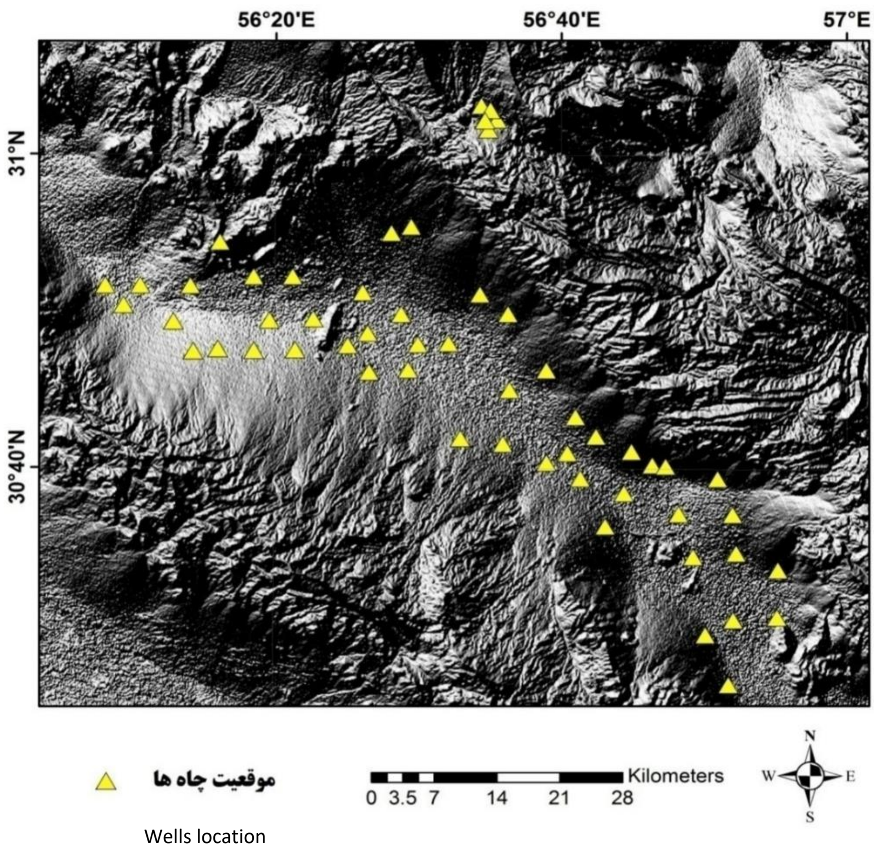

Figure 3: Distribution of piezometric wells in Zarand

In the study area, according to available statistics, water level fluctuations of piezometer wells in the years 2002-2012 have been measured and recorded. The difference between the statistics of wells water levels are used to show the changes (Figure 4).

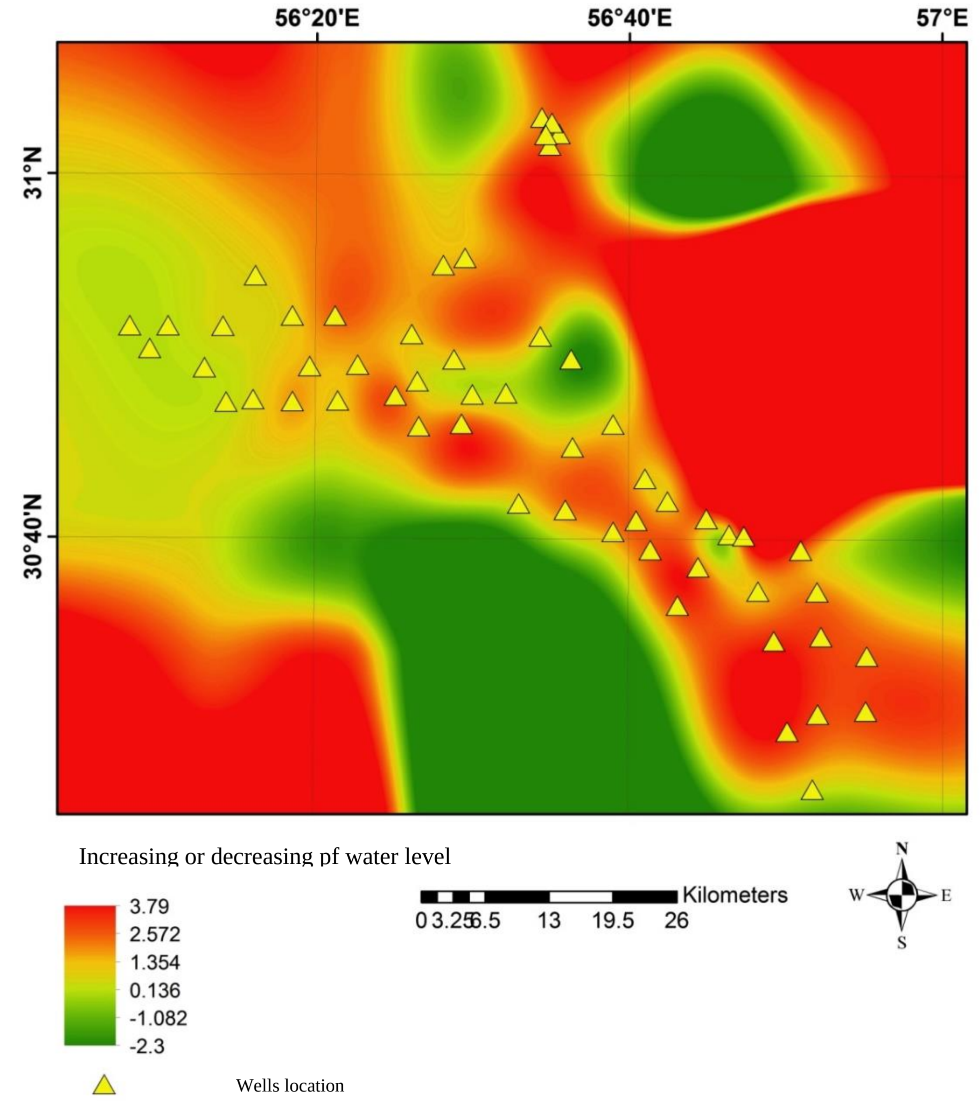

Figure 4: Map of surface and contour drawdown in piezometric wells in years from 2002-2003 to 2011-2012

Correlation between precipitation and groundwater level at different times

The correlation coefficient and linear regression between rainfall and water level changes in wells are calculated in order to quantify the relationship between annual precipitation and annual fluctuations of groundwater level. The result is displayed in the following table (Table 5).

Table 5: The results of the relationship between precipitation and water levels in piezometric wells and during the study period

Period	Sig	Correlation coefficient
Fall	0.008	-0.750
Winter	0.425	0.269
Spring	0.879	0.052
Summer	0.735	0.116
6 months (March to August)	0.349	-0.313
6 month (September to February)	0.831	0.073
6-month winter and spring	0.738	0.114
9 farming months	0.318	-0.332

Based on the results from the table above, the correlation coefficient of changes in rain in autumn, winter, spring, and timescales shown, and the water level of piezometric wells is not direct and significant. This is because first, significance in all the periods is greater than 0.005, and the correlation coefficient has distanced from 1 and -1 and is close to zero.

The effects of rainfall on agricultural production

Water shortage in July and August is one of the main factors limiting agriculture. Irrigation of products starts from mid and late April and continues until mid-September and rarely until October. Pearson correlation coefficient is used to estimate and analyze the relationship between rainfall and the amount of pistachios. The results are shown in Tables (6 and 7) and Figure (5).

Table 6: Annual Pistachio production in Zarand during 2006-2013 (Zarand Agriculture Organization)

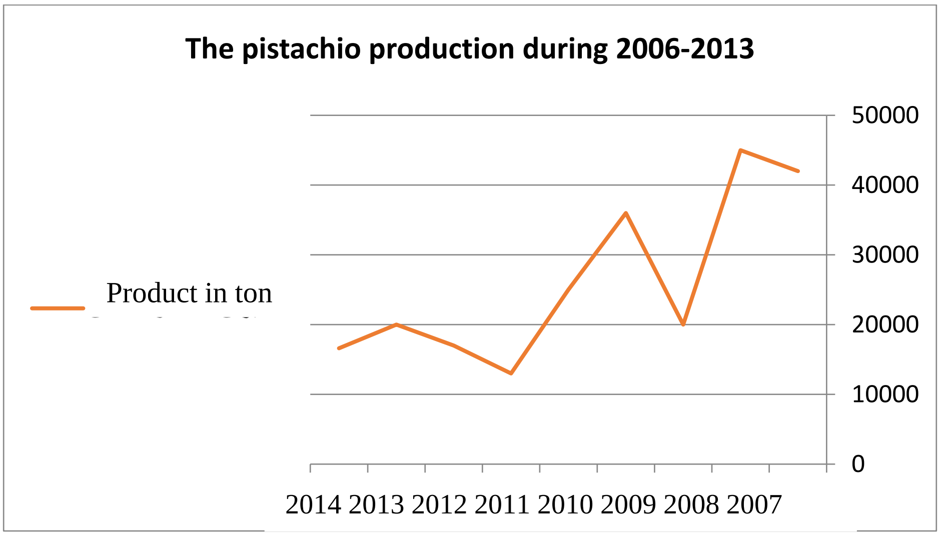

Figure 5: Graph of pistachio production during the period 2006-2013

Year	The area under cultivation (ha)	Amount of product (in ton)
2006	46500	42000
2007	45400	45000
2008	45400	20000
2009	45400	36000
2010	45400	25000
2011	45400	13000
2012	45000	17000
2013	42000	20000

Table 7: The results of the correlation between precipitation change and pistachios product

Pistachio	**Correlation coefficient**	**Sig**
Pistachio	0.411	0.312

Based on the results from the table above, the correlation coefficient between rainfall and production of agricultural products is not direct and significant. In these calculations, the significance coefficient is higher than 0.005, and the correlation coefficient has distanced from 1 and -1 and is close to zero. Although there is a weak correlation, this is neither acceptable nor significant.

Conclusion

According to analysis carried out in the research, all the stations within the research area have shown similar results and in most of the years, we have faced drought close to normal and only in 1999-2000 and 2005-2006, there was a severe drought and in 1992-1993, there was an extremely wet year. What are significant in the long-term periods are droughts and wet periods, which are frequently changing. Generally, in recent years, the continuance of wet periods has reduced and dry years have increased. Moreover, studying the charts shows that wet and dry years throughout the study area have occurred with different intensities.

According to analyses carried out and a weak correlation between fluctuations in precipitation and groundwater levels there, the reasons for this decline and fluctuations could be excessive drilling of wells, the lack of efficient use of water and cultivation of water-intensive crops.

Next, correlation analyses were performed between the fluctuation of rainfall and the amount of pistachios, the results of which showed no significant correlation between these two factors. Overall, there were fluctuations in pistachio production, but not all these fluctuations can be linked to rainfall. Items such as fertilizers, pesticides, and generally the progress of agricultural science and technology as well as the interests of farmers can have an impact on this issue.

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