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Impacts of drought phenomenon on the chemical quality of groundwater resources in the central part of Iran—application of GIS technique

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Abstract In the recent decades, global warming has caused water shortages all over the world. This study aimed to investigate the impacts of drought caused by climate change on the chemical quality of groundwater in Saveh County, Markazi province, Iran. The physicochemical parameters of 29 wells were analyzed by the Standardized Precipitation Index (SPI) during the drought period 2004–2015. Wilcox and Schoeller diagrams were applied to evaluate the water quality of wells for irrigation and drinking purposes, respectively. Schoeller diagram was consulted to show the relative concentrations of anions and cations typically expressed in milliequivalents per liter. Also, the Wilcox diagram was consulted to determine the suitability of water for agriculture purposes. Finally, the geographic information system was applied to the zoning of the groundwater quality parameters. According to the results, almost 90% of wells were in the category of "very salty and harmful for agriculture uses" in the last year of the study period (2015). The Schoeller diagram suggests that the water quality of 72.5, 10.4, 65.5, 100, 44.9, and 69% of wells were inappropriate and exceeded the Iranian National Standard level, in terms of TDS, TH, Na^+ Mg^{2+}, Cl^-, and SO_4^{2-} in 2015, respectively. A decrease in yearly average precipitation during the studied period has not only caused overuse of groundwater as the primary water resources but also led to a significant decline in its chemical quality.

Keywords Drought · Chemical quality · Schoeller and Wilcox diagram · Climate change · Irrigation · GIS · Saveh

Introduction

In the recent decades, earth has become warmer, and water shortage has been an issue, almost all over the world, because of changes in climate (Bostrom et al. 1994; Abbasnia et al. 2019b). The increase in average

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global temperature and sea level (Hasan et al. 2014; Yousefi et al. 2017), amplifies coastal erosion, generates greenhouse effect (Ali 1999; Khamutian et al. 2015), melts ice caps and glaciers (Karamia et al. 2019), creates imbalance of levels of precipitation and evaporation (Kumar 2012), decreases the groundwater level (Döll 2009), and especially heightens the drought (Mizyed 2018); these are already the most common consequents of climate change (Green et al. 2011). Consequently, these changes can directly or indirectly influence the hydrological processes and mainly groundwater aquifers (Kumar 2012; Qasemi et al. 2019; Yousefi et al. 2018).

Groundwater aquifers are the second most abundant reservoir for freshwater in the world, after glaciers (Saito et al. 2016; Abbasnia et al. 2018; Cancelliere et al. 2007; Mirzaei et al. 2015). In Iran, groundwater supplies a significant part of water demand for irrigation, drinking, and industrial purposes (Abbasnia et al. 2019a; Jalili et al. 2018). Irrigation sector, which consumes the highest amount of water in Iran (Qasemi et al. 2019) with more than 80% of exploitation of groundwater resources (Qasemi et al. 2018), plays a critical role in qualitative and quantitative changes in aquifers (Alizadeh and Keshavarz 2005; Radfard et al. 2019; Rezaei et al. 2019; Dehghani et al. 2019). Unfortunately, within the last decades, withdrawal of these resources for expanding irrigation and other purposes, together with climate changes and global warming, has caused prolonged drought in many regions of Iran.

Drought is a condition of reduction in rainfall and increases in temperature that can occur during long or short periods (such as a season or a year) in all types of climate (Bloomfield et al. 2019). This catastrophic environmental phenomenon leads to a change in hydrological regimes and consequently makes a significant decrease in the chemical quality of water resources (Ranjpisheh et al. 2018; Yousefi et al. 2018). Therefore, protection and proper management of groundwater resources as vital water reservoirs also undertake a qualitative and hydrologic assessment during the drought, and the global water crisis should be a necessary and undeniable response (Mirzaei et al. 2015).

In order to evaluate the effects of climate change and drought on the quality of groundwater, research has been carried out (Karamia et al. 2019; Soleimani et al. 2018b; Radfard et al. 2018; Ali 1999; Bloomfield et al. 2019; Hasan et al. 2014; Green et al. 2011). Accordingly, several indices used for forecasting the drought include Palmer drought severity index (PDSI) (Palmer 1968), soil moisture drought index (SMDI) (Hollinger et al. 1993), reconnaissance drought index (RDI) (Zarei et al. 2019), and Standardized Precipitation Index (SPI) (Mckee et al. 1993). Also, a comprehensive review of drought concepts has been carried out by Mishra and Singh (2010). Besides, there are various methods to analyze water quality, such as the Schoeller and Wilcox diagrams (Choramin et al. 2015).

Schoeller's diagram is one of the most common methods to assess water quality for drinking purposes that presents the possibility of water samples at a specified point in an area, but the spatial variability of groundwater quality cannot be evaluated by this method (Afzali et al. 2014). Also, the Wilcox diagram is commonly used for agricultural water classification in hydrological studies. It was suggested by Wilcox in 1948 and completed by Torn in 1951. The studied indices and methods present a clear picture of drought and water quality (Choramin et al. 2015; Afzali et al. 2014; Shams et al. 2014). Since major parts of Iran have an arid and semi-arid climate with average annual precipitation of less than one-third of the international standard (Alizadeh and Keshavarz 2005), it is necessary to evaluate drought conditions and water quality changes to proper management of water resources.

The study area of the present investigation (Saveh) is the largest industrial-tourism city in Markazi province with a warm arid climate that is the hub of agricultural production. Wells play a significant role in the potable water of Saveh, but their qualitative and quantitative features have been lowered in the recent drought period (Mohammadi et al. 2012). Thus, this study sheds new light on the effects of drought and decline in precipitation on water chemical quality of wells in various regions of Saveh for 12 years, from 2004 to 2015. For this aim, physicochemical parameters of 29 wells in the studied area have been analyzed by the Standard Precipitation Index (SPI) and were compared with national and international standards. Also, the Wilcox and Schoeller diagrams were used to evaluate the water quality of wells in terms of irrigation and drinking purposes, respectively. Finally, the GIS software was applied for the zoning of the groundwater quality parameters.

Materials and methods

Description of the study area

Saveh is the largest city of the Markazi province, with a population of about 220,762 and an area of approximately 4748 km^2. This city is located at the height of 960–1110 m above sea level, with 50.20° E and 35.3° W geographical longitudes and latitudes, respectively. It has a semi-arid climate with warm summers and slightly cold winters. Its average temperature and average annual precipitation are 18.2 °C and 202.2 mm, respectively.

In the present investigation, to run a more exhaustive survey of water chemical quality of Saveh wells during the study period, the wells were grouped into five areas as follows:

1. Sayyed Gholi area with fifteen wells
2. Yahyaabad area with seven wells
3. Surkan area with two wells
4. Shahrak area with two wells
5. Alavi area with three wells

Figure 1 presents the location of the study area in Markazi province.

Sampling procedure and data analysis

This descriptive cross-sectional study intends to assess the impacts of drought and decline in precipitation on water chemical quality of wells in various regions of Saveh for 12 years, from 2004 to 2015. Twenty-nine groundwater samples were collected from active wells of five parts of Saveh County (Fig. 1). Before sampling, all dug wells were pumped for about 4 mins to remove the impacts of stagnant water, and all sample containers (polyethylene containers with 1-L capacity) were rinsed three times by deionized water. Then, the samples were labeled, stored at 4 °C, and transported to the laboratory for chemical analysis of essential parameters. All

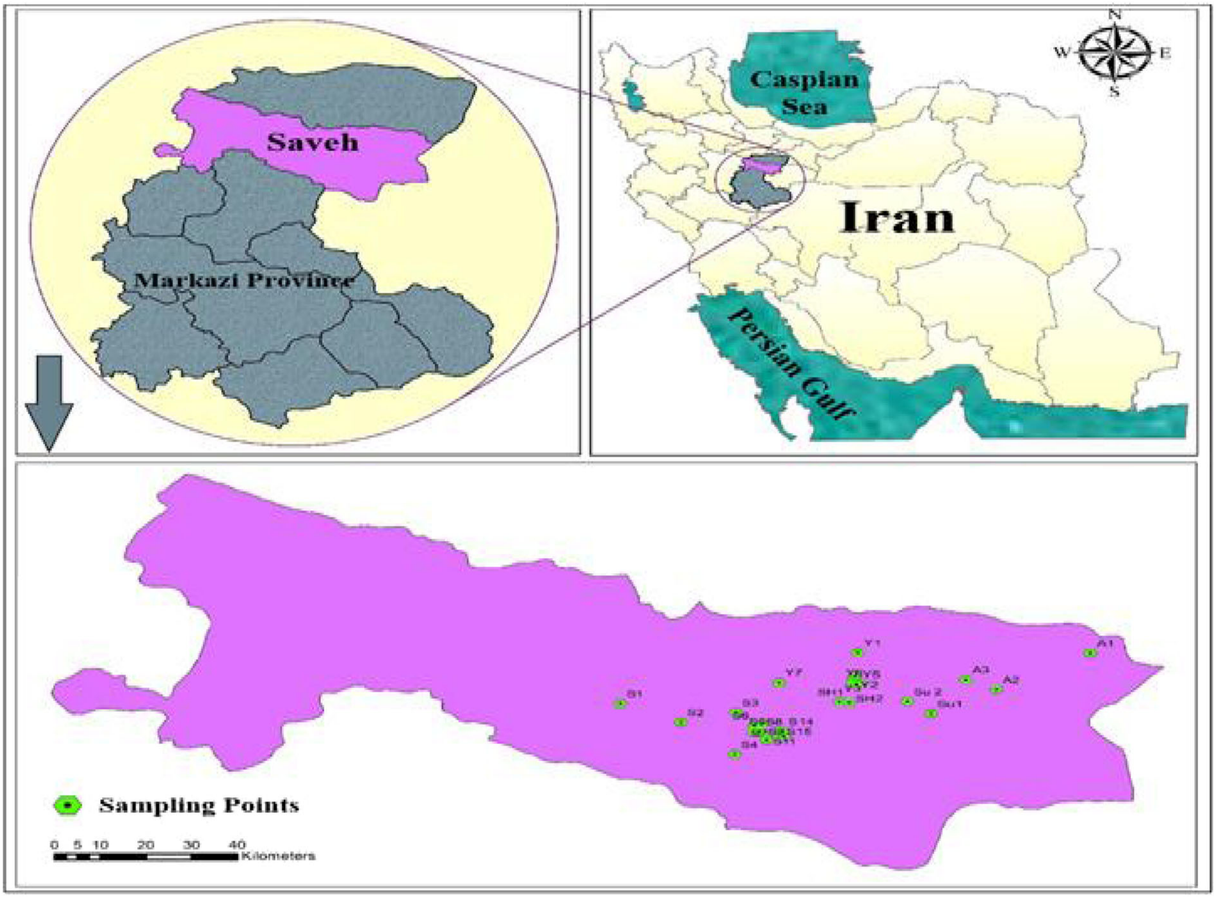


Fig. 1 Location of Saveh County and sampling points in the Markazi province

specific analysis was performed according to the *Standard Methods for Examination of Water and Wastewater* (Federation and Association 2005).

In order to investigate the changes of water quality during the study period, various parameters such as total dissolved solids (TDS), electrical conductivity (EC), total hardness (TH), level of cations such as $Ca^{+2,}$ Na^{+}, Mg^{+2}, and K^{+} as well as anions such as Cl^{-} and So_4^{2-} were analyzed (Table 1). These parameters are effective in the determination of the best water quality in drinking and irrigation purposes in the index years of drought based on the Wilcox and Schoeller diagrams (Mir et al. 2017). Also, the precipitation level was surveyed through the SPI by the application of the DIC™ program. The Schoeller and Wilcox diagrams were plotted by the CAD™ package. Finally, data were mapped by Arc Map GIS 10.3 software.

Standardized precipitation index

Generally, the drought process is analyzed monthly and annually. Although an annual period is long, it is used to collect and interpret regional data. Severity and duration of drought, as well as its spatial orientation, are among the commonly employed criteria to study the drought process. Some indices such as Palmer drought severity index (PDSI) (Palmer 1968), surface water supply index (SWSI) (Jang et al. 2017), rainfall anomaly index (RAI) (Rangarajan et al. 2019), and reconnaissance drought index (RDI) (Zarei et al. 2019) are among the most well-known criteria to investigate drought. In the present research, which is the well-documented one, Standardized Precipitation Index (SPI) was primarily developed for determining and assessing the drought. This index is based on the probability of hydrologic rainfall variable for multiple time scales (Eq. 1) (Gandhi and Parekh 2017; Cancelliere et al. 2007). A striking feature of SPI is its applicability for several spatial series, including year and month. Taking its advantage, we can use the index to assess all kinds of long-period (surface and groundwater resources) and short-period (existent moisture in agriculture soil) water resources (Gandhi and Parekh 2017).

$$SPI = (X_{ik} - X_i)/\sigma_i \quad (1)$$

where

X_{ik}	precipitation level of the *i*th station and *k*th observation
X_i	the mean of long-term precipitation for the *i*th station
σ_i	standard deviation of the *i*th station

Table 1 SPI classification, according to Abba (2015)

SPI	Classification	Probability (%)	Δ*P* (%)
2.00 >	Extremely wet	0.977–1.000	2.3
1.99–1.50	Very wet	0.933–0.977	4.4
1.49–1.00	Moderately wet	0.841–0.933	9.2
0.99–0	Mildly wet	0.159–0.841	34.1
0 to −0.99	Mild drought	0.067–0.159	34.1
− 1 to − 1.49	Moderate drought	0.023–0.067	9.2
− 1.50–1.99	Severe drought	0.000–0.023	4.4
2.00 <	Extreme drought	0.977–1.000	2.3

Table 1 shows the classification of climate according to the SPI.

The SPI can be calculated by Drought Indices Calculator (DIC) software, in which 12 years of data of annual average precipitation from Saveh rain gauge and weather stations were applied as input data (Chaussard et al. 2017).

Wilcox diagram

Excessive sodium in water resources produces the undesirable influence of altering soil characteristics and decreasing soil permeability. Also, high concentrations of this metal lead to higher alkaline levels in soil. A Wilcox diagram can be used to determine the suitability of water for agriculture purposes (Shams et al. 2014). Wilcox plot is evaluated by two main parameters of EC and SAR (Table 2), where *C* and *S* refer to the EC and SAR classification, respectively. According to the values of these two parameters, the water classification for agricultural purposes in the Wilcox diagram has four categories (Table 3). This diagram is a simple scatter plot of the sodium adsorption ratio (SAR) on the *Y*-axis and salinity hazard (conductivity (μS/cm)) on the *X*-axis. SAR is measured by the following equation (Eq. 2), where all the ions (Ca^{+2}, Na^{+}, Mg^{+2}) are expressed in milliequivalents per liter unit (meq/L). (Shammi et al. 2016).

Table 2 Classification of irrigation water based on SAR and EC values (Richards 1954)

Quality parameter EC (μS cm)	Water class	Score	Quality parameter SAR (√mg/L)	Water class	Score
$250 \geq EC$	C1 (low salinity)	Excellent	$10 \geq SAR$	S1(low sodium)	Excellent
$750 \geq EC \geq 250$	C2 (medium salinity)	Good	$18 \geq SAR \geq 10$	S2 (medium sodium)	Good
$750 \geq 250 \leq EC$	C3 (high Salinity)	Average	$26 \geq SAR \geq 18$	S3 (high sodium)	Average
$2250 \leq EC$	C4 (very high salinity)	Unsuitable	$26 \leq SAR$	S4 (very high sodium)	Unsuitable

$$\mathrm{SAR} = \frac{Na^{+}}{\sqrt{{}^{1}/_{2}(Ca + Mg)}} \qquad (2)$$

According to the Wilcox classification, which is based on electrical conductivity (EC) and sodium absorption (SAR), water is grouped into four main grades, including excellent, good, average, and unsuitable (Table 2).

Table 3 illustrates water classification for agriculture purposes based on the Wilcox plot (Shams et al. 2014).

Schoeller diagram

The Schoeller diagram is a semi-logarithmic diagram that portrays the relative concentrations of cations and anions and is typically expressed in milligrams per liter. If ions are plotted in a Schoeller diagram, it is suggested to use the milliequivalents per liter unit since it allows the comparison of the ion ratios directly (Abba 2015). Generally, this diagram is drawn and analyzed in order to classify potable water in the hydrologic reports. In this diagram, water samples are divided into six types, including good, acceptable, average, inappropriate, generally unpleasant, and non-drinkable (Table 4) (Choramin et al. 2015).

Table 3 Water classification for agriculture purposes based on the Wilcox plot (Shams et al. 2014)

Class	Water quality for agriculture purposes
C1S1	Sweet—completely innocuous for agriculture
C1S2-C2S2-C2S1	A little salty—almost good for agriculture
C1S3-C2S3-C3S1-C3S2-C3S3	Passion—usable for agriculture
C1S4-C2S4-C3S4-C4S4-C4S3-C4S2 -C4S1	Very salty—harmful for agriculture

Result and discussion

Average precipitation and SPI

Average annual precipitation in Iran is 250 mm per year that is less than one-third of the world's average (Madani et al. 2016). Primary reasons for low average annual precipitation of Saveh County (that is estimated to be 176 mm per year) can be related to regular drought in recent decades in Iran, as well as the climatic condition (Tahrudi et al. 2016). The amount of average annual precipitation of this area was 288 and 126.3 mm in 2004 and 2015, respectively. Figure 2 indicates the annual average rainfall of Saveh during the studied period.

The Standardized Precipitation Index (SPI) is a universally accepted index to characterize meteorological drought on a range of timescales. In short deadlines, this index is almost related to soil moisture, while at longer timescales, the SPI can be related to groundwater resources and reservoir storage (Bordi et al. 2001; Bonte et al. 2013). Figure 3 shows that during the studied period (2004–2015), the catchment area of Saveh has faced such a severe drought that SPI had been varied from 1.25 (moderately wet class) in 2004 to −2.79 (extreme drought) and −1.88 (severe drought) in 2014 and 2015, respectively (Table 1).

The results show a negative trend of SPI for study years. At the beginning of the study period (2004), the SPI was moderately wet, but continuous drought during 12 years, severe drought in 2014 (SPI = −2.79), and overuse of groundwater resources in recent years could have caused changes in qualitative and quantitative features of water reservoirs (Jang et al. 2017). According to previous investigations, drought plays a critical role in diminishing well's water and consequently, a significant drop in groundwater (Rangarajan et al. 2019; Cancelliere et al. 2007; Abba 2015; Chaussard et al. 2017; Gandhi and Parekh 2017). Moreover, previous studies suggested

Table 4 Standardized classification of drinking water based on the Schoeller diagram (Choramin et al. 2015)

Class	Water quality	SO_4^{2-} (mg/L)	Cl^- (mg/L)	Na^+ (mg/L)	TH (mg/L)	TDS (mg/L)
1	Good	145 <	175 <	115 <	250 <	500 <
2	Acceptable	145–280	175–350	115–230	250–500	500–1000
3	Average	280–580	350–700	230–460	500–1000	1000–2000
4	Inappropriate	580–1150	700–1400	460–920	1000–2000	2000–4000
5	Generally unpleasant	1150–2240	1400–2800	920–1840	2000–4000	4000–8000
6	Non-drinkable	2240 >	2800 >	1840 >	4000 >	8000 >

a meaningful and robust link between SPI and decline in groundwater resources (Shammi et al. 2016).

Effects of drought on the chemical quality of wells based on Wilcox classification

Chemical quality is among the main parameters of water resources management and sustainable development and should be considered in terms of human and ecosystem health (Shams et al. 2014; Choramin et al. 2015). Figure 4 indicates a qualitative change of the studied wells in terms of salinity and sodium absorption ratio for agricultural purposes in 2004 and 2015.

According to Fig. 4, the water quality of 13.8, 20.7, 37.9, 3.4, 3.5, and 17.2% of studied wells are grouped as C2S1, C3S1, C3S2, C3S4, C4S4, and C4S3, respectively, in 2004 (Table 3). Also, the results of the study in 2015 show that water quality of 37.9, 34.5, and 27.6% of wells were in C4S2, C4S3, and C4S4 classes, respectively, which means that the water quality was in the very salty—harmful for agriculture class (Table 3) (Shammi et al. 2016).

Water with a high level of Sodium is not acceptable for agriculture purposes, because the high level of salt leads to lower soil aggregation, osmosis potential of agriculture products, and soil permeability (Yidana et al. 2010; Tweed et al. 2009).

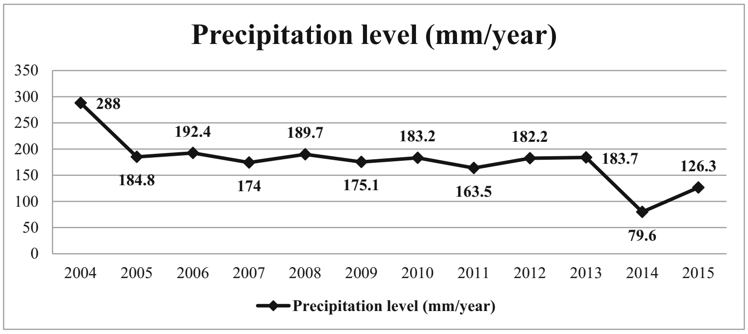
Chemical quality changes based on Wilcox and Schoeller diagrams

As discussed earlier, the studied area was grouped into five regions in order to conduct a more detailed study ("Description of the study area") and changes in chemical quality of water were studied by the Schoeller and Wilcox diagrams. First, the primary chemical qualitative parameters of studied wells were examined. TDS, EC, and levels of sodium, magnesium, calcium, chlorine, sulfate ions, and pH were examined in order to check water quality for agricultural and drinking purposes, and then they were analyzed by the Schoeller and Wilcox diagrams for drinking and agriculture purposes, respectively. Table 5 shows the results of the annual average of qualitative parameters in 2004.

Changes in water chemical quality of Sayyed Gholi's wells

Figure 5 represents changes in water quality of fifteen wells in the Sayyed Gholi region. The figure was plotted by obtained data of TDS, TH, levels of Ca^{+2}, Mg^{+2}, Na^{+1}, Cl^-, SO_4^{-2}, and HCO_3^- based on the Schoeller diagram (Alavi et al. 2016). The diagrams showed that although water quality of most of the wells in the region

Fig. 2 Annual average precipitation in Saveh from 2004 to 2015



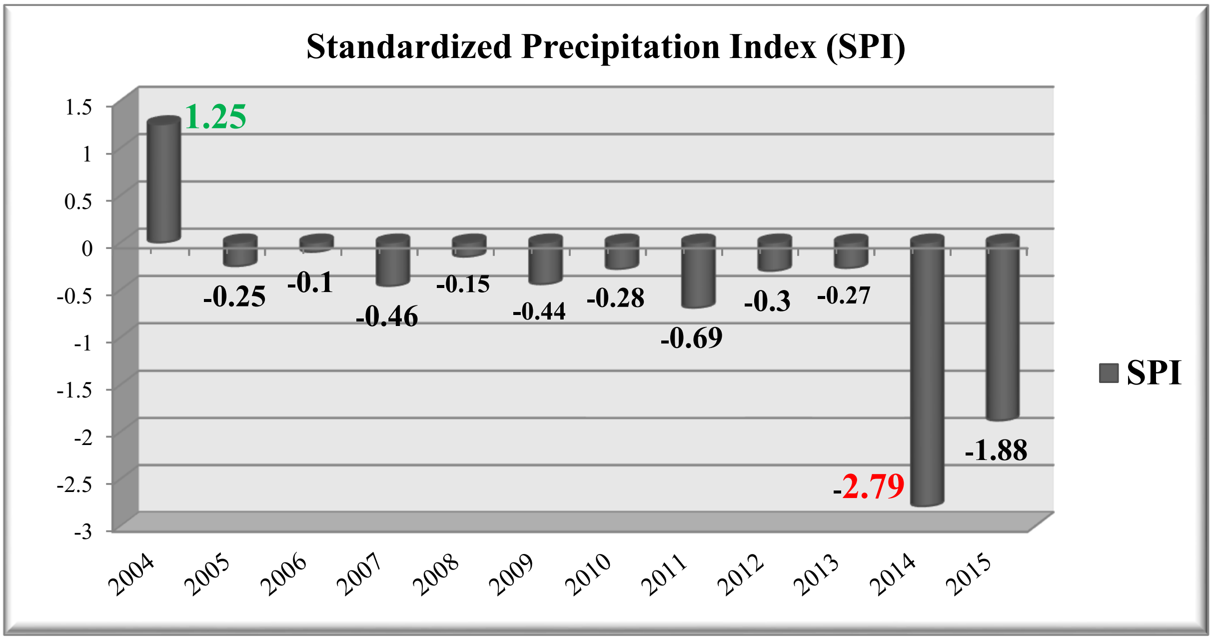


Fig. 3 The amounts of standardized precipitation index of Saveh from 2004 to 2015

was normal in 2004, their quality was unacceptable for drinking purposes in 2015.

Moreover, Fig. 6 represents levels of well qualitative changes in terms of salinity and sodium absorption from 2004 to 2015. According to the diagram, each well is classified into four groups regarding both salinity and sodium adsorption. The Wilcox classification suggests qualitative changes in water quality for agriculture purposes. The diagram suggests that, in 2004, although most of the wells in the studied region were grouped as C3S1 and C3S2 (Table 3); they gradually changed into C4S2, C4S3, and C4S4 over the study period (Alavi et al. 2016; Mishra and Singh 2011).

Changes in water chemical quality of wells located in the Yahyaabad region

Figure 7 represents changes in the water quality of seven wells in the Yahyaabad region. The figure was plotted by using obtained data of TDS, TH, levels of Ca^{+2}, Mg^{+2}, Na^{+}, Cl^{-}, SO_4^{2-}, and HCO_3^{-} based on the Schoeller

Fig. 4 Classification of studied wells according to the Wilcox diagram (2004–2015)

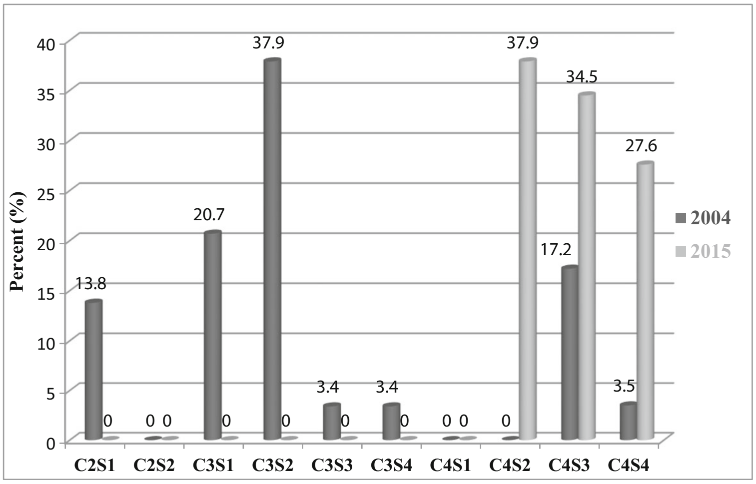


Table 5 Annual average results obtained from analyzing qualitative parameters of the studied wells in 2004

Sample point	SO_4^{2-} (mg/L)	CL^- (mg/L)	CO_3^{2-} (mg/L)	HCO_3^- (mg/L)	Na^+ (mg/L)	Mg^{2+} (mg/L)	Ca^{2+} (mg/L)	pH	TDS (mg/L)	EC (µs/cm)
Sayyed Gholi (well.1)	323	351	0	170	263	46	106	7.3	1204	1709
Sayyed Gholi (well.2)	364	369	0	165	245	41	113	7.4	1237	1755
Sayyed Gholi (well.3)	295	212	0	178	198	26	77	7.5	925	1296
Sayyed Gholi (well.4)	287	234	0	178	216	27	98	7.5	989	1385
Sayyed Gholi (well.5)	279	189	0	157	195	23	67	7.6	863	1210
Sayyed Gholi (well.6)	678	420	0	221	505	29	116	7.4	1887	2641
Sayyed Gholi (well.7)	305	248	0	177	211	33	82	7.5	982	1375
Sayyed Gholi (well.8)	543	345	0	188	404	30	98	7.4	1523	2132
Sayyed Gholi (well.9)	362	327	0	206	243	34	118	7.4	1210	1718
Sayyed Gholi (well.10)	378	311	0	215	223	32	119	6.8	110	1562
Sayyed Gholi (well.11)	232	243	0	185	169	28	98	7.5	892	1248
Sayyed Gholi (well.12)	269	285	0	124	198	29	88	7.5	967	1353
Sayyed Gholi (well.13)	231	255	0	90	218	29	84	7.6	997	1395
Sayyed Gholi (well.14)	288	260	0	184	207	26	89	7.5	986	1400
Sayyed Gholi (well.15)	291	281	0	168	218	32	97	7.7	1038	1453
Surkan (well.1)	542	289	0	285	486	13	44	7.5	1537	2151
Surkan (well.2)	564	314	0	290	472	20	66	7.5	1597	2235
Yahyaabad (well.1)	132	76	0	122	108	8	36	7.5	443	620
Yahyaabad (well.2)	136	104	0	185	142	11	39	7.5	546	764
Yahyaabad (well.3)	117	59	0	192	126	7	24	7.6	460	644
Yahyaabad (well.4)	122	136	0	128	136	11	28	7.7	530	742
Yahyaabad (well.5)	133	74	0	180	132	3/8	25	7.5	404	656
Yahyaabad (well.6)	149	117	0	186	158	5/9	41	7.6	604	846
Yahyaabad (well.7)	214	251	0	222	211	28	83	7.5	626	1296
Shahrak (well.1)	867	648	0	195	643	45	167	7.4	2530	3542
Shahrak (well.2)	785	614	0	225	353	50	165	7.5	2286	3200
Alavi (well.1)	619	587	0	239	564	32	105	7.6	2063	2888
Alavi (well.2)	666	485	0	288	545	34	118	7.6	2010	2814
Alavi (well.3)	809	710	0	166	678	46	148	7.4	2493	3490
Minimum	117	59	0	90	108	7	24	6.8	110	620
Maximum	867	710	0	290	678	50	167	7.7	2530	3542
Average	378.62	303.24	0	189.96	291.96	27.16	87.55	7.48	1170.31	1707.85
WHO* Standard (Organization 2019)	500	250	500	500	200	75	100	6.5–8.5	1000	> 1500
ISIRI** (No. 1053) (Saleh et al. 2019)	400	400	–	150	200	30	300	6.5–8.5	1500	1500

*World Health Organization, **Institute of Standards and Industrial Research of Iran

diagram. The diagrams showed that although water quality of most wells in the region was acceptable in 2004, their quality was normal for drinking purposes in 2015.

Moreover, Fig. 8 represents qualitative changes in wells in terms of salinity and sodium absorption from 2004 to 2015. According to Wilcox classification, changes in water quality of wells for agricultural purposes in 2004 for the most wells in the studied region was C2S1, C3S1, and C3S2, but they gradually changed into C3S2 and C3S3 (Raju 2007).

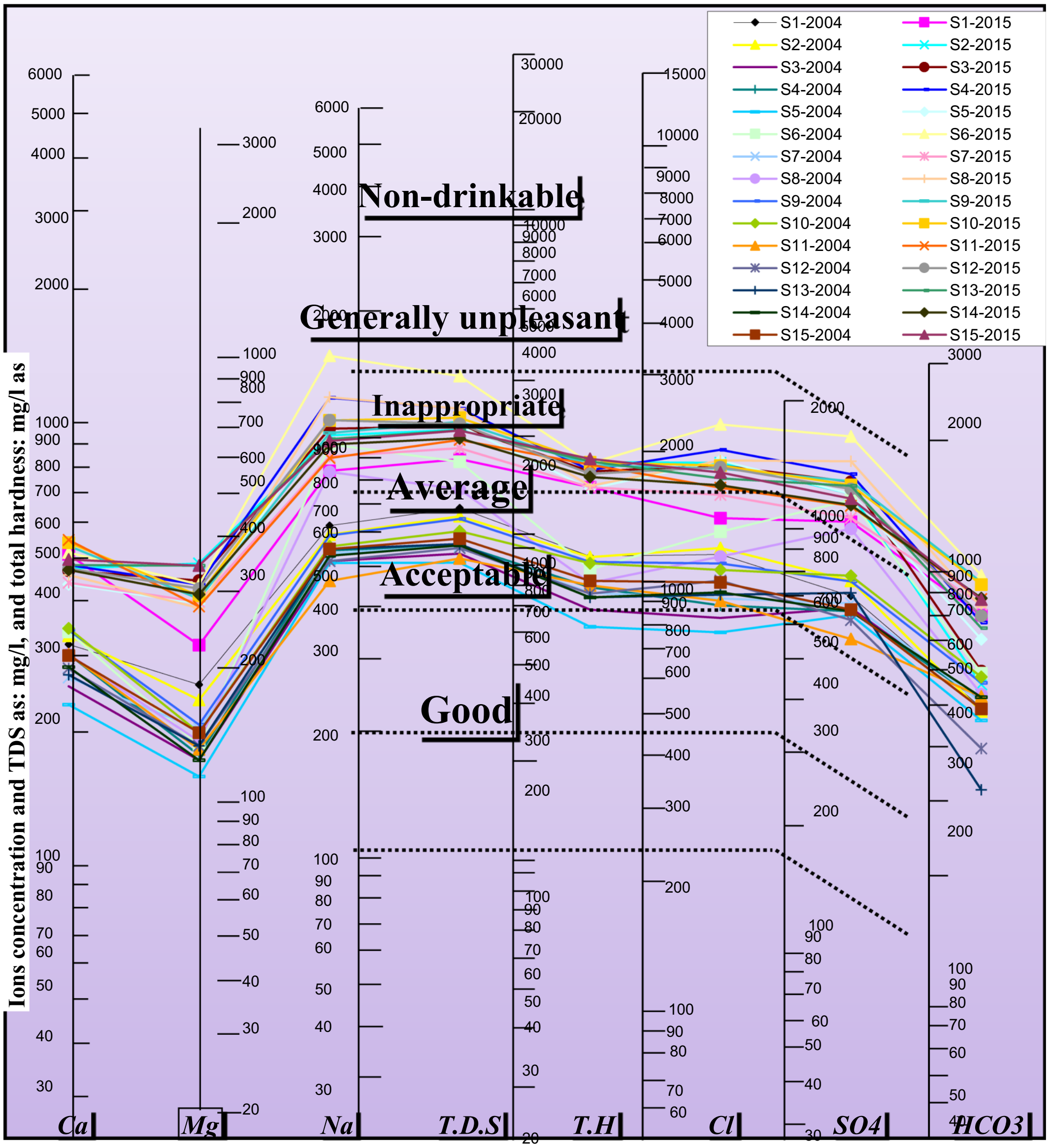


Fig. 5 The Schoeller diagram—comparison of water quality of wells located in the Sayyed Gholi region in 2004 and 2015

Changes in chemical quality of wells in the other areas

Figures S.1, S.2, S.3, S.4, S.5, and S.6 represent changes in water quality of other seven studied wells located in Surkan, Shahrak, and Alavi regions. These diagrams were plotted using obtained data of TDS, TH, Ca^{+2}, Mg^{+2}, Na^{+}, Cl^{-}, SO_4^{-2}, and HCO_3^{-} based on the Schoeller and Wilcox diagrams (Raju 2007).

About Surkan area, the diagrams showed that although water quality of most of the wells was acceptable in 2004, their quality was inappropriate in 2015 (Fig. S.1).

Moreover, although the water quality of most of the wells in the Shahrak region was average in 2004, it was generally unpleasant in 2015 (Fig. S.3). Also, the water quality of three wells of the Alavi region was unacceptable in 2004, and they changed to generally unpleasant in 2015 (Fig. S.3).

Regarding salinity and sodium adsorption, surveying of water in all Surkan, Alavi, and Shahrak regions showed that water quality in these wells was C4S3, C3S4, and C4S3 in 2004, respectively, but it changed to C4S4 in 2015 (Table 2) (Figure S.1).

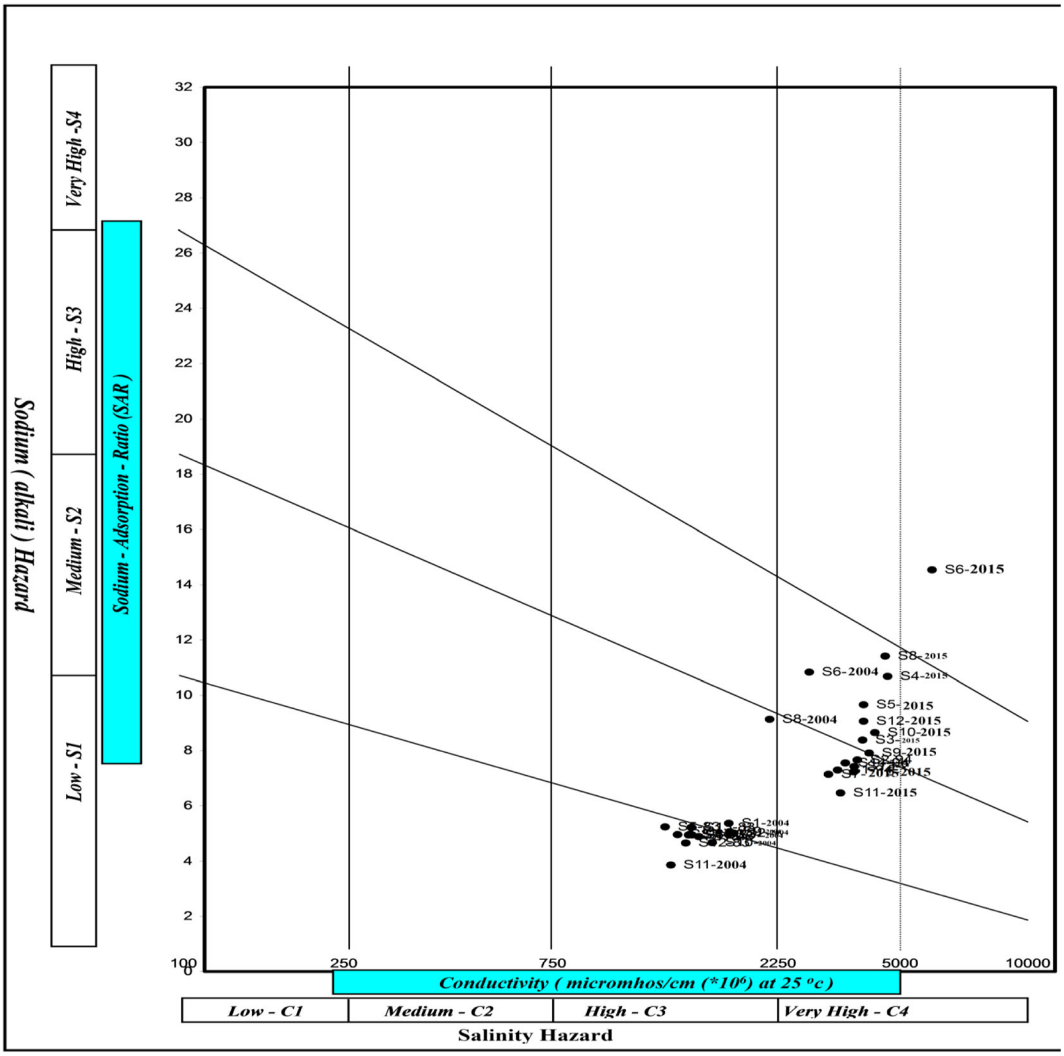


Fig. 6 The Wilcox diagram compares the water quality of wells located in the Sayyed Gholi region for drinking purposes in 2004 and 2015 (S:Sayyed Gholi)

Effect of drought on the study parameters during the study period

As discussed earlier, for this research to run a more exhaustive survey of water chemical quality, the wells were grouped into five areas and different parameters including pH, TDS, TH, Ca^{+2}, Mg^{+2}, Na^{+}, Cl^{-}, and SO_4^{-2} were surveyed regarding the changes during the study period and these changes were finally mapped by GIS.

Effect on pH levels

The Schoeller diagram is a tool used to evaluate the quality of water for drinking purposes (Tahrudi et al. 2016; Bordi et al. 2001). Based on the Iranian National Standard, the pH level of potable waters ranges from 6.5 to 8.5 (Bonte et al. 2013). The results of the Schoeller diagram showed that the water pH of 72.4% of wells was acceptable for drinking purposes in 2004, and these amounts did not change much in 2015. The pH of wells in the studied period meets the Iranian National Standard (Fig. 9) (Yidana et al. 2010).

Effect on TDS levels

According to the Iranian National Standard, the TDS level of potable water is 1000 mg/L (Madani et al. 2016). The Schoeller graph showed that the chemical

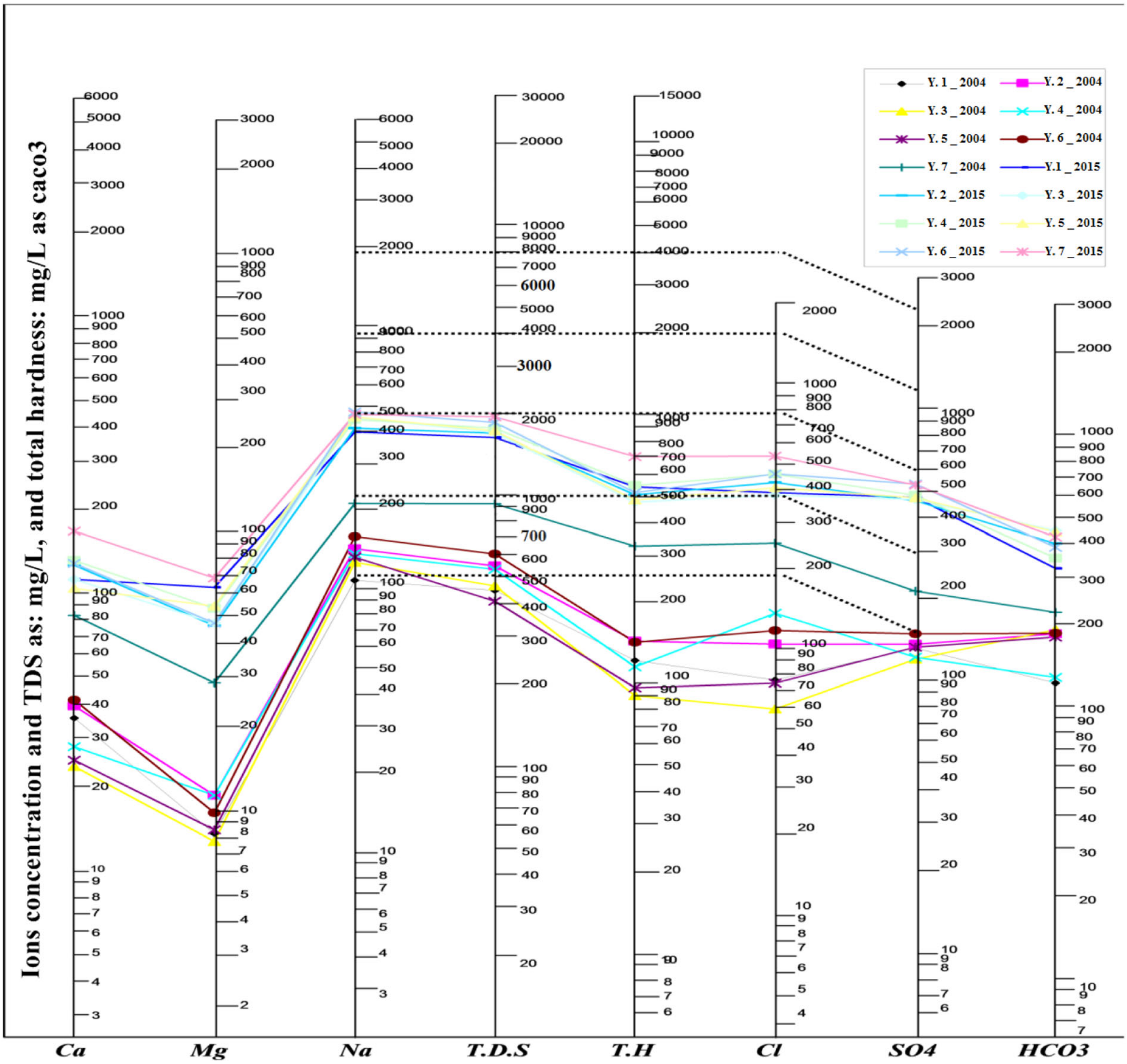


Fig. 7 The Schoeller diagram—comparison of water quality of wells located in Yahyaabad region in 2004 and 2015

quality of 17.2% and 72.5% of wells was unacceptable for drinking purposes in 2004 and 2015, respectively. Findings showed that the TDS level of 46.1% of wells located in Sayyed Gholi, Surkan, Shahrak, and Alavi regions was above standard levels of Iran in 2004. However, the TDS of all wells was higher than the Iran National Standard in 2015 (Fig. 10). Thus, the quality of these wells is unacceptable for drinking purposes. Total dissolved solids in drinking water sources originate from factors such as natural resources, industrial wastewater, sewage, urban runoff, and chemical materials used in the water treatment plant (Bonte et al. 2013). Potable water with a high level of TDS is the primary cause of digestive difficulties. Our findings are consistent with previous results (Madani et al. 2016; Bordi et al. 2001).

Effect on TH levels

Soluble minerals are among the causes of water hardness. Generally, hard water is high in dissolved mineral content, mainly calcium and magnesium (Tweed et al. 2009), and it is an essential parameter in the study of water resources for drinking purposes. According to the

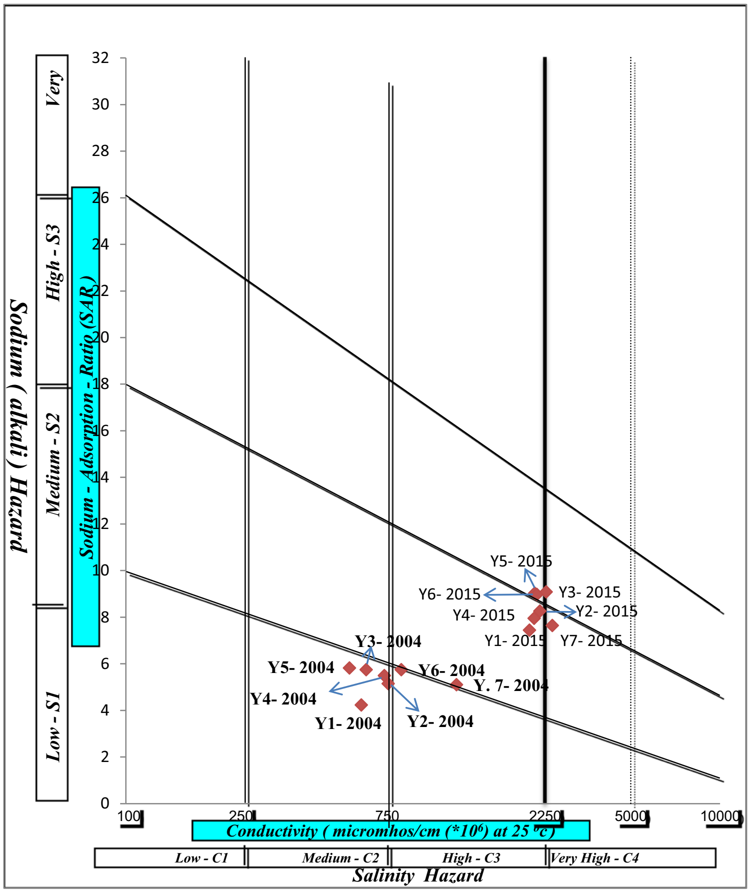


Fig. 8 The Wilcox diagram compares the water quality of wells located in the Yahyaabad region for agricultural purposes in 2004 and 2015 (Y: Yahyaabad)

Iranian national standard, and the WHO guidelines, the permissible limit of drinking water hardness is 200 mg/L (Bonte et al. 2013; Alavi et al. 2016). The Schoeller diagram illustrated that 62% of wells were in the range of acceptable for drinking in 2004, whereas, at the end of the study period, 13.8% and 4.4% of wells were in the

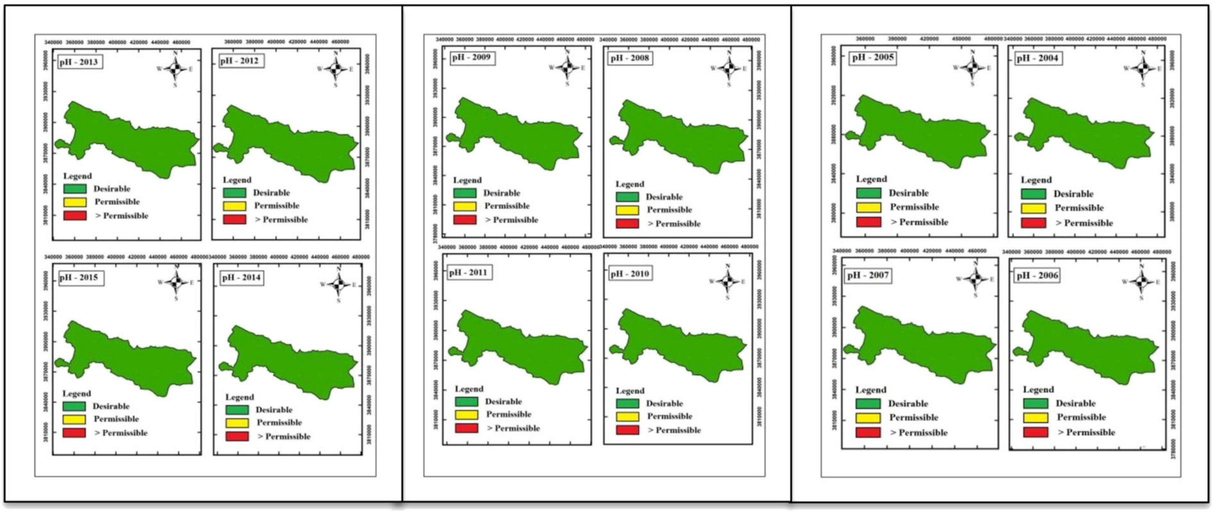


Fig. 9 Spatial distribution of well water pH of the study area (2004–2015)

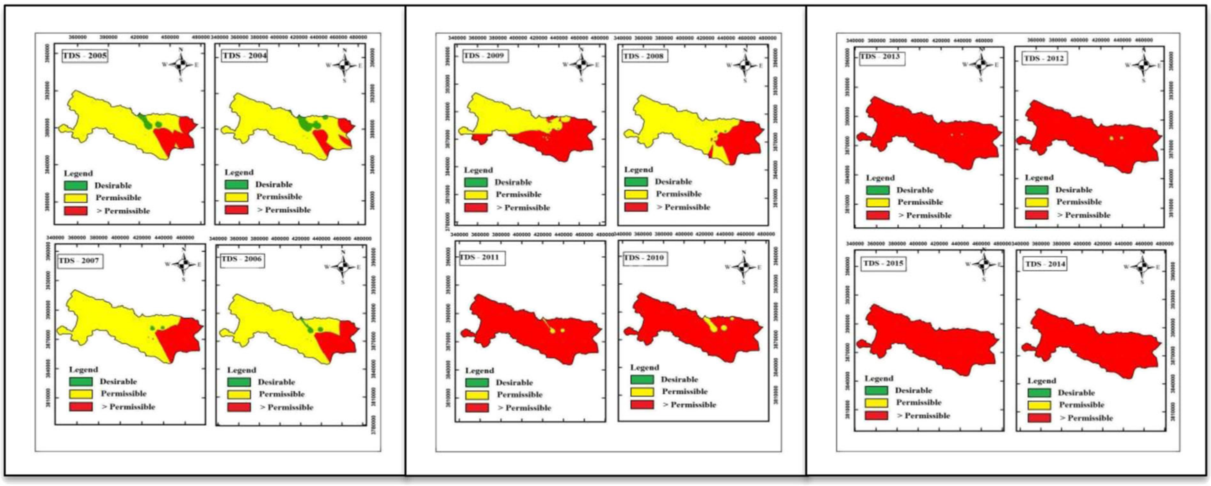


Fig. 10 Spatial distribution of well water TDS of the study area (2004–2015)

category of acceptable and inappropriate quality for drinking purposes, respectively (Table 4).

Furthermore, the spatial variation maps of TH in 2004 showed that whereas the total water of wells in the Shahrak area, 50% of the wells in Surkan and 40% in Alavi regions, were higher than the standard limits, TH level of all wells were not compatible with the standard level, in 2015 (Fig. 11). Drinking water with excessive hardness can damage the urethra, kidneys, bladder, blood vessels, and stomach (Sharma et al. 2017).

Effect on Ca^{+2} levels

Calcium can be naturally found in water. The natural occurrence in the earth's crust, as well as high solubility of $Ca^{2+,}$ has led to its presence in groundwater (WHO 2011). According to WHO and Iranian National Standard guidelines, the acceptable limit of this element in potable waters is 200 mg/L (Alavi et al. 2016). The spatial variation maps of Ca^{2+} showed that during the study period, all wells had acceptable quality for drinking purposes, and the levels of the calcium ion gradually became standard from 2004 to 2015 (Fig. 12) (Raju 2007).

Effect on Mg^{+2} levels

The notable feature of magnesium cations is forming the water-soluble salts. The Iranian National Standard and WHO guidelines suggest that the standard level of the magnesium in potable waters needs to be 30 and 50 mg/L, respectively (WHO 2011). The Schoeller diagram

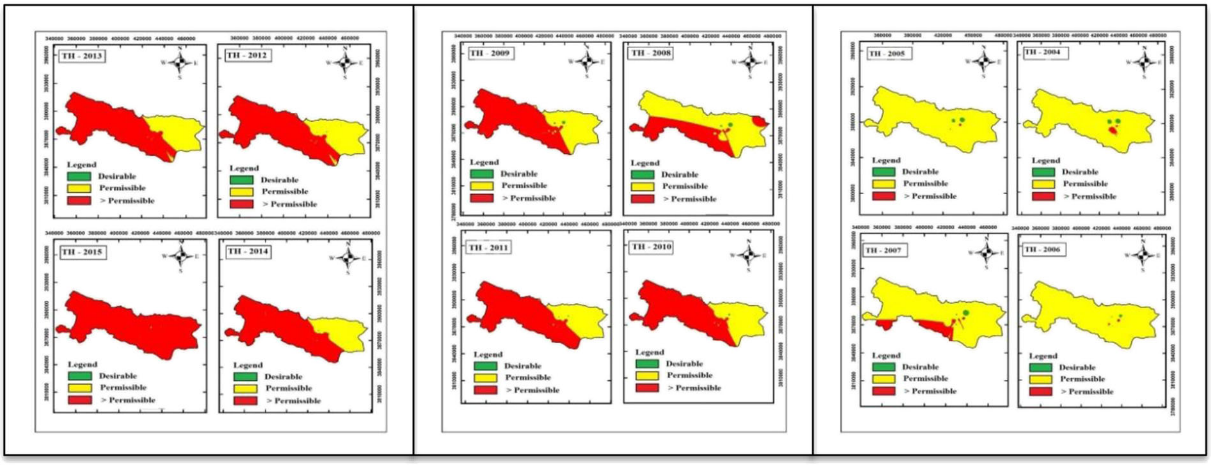


Fig. 11 Spatial distribution of well water TH of the study area (2004–2015)

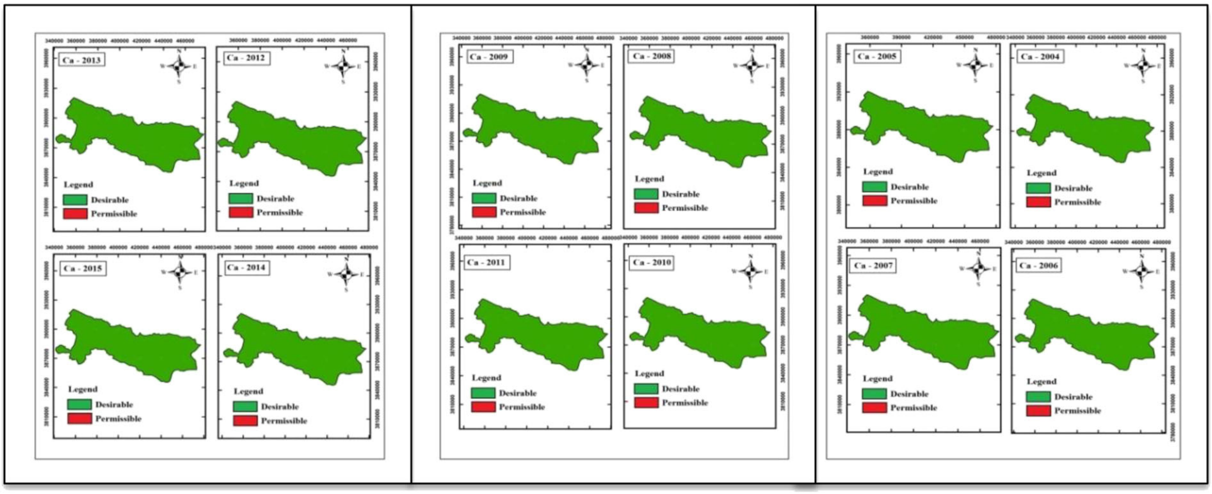


Fig. 12 Spatial distribution of well water Ca^{2+} of the study area (2004–2015)

suggests that the water quality of all wells was unacceptable in the year 2015. The level of magnesium ion during the studied period changed significantly. Findings indicated that although the concentration of the Mg^{2+} ion in the wells of Yahyaabad and Surkan regions met the Iranian National Standard in 2004, it was above the standard in 2015 (Fig. 13) (Soleimani et al. 2018a).

Effect on Na^{+} levels

Sodium cations make the water salty and the sodium level is affected by the cations exchange mechanism (WHO 2011). According to the Iranian National Standard, the maximum standard concentration of the sodium ion in potable waters needs to be 200 mg/L (Bonte et al. 2013). Results of the Schoeller diagram in 2004 suggest that although 27.6% of wells had high levels of sodium ion and the water quality was unacceptable for drinking purposes, it was 65.5% in 2015 which indicates a marked increase in the level of the sodium (Fig. 14) and consequently salinity.

Although the level of the sodium ion was above standard only in wells of regions 3–5 ("Description of the study area") in 2004, there has been a general increase in all wells of the county in 2015 (Fig. 15). Results suggested that there has been a significant decline in water quality of the wells due to a general shortage of precipitation and, consequently, drought in the area.

Findings also indicated that the water quality of the wells was unacceptable for drinking and agriculture purposes from 2004 to 2015. In a study, Saito et al. investigated how global warming affects the static level and quality of groundwater resources of thirty-four wells in Japan. The present study was carried out in

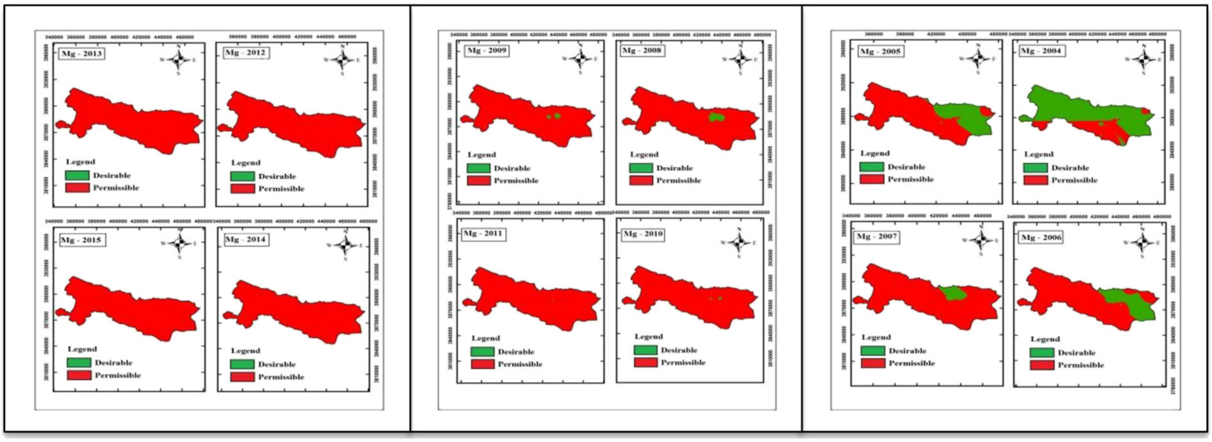


Fig. 13 Spatial distribution of well water Mg^{2+} of the study area (2004–2015)

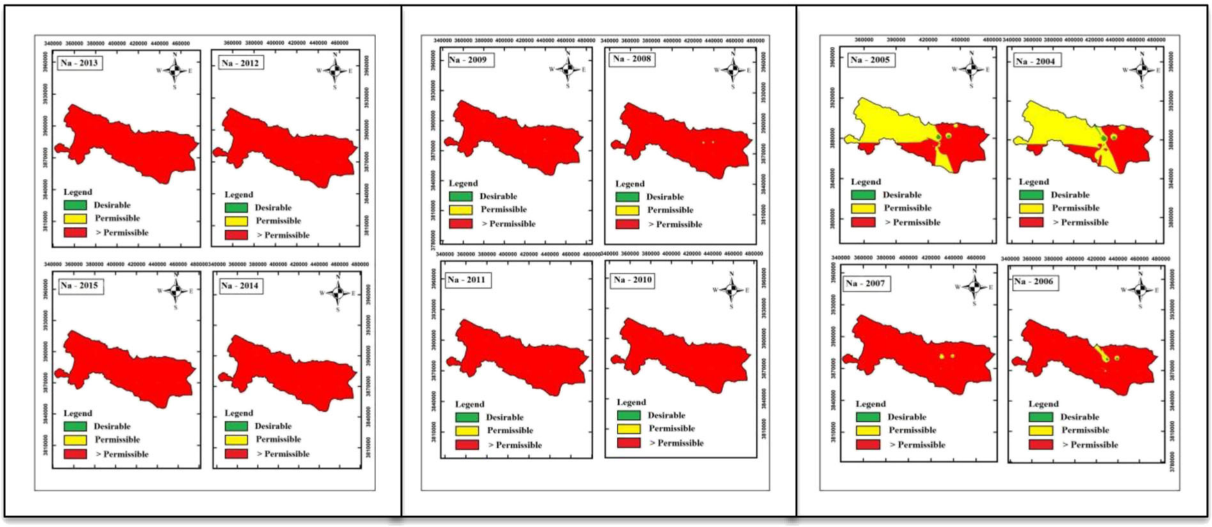


Fig. 14 Spatial distribution of well water Na^+ of the study area (2004–2015)

27 months, and significant changes in the static level of underground waters and levels of ammonium, sodium, potassium, and magnesium ions were observed. Observed changes in temperature were around 7 °C (Saito et al. 2016). Generally, it can be said that drought, decline in precipitation, and changes in temperature during the study period are among the main causes of changes in the water quality of Saveh wells.

Effect on Cl^- levels

Levels of Cl^- anion play a pivotal role in the taste of water (Soleimani et al. 2018a). The standardized level of the ion in potable waters is 250 mg/L (Tweed et al. 2009). According to Schoeller diagram, 3.4 and 44.9% of the water wells were in the category of inappropriate for drinking purposes in 2004 and 2015, respectively (Table 5). Figure 15 shows the spatial distribution of Cl^- changes during the studied period.

There has been a general increase in the level of Cl^- during the studied period, to the extent that at the beginning of the period, the level of Cl^- in most of the wells was lower than the standard, but in 2015, it was higher than the Iranian National Standard level (Fig. 15). Some natural phenomena such as high rates of vaporization, passing water through salty parts of the soil, and

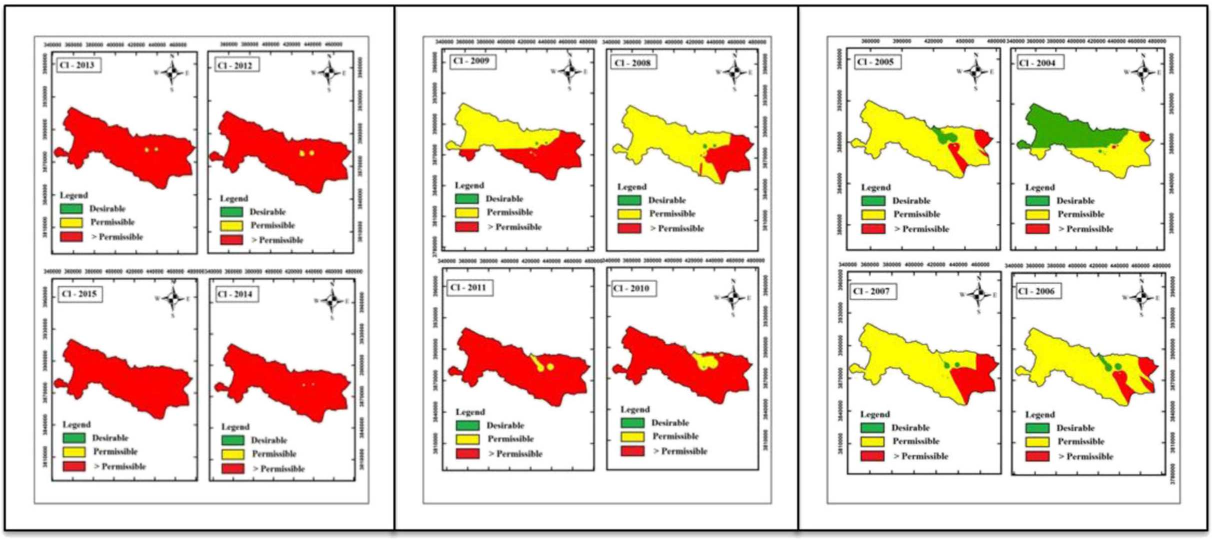


Fig. 15 Spatial distribution of well water Cl^- of the study area (2004–2015)

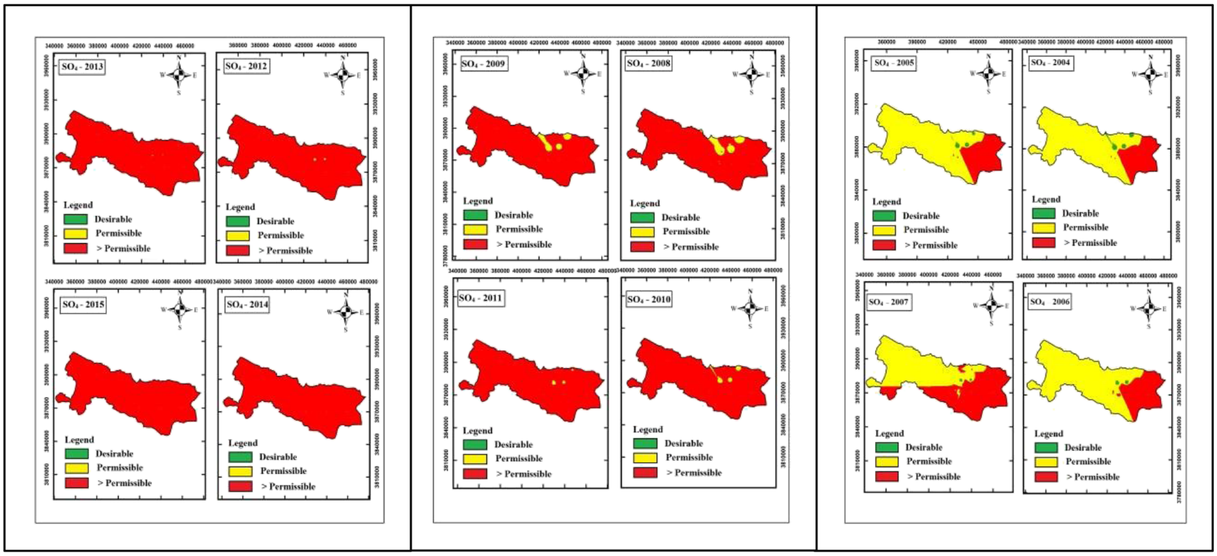


Fig. 16 Spatial distribution of well water SO_4^{-2} of the study area (2004–2015)

pumping urban or industrial sewage into the groundwater cause to raise levels of Cl^- (Bordi et al. 2001). High levels of Cl^- in potable water cause some diseases such as high blood pressure, kidney stone, asthma, and osteoporosis (Soleimani et al. 2018a).

Effect on SO_4^{2-} levels

High levels of sulfate and magnesium ions may cause laxative effects (Abbasnia et al. 2019b). The Schoeller diagram suggests that levels of SO_4^{2-} in 20.7 and 69% of wells were in the category of inappropriate in 2004 and 2015, respectively. According to the Iranian National Standard, the maximum amount of SO_4^{2-} in potable water needs to be 250 mg/L (WHO 2011). Although there has been an increase in SO_4^{-2} levels only in some wells in 2004, it was above standard limits in all wells in 2015 (Fig. 16).

Even though previous works found that drought has only increased levels of Cl^- in groundwater resources of Yazd desert in the center of Iran during 2000–2004, in the present study, we found that there has been a general increase in levels of both SO_4^{2-} and Cl^{-1} anions during 2004–2015 (Soleimani et al. 2018a). Rapid population growth around wells, higher cost of living, and overuse of valuable water resources are among the common causes of the decline in the quality of groundwater in dry climates. Overuse of groundwater not only decreases the water level and its quality but also leads to subsidence (Akbari et al. 2018).

Conclusions

To investigate the causes of decline in quality and quantity of groundwater resources, the focus has always been on climate change and the prolonged drought, among which changes in the amount of precipitation directly affect soil humidity, surface flow, and variation in water resources. The shortage of rainfall in Saveh during the studied period has led to a significant decline in the chemical quality of groundwater and reusing water plays a vital role in preserving the resources and supplying water. The decline in factors such as TDS, TH, Na^+, Mg^{2+}, Cl^-, and SO_4^{2-} was marked. It is clear that supplying drinking water requires setting an apparatus to make a reduction in the level of water salinity and hardness or use alternative resources, if possible.

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References

Abba, G. (2015). Graphical techniques of presentation of hydrochemical data. *Journal of Environment and Earth Science, 5*, 65–76.

Abbasnia, A., Radfard, M., Mahvi, A. H., Nabizadeh, R., Yousefi, M., Soleimani, H., & Alimohammadi, M. (2018). Groundwater quality assessment for irrigation purposes based on irrigation water quality index and its zoning with GIS in the villages of Chabahar, Sistan and Baluchistan, Iran. *Data in Brief, 19*, 623–631.

Abbasnia, A., Ghoochani, M., Yousefi, N., Nazmara, S., Radfard, M., Soleimani, H., Yousefi, M., Barmar, S., & Alimohammadi, M. (2019a). Prediction of human exposure and health risk assessment to trihalomethanes in indoor swimming pools and risk reduction strategy. *Human and Ecological Risk Assessment: An International Journal, 25*, 2098–2115.

Abbasnia, A., Yousefi, N., Mahvi, A. H., Nabizadeh, R., Radfard, M., Yousefi, M., & Alimohammadi, M. (2019b). Evaluation of groundwater quality using water quality index and its suitability for assessing water for drinking and irrigation purposes: case study of Sistan and Baluchistan province (Iran). *Human and Ecological Risk Assessment: An International Journal, 25*, 988–1005.

Afzali, A., Shahedi, K., Roshan, M. H. N., Solaimani, K., & Vahabzadeh, G. (2014). Groundwater quality assessment in Haraz Alluvial fan, Iran. *International Journal of Scientific Research in Environmental Sciences, 2*, 346.

Akbari, H., Soleimani, H., Radfard, M., Abasnia, A., Hashemzadeh, B., Akbari, H., & Adibzadeh, A. (2018). Data on investigating the nitrate concentration levels and quality of bottled water in Torbat-e Heydarieh, Khorasan razavi province, Iran. *Data in Brief, 20*, 463.

Alavi, N., Zaree, E., Hassani, M., Babaei, A. A., Goudarzi, G., Yari, A. R., & Mohammadi, M. J. (2016). Water quality assessment and zoning analysis of Dez eastern aquifer by Schuler and Wilcox diagrams and GIS. *Desalination and Water Treatment, 57*, 23686–23697.

Ali, A. (1999). Climate change impacts and adaptation assessment in Bangladesh. *Climate Research, 12*, 109–116.

Alizadeh, A., & Keshavarz, A. (2005). *Status of agricultural water use in Iran. Water conservation, reuse, and recycling: proceedings of an Iranian-American workshop* (pp. 94–105). Washington: National Academies Press Washington DC.

Bloomfield, J. P., Marchant, B. P., & Mckenzie, A. A. (2019). Changes in groundwater drought associated with anthropogenic warming. *Hydrology and Earth System Sciences, 23*, 1393–1408.

Bonte, M., VAN Breukelen, B. M., & Stuyfzand, P. J. (2013). Temperature-induced impacts on groundwater quality and arsenic mobility in anoxic aquifer sediments used for both drinking water and shallow geothermal energy production. *Water Research, 47*, 5088–5100.

Bordi, I., Frigio, S., Parenti, P., Speranza, A. & Sutera, A. 2001. The analysis of the Standardized Precipitation Index in the Mediterranean area: large-scale patterns. *Annals of Geophysics,* 44.

Bostrom, A., Morgan, M. G., Fischhoff, B., & Read, D. (1994). What do people know about global climate change? 1. Mental models. *Risk Analysis, 14*, 959–970.

Cancelliere, A., DI Mauro, G., Bonaccorso, B. & Rossi, G. 2007. Stochastic forecasting of drought indices. Methods and tools for drought analysis and management. Springer.

Chaussard, E., Milillo, P., Bürgmann, R., Perissin, D., Fielding, E. J., & Baker, B. (2017). Remote sensing of ground deformation for monitoring groundwater management practices: application to the Santa Clara Valley during the 2012–2015 California drought. *Journal of Geophysical Research - Solid Earth, 122*, 8566–8582.

Choramin, M., Safaei, A., Khajavi, S., Hamid, H., & Abozari, S. (2015). Analyzing and studding chemical water quality parameters and its changes on the base of Schuler, Wilcox and Piper diagrams (project: Bahamanshir River). *WALIA J, 31*, 22–27.

Dehghani, M. H., Zarei, A., Yousefi, M., Asghari, F. B., & Haghighat, G. A. (2019). Fluoride contamination in groundwater resources in the southern Iran and its related human health risks. *Desalination and Water Treatment, 153*, 95–104.

Döll, P. (2009). Vulnerability to the impact of climate change on renewable groundwater resources: a global-scale assessment. *Environmental Research Letters, 4*, 035006.

Federation, W. E. & Association, A. P. H. (2005). *Standard methods for the examination of water and wastewater.* Washington: American Public Health Association (APHA).

Gandhi, F. R. & Parekh, F. P. 2017. Assessment of drought using standard precipitation index and rainfall deciles: a case study of Patan District. *VIER Journal of Engineering Research***,** 1–7.

Green, T. R., Taniguchi, M., Kooi, H., Gurdak, J. J., Allen, D. M., Hiscock, K. M., Treidel, H., & Aureli, A. (2011). Beneath the surface of global change: impacts of climate change on groundwater. *Journal of Hydrology, 405*, 532–560.

Hasan, S., Adham, A., Islam, M. T. & Islam, D. 2014. Effect of climate change on groundwater quality for irrigation purpose in a limestone enriched area. Doctoral Dissertation.

Hollinger, S., Isard, S. & Welford, M.. (1993) A new soil moisture drought index for predicting crop yields. Preprints, Eighth Conference on Applied Climatology. American Meteorological Society Anaheim, CA, 187–190.

Jalili, D., Radfard, M., Soleimani, H., Nabavi, S., Akbari, H., Akbari, H., Kavosi, A., Abasnia, A., & Adibzadeh, A. (2018). Data on nitrate–nitrite pollution in the groundwater resources a Sonqor plain in Iran. *Data in Brief, 20*, 394–401.

Jang, S. H., Lee, J.-K., Oh, J. H., Jo, J. W., & Cho, Y. (2017). The probabilistic drought forecast based on the ensemble technique using the Korean surface water supply index. *Nature Hazards Earth Syst Sci Discuss*. https://doi.org/10.5194/nhess-2017-163.

Karamia, L., Alimohammadia, M., Soleimania, H., & Askaria, M. (2019). Assessment of water quality changes during climate change using the GIS software in a plain in the southwest of Tehran province, Iran. *Desalination and Water Treatment, 148*, 119–127.

Khamutian, R., Najafi, F., Soltanian, M., Shokoohizadeh, M. J., Poorhaghighat, S., Dargahi, A., Sharafi, K., & Afshari, A. (2015). The association between air pollution and weather conditions with increase in the number of admissions of asthmatic patients in emergency wards: A case study in Kermanshah. *Medical Journal of the Islamic Republic of Iran, 29*, 229.

Kumar, C. (2012). Climate change and its impact on groundwater resources. *International Journal of Engineering Science, 1*, 43–60.

Madani, K., Aghakouchak, A., & Mirchi, A. (2016). Iran's socio-economic drought: challenges of a water-bankrupt nation. *Iranian Studies, 49*, 997–1016.

Mckee, T. B., Doesken, N. J., & Kleist, J. (1993). The relationship of drought frequency and duration to time scales. In *Proceedings of the 8th Conference on Applied Climatology* (pp. 179–183). Boston: American Meteorological Society Boston.

Mir, A., Piri, J., & Kisi, O. (2017). Spatial monitoring and zoning water quality of Sistan River in the wet and dry years using GIS and geostatistics. *Computers and Electronics in Agriculture, 135*, 38–50.

Mirzaei, N., Ghaffari, H. R., Karimyan, K., Moghadam, F. M., Javid, A., & Sharafi, K. (2015). Survey of effective parameters (water sources, seasonal variation and residual chlorine) on presence of thermotolerant coliforms bacteria in different drinking water resources. *International Journal of Pharmacy and Technology, 7*, 9680–9689.

Mishra, A. K., & Singh, V. P. (2010). A review of drought concepts. *Journal of Hydrology, 391*, 202–216.

Mishra, A. K., & Singh, V. P. (2011). Drought modeling–a review. *Journal of Hydrology, 403*, 157–175.

Mizyed, N. (2018). Climate change challenges to groundwater resources: palestine as a case study. *Journal of Water Resource and Protection, 10*, 215.

Mohammadi, G. M., Ebrahimi, K. & Araghinejad, S. 2012. Evaluation impact of drought, extraction and construction of dam on the groundwater drop-case study saveh aquifer.

Organization, W. H. (2019). Guidelines for drinking-water quality. In *incorporating the 1st addendum* (4th ed.). *Geneva*: *World Health Organization https://www. who. int/ water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/. Accessed,* 13.

Palmer, W.C. 1968. Keeping track of crop moisture conditions, nationwide: the new crop moisture index.

Qasemi, M., Farhang, M., Biglari, H., Afsharnia, M., Ojrati, A., Khani, F., Samiee, M., & Zarei, A. (2018). Health risk assessments due to nitrate levels in drinking water in villages of Azadshahr, northeastern Iran. *Environmental Earth Sciences, 77*, 782.

Qasemi, M., Shams, M., Sajjadi, S. A., Farhang, M., Erfanpoor, S., Yousefi, M., Zarei, A. & Afsharnia, M. 2019. Cadmium in groundwater consumed in the rural areas of Gonabad and Bajestan, Iran: occurrence and health risk assessment. *Biological trace element research***,** 1-10.

Radfard, M., Soleimani, H., Azhdarpoor, A., Faraji, H., & Mahvi, A. H. (2018). Dataset on assessment of physical and chemical quality of groundwater in rural drinking water, West Azerbaijan Province in Iran. *Data in Brief, 21*, 556–561.

Radfard, M., Yunesian, M., Nabizadeh, R., Biglari, H., Nazmara, S., Hadi, M., Yousefi, N., Yousefi, M., Abbasnia, A., & Mahvi, A. H. (2019). Drinking water quality and arsenic health risk assessment in Sistan and Baluchestan, Southeastern Province, Iran. *Human and Ecological Risk Assessment: An International Journal, 25*, 949–965.

Raju, N. J. (2007). Hydrogeochemical parameters for assessment of groundwater quality in the upper Gunjanaeru River basin, Cuddapah District, Andhra Pradesh, South India. *Environmental Geology, 52*, 1067–1074.

Rangarajan, S., Thattai, D., Cherukuri, A., Borah, T. A., Joseph, J. K. & Subbiah, A. 2019. A detailed statistical analysis of rainfall of Thoothukudi District in Tamil Nadu (India). Water Resources and Environmental Engineering II. Springer.

Ranjpisheh, M., Karimpour Reihan, M., Zehtabian, G. R., & Khosravi, H. (2018). Assessment of drought and landuse changes: impacts on groundwater quality in Shabestar basin, north of Lake Urmia. *Desert, 23*, 9–19.

Rezaei, H., Zarei, A., Kamarehie, B., Jafari, A., Fakhri, Y., Bidarpoor, F., Karami, M. A., Farhang, M., Ghaderpoori, M., & Sadeghi, H. (2019). Levels, distributions and health risk assessment of Lead, cadmium and arsenic found in drinking groundwater of Dehgolan's villages, Iran. *Toxicology and Environmental Health Sciences, 11*, 54–62.

Richards, L. 1954. *Diagnosis and improvement of saline and alkali soils*. Handbook No. 60. US Department of Agriculture, Washington, DC.

Saito, T., Hamamoto, S., Ueki, T., Ohkubo, S., Moldrup, P., Kawamoto, K., & Komatsu, T. (2016). Temperature change affected groundwater quality in a confined marine aquifer during long-term heating and cooling. *Water Research, 94*, 120–127.

Saleh, H. N., Panahande, M., Yousefi, M., Asghari, F. B., Conti, G. O., Talaee, E., & Mohammadi, A. A. (2019). Carcinogenic and non-carcinogenic risk assessment of heavy metals in groundwater wells in Neyshabur Plain, Iran. *Biological Trace Element Research, 190*, 251–261.

Shammi, M., Rahman, R., Rahman, M. M., Moniruzzaman, M., Bodrud-Doza, M., Karmakar, B., & Uddin, M. K. (2016). Assessment of salinity hazard in existing water resources for irrigation and potentiality of conjunctive uses: a case report from Gopalganj District, Bangladesh. *Sustainable Water Resources Management, 2*, 369–378.

Shams, G. K., Yusefzadeh, A., Godini, H., Hoseinzadeh, E., & Khoshgoftar, M. (2014). Water quality zoning based on water quality index and Wilcox index using geographic information system. *Jundishapur Journal of Health Sciences, 6*(3), 1–10.

Sharma, D. A., Rishi, M. S., & Keesari, T. (2017). Evaluation of groundwater quality and suitability for irrigation and drinking purposes in Southwest Punjab, India using hydrochemical approach. *Applied Water Science, 7*, 3137–3150.

Soleimani, H., Abbasnia, A., Yousefi, M., Mohammadi, A. A., & Khorasgani, F. C. (2018a). Data on assessment of groundwater quality for drinking and irrigation in rural area Sarpol-e Zahab city, Kermanshah province, Iran. *Data in Brief, 17*, 148–156.

Soleimani, H., Nasri, O., Ojaghi, B., Pasalari, H., Hosseini, M., Hashemzadeh, B., Kavosi, A., Masoumi, S., Radfard, M., & Adibzadeh, A. (2018b). Data on drinking water quality using water quality index (WQI) and assessment of groundwater quality for irrigation purposes in Qorveh & Dehgolan, Kurdistan, Iran. *Data in Brief, 20*, 375–386.

Tahrudi, M., Khalili, K. & Ahmadi, F. 2016. Spatial and regional analysis of precipitation trend over Iran in the last half of century. *Journal of Water and Soil,* 30.

Tweed, S., Leblanc, M., & Cartwright, I. (2009). Groundwater–surface water interaction and the impact of a multi-year drought on lakes conditions in South-East Australia. *Journal of Hydrology, 379*, 41–53.

WHO, G. (2011). Guidelines for drinking-water quality. *World Health Organization, 216*, 303–304.

Yidana, S. M., Banoeng-Yakubo, B., & Akabzaa, T. M. (2010). Analysis of groundwater quality using multivariate and spatial analyses in the Keta basin, Ghana. *Journal of African Earth Sciences, 58*, 220–234.

Yousefi, M., Mohammadi, A. A., Yaseri, M., & Mahvi, A. H. (2017). Epidemiology of drinking water fluoride and its contribution to fertility, infertility, and abortion: an ecological study in West Azerbaijan Province, Poldasht County, Iran. *Fluoride, 50*, 343–353.

Yousefi, M., Saleh, H. N., Yaseri, M., Jalilzadeh, M., & Mohammadi, A. A. (2018). Association of consumption of excess hard water, body mass index and waist circumference with risk of hypertension in individuals living in hard and soft water areas. *Environmental Geochemistry and Health, 185*(2), 282–288 1–9.

Zarei, A. R., Moghimi, M. M. & Bahrami, M. 2019. Comparison of reconnaissance drought index (RDI) and effective reconnaissance drought index (eRDI) to evaluate drought severity. *Sustainable Water Resources Management*, 1–12.