

Investigation of groundwater quantitative change, Tehran Province, Iran

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Abstract: Changes in groundwater level in Homand-Absard plain, located in north-west of Kavir-e-Markazi watershed and east of Tehran province, were studied. The used research method was descriptive approach, and the research study was conducted based on field and desk surveys. The data needed was provided from field surveys, contours maps, and data of observation wells. There were 17 observation wells in the study area where the changes in groundwater levels were measured during 1996-2013, and an index hydrograph was prepared for the aquifer of plain. The sharpest decline in the groundwater level was in the central of Homan-Absard plain. There was 1.43 m decline in the groundwater level of aquifer annually, compared with similar studies in other parts of Iran, it has a high rate, and to the average, the groundwater level of plain has dropped equal to 25.76 m, 1996-2013. According to the study findings, the groundwater level changes with those in rainfall weren't match and the drop in groundwater level during wet years and then has continued which represents the high water extraction factor on the groundwater level drop.

Keywords: Groundwater; Aquifer; Level changes; Decline; Homand-Absard; Iran

Introduction

Except for frozen water in ice and glaciers, groundwater is the world's largest distributed store of freshwater and has strategic importance to global food and water security (Wada Y, 2016). Groundwater is the essential source of drinking and irrigation water supplies in most parts of the world (Huo A *et al.* 2016). Increase in population, immoderate use of groundwater in agriculture, and irregular rainfall due to climate change all have a negative effect on groundwater potential (Çelik R, 2015).

In Iran, $89.5 \times 10^9 \text{ m}^3$ of the total of $130 \times 10^9 \text{ m}^3$ of annual renewable water resources, is used for different purposes. Of this water volume; 93% for agricultural use, 6% for household consumption and drinking use and 1% is used in the industry and for other purposes and Iran for 90 percent of

its food production relies on irrigated cultivation (Ehsani M and Khaledy H, 2003).

In Iran and many other countries, groundwater resources secure many water needs of them; therefore, protection and monitoring of groundwater resources is very important. Werner A D *et al.* (2013) claimed that the state of groundwater systems worldwide is presently not well defined, and in particular there is little context for agencies responsible for managing water resources to evaluate occurrences of groundwater depletion against other cases globally. Some of the studies about groundwater have revealed groundwater depletion in different plains. Analysis based on satellite gravity measurements from the Gravity Recovery and Climate Experiment (GRACE) and land surface models indicates that groundwater storage in Victoria, Australia had been declining steadily, until a trend reversal around early 2010, attributed to two wetter seasons in 2010 and 2011 (Chen J L *et al.* 2016). Groundwater depletion rates for 2005 to 2009 are relatively large as indicated by both GRACE estimates ($8.0 \pm 1.7 \text{ km}^3/\text{yr}$) and in

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situ measurements ($8.3 \pm 3.4 \text{ km}^3/\text{yr}$). The strong correlation suggests that this groundwater depletion is primarily related to drought with related groundwater pumping for agricultural and domestic consumption.

Steward D R and Allen A J (2016) provide estimates of saturated thickness and changes in groundwater storage, and peak groundwater depletion from 1930 to 2110 in US. The annual rate of depletion in High Plains Aquifer of the central USA is estimated to have peaked at $8.25 \times 10^9 \text{ m}^3/\text{yr}$ in 2006 followed by projected decreases to $4.0 \times 10^9 \text{ m}^3/\text{yr}$ in 2110. The timing of peaks follows a south–north progression, with peaks occurs in 1999 for Texas, 2002 for New Mexico, 2010 for Kansas, 2012 for Oklahoma and 2023 for Colorado; peaks do not occur before 2110 for Nebraska, South Dakota and Wyoming. The study results of Aidi Huo *et al.* (2016) demonstrate that the total groundwater depletion occurred at the rate of $529.73 \text{ km}^3 \text{ yr}^{-1}$ in the Loess area (2002–2014). The Loess area is one among the largest manufacturers of agricultural merchandise in China. Also, Chinnasamy P and Agoramoorthy G (2015) have reported the groundwater depletion at the rate of $21.4 \text{ km}^3 \text{ yr}^{-1}$ across the state of Tamil Nadu over a period of 11 years, from 2002 to 2012, which is 8% more than the annual recharge rate ($19.81 \text{ km}^3 \text{ yr}^{-1}$) owing to the total rainfall of $1\,016 \text{ mm yr}^{-1}$. ZHANG Xi-feng *et al.* (2014) have demonstrated that the agricultural land use was the main cause of the declining groundwater table at the Dunhuang oasis in the arid Northwest China from 1987 to 2007 based on the study of impacts of land use/land cover (LU/LC) changes on the groundwater fluctuations. Werner A D *et al.* (2013) said that the causal factors leading to mega-depletion are varying across the globe and each mega-depletion case contains unique elements, although population appears to be an important factor.

In Iran, Fallah S A *et al.* (2012) in evaluating the sustainability of groundwater resources of Darab in Fars province in 2012 suggested that increased water consumption due to population growth, reduced the qualitative and quantitative of recoverable waters. Also, many other studies report the depletion of groundwater resources (Rahimi D, 2012; Ansari H and Naderian-Far M, 2013; Seif M *et al.* 2012; Hosseinzadeh J *et al.* 2012; Zare-

Abyaneh H *et al.* 2012). Considering the above mentioned research results, increasing the number of water wells and following that the excessive harvest of groundwater, the reduction of the level of groundwater in the plains of the country, drought effect in reduction of plains groundwater level, decrease of storage and the volume of groundwater in the aquifers, quality drop of groundwater and the effect of excessive use of groundwater resources in reducing the level of groundwater of plains are notable.

This article is the result of a study that in order to understand the quantitative situation of groundwater resources and as a sub-plan has been conducted in one of the plains of Tehran province (Homand-Absard) until in the next steps necessary actions to be done in it for optimum management and reducing water consumption.

1 Materials and methods

Homand-Absard watershed is located at the end of North West of Kavir-e-Markazi watershed and East of Tehran province. This watershed consists of a main plain which has an alluvial aquifer. The total area of the studied watershed is 548 km^2 of which 174 km^2 is plain (up to 10% slope). In this study, the area of alluvial aquifer was considered equal to the plain area (Fig. 1). The highest point of the study area is 3 830 m and the lowest is about 1 400 m above sea level. Its important rivers are Jaam-Abrod and Doab which enter the Eyvanekay area and ultimately end to the Dasht-e-Kavir desert. Of the towns and villages in this study area can mention to Hamand, Absard, Kilan, Atabak, Amirabad and Goldasht too.

The general water balance of the study area is shown in Fig. 2. The amount of outlet water of the watershed is $234.83 \times 10^6 \text{ m}^3$ while the amount of inlet water is $223.76 \times 10^6 \text{ m}^3$ (Iran Water Resources Management Company, 2011). Thus, the volume of outlet components of the study area compared with the volume of inlet components to this range is $11.07 \times 10^6 \text{ m}^3$ more. In other words, the changes in the volume of water resources in the study area are $11.07 \times 10^6 \text{ m}^3$ which is equal to the changes of groundwater reservoir volume in Homand-Absard Plain.

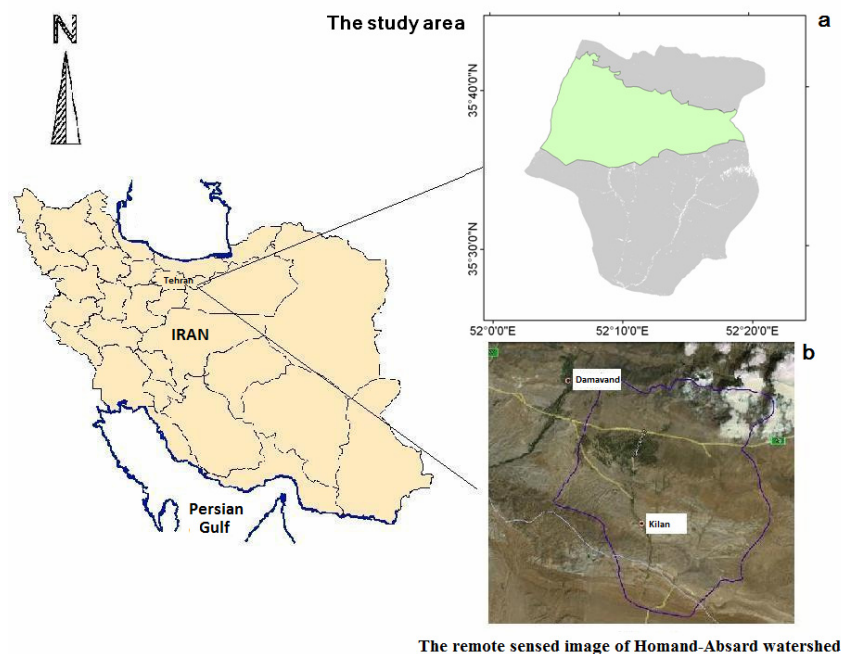


Fig. 1 The geographical introducing of study area in southeast of Tehran province. The image (a) shows the plain area by green color

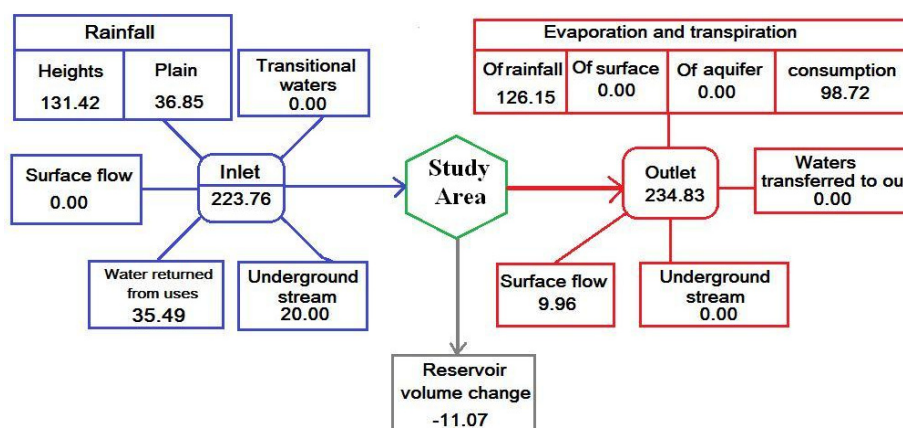


Fig. 2 The conceptual model of water general balance in the study area of Homand-Absard (volume in million cubic meters)

Research method in this study was descriptive studies which aimed to identify and evaluate the changes position in the groundwater resources of mentioned plain. The required data were provided from field surveys, contours maps, data of observation wells and *etc.* then the provided data were analyzed.

To assess the changes trend of groundwater depth, 17 observation wells were drilled in Homand-Absard plain (Fig. 3). Data on groundwater level in years 1996 and 2013 were prepared based on inventory providing from the observation wells. The observation well data came from the latest information obtained in 2016.

For survey of groundwater level change during the study, the index hydrograph of alluvial aquifer was prepared. For this purpose, the coverage area of each observation well was calculated and positioned by using Thiessen polygons (Thiessen) in ArcGIS software, and the area of every polygon was calculated (a_1 to a_n). The sum of thiessen polygons is equal to the area of alluvial aquifer (a). Also, the annual average of groundwater elevations of every observational well (h_1 to h_n) was calculated during the study.

If, the numbers of polygons are n and their areas and the area of aquifer are a_1 , a_2 to a_n and a respectively, there is this relationship between

them:

$$a = a_1 + a_2 + a_3 + \dots + a_n \quad (1)$$

If, annual average elevations in every observational well are h_1, h_2, h_3 to h_n , therefore average of aquifer groundwater elevation for every year (H_m)

is calculated by below formula.

$$H_m = (h_1 \times a_1) + (h_2 \times a_2) + \dots + (h_n \times a_n) / a \quad (2)$$

By the annual average groundwater elevations of aquifer (H_m), the index hydrograph of alluvial aquifer was prepared (Fig. 5).

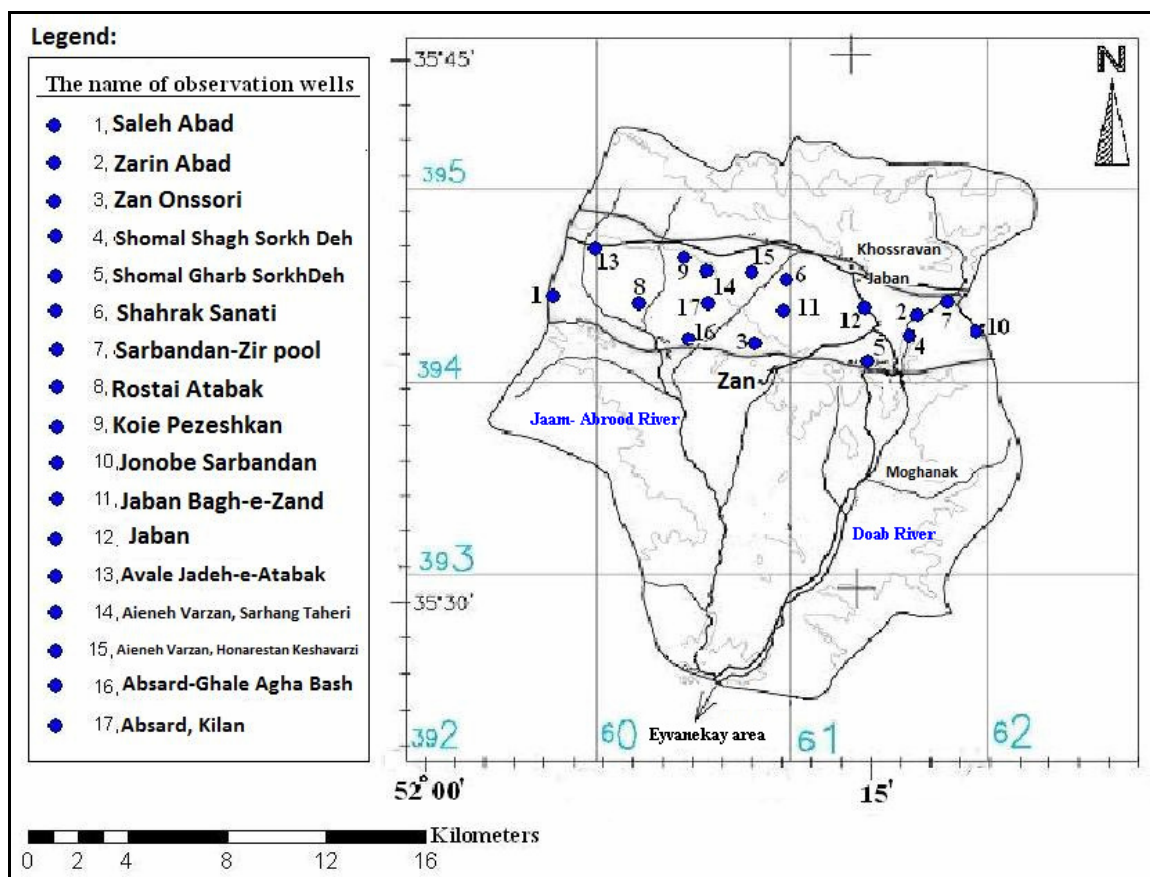


Fig. 3 The location of observation wells in Homand-Absard plain

Also, to determine the location of groundwater decline, the coverage area of each observation well was calculated and positioned by using Thiessen polygons (Thiessen) in ArcGIS software and the decline in groundwater level in the coverage area of each well was considered. In the next step, the annual decline of groundwater of aquifer was calculated by interpolation method using IDW (Inverse Distance Weighting) method in ArcGIS software, and the result of interpolated data layer was finally classified in proper intervals (Fig. 8).

2 Results

2.1 Topography

The watershed of Homand-Absard is a

mountainous area and its plain surface is 174 km². The Northern District of watershed is elevated and the highest point has 3 830m height. By providing the elevation levels map and digital elevation model for the area, it's clear that the altitude increases from sea level toward the geographic north. The elevation class of 1 800-2 200 m has the most area with an area of 347.74 km² and the lowest area belongs to the elevation class of 1 000-1 400 m with an area of 3 ha.

In connection with the classification of slope, slope class of 35-65% has the largest area of 194.74 km² and the least area for the class of 15-12% is 17.48 km². In relation to the geographical directions, southern direction with an area of 196.63 km² has the maximum surface and western, eastern and northern directions, respectively, have less area. Fig. 4 is a map of the study area slope.

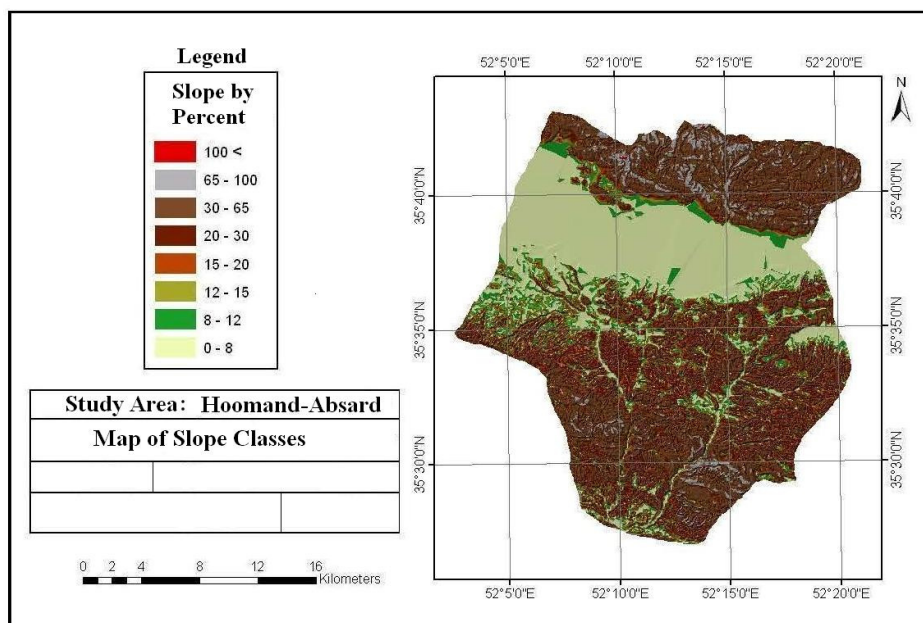


Fig. 4 The slope map of Homand-Absard watershed in percent

2.2 Meteorology

According to meteorological data, the annual average temperature in the highlands of the study area is 9.97 °C and in the plain 10.03 °C, the highest average daily temperature 22.4 °C in July and the minimum -2.47 °C in January. The

evaporation from pan in plain and highlands of Homand-Absard are 1 453.4 and 1 468 mm respectively. Fig. 5 shows the annual rainfall of Homand-Absard climatological station. The annual average rainfall in this station was 322 mm from 1996 to 2012.

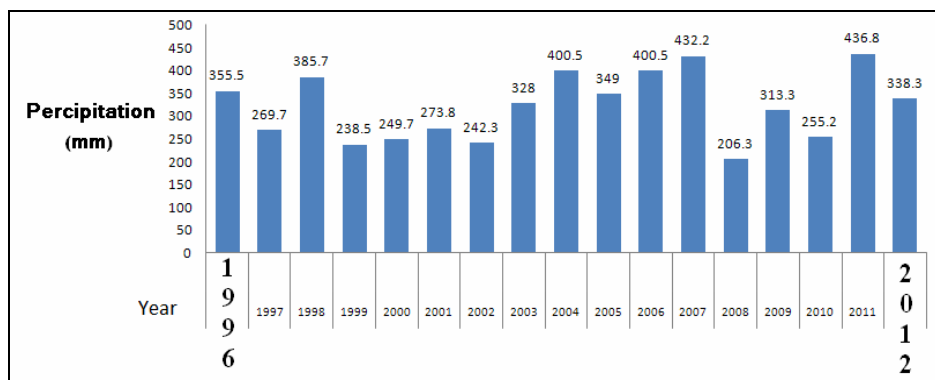


Fig. 5 The annual rainfall in Homand-Absard climatological station from 1996 to 2010

2.3 Surface water

The most important surface flow of the study area is Jaam-Abrood and Doab that emanates from the heights of North West limit of watershed of Central Kavir including Zarrin-kooh. After crossing the plain and southern highlands of Homand-Absard study area it enters to northern heights Eyvanakey area and spreads on some playas (Dasht-e-Kavir desert).

2.4 Groundwater

The study area has an alluvial aquifer; the alluvial aquifer with east-west extension is placed between north and south mountains of the study area. The area of this aquifer is about 174 km², and the area of aquifer was considered equal to the plain area. In the highlands of study area, there are some formations in which water is stored such as Carbonated Formation, also there are

non-carbonated formations with low water storage, and these formations play a role in the alluvial aquifer recharge. In the plain, there are destructed

and alluvial deposits which has accumulated more than 250 m. The Fig. 6 presents the hydro-geological specifications of the study area.

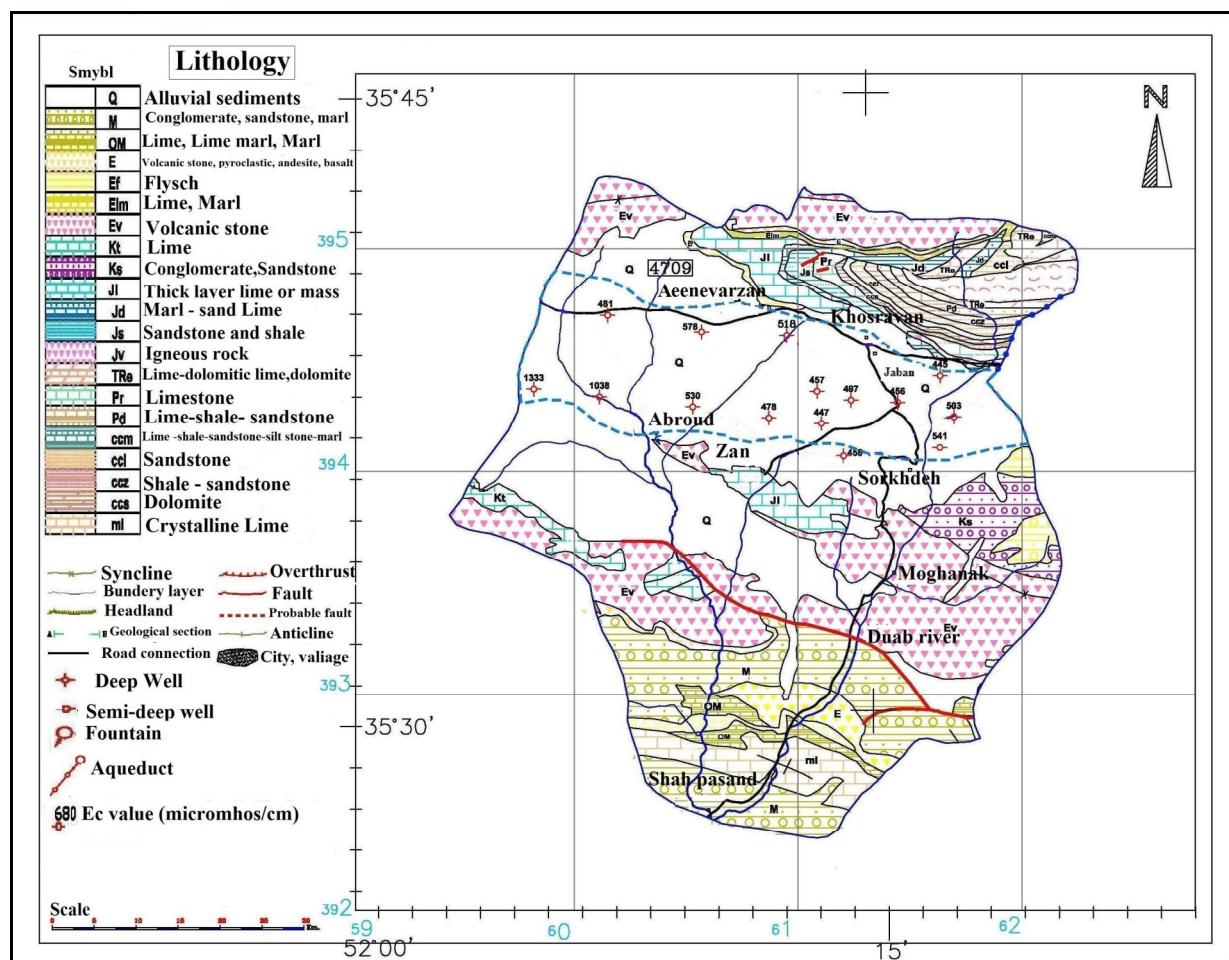


Fig. 6 The map of geological and groundwater specifications of the study area

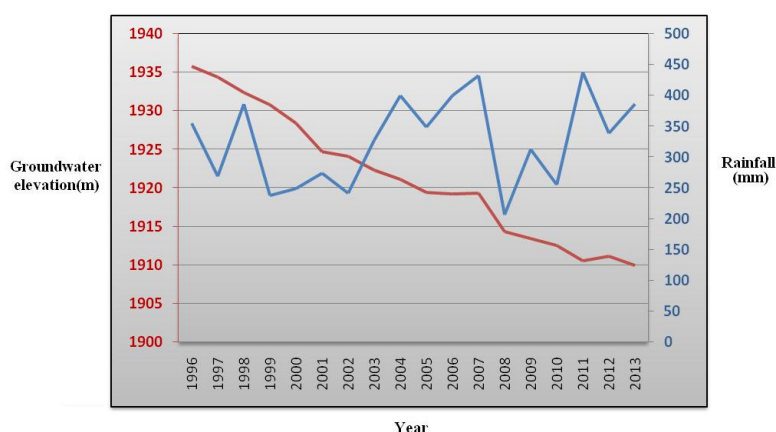


Fig. 7 The index hydrographs of groundwater elevation changes of aquifer (above sea level) and annual rainfall (right side)

Fig. 7 presents the annual index hydrograph of the study area and the rainfall during the study. There is about 25.76 m decline in the average

groundwater elevation of aquifer during the study, and the groundwater decline has a uniform trend at the study duration. The groundwater level changes

with changes in rainfall were not match and the drop in groundwater level during wet years and then has continued.

According to calculations, during the study years, the groundwater level had averagely 1.43 m decline annually and in the whole plain, the groundwater elevation had averagely 25.76 m drop from 1996 to 2013.

Fig. 8 shows the location of annual drop of

groundwater level in the study area. As can be seen, the highest annual drop of water is in the center of the plain. The yellow color shows the coverage area of Shahrak-e-Sanati observational well was dried. There is an exception in the plain that the groundwater elevation of Jaban observational well coverage area was increased by 0.05 m during the study annually (Blue color).

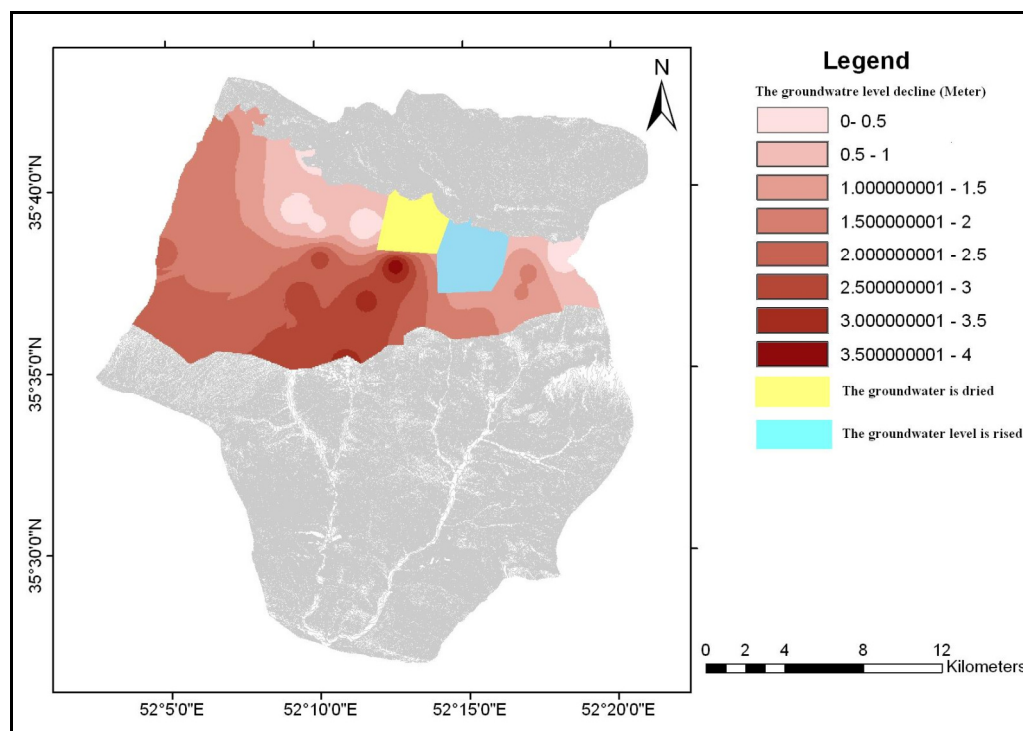


Fig. 8 The annual decline of groundwater elevation in the plain during the study (1996-2013)

3 Discussion and conclusion

The index hydrograph of Homand-Absard aquifer has had a uniform trend towards decline in groundwater level and changes in rainfall in the rainy years, have not changed this trend and this could indicate high levels of water extraction by human and this point shows that the main factor of reducing the level of groundwater is over extraction rather than factors such as drought and climate change.

Other studies about groundwater situation in Iran and other countries show depletion of groundwater quantity. In Iran, the studies about groundwater such as studies that have been performed by Zare-Abyaneh H *et al* in 2012, Ekrami M *et al* in 2011, Daneshvar-Vosoughi F

and *et al.* (2011) indicate the drop of groundwater in various regions is similar with the obtained results in Homand-Absard Plain, although the groundwater of this plain with the annual decline of 1.43 m has the most undesirable situations.

In international level, also, different studies such as the studies that have been performed by Chen J L *et al.* (2016), Steward D R and Allen A J (2016), Huo A *et al.* (2016) and Chinnasamy P and Agoramoorthy G (2015) have showed the groundwater depletion in different regions. Therefore, there is the groundwater decreasing around most of the world. It can be a dangerous condition for regions with a dry climate.

The main aim of the research was to monitor the groundwater quantity in a sample aquifer. With the obtained results, we can understand the situation of our water resources. Also we can apply

the appropriate management for the groundwater conservation. Blocking unauthorized wells and preventing overuse of water of the authorized wells, increasing the agricultural irrigation efficiency, reusing of treated wastewater in agriculture and industry uses, optimizaing of farming pattern in order to reduce the consumption of water, artificial recharge of aquifers and preventing human overpopulation are some solutions to groundwater depletion.

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