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Detection of Ground Water Changes Using Geographic Information System (A Case Study; Arak Plain, Iran)

[1]K. Solaimani and [2]S. Sadeghi
[1]GIS and RS Centre, University of Agriculture and Natural Resources, P.O. Box 737, Sari, Iran
[2]University of Agriculture and Natural Resources, P.O. Box 737, Sari, Iran

Abstract: The aim of this study is to investigate the detection using hydrometric data and GIS technique for the central part of Iran because of the water shortage for agricultural and industrial activities. In many parts of Iran, the pressure of agricultural development is causing a surface-water scarcity. That means groundwater resources recharge will be effected for this reason which caused a major problems in future. The study area of Mayghan is located in Central Iran with 2854.63 km^2 as a part of Arak plain and near to 110 km^2 as a playa. Before 1951, there was no evidence of deep well in this area and the related activities were depended on the low stream rivers, aqueducts and wells. According to the hydrometric records of the regional water organization 3161 wells added to the injection wells, between 1970 and 2004. The qualitative increasing of these wells can be calculated as annually growth of 94 for the study area which are totally pumping about 531.5/million/m^3 with annual increasing of 15.63/million/m^3. The growth of annual demands for water supply has caused some environmental problems since there was no sufficient water intrusion to the aquifer plain which causes constantly the height of ground water reservoir declination as shown in related graphs. In this study, groundwater data were analysed using ArcGIS, statistical methods, geographic information techniques of Arc view and Ilwis.

Key words: Water resources, hydrology, semi-arid basin, aquifer, Arak

INTRODUCTION

The sustainability of groundwater utilization must be assessed from an interdisciplinary perspective, where hydrology, ecology, geomorphology and climatology play an important role. Shallow groundwater flow systems should be distinguished from deep groundwater flow systems; the former interact with surface water, while the latter do not. Generally, groundwater does not recycle as fast as the surface water, with rates of groundwater turnover varying from years to millennia, depending on aquifer location, type, depth, properties and connectivity. Excessive pumping can lead to groundwater depletion, where groundwater is extracted at a rate faster that it can be replenished. Unregulated groundwater use leads to the Tragedy of the commons, with the eventual depletion of the resource and ruin to all. The effects of excessive groundwater development tend to become apparent gradually, with time often measured in decades. To assure sustainability, studies must show that the hydrological, ecological and other impacts of groundwater utilization are minimal. In addition to water quantity, sustainability must imply the preservation of water quality. The pervasive and seemingly abundant supply of groundwater has led to its indiscriminate and sometimes excessive use. However, this use can have diverse and often wide ranging effects on the local and regional hydrology and ecology. These interdisciplinary aspects of groundwater utilization have brought into question the concept of safe yield, defined as the maintenance of a long-term balance between the amount of withdrawal and the amount of recharge (Sophocleous, 2000). Thus, the issue of groundwater sustainability has arisen (Alley and Leake, 2004). To what extent can a region's groundwater resources be exploited without unduly compromising the principle of sustainable development? Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (UN, 1987).

The problem of shortage water, bad quality water and lack of the optimized managing for the water resources is notified by the head organism of Markazi province of Iran (Mohajerani, 2000). There is no any evidence of the deep wells before the last decade of 2000 in the study area, in the other words the deep wells have gradually developed

Corresponding Author: Dr. Karim Solaimani, GIS and RS Centre, University of Agriculture and Natural Resources, P.O. Box 737, Sari, Iran Tel: +989111521858

when the related drilling instruments imported to Iran. However, the economical growth related to the agricultural activities was depended to the groundwater extraction and surface flows which increased from last 10 years in this area. The first recorded data of ground water in Arak Plain during last decades is shown a number of deep and semi deep wells of 265 which have increased to 3456 in 2003. Statistically, during these years with 3191 wells the range of growth was 94 wells per year. Also according to this statistics the mentioned wells were totally discharged with 531.5 Mm^3 (The General Water Organization of Central Province, 2005). Therefore the declination of the pysometric level of plain volume ground water reservoir and its problems forced to have attention a more carefully about this aquifer and preparing a plan in order to have an optimal exploitation management on the ground water resources.

According to the hydrological investigation in the western and northern parts of China and Otarpradesh of India (Yonghua *et al*., 2004; Ma, 2005; Rashid, 2006). Hydrogeological environment believed that, the population growth and their daily demand of consumption for ground water, over use of surface water and also the declination of recharge of the ground water were as important factors to decrease the level of ground water in these areas. Etebari's (1999) studies in Turbat Haydarieh in north eastern part of Iran has shown that the volume of supplemental water is predicted to decreasing with a sequential declination in the future. Also Velayati (2002) believes that the annual consumption which is more than the affections of water to the forest plain aquifer (Turbat Haydarieh) is an important reason for the constantly declination of the ground water. Zehtabiyan *et al*. (2003) have identified that the lake of technical points in using of water and over consumption from aquifer accelerated the trend of declination and saltation in Qum plain of the central Iran during the last 20 years. The objective of this study is change detection on ground water using GIS technique to protect the study area environment as a sensitive biome of the central part of Iran.

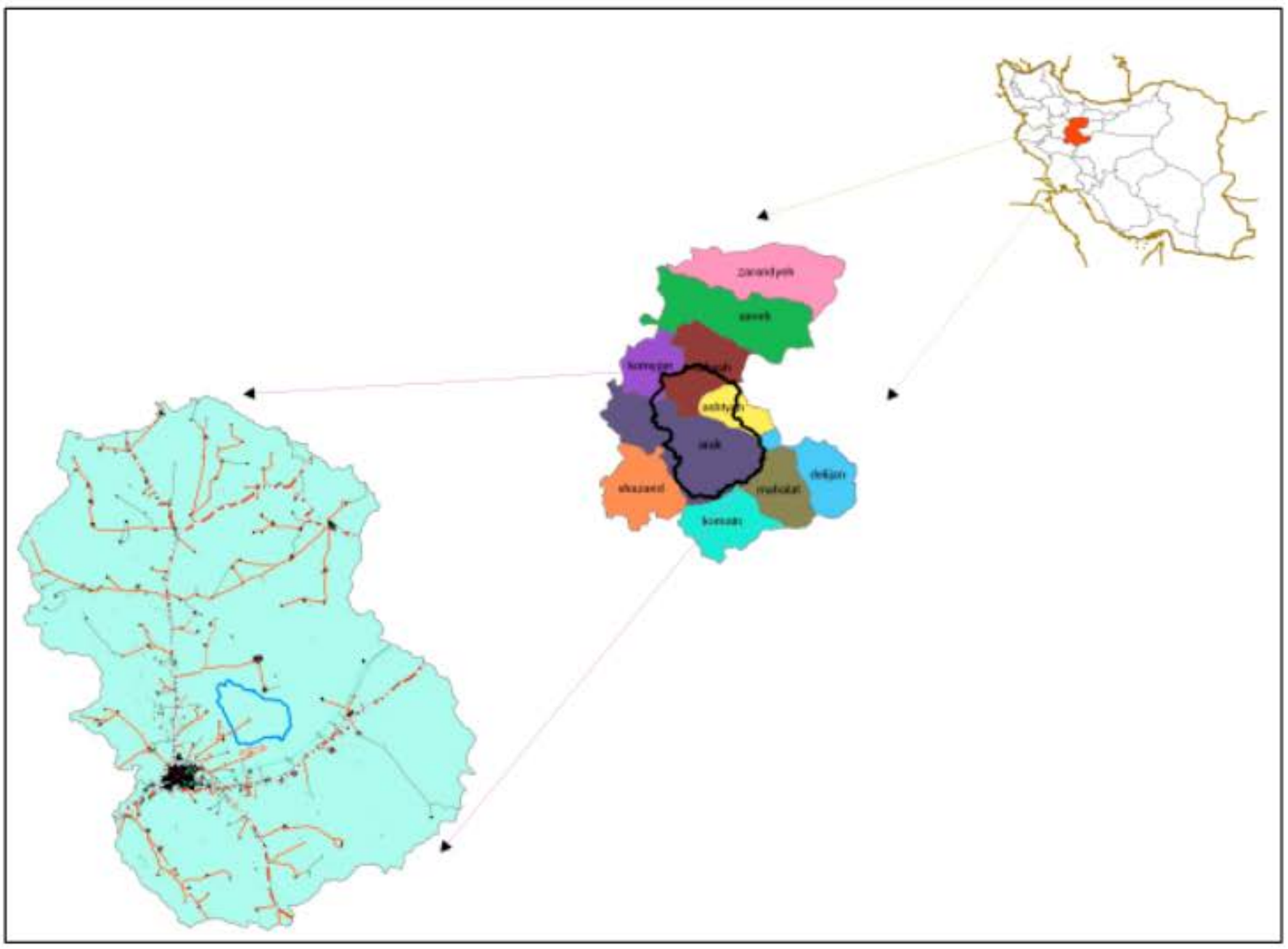

Fig. 1: Geographical location of the study area in Iran

MATERIALS AND METHODS

This study was conducted during 2005-6 as M.Sc. Thesis on Mayghan in Arak province of the central Iran where is about 2854.63 km^2 with Arak plain between 100-110 km^2 including Mayghan playa, lake or Kavir which is called as a village with the same name and is called Tozlogol as the old name on maps. This area is elongated about 100 to 110 km where is 15 km far from Arak city and geographically is limited between 49°46' to 49°55' E. and 34°9' to 34°16' N. with a most famous phenomenon which is in Arak province (Fig. 1). The highest point of altitude of basin is 3170 m (Noghreh Kamar Mountain) and the lowest point is 1650 m (Mayghan Playa) from the Persian Gulf sea level (Zamani, 1999). The annual average of precipitation in the mountain parts is recorded 383.5 mm and in the plain is 264 mm according to 32 years data and annual average temperature is maximum in the mountain parts 17.4°C and in Mayghan plain is 19/8°C and minimum is 2.3°C and 5/3°C (The General Water Organization of the Central Province of Iran, 2005). According to the climatic data analysis the study area of Mayghan using Gosen's model has classified in Mediterranean climate and in Ambrje's model is located in mid dry cold area (Zamani, 1999).

According to the gained results from geological investigation and comparing with the features, recent conditions and also the result of exploration digging it can be concluded that there is only an individual aquifer in Arak alluvium plain (The General Water Organization of the Central Province, 2005):

- In the process of this study the coordinate system of UTM has used in relation to the wells (agricultural, drinking and industrial) and the Pysometer wells have distinguished
- The statistical data of the wells were extracted separately
- For the wells depth measuring of the water surface and the height of water at the hydrometric network of groundwater 46 pysometer networks were used during 12 months of the years for each one for the period of two decades between 1985 and 2006
- Isophys maps (quantity). The maps of the pysometer conditions of the wells were used for drawing Isophys maps and details about each well set in Arcview GIS environment and the maps with the same height was drawn. For surveying of water level in Arak plain an annual average Isophys maps was drawn
- For calculating Isophys numbers by using Arcview and the capable of drawing and Thiessen triangle the coefficient α of each well and then the exact height of water plain (monthly and annually) were calculated drawing a graph for pysometric level changes of Arak plain

RESULTS

The pysometric level changes of the plain: The level of ground water in 46 physometer wells in Arak plain which compared 1985 and 2006 is showing a sensible declination during the last 20 years which is drawn based on a calculated numbers (Fig. 2).

Change detection of ground water: When the recorded hydrometric data plotted on the pysometric level changes, it shows that Arak plain water level is decreased some about 1659.27 meters during 20 years from 5/3/86 to 5/3/2006. Therefore with a total declination of 8.78 meter with the width of Arak plain which was estimated 1489.64 km and 4% coefficient then the rate of declination related to the ground water volume can be calculated as follow:

Coefficient S: 4×10^{-2}
The width of area A = 1489/64×106 m^2
20 years declination = $\Delta h = 8.78$ m
The changes of the volume → $\Delta V = \pm \Delta h.\ A.S$
$\Delta V = (-8.78)\ (1489.64 \times 106)\ (4 \times 10^{-2})$
$\Delta V = 523161568 = 523.161 \times 106\ mm^3$

In this method the annual average declination of the mentioned plain is estimated about 0.439 m and its annual declination is about 26.158 million.

Isophys maps: Investigating of each map with different annual statistical data and surveying on changes of the level of ground water of Arak plain, it can be resulted that from 1986 to 1987 the measured curves from the same field

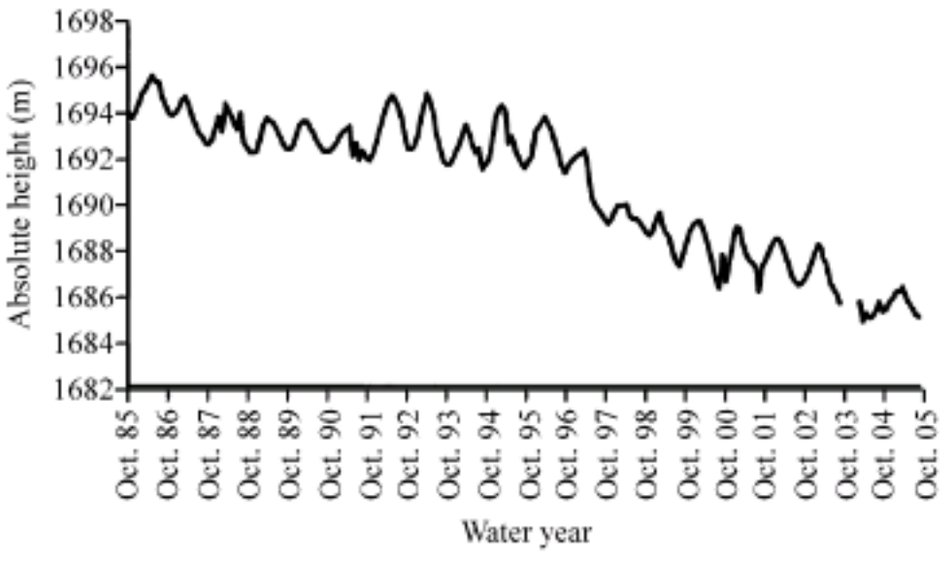

Fig. 2: The Pysometric level changes of Arak plain

toward Mayghan Kavir and the west side of Kavir has been decreased. Geomorphologically this area is located in the lowest part of the plain as a depression, therefore the level of groundwater related to the plain where the recent water is observed as a subsoil drainage ground water. The routine changes in groundwater is shown that the Isophys lines are gradually reach to the west of the basin as closed curves, getting distance from the Mayghan Kavir and reach at the western part with the lowest height. The study area is shaped as circle form which is provided to deposited alluvial sediments in it's center part. In the past the trend of groundwater flow was from rounds of basin to the Mayghan Lake, because the surface drainage system has effected by the geological structure of the study area. Therefore the remained surface flow and continuing of interflow has gathered in the centre to form a lake. In recent years, this routine changes shown that because of some reasons such as over extraction and low precipitation the role of Kavir and natural drainage of aquifer become less than previous and recently the place of drawdown is located in western part of the basin (Fig. 3, 4).

The final conditions of the exact height of the ground water for the study area in recent years to 2006-07 shows that the formed curves with decreasing of the elevation of the surface ground water in the centre of Mayghan village in the western part with 1640 m, in the southern part at Haji Abad is about 1640 m, around Mehrabad village in the south west with 1630 m. The hydraulic slope of aquifer is completely focused to the west, south west and south of the plain which shows a trend of high declination of the ground water in these places during the last 20 years.

By comparison of two isopyes maps is shown that the most changes are happened around Mayghan Lake and it's western part. The absolute level of ground water is decreased and its lowest level is belonged to Mayghan Lake. It means that the trend of groundwater flow was toward to this place and intercepted the salinity aquifer intrusion but now the absolute level of ground water is less than 20 years ago and the lowest level belong to the west of plain and the probably risk of intrusion salinity aquifer toward fresh water aquifer is increased.

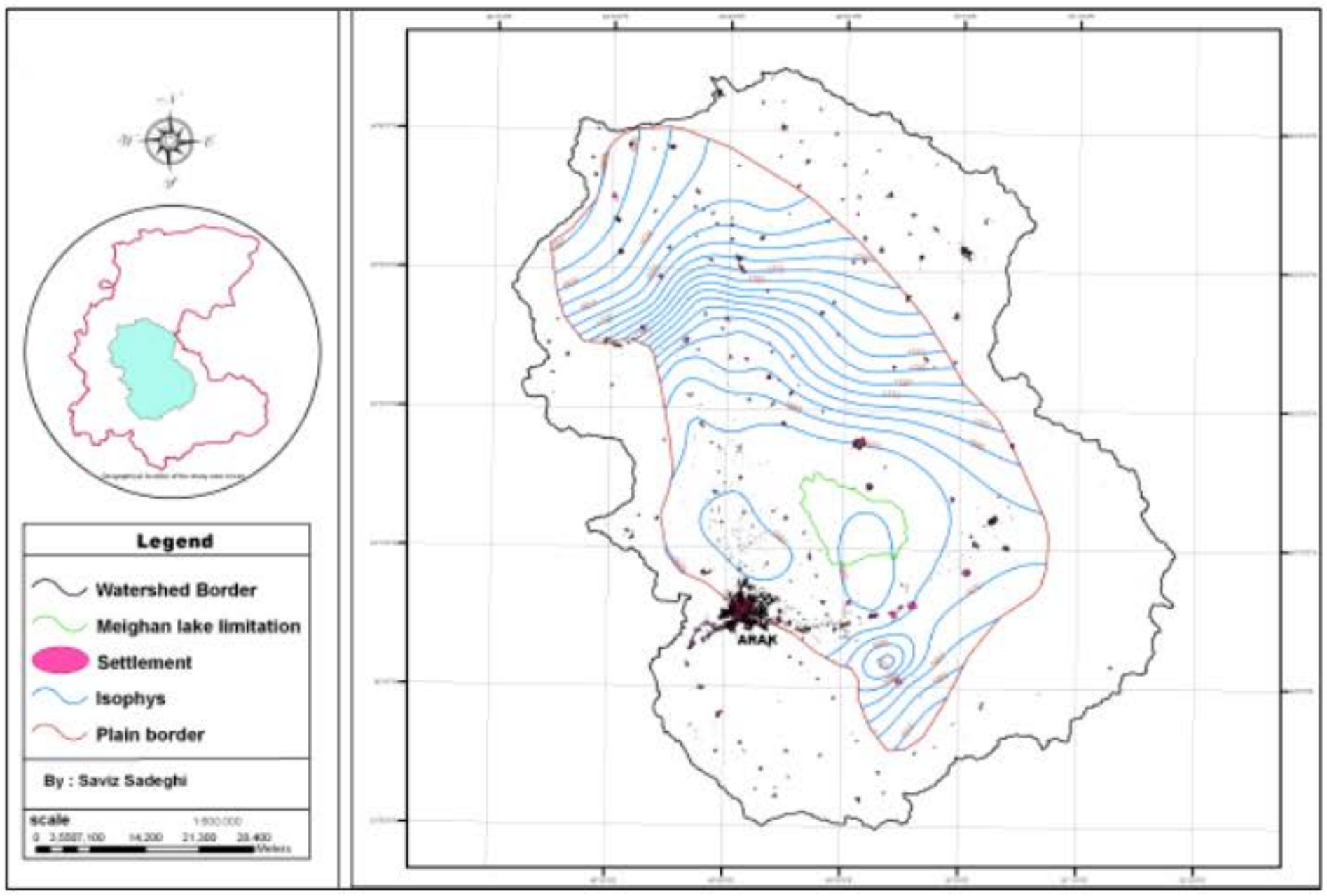

Fig. 3: Isophys map of Mayghan Kavir in 1986

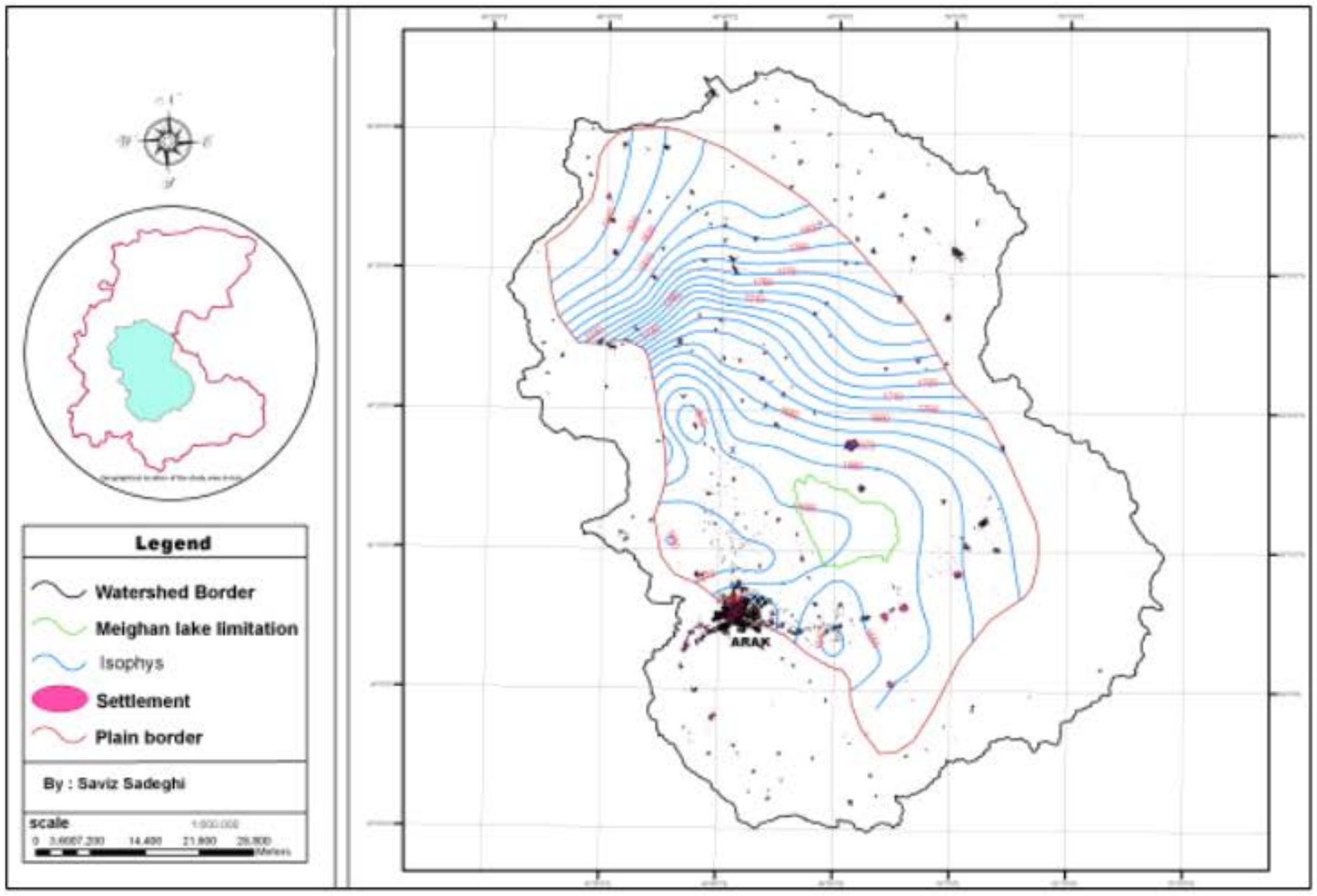

Fig. 4: Isophys map of Mayghan Kavir in 2005

DISCUSSION

During the last twenty years the results are indicated a rapid growth of the wells in the west portion. The south west of the plain was induced from a declination of the groundwater which can be concluded that in Arak plain from the north to the south and from the east to the west, the exact level (absolute water height) of the ground water has a trend of decreasing process and the aquifer hydraulic slope will shifting to the west part of the study area.

Comparing of the precipitation graph and pysometric level changes graph of this plain shows that Mayghan is located in a mid arid area and droughts phenomena which is occurred in this area, caused a low water level in aquifer and also is related to the people's consumption. Some factors such as over discharging, gape of legal permission, low level of the old wells, traditional systems, over consumption of drinking water, techniques and watering, absence of controlling and management of using, absence of performance of powering and recharging the aquifers and so on caused the declination of aquifer in the study area.

Investigation of the changes on the level of plain ground water during the twenty years period can be found that the most falls of the wells with 10 to 37 m in the west and south west this area have occurred and have transferring to the eastern part of Mayghan. Most of the changes on ground water during these years is about -1 m in the northern east, the north, northern west and the southern east parts of the study area. Briefly it can be recommended to stop any digging permission and using or deepen and changing the place of well in the critical parts, of the plain and controlling of the use of ground water of the wells under using permission. Keeping the height of water in the aquifers with leading the formers to grow the plants which are compatible with this area. Necessity of controlling and management of using and a scientific managing of water resources in order to avoid of over decline of resources is referred. For prevention of evaporation of the water resources it is possible to lead it into underground, which is prevented of wasting evaporation. Also it can be used of mechanical activities such as detention dam, flood control, artificial recharge of ground water and seasonal use of the surface water. Planning in

consumption of drinking and watering to use advanced techniques. Thus, it must be irrigated the plant as its need and it should be prevented the over plus water in a critical and hazardous conditions. The other way is improving and changing the conditions of irrigation which can be decreased the volume of required water. It can be prevented of wasting of water in citizen areas and industrial part and avoiding of over consumption. Biological activities, renovation and plantation are also the important solutions.

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