DESERT

DESERT
Online at http://jdesert.ut.ac.ir

DESERT 12 (2008) 185-197

The effect of 1991-2001 droughts on ground water in Neishabour plain

H. Mohammadi[a*], M. Karimpour Reihan[b]

[a] *Associate Professor, Faculty of Geography, University of Tehran, Tehran, Iran*
[b] *Associate Professor, International Research Center for Living with Desert, University of Tehran, Tehran, Iran*

Received 29 March 2007; received in revised form 15 November 2007; accepted 26 March 2008

Abstract

This research investigates the effect of drought on ground water table of Neishabour plain. The precipitation data of Nishabour synoptic station during 1990-2001, the Bar climatology station during 1964-2001 and the data of hydrometric stations of Kherv and Bar in 1996-2001 have been used as the base of analysis. The method of Herbest et all has been used to analyze the drought. Using the effective precipitation and effective flow, the date of start and end of drought for the study region has been specified and then the time and intensity of drought have been calculated. The analysis shows that the main reason for the fall of the underground waters table level is the irregular use for agricultural consumptions. The climatic drought has had a direct effect on running water and it has also had direct effect on underground water of the region with a time lag. It was appeared that alluvial fan areas of Neishabour plain have a less decrease compared with the central and southern areas in spite of much consumption of water by deep wells.

Key words: Climatic drought; Effective precipitation; Depletion of water table; Hydrograph; Ground water

1. Introduction

Water is the source and thriving state of life. The importance of water is obvious in all economic, social and cultural aspects of human life and is known to everybody. Its value and credit in the arid and semi-arid zones of the world is much higher than other regions. Water has been of specific and vital importance in Neishabour plain which has a semi-arid climate. The existence of Qanats and irrigation chanals in this city confirms this fact that the people of this region have frequently strived to have a greater and better use of water resources (Velayati, 1991).

Drought is a climatic phenomenon and their characteristic depends on time, intensity and vastness of the region under its control. Drought is a of precipitation shortage condition and temperature increase which might occur in any climatic (Goupta, 2006, Srivastava, H.N. and Gupta 2006). The formation processes of drought are four detachable different stages. The beginning, it happens along with the atmospheric variable changes including, increase of temperature and higher evaporation following the less precipitation, then occurs drought.

With increasing of water consumption as a result of meteorological drought event, the reduction of surface running water and discharge of rivers, the shortage of penetration of water in soil and discharge of the stored water in the ground, the reduction of rate of the water appears in reservoirs of dams. In this stage, the hydrological drought occurs and starts botanical tension. This is only subject to the intensity and durability of drought. In this stage which is concurrent with the reduction of the performance of agricultural components, the agricultural drought has started. The fourth stage of drought is associated with the economic, social, health, environmental and political consequences for human which impose life and financial loss on humans (Smith, 2001).

[*] Corresponding author. Tel.: +98 912 3849767;
fax: +98 21 66404366.
E-mail address: hmmohammadi@yahoo.com

The occurrence of intensive and frequent droughts cause of destructive effects on the resources of surface and underground waters. Its impact on surface and running water occurs quickly and in a short term period. It affects on underground water in a long-term period and is more unpleasant. The destructive effect of drought on running surface waters emerges with the reduction of water production and dryness of rivers and if continues, it will give rise to drought and intense reduction of surface waters such as lakes. The impact of drought on underground waters which is in fact the water reserve of a country and is of great significance in particular is observed in arid and semi-arid area. This will make the fall of the level of yielding water table and if continues, it will make them dry (Mohammadi, 2005, 2006).

1.1. The study area

Neishabour plain is part of the river basin of Kal Shoor which belongs to the basin of the central desert of Iran and is located in the north east of the central desert and southern slope of the mountain heights of Neishabour. This basin is situated in the 58°17' to 59°30' longitude and 35°40' to 39°36' latitude. It is limited from north to the watershed of Binaloud heights, from east to the Leila Joogh heights and Yalpalang, from the south to Neizeband hills, from the west to Siyah Kooh and Koh Namak and to the basin of Sabzavar plain. Neishabour plain is limited from the north side to Qouchan and Chenaran and from the east to Mashhad and from the west to Esfrayen and Sabzevar and from the south to Kashmar and Torbate Heydariyeh. The historical city of Nishabour located in 115 kilometers from Mashad and 779 kilometers from Tehran and center of this plain (Figure 1). The area of the basin is 7300 square Kilometers which 4100 square kilometers are plain and the rest are heights (mountainous areas). The highest point of the region is Binaloud heights and it has 3300 height from the sea level. The lowest point is the exit place of the plain and has 1050 meter height on the sea level (Velayati 1991).

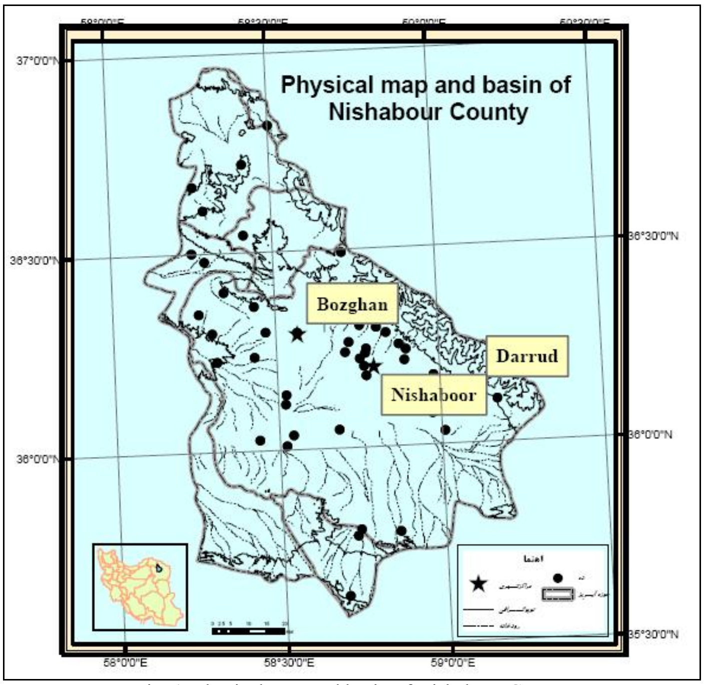

Fig. 1. Physical map and basin of Nishabour County

1.2. Problem Design and drought study

The average annual precipitation in Iran is less than one third of the world. In addition due to the shortage of rain, spatial and temporal atmosphere distribution is also very inappropriate even our highest precipitation place point of our country needs irrigation in the summer (Kardavani, 2001). Iran is a limit of the earth which most of the arid and semi-arid zones of the world are located. The cause of this dryness originates from the general circulation of atmosphere in the earth. With regard to the location of Iran, the water crises indices are more unfavorable as compared with the average of the world (Alizadeh, 2001).

The groundwater resources have specific importance among the water resources, since after oceans and polar ices, they are the most useable resources in the earth. Advantages such as much quantity of water, easy access and purification has made higher use of this resource for different industrial, agricultural and domestic consumptions (Arbabi, 2001).

The possibility of drought occurrence is high in Neishabour plain. So the necessity of knowledging and preparedness against its negative impacts in the limits under investigation is of great significance from the economic, agricultural and residential aspects. In this region, the frequent fall and decrease and intensive level of stagnation have been observed over last years. Of the signs of shortags, the dryness of some of the qanats and lowering the average depth of wells can be mentioned which is prevailing in the region as a serious problem.

Since drought imposes great damages on the country both directly or indirectly, so that the study, identification and finally the implementation of appropriate policies in facing this natural disaster seems to be necessary. Droughts are among the natural disasters which occur in the condition of negative fluctuations or in other words the reduction of atmospheric precipitation as compared with the long - and short term average. Basically, the damages resulting from drought depend on the plans of the countries. If planning takes place with regard to the limitations of dry regions, the damages resulting from drought will be minimal. In the other hand, the more these distances are great, the damages resulting from drought will be greater and the region will be more vulnerable and fragile. Basically, it can be concluded that the study of the damages of drought in the region and implementing it in planning will be more useful and will prevent from further damages.Also, with regard to the fact that the hidden damages of drought appear many years after removing those effects, its recognition becomes necessary. For example, many immigrations and leaving of villages which are created as a result of intensive droughts and its effects remain for many years (Kamali, 2001).

The statistical studies show that 11% of the natural disasters are related to the occurrence of droughts (Smith, 2001). The number of the victims of the droughts was one million and 851 thousands people between 1993-1995 which is 51 percent of the total victims of other natural disasters. The total number of people being damaged by drought from 1988 to1996 was over one billion and 579 million people which are considered 52 percent of other natural disasters (Smith, 2001).

In Iran, drought has imposed many damages on infrastructural installations and agriculture in most of the years (Ganji 1974). Payment to the damaged persons in the agricultural year 1998-1999 and 1999-2000 has been equal to 4.3 percent of the budget of the country. By these figures, only part of the damages have been componsated and the indirect impact of drought has still remained (Kamali and Khazaneh Dari, 2002). Regarding to the rate of damages which has been created by drought, its identification and review become important. It is possible to reduce the damages resulting from natural disasters only by adopting appropriate management methods. Due to agricultural and industrial importance of Nishabour plain, the study of drought in this plain becomes important. So, the most important objective of this research is to identify the effects of recent drought on the resources of ground water in Neishabour plain.

1.3. Literature Review

One of the obstinate enemies of human is drought which has been attacking himher since past times. It has been written many different books and papers about drought. Some important drought and famine of Palestine have been mentioned in the old Testment, and it is interesting that the constant periods of drought and famine have been cited more than 11 times (Siyahpoush, 1973). The story of Joseph in Egypt in 3500 years ago is perhaps the first and only document indicating the occurrence of harsh drought, its forecast and presenting a model to modify its effects. (Mack Kuchan, quoted by Khosh Akhalagh, 1998) and the mentioned story has been presented in the Holy Qu-ran in the Surat Mobarakeh Yousef, verses 43 to 49.

The existence of specific ceremonies such as playing drums and clamor in the primary tribes of America, Africa and Asia in the events of lack of atmospheric precipitation confirm this claim (Faraj Zadeh, 1996).

The related literature to drought is diverse, it so that some are directed at climatic drought, a group to its hydrological one and some others are directed at agricultural drought and finally to that of economic drought. Of the most important works which have been performed since 1960's onward, the work by Palmer can be mentioned. He is one of the first scholars who has studied drought scientifically and by using the physical and mathematical rules. He published his report under the title of "metrological drought", he presented his methods which was on the basis of meteorological and hydrological data. After, Palmer the works of Ni Mais (1966-67), the American famous meteorologist who conducted some researches on droughts of the north east of America in 1960's. Also, Padker works (1969) on weekly periods of wet and dry in Britain by using Synoptic analysis can be mentioned (Faraj Zadeh, 1996).

In relation of the written books, many resources and references have been prepared. For example Tanhil Ivanari (1947) or the Proceedings of the World Seminar of UNESCO in Australia which has been published by Chapman (Khosh Akhlagh, 1998) and Smith (2001) reviews the destructive effects of drought.

Karimi (2003) considered in an article entitled "Application of Palmer Drought Intensity Index in Iran", while doing a precise study of the methods of indices of evaluating the intensity of drought, the advantages and disadvantages of each from the climatic point of view and finally with a specific emphasis on the method of index of Palmer drought intensity, some suggestions have been made on employing them in evaluating drought in our country.

Bazrafshan (2000) in his paper under the title, "Effective Precipitation: have named four basic problems regarding to the indices of drought as follows:

A: Most of the prevailing indices in studying drought have no correct attention in determining the time of start, end and accumulation tension of drought.

B: In these indexes are not considered, the intensifying effects of run off, evaporation with the time.

C: These indexes do not have efficiency in studying the behavior of the period of continum drought, because they act on the basis of the monthly time or longer.

D: Most of these indexes of drought are unable to distinguish the effects of drought on the resources of surface and underground waters. In order to make a daily and precise study of drought and solve the above-mentioned problems, a new concept under the title of "Effective Precipitation" has been presented by two researchers (Bayan and Wilhite). In this study, in order to introduce this method, the quantitative analysis and two dimension analysis (intensity and continum) of drought have been performed on the basis of effective precipitation and using the daily precipitation data in some selected stations of Kasilian basin. Then in accordance with the daily effective precipitation, three statistical indices have been used to determine the continuation of drought. These indices are as follow:

A: Index of the daily average effective precipitation

B: Index of deviation from the daily precipitation average

C: Index of deviation from the standardized average daily precipitation

The dates of start, end and continuation of the shortage of water have not been correctly investigated by using these three indexes (Karimi, 2003). Abdi et al. (2000) in an article under the title of "A Study of the Situation of Water Resources in Zanjan Plain and Presenting Approaches to Meet the Drought of the Region" state that in accordance with the analysis, annually about 338 million square meter of surface running water are exited from the region without any usage and also the level of underground waters have been intensively fallen. The status of underground waters has been studied and in line with that, the hydrodynamic features of the underground water table levels, type of water table level and its expansion and the situation of geology condition and sediments of the region have been determined.

Mohammadi and Shamsipour (2005) have estimated the effect of drought on underground waters in the Hamadan northern plains and its intensity in 1999 and 2000. They have concluded that drought has effects on the resources of surface waters of the region directly in form of reduction of irrigation and on the resources of underground water indirectly with a time lag by reducing the feeding of surface waters, reduction of feeding the water beds and, increasing of temperature and evaporation.

Karimi (2003) in his thesis entitled, "The Effect of Drought on ground water of Middle Plains of Sivand River Basin, reviewed the impact of droughts on ground water of the region. Alijani et al. (2005) dealt analysis and forecasting the precipitations of Larestan region by using the Markov chain and also analysis of the droughts of the cold period in Sea southern coast of the Caspian.

1.4. Data Sources

Statistical data of the plain under investigation were reviewed in many stations. In this plain, two precipitation gauging stations and 2 hydrometric stations were used for the research whose specifications are presented in the Table 1. Also has been used existence observed wells data in the plain for the study of groundwater.

Table 1. Characteristics of the precipitation and hydrometric gauging stations in Neishabour Plain

Station Name	Longitude	Latitude	Elavation	Station Type
Nishabour	58˚48´	36˚ 16´	1213	Synoptic
Bar	58˚42´	36˚ 29´	1520	Climatology
Barariyeh	58˚42´	36˚ 37´	1560	Hydrometric
Kherv	59˚42´	36˚ 12´	1564	Hydrometric

1.5. Groundwater of Neishabour Plain

1.5.1. Introduction

Concerning groundwater, Neishabour plain is one of the important plains in Khorasan [Razavi] province and its rank is second plain of Khorsan from the view point of water after Mashhad plain, so that annually, more than 700 m^3 of groundwater are extracted by the deep and semi-deep wells from its water resource. But the quality of the ground water of this plain has many changes and varies in different spots (Velayati 2000).

1.5.2. Groundwater Recharge

Neishabour plain is fed by the rivers, atmospheric rains, floods and groundwater flows. The groundwater flows are extracted from the infiltration of water in the mountainous regions and alluvial fan areas which are the places of infiltration, in particular the alluvial fan areas or Binaloud mountain ranges are of great importance due to their infiltration capabilities.

1.5.3. Number, Discharge and other Characteristics of Groundwater Aquifers of Nishabour Plain

In order to make a more precise study of the method of utilization of ground water in the region, the water resources are divided into three groups: wells, Qantas and springs. The rate of annual discharge from wells, Qantas and springs have been estimated as 153, 704 and 14 mm^3 square meter respectively.

1.5.4. Wells: The classification of wells on the basis of the date of digging

In 1959 at Nishabour plan, there were only 2 wells. Due to the water demand, gradually the number of wells has been increased. The highest number of dug wells is related to the year 1986 which was equal to 147 wells. It can be said that annual mean, about 44 wells have been dug in Nishabour plain.

1.5.5. Classification of wells on the basis of discharge and depth

It can be said that about 38 percent of the wells have a discharge between 20 to 39 liter per second and about 87 percent of them have a discharge between 10 to 79 liter per second. Only 22 percent of the wells have less than 9 liter per second. Also the minimum and maximum of discharge by the wells of Neishabour plain is 22.5, 0, and 78 liter per second respectively. 56 percent of the wells have a depth between 100 to 149 meters. The main part of the ground water of Nishabour plain is extracted from the 1721 deep and semi-deep wells which have been dug. In Table 2, the number, type of consumption, rate and percentage of discharge in the wells of Nishabour plain have been presented.

Table 2. Number, consumption type, amount and percentage of discharge of wells in Neishabour plain.

Nishabour Plain	Agricultural consumption	Industrial consumption	Cattle and poultry consumption	Urban drinking	Rural drinking	Individuals drinking	Other consumptions	Total number
Number	1323	62	86	33	156	26	37	1721
Percentage of wells	77%	4%	5%	2%	9%	10%	2%	100%
Rate of taking 100 square meter per year	531.376	10.122	2.456	14.613	31.931	272%	17.369	7.867.373
Percentage of payment	87%	2%	4%	2.4%	4.3%	04%	2.5%	99%

As it is observed, the agricultural sector with the consumption of 87 percent of extracted water is the highest rate of consumption of underground water. After that, the sections of rural drinking and other consumptions stand in the following ranks with 5% and 3% respectively. Table 3, shows the number of dug wells over each five year. According to the data of Table 2, in each five year, the number of wells have been increased, as it was mentioned earlier, in average each year, 44 wells have been dug in this plain.

Table 3. The Number of dug wells in Neishabour Plain

Years	Number of Dug Wells	Total Number
Before 1961	2	2
1961-1966	105	107
1966-1971	132	239
1971-1976	168	407
1976-1981	323	730
1981-1986	338	1068
1986-1991	415	1483
1991-1996	130	1613
1996-2001	108	1721

If we make a comparison in different years for deep and semi-deep wells in Neishabour plain, we will notice the increase of the number of wells per year and also the increase of consumption from these wells. With regard to the presented statistics in Table 4, the numbers of the wells have been 306 rings in the year 1968 and the rate of discharge has been 176 mm^3. The amount of wells are 729 in 1981 with the rate of discharge in this year amounts to 513 million m^3 which shows an increase equal to 191 percent. Also in the year 1986, the number of the wells reached amounts to 1080 which shows a growth equal to 48 percent as compared with the year 1981 and the rate of discharge is 589 million cubic meters. In the year 2001, according to the latest statistics, the numbers of the wells have been reported as equal to 1721 which has had a growth equal to 59.4 percent as compared with the year 1986 and the rate of the discharge by the wells has reached to 704 mm^3 which shows a growth equal to 19.5 percent.

Table 4. Number and discharge of ground water resources of Nishabour region (mm^3)

Year	Well	
	Number	Discharge
1968	306	176
1981	729	513
1986	1080	589
2001	1721	704

1.5.6. Springs and Qanats

There are 639 Quanat ranges with an annual discharge of 152 mm^3 and 101 springs with an annual discharge of about 14 mm^3 in Nishabour plain. In recent years, due to the shortage of annual precipitation, their average discharges have been reduced. Of course, another reason of this deficiency is the increase of the number of wells and also the average increase of the depth of wells with regard to the lowering of the level of their waters. The volume of the extracted water by the springs and wells are about 27 percent of the total resulted water and more than 96 percent them are used for agricultural consumptions. In general, with regard to the Table No. 5, the rate of average annual discharge of the wells have been estimated as 704 million square meter and the rate of the discharge of the Qanats and springs are estimated to be equal to 153 and 14 million square meter respectively. The numbers of the deep and semi-deep wells on the basis of the latest statistics are 1721 and the number of springs and Qanats are 101 and 639 respectively.

Table 5. The Number and amount of groundwater discharge in Neishabour plain

Type	Number	Annual Discharge
Well	1721	704
Spring	101	14
Qanat	639	153
Total Annual Discharge		871

2. Material and methods

Before reviewing, processing and analyzing the data, it is necessary to explain and introduce some concepts.

2.1. Groundwater

The observable wells of Neishabour plain 1996-2001 have been used for drawing the hydrograph of Nishabour unit and reviewing the relationship between drought and the effect of drought and its impact on groundwater.

2.2. Software's Programs

SPSS and EXCEL software have been used to calculate and analyze the data of climatology, synoptic stations, discharge of rivers and observed wells. In order to obtain the correlation coefficiencies, the method of linear correlation have been utilized. As it was explained earlier, after collecting the precipitation data, river discharge of surface waters and underground waters, drought was calculated by the use of Herbest et al. (1966) method and its impact on the resources of underground water. This method was initially presented in 1966 by Herbest et al. to estimate the drought through precipitation data. Then this method in 1991, has been modified by Mahan and Rangcharia for the dry regions. This method has been selected and used for the following reasons:

1. Most of the prevailing indices of drought do not have good preciseness in determining the time of start and end of drought.
2. Most of these indexes are not able to distinguish the effects of drought in the resources of surface and underground waters.
3. They notice more the real precipitation and do not pay attention to the effective precipitation.
4. Most of the indexes do not have a considerable efficiency in behavior measuring of the period of continuation of drought.
5. Another advantages of this method is to use the weight co-efficiency in calculations. Also, in this method, droughts are reviewed in monthly form and the effects of previous and the following months are studied. Also the time of start and end of drought, intensity of drought and index of drought is determined and calculated. In this method, first, the effective monthly precipitation should be calculated:

1- The average of the data of each month is calculated for the same period:

$$Tt = \frac{\sum Tr}{n}$$

2- Then actual rainfalls or flows reduces from average.

$$Dt=Q-Tt$$

3- In the third stage , the weight co-efficiency is calculated.

$$Wt = 0/1\left(\frac{Tt}{\sum \frac{Tt}{12}}\right)$$

4- In the fourth stage , the effective precipitation (ET) is obtained.

$$Et=Q+(Dt-1)x\ Wt$$

5- In the fifth stage, the effective precipitation is deducted from the average effective precipitation.

$$Et-\bar{E}t$$

6- After effective precipitation, it is the turn of calculation of the average monthly shortage (MMD) which is obtained from the equation (Q-Tt) and from the summing up the negative quantities, the annual shortage (MAD) is obtained from the total shortages of annual quantities (The positive quantities are not included in the calculation).

7- In the following stage, the highest monthly average quantity of the precipitation is obtained. It is so that among the months of the year, the highest monthly average is selected and considered as MMM1.

2.3. Drought Start Test

The differences from the first month of period are reviewed. Whenever we face negative difference, this quantity is compared with MMM1. If the quantity of shortage is equal or more than MMM1, that month is considered as the beginning of drought, otherwise, it is compared with the difference of the next month. If the difference of the following month was negative, the total of the two differences are compared with the quantity of MMM1+x.

$$X= (MAD- MMM1).11$$

In the event the shortage of precipitation flow is higher than this standard, one drought period has begun from the first month. This action is continued up to last month of the period of each station.

2.4. End of Drought

Concurrent with this test, frequently, the sum algebra of all monthly differences are calculated from the first month. Whenever the total algebraic becomes positives, it is assumed that the drought has ended.

2.5. Tests

In order to study whether or not the drought has ended, in the same manner, the action begins by using the positive difference of each month after the start of drought, one condition for action is that the one month of the first two months to have positive differences. If this condition occurs, the drought will consider as finished without continuation of test. In order to check the pre-condition, the two tests should be used concurrently. The first test is used to determine the temporary end of drought and with this assumption that the period with higher than average of precipitation or the current includes only one stop or cut of drought before the end. This test includes the total algebraic addition of differences from the first month to the last month. In this test, if the algebraic addition before the end which is obtained by the second test is negative, so drought has ended temporarily. The second test includes ten frequent tests and contains the total flows real of the first to third months and is compared with the addition of three quantities of maximum of monthly average (MMM1+MMM2 +MMM3).

If the total horizontal currents are more than the total of three mentioned maximum, the drought has ended. Otherwise, the additional flow of the four months is compared with the total of the four maximum months and this will continue to the end accordingly.If up to the last month, the drought is not ended in this method, the same first test (when the algebraic additions of differences becomes positive) is considered as the base and with the end of the drought , the test is conducted for the beginning next drought.

2.6. Intensity and Duration of Drought

It is necessary that droughts could be compared with different duration and intensity in the regions w ith low or high precipitation without considering the seasonal changes in precipitation which are calculated as follows:

$$Y = \frac{X}{\overline{\overline{X}}}$$

YD=Y.D

Y= Monthly Average of the drought intensity,
X= Total shortages higher than monthly average shortages (mm)
X= Total average of monthly shortages for the same period (mm)
From the above equation, the drought can be defined as follows:
YD= drought index
D= drought time period

2.7. The survey of the precipitation rain gauges in Nishabour plain

2.7.1. Nishabour rain gauges

The average precipitation of Nishabour station has been calculated 224.2 mm during 11 statistical years. The minimum precipitation in this station is related to the year 1999 which is equal to 117 mm and the maximum of precipitation is related to the year 1992 in which the rate of precipitation of the station is 387.2mm. The highest rate of precipitation was in winter and the minimum rate of precipitation was in summer. The seasonal distribution of precipitation, in Nishabour station, about 31.3 percent take place in spring, 1.2 percent is related to summer, 17.6 percent is related to fall and 49.9 percent of the annual precipitation occurs in winter.

2.7.2. Neishabour Bar rain gauges

The average of precipitation of Nishabour Bar station is 345.7 mm in a 37-year period from 1964 to 2001. The minimum precipitation during the index period is related to the year 1999 which is equal to 166.5 mm and the maximum precipitation is related to the year 1992 with 560 mm. Regarding to the seasonal distribution of precipitation in this station, 29 percent is related to spring, 2.6 percent is related to summer and 26.4 percent is related to autumn and 42 percent of precipitation is related to winter.

2.8. The study of Nishabour plain drought analysis by the Herbest et al. method

In order to study the drought of the region under investigation, the monthly precipitation data of the stations of Nishabour and Bar have been used. On the basis of Herbest et al. method, the time of start and end of drought and also intensity and duration of drought have been calculated.

2.9. Study and analysis of drought in accordance with the effective precipitation (in Herbest et al. method) in Nishabour station

In order to study the drought of Nishabour, the 11-year statistics have been analyzed. First, the effective precipitation was calculated. Then in accordance with (Et-Ēt), the effective precipitation higher than effective average of the drought in the region under investigation was calculated. The first state of the beginning of drought in Nishabour station began from September 1993 and ended in April 1997 which lasted for 43 months. The intensity of drought was calculated for this period as 36. The second stage of drought which began from June 1998 and ended in July 2001 continued for 36 months. The intensity of drought in this stage was 20.9 (Table 6).

Table 6. Start and end of drought in the area study

Monthly average	Duration of wet year	Precipitation in wet year	Stage	Start	End	D	Y	YD	Total precipitation in drought month	Monthly average
21.8	7	152.4	1	Sept.1993	Apr.1997	43	36	1548	469.3	13
16	7	111.7	2	Jun.1998	July 2001	36	20.9	802.4	365	10.1

In total, two drought periods have been obtained for Nishabour station. The first period is a very long period and its intensity is higher as compared with the second period. In total have been studied, 126 months of precipitation to determine drought. In these 126 months, there has been two stages of drought. The first stage of drought has been 43 months and the second stage has been 36 months. In total, 79 months of 126 months, i.e. about 62 percent of the duration of the statistic period, there has been drought, and this indicates that the region under investigation is facing a severe drought and the rate of drought in the region is more than the average of precipitation.

2.10. The study and analysis of Nishabour plain drought in the Bar station based on effective precipitation (Herbest et al method)

At first, the effective precipitation of the region was calculated and the basis of (Et-Ēt), has been calculated the fraction of the effective precipitation of the average of that drought in the region. As it has been presented in the Table No. 7, the drought of the region for a 39-year period (1964-2002) has been studied. The first stage of drought is March 1964 and its end is April 1967 which has continued for 25 months and the intensity of drought was 19. The second stage of drought began from December 1969 and ended in April 1971 for 15 months and the intensity of drought was 12. The third stage of drought began from May 1973 and ended in May 1976 with intensity of 18.9 and for 36 months. The fourth stage of drought began from April 1969 and ended in February 1980 with intensity of 20 and for 23 months. The fifth stage of drought began from January 1981 and ended in April 1986 for 50 months and with an intensity of 38. The sixth stage of drought began from January 1993 and ended in December 1996 with intensity of 25.8 and for 35 months. The last stage of drought began from February-March 1997 and continued up to November 2001 whose intensity was 39 and its duration was 46 months. In total, a 38 years and 459 months statistical period have been reviewed in which in 230 months, we have been facing drought and have observed seven stages of drought. From the viewpoint of duration of drought, the years of February 1981 up to April 1986, i.e. the fifth stage of drought with 50 months, we have had the longest period and from the intensity of viewpoint, in the last stage, i.e. from the February 1997 to November 2001 with 46 it has had the highest rate of intensity.

In total, 50.1 percent of the statistical period, we have observed drought which indicates that drought in the region is a little bit more than average precipitation.

Table 7. Start and end of drought in area study.

Monthly average	Duration of wet year	Precipitation in wet year	stage	Beginning of drought	End of drought	D	Y	YD	Total precipitation in drought year	Monthly average
34.4	5	171.8	1	March 1963	April 1967	25	19	475	331.5	16.6
17.2	2	34.4	2	Jan. 1969	April 1967	15	12	180	305.3	23.4
56.8	8	345.4	3	May 1973	May 1971	36	18.9	680	471.4	16.8
33.3	3	100	4	April 1979	Feb-Mar. 1980	23	2	460	350	17.5
45.9	11	504.9	5	February 1981	April 1986	50	38	1900	810.3	20.8
36	7	252.1	6	February 1993	Jan. 1996	36	25.8	903	602.7	21.5
18.8	5	94	7	Feb-Mar. 1997	Dec. 2001	46	39	1794	605.1	14.8

2.11. A review of Neishabour plain unit hydrograph

In order to study and review the situation of ground waters of Neishaour plain, the unit hydrograph of this plain for water years of 1996-2002 up to 2001-2002 has been drawn. In this plain the maximum level of water source in the year 1996 is equal to 1138.45 meter and its minimum in the year 1997 is equal to 1133.111 meter which shows a decrease equal to 5.34 meter (figure 1). In the year 1996, the maximum balance of water source is 1138.45 and its minimum in September-October and November is equal to 1137.20 meters which shows a decrease equal to 0.99 meter (about 1 meter). In the year 1998, the maximum of water balance level is 113784 meter in April and its minimum is in November equal to 1136.78 meter its rate level decrease shows about 1.06 meter. In the year 1999, the maximum of water balance in April is equal to 1137 meter and its minimum in December is equal to 1136.04

meter which shows a decrease equal to 0.96 meter. In the year 2000, the maximum level of water in April is equal to 1137 meter and its minimum in the December is equal to 1136.04 meter which shows a decrease equal to 0.99 meter. In the year 2001, the maximum of the balance level water is 1134.89 meter in April and its minimum is equal to 1133.75 meter in November which shows a decrease equal to 1.14 meter. In the year 2002, the maximum level of water is 1133.96 meter in September and its minimum in November is equal to 113.86 meter which shows a decrease equal to 1.1 meter.

The maximum decrease of the water level in the year 2001 is equal to 1.14 meter and its minimum in the year 1996 is 0.20 meter. The average of the changes of the level of water has reduced from September-November 1996 to January 2002 0.92 meter. In total, the annual reduction trend is 0.92 centimeters average year. In general, the rate of the decrease from September-October up to January 2001 shows a figure equal to 4.72 meter. The annual precipitation of Nishabour Bar and Nishabour stations show the correlation co-efficiency equal to 0.48 and 0.52 on the basis of the statistics of observable wells respectively (Table No.8 and 9).

Table 8. Calculation of the correlation co-efficiency of precipitation in pluviometer with hydrometric stations

station Name	Nishabour pluviometer	Bar pluviometer	Bar hydrometric	Kherve Bozorg hydrometrics
Nishabour pluviometer	1	0.741	0.774	0.972
Bar pluviometer	0.741	1	0.941	0.77
Bar hydrometerics	0.774	0.942	1	0.804
Kherve Bozorg hydrometrics	0.972	0.77	0.804	1

Table 9. The correlation fficiency calculationof the precipitation in the Nishabour plian stations with the Pizometry plain wells

	Nishabour observable wells	Bar station	Nishabour station
Nishabour observable wells	1	0.48	0.52
Bar pluviometer station	0.48	1	0.741
Nishabour pluviometer station	0.52	0.741	1

2.12. Comparison between the precipitation abnormalies and the height of the balance of water table in stations of the region

The two pluviometer stations and Pizometric stations are reviewed and compared from September-October 1996 to September-October 2002 based on the basis of the statistics related to Pisometric at the water level. The rainfall average in the two stations of the region in the years 1996-2002 is 250 mm. In the year 1996-1997, it is equal to 311.5 mm in which the rate of the fall of the ground water is 1.11mm. In the water year 19997-1998, the average of rainfall of the station is 344 mm and the rate of decrease is 0.21. In the year 1998-1999, the average of precipitation in two stations is 274.8 and the rate of decrease is 0.71. In the year 1999-2000, the average of precipitation of the two stations is 144.3 which show about 106 mm reduction as compared with the average and the rate of decrease is about 1.03. The average of precipitation in the station is 299.1 and the rate of decrease is 0.1 In the year 2000-2001. The maximum of the water balance in this year is 1134.11 meter related to February and its minimum is related to August by 1133.13 meter (Table 10).

2.12.1. Hydrometric study of the Nishabour plain stations

2.12.1.1. Bar discharge measuring station

In order to review the annual discharge of the Bar river, 18-year period has been studied. This period begins from the water year 1981-1982 up to1999-2000, in this period, the highest average discharge is related to the water year 1991-1992 with 1.16 m^3 per second and its annual volume is equal to 31.373 m^3. The minimum discharge in the period is related to the water year 1999-2000 in which it is 0.1 m^3 per second. The maximum discharges during this period are related to the April and it is equal to 4.54 and the minimum of discharges are related to September which is equal to 0.02 m^3 per second.

2.12.1.2. Khreve Bozorg discharge measuring station

In order to study the annual discharge of Kherve Bozorg River (Cheshme Ali), the existing statistics of this station from the year 1974-1975 to 1999-2000 have been reviewed. In this period, the highest discharge is related to the year 1975-1976 with 0.94 and the minimum discharge is related to the year 1999-2000 with 0.2 m^3 per second and the maximum discharge is related to May which is 3.93 m^3 per second.

2.13. Precipitation fluctuations comparison in different stations with hydrometric stations

Table 8 has reviewed the calculation of the correlation co-efficiency of the annual precipitation in pluviometer stations, the correlation co-efficiency between the Bar hydrometric stations and Kherver Bozorg hydrometric station is 0.80. According to the figures of the Table No. 8, the rate of correlation between Bar Nishabour station with Bar hydrometric station is 0.94 and the rate of correlation coefficient of Bar Nishabour station with Kherve Bozorg hydrometric station is 77%.The rate of correlation coefficient of Nishabour station with Bar hydrometric station is 0.774 and with Kherve Bozorg hydrometric station is 0.972.

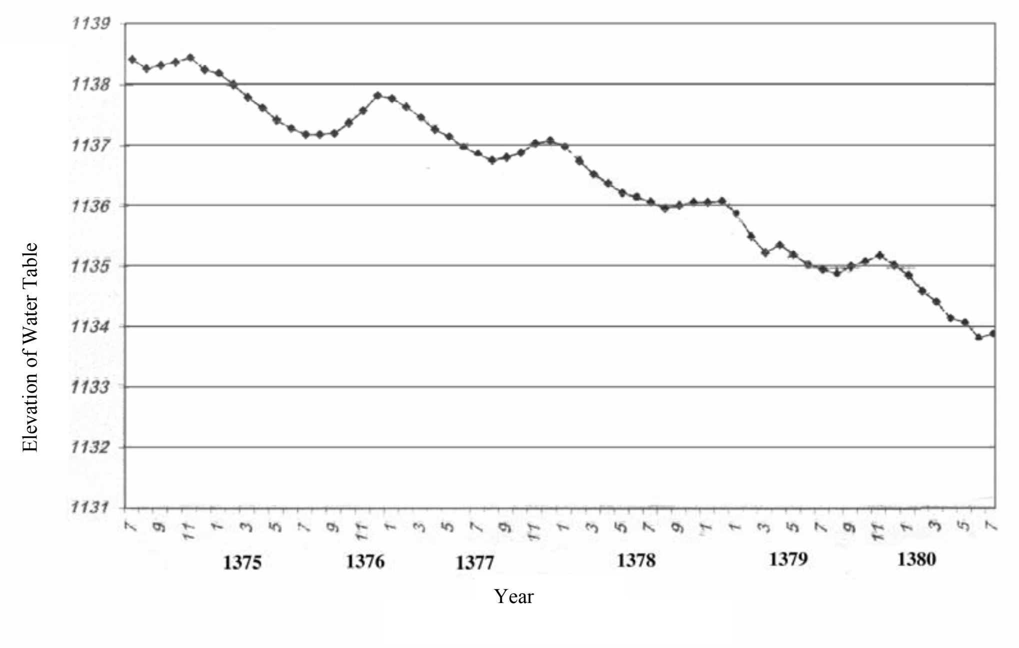

Fig.1. Neishabour Plain Hydrograph (Elevation of Water Table)

Table 10, Comparison between the balance of water table with monthly rainfall of Nishabour plain (1996-2001)

August-September	July-August	June-July	May-June	Apr.-May	Mar.-Apr	Feb.-Mar	Jan.-Feb	Dec.-Jan	Nov.-Dec	Oct.-Nov	Sept-Oct	
1137.30	1137.43	1137.63	1138.80	1138.01	1138.19	1138.25	1138.45	1138.37	1138.32	1138.26	1138.41	Balance of water table 1996-1997
0	0	0	13.4	31.7	39.6	39.6	21.7	21.7	0.8	9.8	0.3	Precipitation 1996-1997
1136.99	1137.17	1137.29	1137.48	1137.65	1137.84	1137.84	1137.39	1137.39	1137.22	1137.20	1137.20	Balance of water table 1997-1998
0	0	0	3.1	13.7	29.5	29.5	39.1	39.1	23.5	37.4	0	Precipitation 1997-1998
1136.17	1136.24	1136.39	1136.55	1136.77	1137.11	1137.11	1136.90	1136.90	1136.83	1136.78	1136.88	Balance of water table 1998-1999
0.2	2.6	4.7	4.4	10.8	88.2	88.2	37.2	37.2	10.4	6.6	0	Precipitation 1998-1999
1135.06	135.22	1135.38	1135.45	1135.52	1136.11	1136.11	1136.09	1136.09	1135.04	1135.99	1136.09	Balance of water table 1999-2000
1.5	0	0	5.3	0.2	11.2	11.2	8.1	8.1	15.9	12.3	3	Precipitation 1999-2000
1133.80	1134.06	1134.13	1134.40	1134.58	1135.05	1135.05	1135.11	1135.11	1135.03	1134.91	1134.98	Balance of water table 2000-2001
2.8	0.1	¾	2.3	19.1	32.1	32.1	4.1	4.1	43.6	34.9	12.5	Precipitation 2000-2001

3. Result

The water resources in Neishabour region includes the surface and groundwater. In The highest potential the surface waters is in the north parts of the region and in the foothill part of Binaloud mountain ranges. If it be more than consumption, they will pour into the main drainage of the region in the southern parts of the plain which flows from the east to the west. This drainage beside of northern sub-branches also has southern sub-branches which originate from the southern mountains of plain.

The increase of demand for digging wells and using the groundwater has gradually become the decrease of the underground water level of plains and at present, despite the fact that digging the well has been banned as a result of the high decrease at the plain level water, but every year, due to the increase of the depth of wells or digging wells as a result of dryness of Qanats, we are facing a great volume of deficiencies of aquifers. This shortage is 201 mm^3.

In Neishabour plain, the number of dug wells was 2 wells in 1959 whereas in the year 2001, the number of deep and semi-deep wells is 1721 which rate of water extraction through these wells is 704m^3. The was growth of wells and extracted water indicates that the most important factor of the decrease of groundwater level is the irregular consumption of water for agricultural. Among this situation, the recent drought event has imposed irreparable on the water resource of Neishabour plain. The reduction of atmospheric rain or snow falls has reduced the waters of the rivers of this region on one hand and on the other hand further pressure for groundwater to compensate the shortage has reduced the level of water source. It became apparent that the atmospheric rain or snow falls has had a considerable reduction as compared with long-term average in this research. The highest rainfall reduction is in the years 1998-1999 and 1999-2000 and the highest decrease of the groundwater table is related to the year 2001 which shows the decrease of the groundwater table with time lag. Of course, the rate of rainfall has almost been balanced in the years 2000-2001 and 2001-2002, but the decreasing the water table is still continuing. The quantity of surface water in drought years of the region show a considerable decreases.The reduction of the surface waters which supplies water needed for agricultural lands and in particular the gardens, has had unfavorable impacts on agricultural and gardening scenes, since in these areas, due to having height, deep wells and Quanat have no application and the surface waters are the only water supply resources in these kinds of gardens.

Hydrograph of Nishabour plain (1996-2001), shows that in recent years the level of ground waters has had a sensible reduction so that in Nishabour plain, this reduction is equal to 4.72 meter whose amount of average decrease at the water table level in recent 5 years has been 0.94 meter in each year.

Recommendation

1. Establishment of dam on branches of Kalshour to reserve the winter rainfall which is the most important rainy season of the region and at the same time the most important living factor of the farmers in the region.
2. Regarding to the alluvial fans penetrable of the plains the rivers waters which are mostly in flood form in winters, it is important to establish small dams to make waters infiltrate into the lands.
3. Appropriate control in utilizing the underground waters and preventing from further digging of the wells in the region
4. Changing in traditional irrigation method which is mostly in form of deep watering and (a greate quantities of waters are lost through evaporation) and mechanizing the irrigations.

References

Alijani, Bohlool, Zeinalabedin Jafarpour and Heidar Qaderi, 2005. Analysis and forecasting the precipitation in Larestan region by using Marcov chain model, Quarterly Geographical Journal of Territory, No. 7.

Alijani, Bohlool , Zeinalabedin Jafarpour and Qolam Reza Janbaz Qobadi, 2005. Analysis of the droughts of cold period of southern shores of the Caspian Sea, Quarterly Geographical Journal of Territory, No. 7.

Alizadeh, Amin , 2001. Principles of applied hydrology, 13th edition, Imam Reza University Press.

Arbabi, Azadeh, 2001.The effect of drought on groundwater resources of Qazvin plain, M.S. Thesis, University of Tehran.

Faraj Zadeh, Manouchehr, 1999. Forecasting the droughts of Iran, Doctorate Dissertation, Tarbiat Modaress University, Tehran.

Ganji, Mohammad Hassan, 1974. 32 Geographical Articles, Publications of Institute of Geography and Cartography of Sahab.

Gupta, V. J. 2006. Natural Disasters and Environment, SS. Publishers, Delhi, India.

Kamali, Qolamali, 2001. Indexes of drought and its durability, Quarterly of Drought and Agricultural Drought, No.1, Ministry of Jihad of Agriculture.

Kamali, Qolamali and Khazaneh Dari, Leili, 2002. Analysisof recent droughts of Mashad by using some of the indexes of drought, Scientific and Technical Journal of NIWAR, Nos. 44, 45.

Kamali Qolamali, 2001. A study of the changes of precipitation in Mashahd, Journal of Geographical Researches,Nos.58, 59.

Kardavani, Parviz, 2001. Drought and ways to cope with it, University of Tehran Press.

Karimi, Mahmoud, 2003. A study of the drought and its impact on the underground water in the river basin of Sivand, M.A. thesis, University of Tehran.
Khosh Akhlaq, Faramarz, 1998. Pervasive drought of Iran by using synoptic analysis, Ph.D. Dissertation, University of Tabriz.
Metrological Organization, Statistical Yearbooks, (1966-2001).
Mohammadi, Hossein, 2005.The Concepts and Technical Terms of Climatology, University of Tehran Press.
Mohammadi, Hossein, 2005. Applied Climatology, Universityof Tehran Press.
Mohammadi, Hossein, and Ali Akbar Shamsi Pour, 2005. A Reviewing the effects of drought on the groundwater resources of Hamadan plains by using multi variables statistical analysis and GIS, Quarterly Geographical Journal of Territory, No. 7.
Mohammadi, Hossein Morad and Shamsipour, Ali Akbar, 2003. The effect of recent droughts in the fall (reduction) of the underground water sources in Hamadan plains, Geogrpahical researches of the University of Tehran, No. 45.
Smith, K. 2001. Environmental Hazards , Routledge, UK.
Srivastava, H.N. and Gupta, G.D. 2006. Management of Natural Disasters in Developing Countries, Daya Publishing House, Delhi, India.
Velayati, Sadolah, 2000 The most important factors effecting on the qualitative changes of water bed of Nishabour plain, Journal of Geographical Researches, Nos. 58, 59.
Velayati, Sadolah, Tavasoli Saeed, 1991. Resources and issues of water in Khorasan Province, Astane Qodse Razavi Publications.