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Studying the Effect of Climatic Changes on Water Systems: A Case Study of Marghab River

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Abstract

Water is one of the essential needs of humans. Although it has taken two thirds of the Earth's surface, water management and planning seems inevitable due to its time and place limitations on one hand and the little volume of sweet and accessible water on the other hand. Basically, change and movement are elements of natural systems. However, the subject of change in climate is nowadays one of the widespread scientific and even political and social issues. Climate as undeniable fact of our life environment has fairly regular periods of variations and change on time-place scale and fairly irregular changes due to human interference in the cycle of the Earth's ecosystem. Since one of the important aspects of climate is the climatic changes' effect on water systems of Marghab River, the process of climatic changes were studied in a 25-year-old statistical period from 1996 to 2011 regarding time and place parameters of climatic elements of temperature, and effective precipitation in the area. The present research was done using the ambit or range of the watershed method and the data was gathered by library-field research methods using geographical information system. In the present research, the results of linear relationship of climatic changes' process show that the double increase of temperature and the decrease of precipitation in the area and their relationship with the decrease of water of Marghab River are significant. In addition, the above factors are effective in the break of Tondaran Lake and have caused Marghab River to become seasonal.

Keywords: Marghab River, process, climatic changes, water systems

1. Introduction

Marghab River is located between 313450 and 295050 longitude and 374932 - 9232 latitude in the west of Isfahan and Najaf-Abad city and forms part of Tiran and Karon plains. Geographically, it is bordered with Friedan city from the west, with Dehagh and Alavijeh from the north, with Chadegan from the south and Tiran and Karon from the east. Figure 1 shows the mathematical position of Marghab River.

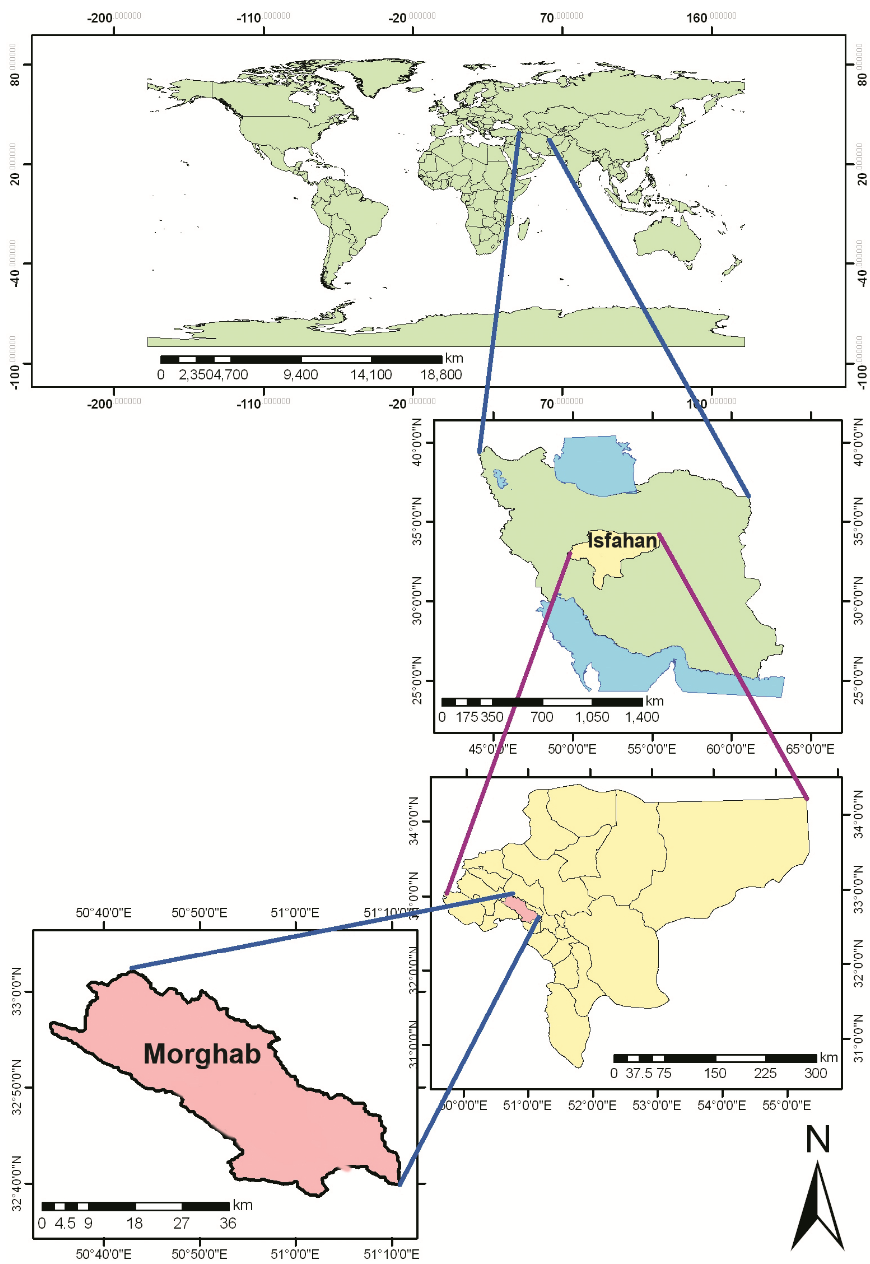

Figure1. Geographical position of Marghab River

Marghab River is located in 50 kilometers away from the west of Najaf Abad. The river originates in the southwest of Asgaran village which is located at the apex of the fan of one of the valleys in Dalankooh. Marghab River is a river that flows in Karon plains, and is one of the branches of Zayanderood River and originates from Dalankooh mountains. At present, it has little water and it is seasonal. There is large reservoir whose geomorphological evidences show that there used to be a relatively better water flow in the past. The main reason why this river has changed from a permanent river to a seasonal river is the climatic changes in the area. Since this area is one of the sources providing water to Zayanderood River and climatic changes have affected its water supplies, then studying the degree to which these water sources are affected by climatic changes in the area is considered a critical issue.

Marghab River which used to be full of water and strong is the only source providing surface water in Najaf Abad and has had an impressive role in irrigation and sealing the area under cultivation in part of the province. Its water used to be sweet and its headstream is 50 kilometers northwest of Najaf Abad (southwest of Asgaran and close to Ghalenazer and Dotoo villages in Karoon) (Shafaghi, 2002, 155).

Marghab river is traditionally a place of recreation, tourism, and ecotourism in the area, with a height of 2200 meters above sea level and is located on a hillside called in the Ahmad Raza mountains in Dalankooh and originates from several springs.

Because of the special position of the area under high mountains, moisture-bearing humid air masses lose much of their moisture before reaching the area. However, the core of high rainfall in this region is in the western highlands. Rainfall in northwestern basin is more than 300 mm per year while the average annual rainfall is 120 mm in Najaf Abad. Marghab spring that flows in the Dalankooh mountains has about thirty Stones (each Stone is equal to 1 liter per second) and about 4 inches of water. Given that Marghab is a seasonal river, discharge (the volume or amount of available water in the studied basin per unit of time) has a direct relationship with rainfall seasons so that it falls down to 2000 liters per second of water in the spring and 200 liters per second in the summer season and seasons with water shortage. Aside from the recent droughts, the greatest amount of its water flows in the early spring and reaches its minimum level in the late summer.

2. Materials and Methods

Field research method is one of research ways in which the boundaries and limitations of the realm of research and studies are delimitated based on natural units. In this method, the major factor is convergence and independence of the basins of communication network in which levels are created using streams and waterways in drainages. Watersheds are the most basic natural units in the local scale which have a defined independence and identity. Therefore, the impact of climate changes on water systems in Marghab basin was analyzed and evaluated using SURFER, GLOBAL MAPER geographical information system techniques in the watershed of the river. Furthermore, the relationship between temperature and precipitation and the relationship between temperature and altitude in the area were studied for determining the situation and discharge of the river in the past and at the present based on correlation and setting linear equation between variables.

3. Review of Literature

Vikona and Derakop (2007) categorized the effects of climatic changes on hydrology and water sources in California into three categories.

Pole et al. (2007) studied modeling the effects of climate change on water balance and current flow of annual water in Headwater basin in the South Pole. The results showed that the volume of current flow of water and water vapor would increase in the future as a result of the increase in the temperature and precipitation up to 48%. Islam and Sikko (2010) studied the effect of climatic change on water sources in India. According to this study, the Earth's climate is getting warmer and this change has had the greatest effect on water resources.

Jee Shio et al. (2003) studied the effect of climate change on water resources of the basin of Heehe River. The outcomes of the study revealed that the temperature increased about 0.5 to 1 degree centigrade in 1990s in comparison to the temperature average during 1960 to 1990 and water sources decreased about 260 million cubic meters in the 1990 in comparison to 1950s.

Varesi and Mohammadi (2007) wrote an article entitled the role of human factors in climatic changes and evaluating their effects. They came to the conclusion that the most important factor that had caused climatic change during the last decades is the greenhouse gas emissions in energy section.

Montazeri and Fahmi (2003) studied the effects of climatic change on water resources of the watersheds of some rivers and lakes in Iran and concluded that evaporation increases in most of river basins throughout the year as temperature increases.

Ahmadi (2004) carried out a research about geomorphology of Noghan River basin and concluded that neo-techtonic factors on one hand and glacier operations on the other hand played the first role in forming the new geomorphology of the area so that the operation of water erosion was influenced by these two factors at that time.

Baghersad (2004) studied the geomorphology of Ghahrood River in his dissertation and stated that in the area techtonic factors resulting from glacier operations played an important role in forming the area.

4. Climatic Features

In order to study climatic features, Marghab area was distinguished from the neighboring stations by considering height position and height direction using statistical methods (linear equation). Figure 2 shows the position of selected stations in Marghab area in the statistical 25-year period (1996-2011).

Table 1. The features of the studied stations in the area

Row	Statistical Year	Station Name	Kind of Station	Longitude	Latitude	Altitude in meters
1	1996-2011	Damaneh	Climatology	50-48	33-02	2300
2	1996-2011	Chadegan	Climatology	50-62	32-77	2156
3	1996-2011	Najaf Abad	Climatology	51-37	32-63	1649
4	1996-2011	Sanigard	Climatology	50-43	32-78	2169
5	1996-2011	Badijan	Climatology	50-33	33-08	2450
6	1996-2011	Daran	Synoptic	50-37	32-97	2290

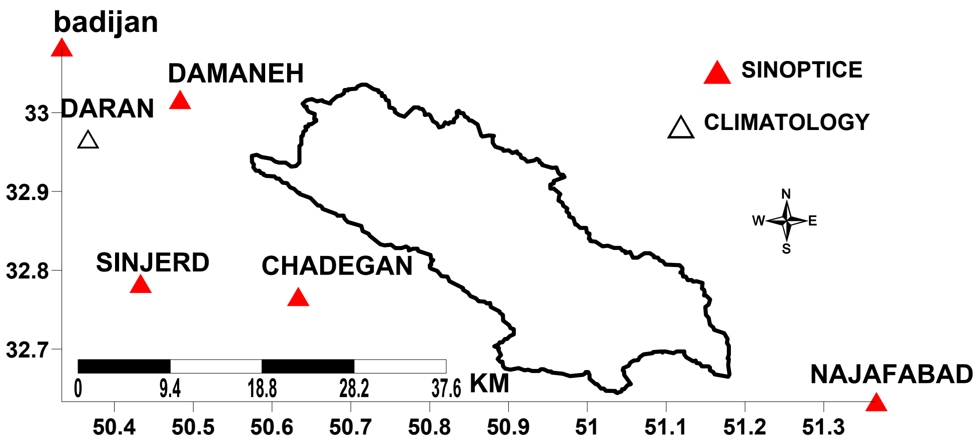

Figure 2. The position of selected stations in the studied area

5. Glacier Cirques and Their Role in the Region

One of the most important glacier effects on the mountains in Iran is the effect of glacier cirques which show that geomorphic effects and evidences of the Cold Period in the area are effective on the basin discharge rate (the volume or amount of the basin water per unit of time) (Ramesht, 2004, 123). Based on the evaluation, 132 glacier cirques in the Marghab River highlands have been identified and the cirques are located in the lowest altitude of 2454 meters and the highest altitude of 3271 meters. Figure 3 and Table 2 show the dispersion and height of cirques in the area. According to them, the presence of cirques provide evidences that glacial and interglacial processes resulting from climatic changes in Quaternary era have had an impact in the basin and has influenced the break (the opening of the lake's limit or circumference) of Tondaran Lake as a result of glacial erosion and turning Marghab river into a seasonal river.

Table 2. Altitude dispersion of cirques of Marghab River

Number of cirques	Altitude/height	Percentage of cirques
8	2300-2500	%6/06
40	2500-2700	%30/31
46	2700-2900	%34/85
26	2900-3100	%19/69
12	3100-3300	%9/09

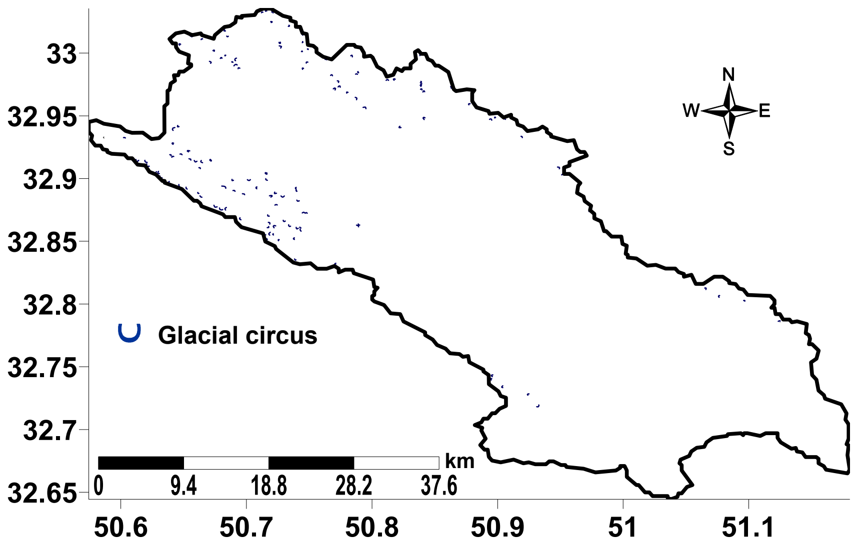

Figure 3. Cirque dispersion map in the area

6. Temperature Analysis in the Area

According to the height difference between the lowest and the highest cirques, the line of zero degree temperature determines the altitude of 2900 m in the area. In other words, the temperature on this line is zero degrees Celsius. The permanent snow line in this basin is shown in Figure 4. Spatial analysis of climate elements is done based on three factors of length, width, and height or longitude, latitude, and altitude. Atmospheric conditions change depending on altitude. The altitude of 2900 meters of permanent snow line or boundary (the degree of absolute zero point for the accumulation of snow in the mountains) is considered the annual zero centigrade temperature line. In addition, due to changes in altitude in the area, the zero temperature lines in the past (Figure 5) and the present time (Figure 6) are calculated and plotted.

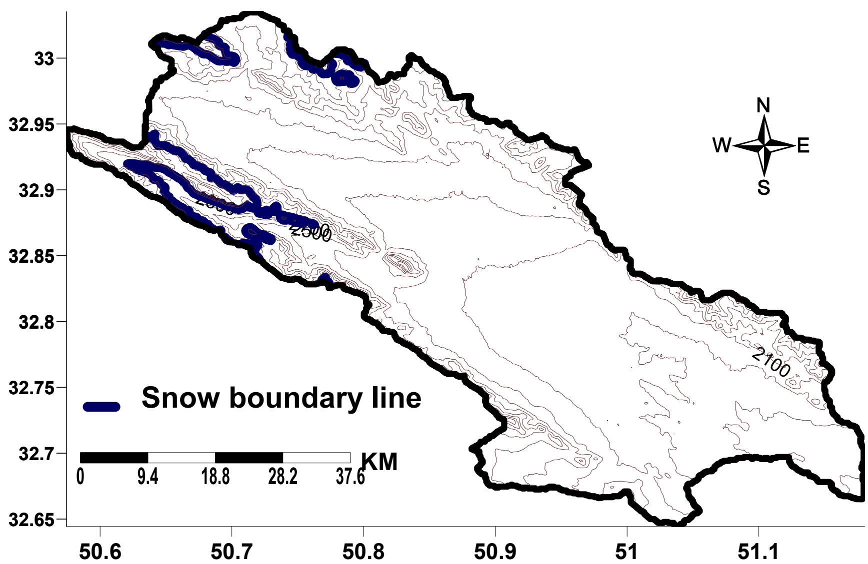

Figure 4. Permanent snow line map of the area

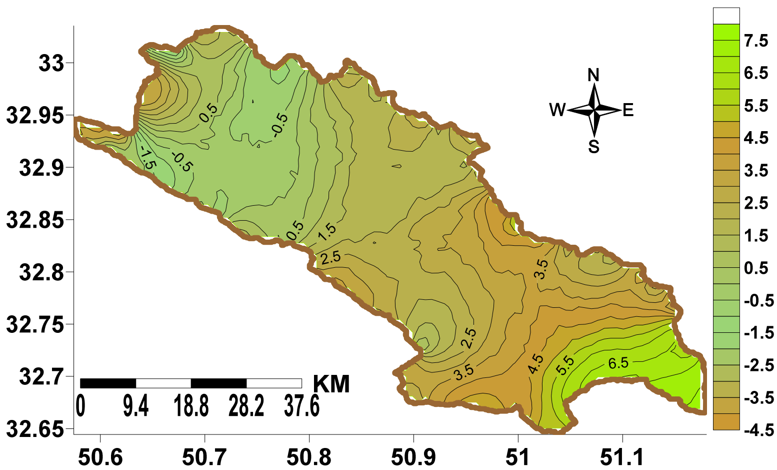

Figure 5. The former environmental temperature map of the area

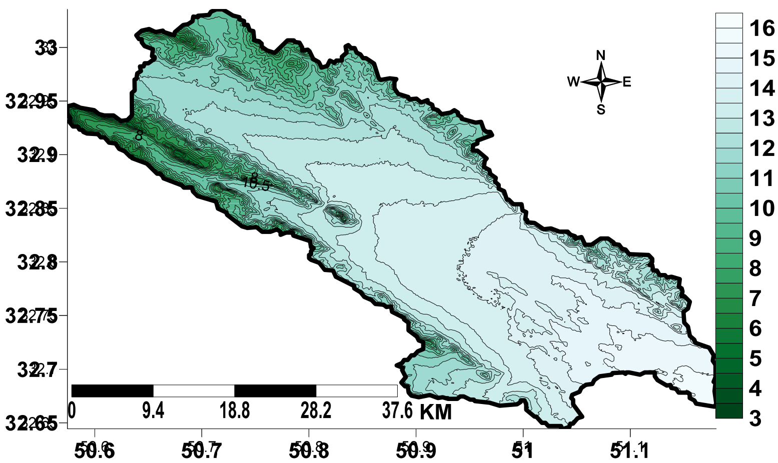

Figure 6. The current environmental temperature map of the area

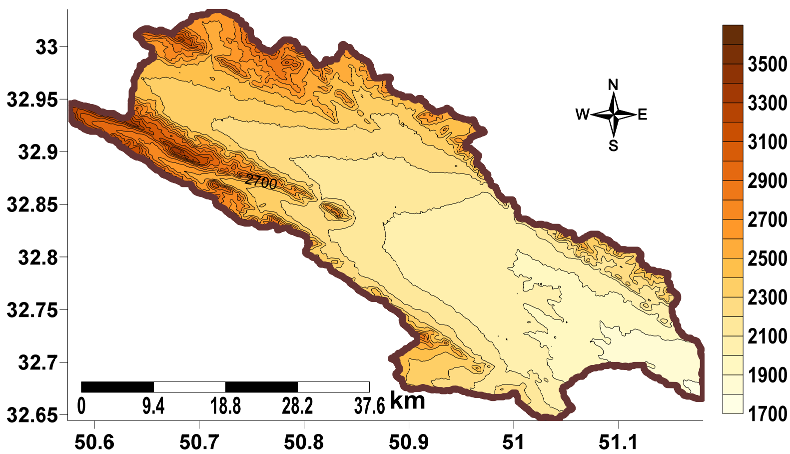

Figure 7. The altitude map of the area

The air temperature and its various components as one of the two most important factors are necessary to introduce climate identity of each site and as a profile of the intensity of heat are of the basic elements of the air cognition (Alizadeh, 2006, 180). Using the obtained results and the altitudinal distribution map (Figure 6), the annual current isothermal map of the area is prepared (Figure 7). The results show that the maximum temperature of 15/5 is at the altitude of 1700 m and the minimum temperature of 3 degrees is related to the altitude of 3500 m. To investigate the effect of the factor of height on the monthly and annual values of temperature, correlation is used and this relationship is linear as $y = bx + a$. In this equation, a is the value of angular coefficient, b is the constant, y is the temperature in Celsius, and x is the height of the station above sea level in meters. First, the correlation between height and temperature of all stations was obtained which was not a good correlation. Therefore, among the available data, the statistics was deleted or amended. On this basis, the correlation between height or altitude and precipitation was obtained. Figure 8 shows the correlation between height or altitude and temperature in the studied stations.

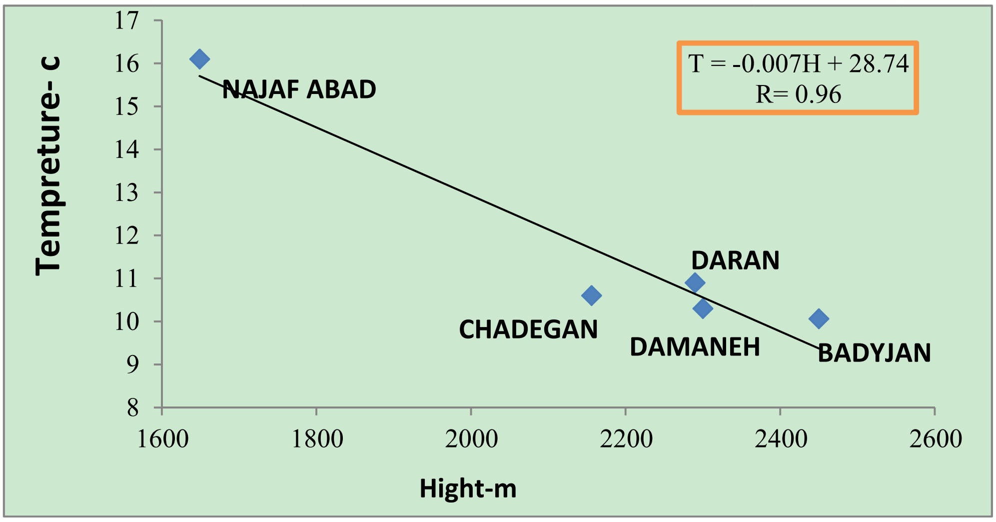

Figure 8. The correlation between altitude and temperature in the statistical period of 1996-2011

The analysis of the area's temperature shows that the temperature drop at Marghab Basin follows the linear relationship T =% 007h +28 / 74 with a correlation coefficient of 96%. For every 100 m increase in height, there is a decrease of 0/7 degrees in temperature in the area. The correlation between different parameters of temperature and height was obtained for different months of the statistical period of 25 years. The above equation shows the temperature changes trend during a 25-year statistical period has increased 1.5 times which indicates the effect of climate change and the reduction of precipitation in the region.

7. Precipitation and Its Spatial Analysis

Precipitation is the main source of life on the Earth and every drop of rain that falls on the ground is promising life and verdure (Nazemosadat, 2009, 154). Precipitation on the Earth's surface has a lot of spatial and temporal changes. In Iran, precipitations are mostly in winter and spring (Alizadeh, 2006, 166). The correlation between precipitation and altitude (considering the linear equation in Figure 9) was established and calculated for different statistical years as it can be seen in Table 3.

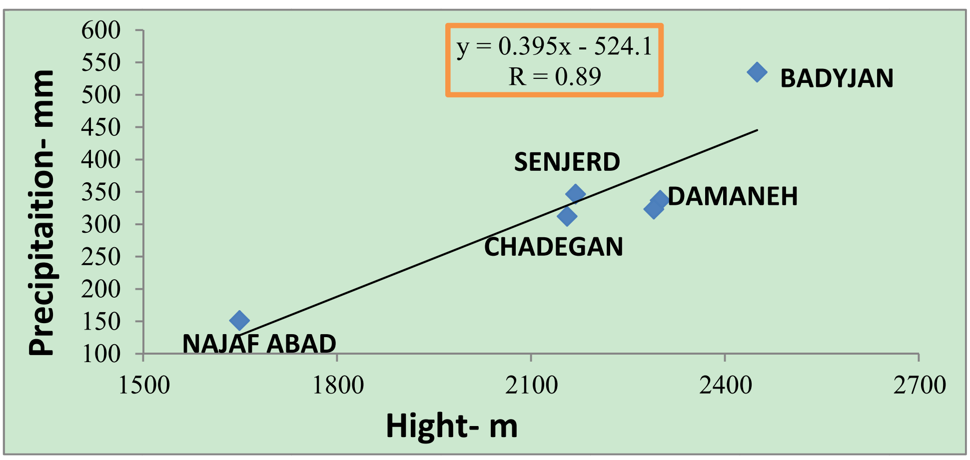

Figure 9. The correlation between precipitation and height of the stations of the studied basin in the statistical period of 1996-2011

The correlation coefficient of 0.89 between annual precipitation and height or altitude is indicative of a good correlation. Therefore, for better results throughout the year, the relationship between height and monthly precipitation was assessed and their linear equations are presented in Table 6. Overall, per 100 m increase in height 39.5 millimeters is added to the degree of precipitation and rainfall. The isohyet map shows not only the precipitation and rainfall but also precipitation changes and distribution of a certain amount of precipitation or rainfall throughout the basin. The air temperature changes cause changes in other meteorological parameters such as precipitation which is a function of temperature and the increase or decrease in temperature will change the degree of precipitation. Assessing the correlation between temperature and precipitation in the studied area considering the linear relationship P=-29/72T+633/4 (Fig. 9) shows that there is a significant relationship between temperature and precipitation and precipitation will decrease or increase about 30 mm per a degree of increase or decrease in temperature. Based on the above relationship, the former isohyet map (in the past) (Figure 10) and the current isohyet map (at the present) of the area (Figure 11) was drawn. According to the map, the main summit receiving the peak of precipitation is located in the highlands of the northwest of the area with an altitude of 3,500 meters, with 850 mm of precipitation and it receives the highest or largest amount of solid precipitation (snow and hail). The minimum precipitation in the basin is 150 mm in the highlands of the southeast with the altitude of 1700 meters. The average annual and monthly precipitations are shown in Table 3. The most frequent and suitable ways for calculating the amount of precipitation is by drawing isohyet maps. An isohyet map shows not only the amount of precipitation but also precipitation changes and distribution (change or difference) of a certain amount of precipitation throughout the basin. Based on the former and current isohyet maps of the area, as it can be seen on the former and current maps of the area, the minimum former precipitation of the area in the past was 450 mm a year and presently it has decreased to 150 mm considering the correlation between temperature and precipitation (Figure 9). On the same grounds, precipitation changes have a decreasing or descending trend which indicates the impact of climate change on precipitation decrease and makes Marghab River a seasonal river.

Table 3. The average of monthly and annual amount of precipitation in the area

Row	Month	The average of monthly precipitation	Amount of precipitation mm3
1	April	79/18	78/49
2	May	27/19	26/95
3	June	-	-
4	July	-	-
5	August	-	-
6	September	2/03	2/01
7	October	13/90	13/77
8	November	57/26	56/76
9	December	67/74	67/15
10	January	62/19	61/64
11	February	71/85	71/22
12	March	89/95	88/77

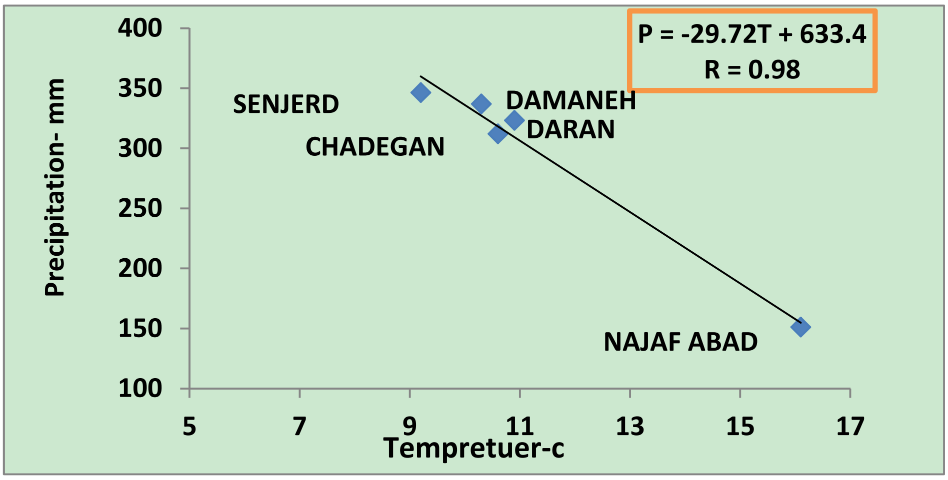

Figure 10. The correlation between temperature and precipitation in the stations of the studied basin in the statistical period of 1996-2011

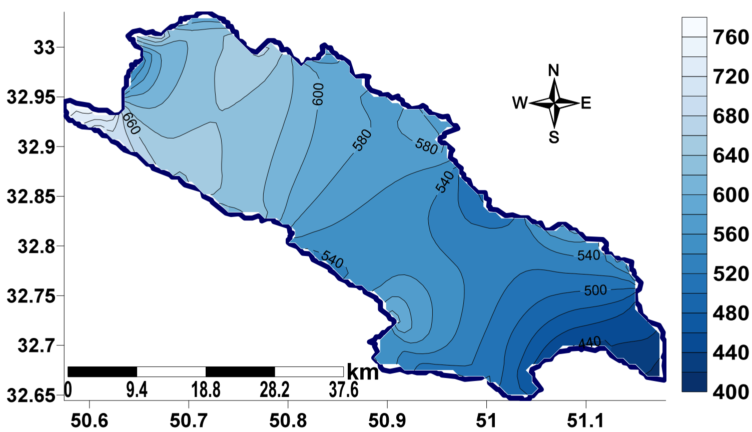

Figure 11. The former isohyet map of the area

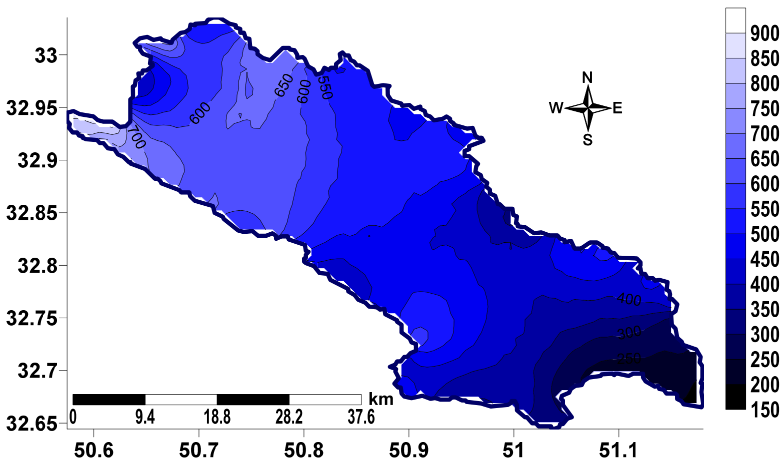

Figure 12. The current isohyet map of the area

8. Persistence Time and Height of Solid Precipitation (Snow and Hail) in the Area

Across the planet, the most significant part of the precipitation is snow and for periods varying from a few hours to several months, it is stored more than it melts (Khaledi, 2002, 464).

Regardless of how the phenomenon of snow melting in mountainous areas occurs, it is necessary to be aware of and have information about the persistence level of snow and its continuity and stability in different months of the year. In this study, the mean of the snow-covered surfaces in different months of the year is estimated using data related to the average of monthly and annual mean temperature in the mentioned stations (Table 4). In addition, the relation between temperature change and altitude was calculated in the form of linear regression equations using the monthly mean temperature of the stations in the area. The results of which are presented in Table 5 separately according to the average of the monthly temperature mean. Based on these equations, the altitude corresponding to the height of the zero degree related to the monthly average is used as the mean of melting line and snowfall. The average height of the zero degree curve in December is 2341 meters, i.e. the snow fallen in this month at the altitudes lower than 2341 meters is melted. As the calculations show, the significant correlation of the impact of climate change on the water system of the basin and the decrease of the snow line height from the sea level is because of the increase in temperature.

Table 4. The amount of solid precipitation

Row	Month	Snow-covered surface	The average of monthly precipitation	Amount of solid precipitations mm3
1	April	-	-	-
2	May	-	-	-
3	June	-	-	-
4	July	-	-	-
5	August	-	-	-
6	September	-	-	-
7	October	-	-	-
8	November	-	-	-
9	December	343/71	67/74	232/82
10	January	931	62/19	578/98
11	February	548/6	71/85	394/16
12	March	58/38	89/95	51/82

Table 5. Equations of temperature return lines in relation to altitude

Row	Month	Correlation coefficient	Linear Equation	The altitude of zero degree
1	**April**	**%97**	**T=-0/008h+29/58**	**3697/5**
2	**May**	**%90**	**T=-0/007h+32/30**	**4614/2**
3	**June**	**%87**	**T=-0/007h+36/83**	**5261/4**
4	**July**	**%91**	**T=-0/006h+39/46**	**6576/6**
5	**August**	**%93**	**T=-0/006h+37/58**	**6263/3**
6	**September**	**%89**	**T=-0/006h+32/7**	**5450**
7	**October**	**%97**	**T=-0/007h+29/77**	**4252/8**
8	**November**	**%87**	**T=-0/005h+19/85**	**3970**
9	**December**	**%97**	**T=-0/008h+18/73**	**2341/2**
10	**January**	**%96**	**T=-0/01h+19/35**	**1935**
11	**February**	**%97**	**T=-0/011h+24/12**	**2192/7**
12	**March**	**%99**	**T=-0/009h+25/59**	**2843/3**

9. Research Results

Climate change is a significant change in the average of meteorology data over a given period of time, which is a period of 10 years or more. Climate change is one of the important issues that recently has attracted a lot of attention from the scientific communities in the world. In addition to researchers and scientists interests in climate change and its impacts on various aspects of life, it has also attracted the attention from planners, politicians and economists at different academic and international levels. Different climatic parameters such as temperature, humidity, and precipitation in one location are factors that affect the climate of that region and their recognitions are determiners of the climate of that region. Understanding climate issues through the dynamics and processes and review of major climatic parameters' changes, climate, particularly precipitation and temperature could be indications of an increasing trend of droughts and desertification of climate. Population growth on the Earth and the increasing need of humans to sweet water on one hand and the shortage of sweet water on the other hand have revealed the importance of this vital substance and its role in the independence of nations. Furthermore, besides sweet water for drinking, the water for industry and agriculture is provided by rivers. As a result, maintaining rivers against unnatural abnormal seizures and their organizations by preserving natural conditions is considered a national duty.

Marghab River is between 50 °34 ′31″ and 50 °50 ′29″ longitude and 32 °49 ′37″and 32° 0 ′29 ″ latitude. It is located in the west of Isfahan Province and Najaf Abad Province. The annual temperature mean of the basin is 13.5 degrees Celsius and the precipitation mean in the basin is 332/6 mm which is calculated by zoning or location method (Kriging interpolation method). The river has been a place of recreation, tourism, and eco-tourism in the area with an altitude of 2200 meters above sea level. The river's water was divided among all regions by Sheikh Bahai with precise terms and conditions and each had a clear share of water.

The analysis of the temperature of the basin shows that the drop in temperature in Marghab Basin follows the linear correlation of 96% and each 100 meters increase in height well lead to 0.7 degrees Celsius decrease of temperature. The above relationship shows that the temperature changes' trend in during a statistical period of 25 years has increased 1.5 times which indicates the impact of climate changes and the decrease of precipitation in the studied area. Moreover, the correlation coefficient between precipitation and annual altitude is 0/89 which is a good correlation. The above relationship shows that for every 100 meters increase in height, 39/5 millimeters is added to the degree of precipitation. On the other hand, according to the map, the main summit receiving the peak of precipitation is located in the highlands of the northwest of the area with an altitude of 3,500 meters with 850 mm of precipitation and it receives the highest or largest amount of solid precipitation (snow and hail). The minimum precipitation in the basin is 150 mm in the highlands of the southeast with the altitude of 1700 meters. Based on former and current isohyet maps of the area, as it can be seen, the minimum former precipitation in the past was 450 mm a year and presently it has decreased to 150 mm a year considering the correlation between temperature and precipitation (Figure 9). On the one hand, 1.5 times increase of temperature So far, in other words an increase of 4 ° C to 8 ° C (Fig. 5 and 6), and on the other hand the reduction of precipitation to one third in comparison to the past (Fig. 10 and 11) show the changes in precipitation have a decreasing or descending trend due to climate change. The results show the impact of climate change on the reduction of precipitation and making Marghab River a seasonal river. Experimental methods in this research show that the snow-covered surfaces are of a height of 2900 meters using the data related to monthly precipitation of stations and the altitude map of the area and snow line in the past. Snow-covered surfaces in the past were estimated to be of 35 square kilometers. The amount of ice over the past 12 months, according to the precipitation rate over the area was nearly 15 million cubic meters which remained in the region. Presently the snow over the area in one month, its average is about 5 million cubic meters of iced water. This comparison shows that the water storage is about 3 times less than the coldest period of glacier phase in Quaternary era. Consequently, climate changes have an impressive impact on the water system of the basin. As the calculations in Tables (4 and 5) show, the significant correlation for the impact of climate change on the water system of the basin and the reduction of the altitude of snow line or boundary of the sea level are due to the increase in temperature. Because of specific climatic conditions and irregular dispersion of precipitation in most of the areas in the country especially in arid and semi-arid areas and the studied area, it is necessary to predict the time and amount of precipitation precisely in order to exploit it for planning or predicting sudden floods considering the creation of environmental problems. Therefore, proper planning for principal exploitation of precipitation and seasonal streams is needed in the region. Mechanized designing for controlling the amount of water is required.

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