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Studying the Impact of Dam Construction on the Hydrologic Regime in the Garmsar Plain

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Abstract

In arid and semi-arid regions, dams are crucial for managing water resources sustainably for agriculture. The construction of dams, diversions, and urban development can alter river flow, leading to drought, reduced water supply, and environmental issues. Knowing the flow conditions and hydrological regime is crucially important. The purpose of the present research work is to evaluate the effects of dam construction on the changes in the flow regime downstream of the Hableh Rood River. In this research work, quantitative and qualitative data of the surface and groundwater of Garmsar Plain were analyzed based on the periods before and after the construction of dams, and the effects of each parameter were investigated. The results showed that after the construction of the dam, the hydrological system downstream of the dam changed including an increase in the salinity of groundwater, a decrease in the volume of river water, a drop in groundwater in the region, and the Garmsar Plain, a reduction in the water level, changes in the quality of water.

1. Introduction

The hydrological regime in many rivers has dramatically changed due to human activities around the globe, like dam building and irrigation (Alizadeh, 2001). The hydrological regime is a key power for the river ecosystem and current control of many ecological facts, like velocity, depth, and environmental volume control (Skalak et al., 2013). The hydrological regime in a zone is measured by amount, duration, and high frequency (Wu et al., 2012). Time is a very important factor for growing different plants. The human role is an important link for changing hydrological systems in many rivers (Jin & Yong, 2011) since human activities have been increased in hydrological systems and around rivers have changed (Jin & Yong, 2011). Building dams is mainly for water power controlling destructive floods, and supplying enough water for farming (Arman et al., 2009; Emamgholizadeh et al., 2018; Emamgholizadeh & Fathi Moghadam, 2014; Manoochehr Fathi-Moghadam et al., 2011; M Fathi-Moghadam et al., 2011; Magilligan & Nislow, 2005; Parsaie et al., 2018). Building dams in Iran is essential because our country is in dry and semi-dry regions in the

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world, and since the rainy season is when there is less water for farming. In such countries, groundwater is a very important source to supply water for different consumptions such as drinking, industrial, and agriculture (Emamgholizadeh et al., 2014; Parhizkar et al., 2015). The results of many researchers show that water quality of many rivers and groundwaters is changing and the trend of quality parameters is decreasing over time (Begum et al., 2023; Emamgholizadeh, 2009; Emamgholizadeh et al., 2014; Najafzadeh et al., 2019; Smith et al., 1987; Turner & Rabalais, 1991).

Increasing population, health, welfare, developing economic and farming sectors, and Afghan migration to Iran and especially to Garmsar.SRWC (2015a) created a high demand for water supply. Lack of expertise and poor management are causing problems for building dams (SRWC, 2015c). Having educated dam experts and building mechanisms is a foundation for future hydrological zones.

In this study, physiographic and river system, geology, hydrology, water development system, basically on flood system control has been used. Also, the main meteorology parameters and hydrological activities like rain and evaporation will be argued or discussed.

The purpose of this research work is to evaluate the construction of dams on the changes in the hydrological regime of the Hableh Rood River downstream of the dam and the Garmsar Plain. The impact of building dams on the quantity and quality of groundwater in the Garmsar Plain is another goal of this research work

2. Materials and Methods

2.1. Studied area

The studied area is located at the Garmsar city, Semnan province, Iran. Garmsar is one of the five cities in the state of Semnan, and it is located in the west of Semnan. It is in the south of Firoozkooh and Damavand, from the East is Aradan, and from the west is Pakdasht and Qum. From the south is a city of Aran and Beedgoal. The area of the city is about 5182 km^2. In terms of geographical location, Garmsar is located between $34^{0}28'$ and $34^{0}30'$ north latitude and between $51^{0}52'$ to $52^{0}55'$ east of the Greenwich meridian. Garmsar is located on the alluvial cone of Hable Roud, one of the permanent rivers of this city, and it is surrounded by mountain ranges from three directions, and only its southern side is open due to the desert, which ends in the Black Mountains (Fig. 1). The average height of Garmsar is 856 meters above the sea level. The city of Garmsar is the junction of the North (Gorgan) and Mashhad national railways, and the main Tehran-Mashhad road is located next to it (SRWC, 2015b).

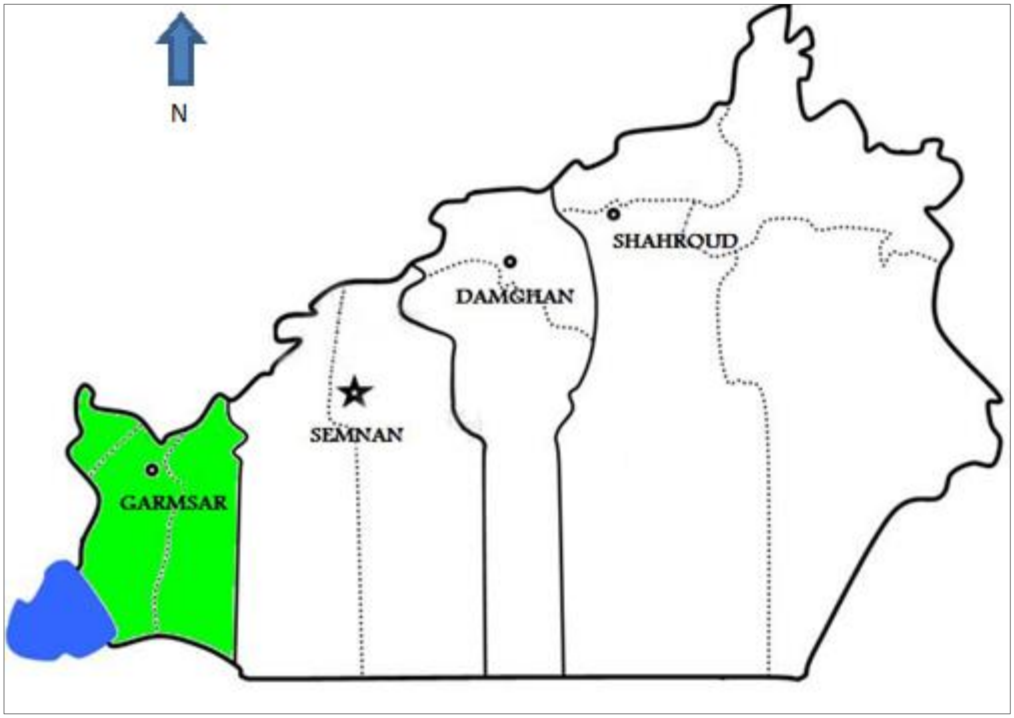

Figure 1. Political deviation map of Semnan province and Garmsar city.

Hableh Roud watershed with longitude 52°25'08" to 52° 42' 25" East and latitude 35° 43' 04" to 35°44'06" North is one of the important watershed areas of the Namak Kavir. This watershed, which includes areas of Tehran provinces (Damavand and Firouzkoh cities) and Semnan province (Semnan and Garmsar cities), is located in the northwest of Dasht Kavir watershed, and belongs to Semnan and Garmsar Kavir watershed. Its area up to Boneh Kouh station is 3209 square km^2 (Fig. 2).

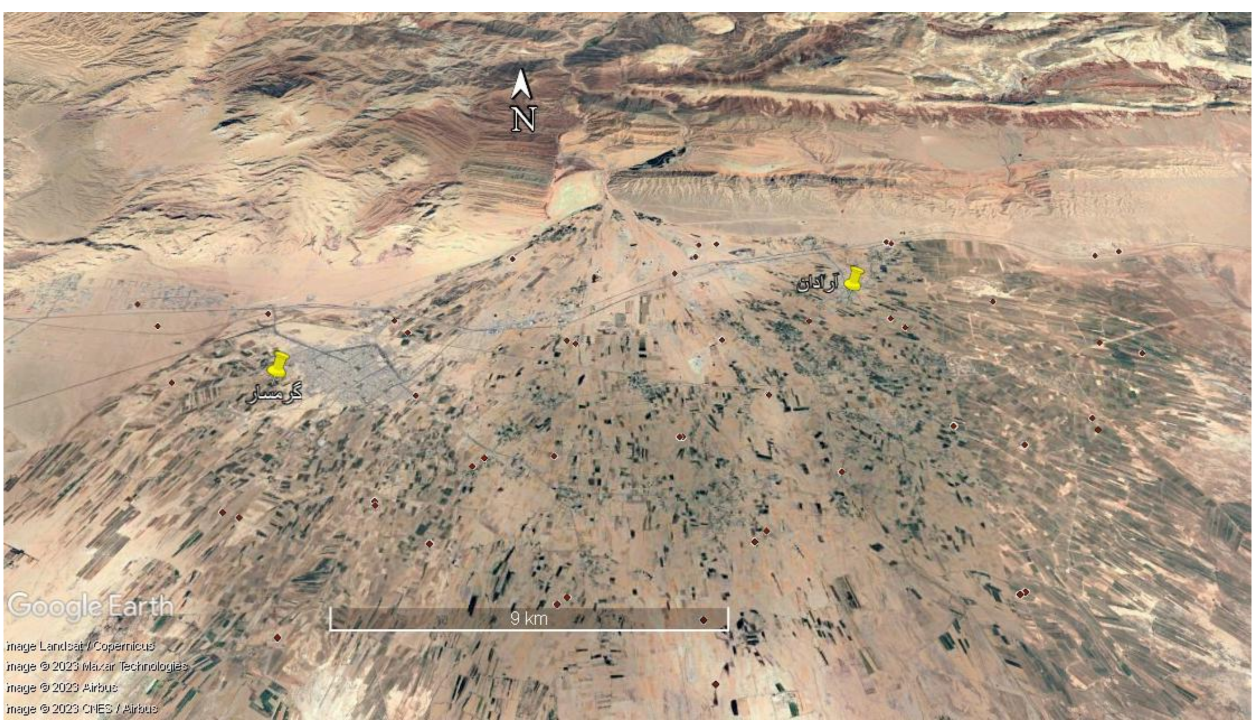

Figure 2. Google map of studied area.

The studied area is surrounded by cold mountainous desert and dry land. The northern highlands include the central Alborz Mountain, which is cold and temperate in the mountainous region. Garmsar Plain in the southern region of the city is a dry and hot desert. Information is continuously recorded at Benkoh rain gauge stations and Dahnmak evaporation station. According to the information received, the long-term annual rainfall in this Plain is equal to 143.4 mm in high water years such as 2016-2017 and 76.5 mm in low water years such as 2018-2019. The total annual rainy is 40.68 mm in stations (SRWC, 2015a). Figure 3 indicates the average rainfall for the studied area of Garmsar Plain. Also Table 1 shows the average value of aerology parameters of Garmsar area.

Table 1. Average value of aerology parameters of Garmsar.

Parameters		Area (km^2)	Precipitation (mm)	Evaporation (mm)	Temperature (°C)
Long-term studied area of Garmsar	Plain	2792	131.5	116.5	17.9
	Altitudes	2738	261.9	210.95	13.8
Studied area of Garmsar, 2007-2008	Plain	2792	55	52	18
	Altitudes	2738	270	220	13.8
Balance range 2007-2008		531.78	76.5	118.6	18

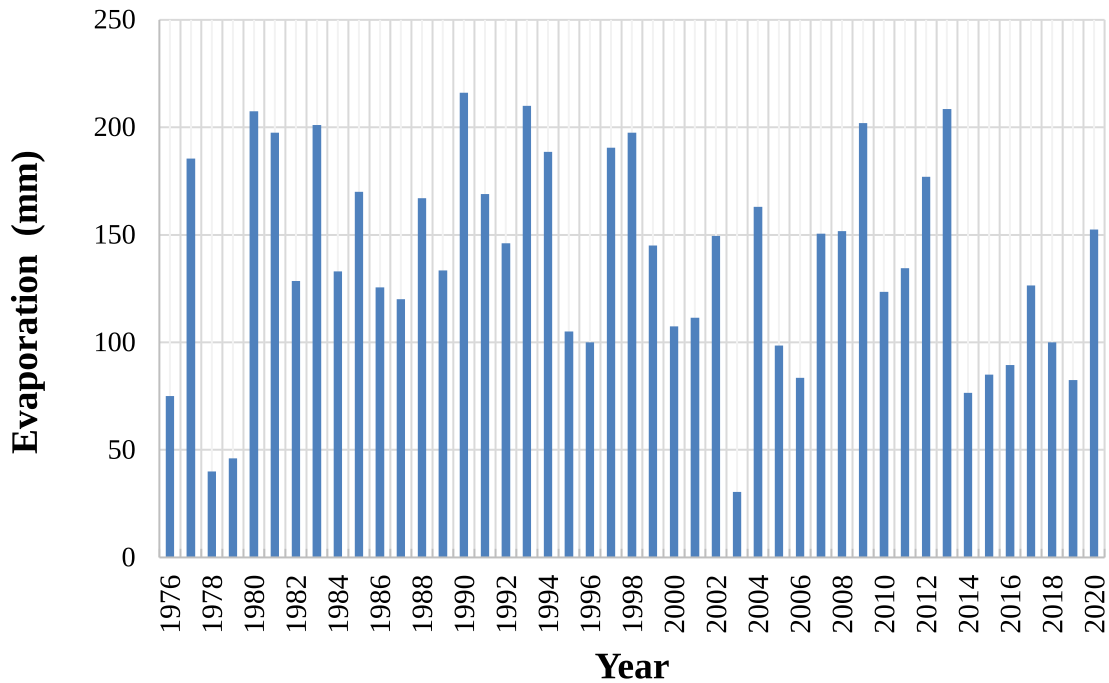

Figure 3. Average rainfall for the studied area of Garmsar Plain.

2.2. River of Hableh-Roud

Hableh-Roud River is one of the largest rivers in the southern Alborz Mountain range in the region of Semnan province and also one of the largest rivers in Iran. The source of this river is from the northeast of Gadok Mountain in the north of Firuzkoh, Gor Sefid River (with fresh water), Namrod River, and Delichai River. Approximately 56% of the water of this river is supplied by two rivers, Namrod and Delichai (SRWC, 2015a).

This river is in the southern range of the central part of the Alborz Mountain. Situated between 52°25'08" to 52°42'25" East and latitude 35°43'04" to 35°44'06" North is one of the important watershed areas of the Namak Kavir.

The area of the catchment area is about 3200 Km^2 and its perimeter is 278 Km. The maximum height above sea level is 4075 m, the minimum height at the entrance to Garmsar Plain is 980 m, and the average height of the area is approximately 2300 m above sea level. About 12% of the area is above 3000 m, and about 27% is above 2000 m. The Gravilius coefficient (c) of the area is 1.43, the form factor is 0.23, and its general shape is pear-shaped. The length of the main branch is 124 km, and its concentration time is estimated to be about 12 hours, according to Kerpich's formula. The average slope of the river is 1.2%; in the first 20 km, it is 6.5%, and in the rest of the route, it is 1.35%. The river of Hableh Rood is the most important river in Garmsar Plain and the major supplier of groundwater for Garmsar Plain.

Hableh Roud River is the most important river leading to the Plain and the main source of surface and ground flows of Garmsar Plain. This basin, with an area of 3119 km^2, annually discharges an average of 250 m^3 of surface runoff into the Plain (SRWC, 2015a).

2.3. Groundwater tables

In addition to the Hableh Roud River, which is the main water supplier of the Garmsar Plain, groundwater sources are another source of water supply for the Garmsar Plain. The conical shape of the Garmsar Plain is the result of the activity of the Hableh Rood stream for many years. Irrigation canals transfer the water of the Hableh Roud River to the agricultural lands in the Garmsar region. In this Plain, 142 m^3 of water is extracted and consumed from groundwater sources through deep and semi-deep wells and Qanats. In 1967, an extensive study was conducted by FAO on the construction of an irrigation network in the Garmsar Plain. After that, changes in the system, control, and study continued continuously.

Finally, in 1372, about 32 wells under the piezometer network were completed. The number of deep and semi-deep wells in the Garmsar area of study are 911 cases, in which 587 wells are deep, and 330 walls are semi-deep. Also, there are 468 springs and 53 Qanats in the overall study of Garmsar Plain. Based on the latest natural water resource map in Garmsar Plain, the number of total exploited wells is 600, and most of them are concentrated in the northeast and southeast, in which there are fewer wells in western and south western Garmsar Plain. Also, deep wells and semi-deep wells are mostly in the southern and southeastern parts of Garmsar. Most of the deep wells are concentrated in the upper regions of Garmsar and Aradan for industrial purposes.

Based on this, 500 of these wells are electrical, and the rest are operating with fuel. The highest depth is 200 m, and the highest discharge is 51 l/s. The average discharge in deep wells is 13, and in semi-wells is 1.2 l/s.

According to the latest statistical surveys regarding the increase in the activity of wells or the decrease of aqueducts in the Garmsar Plain, there is enough information. The first statistics related to 1346 and the last statistics were done by consultants in 1382 and 1383 in Garmsar.

The statistics of the recent years show that the water resources of Garmsar Plain are related to the water level in deep wells and the drop of the water level, as well as the adjustment to benefit from the water license in recent years.

Water consumption in Garmsar Plain in 2007 and 2008 was equal to 164.55 m^3. Of this amount of 151.76 m^3 of water, about 92% is used for irrigation and 29.9 m^3, which is equivalent to 6%, for drinking and the other is used in industry. Almost every year, there are 493 deep wells with a water supply of 147.79 m^3, 107 semi-deep wells with a water supply of 6.88 m^3, 39 springs with a water supply of 7.33 m^3, and 33 aqueducts with a water supply of 2.56 m^3 in Garmsar Plain. Table 2 presents the statistical estimations of the discharge of Hableh-Roud in the hydrometric station of Bonekouh (MCM/year).

Table 2. Statistical estimation of discharge of Hableh Roud in hydrometric station of Bonekouh (MCM/year).

Year	Volume of discharge	Discharge average (m^3/s)	Volume of setting water by water supply network of Garmsar
1990-1991	162.1	5.16	104.1
1991-1992	320.06	10.1	239.4
1992-1993	311.55	9.85	274.4
1993-1994	220.99	7.01	196.1
1994-1995	212.82	6.75	216.22
1995-1996	343.16	10.88	232.48
1996-1997	169.59	6.15	164.86
1997-1998	226.97	7.05	173.56
1998-1999	166.79	5.29	132.9
1999-2000	125.22	3.96	117.21
2000-2001	93.08	2.95	78.43
2001-2002	119.32	3.79	100.91
2002-2003	181.65	5.76	163.29
2003-2004	177.07	5.61	160.11
2004-2005	195.14	6.18	182.35
2005-2006	194	6.16	191.86
2006-2007	225.83	7.15	207.32
2007-2008	162.65	9.62	140.89

2.4. Dams and dikes at the studied area

2.4.1. Garmsar diversion dam in Bonekooh

This dam is 120 m long, made of concrete, and has two semi-metal basins with two Avio gates, one Avis gate, and two redialing gates. The two sedimentation basins have a flow rate of 9 m^3. The length of each sedimentation basin is 140 m, and its width is 15 m. From the dam, two main channels are divided, namely the Garmsar channel with a flow rate of 8 m^3 and the Aradan channel with a flow rate of 12 m^3. The main canals are 120 km long and have 127 valves. The length of the sub-channels is 225 km. This diverging dam was put into operation in 1366 and covers 22,000 hectares of land. Garmsar dam is located at longitude 51°16' and latitude 35°17' (Fig. 4).

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Figure 4. Aerial view of diversion dam in Garmsar.

2.4.2. Garmsar Chandab earth dam

This earthen dam was built to control floods and store groundwater in the Chandab region. The area of the Chandab region is 1500 hectares, and the minimum annual rainfall is about 160 mm. The overflow design flow of this dam is 10 m^3/s. The volume of the embankment is 89,000 m^3. Polyethylene pipes with a pressure of 4 atmospheres, a length of 53 mm, and a diameter of 250 mm have been used in this earthen dam. This project was put into operation in 1380. Chandab dam is located at longitude 51° 56' 16" and latitude 35° 25' 12".

2.4.3. Dehnamak Earth dam

This dam is basically built for various purposes, such as water storage, flood control, groundwater recharge, increased vegetation cover, and prevention of dust erosion. This dam is at 52.36 longitude and 35.34 elevation. Rameh and QaliBaf Rivers are fed by this dam. The area covered by this dam is about 24325 hectares, and its annual volume is 49.4 m^3. The length of the Rameh River is 28 km, and its slope is from 2% to 60%. The annual rainfall is 295 to 305 mm.

3. Results and Discussion

In this section, we studied the effects of building dams on the groundwater of the Garmsar Plain, as well as their impact on surface water hydrology. Additionally, we investigated the morphological changes in rivers resulting from dam construction.

3.1. Hydrological effects of building dams in the groundwater basin in Garmsar

3.1.1. Changes in groundwater direction

To investigate the situation of groundwater water resources of Garmsar Plain, the groundwater water maps of Garmsar Plain and Aradan were used in May 2017. As a result of this investigation and comparing it with the past statistical periods, it was found that the amount of groundwater water extraction in the Aradan region has changed. Also in areas such as Narohe village and north of Tehran-Gorgan railway, there has been a change in groundwater water harvesting. Therefore, the direction of the groundwater movement has changed due to the drop in the groundwater level. In other words, the flow of salty water from the lands adjacent to the Plain, which are mostly salt marshes, has taken place towards the groundwater table of the Garmsar Plain. These changes threaten the studied Plain as a serious danger and will cause the loss of sustainable resources in this Plain. Figure 5 shows the isopotential map of the groundwater level in the Garmsar alluvial aquifer in 2018.

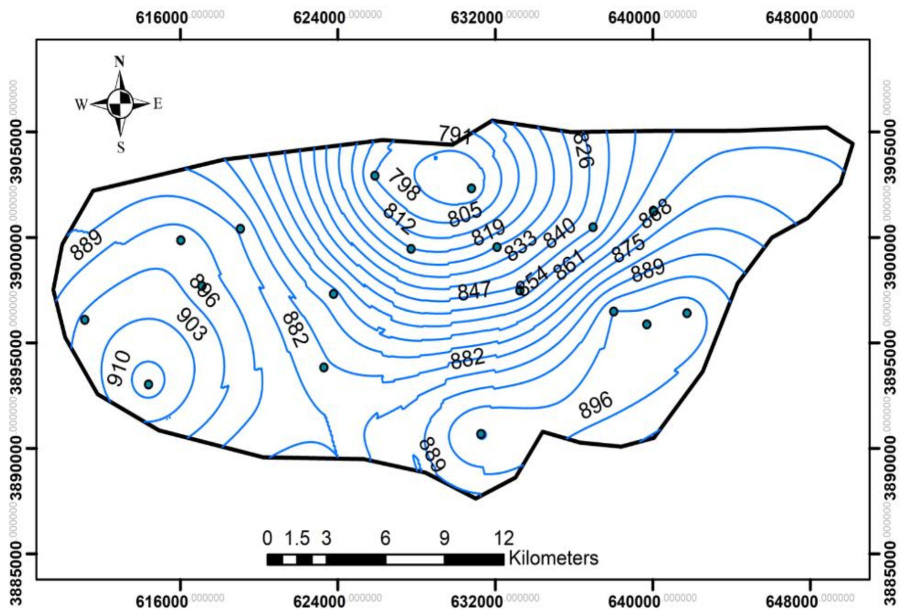

Figure 5. Isopotential map of groundwater level in Garmsar alluvial aquifer in 2018.

In order to investigate the latest situation of groundwater resources in Garmsar Plain, the information received in May 2018 based on the groundwater maps that were discussed in this research was used. The optimal use of groundwater in the Aradan region has changed. The natural flow of this problem is a serious threat to changes in the quantitative and qualitative balance in the Plain, and the rest has not changed. Of course, in Naroha and north of the railway, the flow of the river has changed drastically.

3.1.2. Quantitative changes in groundwater

The study of the groundwater level data in the study Plain shows that the level of groundwater has continuously decreased, which has led to the drying up of wells such as Tatha Rostam, Rokn, and Mahmood Abad Asadi around the village of Akbar Abad. As a result of the wells drying up and the lack of seasonal flow and flooding, the number of unauthorized wells has increased and the groundwater resources in this Plain have greatly decreased.

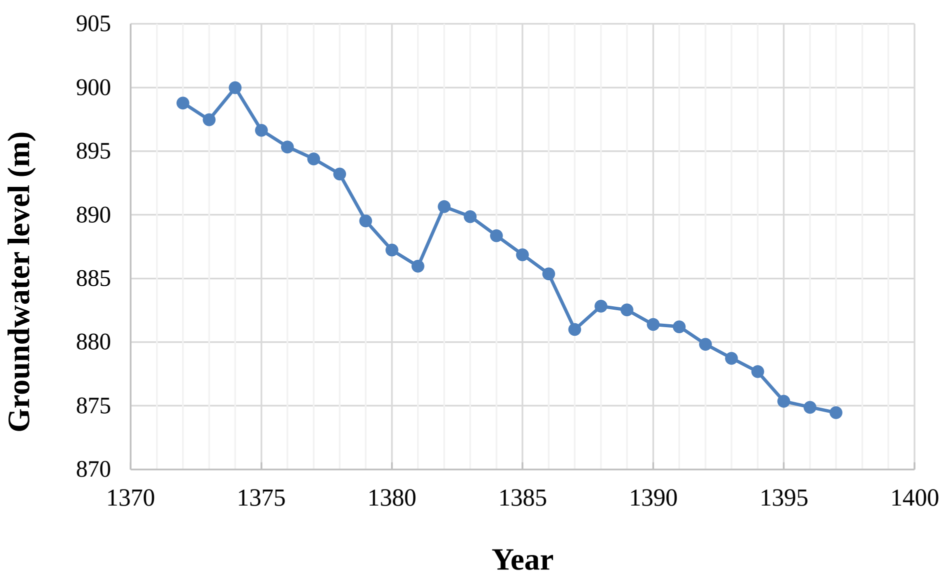

Figure 6. Annual changes of the groundwater level (m) of the Garmsar Plain.

3.1.3. Quality changes in groundwater

A qualitative study of water resources in the spring of 2017 showed that more than 90% of the volume of water is unsuitable for industry and drinking. This is due to the presence of high sodium in the course of the river flow and salt rocks in the ground Plains. The sharp decrease in river flow and the introduction of salty currents into rivers are the main reasons for the decrease in water quality in many areas. As a result, dams and embankments on rivers are one of the main reasons for this problem. Figures 7 and 8 indicate the TDS and Ph changes in aquifers from 2002-2018, as results of these figures show that the TDS value increased over time, and Ph decreased from 8 to 7.5 from 2002 to 2018.

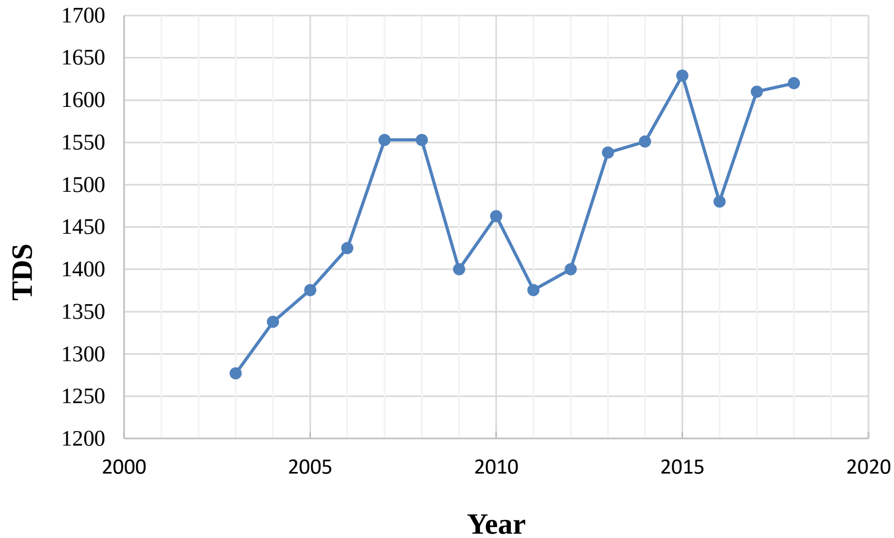

Figure 7. The amount of TDS changes in aquifers from 2002-2018.

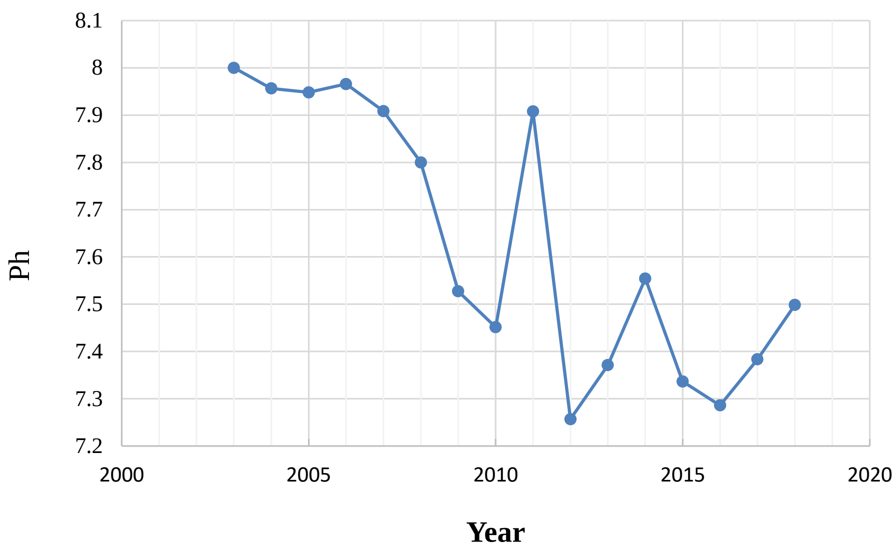

Figure 8. The amount of Ph changes in aquifers from 2002-2018.

3.2. Hydrological changes in surface water because of building dams

The volume of river water is the most important quantity parameter. By searching at Bonekoh hydrometer station before entering Garmsar dam, it can be seen that there is the decrease of water from top to bottom. It is probably due to the improper use of river water.

One of the hydrological effects on lower parts regions are changes in different parameters like velocity, current, depth, and the size of lower parts erosion in river way. Results of research and study in different periods of time show that the speed and current depth are the major factors in this case.

For presenting changes in this system, we explained the volume of evaporation in Garmsar Plain and the effects of high elevation's effects in Firoozkoh areas. Based on information we obtained from the evaporation station, this Plain benefiting variance in this area, which evaporation changes in two periods, before building dams, and after, was discussed. This study shows that the evaporation volume compared to before (building dam) has been increased. This is also essential that continuous drought is one of the main factors for building dams.

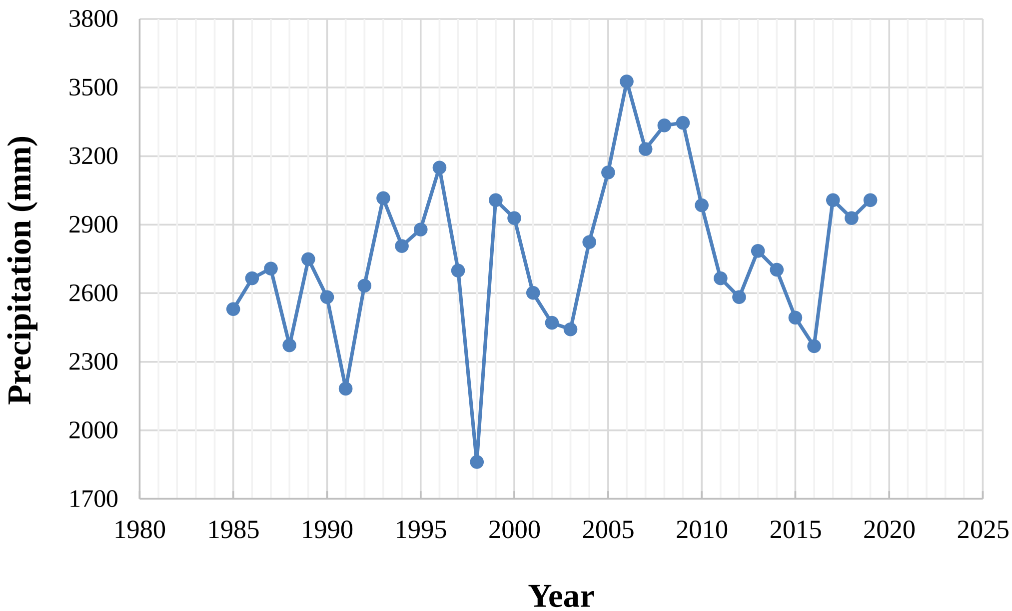

Figure 9. Evaporation of the studied area.

3.3. Changes in river morphology

Factors like, water river volume, caring sedimentation, floods power, lithology of river bottom and walls, and the earth's topography are forming the river. Now by looking at the reduction of water level and changes in flood periods, the formation river bed has been seriously changed. Hableh Roud River was studied by google earth image at two different period of times of 2009 and 2012 (Fig. 10).

Figure 10. Google Earth map of the Hableroud River in 2009 and 2012.

4. Conclusion

In this research work, the effect of dam construction in the Garmsar Plain was investigated in terms of the hydrological regime. The results show that the effects of dam construction in the region have caused a change in the frequency and volume of flow in the upstream and downstream of the studied area and, as a result, produced a new hydrological system completely different from the natural flow of the river. Also, the level of groundwater in the region has dropped. As a result, the quality of water has changed, and salty water has moved towards the aqueous layer. The main reason for these problems is the change in the morphology and hydrological system of the river, The construction activities in Hableh Roud river. One of the other effective factors is the changes in the natural ecosystem. This impact is caused by the irregular and illegal use of the groundwater level, so the hydrological effects of dam construction have caused problems with the improper use of water. After the construction of these dams and the optimal use of water, sometimes the production performance has increased. So that we are witnessing changes in the agricultural system. In addition, the analysis in the water system shows that the water for irrigation is sufficient for some time. However, the traditional irrigation system is still active in the region. Perhaps, in the recent decades, building small and large dams and changing the course of rivers has been an effective way to fight drought. But it seems that with the occurrence of drought crises and the negative effects of inappropriate dam construction and changes in the ecological system of the region, an effective solution should be considered to deal with these problems.

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Conflicts of Interest

The author declares no conflict of interest.

References

Alizadeh, A. (2001). *Principles of Applied Hydrology*. Ferdousi University.

Arman, A., Fathi-Moghadam, M., Samadi, H., & Emamgholizadeh, S. (2009). Fall velocity of cohesive sediments in Dez Dam reservoir. *Research Journal of Environmental Sciences*, *3*(1), 71-79.

Begum, W., Goswami, L., Sharma, B. B., & Kushwaha, A. (2023). Assessment of urban river pollution using the water quality index and macro-invertebrate community index. *Environment,* *Development and Sustainability*, *25*(8), 8877-8902.

Emamgholizadeh, S. (2009). Water quality assessment of the Kopal River (Iran).

Emamgholizadeh, S., Bateni, S. M., & Nielson, J. R. (2018). Evaluation of different strategies for management of reservoir sedimentation in semi-arid regions: a case study (Dez Reservoir). *Lake and Reservoir Management*, *34*(3), 270-282.

Emamgholizadeh, S., & Fathi Moghadam, M. (2014). Pressure Flushing of Cohesive Sediment in Dam Reservoir. *Journal of Hydrology*, *19*(1), 674-681.

Emamgholizadeh, S., Kashi, H., Marofpoor, I., & Zalaghi, E. (2014). Prediction of water quality parameters of Karoon River (Iran) by artificial intelligence-based models. *International Journal of Environmental Science and Technology*, *11*, 645-656.

Emamgholizadeh, S., Moslemi, K., & Karami, G. (2014). Prediction the groundwater level of bastam plain (Iran) by artificial neural network (ANN) and adaptive neuro-fuzzy inference system (ANFIS). *Water resources management*, *28*, 5433-5446 .

Fathi-Moghadam, M., Arman, A., Emamgholizadeh, S., & Alikhani, A. (2011). Settling properties of cohesive sediments in lakes and reservoirs. *Journal of Waterway, Port, Coastal, and Ocean Engineering*, *137*(4), 204-209.

Fathi-Moghadam, M., Kashefipour, M., Ebrahimi, N., & Emamgholizadeh, S. (2011). Physical and numerical modeling of submerged vegetation roughness in rivers and flood plains. *Journal of Hydrologic Engineering*, *16*(11), 858-864.

Jin, L., & Yong, P. (2011). Study on general impact of territorial water diversion on improvement of water environment in Wuchengxiyu Zone in Taihu Lake Basin. *Procedia Environmental Sciences, 10*, 45-50.

Magilligan, F. J., & Nislow, K. H. (2005). Changes in hydrologic regime by dams. *Geomorphology*, *71*(1-2), 61-78.

Najafzadeh, M., Ghaemi, A., & Emamgholizadeh, S. (2019). Prediction of water quality parameters using evolutionary computing-based formulations. *International Journal of Environmental Science and Technology*, *16*, 6377-6396.

Parhizkar, S., Ajdari, K., Kazemi, G. A., & Emamgholizadeh, S. (2015). Predicting water level drawdown and assessment of land subsidence in Damghan aquifer by combining GMS and GEP models. *Geopersia*, *5*(1), 63-80.

Parsaie, A., Ememgholizadeh, S., Haghiabi, A. H., & Moradinejad, A. (2018). Investigation of trap efficiency of retention dams. *Water Science and Technology: Water Supply*, *18*(2), 450-459.

Skalak, K. J., Benthem, A. J., Schenk, E. R., Hupp, C. R., Galloway, J. M., Nustad, R. A., & Wiche, G. J. (2013). Large dams and alluvial rivers in the Anthropocene: The impacts of the Garrison and Oahe Dams on the Upper Missouri River. *Anthropocene*, *2*, 51-64.

Smith, R. A., Alexander, R. B., & Wolman, M. G. (1987). Water-quality trends in the nation's rivers. *Science*, *235*(4796), 1607-1615.

SRWC. (2015a). Garmsar city water resources management report. Semnan Regional Water Company. Internal unpublished report. .

SRWC. (2015b). -Report of Garmsar Plain Irrigation and Drainage Company. Semnan Regional Water Company. Internal unpublished report. .

SRWC. (2015c). Semnan Regional Water Company. Annual Report of Semnan Regional Water Company. Internal unpublished report.

Turner, R. E., & Rabalais, N. N. (1991). Changes in Mississippi River water quality this century. *BioScience*, *41*(3), 140-147.

Wu, W., Xu, Z., & Liu, X. (2012). Impact of Baojixia water diversion works on the hydrologic regime in the Wei River basin. *Procedia Environmental Sciences*, *13*, 1653-1662.