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Assessing the Available Surface Water Resources of Torogh Dam for Agricultural Consumption-Problems and Solutions for Future

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Abstract: Shortage of water resources in Iran especially the Mashad area is a very severe problem due to the prevailing condition of arid and semi-arid climate. Prolong droughts will affect the availability of water in Iran. Therefore Torogh Dam Watershed of Mashad has been studied. It is located in a semi arid zone of the southeast corner of Mashad city with a population of 2.5 million covering an area of 16400 km^2. Water scarcity is a major issue in the study area. About 40% of the surface water resources of Torogh Dam are used to irrigate agricultural land. Lack of precipitation and inefficient management of the irrigated water have caused the cultivated land not fully exploited. In summer water demand and water supply is not equal for irrigation because amount of water for irrigation is not sufficient. This Paper reviews current and future scenario, problems and solutions in sustaining water resources at the downstream of Torogh Dam for agricultural consumption for the centre of Khorasan Razavi County. Result of this review indicated that low efficiency of irrigation, lake on modern irrigation system and lack of participatory irrigation management are important factors for surface water resources management.

Key words: Surface Water resources % Water demand % Water supply % Irrigation efficiency % Mashad % Torogh Dam

INTRODUCTION

Water scarcity in Iran has been a serious issue and water-stress is increasing as the populations are increased. The availability of water for human consumption and uses need to be managed. In an arid and semi arid regions water resources management is important and vital for the survival of the population. Therefore for management of available water resources and its preservation in terms of quantity, it will be necessary to study the source of water and appropriate method of utilization [1]. Recent droughts in Iran had decreased the quality and quantity of surface water and ground water sources [2]. Mashad is capital of Khorasan Razavi province and located to the North East of Iran covering an area of 16,400 km^2 with a population of 2.5 million people. The main feature of this region compared to the other regions is that the Emam Reza holy Shrine is located in Mashad city, therefore causing a temporary surge in population of over 10 million pilgrims per year [3]. Torogh River is one of the most important sources of surface water supply for 2.5 million residents in the region of Mashad and 1300 hectares downstream agricultural lands and also controls the main drainage system in this region [4]. This Paper reviews current and future scenario, problems and solutions in sustaining water resources at the downstream of agricultural land of Torogh Dam for agricultural consumption in the centre of Khorasan Razavi County.

Study Area and Data: The study area is located in North-East of Iran, between latitude 36° 15' to 36° 17' North and longitude 59° 18' to 59° 36' East covering 1300 hectares of irrigated area downstream of Torogh Dam (Fig. 1).

Temperature: According to historical records from Kurtian synoptic station, 40 years of the recorded temperature of the area varied between an average maximum of 32.9°C in July and a minimum of -3.9°C in January with average of 13.7 °C per month (Table 1). July is the hottest and February is the coldest months.

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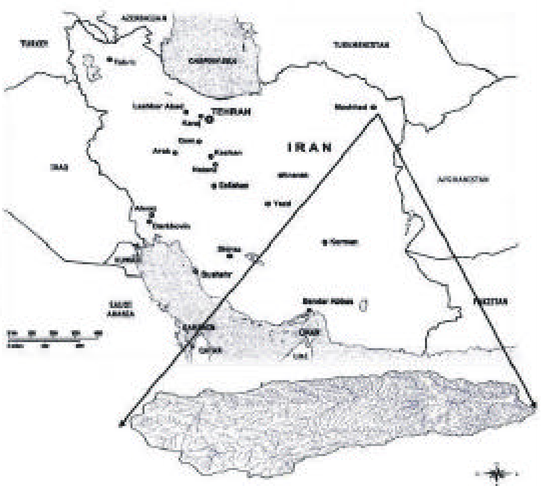

Fig. 1: Location of the study area

Relative Humidity: Maximum relative humidity is in the winter season and minimum relative humidity in the summer season (Table 2). Considering the data of Kurtian synoptic station, generally the mean relative humidity per year ranges between 75% in January and 33.8% in July.

Precipitation: In Iran, the precipitation originated from humid flows with low-pressure centers, which moved from west to east (Mashad) within seven months of the year (from October to May). In Torogh Dam watershed, the form of precipitation especially in winter is snow and rain. Based on the last 40 year of precipitation record (1967-2007), the average annual precipitation was approximately 274.1 mm, ranking Mashad amongst the semi-arid cities in Iran. Maximum rainfall was in the spring season in April (128 mm) and minimum precipitation occurred in the summer. Some rainfall statistics are shown in Table 3 and also the Isohyets of rainfall are shown in Fig. 2.

Surface Water Supply: The study area consists of one seasonal tributary (Ardameh) and one permanent river (Torogh) that flow into Torogh Dam. In the Torogh region, the major river system is the Torogh River. The Torogh River is the most important permanent river in the southern part of Mashad city, which controls the main drainage system in the region. It rises from North Binalod Mountains and flows from southwest to southeast along

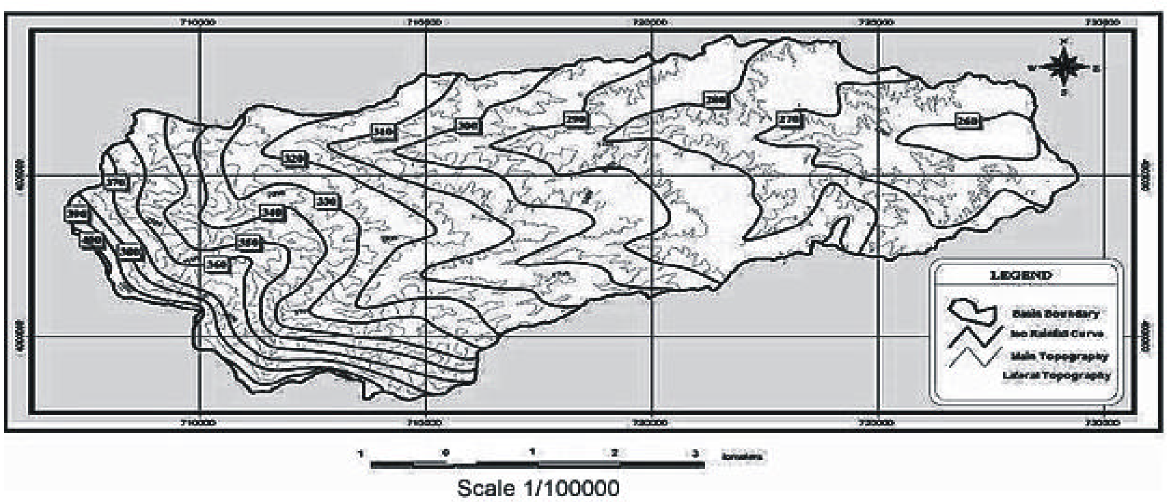

Fig. 2: The Isohyets of Rainfall in Torogh Dam Watershed (mm)

Table 1: Temperature at Kurtian Station (°C)

Month	Abs. Max.	Max. Mean	Mean	Min. Mean	Abs. Min.
Oct.	39	23.7	15.9	8.1	-6
Nov.	34	17.5	10.5	3.5	-9
Dec.	33	11.8	5.8	-0.04	-16
Jan.	29.5	7.6	2.2	-3.1	-22
Feb.	23	7.4	1.7	-3.9	-20
Mar.	28	11.2	5.3	-0.5	-18
Apr	33.5	17.9	11.4	4.9	-10
May	37	23.8	16.9	10.1	-2
Jun	41	29.4	22	14.6	2
Jul.	44	32.9	25.6	18.3	11
Aug.	42	32.5	25.1	17.6	6
Sep.	39	29.4	21.5	13.6	2

Table 2: Relative humidity (RH %) for Kurtian Station

Relative humidity	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
At 6:30	83.9	78.9	76.1	66.1	52.3	43.3	42.5	46.1	56.6	67.3	74.1	82.5
Mean	75	68.5	63	54.1	42	34.9	33.8	36.5	44.9	56	63.5	71.9
At 12:30	66.1	58	49.9	42	31.8	26.5	25	26.8	33.3	44.8	52.9	61.3

Table 3: Rainfall Statistical Parameters in Kurtian Synoptic Station

Parameters	Oct.	Nov.	Dec.	Jan.	Feb.	Mac.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Year
Max (mm)	31	91.3	61	73	125.9	117	128	94	87	30	8	35.5	436.3
Mean (mm)	5.8	19.3	23.8	28.8	41.7	51.2	53.5	33.7	11.8	2.4	0.4	1.7	274.1
Min (mm)	0	0	1	5	4.5	7	15	0	0	0	0	0	111
Standard Deviation	9.3	22.2	13.7	15.9	26.3	27.5	30.7	27.7	18.4	5.6	1.5	6	93.9
Coefficient of Variations	6	9	1.7	1.8	1.6	1.9	1.7	1.2	6	4	3	3	2.9

Table 4: Physical Characteristics Torogh Dam Watershed (TDW)

Area (km^2)	Perimeter (km)	Max Height (m)	Min Height (m)	Main River Length (km)	Main River Slope (%)	Time of Concentration(hr)
163.2	66.9	2677	1358	28.5	5	2.8

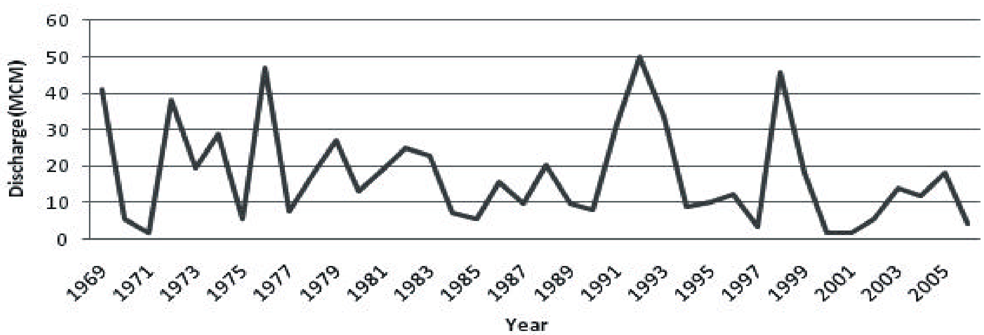

Fig. 3: The Discharge Variable in Torogh Dam Watershed (MCM)

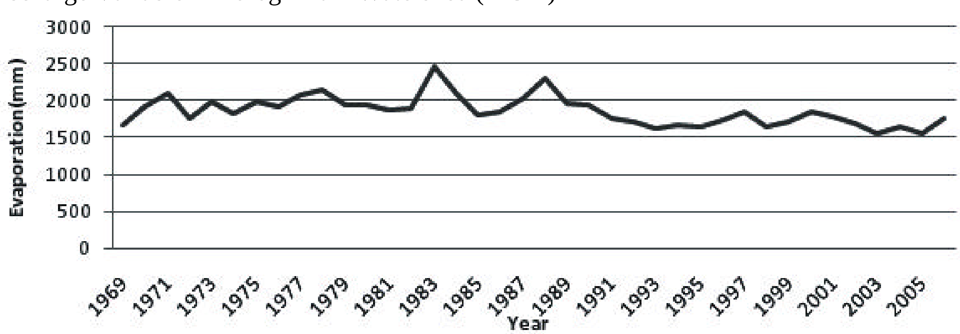

Fig. 4: The Evaporation Variable in Torogh Dam Watershed (mm)

the Mashad Plain and the seasonal rivers such as Ardameh flow during winter and spring when the precipitation was at its peak. The main characteristics of basin and river are summarized in Table 4. The result of review the last 38 years record showed that available surface water in Torogh Dam area is very much depended on climate condition. Figure 3 shows that amount of discharge difference between 1969 until 2005 is very high and also this period is include some drought period in this region. In the last decade, the mean value of available surface water was about 19 MCM per year that was about 55 percent (10.5 MCM) for only drinking consumption and about 45 percent for agricultural consumption (8.5 MCM).

Surface Water Supply for Irrigation: Available surface water for irrigation was determined using discharge data, which were recorded by the Khorasan Razavi Regional Water Authority. Water distributed for downstream agricultural land by two main canals from Torogh Dam. As mentioned above, the amount of water that forms the input and output of irrigated lands were measured at five flow gauges in the Torogh irrigated area. Kurtian discharge was used as the main input of surface water into Torogh irrigated area, but there were some un-gauged streams. The estimated water supply for agricultural consumption was 8.5 MCM but water demand in this area for agricultural consumption was about 10.5 MCM. Therefore agriculture section in this region has been 2 MCM water deficits in summer.

Evaporation: Some valuable historical assessments of evaporation losses in Mashad were available, but the measurement of evaporation is technically and logistically challenging. Fortunately, evaporation is a conservative parameter with limited spatial variability. Normally, over two-thirds of the annual evaporative loss occurred between May until September [5]. Evaporation calculation was based on the Penman Model [6] to provide daily and monthly estimates for 163.2 square kilometers (Fig. 4).

RESULT AND DISCUSSION

Water Balance Model (WBM): The water balance of a watershed follows the conservation of mass principle. The water that enters a Torogh watershed through precipitation less that which exits through evapotranspiration, stream flow and groundwater flow must be equal to the change in storage in the region [7].

An annual water balance for irrigated area can be written as:

$$\Delta S = P + G_{in} + Q_{in} - Q_{out} - E - G_{out} \quad (1)$$

Where ΔS is the storage change, P is precipitation, Q_{in} is surface flows into the region including artificial transfers, Q_{out} is stream flow, E is evapotranspiration and G_{in} and G_{out} are groundwater flow to and from the region, respectively [8]. Based on the last 40 years record (1967-2007) amount of water balance is +10.98 MCM that it shows water balance equation (Eq. 1) is positive in this area but there isn't sufficient water for agriculture consumption in summer season (Table 5).

Impact on Agriculture: The economy of Torogh regions is depending on agriculture. One thousand three hundred hectares of irrigated lands in this area are a source of agricultural products for about 324 families. According to data from the Khorasan Razavi Jihad-e-Agriculture Organization, wheat and tomato are the predominant crops in this area. Other crops are cantaloupe and sugar beet. Farmer's net income per hectare is about two thousand three hundred US dollars per year in downstream of Torogh Dam. The production of wheat was about 5 ton per hectare and tomato about 30 ton per hectare. All of the farmers sell their products to the government and private sectors. Irrigation has played a vital role in the agricultural production, but unfortunately it has been practiced traditionally in the Torogh area. Row irrigation method is used in this area and the size of irrigation canals is small and unlined. An on-farm water application rate is high and irrigation practice has a low efficiency of about 36 percent. Apart from seepage losses via unlined irrigation canals, the major loss is at farm level via evaporation [9, 10]. Since 1943, provision and management of surface water has been officially controlled by a Government Water Office [1]. Later, Regional Water Organization was established to monitor dams and distribute water among villages.

About 8.5 MCM of water was used in agriculture sector, of which more than 64 percent was wasted due to evaporation, seepage and lake of cemented canal and lake of irrigation systems. Water use efficiency in agriculture sector was about 36 percent [11].

There were many factors responsible for low irrigation efficiency in the field; the most important ones were as follows [12]:

- About 90% of small and scattered pieces of Torogh agricultural land (about 1500 m^2-21000 m^2) were not suitable for modern irrigation systems and also farmers cannot apply mechanization methods for improve irrigation efficiency;
- Lack of agriculture land levelling for using modern irrigation systems for increasing efficiency irrigation;
- Inadequacy of financial supports from government for construction, maintenance and operation of irrigation facilities such as, dams and irrigation and drainage systems at farm level;

Table 5: Calculation of Water Balance in Torogh Dam Area (MCM)

P	G_{in}	Q_{in}	Q_{out}	E	G_{out}	ΔS
44.73	0	29.4	19	44.15	0	10.98

- Lack of proper management for increasing water efficiency and productivity in agriculture section;
- Selling water to beneficiaries on area (ha) basis and with low price;
- Lack of information services in agriculture section such as technical information dissemination for increasing framer's knowledge and also short and long time plans for improve productivity.

Future Scenario: Water is the most precious natural resource and is linked to other natural resources. This must be the responsibility of national governments. Farmers should use new methods for irrigation such as sprinkler and trickling irrigation systems because they will improve productivity and water efficiency. Moreover, consolidation and integration of agricultural land as well as mechanization and renovation of farms irrigation systems will have positive effects on optimizing the water efficiency and also change in crop pattern such as excluding sugar beet because this crop use a lot of water [2].

Problems: There were many problems that obstructed the capabilities of participatory irrigation management, which must be sorted out to promote and encourage farmers to take more responsibility. These problems are summarized as follows [13]:

- Lack of a rational relationship between the price of agricultural products in before and after produce and also disorder and chaos in marketing of agricultural products e.g. difference price between tomato and tomato paste;
- Low price of water (about 0.05 US dollar per m^3) and charging for water on the basis of area (ha) rather than on the basis of volume;
- High costs of water supply installations under economic present situation for farmers that will effective on products price;
- Lack of agriculture land levelling and also existing scattered pieces that effective on of costs of supplying and distribution irrigation water;
- Lack of effective legislation in water and agriculture affairs for establishment modern agriculture in Torogh area;
- Absence of an integrated plan for sustainable development and inadequate attention to the economic, social, cultural and development problems that will affect in future programs;
- Lack of suitable agricultural plan for this region;
- Lack of appropriate legislation for establishment and supervising NGOs effective in suitable water allocation, planning and management for future;
- Inadequate attention to the rights and principles of ownership in the Torogh area;
- Unreliability and distrust of farmers about the organizations due to the failure of similar organization in the past for support them;
- Uncertainty in land ownership in Torogh region effective in amount of productivity;
- Different sorts of land utilization and ownership (owning, rental, temporary cession of land) in area;
- Distrust of people on authorities for applies NGO;
- Little confidence of farmers on the success of the project effective in idea change;
- Weak financial capability of water users for applies irrigation systems;
- Fear of farmers of getting less water if an organization is established for different consumption in around area;
- Unawareness of farmers about the advantages of participation effective in applies NGO and decrease cost of production procedure [14];
- Possible ways of breach and infringement of farmers in getting high volume of water, cheap and free water in the absence of NGO;
- Lack of reliable, technical and legal management systems in Torogh villages;

Solutions: Some solution to improve participatory irrigation management in the study area as follow as:

- Creation of a powerful management structure which is elected by rural people to carry out integrated projects to achieve sustainable development by considering people participation and less executive departments;
- Carrying out integrated planning studies (recognition of environment, potentials and capabilities, the socio-economic situation, difficulties and people's needs) in Torogh region and on the basis of people participation;
- Preparation and approval of appropriate regulations to support guide and supervise integrated management schemes and related NGOs;
- Development and extension of a culture of hardworking, cooperation, order and regularity, legality, providence and comprehensive vision in society's farmers;

- Paying special attention to education and extension of scientific principles in all socioeconomic and cultural aspects in this area;
- Development of a long-term national water policy and strategy is essential, including water legislation and laws especially for safe water bodies.
- The integrated water resources management must emphasize the demand management, in addition to the supply management. This must be undertaken by both the government and private sector.
- Water has an economic value and its valuation is urgently needed, taking into account production and distribution costs in water services.
- There must be contingency plans for alternative water security and supply during emergencies.
- Coordination among different institutions dealing with water resources is needed.
- It is deemed essential that people are involved in the integrated water resources management enterprise through education emphasizing the cultural and economic linkages to water resources. This must be done by educational and research institutions, NGOs and stakeholders.

CONCLUSION

Water shortage in arid and semiarid regions of the world has motivated the development of the innovative management measures. Without improvement in water management, agricultural water demand will continue to increase as population and water supplies will diminish for products agricultural production. Irrigation in the study area was done by traditional methods, for this reason on-farm water application was high and the irrigation practice has a low efficiency of about 36 percent for surface water recourses. Although for agricultural purposes water supplied by Torogh Dam but the important reason of water shortage is variable annual rainfall in this region. This resource supplied just a part of agricultural demands. Lack of cemented irrigation canals coupled with low irrigation efficiency have caused the improper use of existing water. There was no equivalent condition of demand and supply of water resources for irrigation purposes. Integrated water resources management must emphasize the demand management and supply management. This issue must be undertaken by both the government and private sectors.

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