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Socio-economic considerations of rooftop catchment systems (Case study: Golestan Province, Iran)

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Abstract

Socio-economic assessment of rainwater harvesting systems considered as one of the efficient approaches in water resource management under deficit conditions, leads to a better management practice in the implementation of such systems. This work was aimed at analyzing the socio-economic limitations and potentials of rooftop catchment systems in Golestan province. The methodology was based on field surveying and questionnaire filling at 12 selected sites in Golestan province. Then, each site was hydrologically simulated according to different rainfall conditions, spill over magnitude, number of beneficiaries and volume of demand and reservoirs' volumes were optimized. To evaluate the economic performance of the rooftop catchment system, Net Present Value (NPV) of a typical site was computed. Results showed that the system would not be economically justified even with a discount rate of 20% during 30 years of simulation. The total cost of implementation of a medium system and its maintenance was estimated to be 70 million Rls., while it only benefits 27000 Rls., annually. This could be a result of low price of water, a fact also confirmed by questionnaires results. Based on the social analysis of rooftop catchment systems, it was revealed that there was a high degree of satisfaction with these systems by residents and users, but it was not welcomed by the new generation of residents in the study area. This issue was mainly arisen from the entry and development of urban and rural water networks which were more convenient to use as compared with traditional systems. There were some other reasons in this background such as low level of knowledge and education about rooftop catchment systems, especially for new generations, as well as the initial cost of executing such systems.

Keywords: *Golestan province, rainwater harvesting, socio-economic assessment, rooftop catchment system, Net Present Value.*

1. Introduction

Rainwater harvesting through traditional methods, aiming at meeting potable water for humans and animals as well as small-scale irrigation in arid and semi-arid areas of the world dates back to 4000 years ago (Khoury-Nolde, 2010). Rainwater catchment systems are divisible into two general categories depending on the runoff source, namely: ground and roof. The first category includes systems in which the runoff from the ground level is directed into streams, canals, ponds and / or artificial storage resources. But in the second group, usually cleaner water is harvested and there is an emphasis on the use of rooftop runoff (Gould and Nissen-Petersen, 1999). According to conducted studies, collecting rainwater from rooftops is not limited to specific locations on the planet, such that this method has long been used in many parts of the world. In countries such as China, India, Thailand, Malaysia, Singapore, Guam, the United Kingdom, Germany, Taiwan, Fujian and even in Iran, collecting rainwater from rooftop has been commonly used to provide potable water and domestic consumption (Ghoddousi, 1976). In northeast Iran on the Caspian Sea littoral, especially in the predominantly Turkmen areas such as Aq Qala and Maravetappe, due to the scarce rivers with low baseflow and low quality of the surface water and salty groundwater resources, collecting rainwater from rooftops has been one of the most prevalent methods of water supply for drinking and domestic consumptions in such areas (Ghoddousi, 1976).

The results of studies conducted on rainwater harvesting which can secure a large part of non-potable or even potable water of the residents (Stanton, 2005; Saadodin et al., 2012; Rashidi Mehrabadi, 2011; Zehtabian et al., 2013; Komeh et al., 2015) shows that using such systems has not yet become prevalent, especially in a country like Iran. In many parts of the country, due to frequent droughts, lack of water supply network, rationing in network, and high costs of transferring water from other watersheds, the issue of fresh water shortage has become a serious crisis (Esmaili et al., 2009). Considering climatic conditions and usage of water above the standard in most large cities, water shortage can be solved to some extent by collecting rainwater (Rashidi Mehrabadi, 2011). Using urban impervious surfaces, in particular rooftop rainwater catchment systems of residential buildings, provides the possibility to secure a part of the drinking or non-drinking needs of citizens and residents of residential buildings, by collecting rainwater during the rainy season, so that costs of supplying water for washing open spaces, toilets, irrigation of gardens and green spaces, and other non-potable uses are reduced (Rashidi Mehrabadi, 2011). Thus, despite the water crisis we see in all parts of the country, rain water harvesting can be one of the most important management strategies to store rainwater. For this purpose, it has become essential to consider the limitations and potentials of rooftop rainwater catchment systems, in order to design and implement such systems in buildings more efficiently. These plans can be useful if they are implemented correctly, in principle, and in accordance with standard criteria and taking into account all climatic, edaphic, and environmental conditions. Also their efficiency can be increased day to day by conducting an eco-social assessment of the implementations (Chag, 2000). In this regard, Tang (2009) analyzed the benefit/cost ratio of rainwater harvesting techniques in Kuttanad area, India. He considered all the costs necessary in the design and the implementation of rainwater harvesting systems in the region. Economic analysis of the project finally showed that establishment of rainwater harvesting systems increased the income of residents and reduced diseases caused by drinking polluted water among natives of the region.

The present study was aimed to conduct a comprehensive study on implementation of rooftop rainwater catchment systems in Golestan province, limitations and potentials of the rainwater catchment systems, transferring equipment, storage, and harvested water quality. Therefore, through selecting and visiting 12 different sites in Golestan province, useful information from these sites was collected, and a questionnaire, prepared for this purpose, was completed with help of inhabitants of the site. Rainwater harvesting systems were simulated at studied sites, and socio-economic considerations of rooftop rainwater catchment systems were investigated and administrative constraints were socially and economically identified.

2. Materials and Methods

According to records available in the field of rainwater storage at houses in Kalaleh, Torkaman harbor, and AQ Qala in Golestan Province, these three cities were defined as the study area. After preliminary investigations of the authorities and the indigenous inhabitants, Maravehtappe, Gomishan and AQ Qala of the three above-mentioned cities, which had the largest number of buildings and active sites, were selected and surveyed. The geographic locations of these areas are illustrated in Fig. 1.

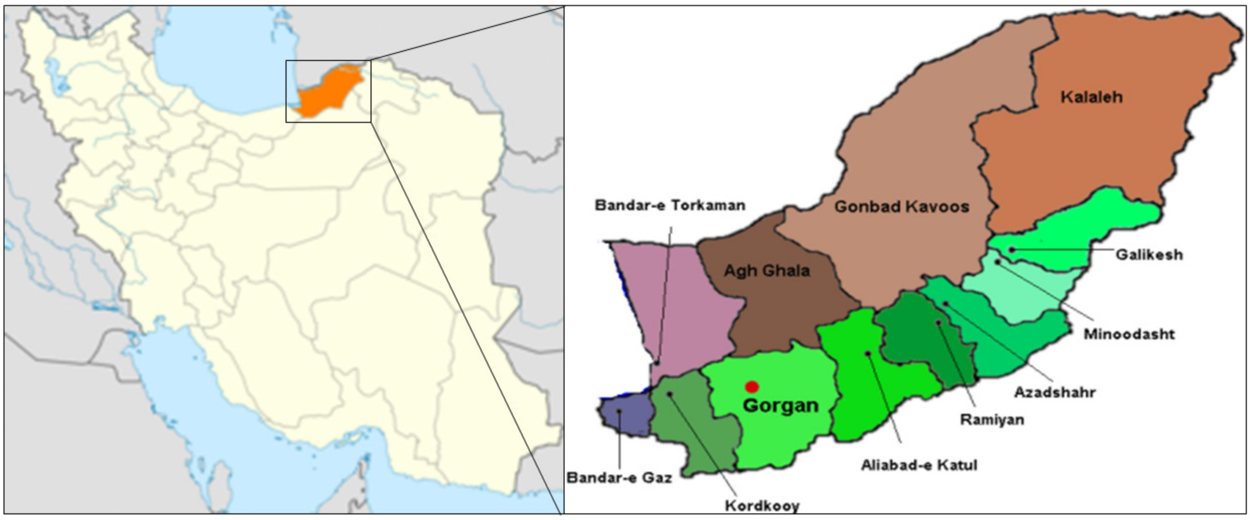

Fig. 1. Geographic locations of the studied sites

After presence in the related cities and interview with the informed residents, attempts were made to visit at least one sample of each item according to the diversity of the available systems in terms of reservoir type, usage type, and rooftop area, in order to have shape and technical diversity besides observing the physical distribution. After field surveys and visits, 12 sites were studied in total; 3 cases in Maravetappe, 6 cases in Gomishan and 3 cases in AQ Qala were visited (Table 1). Thereafter, in order to obtain the desired information, an 8-page questionnaire was developed and prepared. This questionnaire contained all information required to fully understand the visited system including design, implementation, operation, and maintenance with respect to economic and social aspects. In preparation of this questionnaire, required information to redesign and optimize the function were considered in accordance with the foreign existing guidelines and research and some successful domestic experiences (Zehtabianet al. 2011, Saad Eddin et al. 2012, Gould et al. 1999, KANRRC., 2011). Available sections in the questionnaire included visiting site coordinate, specifications of the respondent individual and technical information of the system including rainwater catchment, transport system, reservoir, consumption and consumers (social and economic), and technical – executive problems of the system, with each of these factors having its own related subdivisions. For this purpose, the intended information was analyzed separately in four main sections. The first three sections were related to the three main parts of a water harvesting system (including the rainwater catchment surface, water transport system, and water storage tank) and the fourth part discussed socio-economic considerations in order to determine technical and executive problems of the system.

NPV (Net Present Value) was used to evaluate the system performance in economic terms. In engineering economics, NPV is one of the standard methods of economic evaluation projects. In this way, cash flow (income and costs) is discounted to the current rate, based on the time of occurrence (income or cost). In the cash flow, the time value of costs or earnings is also considered:

$$NPV = K_0 + \sum_{t=0}^{N} \frac{B_t - C_t}{(1+r)^t} \qquad \text{Eq (1)}$$

,where K_o is the capital expenditure in the year zero, N is the time horizon (year), B_t is benefit of the project in year t, Ct is the cost at year t, and r is the discount rate (Khorasan Agricultural and Natural Resources Research and Education Centre (KANRRC, 2011).

Table 1. The relationship between discount indicators in the project engineering economy

	Discount Indicators				
	Net Present Value (NPV)		*Internal Rate of Return (IRR)*		*Benefit to cost ratio (B/C)*
IF	*Greater than zero*	**Then**	*Greater than or equal to the* interest *rate (The minimum acceptable rate)*	**&**	*Greater than 1*
	Less than zero		*Smaller interest rate (The minimum acceptable rate)*		*Less than zero*
	Zero		*Equal to the interest rate (The minimum acceptable rate)*		*1*

A summary of the information gathered at the studied buildings, based on three main components of a water harvesting system (including catchment surface, transport system, and water storage tank) are presented in Tables 2 to 4.

Table 2. Characteristics of Sites and a summary of information about the catchment surface

Site #	**Location**	**Building Type**	**Geographic coordinates**		**Elevation on above sea level (m)**	**Size (m^2)**	**Material**	**The height of the tiles (m)**	**Time and method of cleaning and grooming**
			X	**Y**					
1	West GHARAGUL Village	Residential	376059	4199329	108	12*10	Tin	3.5	Once a year using chlorine
2	GHARAGUL Village	Residential	378129	4198422	118	12*11	Tin	3	Once a year using chlorine

3	CHENARAN Village	Residential	406726	4183839	500	10*10	Asbestos	3.20	Once a year using chlorine
4	GOMISHAN City	Residential	239902	4106688	-20	6*5	Tin	7	Before the rainy season with a broom
5	AQ QALA	Residential	273732	4100065	-11	48	Tin	3	Before the rainy season with a broom
6	GOMISHAN City	Residential	239932	4106669	-22	240	Tin	8	Destroyed reservoir
7	GOMISHAN City	Residential	239932	4106669	-22	96	Tin	7	Before the rainy season with a broom
8	GOMISHAN_ Suburb	Residential	239414	4109194	-25	32	Tin	5	Before the rainy season with a broom
9	GOMISHAN City SAFAISHAN	Residential	289559	4108838	-23	25	Tin	3.5	There was a fresh and clean
10	AQ QALA-Lari	Residential	253568	4101093	-14	102	Tin & Asbestos	Tin: 4 Asbestos: 2.5	Before the rainy season with a broom
11	SARI AKHOND Mosque	Mosque	272875	4099714	-22	350	Tin	5	Before the rainy season with a broom
12	GOMISHAN	Mosque	239901	4107576	-21	180	Tin	4	Before the rainy season with a broom

Table 3. Summary of characteristics of water transport system

Site#	Length of gutter(m)	Type of gutter	The number of downpipe	length of downpipe (m)	Diameter of downpipe	Material type of downpipe	Existence of filters at the entrance to drains
1	5	Piped	1	12	5	plastic	No
2	4	Piped	1	3	5	plastic	No
3	6.20 & 8.20	Piped	2	2	5	plastic	Yes
4	5	Open	1	12	5	plastic	Yes
5	-	Open	2	4	10	Plastic - Tin	Yes
6	12	Open	2	12	7	Metal	Demolished
7	12 & 8	Open	2	8 & 12	5 & 7	plastic	Yes
8	10	Open	2	20	7	plastic	Yes
9	4	Open	1	10	5	plastic	No
10	8	Open	3	8	7	Tin	Yes
11	-	Open	7		5 & 7	plastic	Yes
12	54	Open	4	40	7	plastic	Yes

Table 4. Summary of characteristics of cisterns

Site #	Type of tank	Depth (m)	Type of material	Coverage type	Volume (m^3)	The location of the drain valve	Cleaning Time	Cleaning method
1	underground	2	Concrete	Metal doors covered with cement	24	Without drain valve	Fall	Washing with a broom and salt - disinfection with chlorine
2	underground	2	Concrete	Metal doors covered with cement	24	Without drain valve	Fall	Washing with a broom and salt - disinfection with chlorine
3	underground	3	Concrete	Metal doors covered with cement	36	Without drain valve	Fall	Washing with a broom and salt - disinfection with chlorine
4	Underground - Circular Sink	6	Concrete	Metal doors covered with cement	15	Without drain valve - Picking up by bucket	Summer	Washing with a broom and salt - disinfection with chlorine
5	underground	2	Concrete	Mosaic - home terrace	12	Without drain valve - Picking up by bucket	Summer	Washing with a broom - disinfection with chlorine and salt - Sediment discharge pump

6	underground	1.5	brick veneer with cement	Domical-brick	36	Without drain valve	Unknown - degraded	Unknown - degraded
7	underground	2.5	Concrete	Concrete	32	Without drain valve - Picking up by bucket	Summer	Washing with a broom - disinfection with chlorine
8	Underground - Circular Sink	5	brick veneer with cement	Domical with metal doors	24.5	Without drain valve - Picking up by bucket	Not cleaning	Not cleaning
9	Surface-Galvanized tank	-	Galvanized	-	1	Tap at the bottom of the tank	It’s the first year	It’s the first year
10	underground	2	Concrete	Mosaic - home terrace	24	Without drain valve - Picking up by bucket	Summer	Before the rainy season - Washing with salt - disinfection with chlorine
11	underground	2.7	Concrete	Concrete - The mosque courtyard	66	Two valves, out of the mosque	Summer	Washing with a broom and salt - disinfection with chlorine
12	underground	2	Concrete	cement	16	Without drain valve - Picking up by bucket	Not cleaning	Not cleaning

3. Results and Discussion

Results of information on rooftop catchment systems in the studied sites indicate that in most cases, clearing and cleaning of the cisterns are done only once a year using a broom and regular washing utensils. Chlorination is only applied in some cases. Clearing and cleaning of the tank is very important and given the weakness in this sector of the study area, it’s necessary to provide the local people with necessary training in this field, and to even provide them with necessary materials for cleaning, disinfecting, and cleansing in order to encourage residents to use this system. Besides, users of this system isolate the first flash in all study sites using manual separation of inlet pipe into the tank in the first month of rainy season, and do not allow entrance of runoff from the first rain into the tank. On most sites visited, residents had sufficient knowledge of the need to install the filter before entrance of the downpipe into the tank, and they did so by using a simple metal or fabric mesh. In some of the sites, small electric pumps were used in order to take water from the reservoirs. Therefore, using discharge valves and pumps remarkably contribute to more hygienic and easier harvesting of water from the reservoirs.

Socio-economic survey

A summary of the social information (number of consumers, rate and type of using rooftop captured runoff, the satisfaction of the residents with these systems, etc.) and economic considerations (costs and benefit) are presented in Table 5.

Table 5. Summary of information about consumption and consumers (socio-economic aspects)

Site#	The number of consumers	Type of use	Type of purposes	Average non-drinking consumption	Useful life of system	Average daily use in		Satisfaction degree
						Dry season	Wet season	
1	12 people 3 families	Drinking and non-drinking	WC, washing, livestock	60% for cleaning, the rest for drinking and livestock	40 years	100 liters	50 liters	high
2	5 people	non-drinking	livestock	60% for cleaning, the rest for	40 years	100 liters	50 liters	high

3	4 people	Drinking and non-drinking	WC, green space, cleaning	drinking and livestock 60% for cleaning, the rest for drinking and livestock	30 years	150 liters	60 liters	high
4	32 people 8 families	Mostly for drinking	-	-	90 years	120 liters	70 liters	very high
5	16 people 4 families	Drinking	-	90 %	20 years	-	2 liters/ family	very high
6	The whole neighborhood	Mostly for drinking	-	Unknown	More than a century	Unknown	Unknown	very high
7	24 people 6 families	Mostly for drinking	-	>90 % is secured by municipal tap water supply	20 years	20 liters/ family	20 liters/family	very high
8	The only domestic animals	Livestock Drinking	-	100 % is secured by municipal tap water supply	35 years	Proportional to the needs of livestock	Proportional to the needs of livestock	very high
9	3 people	Drinking and non-drinking	WC, dish washing, showers, washing	90 %	3 months	70 liters during the season	not using	very high
10	30 people 6 families	Mostly for drinking	Winter wash clothes	>90%	28 years	20 liters/family	15 liters/family	very high
11	Most Neighbor's house	Drinking	-	-	8 years	Water drawing rights as one hour per day	1 liters	very high
12	The only domestic animals	Livestock, Drinking	-	100 % is secured by municipal tap water supply	25 years	No use in mosque	discharge for livestock before the wet season	high

In order to conduct an economic analysis, all costs and benefits were determined based on the discount rate of the project. Accordingly, in the following, the estimations related to the study Site No. 1 have been presented assuming construction in the year 2015.

Table 6. Total cost estimation of the system implementation for residential houses (Pricing based on the price list of irrigation and drainage, 2015)

Description of operation	**Total price by coefficients**		
	(Rial)	**(Thousand Rial)**	**(Million Tomans)**
Structural operations	17936498	17936	1.79
Required materials and wages	25560000	25560	2.56
Total	43496498	43496	4

Table 7. Cost estimation of the maintenance and exploitation of the system during a year

Description of Operation	**Unit**	**Unit price (Rial)**	**Amount**	**Price (Rial)**
Disinfectants	Liter	200000	5	1000000
Disinfection wages	Time	500000	1	500000
Cost of electricity for water pumps	Monthly	100000	12	1200000
Sum	-	-	-	2700000

Table 8. Potential volume of harvestable runoff from rooftop at site#1

	P	C	A	Yt
Factor	Annual precipitation	Runoff coefficient	Rooftop area	Water volume
Unit	Millimeter	Percent	Square meters	Liter
Quantity	419	90	48	18089

Table 9. Potential volume of harvestable runoff from rooftop at site#1 considering optimized reservoir volume

	Vb	Yt1	Sp	C	Yt2
Factor	Optimized volume of reservoir	The volume of stored water in reservoir during a normal year	The volume of water overflow from the optimized reservoir	The overflow correction factor for optimized reservoir	The volume of stored water in optimized reservoir
Unit	Liter	Liter	Liter	Percent	Liter
Quantity	6000	18079	305	1.7	17774

Table 10. Benefit estimation of site #1 with and without consideration of optimized reservoir volume

	Cw	N	Bt1	Bt2	N	Bt1	Bt2
Factor	Price per cubic meter of water	Annual	Benefits of the project based on water storage potential	Benefits of the project on the basis of stored water	Lifetime of reservoir	Benefits of the project based on water storage potential	Benefits of the project on the basis of stored water
Unit	Rial	Year	Rial	Rial	Year	Rial	Rial
Quantity	15000	1	271188	266616	30	8135640	7998480

Table 11. Net present value estimated for rooftop catchment system of site #1

		Ct	Bt	Cash flow	Npv
Fact	**Year**	**Cost**	**Benefit**	**The difference between cost and benefit**	**Net present**
Unit		**Rial**	**Rial**	**Rial**	
	0	43496498	0	- 43496498	- 43496498
	1	2700000	266616	- 2433384	- 2027820
	2	2700000	266616	- 2433384	- 1689850
	3	2700000	266616	- 2433384	- 1408208
	4	2700000	266616	- 2433384	- 1173507
	5	2700000	266616	- 2433384	- 977922
	6	2700000	266616	- 2433384	- 1173507
	7	2700000	266616	- 2433384	- 977922
	8	2700000	266616	- 2433384	- 1173507
	9	2700000	266616	- 2433384	- 977922
	10	2700000	266616	- 2433384	- 1173507
	11	2700000	266616	- 2433384	- 977922
	12	2700000	266616	- 2433384	- 1173507
	13	2700000	266616	- 2433384	- 977922
	14	2700000	266616	- 2433384	- 1173507
	15	2700000	266616	- 2433384	- 977922
	16	2700000	266616	- 2433384	- 1173507
	17	2700000	266616	- 2433384	- 977922
	18	2700000	266616	- 2433384	- 1173507
	19	2700000	266616	- 2433384	- 977922

20	2700000	266616	- 2433384	- 1173507
21	2700000	266616	- 2433384	- 977922
22	2700000	266616	- 2433384	- 1173507
23	2700000	266616	- 2433384	- 977922
24	2700000	266616	- 2433384	- 977922
25	2700000	266616	- 2433384	- 1173507
26	2700000	266616	- 2433384	- 977922
27	2700000	266616	- 2433384	- 977922
28	2700000	266616	- 2433384	- 1173507
29	2700000	266616	- 2433384	- 977922
30	2700000	266616	- 2433384	- 977922
				- 50773805
			Discount rate	0.2

Conclusions of the questionnaires indicate that the satisfaction level of consumers of rooftop catchment systems is high, but the new generation has not yet widely welcomed this system. According to field surveys and official analyses, the most important issue related to rainwater harvesting from the rooftop in Golestan province, is that the new generation has not welcomed this system, due to the following issues:

1. Entrance and development of urban and rural water networks and its more convenient use compared to traditional systems of rainwater harvesting and low water charges in many areas, especially rural areas. Results of the economic analysis indicate that in the study sites, rain water harvesting system, even with a discount rate of 20% is not economically justified after 30 years. This is due to the low water rates in the region and almost throughout Iran. Water rates used in this analysis (15000 Rls. for each cubic meter) were determined according to prices stated in Information Center of the Ministry of Energy (http://news.moe.gov.ir). However, the price per cubic meter of water is less than 4000 Rls. for the consumer, taking into account the subsidy, which is much lower than water rates in many countries of the world. Therefore, it is necessary that water price is determined and water charges are truly determined and received for each separate area in the specialized related commissions, so that it could operate as an incentive to develop rooftop catchment systems.
2. Lack of optimization and modernization of old traditional systems and improvement of their efficiency. For example, the pump can contribute in part to the ease of use of this system. Also it is necessary to examine the old cisterns due to leaks or water infiltration and the measures needed to remove the defects and optimize them to be proposed to the locals.
3. Lack of promotion, education, and acculturation of the importance and value of water, especially for the new generations. In this context, with the assistance of leaders and elders, especially clergymen, the importance and value of water can be introduced. In the meantime, managers of relevant agencies remind regional water problems of the moment and future conditions (especially with consideration of climate change in the future) to locals and to them the importance of using alternative water sources such as water collected from the rooftops. Comprehensive studies should be conducted regarding social aspects such as

social and cultural level of acceptance and the rate of satisfaction of the people regarding implementation of this system in the region. In other words, social and cultural justification of the action should be prepared to avoid facing problems of social acceptance.

4. Disapproval of the related sites on harvested water quality. In this context it is necessary for city health centers to closely monitor the collected water quality and approve its quality if the collection and storage system is technically and hygienically standard, and therefore, assure the minds of consumers regarding quality of the collected. Giving chlorine to people on behalf of health care centers and providing the necessary training for cleaning tanks and rainwater catchment surface can also be beneficial in this regard. To our knowledge, no detailed and comprehensive studies have been done on the role of air pollution on rainwater harvested, which is deemed a necessity.
5. Falling of insects and animals into old reservoirs and people's belief in its uncleanliness.
6. Construction of new home ceilings made of inappropriate quality such as Asbestos. It should be noted that using Asbestos could not have a significant impact on the quality of harvested water. However, according to local people's mentality regarding the pollutant nature of Asbestos, use of tin or pottery is recommended.
7. The initial cost of implementing the system, which is negligible compared to the cost of splits, subscription, etc. However, according to the fact that paying this fee is difficult for the villagers at the beginning, it is recommended that governments contribute to the boom and the setup of this system in these regions by providing facilities with low interests. It should be noted that compared to the high costs of transportation and water refinery, the cost of setting up this system, which mainly includes the construction of the reservoir (about Rls. 20,000,000 for each reservoir) is so low that is payable through government loans. However, the benefit of implementing such systems due to the stable supply of potable and non-potable water, and especially for residents of cities and remote villages in the border areas is very high. Nevertheless, another proposal that arises is that detailed performance and economic efficiency of this system are discussed and solutions to improve economic efficiency are evaluated in another plan. In fact, detailed studies should be conducted on the economic dimension, in terms of costs of implementation of these methods with various and conventional systems in the region and the resulting benefits, so that sufficient information become available to managers for decision making. In other words, the economic justification of the project must be provided so that people will be convinced that the implementation of this system is in their favor and they become willing to implement it (Eftekhari, 2011; Nazarian, 2012).
8. Lack of necessary legal and financial support on the implementation of the system on behalf of the government.

Despite the high cost of transporting water from Gorgan to AQ Qala and other regions of the province with limited quality, no comprehensive study has been carried out on these systems with more than a hundred years old. Therefore, it is recommended that research centers and academic plans be developed to solve problems of the system and come into force as complementary project guidelines in this field by engaging relative consultants. For example, in Texas, since 2007, annual awards have been allocated to the best performers of rainwater systems, and competitions have been held to promote these systems which are domestically advisable and designable as well (Texas water development board, 1997). In the past, large centers, such as houses of Khans or mosques, were a place for collection and storage of rainwater and other inhabitants used the collected water. According to the initial cost of these systems, setting up such centers would also be recommended. It should be said that this process is manageable, and health and technical notes can be treated with more respected.

4. Conclusion

With regard to the current water crisis and water shortage in Iran, using extracted water from rooftop catchments can secure a part of water requirements of the residents and results in a decrease of pressure on urban/rural water resources. Therefore, it would be necessary to implement rooftop catchment systems, especially in buildings under construction. In this way, the governmental authorities or NGOs must prepare financial and legal supports and remind people, especially new generations about the importance of water. This requires education and acculturation and payment of interest-free loans to people for launching rooftop catchment systems.

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