Water Harvesting Research, 2017, 2(2): 47-53
DOI: 10.22077/JWHR.2018.829
www.jwhr.birjand.ac.ir
P-ISSN: 2476-6976, E-ISSN: 2476-7603

Floodwater Harvesting for Improving Dryland Agriculture

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Received: 3 March 2017 / Accepted: 2 july 2017

Abstract

This paper proposes floodwater harvesting as a countermeasure for ever-increasing water shortages in a semi-arid region of Iran. Characteristics of local Mediterranean climate are highlighted as a major constraint for direct use of seasonal runoff produced by small catchments. Rainfall and runoff measurements were carried out during four consecutive years in order to evaluate hydrological data obtained by regional analysis. The result indicates that regional analysis might have caused overestimation for runoff volume and unreliable monthly distribution. Registered data, shows that occasional rainfalls (In this case only once a year) are the only opportunities for floodwater harvesting. It is therefore understood that the water storage is very important for regulating the individual runoff in order to support crop water requirements along the year. A design chart has been developed to be used for optimization of storage capacity with respect to cultivated area and the corresponding risk of water shortage.

Keywords: *Floodwater harvesting, Arid region, Regional analysis, Reservoir optimization, Runoff estimation.*

1. Introduction

The area of Iran is 1648000 km2 and receives an average of 255 mm of precipitation per year. More than 80% of Iran's land has an arid and semi-arid climate with temperature changing from -30 to +50 Celsius. Potential evaporation varies from 1000 to 4000 mm per year. The whole country receives about 400 Billion Cubic Meter (BCM) rainwater out of which 270 BCM evaporate directly from ground surface or indirectly from vegetation cover. From a total of 130 BCM renewable water resources (including 38 BCM groundwater and 92 BCM surface water) 93 BCM are being used in different sectors (i.e. 93% in agriculture, 5.8% for domestic purposes and 1.2% by industry) whereas the remaining 37 BCM has not been controlled and is being wasted in a different manner (Fahmi, H. 2014). Aforementioned statistical perspective has been prepared according to the long-term average data whereas the country is now experiencing a dramatic shortage in available water resources which is very likely because of climate change and periodical drought condition (Ministry of Jahad-e-Keshavarzi, 2010).

Current water supply systems of the country consist of deep wells and large dams employed for underground and surface water utilization. River diversion, spring water, and aqueduct (underground gallery) are uncontrolled systems which are used directly without collection. Due to recent country's population growth, most of the major groundwater aquifers have been overexploited (over 6 BCM) resulting decline of the water table to more than 1 meter per year (in average) and consequent drying and deteriorating of many wells, spring and aqueducts water. In order to make use of surface water potentials, many large and medium-size dam has been constructed during the last decades and many others are under construction. In addition to a long time and large investment encountered in the planning and construction of dams, only about 4% of total arable land has been covered by irrigation via the dam system. High land erosion rate has caused rapid sedimentation behind many of them so that dam's lifetime is being diminished far quicker than predicted. Therefore, no further development can be considered based on groundwater resources and conventional surface water systems and networks (Velayati, 2016).

Floodwater harvesting had been traditionally employed throughout the country by constructing earth and rock obstacles across the shallow and seasonal stream beds. Water and sediment could have been trapped and settled along the stream bed or being diverted towards flat areas located in two sides of the stream in a sequential manner. Sediment could have been first accumulated behind the obstacle providing fertile soil for any possible cultivation during the year whereas the complementary soil moisture could have been provided during successive flooding. Most of these systems have been gradually destroyed as a result of vulnerability to drought condition and occasional high discharge flooding (Nazari Samani, et. al, 2014).

In order to investigate the shortcoming of traditional methods, and demonstrating the potential of floodwater harvesting to combat water shortage and desertification in arid zone of the country, an evaluation is carried out in one of the representative catchments and some countermeasures are proposed for providing supplementary irrigation during critical stages of crop growing times when the in situ soil moisture would not be enough.

2. Materials and Methods

In order to evaluate the potential of flood water harvesting, Baharieh catchment located in Khorasan-Razavi province (N-E of Iran) with 33.5 km2 area is considered (Fig. 1). The selected catchment is mountainous with an average slope of 40% and long-term average rainfall of 290 mm.

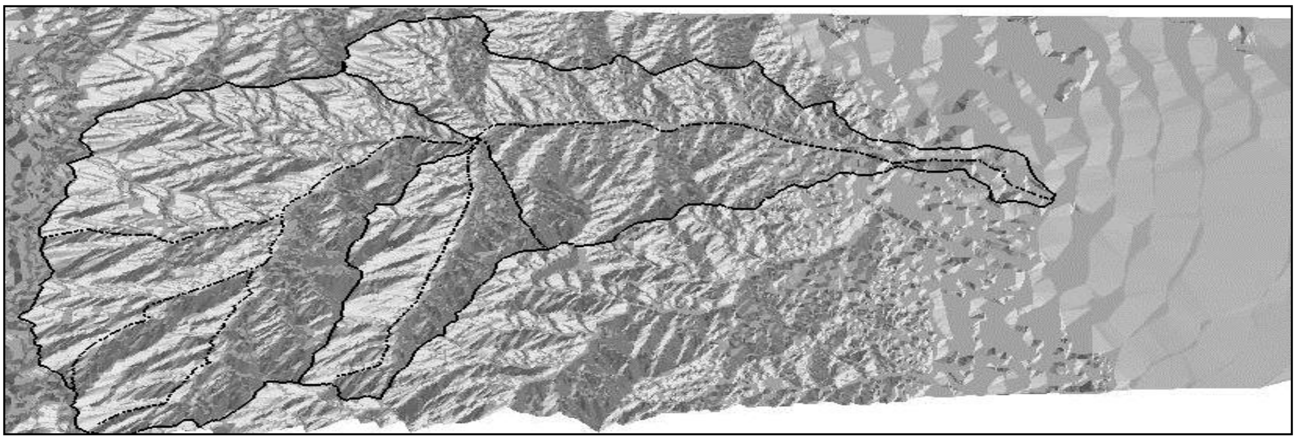


Fig. 1. The configuration of Baharieh catchment

Monthly rainfall distribution of Baharieh catchment along with water requirement for two typical local plant species are given in fig. (2) (i.e. pistachio and fruit trees, Farshi, 1997). Mismatch of the rainy season and crop growing season indicates one of the most important limitations in traditional floodwater harvesting which has been mainly dependent on the direct use of water for plant irrigation.

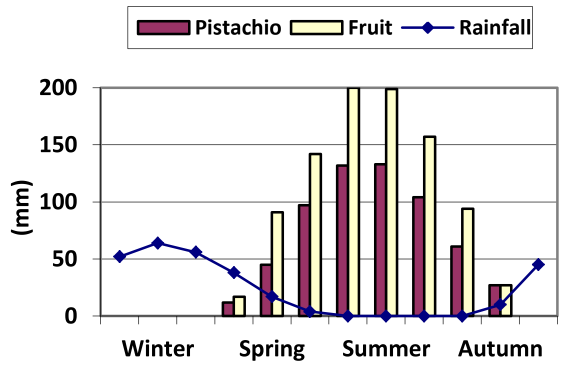


Fig. 2. average monthly rainfall and two typical crop water requirement distributions

Hot weather and longer dry seasons are coinciding together so that rainwater cannot be used for direct plant irrigation. It is well documented that in regions similar to what is considered in this study, micro-catchment water harvesting which is based on preserving soil moisture within the soil pores, would have never been enough for compensating the existing long dry period (about 7 months) with no rain at all. A water storage system with appropriate capacity should have been therefore considered in order to store winter and spring runoff (if it happens) and used for plant irrigation during the subsequent dry period of the year (Owais, T. Y, 2012).

In order to evaluate the potential of floodwater harvesting from the study area, the following stages were undertaken and are explained in the following sections of this paper:

- Using long-term rainfall data, potential runoff generation from selected catchment is estimated.

- A simple balance equation is employed for the determination of the required storage volume with respect to the risk of water shortage and cultivated area.

- The comparison is made between estimated runoff and in situ flood measurements during four years time (2005-2009).

3. Results and discussion

Floodwater estimation

a. Floodwater estimation

The selected catchment has not had long-term runoff data. There are only two hydrometric stations near the study area which are located along the Shast Darreh and Shesh Taraz rivers. Recorded inflow in the so-called Senobar station along the Shast darreh river was found more reliable because of having comparable catchment with study area (i.e. 75 km^2). Senobar hydrometric station is located in about 40 km east of the baharieh catchment from which precise flow water data are available about 26 years. Aforementioned information has been used for developing the following relationship between the most effective physical and climatic factors of the study region:

$$C = 0.084 – 0.0016\ A + 0.0014\ P$$

In which

C is yearly runoff coefficient, A is catchment area (km^2) and P is yearly rainfall (mm). This model is developed based on 20 years of runoff measurements for 13 nearby catchments with area changing from 37 km^2 to 108 km^2. Applying the model for Baharieh Catchment (A= 33.5 km^2 and P= 293.3 mm), runoff coefficient can be determined as:

$$C = 0.084 – 0.0016 * 33.5 + 0.0014 * 293.3 = 0.44$$

Yearly runoff volume can be obtained as:

$$V= C * A * P = 0.44 * 33.5 * 293.3 = 4.3\ Mm3$$

In order to obtain a monthly runoff distribution of Baharieh catchment, simulation is made according to a representative nearby basin and the results are shown in Table (1) (Ghafourian, 1996).

Table 1. Monthly runoff distribution for baharieh catchment

Month	1	2	3	4	5	6	7	8	9	10	11	12	sum
Runoff (%)	4	8.3	25.8	28.9	13.3	6.2	2.5	1.6	1.5	2.1	2.5	3.3	100
Runoff (Mm3)	0.17	0.38	1.03	1.13	0.53	0.25	0.1	0.06	0.06	0.08	0.1	0.13	4.3

a. Reservoir operation

One of the characteristics of study region which makes it different from dry lands of other countries (e.g. deserts and sandstones in Arab peninsula) is that the dry season in coinciding with summer time with hot temperature and maximum evaporation potential. This makes it impossible to grow many types of crops without complementary irrigation. It means that within the study area and any other region with similar climate, direct use of rainfall and runoff may not be useful enough for growing many crop types unless it can be collected in an appropriate reservoir for irrigation during the subsequent dry season (Owais, T. Y, 2012).

For the most cost-effective water harvesting scheme, a relationship between reservoir capacity, catchment size, and crop areas can be obtained according to runoff data and crop water requirements (Liaw, 2004). A simple flow balancing approach was followed, using monthly runoff crop water requirements. The balance equation ($\Delta S=I-O$, where I is a runoff, O is crop water requirement and ΔS is changing in storage) was repeatedly solved for the different crop to catchment area ratio r =a/A (where **a** is crop area and A is catchment size). A shortage criterion was introduced every time the reservoir ran dry and plant requirement exceeded available runoff volume. The shortage corresponding to a presumed reservoir size and crop area was calculated by summing up the monthly shortages and dividing it by total crop water requirements during one complete calculation cycle. Following the above-mentioned strategy, a design chart was developed that can be used to find the optimum combination of reservoir size and crop area ratio with respect to an acceptable risk of water shortage (fig. 3).

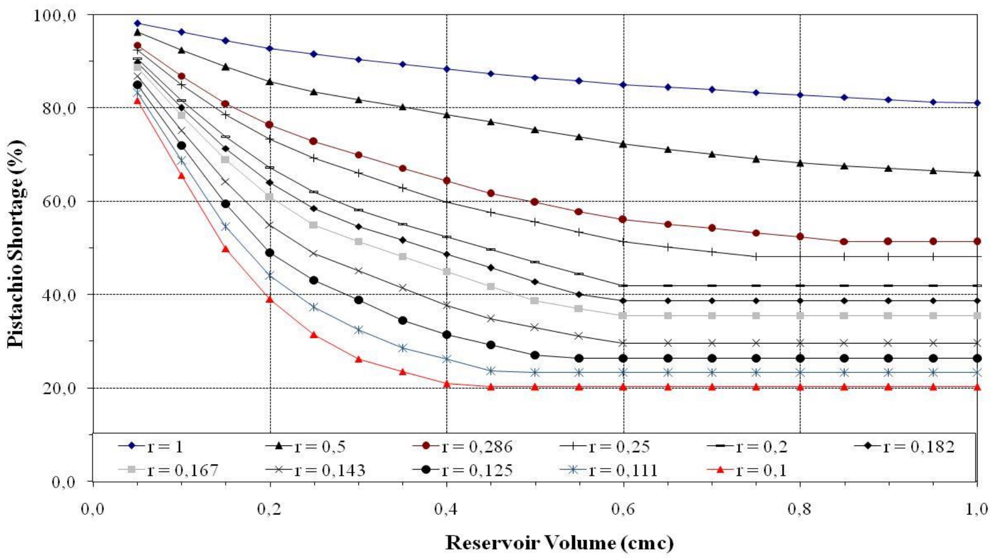
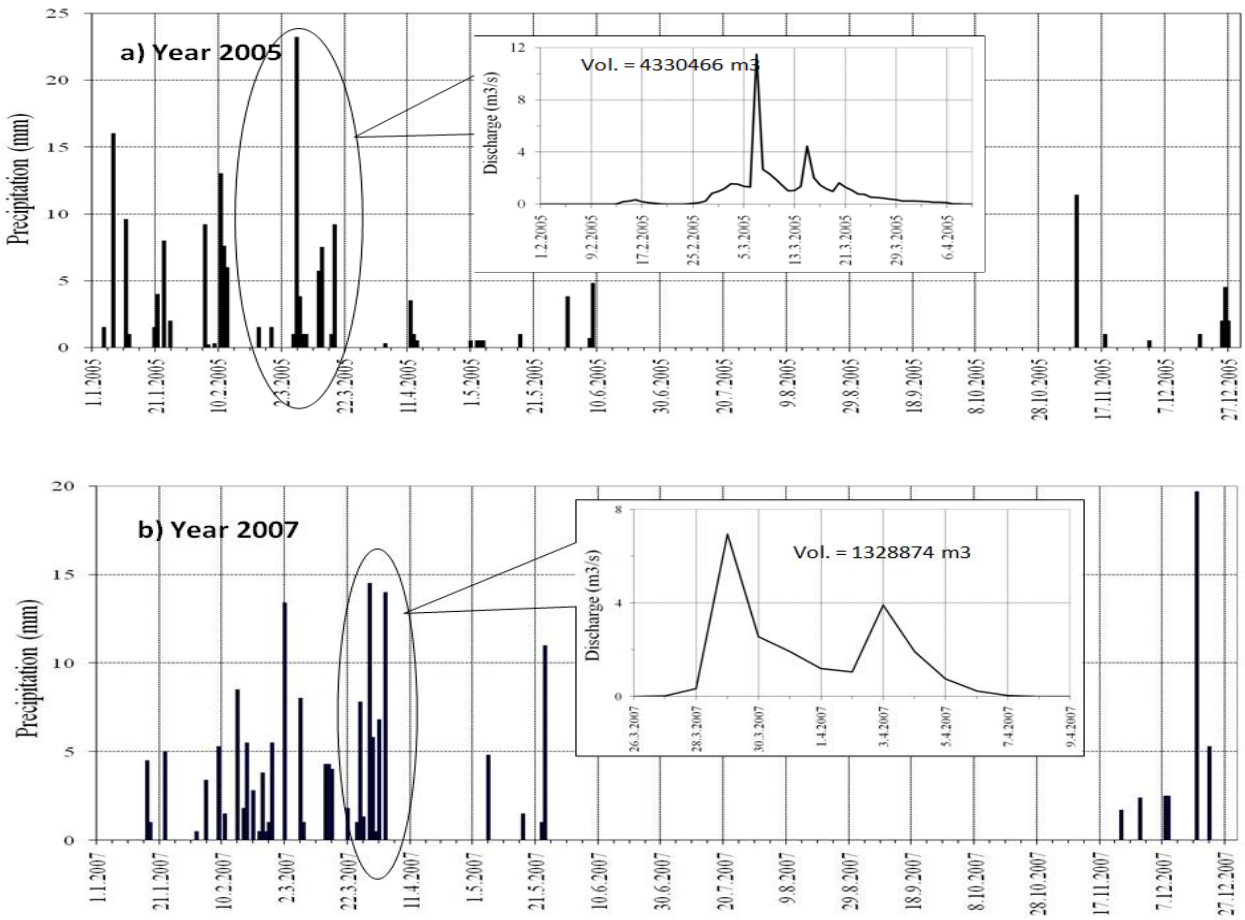


Fig. 3. Design chart for selecting reservoir size with respect to r ratio and shortages

It can be seen from the results that for a ratio of r=0.2 (as an example) if one selects a reservoir volume of 0.4 MCM, a shortage of about 50% may happen. By increasing the reservoir 0.6 MCM, the risk of water shortage may be reduced to about 40%. It is worthwhile to mention that if one selects the ratio of catchment to crop area r=0.2, then the reservoir capacity of more than about 0.6 MCM is not advisable since no more water can be collected from the catchment.

a. Field investigation

It is always advisable that any uncertainties about statistical analysis and correlation made for rainfall and runoff should be supported by field observations. This could be more important for small catchments when regional variation might affect the local behavior very considerably (FAO,1991). Therefore, three years of continuous measurements have been carried out at the outlet point of Baharieh catchment using a recording water level metering apparatus. Water level measurements have been made at a stabilized section of an outlet channel having a uniform cross section and constant bottom slope. Manning equation has been used to convert water level into the discharge. Daily rainfalls have been recorded simultaneously using a recording rain gage. The results of field measurements for rainfall and runoff are shown in Fig. (4-a, b, and c).



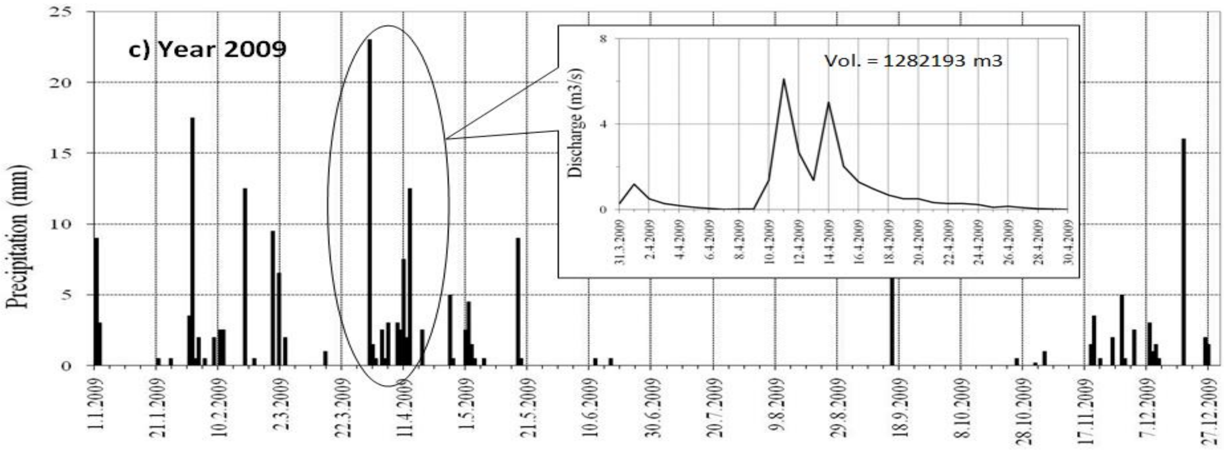


Fig. 4. Observed daily rainfall and runoff distribution, a) 2005, b) 2007, c) 2009

It can be seen that compare with the average historical rainfall data shown in Fig. (1), recent measurement has shown lower magnitudes (270 mm, 135.7 mm and 208.7 mm during 2005, 2007 and 2009 respectively). It means that the behavior of a small catchment may not be representative of some larger area. It is also demonstrated that most of the individual rainfall cannot be changed into a runoff since that only three considerable flood events have been recorded during the study period. It seems that rainfall magnitude and antecedent events should have had a predominant effect on runoff generation. It was observed that only high magnitude rainfall (more than about 20 mm) could have led to accountable runoff (see Fig. 4-a and c). Rainfall with less than about 15 mm magnitude can turn into runoff very occasionally depending on rainfall intensity and/or antecedent events (Fig. 4-a,b and c). It is shown that runoff generated during three-four years observations were more concentrated during the wet season when it is compared to more distributed model estimated by regional analysis shown in Table (1). It can be understood that Baharieh catchment has experienced a runoff coefficient equal to 0.48, 0.29 and 0.18 during the years 2005, 2007 and 2009 respectively.

4. Conclusion

Summary and conclusion

This paper proposes a countermeasure for ever-increasing water shortages in a semi-arid region of Iran. The characteristic of local Mediterranean climate is highlighted as a major constraint for direct use of seasonal runoff produced by small catchments (i.e. micro-catchment water harvesting). It is concluded that water storage is the only effective means of floodwater harvesting and utilization in the study region. A design chart has been developed and used for optimization of reservoir capacity with respect to cultivated area and the corresponding risk of water shortage. Rainfall and runoff measurement were carried out in order to evaluate hydrological data obtained by regional analysis. The results indicate that regional analysis might have caused overestimation for runoff volume unreliable monthly distribution. Taking into account the characteristics of recorded rainfall and resulting runoff, it can be understood that in most cases, the rainfall would not change into runoff and very occasional rainfall with the magnitude of about 20 mm are the only opportunities for floodwater harvesting. It is, therefore, the role of reservoir capacity to regulate the individual massive runoff for supporting distributed crop water requirements along the year.

5. References

Fahmi, H., (2014), "water crisis", Office of water and sewage major planning, Ministry of power (Oral presentation in Farsi).

Farshi, A.A., (1997). Estimation of water requirement for the main agricultural products, Soil and Water Institute, Ministry of Agriculture, Iran.

FAO, (1991), Water harvesting, A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production, FAO, Rome.Ghafourian, (1996). Feasibility study of Kashmar flood water spreading and aquifer recharge project.

Khorasan Agricultural and Natural Resources Research Center., Vol. 1.

Liaw, C.H., (2004). The optimum storage volume of rooftop rainwater harvesting systems for domestic use, J. of American Water Resource Association.

Ministry of Jahad-e-keshavarzi, (2015), "Upcoming crisis facing Iranian agricultural sector, Agri. PlaningT economic and rural development research institute, in Persian.

Nazari Samani, A.A., Khalighi, S., Arabkhedri, M. and Farzadmehr, J. (2014) Indigenous Knowledge and Techniques of Runoff Harvesting (Bandsar and Khooshab) in Arid and Semi-Arid Regions of Iran. Journal of Water Resource and Protection, 6, 784-792.

Oweis, Theib Y, Dieter Prinz, and Ahmed Y. Hachum, (2012), Water harvesting for agriculture in the dry areas, CRC Press/Balkema.

Velayati, (2016), water resources and water problems of Iran, Binalood Institute, Mashhad, Iran (in Persian).