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The Role of the Bandsar in Flood Control, Infiltration and Recharge of Water Resources

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Abstract

The need to provide food for farms and the lack of roads and cars for transportation in the past led to the invention and innovation of a check dam called Bandar. Bandsar as a watershed check dam is the most important rain fed lands in semi-arid climates (such as South Khorasan Province). This structure turns threats (season flooding) into opportunities. Bandsar is a traditional structure with several main goals such as: cultivation, flood mitigation and erosion control, water harvesting and infiltration, flood water spreading and groundwater recharge. Accordingly, in this research detected 435 Bandsar with 205 thousand cubic meter by using satellite images and field measurement , finally investigating the role of Bandsar in the floods hydrographic characteristics, water harvesting and infiltration of water resources in Seyujan-Tejk plain of Khosf city in South Khorasan province. For this goal, using climate data (1982-2020 period), topography map, cover plant, land use and features and capabilities of ArcGIS10.4 and HMS software. The results showed that Bandsars control 100% of the runoff from rainfall up to a 10-year return period and Bandsar output relative input hydrograph has 2 sharp characteristics; 1- lag to peak and 2- peak attenuation and 76.75% of the water harvesting is infiltration and recharge groundwater recourses.

Keywords: Bandsar, flood control, Hydrographic characteristics, Infiltration, GIS and HMS, South Khorasan Province.

1- Introduction

Flood-based farming systems (FBFS) are rainfed farming systems that occur in dryland areas and rely on supplementary water derived from various types of floods. Herein, floods are understood in terms of natural variability such as the rise of water in reservoirs (e.g., rivers, lakes, or dry wadis) during periods of high water (Junk et al, 1989). They should not be confused with flood disasters, but seen as a source of water farmers use to irrigate crops by virtue of agronomic flooding (Hail et al., 2010). In some areas, farmers invest substantial effort in building and maintaining complex physical infrastructures for water acquisition and sharing (Van Steenbergen et al, 2010). In other areas, farmers invest relatively little effort, since they deliberately plant crops on flood-prone land to be naturally irrigated by the coming floods, or on residual moisture from previous flooding (Harlan, 1969). FBFS usually occurs in relatively low-lying areas with gentle topography. Various forms of FBFS are found across the world's drylands, including many locations where farmers have been relying on these systems for centuries (Liman et al, 2017).

Water supply in FBFS is often difficult to predict due to uncertainties in the timing, duration, size, and frequency of floods (Hail, 2010). By making flood water available for use in agriculture, these farming systems contribute to food security and deliver many other benefits for millions of people in a wide range of geographies (Puertas et al, 2011).

The low precipitation and Mediterranean pattern in central and eastern Iran caused the winters to be floody and summers are dry and rivers are seasonal .Therefore, living conditions for animals, plants and humans have been associated with many difficulties and challenges (Dehghani, 2019). Floodwater harvesting has 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 be 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 conditions and occasional high discharge flooding (Nazari Samani et al, 2014). Lack of modern machinery and civil infrastructure in the past in Iran and the need to provide food on site caused the ancestors of our experts to overcome and manage flash floods with the creation of Qanat and Bandsar and runoff harvesting and infiltration, mitigation of summer water shortages and flood prevention. These structures are high tech in age past and present (Akbari, 2016; Aliabadi; Tabatabaee Yazdi and Han, 2017).

In the past, Bandsar was built with simple tools such as Pangekash[1] and today we use road construction machines (Bagheri, 2021). In the investigation of Bandsar, we find very rich indigenous knowledge based on sociology and human behavior versus the challenge of natural nature (Arabkhedri and Kamali, 2017).

Arabkhedri and Kamali (2017) studied Iranian Bandsar, showing that in addition to the suitable adaptation of this structure to the environment, Bandsar has a major and effective role in runoff and sediment control, charging groundwater, creating flood farming such as watermelon, melon and wheat and income and employment.

Flood harvesting in Bandsar improves the physical (clay, silt) and chemical properties of soil (Arabkhedri and Kamali, 2017; Akbari, 2016). Sheikh and et al. (2012) show that the traditional water harvesting system in the northeastern region of Iran, called Soma (a Turkmen word) has similar purposes. Bandar. This system is designed u-shaped with a height between 50 to 200 centimeters and intervals of 20 to 100 meters, Soma suitable for small watersheds. The aim of this study is to investigate Bandsar's role (the watershed check dam) in flood control, infiltration and charge of water resources, which is done using field measurement, satellite image interpretation, rainfall-runoff simulation and reservoir flood routing with the HEC-HMS model and GIS technique in Seyujan-Tejk watershed in the east of Iran.

The purpose of this study was to analyze the relationship of rain runoff in the arid area and the role of traditional systems in flood and runoff efficiency, so that it can be a good model for livelihood and prevent environmental degradation.

2. Data and Methodology

2.1. Study Area

Seyujan-Tejk plain is one of the most important agricultural plains of the province that people have employed the Bandsar watershed check dam for management Floodwater harvesting (Bagheri, 2021). This plain is located in Khosf city in South Khorasan province, between 58° 38' 48'' to 59° 2' 49'' E and 32° 53' 25'' to 33° 1' 32'' N. The upstream

1 - Local name

watershed of this area includes 30 hydrological basins by total area 356.7 Km^2. Elevation of general landscapes of the area ranges from 1372 m to 2399 m above the mean sea level. The mean annual rainfall is 160 mm (Birjand station), land use included rangeland, agricultural and bare (Rock) land. Figure (1) and table (1) show location and its physiographic characteristics upstream watershed.

2.2. Methodology

In this study, we used Birjand synoptic station, satellite image interpretation, field measurement and HEC-HMS and ArcGIS 10.4 software. The methodology can be divided into four major tasks: (1) selecting the geographic locations of the studied basins; (2) DEM processing, delineating watershed characteristics, 2 stream, and basin processing; (3) importing the processed data to HMS; and (4) merging the observed and historical data with the watershed characteristics for model simulations.

2.2.1. Digitizing Bandsar position and upstream basin

The basin model is the most important input to run the model and simulate rainfall-runoff. Based on satellite images, Google Earth and field measurements in Seyujan-Tejk plain steps are as follows. In first step, detect available Bandsar, and find 435, 2 step, measurement mathematical volume Bandsar that total volume of Bandsar have 205,000 cubic meters. 3 step watershed's boundary was defined in ArcGIS 10.4 software using topography map in 1:25000 scale that determine 31 sub basin in upstream Bandsar and Computed digital elevation model and physiographic characteristics of watershed such as: area, perimeter, time of concentration for each sub-basin (Table 1), In this study, four methods including Kirpich, California, Chow and SCS were used to calculate time of concentration Then model run's results indicate that using Kirpich method leads to more harmony and In final step integrated 435 Bandsar into 8 Bandsar for HMS reservoir routing design (Table 3).

2.2.2. Calculation of climatic parameters

The Seyujan-Tejk Watershed has ungauged rainfall statistics, therefore, to calculate the required parameters for the rainfall - runoff model used to use Birjand synoptic station which is located near to the watershed (30 Kilometers). To convert excess rainfall to runoff, daily continuous recorded rainfall data for the years 1982 to 2020 were collected from the South Khorasan Province Meteorological Organization. In the next step, calculated rainfall intensity-duration-frequency (IDF) by daily rainfall and Bell's formula and they determined daily rainfall in different return periods by using Hyfran software.

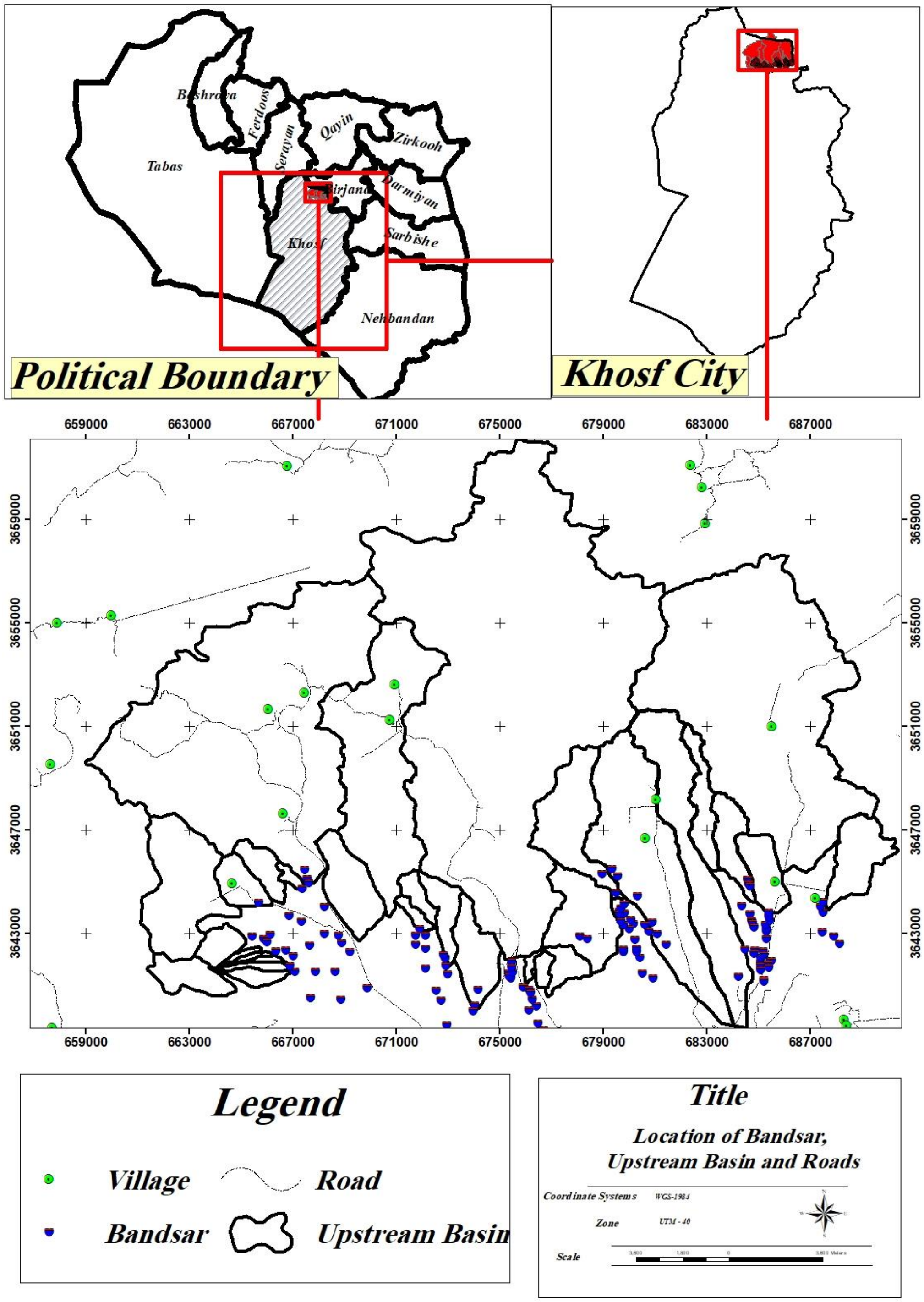

Fig. 1. Bandsar and upstream watershed location

Table 1. Physiographic characteristics of upstream watershed

Basin Name	Area (Km^2)	time of concentration (H)	Basin Name	Area (Km^2)	time of concentration (H)	Basin Name	Area (Km^2)	time of concentration (H)
Basin1	1.18	0.64	**Basin12**	4.84	0.76	**Basin22**	5.38	0.77
Basin2	0.66	0.54	**Basin13**	2.71	069	**Basin23**	3.59	0.93
Basin3	0.41	0.53	**Basin14**	1.40	0.49	**Basin24**	8.98	0.86
Basin4	3.27	0.49	**Basin15**	0.55	0.40	**Basin25**	23.47	1.42
Basin5	0.27	0.34	**Basin16**	7.65	0.78	**Basin26**	3.72	0.93
Basin6	0.77	0.39	**Basin17**	2.87	0.37	**Basin27**	15.78	0.74
Basin7	0.41	0.35	**Basin18**	2.32	0.50	**Basin28**	27.05	1.85
Basin8	0.29	0.35	**Basin19**	3.78	0.64	**Basin29**	74.02	2.23
Basin9	1.90	0.67	**Basin20**	5.95	0.52	**Basin30**	62.68	2.51
Basin10	1.99	0.30	**Basin21**	12.83	0.89	**Basin31**	120.08	4.13
Basin11	0.77	0.29						

2.2.3. HEC-HMS Model

HEC-HMS, also known as Hydraulic Engineering Center-Hydrologic Modelling System is a development of the United States Army Corps of Engineers, designed to simulate the precipitation-runoff processes of watershed systems belonging to the famous HEC (HEC-RAS, HEC-GeoRAS, HEC-GeoHMS) (Song et al., 2011). The HEC-HMS offers the opportunity to represent all natural or artificial entities installed in a basin (Scharffenberg, 2013). These elements influence the rainfall-flow transformation from sub-basins, outfalls to rivers and diversion of water channels.

Table 2. Daily rainfall height and 6 hours

return period	2	5	10	25
6 hours rainfall	3.2	4.9	6.0	7.4
daily rainfall	19	27.4	33.5	42.2

HEC-HMS, rainfall runoff which is happening in the watershed is described into six major components, i.e., meteorological component, loss component, direct runoff component, baseflow component, routing component, and reservoir component. For developing an HEC-HMS project, it needed four main contains the hydrologic elements (Sub-basin, reach, junction, reservoir, diversion, source, and sink) and their connectivity that represents the movement of water through the drainage system. Control specifications manager is one of the main components of the project and is principally used to control the time interval of simulation. (Sarminingsih et al, 2018).

The Seyujan-Tejk Watershed is ungauged flow statistics therefor for assessment bandsar role in floods hydrographic characteristics and runoff harvesting we selected HEC-HMS software. The HEC-HMS model is a developed version of HEC-1 under windows for surface runoff simulation in a watershed. Hydrologic Engineering Centers Hydrologic Modeling System (HEC-HMS) is user friendly and popularly used watershed model to simulate rainfall-runoff process and can solve different problems using graphical and widely in different studies, this software for studies of water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and systems operation(Majidi and Shahedi, 2012; Sardoii et al, 2012 and Choudhari et al, 2014). watershed network was created in HECHMS and used SCS models for precipitation converted to runoff This model estimates surplus precipitation as function of cumulative precipitation, soil cover, land use and previous moisture condition. Soil map of this study area prepared by consulting engineers of natural resources of and watershed management general office of South Khorasan and land use was prepared using Google Earth images and field management. for flood routing in river Muskingum method was chosen and calculated discharge in outlet basin number 29, 30 and 31 by measurement tide mark and Manning equations computed discharge and then calibrated model HMS output by change curve (CN) number by trial and error. The schematic drawing of the Seyujan-Tejk watersheds is shown in Figure 2

The study is based on analysis of climate and stream flow data used for HEC-HMS model calibration and validation. Field visits were done to ascertain the current land use in the basin for the model setup. The major inputs for the HEC-HMS model included the DEM, soil data, land use, and land management. The model was first calibrated and validated before simulating hydrologic processes scenarios. Multiple parameters such as CN and Time concentration were individually and manually adjusted (maximum-minimum) and the model was executed with identified reasonable ranges of the most sensitive parameters (Msaddek et al, 2020) The basin model (structural module of the basin) involves schematizing the catchment area in basic elements connected in form of a branched tree. HEC-HMS, also known as Hydraulic Engineering Center-Hydrologic Modelling System, is a development of the United States Army Corps of Engineers, designed to simulate the precipitation-runoff processes of watershed systems belonging to the famous HEC (HEC-RAS, HEC-GeoRAS, HEC-GeoHMS) (Song et al, 2011).

Table 3. Bandsar volume in HMS

No of Bandsar	1	2	3	4	5	6	7	8	Total volume (m^3)
Volume(m^3)	21285	42570	30745	23650	47300	7095	4730	28380	205755
No of Bandsar equivalent	45	90	65	50	100	15	10	60	435

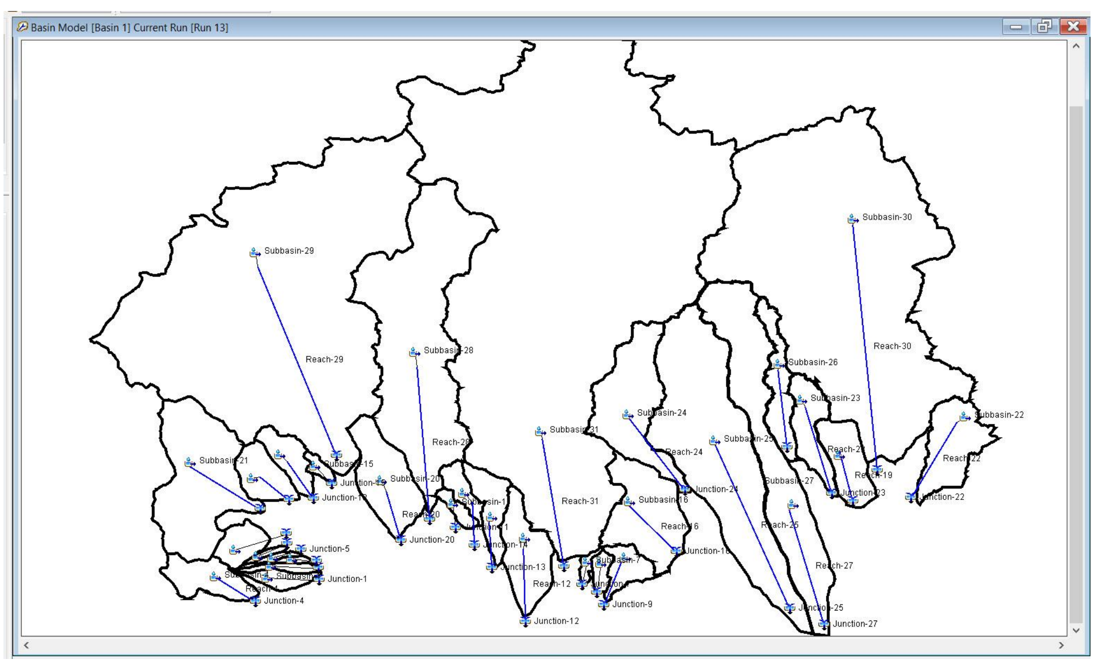

Fig. 2. Sub-basin division and model construction.

3. Results and discussion

3.1. The Bandsar role in runoff harvesting

The model was implemented in 2 conditions of daily precipitation and 6-hour precipitation.

The results showed (Table 4) that the Bandsar of the study area can control 100% of runoff in the 5-year return period; the amount of controlled runoff in the 10 and 25 year return periods is 71.6 and 48.7%.

3.2. The Bandsar role in floods hydrographic characteristics

The results of this study show that Bandsar, in addition to the role of runoff storage, can affect the peak flow and time to peak also increases the base time of the flood hydrograph. The input and output Bandsar hydrographs show in which the time to peak and peak attenuation has changed sharply. Statically, comparison of input and output Bandsar hydrographs were done by SPSS software. Due to the abnormality of the hydrograph data (Table 5), a non-parametric sign test was used which shows that dimensions of input and output hydrographs with P value 0.015 at 5% level are different (Table 6). Accordingly, the peak flow decreased from 8.7 to 3.1 m^3/s and the time to a peak increased by 1.5 hours (fig. 3).

Table 4. Runoff harvesting in return period

return period	**2**	**2**	**10**	**25**
Percentage of runoff harvesting from total runoff(daily rainfall)	8.9	4.8	3.5	2.5
Percentage of runoff harvesting from total runoff(6 hour rainfall)	100	100	71.6	48.7

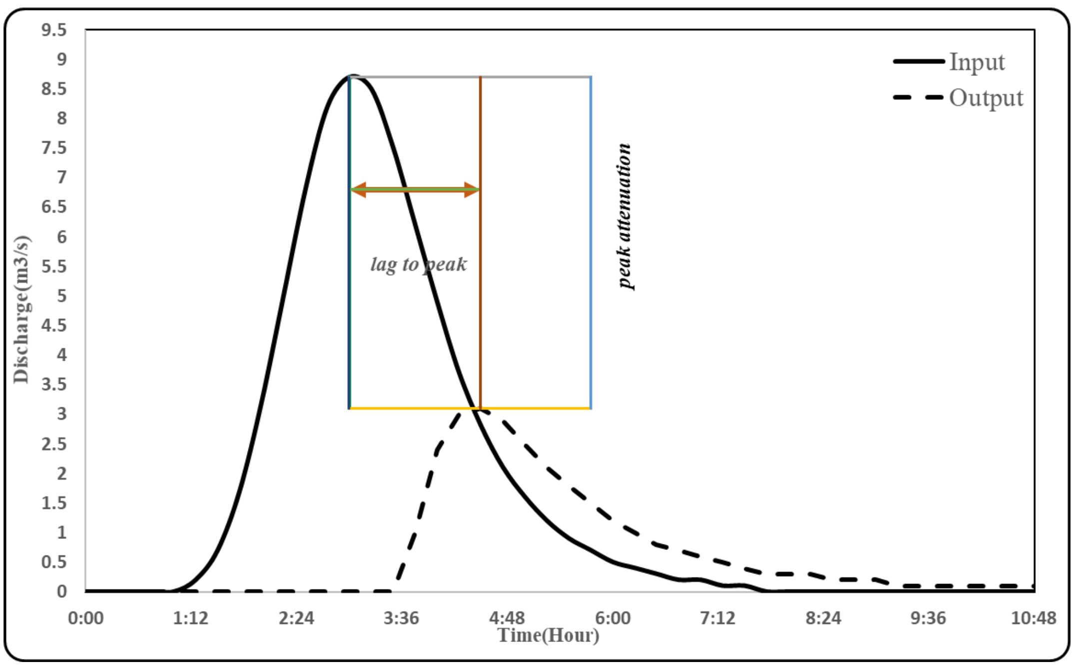

Fig. 3. Inflow and outflow hydrograph in Bandsar No. 2

Table 5. The results of Normality test

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Input	0.394	94	0.000	0.459	94	0.000
Output	0.377	94	0.000	0.487	94	0.000

Table 6. The results non-parametric sign test

	Output - Input
Z	-2.440
Asymp. Sig. (2-tailed)	0.015

3.3. The Bandsar role in infiltration

It is very important to investigate the infiltration status of the floods extracted in Bandsar. In this study, to investigate water infiltration in the Bandsar due to the occurrence of rainfall in the whole of the sub watersheds on 3th of Feb 20210 in the basin and produced flood in upstream and runoff harvesting in the bandsar, The height of water was measured daily during 6 days in 3 Bandsar. The height evaporation calculated by data evaporation recorded in same day at Birjand synoptic station then evaporation and infiltration height of each Bandsar are given per day that results showed in Table 3 and figure 4. Therefore, 76.75% of the water harvesting is infiltration.

Table 7. The results Infiltration and evaporation height daily (cm)

Statistical index		Infiltration			evaporation	water height			Time
Standard deviation	Average	No of Bandsar				No of Bandsar			
		3	2	1		3	2	1	
0	0	0	0	0	0.65	90	110	150	Day 1
4.08	29.77	24.77	29.77	34.77	0.23	65	80	115	Day 2
2.36	23.18	19.85	24.85	24.85	0.15	45	55	90	Day 3
2.05	16.79	16.46	14.46	19.46	0.54	28	40	70	Day 4
0.94	14.00	12.67	14.67	14.67	0.33	15	25	55	Day 5
2.05	6.44	6.11	4.11	9.11	0.89	8	20	45	Day 6

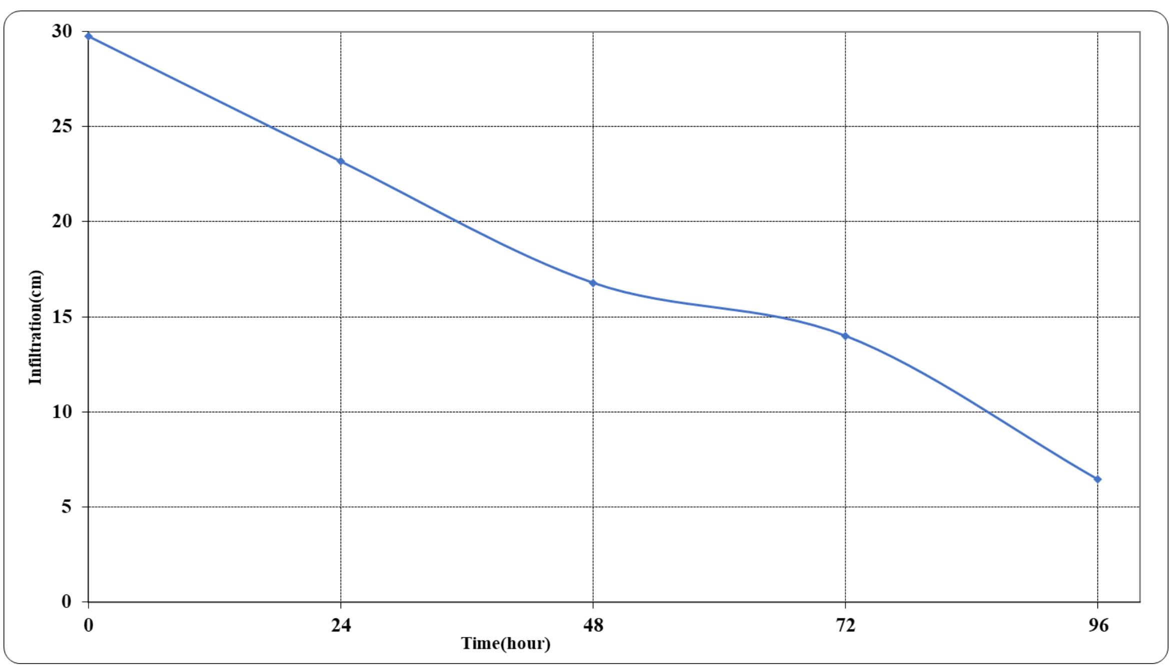

Fig. 4. Average instantaneous infiltration

4. Conclusion

Bandsar is a traditional structure with several and varied goals such as: cultivation, flood mitigation, water harvesting and infiltration, recharge groundwater resources, sedimentation. The purpose of this study was to investigate the role of traditional check dam structure for flood extraction, recharge of water resources and its effect on flood hydrograph characteristics, which is described by using field visits, satellite images, measuring water infiltration height, flood modeling and flood routing in Bandsar reservoir. In general, the Bandsar is part of the effort by Iranian local communities such as South Khorasan province to adapt to drought and water shortages.

The results can be divided into 3 major conclusion:

1- The Bandsar can be infiltrated by 76.75% of extracted water harvesting, 2- Traditional Bandsar is able to control 76% of runoff by a 10 year return period 3- Output hydrograph properties show the Babdsar can reduce the peak flow and increase the flow time.

5. Conflicts of Interest

No potential conflict of interest was reported by the authors.

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