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DOMESTIC RAIN WATER HARVESTING SYSTEM: A MODEL FOR RURAL DEVELOPMENT

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ABSTRACT
Rural India has a long tradition of rain water harvesting, but now a days the problem of availability of water is much more acute and serious. Demand of water is increasing very fastly due to increase in population, urban, industrial and agricultural development. Hence, here an attempt has been made to reveal the potential of roof rain water harvesting (RRWH) to satisfy the domestic water demand. The region selected for the present study is Dudhganga basin of Kolhapur district, Maharashtra as it was having the problem of water scarcity in summer season. Eight villages have been selected as a case study by stratified random sampling method and the roof top area and potential of rain water harvesting of these villages has been calculated by applying the Gould and Nissen formula. Saravade village is having the highest roof rain water harvesting potential as compare to others villages. The total roof rain water harvesting potential comes to about 365021.6 cu. m (365021600 lt). By applying the method of Dwivedi and Bhaduria (2009), a sample estimation of water tank capacity to fulfill the drinking and cooking water demands @ 8 liter per capita per day (LPCD) has been estimated from fifty five sq m roof top area. The total RRWH potential accounts for 60715 lt. and the overall cumulative demand of domestic water @ 8 LPCD is 17520 lt and @ 20 LPCD is 43800 lt. It also shows that only 28.85 per cent potential is sufficient to fulfill the domestic demand of water @ 8 LPCD.

KEY WORDS: Roof rain water harvesting, Collection efficiency, Runoff.

INTRODUCTION

Water is the most common and major substance on the earth, covering more than 71% of its surface. Out of the total volume of water available on the surface of the earth, only 2.5 per cent is fresh water. The fresh water is used for the purpose of human use, industries and agriculture (CGWB, 2007). In India, the per capita average annual freshwater availability has been reduced from 5177 cubic meters from 1951 to 1820 cubic meters in 2001 and it is estimated to further come down to 1341 cubic meters in 2025 and 1140 cubic meters in 2050 (Ministry of Water Resources, GOI, 2003).

India has a long tradition of rain water harvesting, but now a days the problem of availability of water is much more acute and serious. Demand of water is increasing very fastly due to increase in population, urban, industrial and agricultural development. According to the Ministry of Water Resources, water shortages in India will become even more pervasive by 2025 and may cause stress on human and economic development. It is crucial to make available the water at local levels by reducing its cost of transfer from great distance. In areas of Rajasthan, such type of attempt has been made where rainfall availability is at its minimum (Mishra, 1995). Rainwater harvesting has assumed overriding significance all the more in view of the depleting ground water levels during the recent droughts in various parts of India (Anyabandu, 2001).

The term rain water harvesting refers to direct collection of precipitation falling on the roof or onto the ground without passing through the stage of surface runoff on land (Athavale, 2003). Rainwater harvesting via roof top and ground catchments is an ancient technique of providing domestic water supply (Agarwal and Narain, 1997). Rainwater harvesting was invented independently in various parts of the world and on different continents thousands of years ago. It was especially used and spread in semiarid areas where rainfall occurs only during some months and at different locations creating inadequacy for major period of a year. Rainwater in many cases is the easiest to access, most reliable, and least polluted source. It can be collected and controlled by the individual household or community as it is not open to abuse by other users (T.W.D.B., 2005).

In view of the above, present investigation aims to measure the potential of domestic roof rain water harvesting in selected villages of Dudhganga basin and a sample estimation of water tank capacity to fulfill drinking water at domestic level has been carried out.

STUDY REGION

The region selected for the present study is Dudhganga basin of Kolhapur district. This basin drains south western part of Radhanagri, northern part of Kagal and southern part of Karveer tahsil of Kolhapur district comprising eighty villages. It is located between 16° 7’ to 16° 37’ north latitudes and 73° 53’ to 74° 20’ east longitudes. The region has diversified physiography, whose western border is demarcated by Western Ghats. The soil vary from laterite patches in the west to deep medium black alluvial of the river tracts in the central part and poor grey soil in the east. The monsoon climate dominates the region. The region receives rainfall mainly from south west monsoon, ranging between 3700 mm in the west to 1000 mm in the east. The total area of the study region is about 52,849 hectares.

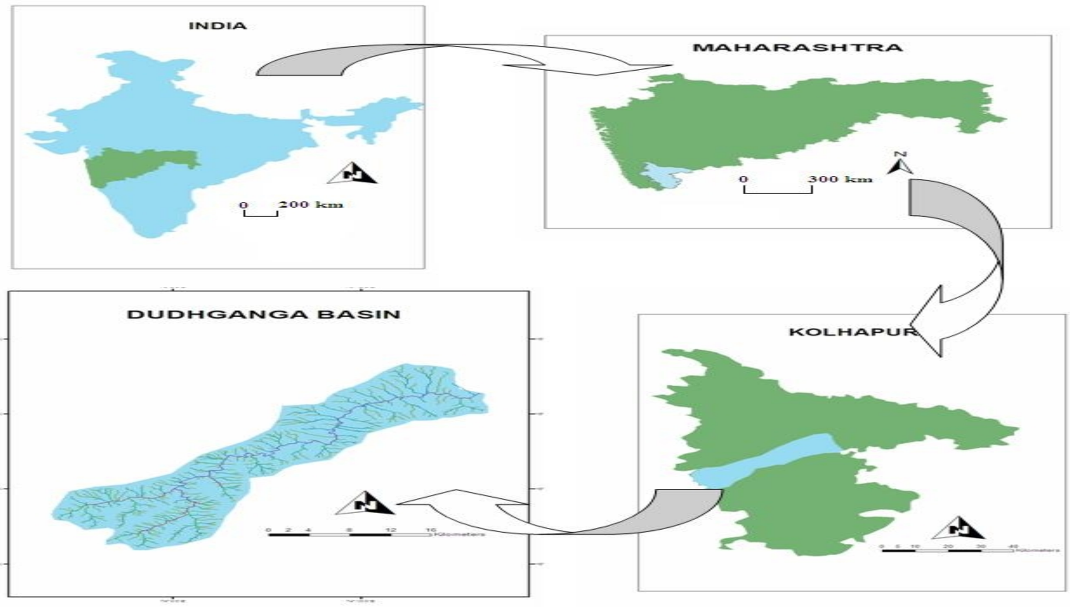

FIGURE 1: Study Region

METHODOLOGY

The present study is based on intensive field work while some secondary information such as population, agriculture, climate, rainfall, number of rainy days etc. were collected from the related departments.

The availability and type of roof for Domestic rain water harvesting has been collected from the concerned villages Gram Panchayat offices (Assessment records). During summer season, field trips were organized to know the severity of water scarcity by applying schedule technique. Collection Efficiency is not same for all type of roofs. It varies according to the type of roof. Ranade's collection efficiency index (Table 1) has been used here to calculate the coefficient of runoff. Here the villages have been selected by stratified random sampling method. The distance from the river basin is taken as strata to select the sample villages. Gould and Nissen formula (1999) has been adopted for calculating the potential of roof rain water harvesting in the selected villages.

The sample estimation of water tank capacity to fulfill drinking and cooking water demand @ 8 LPCD from roof top of fifty five sq. m is done by considering cumulative mean monthly demand and cumulative roof rain water harvesting (RRWH) potential.

Roof Rainwater Harvesting

In roof rainwater harvesting, the roof becomes the catchments, and the rainwater is collected from the roof of the house/building. It can either be stored in a tank or diverted to artificial recharge system. It is a system of catching rainwater where it falls. This method is less expensive and very effective and if implemented properly helps in augmenting the ground water level of the area. Roof rainwater harvesting is essentially one of such micro level attempt needs to be practiced. Traditionally, the rainwater collected from roofs was always stored in sumps. In modern days, the roof water is stored in a sump or recharged into the local aquifer. If roof water harvesting is practiced on a large scale in hilly area, then it will also help in reducing the severity of floods, which follows a heavy downpour. Similarly if it will be used for spot recharging by a large number of households, then it will help in restoring the water table and also in improving the quality of water. Water logging problem which is very common in rainy season could also be minimized. It will help to reduce the burden on the municipal water system that in general is always inadequate to meet the needs of each and every household (Panhalkar, Sapkale and Pawar, 2009). It also provides economic benefits to the householders. In view of this, present study aims to explore the potential of the roof rain water harvesting in Dudhganga basin.

Roof Rainwater Harvesting System:

In domestic Roof Rainwater Harvesting Systems, rain water from the house roof is collected in a storage tank to be used for domestic purpose during the periods of scarcity. Usually these systems are designed for drinking and cooking needs of a family. Such a system usually comprises a roof, a storage tank and gutters to transport the water from the roof to the storage tank. In addition to it a first flush diverter also put to prevent the entry of first monsoon shower in the storage tank. Therefore, a typical roof top Rainwater Harvesting System (Figure 2) comprises the following components:

* Roof catchments
* Gutters
* Down pipe
* First flush chamber
* Filter unit
* Storage tank

Among the above components, storage tank and filter unit are the most expensive and critical components. The capacity of the storage tank determines the cost of the system and reliability of the system for assured water supply and the filter unit assures the quality of the supplied water. Use of locally available materials reduces the overall cost of the system

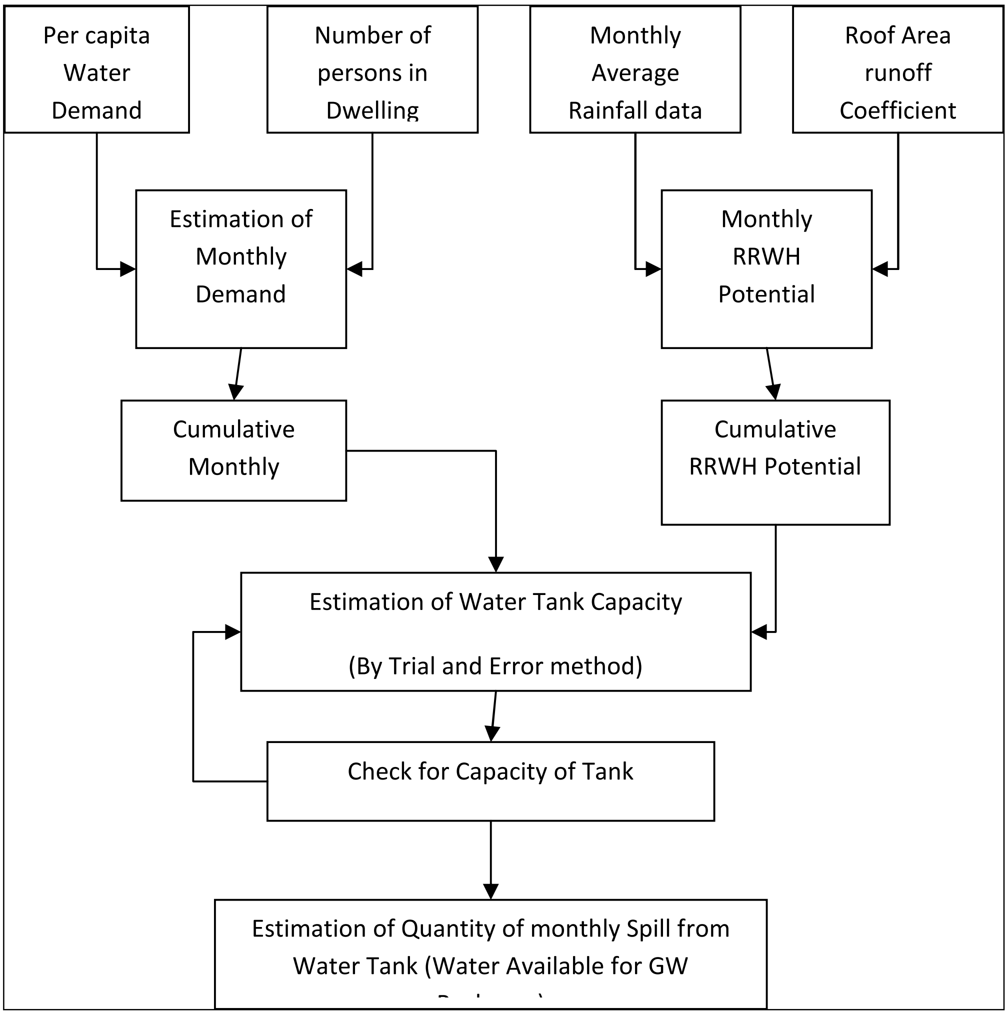

FIGURE 2: Flow Chart Showing Estimation of Water Tank Capacity and Water Available for Ground Water Recharge (Source: Dwivedi and Bhadauria, 2009)

Potential of Roof Rain Water Harvesting

Roof yield or the potential rainwater from a roof is normally referred to the annual yield from a given roof area. Annual yield is the quantity of water in liters collected from a given roof over a period of one year covering all the rainy days. It is the product of roof area and the annual rainfall. Quantification of the potential of RRWH depends upon the amount of rainfall, the area and type of the roof. Potential of roof rain water harvesting of sample villages is calculated by using following formula.

Gould and Nissen Formula (1999): $S = R \times A \times Cr$ (1)

Where,

S= Potential for roof rain water harvesting (In cu.m.)

R=Mean Annual Rainfall in m.

A= Catchment Area in m^2

Cr= Coefficient of Run off.

By applying the above formula, the potential has been extracted as per Table No. 2

TABLE 1. Coefficient of Run Off

Sr. No.	Type of Roof	Estimated Collection Efficiency (as % of precipitation)
1	Cement Concrete	85
2	Baked Tiles	60
3	Tin Sheets	75

Source: Ranade (2000)

TABLE 2: Potential of RRWH in Sampled Villages of Dudhganga Basin (In cu. m)

Sr.No.	Name of Village	No. of Households (2010)	Population (2001)	Roof Area in sq. meter	Potential in cu. m
1	Ispurli	609	2171	Cement Concrete-5511	8619
				Baked Tiles-23138.9	25545.3
				Tin Sheet-6822	9414.3
2	Yevati	593	3178	Cement Concrete-4134.1	4135.5
				Baked Tiles-24870.5	27457
				Tin Sheet-2985.8	41193
3	Majgao	320	1296	Cement Concrete-651.4	1018
				Baked Tiles-13079.5	14439.2
				Tin Sheet-1524.5	2103.8
4	Kurhadwadi	126	462	Cement Concrete-53.5	83.6
				Baked Tiles-6360.6	7022
				Tin Sheet-nil	-
5	Saravade	1994	6610	Cement Concrete-18477.8	28898
				Baked Tiles-88008.6	97161
				Tin Sheet-2764.8	3815.4
6	Solankur	854	2671	Cement Concrete-8225.2	12864.2
				Baked Tiles-35759.5	39478
				Tin Sheet-1198	1653.24
7	Boravade	1388	5493	Cement Concrete-2579.2	4033.8
				Baked Tiles-54462.6	60126.7
				Tin Sheet-115.1	158.8
8	Hanbarwadi	256	955	Cement Concrete-378.6	592.1
				Baked Tiles-10478.8	11567.7
				Tin Sheet-348.7	522.6

Source: Assessment Reports, Gram Panchayat Offices, Kolhapur, MS.

Sample Estimation of Water Tank Capacity and Ground Water Recharge

By applying the method of Dwivedi and Bhaduria (2009), a sample estimation of water tank capacity to fulfill the drinking and cooking water demands @ 8 LPCD has been calculated as per Table 3 from fifty five sq m roof top area. Mean monthly rainfall data of the study region is used to estimate the monthly roof rainwater harvesting potential by applying Gould and Nissen method.

The rainfall of the study region is seasonal as it is mainly limited for four months. A domestic water demand of a family (six persons) @ 8 LPCD for each month has been calculated. It ranges between 1488 lt. to 1344 lt. per month. The cumulative demand of a family is also calculated to find out the total yearly requirement of water. It comes to about 17520 lt. The overall cumulative demand @ 20 LPCD (UNO) comes to about 43800 lt. The graph shows that RRWH potential is quite high as compare to cumulative demand of domestic water. The total RRWH potential accounts for 60715 lt. and the overall cumulative demand of domestic water @ 8 LPCD is 17520 lt and @ 20 LPCD is 43800 lt. It also shows that only 28.85 per cent potential is sufficient to fulfill the domestic demand of water @ 8 LPCD. Monthly RRWH potential ranges between 23981 lt. to 36 lt. It is highest for July and lowest for February month.

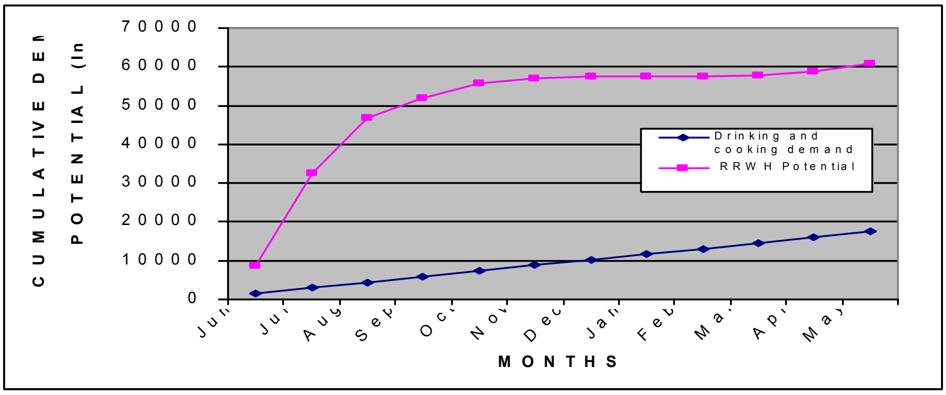

FIGURE 3. Comparison between Cumulative Water Demand and RRWH Potential

Estimation of optimum water tank capacity is very much crucial for proper functioning of RRWH system. Over or under estimation of storage tank can cause failure of RRWH system. The estimation of tank size to fulfill the drinking and cooking water demand @ 8 LPCD is done by considering the monthly water requirement of a family and monthly RRWH potential. The analysis reveals that sufficient RRWH potential to fulfill monthly domestic demand of water can be created for May, June July, August, September and October months. For rest of the months, water should be stored to fulfill the demand. The total water should be stored to utilize for the non monsoon period comes to about 5817 lt. Hence, the optimum capacity of water tank should be 6000 lt. The details of storage of the tank at end of the month have been given in figure 4.

However, as the estimated capacity of water tank is only 6000 lt, the overflow from the tank to ground water recharge is calculated. The analysis reveals that overall 60,715 lt RRWH potential can be created out of 17520 lt. is being used for domestic purpose and the remaining 43195 lt. water can be used for ground water recharge.

Thus this sample estimate gives the details of water tank capacity, RRWH potential and water available for ground water recharge from 55 sq. m roof top area of baked tiles.

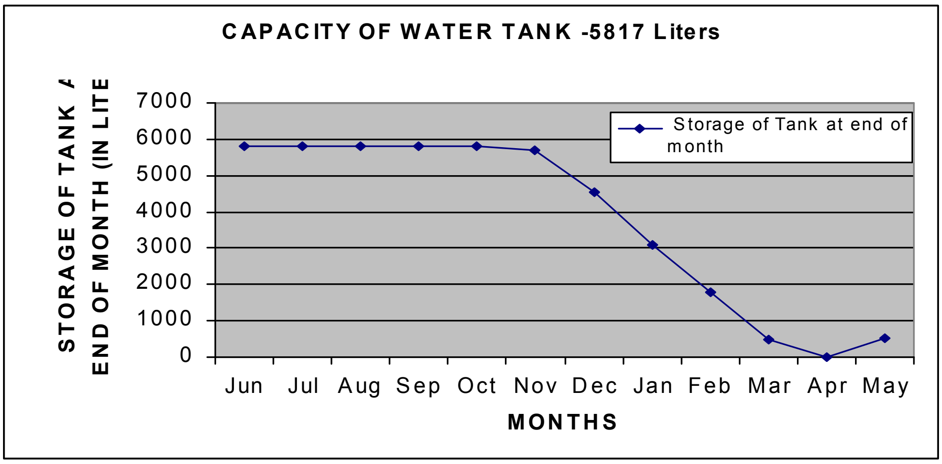

FIGURE 4: Storage of Tank at the End of Each Month

RESULTS AND DISCUSSION

The rainfall data of Dudhganga basin reveals 1840 mm mean annual rainfall as total rainwater supply. Eight villages have been selected by stratified random sampling method and the roof top area and potential of roof rain water harvesting of these villages has been calculated. The selected sample villages have 6140 households and the total population of 22836 (Census report, 2001). The analysis of roof area available for rain water harvesting reveals that about 62577.2 sq m. cement concrete, 282799.5 sq. m baked tiles and 19645.6 sq. m tin sheet roof area is available (Table 3). The overall percentage of baked tiles (77.47 %) is highest as compare to cement concrete or tin sheet type of roof area. As most of the peoples of this region prefer baked tiles over other available materials to construct roof of their individual houses.

However, the collection efficiency varies, according to the types of roof. The highest collection efficiency is observed for cement concrete roof and lowest for baked tiles (Ranade, 2000). By applying the Gould and Nissen formula, the potential of sample villages is calculated. Saravade village is having the highest roof rain water harvesting potential as compare to others villages of the study region. The total numbers of houses are mainly responsible for this. On the other hand, Kurhadwadi village is having the minimal roof rain water harvesting potential. The total roof rain water harvesting potential comes to about 365021.6 cu. m (365021600 lt.)

TABLE 3. Total Roof Top Area and Potential of Sample Villages.

No of villages	No. of Households (2010)	Type of Roof Area in sq.m	Potential in cu.m
Eight	6140	Cement Concrete-40011	62577.2
		Baked Tiles-256159	282799.5
		Tin Sheet-14236	19645.6
Total	6140		365021.6

Source: Compiled and computed by researcher

According to United Nations Organisation (UNO), it is assumed that 20 liters/capita/day water is inevitable for the rural communities in the developing countries. The United Nation targets it as minimum water requirement for all domestic purpose including personal hygiene also. The norms were set during International Drinking Water Supply & Sanitation Decade (IDWSS). Out of this 20 liters/capita/day water, 8 liters/capita/ day is required for drinking & cooking purpose. Therefore, if rooftop water harvesting is practiced in selected villages, that water would be sufficient for 799 days (20 liters/capita/day) and only 15 % of the total potential would be sufficient to fulfill the requirement of water during summer season.

TABLE 4: Estimation of Water Tanks Capacity to Fulfill the Domestic Water Demand by RRWH

MONTHS	DAYS	AVERAGE RAINFALL (IN mm)	DEMAND (COOKING AND DRINKING)@ 8 LPCD for six family members	CUMULATIVE DEMAND @ 8 LPCD	DEMAND @ 20 LPCD	CUMULATIVE DEMAND@ 20 LPCD	FROM ROOF TOP AREA OF 55 M^2 AND RUNOFF COEFFICIENT 0.60 (BAKED TILES)			
							RRWH POTENTIAL (In liters)	CUMULATIVE RRWH POTENTIAL (In liters)	TABLE(8-4)	STORAGE OF TANK AT END OF MONTH
1	2	3	4	5	6	7	8	9	10	11
Jun	30	259.6	1440	1440	3600	3600	8566	8566	7216	5817
Jul	31	726.7	1488	2928	3720	7320	23981	32547	22493	5817
Aug	31	431.7	1488	4416	3720	11040	14246	46793	12758	5817
Sep	30	154.8	1440	5856	3600	14640	5108	51901	3668	5817
Oct	31	118.7	1488	7344	3720	18360	3917	55818	2429	5817
Nov	30	39.7	1440	8784	3600	21960	1310	57128	-130	5687
Dec	31	10.22	1488	10272	3720	25680	337	57465	-1151	4536
Jan	31	1.5	1488	11760	3720	29400	49	57514	-1439	3097
Feb	28	1.1	1344	13104	3360	32760	36	57550	-1308	1789
Mar	31	5.9	1488	14592	3720	36480	194	57744	-1294	495
Apr	30	28.7	1440	16032	3600	40080	945	58689	-495	0
May	31	61.4	1488	17520	3720	43800	2026	60715	538	538
Total	365	1840.3	17520		43800		60715		-5817	

CONCLUSION

In the villages of Dudhganga basin, water deficiency conditions of summer season can be changed in to water surplus conditions by applying roof rainwater harvesting techniques. The total roof rain water harvesting potential of sample villages is 365021.6 cu.m. Therefore, if rooftop water harvesting is practiced in selected villages, that water would be sufficient for 799 days (@ 20 LPCD according to UNO) and only 15 % of the total potential would be sufficient to fulfill the requirement of water during scarcity period. A sample calculation of RRWH for fifty five sq. m roof area reveals that a potential of 60,715 liters can be created to fulfill the domestic water need and a water tank of 6000 liters would be sufficient to store the rain water which can be utilized throughout scarcity period for six family members.

The aforesaid analysis reveals that rain water harvesting would be the best alternative to deal with water deficiency conditions at domestic level in rural areas.

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