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Potential and Limits of Domestic Rooftop Water Harvesting in Una Area of Shiwalik Hills

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ABSTRACT: Water is very scarce resource in Shiwalik hills of Himachal Pradesh. It is very important for the survival of every human being but little attention is being paid for its conservation. Due to indiscriminate use of groundwater the water table is going down abnormally. Rainwater is the main source of water and if rainwater is harvested properly the water shortage problem can be eliminated to a large extent. Rainwater is free from organic matter and soft in nature. It is also bacteriologically pure. This is an ideal solution for a water problem, especially related to hilly areas where the ground water table is low and the surface sources are few and that too are found at a very low elevation in the valleys. The water has to be pumped to a high elevation where the habitations are situated. The rainwater harvested from rooftops can be stored in a tank and can be used directly. It can be used indirectly by diverting it to recharge the aquifer. Though Himachal Government has provided piped drinking water facilities to all of its population in state yet there are areas which face acute shortage of water during dry months. The paper aims toward the development of the framework for domestic rooftop harvesting for household use. The paper is based on the analysis of survey record of 40 houses of different roof areas of Una district in Shiwalik hilly region of Himachal Pradesh in India. The estimation of the appropriate size of the water tanks to fulfill the annual drinking water demand through Domestic Rooftop Harvesting has been done. The domestic rainwater Harvesting (DRWH) has been designed considering the existing rainwater outlets and types of roof prevailing in the area.

Keywords: Domestic Rooftop Rainwater harvesting, Shiwalik hills, Water shortage

INTRODUCTION

Water is the most valuable resource on earth and an integral part of the environment. The water scarcity is a serious problem throughout the world both for rural and urban communities due to increasing population, urbanization, industrialization and use of chemicals in agriculture. Water forms three fourth of our planet and is vital for all known forms of life. On our earth 96.5% of water is found in oceans, 1.7% in ground water, 1.7% in glaciers and ice caps, and a small fraction in other large water bodies. Only 2.5% of the Earth's water is fresh water and 98.8% of this water is in the icecaps and groundwater. Less than 0.3% of all freshwater is in rivers, lakes and atmosphere (CGWB 2007). In India per capita average annual freshwater availability has declined from 5177 cubic meters from 1951 to 1820 cubic meter in 2001 and it is estimated to further come down to 1341 cubic meters in 2025 and 1140 cubic meters in 2050 (MOWR 2003).

In fact India is blessed with adequate rainfall as a whole and the average annual precipitation is about 1170 mm. This is much higher than the global average of 700 mm. However the rainfall distribution in time domain is skewed with 75% of it taking place only in monsoon season. There is also very large spatial variation (Athavale 2003).

Rain is ultimate source of water. The demand for water is increasing due to increase in population, urbanization, industrialization and agriculture development. According to Ministry of Water Resources, water shortage in India will be more acute by 2025 and may cause stress on human and economic development. India has an age old tradition of water harvesting. Mohenjodaro, the largest city belonging to Harappa culture had over 700 open wells (Dhavalikar 1999). The citizens of Dholavira had constructed check dams across streams (Bisht 1994). The rainwater harvesting has assumed overriding significance all the more in view of depleting groundwater levels during recent years in many parts of India. In Shiwalik hills of Himachal Pradesh people face acute shortage of water every year (Singh et al 2010[a]). The Shiwalik region is characterized by slope wash material comprising of loose soil deposits underlain by boulders and pebbles. The deposits have generally moderate to high percolation rates where the soil cover is thin. Often the ground water gradient is steep which is conducive to quick drainage of ground water into nearby stream (Singh et al 2010[b], Singh et al 2011)

The term rainwater harvesting refers to direct collection of precipitation falling on the roof or on the ground without passing through the stage of surface runoff on land (Verma et al 2012). Rainwater harvesting through roof and ground catchments is an ancient technique of providing water supply (BIS 1742-1983). This is an ideal solution for a water problem, especially related to hilly areas where the ground water table is low and the surface sources are few and that too are found at a very low elevation in the valleys (Yie-Re Chiu et al 2009). The water has to be pumped and transported to a high elevation where the habitations are situated (IE, 2006). Rainwater harvesting has assumed significance in view of depleting ground water levels (Ariyabandhu 2003). Rainwater harvesting is an innovative energy saving approach for hilly communities to growing water-energy shortage dilemma (Mishra, 1995, Sharma and Chandel, 2012[a]). The rainwater harvested from rooftops can be stored in a tank and can be used directly (Sharma and Chandel 2013).

Though the practice of rooftop rainwater harvesting and storing has been in vogue since time immemorial, scientific and systematic planning has got the attention during the last few decades only. Since then many studies have been reported and are being undertaken in the country and the world over (Frasier 1980, Michaelides 1990, Khan, 1995, Saleem and Gupta 2000, Dwivedi and Bhadauria 2009, Panhalkar, 2011). Many studies from water deficient area of south India have also been reported (Vishwanath 2001, Pathak et al 2002, Sharma & Chandel 2012[b], Shivkumar 2005, Yadupathi and Raje 2005).

In view of the above, present study aims at measuring the potential of domestic rainwater harvesting in selected villages of Satluj River basin and a sample estimation of water tank capacity to fulfill drinking water needs at household level.

MATERIAL AND METHODS

1. Study Region: The region selected for the present study is Una district in Shiwalik hills of south west part of Himachal Pradesh. It is well developed district in industrial sector due to its close proximity to Punjab. The tract is hilly covered by Shivalik range. It is located between 75^0 58’ to 76^0 28’ E longitude and $31^0$17’ to $31^0$52’ N latitude. The elevation varies from 350 meters to 1200 meters having the configuration ranging from the almost flat-lands that border the portion of Swan to the lofty heights of cliffs and precipitous slopes of hill-ranges. It is situated at lower elevation and comparatively warmer but has some hilly ranges covered with scrub and Pine forests. This district was made in 1972 by carving it out from the Kangra district. It is well connected by roads from all sides. Swan river flows through it. The Monsoon climate dominates the region. The region receives rainfall mainly from south western monsoon, ranging from 731 mm to 2460 mm. In summer the climate is hot and in July to September it is rainy and humid. The total area of the study region is about 1549 square kilometers (GOHP, 2000).

2. Methodology: The study is based on field work done in the region during 2014. Secondary data regarding population, climate, rainfall etc was collected from respective departments. The availability and type of roof for rainwater harvesting has been collected from the concerned village, Panchayat offices. During summer season, field visits were organized to know the severity of water scarcity. The collection efficiency of all the roofs is not same. The collection efficiency index developed by Ranade (Table 1) has been used to calculate the co-efficient of run-off (Ranade 2000). The villages were selected by stratified sampling method. The distance from river basin has been taken as strata to select the sample villages. The potential of rainwater harvesting has been calculated using Guold and Nissen Formula (Guold and Nissen, 1999). The sample estimation of water tank capacity to fulfill drinking water needs @ 40 LPCD from rooftop of 100 Sqm has been done by considering cumulative mean monthly demand and cumulative rainwater harvesting potential.

3. Potential of Rooftop Rainwater Harvesting: The potential of rainwater harvesting from the roof is normally called annual yield from a given roof area. It is the quantity of water in liters collected from a given roof over a period of one year covering all rainy days. It is the product of roof area and the annual rainfall. It depends upon the amount of rainfall, the area and the type of roof. The potential of rooftop rainwater harvesting has been calculated by using the following formula.

$$S = R \times A \times Cr \qquad \text{[Gould \& Nissen Formula, (1999)]} \qquad \ldots\ldots\ldots\ldots (1)$$

Where, S = Potential for rooftop rainwater harvesting (Cu.m); R = Mean annual rainfall in meters; A = Roof Area in Sq.m and Cr = Co-efficient of runoff

The Table 1 below shows the co-efficient of run off for various types of roof materials. In Una district 16.51% of the houses have slanting Slate roofs and 71.65% houses are flat cement concrete roofs (Table 2). The size of the family in Himachal Pradesh varies from single member family to nine and more. Maximum numbers of families' i.e 25% have 4 members in their families followed by 22.7% have 6 to 8 members in their families (Table 3).

Table 1: Coefficient of Run Off

S.No	Type of Roof	Estimated Collection Efficiency (as % of precipitation)
1	Cement Concrete	85
2	Baked Tiles	60
3	Tin sheets	75
4	Slate	80-85
Source: Ranade (2000)		

Table 2: Type of Roofs in Una District

Sr No	Type of Roof Material	No. of Houses	Percent of Total Houses
1	Grass/Thatch/Bamboo	3592	3.27%
2	Plastic Polythene	577	0.53%
3	Handmade tiles	566	0.52%
4	Machine made Tiles	281	0.26%
5	Burnt bricks	2041	1.86%
6	Stone/Slate	18112	16.51%
7	GI Sheet/Asbestos	5758	5.25%
8	Concrete	78608	71.65%
9	Others	164	0.15%
	Total	109699	100%
Source: Govt of India, Census data 2011			

Table 3: Size of House hold in Himachal Pradesh

Sr No	Size of Family (No of persons)	No of Houses	Percentage of Total Houses
1	1	84146	5.7%
2	2	131951	8.94%
3	3	194043	13.14%
4	4	371885	25.19%
5	5	291513	19.74%
6	6 to 8	335807	22.74%
7	9+	67236	4.55%
Source: Govt of India, Census data 2011			

4. Sample Estimation of Water Tank Capacity and Ground Water Recharge: A sample estimation of water tank capacity to fulfill the drinking water demands @40 LPCD has been calculated as per Table 4 from 100 Sq.m. rooftop areas. Mean monthly rainfall data of the study area has been used by applying the Gould and Nissen formula. The rainfall in the region is seasonal and it is mainly limited for four months. Monthly average rainfall data has been used for calculating rainwater harvesting potential (Table 5). It has been observed that the average roof area of houses in villages is 100 Sqm. A domestic water demand of 5 persons @ 40 liters per head per day has been calculated. It ranges in between 5600 to 6200 liter per month. The cumulative demand of a family has also been calculated to find out the total yearly requirement of water. It comes out to be 73000 litre. The graph shows (Fig 1) that DRWH potential is quite high as compared to cumulative demand of domestic water. The total DRWH potential accounts for 112544 litre and the overall cumulative demand for domestic water @ 40 lpcd is 73000 liter. It also shows that only 65% potential is sufficient to fulfill the domestic demand of water @ 40 lpcd. Monthly rainwater harvesting potential ranges in between 587 liter to 35131 liter. It is highest for July and lowest for the month of November.

The estimation of optimum water tank is very much crucial for proper functioning of DRWH system. Over and under estimation storage tank can cause failure of the system. The estimation of tank size to fulfill the drinking water demand @ 40 lpcd has been done considering the monthly water requirement of a family and monthly rainwater harvesting potential. The analysis shows that sufficient DRWH potential to fulfill monthly domestic demand of water can be created for May, June, July, August, September and January and February months. The total water should be stored to utilize for the non monsoon period. It comes out to be 28113 liters. Hence the optimum capacity of water tank should be 28113 liters, say 28200 liters. The details of the storage at the end of the month have been given in Fig 1. However, as the estimated capacity of the water tank is only 28200 liter, the overflows from the tank to the ground water recharge have been calculated (Table 4)

Thus this sample estimate gives the detail of water tank capacity, Rooftop Rainwater Harvesting potential and water available for ground recharge from 100 Sq m rooftop of Concrete roof for a 5 member family. Similar calculations have been made for & 50, 75, and 125 sq.m, 150 sq.m of roof area.

The percentage of water demand that can be fulfilled by DRWH systems from different roof top areas for a four member family has been shown in Table 6.

Table 4: Sample calculation of RWH for 100 Sqm concrete roof areas for 5 member family (Co-eff of Runoff 0.85)

Month	Days	Average Rainfall mm	Water demand @ 40 lpcd	Cummulative water demand @ 40 lpcd	RWH Potential liters	Commu RWH potential	Montly potentail demand @40lpcd	Storage at the end of month after meeting demand @40lpd	RWH potential available for GW recharge	%age of demand that can be met from RWH during month
Jun	30	98.9	6000	6000	8407	8407	2407	2407	0	140
July	31	413.3	6200	12200	35131	43538	28931	28113	818	567
Aug	31	410.7	6200	18400	34910	78448	28710	28113	597	563
Sept	30	160.1	6000	24400	13609	92057	7609	28113	0	227
Oct	31	22.3	6200	30600	1896	93953	-4304	23809	0	31
Nov	30	6.9	6000	36600	587	94540	-5413	18396	0	10
Dec	31	12.8	6200	42800	1088	95628	-5112	13284	0	18
Jan	31	42.4	6200	49000	3604	99232	-2596	10688	0	58
Feb	28	58.1	5600	54600	4939	104171	-661	10027	0	88
Mar	31	41.6	6200	60800	3536	107707	-2664	7363	0	57
Apr	30	25.7	6000	66800	2185	109892	-3815	3548	0	36
May	31	31.2	6200	73000	2652	112544	-3548	0	0	43

Table 5: Rainfall Data of Una District (H.P.)

Year	Jan	Feb	March	April	May	June	July	August	September	Oct	Nov	Dec	Annual Total
1991	2.1	70.2	34.6	10.1	2.0	30.3	172.1	426.5	267.2	0.0	0.0	46.3	**1061.4**
1992	98.1	70.6	55.1	0	45.2	104.0	338.0	770.80	61.0	2.5	24.6	0.0	**1569.9**
1993	27.4	7.3	34.2	0	5.4	43.1	476.3	43.3	91.2	0.0	3.5	0.0	**731.7**
1994	39.7	135.2	2.2	42.4	27.8	71.2	1369.1	421.1	218.6	0.0	0.0	12.1	**2339.4**
1995	75.4	164.5	76.0	84.5	0	101.1	812.6	761.5	384.0	0.0	0.4	0.0	**2460.0**
1996	34.5	129.2	30.0	13.7	11.3	134.6	586.1	547.6	88.9	113	0.0	2.1	**1691.0**
1997	35.2	17.8	16.2	35.8	25.9	47.2	192.6	644.1	226.6	12.9	28.6	66.9	**1349.8**
1998	10.0	93.9	64.2	21.1	6.8	106.4	383.2	406.4	282.3	68.2	0.0	0.0	**1442.5**
1999	47.6	0.4	18.0	13.0	63.0	175.0	338.1	426.6	124.8	0.0	0.0	0.0	**1206.5**
2000	63.0	6.0	24.0	6.0	70.0	100.0	403.0	240.0	123.0	0.0	0.0	0.0	**1035.0**
2001	33.0	5.0	34.0	97.0	55.0	129.0	323.0	448.0	42.2	0.0	22.1	16.3	**1204.6**
2002	26.7	25.0	41.4	52.2	34.3	38.7	223.0	568.0	116.5	0.0	0.0	0.0	**1125.8**
2003	77.2	101.0	93.2	13.0	0.0	84.0	552.0	235.0	366.0	0.0	10.0	0.0	**1531.4**
2004	121.0	15.0	0.0	47.0	12.0	167.0	365.0	199.0	139.0	155.0	5.0	27.0	**1252.0**
2005	65.0	142.0	23.0	4.0	70.0	41.0	292.0	78.0	52.0	0.0	0.0	0.0	**767.0**
2006	41.0	0.0	121.0	0.0	81.0	187.0	333.0	353.3	112.0	8.0	8.0	2.9	**1247.2**
2007	0.0	81.8	130.8	20.4	25.2	48.8	225.0	386.0	51.6	4.2	0.0	23.0	**996.8**
2008	24.8	14.2	0.0	20.4	12.2	246.6	181.2	394.6	152.2	25.8	0.0	0.0	**1072.0**
2009	14.6	45.0	31.8	31.2	25.3	44.2	430.9	454.3	84.1	20.6	30.2	0.0	**1212.2**
2010	10.8	38.4	2.4	1.3	52.4	79.5	270.4	409.6	217.9	35.1	5.8	58.7	**1182.3**
Average	**42.4**	**58.1**	**41.6**	**25.7**	**31.2**	**98.9**	**413.3**	**410.7**	**160.1**	**22.3**	**6.9**	**12.8**	**1323.9**

Table 6: Percent of water demand fulfilled by DRWH from different roof-top area for 5 member family (for Concrete Roof)

Month	Roof Area in Sq. m				
	50	**75**	**100**	**125**	**150**
June	70	105	140	175	210
July	283	425	567	708	850
Aug	282	422	563	704	845
Sept	113	170	227	284	340
Oct	15	23	31	38	46
Nov	5	7	10	12	15
Dec	9	13	18	22	26
Jan	29	44	58	73	87
Feb	44	60	88	110	132
March	29	43	57	71	86
April	18	27	36	46	55
May	21	32	43	53	64

Source: Sharma, M. R. & Chandel R. S. (2013)

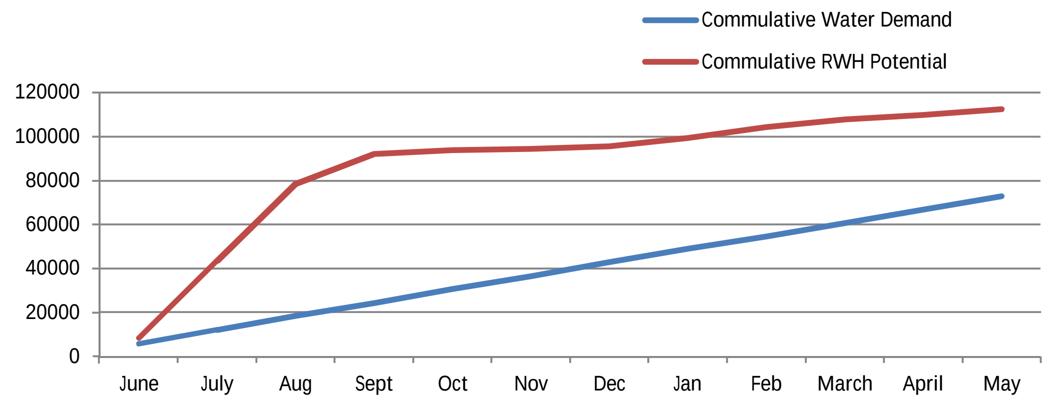

Figure 1: Commulative water demand and Commulative RWH for 100sqm concrete

RESULTS AND DISCUSSION

The rainfall of the Una area reveals 1323.9 mm mean annual rainfall as total water available. 6 villages were selected by stratified random sampling method and the roof area and potential of roof rain water harvesting of these villages has been calculated. The analysis of the roof area available for rainwater harvesting reveals that there are about 16.5% Slate roofs, 71.65% concrete roofs and 5.25% of tin roofs are available (Table 3) The overall percentage of Concrete roofs 71.7% is the highest as compared to slate roof in the area. Earlier most of people of this area preferred slate roofs but now the trend is for the concrete roofs.

According to United Nations Organisation (UNO), it is assumed that 40 liter/capita/day water is inevitable for the rural communities in the developing countries. Out of this 40 liter/capita/day, 8 liter/capita/day is required for drinking and cooking purpose (Athavale 2003). Therefore if rooftop rainwater harvesting from 100Sqm roof area is practiced in selected villages, that water would be sufficient for 562 days and only 64% of the total potential would be sufficient to fulfill the requirements of water for domestic use @ 40 lpcd. It has been observed that if the roof area is 50 Sq.m the surplus water after meeting domestic demand from rooftop is available for three months only but if roof area is increased to or 77 or 100 square meters the surplus water available would be for four months. The surplus water would be available for five months for a roof area of 125 and 150 square meters after meeting domestic demand. The optimum size of tank has been worked out as 28113 litre or 28200 litre (Table 4)

CONCLUSION

Una area, which is affected by water deficiency during summer season, can be changed into a water surplus region by applying rooftop rainwater harvesting techniques. The above analysis reveals that rainwater harvesting would be best alternative to deal with water deficiency conditions at domestic level in rural areas of Shiwalik hills. However the requirement of storage tank size is large as there is little rain in non monsoon months.

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