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Potential and Limits of Domestic Rooftop Water Harvesting in Hamirpur 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 Hamirpur 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 (DWRH) 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.

I. INTRODUCTION

The water scarcity is a serious problem throughout the world both for rural and urban communities due to increasing population. Water forms 71 percent 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* 2010a). 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* 2010b, 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). 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, 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 Beas basin and a sample estimation of water tank capacity to fulfill drinking water needs at household level.

II. MATERIAL AND METHOD

Study Region. The region selected for the present study is Beas basin of Hamirpur district in Shiwalik hills of Himachal Pradesh. The tract is hilly covered by Shivalik range. It is located between 76^{0}18' to 76^{0} 44' E longitude and 31^{0} 25' to 31^{0} 52' N latitude. The elevation varies from 400 meters to 1100 meters having the configuration ranging from the almost flat-lands that border the portion of rivers Beas to the lofty heights of cliffs and precipitous slopes of hill-ranges. There are three principal ranges which run in a South-Easterly direction. It is situated at lower elevation and comparatively warmer but has some hilly ranges covered with 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. Hamirpur is the most literate district in Himachal Pradesh. Beas river flows through the northern part of it and Satluj river flows through the southern part of district Hamirpur. Both of these two rivers namely Beas and Satluj are the famous rivers in Himachal Pradesh. The Monsoon climate dominates the region. The region receives rainfall mainly from south western monsoon, ranging from 1100 mm to 2100 mm. The total area of the study region is about 1, 10,070 hectares (GOHP, 2000).

Methodology. The study is based on field work done in the region during 2012. 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 vaillages 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.

III. 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.

$S = R \times A \times Cr$ [Gould & Nissen Formula, (1999)] ...(1)

Where,

S = Potential for rooftop rainwater harvesting (Cu.m)

R = Mean annual rainfall in meters

A = Roof Area in Sq.m

Cr = Co-efficient of runoff

The Table 1 below shows the co-efficient of run off for various types of roof materials. In Hamirpur district 51.7% of the houses have slanting Slate roofs and 45.7% 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 Hamirpur District.

Sr No	Type of Roof Material	No. of Houses	Percent of Total Houses
1.	Grass/Thatch/Bamboo	1115	1.06%
2.	Plastic Polythene	280	0.27%
3.	Handmade tiles	102	0.09%
4.	Machine made Tiles	96	0.09%
5.	Burnt bricks	643	0.61%
6.	Stone/Slate	53815	51.2%
7.	GI Sheet/Asbestos	962	0.91%
8.	Concrete	48007	45.7%
9.	Others	48	0.045%
	Total	105068	

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	8.93%
3.	3	194043	13.14%
4.	4	371885	25.19%
5.	5	291513	17.74%
6.	6 to 8	335807	22.74%
7.	9+	67236	4.55%

Source: Govt of India, Census data 2011

IV. 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 Sq.m. A domestic water demand of 4 persons @40 liter per head per day has been calculated. It ranges in between 4480 to 4960 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 58400 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 107984 litre and the overall cumulative demand for domestic water @ 20 lpcd is 29200 liter and @ 40 lpcd is 58400 liter. It also shows that only 27% potential is sufficient to fulfill the domestic demand of water @ 20 lpcd and 54% of the potential is required to fulfill the domestic demand of water @ 40 lpcd. Monthly rainwater harvesting potential ranges in between 344 liter to 32192 liter. It is highest for August and lowest for the month of November (Sharma and Chandel 2012).

The estimation of optimum water tank is very much crucial for proper functioning of DRWH system. Over and under estimation of 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 14392 liters. Hence the optimum capacity of water tank should be 14392 liters, say 14400 liters. The details of the storage at the end of the month have been given in Table 4. However, as the estimated capacity of the water tank is only 14400 liter, the overflows from the tank to the ground water recharge has 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 Slate roof for a 4 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 DRWH system for a Slate Roof Area of 100 Square meter for a 4 member family

Table 4.

							Rooftop Area of 100 Sq.m and Run off Co-eff 0.80 for Slate roof							
Month	Days	Average rainfall (mm)	Water demand @ 20 lpcd	Cummulative water demand	Water demand @ 40 lpcd	Cummulative water demand @ 40 lpcd	RWH Potential liters	Commulative RWH potential	Montly potentail-demand @20lpcd	Montly potentail-demand @40lpcd	Commments	Storage at the end of month after meeting demand @40Lpd	DRWH available for GW recharge	% of total demand that can be met from DRWH
Jun	30	158.0	2400	2400	4800	4800	12640	12640	10240	7840	The total	7840	0	263
July	31	330.7	2480	4880	4960	9760	26456	39096	23976	21496	demand can	14392	14944	533
Aug	31	402.4	2480	7360	4960	14720	32192	71288	29712	27232	be met from	14392	27232	649
Sept	30	152.6	2400	9760	4800	19520	12208	83496	9808	7408	DRWH. The	14392	7408	254
Oct	31	29.0	2480	12240	4960	24480	2320	85816	-160	-2640	size of storage	11752	0	47
Nov	30	4.3	2400	14640	4800	29280	344	86160	-2056	-4456	tank = 14392 Liter	7296	0	7
Dec	31	21.3	2480	17120	4960	34240	1704	87864	-776	-3256	The surplus	4040	0	34
Jan	31	46.3	2480	19600	4960	39200	3704	91568	1224	-1256	water can	2784	0	75
Feb	28	69.5	2240	21840	4480	43680	5560	97128	3320	1080	be used for	3864	0	124
Mar	31	50.7	2480	24320	4960	48640	4056	101184	1576	-904	GW recharge	2960	0	82
Apr	30	31.2	2400	26720	4800	53440	2496	103680	96	-2304		656	0	52
May	31	53.8	2480	29200	4960	58400	4304	107984	1824	-656		0	0	87

Table 5. Rainfall data of Hamirpur district (HP) (mm).

District	Year	January	February	March	April	May	June	July	August	September	October	November	Decemb]er	Annual Total
	2004	140.6	21.6	0	41.8	47	137.1	303.6	319.3	98.3	138.8	3.1	38.7	1289.9
Hamirpur	2005	70.2	166.8	74.4	9.7	23	57.9	407.6	298.1	141.7	3.2	0	0	1252.6
Hamirpur	2006	57.2	2.1	99.7	20.3	112	166.5	482.9	394.9	189	31.7	7	28	1591.3
Hamirpur	2007	0	136.8	163.1	41.2	33.1	129.7	247.2	548.5	95.2	2.1	0	19.7	1416.6
Hamirpur	2008	41.9	46.8	0	47.9	57.9	359.1	325.8	396.1	111.8	30.4	0	1	1418.7
Hamirpur	2009	17.3	20.1	26.9	43.5	49.1	55.2	330.5	403.7	196.3	9.4	10.8	0	1162.8
Hamirpur	2010	11.8	52.2	5.8	4.7	38.2	118.1	325.1	346.4	250.2	12.9	13.3	67.7	1246.4
Hamirpur	2011	31.3	109.6	35.7	40.8	70.3	240.7	223	512.1	138.4	3.3	0	15.2	1420.4
Average		46.3	69.5	50.7	31.2	53.8	158.0	330.7	402.4	152.6	29.0	4.3	21.3	1350

Source: Govt of India, IMD Data of Hamirpur district

Table 6. Percent of water demand fulfilled by DWRH from different roof-top area for 4 member family (for Slate Roof).

	Roof Area in Sq. m				
Month	50	75	100	125	150
June	132	198	263	329	395
July	269	400	533	667	800
Aug	325	487	649	811	974
Sept	127	191	259	318	382
Oct	23	35	47	58	70
Nov	4	5	7	9	11
Dec	17	26	34	43	52
Jan	37	56	75	193	112
Feb	62	93	124	155	186
March	41	61	82	102	123
April	26	39	52	65	78
May	43	65	87	108	130

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

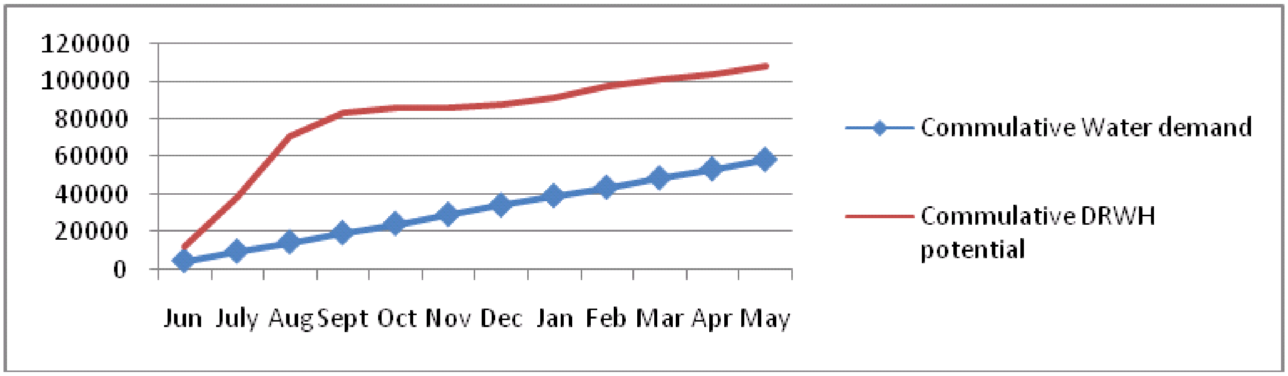

Fig. 1. Showing Cumulative Water & Cumulative DRWH Potential.

V. RESULTS AND DISCUSSIONS

The rainfall of the Hamirpur area reveals 1350 mm mean annual rainfall as total water available. 4 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 51% Slate roofs, 45.7% concrete roofs and 0.91% of tin roofs in the area (Table 3). The overall percentage of Slate roofs (51% is the highest as compared to concrete 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 is practiced in selected villages, that water would be sufficient for 675 days and only 54% 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 or 75 Sq.m. the surplus water after meeting domestic demand from rooftop is available for four months only but if roof area is increased to 100 square meters the surplus water available would be available for five months. The surplus water would be available for seven and eight months for a roof area of 125 and 150 square meters respectively after meeting domestic demand.

VI. CONCLUSIONS

Hamirpur region, 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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