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Narrowing the Demand and Supply Gap Through Rooftop Water Harvesting - a Case Study of Kutlehar Area in Shiwalik Hills of Lower Himalayas

H.P. Singh*, M.R. Sharma**, Quamural Hasan* and Naved Hasan*

**Research Scholar, Department of Civil Engineering, Jamia Milia Islamia, New Delhi*
***Director, MIT College of Engineering and Management, Bani (Mehre) Hamirpur, (HP)*

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ABSTRACT : The biggest challenge of 21st century is to overcome shortage of water. Rainwater harvesting has thus regained its importance as a sustainable and cost effective alternative along with conventional water supply technologies. Though Himachal Government has provided piped drinking water facilities to all of its population in the state yet there are areas which face acute shortage of water during dry months. Rainwater available from roof tops of buildings goes waste. This water can be stored in a tank and can be used directly for non-drinking domestic purposes and also indirectly to recharge the aquifers. The paper analysis the rainfall pattern of Kutlehar area in Siwalik Himalayan region. The quantity of rainwater available from roof tops of 50, 100, 150, 200 and 250 square meters area is estimated. The month-wise percentage of total demand fulfilled from domestic rain water harvesting has also been calculated for different roof top areas.

Keywords : Domestic rooftop rainwater harvesting, Kutlehar area.

I. INTRODUCTION

Although water is important for survival of human being as much as food and air but hardly any attention is paid for its economical use and conservation of this precious resource. In our country the water availability per capita is declining. The per capita availability of water at the national level has reduced from about 5.177m³ in the year 1951 to the present level of 1,869m³. The prominent reasons behind are the increasing demand for water due to the increasing population and extensive use of water by agricultural sector, which continues to be the single largest consumer of water [1, 2].

Though, India is blessed with adequate rainfall as a whole, yet there are large swathes of dry and drought prone area. In many places the quality of groundwater is not good. In such places rainwater harvesting may provide the answer. Every year in summer water shortage problem is experienced in Himachal Pradesh [3]. In Shivalik hills of Himachal Pradesh people face acute water shortage problem every year in summer [4].

Rainwater harvesting

The human civilizations have flourished near the rivers and lakes. However rain is the ultimate source that feeds all these sources. The implication of rainwater harvesting is to make optimum use of rainwater at the place where it falls i.e. to conserve it without allowing it to drain away. It is an ancient technique enjoying a revival in popularity due the inherent quality of rainwater. Rainwater is valued for its purity and softness. It has nearly neutral pH and is free from impurities such as salts, minerals and other natural and man-made contaminants. Archeological evidence attests to the capture of rainwater as far back as 4,000 years ago. The concept of rainwater harvesting in China is as old as 6,000 years. Ruins of cisterns built as early as 2000 B.C for storing runoff from hillsides for agriculture and domestic purposes are still standing in Israel [5].

Need for rainwater harvesting

Due to over population and higher usage levels of water in urban areas. Water supply agencies are unable to cope up demand from available surface sources especially during summer seasons. This has led to digging of individual tube wells by house owners. Even water supply agencies have resorted to ground water sources by digging tube-wells in order to augment the water supply.

The replenishment of ground water is drastically reduced due to paving of open areas. Indiscriminate exploitation of ground water results in lowering of ground water table (GWT) and rendering many bore-wells dry. This has led to drilling of bore wells of greater depth. This further lowers the water table such frequent fluctuations in GWT results in presence of higher concentration of salts in ground water. In coastal areas, over exploitation of ground water results in seawater intrusion thereby rendering fresh ground water bodies saline [6].

In rural areas also, government policies on subsidizes power supply for agricultural pumps and piped water supply through bore and open dug wells are resulting into decline in GWT. The solution to all these problems is to replenish ground water bodies with rainwater by manmade means.

Benefits of rainwater harvesting

This rainwater has environmental advantage and purity over other water alternatives. This makes it the sustainable option, even though the precipitation cycle may fluctuate from year to year. The collection of rain water not only leads to conservation of water but also save energy since the energy input required to operate a centralized water system designed to treat and pump water over a vast service area is not required. Rainwater harvesting also lessens local erosion and flooding caused by runoff form impervious cover such as pavement and roofs, as some rain water is captured and stored. Rain water quality almost exceeds that of ground or surface water as it does not come into contact with soil and rocks where it dissolves salts and minerals and it is not exposed to many of the pollutants that often are discharged into surface waters such as rivers, and which can further contaminate groundwater. However, rainwater quality can be influenced by characteristics of area where it falls, since localized industrial emissions affect its purity. Thus, rainwater falling in non-industrialized areas can be superior to that in cities which are dominated by heavy industry or in agricultural regions where crop dusting is prevalent.

Rooftop water harvesting

Rooftop water harvesting is a process of collecting of runoff during rains from impermeable surfaces on houses or close to houses, its storage in water proof vessels and its subsequent use for the inhabitants of the houses. The use may be temporary (with in a day or so following a rainstorm), seasonal (throughout the rainy season) or permanent (throughout the year) except in years of exceptionally low rainfall. The rain water from the roof may also be used for recharging the ground water through nearby water sources such as open dug wells or bore wells. It may be achieved in the case of storing the harvested water from roof by diverting the excess water for ground water recharge and in absence of storing vessel by diverting all the water for ground water recharge. Rooftop rainwater harvesting for household purpose only represent a small part of the total water balances. In areas with significant variations in the annual rainfall pattern, the matching of water supply and water demand may be difficult. However, in terms of economic and human welfare it has a crucial role to play. 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.

II. STUDY AREA

The study area consists of Bangana development block in Kutlehar constituency in Shiwalik hills. The block has a geographical area of 404.2 square kilometers and it lies between North latitude 310 24’ 28.8” & 310 43’ 18.3” and East longitude 760 10’ 39” & 760 28’ 44.4” and falls in survey of India topographical sheets on 1: 50,000 scale bearing No. 53 A/2, 53 A/6, 53 A/7. Towards north it is bounded by Kangra District & Amb Block of district Una, towards north & east by Hamirpur & Bilaspur districts and towards south-west by Una block of district Una. Physiographically the block is essentially a hilly area in the Siwalik ranges forming part of the lesser Himalayas. There are three major hill ranges in the block trending in north-north westerly & south-south easterly direction. These ranges are the Solasinghi Dhar with maximum elevation of 1041 meters above mean sea level (msl) forming border with district Hamirpur, the Dhionsar Dhar with maximum elevation of 950 meters above mean sea level and the Ramagarh Dhar with maximum elevation of 997 meters above mean sea level. The slopes are steep which accentuate the surface runoff. There are numerous small streams (khads) in the area which are ephemeral in nature. The streams (khads / nallas) are generally running in linear fashions and the overall drainage of 1st to 3rd order with dendritic to sub parallel pattern in nature is observed in the block. Lunkhar khad forms the major river in the block flowing in north-south direction and submerges in Govind Sagar reservoir of Bakhara dam near village Dumkhar. Garni Khad, Takewali khad, Khurd khad and Barera khad all tributaries of the Soan river flowing in the south western direction have considerable catchment’s area in the block. The ridges of Dhonsar Dhar and Ramgarh Dhar form the water divide between the catchment area of Soan river and Lunkhar khad. The southern slopes of these hills (dhars) are drained by the Soan river while the northern slopes form the catchment of Lunkhar khad. Out of the total 402.2 sq. km. around 250 sq. km. is drained by the Lunkhar khad. Most of the area of the block falls in the Sutlej river basin. The Siwalik foot-hill region comprising sandstone, conglomerate and silt have given rise to coarse to silty soil or silt soil or silt loam. The soil layer on rocks is shallow and is prone to easy removal by rains. However, due to short branches of streams with no precise stream bed hill slopes are prone to severe erosion during monsoon rains.

Climatically the area falls in the hot sub-humid tropical zone. The year is generally divided into three seasons i.e. hot season from March to May, rainy season from June to September and cold season from October to February. The temperature during summers is quite hot and mild during winters and varies from 40 C in winter to 440 C in summer. The relative humidity is generally higher during the monsoon period (June to September) and declines sharply after September. The major part of the rainfall in the study area is received during the monsoon season. Pre-monsoon and Post-monsoon showers are experienced in the area but are of erratic nature and the quantum received is low. The average annual rainfall recorded at rain gauge station Bangana from 1991-2008 is around 1338 millimeter while the average monsoon rainfall of the corresponding period is around 1010 millimeter. The average number of rainy days for the last seven years is around 53 days [7].

Geologically most of the area of the block falls in the Siwalik group of rocks. The area on the north western margin of the block comprises of alluvium deposits. This area is facing huge scarcity of water during dry months every year.

Rainfall data for Kutlehar Area

A rain gauge station is located in the central part of the study area at Bangana. The daily rainfall records from 1991 to 2008 are available and used for the purpose of analysis (Table -1).

Table 1: Monthly rainfall data of Bangana area in District Una

Source: - 1. DC Office UNA

Unit: MM

Year	*Jan*	*Feb*	*Mar*	*April*	*May*	*June*	*July*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Total*
1991	2.10	70.20	34.60	10.10	2.00	30.30	172.10	426.50	267.20	0.00	0.00	46.30	1061.40
1992	98.10	70.60	55.10	0.00	45.20	104.00	338.00	770.80	61.00	2.50	24.60	0.00	1569.90
1993	27.40	7.30	34.20	0.00	5.40	43.10	476.30	43.30	91.20	0.00	3.50	0.00	731.70
1994	39.70	135.20	2.20	42.40	27.80	71.20	1369.10	421.10	218.60	0.00	0.00	12.10	2339.40
1995	75.40	164.50	76.00	84.50	0.00	101.10	812.60	761.50	384.00	0.00	0.40	0.00	2460.00
1996	34.50	129.20	30.00	13.70	11.30	134.60	586.10	547.60	88.90	113.00	0.00	2.10	1691.00
1997	35.20	17.80	16.20	35.80	25.90	47.20	192.60	644.10	226.60	12.90	28.60	66.90	1349.80
1998	10.00	93.90	64.20	21.10	6.80	106.40	383.20	406.40	282.30	68.20	0.00	0.00	1442.50
1999	47.60	0.40	18.06	13.00	63.00	175.00	338.08	426.58	124.78	0.00	0.00	0.00	1206.50
2000	63.00	6.03	24.00	6.08	70.06	100.06	403.03	240.02	123.04	0.00	0.00	0.00	1035.32
2001	33.02	5.00	34.02	97.06	55.04	129.03	323.06	448.02	42.20	0.00	22.10	16.30	1204.85
2002	26.70	25.00	41.40	52.20	34.30	38.70	223.00	568.00	116.50	0.00	0.00	0.00	1125.80
2003	77.20	101.00	93.20	13.00	0.00	84.00	552.00	235.00	366.00	0.00	10.00	0.00	1531.40
2004	121.00	15.00	0.00	47.00	12.00	167.00	365.00	199.00	139.00	155.00	5.00	27.00	1252.00
2005	65.00	142.00	23.00	4.00	70.00	41.00	292.00	78.00	52.00	0.00	0.00	0.00	767.00
2006	41.00	0.00	121.00	0.00	81.00	187.00	333.00	353.30	112.00	8.00	8.00	2.92	1247.22
2007	0.00	81.80	130.80	20.40	25.20	48.80	225.00	386.00	51.60	4.20	0.00	23.00	996.80
2008	24.80	14.20	0.00	20.40	12.20	246.60	181.20	394.60	152.20	25.80	0.00	0.00	1072.00
Monthly average	45.65	59.95	44.2671	30.40	103.06	420.30	408.32	161.08	21.64	5.68	10.92	1338.03	

III. METHODOLOGY

Around 50 houses having different rooftop area are surveyed. The DRWH potential for different sizes of rooftop is estimated.

The estimation of the size of the water tanks to fulfill drinking and cooking water demand @ 8.00 LPCD through DRWH from rooftop of different areas are done. The total demand of water for a household of 5 persons at the rate 70 liters per capita per day has also been estimated. The estimation of water to fulfill the drinking and cooking water demand @ 8.00 LPCD has been made. The month wise status of quantity of water available for use is estimated. A sample calculation for 50 m², 100 m², 150 m², 200 m² and 250 m² rooftop area is shown in Table-2 to Table 6.

IV. RESULTS AND DISCUSSIONS

The study has shown that the discharge of most of the water supply schemes, get reduced during dry months. All drinking water sources fall in the lower Shiwaliks. The Shiwaliks are the recent deposits constituting the main geological formations. They comprises conglomerate, friable micaceous sandstone, siltstone and claystone. Water holding capacity of the soils is low. Soils are susceptible to excessive soil erosion and landslides due to water. Due to irregular, undulating topography, shallow depth, steep slopes, coarse texture, poor soil structure, scanty vegetative cover and erratic rainfall, during dry periods the soil profile dries up quickly on account of evaporation and transpiration. The crops experience drought like conditions and consequently the crop yields and discharge of water sources are affected adversely. The discharge of the springs and other sources gets reduced considerably during summers. There are no surface water sources nearby and the water has to be pumped from faraway places by incurring huge expenditures. The ground water is also not available at a low depth. Thus the Rooftop rainwater harvesting can be a cheap and viable alternative.

It has been observed that the size of roof top of houses in the area varies from around 50 square meters to 230 square meters. As the non-monsoon rainfall is almost negligible in the area, hence it is not feasible to fulfill the gross water demand throughout the year from DRWH without large storage. At the same time average number of days of rainfall is only 53 days which is another constraint. Even during the monsoon period this demand cannot be met from rooftop area less than 125 m². It is evident from Table-7 that the gross water demand for four monsoon months can be met from roof top area 125 m² and above.

The surplus water can be used for ground water recharge.

The study has revealed that October, November, December, March, April and May are the most critical months. During the study it was also observed that in rural areas almost every house has a cowshed. The area of the cowshed varies from 50 to 80 square meters. This roof area can be utilized as additional catchment for rainwater harvesting. The harvested water can be stored near the cowshed itself and can be utilized to meet the demand of cattle. The extra water available during rainy season can be stored in polythene lined tanks and utilized for kitchen gardening and car washing etc..

Table 2: Estimation of Water Tank Capacity to fulfill the Drinking & Cooking Water Demand by DRWH from run off of 50 Sqm

Months	*Days Rainfall*	*Average Cooking*	*Drinking Demand water Demand @ 8 litre/day/ person for 5 persons*	*Cumulative Demand @*	*Overall overall 70 LPCD*	*Cumulative DRWH demand*	*Rooftop Area = 50.0 Sq.m Runoff Co-efficient = 0.85* Cumulative Vol liters	*DKWH liters*	*liters*	*liters*	*(8) – (4) (9) – (5)% of Total can be met*
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*14*
June	30	103.06	1200	1200	10500	10500	4380	4380	3180	3180	41.71
July	31	420.3	1240	2440	10850	21350	17863	22243	16623	19803	164.63
Aug	31	408.32	1240	3680	10850	32200	17354	39596	16114	35916	159.94
Sept	30	161.06	1200	4880	10500	42700	6845	46441	5645	41561	65.19
Oct	31	21.64	1240	6120	10850	53550	920	47361	-320	41241	8.48
Nov	30	5.68	1200	7320	10500	64050	241	47603	-959	40283	2.30
Dec	31	10.92	1240	8560	10850	74900	464	48067	-776	39507	4.28
Jan	31	45.65	1240	9800	10850	85750	1940	50007	700	40207	17.88
Feb	28	59.95	1120	10920	9800	95550	2548	52555	1428	41635	26.00
Mar	31	44.33	1240	12160	10850	106400	1884	54439	644	42279	17.36
Apr	30	26.71	1200	13360	10500	116900	1135	55574	-65	42214	10.81
May	31	30.4	1240	14600	10850	127750	1292	56866	52	42266	11.91

Table 3: Estimation of Water Tank Capacity to fulfill the Drinking & Cooking Water Demand by DRWH from run-off of 100 Sqm.

Months	*Days Rainfall*	*Average Cooking*	*Drinking Demand water Demand @ 8 litre/day/ person for 5 persons*	*Cumulative Demand @*	*Overall overall 70 LPCD*	*Cumulative DRWH demand*	*Rooftop Area = 50.0 Sq.m Runoff Co-efficient = 0.85* Cumulative Vol liters	*DKWH liters*	*liters*	*liters*	*(8) – (4) (9) – (5)% of Total can be met*
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*14*
June	30	103.06	1200	1200	10500	10500	8760	8760	7560	7560	83.43
July	31	420.3	1240	2440	10850	21350	35726	44486	34486	42046	329.27
Aug	31	408.32	1240	3680	10850	32200	34707	79193	33467	75513	319.88
Sept	30	161.06	1200	4880	10500	42700	13690	92883	12490	88003	130.38
Oct	31	21.64	1240	6120	10850	53550	1839	94722	599	88602	16.95
Nov	30	5.68	1200	7320	10500	64050	483	95205	-717	87885	4.60
Dec	31	10.92	1240	8560	10850	74900	928	96133	-312	87573	8.55
Jan	31	45.65	1240	9800	10850	85750	3880	100013	2640	90213	35.76
Feb	28	59.95	1120	10920	9800	95550	5096	105109	3976	94189	52.00
Mar	31	44.33	1240	12160	10850	106400	3768	108877	2528	96717	34.73
Apr	30	26.71	1200	13360	10500	116900	2270	111148	1070	97788	21.62
May	31	30.4	1240	14600	10850	127750	2584	113732	1344	99132	23.82

Table 4: Estimation of Water Tank Capacity to fulfill the Drinking & Cooking Water Demand by DRWH from run-off of 150 Sq.m

Months	*Days Rainfall*	*Average Cooking*	*Drinking Demand water Demand @ 8 litre/day/ person for 5 persons*	*Cumulative Demand @*	*Overall overall 70 LPCD*	*Cumulative DRWH demand*	*Rooftop Area = 50.0 Sq.m Runoff Co-efficient = 0.85*				
							Cumulative Vol liters	*DKWH liters*	*liters*	*liters*	*(8) – (4) (9) – (5)% of Total can be met*
1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***14***
June	30	103.06	1200	1200	10500	10500	13140	0	11940	-1200	125.14
July	31	420.3	1240	2440	10850	21350	53588	53588	52348	51148	493.90
Aug	31	408.32	1240	3680	10850	32200	52061	105649	50821	101969	479.82
Sept	30	161.06	1200	4880	10500	42700	20535	126184	19335	121304	195.57
Oct	31	21.64	1240	6120	10850	53550	2759	128943	1519	122823	25.43
Nov	30	5.68	1200	7320	10500	64050	724	129668	-476	122348	6.90
Dec	31	10.92	1240	8560	10850	74900	1392	131060	152	122500	12.83
Jan	31	45.65	1240	9800	10850	85750	5820	136880	4580	127080	53.64
Feb	28	59.95	1120	10920	9800	95550	7644	144524	6524	133604	78.00
Mar	31	44.33	1240	12160	10850	106400	5652	150176	4412	138016	52.09
Apr	30	26.71	1200	13360	10500	116900	3406	153581	2206	140221	32.43
May	31	30.4	1240	14600	10850	127750	3876	157457	2636	142857	35.72

Table 5: Estimation of Water Tank Capacity to fulfill the Drinking & Cooking Water Demand by DRWH from run off of 200 Sqm

Months	*Days Rainfall*	*Average Cooking*	*Drinking Demand water Demand @ 8 litre/day/ person for 5 persons*	*Cumulative Demand @*	*Overall overall 70 LPCD*	*Cumulative DRWH demand*	*Rooftop Area = 50.0 Sq.m Runoff Co-efficient = 0.85*				
							Cumulative Vol liters	*DKWH liters*	*liters*	*liters*	*(8) – (4) (9) – (5)% of Total can be met*
1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***14***
June	30	103.06	1200	1200	10500	10500	17520	0	16320	-1200	166.86
July	31	420.3	1240	2440	10850	21350	71451	71451	70211	69011	658.53
Aug	31	408.32	1240	3680	10850	32200	69414	140865	68174	137185	639.76
Sept	30	161.06	1200	4880	10500	42700	27380	168246	26180	163366	260.76
Oct	31	21.64	1240	6120	10850	53550	3679	171924	2439	165804	33.91
Nov	30	5.68	1200	7320	10500	64050	966	172890	-234	165570	9.20
Dec	31	10.92	1240	8560	10850	74900	1856	174746	616	166186	17.11
Jan	31	45.65	1240	9800	10850	85750	7761	182507	6521	172707	71.53
Feb	28	59.95	1120	10920	9800	95550	10192	192698	9072	181778	103.99
Mar	31	44.33	1240	12160	10850	106400	7536	200235	6296	188075	69.46
Apr	30	26.71	1200	13360	10500	116900	4541	204775	3341	191415	43.24
May	31	30.4	1240	14600	10850	127750	5168	209943	3928	195343	47.63

Table 6: Estimation of Water Tank Capacity to fulfill the Drinking and Cooking Water Demand by DRWH from run off of 250 Sqm.

Months	*Days*	*Average Rainfall*	*Drinking Cooking water Demand @ 8 litre/day/ person for 5 persons*	*Cumulative Demand*	*Overall Demand @ 70 LPCD*	*Cumulative overall demand*	*Rooftop Area = 50.0 Sq.m Runoff Co-efficient = 0.85*				
							DRWH Vol liters	*Cumulative DKWH liters*	*liters*	*liters*	*(8) − (4) (9) − (5)% of Total can be met*
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*14*
June	30	103.06	1200	1200	10500	10500	21900	0	20700	-1200	208.57
July	31	420.3	1240	2440	10850	21350	89314	89314	88074	86874	823.17
Aug	31	408.32	1240	3680	10850	32200	86768	176082	85528	172402	799.71
Sept	30	161.06	1200	4880	10500	42700	34225	210307	33025	205427	325.95
Oct	31	21.64	1240	6120	10850	53550	4599	214906	3359	208786	42.38
Nov	30	5.68	1200	7320	10500	64050	1207	216113	7	208793	11.50
Dec	31	10.92	1240	8560	10850	74900	2321	218433	1081	209873	21.39
Jan	31	45.65	1240	9800	10850	85750	9701	228134	8461	218334	89.41
Feb	28	59.95	1120	10920	9800	95550	12739	240873	11619	229953	129.99
Mar	31	44.33	1240	12160	10850	106400	9420	250293	8180	238133	86.82
Apr	30	26.71	1200	13360	10500	116900	5676	255969	4476	242609	54.06
May	31	30.4	1240	14600	10850	127750	6460	262429	5220	247829	59.54

Table 7: Percent of water demand fulfilled by DRWH from different rooftop area.

Roof top area in Sq. m

Month	*50*	*100*	*150*	*200*	*250*
	% of total demand fulfilled from DRWH				
June	41.71	83.43	125.4	166.86	208.57
July	164.63	329.27	493.9	658.53	823.17
Aug	159.94	319.88	479.82	639.76	799.71
Sept	65.19	130.38	195.57	260.76	325.25
Oct	8.48	16.95	25.43	33.91	42.38
Nov	2.30	4.6	6.9	9.2	11.50
Dec	4.28	8.55	12.83	17.11	21.39
Jan	17.88	35.76	53.64	71.53	89.41
Feb	26.00	52	78	103.99	129.99
Mar	17.36	34.73	52.09	69.4	86.82
Apr	10.81	21.62	32.43	43.24	54.06
May	11.91	23.82	35.72	47.6	59.54

Limitations of the study and Future Scope of Study

The study covers only the Kutlehar area of the lower Himalayas. A study covering more area is required. The size and costs of water tanks for different areas having different rainfall may be estimated. All calculations are based on mean rainfall however the calculations based on median rainfall can give more realistic output. The rainfall intensity should also be taken into consideration.

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