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Estimation of rooftop water potential of college of basic sciences and humanities

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Abstract
Rainwater harvesting is the most common technique used for domestic consumption. It is simple, low cost technique that requires minimum specific expertise or knowledge and offers many benefits. An integrated planning for Rooftop Rainwater Harvesting (RRWH) system for different zones of an educational building was carried out. Main objectives of the study were to identify the runoff generation locations and to estimate RRW potential of selected locations. The study revealed that seasonal and annual rainfall value on the basis of probability analysis of 20 years data (1995-2014) at 75% probability level were found 42 mm, 65.9 mm, 34.2 mm, 243.7 mm, 359.7 mm for June, July, August, September, seasonal and annual basis respectively. Also total estimated rooftop rainwater potential at 75% probability level was observed as 79584, 124871, 64804, 62340, 461778 and 681582 in litres in June, July, August, September, seasonal and annual basis respectively.

Keywords: Runoff generation, rooftop rainwater harvesting, seasonal and annual rainfall, probability analysis

1. Introduction
In the 1950's only a handful countries faced water storages. In the nineties, the numbers of countries facing the water deficit has grown to 26 with the populations of 300 million (Abu-zeid, 1998). Rain water harvesting (RWH) can be a significant mitigation strategy against the impact of droughts. Droughts are hazards in every society although their impact is less life-threatening in countries with higher levels of socioeconomic development (Bruins *et al* 2005) [3]. In India, uncontrolled increase in population and decreasing availability of land and irrigation water for producing agricultural commodities has increased the gap between demand and supply of food commodities.

In The climate of Hisar owes to its continental location on the outer margins of the south-west (SW) monsoon region. It has tropical monsoonal climate and is characterized as arid type of climate. The district has characteristically four seasons during the year *viz*., summer (March to May), SW Monsoon (June to September), Post-Monsoon (October to November) and winter (December to February) season. SW monsoon also known as summer monsoon brings rain during last week of June to mid-September. The period from October onward until next June remains almost dry except, few light showers received due to westerly depressions/western disturbances (WDs). The summers are generally quite hot and winters are fairly cool. The main characteristics of climate of in the district are its dryness, extremes of temperature and scanty rainfall. Rainfall: Around 75 to 80 per cent of the annual rainfall is received during SW Monsoon season (June to September) with 50 per cent coefficient of variation (CV).

The water harvesting term was firstly used in Australia by H.J. Geddes. Rooftop rain water harvesting is the technique through which rain water is captured from the roof captured from the roof catchments and stored in reservoirs. Harvested rain water can be stored in reservoirs. Harvested rain water can be stored in sub surface ground water reservoir by adopting artificial recharge techniques to meet the household needs through storage in tanks. The Main Objective of rooftop rain water harvesting is to make water available for future use.

Existing surface water sources fail to meet the rising demands of water supply in urban areas; groundwater reserves are being tapped and over-exploited, resulting into decline in groundwater levels and deteriorating the groundwater quality. This precarious situation needs to be rectified by immediately recharging the depleted aquifers.

Hence, the need for implementation of measures to ensure that rain falling over a region is tapped as fully as possible through water harvesting, either by recharging it into the groundwater aquifers or storing it for direct use.

2. Materials and Methods

Hisar is located at 20°10'N latitude and longitude 75° 46'E, with an elevation of 215 m above the mean sea level. The area is characterized by semiarid type of climate with an average rainfall of about 420 mm, which is scantly and erratic. The average minimum and maximum temperature is around 5°C and 45°C respectively. An integrated planning for rainwater harvesting is done for College of Basic Science and Humanities, CCSHAU, Hisar. The satellite view of this building is shown below in Fig 1.

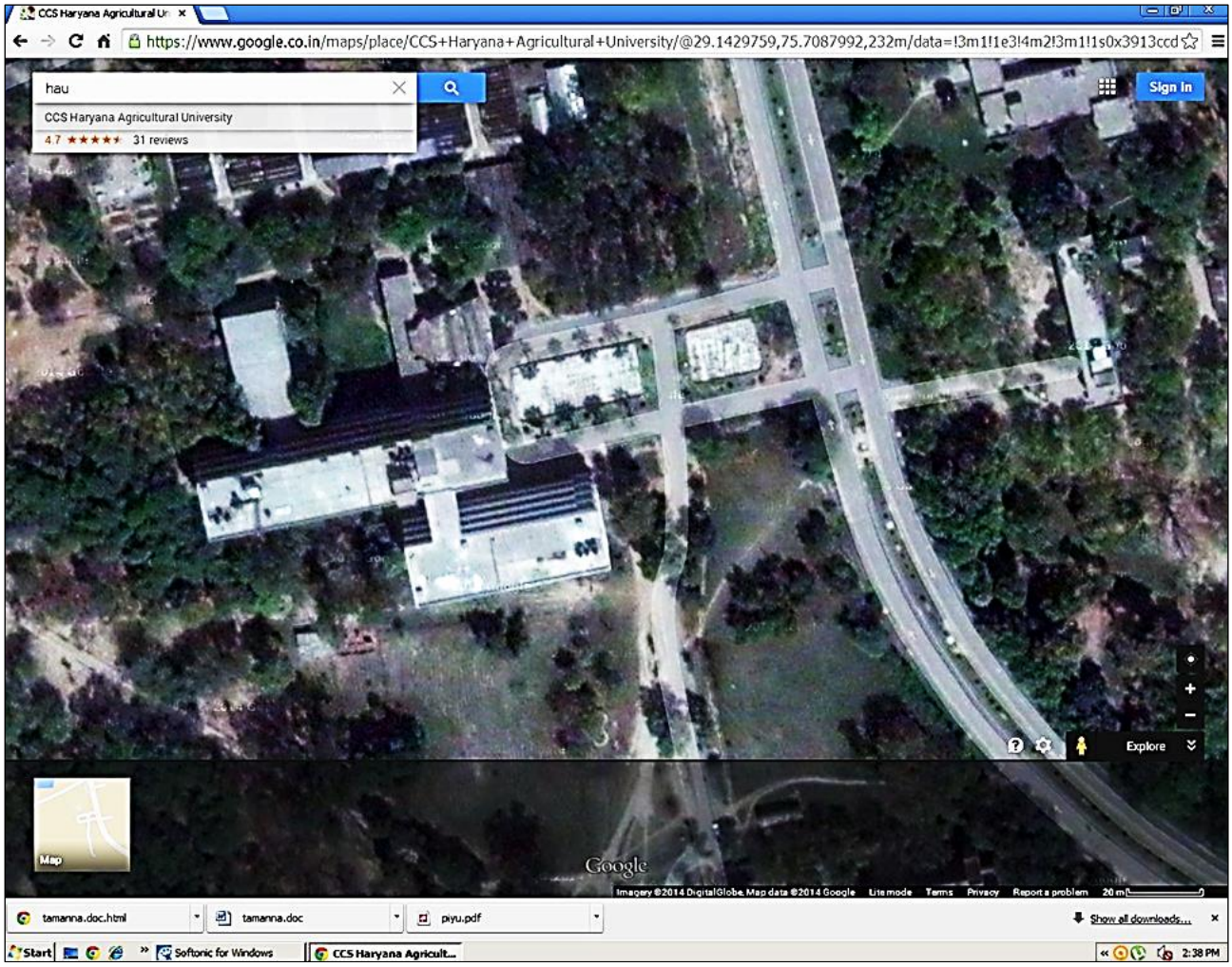

Fig 1: Satellite view of College of Basic Sciences and Humanities

Rainfall data for last 20 years (1995-2014) for Hisar was collected from meteorological observatory situated at CCSHAU Hisar. The annual and seasonal rainfall data was analyzed for estimation of water rooftop rainwater potential.

2.1 Probability Analysis

The probability analysis was carried out on monthly (annual and seasonal) basis for last 20 years by using Weibull's Formula as described below:

$$P = \frac{m}{n+1} * 100$$

Where,
P= Percent probability of occurrence of particular interval.
m= Rank of event arranged in descending order of magnitude
n= total number of events.
Annual and seasonal monthly rainfall data was arranged in descending order and rank number n was assigned to each value, for first value m = 1 for second value m = 2 and so on till m = n. At 75% probability level of rainfall, potential of roof rainwater harvesting was calculated.

2.2 Runoff Generating Location Near the Building

Location: Road, Pavements, depression near the building were selected which can generate the runoff

- **Type and Size of the Catchment:** Runoff coefficients were selected with respect to the land use/land cover. Size of catchment area and the dimensions (length and horizontal width) of the area contributing water towards the catchment area were calculated.
- **Area:** The areas of catchments were measured.
- **Potential of Rainwater Harvesting:** Potential of rain water harvesting of selected locations were calculated by using the technique mentioned in next paragraph.

The total amount of water that is received from rainfall over an area is called the rainwater legacy of that area. And the amount of that can be effectively harvested is called the water harvesting potential. Potential of rooftop rainwater harvesting

refers to the capacity of an individual roof to harness the water falls on that roof in a particular year covering all rainy days. The annual yield of water which is probably measured in unit of litres is the project of roof type and annual average rainfall of an area. Rain water yield varies with the size and texture of the catchment area. Potential of roof rainwater harvesting in a study area has evaluated by using following formula:-

Gould and Nissen Formula (1999)

$$S = R*A*Cr$$

Where,
S = Potential of roof rainwater harvesting (cu. m)
R = Average annual rain fall in m.
A = Roof area in Sq.m
Cr = Coefficient of Runoff.

Table 1: Coefficient of Runoff

Roof type	Estimated collection efficiency (as % Precipitation)
Cement Concrete	85
Park, lawns	25

2.3 Calculation of Rooftop Area

The entire area was divided in seven zones as shown in Figure 2. These zones were planned by considering the elevation of buildings in such a way that the harvested rain water from rooftop will reach to it under gravity through underground conveyance system. Respective effective areas of divided zone and no. of outlets are shown in table 2.

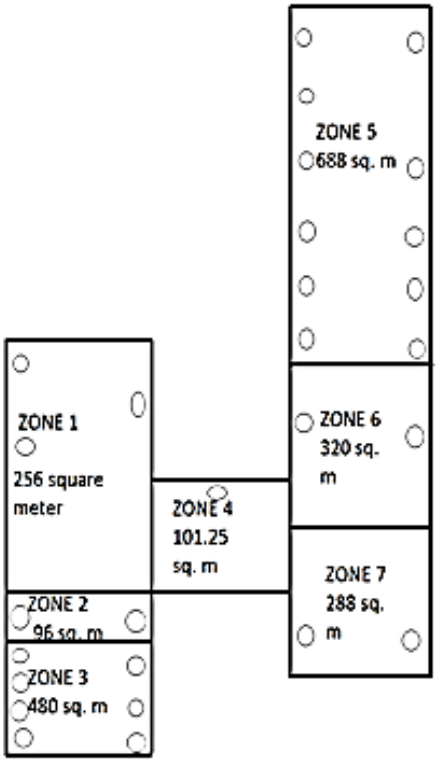

Fig 2: Total rooftop area seprarated in various zones

Table 2: Effective rooftop area (sq.m) and no. of drain outlet of various zones

Zone	Effective Area (Sq.m)	No. of Drain Outlet
Zone 1	256	3
Zone 2	96	2
Zone 3	480	7
Zone 4	101.25	1
Zone 5	688	11
Zone 6	320	2
Zone 7	288	2

3. Results and Discussions

The present study was carried out to estimate the rainwater potential of College

3.1 Probability Analysis

The rainfall data for the years (1995-2014) was analysed by using Weibull's formula. The monthly, seasonal, annual rainfall amount was carried out at 75% probability level. The observed rainfall value at 75% probability level were found 42 mm, 65.9 mm, 34.2 mm, 32.9 mm, 243.7 mm, 359.7 mm for June, July, August, September, Seasonal and Annual basis respectively. It was found that the July month was wettest month and similar results were obtained by of Basic Science and Humanities both by rooftop and through various runoff generating locations near the building Hooda, B.K. (2006) [7] for probability distribution of monthly rainfall of Hisar (Haryana). These results were further used for estimation of runoff potential of various zones of rooftop area and for runoff generating locations near the building.

Seasonal and Annual rainfall during different years is shown in table 3. It was observed that about 40-90% of the annual rainfall received in the months of June, July, August and September. So these months were selected for seasonal period. Highest rainfall was observed in 2010 as 91.34% and lowest rainfall was observed in 2002 as 40.57% of the annual rainfall

Table 3: Seasonal and Annual rainfall (mm) during different years

Year	June	July	Aug.	Sept.	Seasonal	Annual total	% seasonal
1995	79.7	91	253.5	58.1	482.3	590.5	81.68
1996	107.7	69.5	95.5	87.7	360.4	450.5	80
1997	41.2	167.9	224.3	19.5	452.9	771.2	58.73
1998	58.5	160.3	49.7	145.7	414.2	617	67.13
1999	42	65.9	70.6	4	182.5	247.2	73.83
2000	48.9	59.9	8.7	4.7	122.2	145.2	84.16
2001	168.7	209.8	133.3	26.2	538	714	75.35
2002	20.3	12.9	22.6	35.9	91.7	226	40.58
2003	7.2	279.5	119.6	25.2	431.5	518	83.30
2004	61.7	0	86.6	41	189.3	320.7	59.03
2005	71.1	195.9	9.4	181.3	457.7	563	81.30
2006	74.7	91.3	7.9	69.8	243.7	346.1	70.41
2007	167.3	21	68.8	66.3	323.4	505.8	63.94
2008	122.9	148.1	129.1	96	496.1	574.5	86.35
2009	29.4	92.4	14	239.9	375.7	459.3	81.80
2010	50.3	300	209.9	147.6	707.8	774.9	91.34
2011	47.4	76	95.7	141.1	360.2	527.6	68.27
2012	26.5	76.6	282.5	32.9	418.5	506.9	82.56
2013	97.3	159.2	288.2	140.4	685.1	810.1	84.57
2014	62.6	16.7	34.2	81.5	195	359.7	54.21

Table 4: Runoff generating zones near the building

Particular	Zone	Area (sq.m)	June (lts.)	July (lts.)	August (lts.)	September (lts.)	Seasonal (lts.)	Annual (lts.)
Pond	Pond 1	363.8	12959	20378	10575	10173	75359	111230
	Pond 2	765	27310	42851	22238	21393	158465	233894
Total			40269	63229	32813	31566	233824	345124
Roads and pavements	Zone 2	88	2217	3479	1805	1737	12867	18992
	Zone 3	199.5	5027	7888	4093	3938	29170	43056
	Zone 6	343.8	12273	19257	9994	9614	71216	105115
	Zone 7	84	2998	4705	2441	2349	17400	25682
	Zone 8	174	6211	9746	5058	4865	36043	53199
	Zone 9	252	8996	14115	7325	7047	52200	77047
	Zone10	186	6640	10418	5407	5201	38528	56868
Total			44362	69608	36123	34751	257424	379959
Lawns	Zone 1	1240	13020	20429	10602	10199	75547	111507
	Zone 4	60	630	988	513	493	3655	5395
	Zone 5	85	892	1400	726	699	5178	7643
Total			14542	22817	11841	11391	84380	124545
Grand Total			99173	155654	80777	77708	575628	849628

Table 4 showed that the pond 2 has received higher annual water storage (233894lts.) as compared to pond 1 due to its larger area (765sq.m). The amount of rainfall received in ponds(1, 2) during month of June, July, August, September, Seasonal and Annual rainfall is 40269, 63229, 32813, 31566, 233824 and 345124 litres respectively. The road and pavements (Zone 2, 3, 6, 7, 8, 9, and 10) has water generating potential of 44362, 69608, 36123, 34751, 257424 and 379959 litres in the month of June, July, August, September, Seasonal and Annual rainfall respectively. The lawn (Zone 1, 4, 5) has showed the rainwater potential of 14542, 22817, 11841, 11391, 84380 and 124545 litres in month of June, July, August, September, Seasonal and Annual rainfall respectively.

3.2 Potential of Rooftop Rainwater Harvesting

Total estimated rooftop runoff at 75% probability level as observed is shown in table 5.

Table 5: Potential of rooftop rainwater harvesting

Particulars	Zones	Area (sq.m)	Seasonal Rainwater potential (Liters)				Total Rainwater potential (liters)	
			June	July	August	September	Seasonal	Annual
Phase I	Zone 1	256	9139	14339	7442	7159	53029	78270
	Zone 2	96	3427	5377	2790	2685	19886	29351
	Zone 3	480	17136	26887	13953	13423	99429	146758
Total			29702	46603	24185	23267	172344	254379
Phase II	Zone 4	101	3614	5671	2943	2831	20972	30956
Total			3614	5671	2943	2831	20972	30956
Phase III	Zone 5	688	24561	38538	20000	19239	142516	210353
	Zone 6	320	11424	17924	9302	8948	66286	97838
	Zone 7	288	10281	16132	8372	8054	59657	88054
Total			46266	72594	37674	36241	268459	396245
Grand Total			79582	124868	64802	62339	461775	681580

5 showed that the rainwater potential from phase-I (zones-1, 2, 3) 29702, 46603, 24185, 23267, 172344, 254379 liters in month of June, July, August, September, Seasonal and Annual rainfall respectively. The phase-II (zone-4) has showed the rainwater potential of 3614, 5671, 2943, 2831, 20972, 30956 liters in month of June, July, August, September, Seasonal and Annual rainfall respectively. The phase-III (zone-4, 5, 6) has rainwater potential of 46266, 72594, 37674, 36241, 268459, 396245 liters in month of June, July, August, September, Seasonal and Annual rainfall respectively.

3.3 Water Demand Survey

Water requirement of Basic Science building was estimated by a small survey of number of laboratories on each floor of that building. The results are as shown in table 6. It was found that there are total 45 laboratories in the building which results in consumption of more quantity of water.

Table 6: Water Requirement in lab

Floor	No. of Labs
1st floor	13
2nd floor	9
3rd floor	11
4th floor	12
Total	45

The storage tank may be constructed near the building to store the available rainwater from college of Basic Science and Humanities. The detailed demand survey of the building can be done separately to get the estimation of daily water demand in various labs so that available rainwater potential can be utilized in an efficient manner.

4. Conclusion

Rainfall data (1995-2014) was analysed, seasonal and annual rainfall value at 75% probability level were found 42 mm, 65.9 mm, 34.2 mm, 32.9 mm, 243.7 mm, 359.7 mm for June, July, August, September, Seasonal and Annual respectively. It was observed that about 40-90% of the annual rainfall received in the months of June, July, August and September. So these months were selected for seasonal period. Highest rainfall was observed in 2010 as 91.34% and lowest rainfall was observed in 2002 as 40.57% of the annual rainfall. During seasonal months (June, July, August and Sept.) of year 2010 maximum rainfall occurred i.e. 91.34%. whereas 80-86% rainfall was observed in seasonal months of year 1995, 1996, 2000, 2003, 2005, 2008, 2009, 2012 and 2013. Minimum percentage (40.57%) of rainfall was found in year 2002. Total estimated rooftop runoff at 75% probability level were observed as 79584, 124871, 64804, 62340, 461778, 681582 litres in June, July, August, September, Seasonal and Annual respectively. Implementation of RAINWATER HARVESTING method to the College of Basic Science and Humanities will be the best approach to fight with present scenario of water scarcity in all aspects.

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