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 rainfall 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 (Abuzeid, 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.

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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 scanty 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.

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:

\[ P = \frac{m}{n+1} \times 100 \]

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 rooftop 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 rainwater 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. Potential of roof rainwater harvesting in a study area has evaluated by using following formula:-

**Gould and Nissen Formula (1999)**

\[ S = R \times A \times Cr \]

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

\[ Cr = \text{Coefficient of Runoff.} \]

**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.

**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
The amount of rainfall received in 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.

| Particulars | Zones | Area (sq.m) | Seasonal Rainwater potential (Liters) | Total Rainwater potential (liters) |
|-------------|-------|-------------|--------------------------------------|-----------------------------------|
| Phase I     | Zone 1| 256         | 9139 14339 7442 7159 53029 78270 | 53029                              |
|             | Zone 2| 96          | 3427 5377 2790 2685 19886 29351 | 19886                              |
|             | Zone 3| 480         | 17136 2687 13953 13423 99429 146758 | 99429                             |
|             | Total | 29702       | 46603 24185 23267 172344 254379 | 172344                             |
| Phase II    | Zone 4| 101         | 3614 5671 2943 2831 20972 30956 | 20972                              |
|             | Total | 3614        | 5671 2943 2831 20972 30956      | 20972                              |
| Phase III   | Zone 5| 688         | 24561 38538 20000 19239 142516 210353 | 142516                             |
|             | Zone 6| 320         | 11424 17924 9302 8948 66286 97838 | 66286                             |
|             | Zone 7| 288         | 10281 16132 8372 8054 59657 88054 | 59657                             |
|             | Total | 46266       | 72594 37674 36241 268459 396245 | 268459                             |
|             | Grand Total | 79582 | 124868 64802 62339 461775 681580 | 461775                             |

Table 4 showed that the pond 2 has received higher annual water storage (233894lit.) 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.
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.

| 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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