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Estimation of Rainwater Harvesting Potential in an Educational Institute of Faisalabad, Pakistan

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Abstract. Pakistan is on verge of facing severe water scarcity issues by 2025. An exponential increase in population increases the water demand as most of the population in the country depends on groundwater. Over extraction of groundwater is causing depletion in the groundwater table at an alarming rate. Water conservation is becoming the need of time. Rainwater Harvesting is one the best methods that can be used to conserve water. This paper aims to determine the total volume of water that can be conserved from Rainfall on the Rooftop at the University of Faisalabad, Amin Campus located in an industrial city Faisalabad, Pakistan. For this purpose, water usage on the campus is estimated. The area of the campus rooftop is measured by conducting a topographic survey. Rainfall data from the year 1981-2021 is collected and average monthly rainfall is calculated. The soil Conservation Service Curve Number method is adopted to calculate the run-off. Results indicated that about 1300 cubic meters of water can be conserved per year which will cover about 20-25 percent of the total water demand of the campus if a Rainwater Harvesting System is installed at the campus.

Keyword:
Rainwater Harvesting, Water Conservation, Water Scarcity

1. Introduction

Water is an essential need for all ecological and societal activities. Freshwater is one of the fundamental rights of humans. Groundwater is the largest source of water being used in the world [1]. Urbanization and overpopulation are leading to the depletion of groundwater reserves. It is expected that serious issues relevant to groundwater reserves will occur by 2025 if remedial actions will not be taken by applying new policies for water conservation [2].

Pakistan is fifth among the populated countries in the world with a population of over

225 million. Groundwater is the major source of water in the country [3]. Faisalabad is the major industrial city of Pakistan with an approximate population of 3.2 million [4]. The city completely depends on groundwater. Due to the over exploitation of groundwater by pumping, the water table of the city is declining at an alarming rate [5]. On the other hand, most of the rainfall that should be seeping into the aquifer is being drained to the drainage pipes because of the construction of buildings and roads using non-porous materials.

In the coming years, it is expected that water scarcity will become a serious issue for such urbanized and overpopulated cities in the world [6]. Therefore, water conservation is the need for time for better water management and a sustainable environment for humans to live in. Rainwater harvesting (RWH) is the technology in which water is collected and stored for future use. The rainwater can also be used for recharging groundwater with some suitable filtration arrangement [7]. RWH can be used to improve the water security of areas where water scarcity will be a major issue in the future [8].

The study aims to estimate the rainwater runoff volume that can be conserved by using the rainwater harvesting technique in The University of Faisalabad – Amin Campus Faisalabad, Punjab, Pakistan. The main objective is to propose a system of water conservation at the University of Faisalabad to encourage sustainability practices.

2. Materials and Methods

2.1. Study Area

The University of Faisalabad – Amin Campus is located at 31°27'27.42"N and 73° 9'29.31"E in the city of Faisalabad, Punjab, Pakistan.

The total area of the University of Faisalabad – Amin Campus is 16160 square meters (SQM). In the present study, the rooftop areas of the buildings are considered. Areas were measured by conducting an engineering survey on the campus and drawings were made.

Figure 1. Rooftop Area under Study (Catchment Area)

Table 1. Total Catchment Area

Building Name / Description	Area [SQM]
Main Building	2895.9
OPD Block	641.9
Cafeteria	365.8
Labs	138.1
Bank	138.0
Generator Room	27.9
Total Area	4207.6

2.2. Water Consumption

The source of water on the campus is groundwater. Water is supplied for daily usage from the storage tanks installed on the rooftops of the Main Building and OPD Block. The total population of the campus including Faculty, Students, and other staff is estimated to be 1975. There is one six cubic meters capacity water storage tank in the main building and three one cubic meters capacity water storage tanks are in the OPD Block. These tanks are filled by pumping water from the aquifer. An estimated per annum filling of these tanks is observed. Main Building's tank is filled approximately 653 times per annum and OPD Block's tanks are filled 365 times per annum. By using the above values, water consumption in the campus is calculated to be 5013 cubic meters per annum.

2.3. Rainfall Data and Calculations

Daily Rainfall data was collected from the Pakistan Meteorological Department (PMD) from January 1981 to June 2021 for the city of Faisalabad, Pakistan. The monthly Average Rainfall for all months from 1981 to 2021 is shown in Figure 2. Total Rainfall depths and runoff depths are also calculated for the same years. Daily rainfall data is used in the calculations of rainfall-runoff volume that can be conserved.

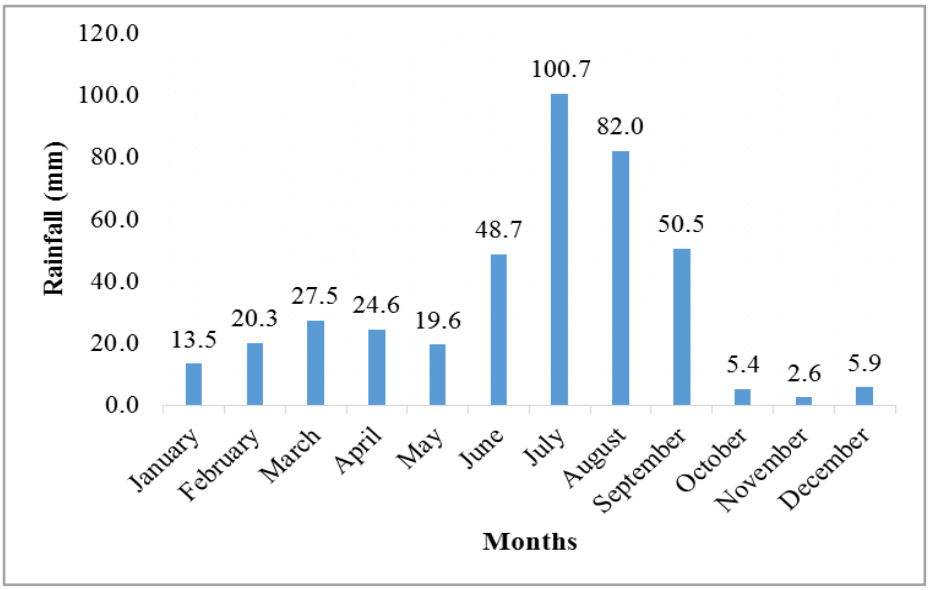

Figure 2. Average Monthly Rainfall (1981-2021)

2.4. Soil Conservation Service Curve Number Method (SCS CN Method)

Soil Conservation Service (SCS) Curve Number Method was developed by The United States Department of Agriculture, now known as the National Resources Conservation Service (NRCS) SCS CN Method. They developed the relationship between rainfall and runoff for a watershed. This method is adopted for the calculation of Run-off in various studies [8,9,10,11].

$$P_e = (P-0.2S)^2/(P+0.8S) \text{ [mm]} \quad (1)$$

$$S = (25400/CN)-254 \text{ [mm]} \quad (2)$$

P_e is the effective rainfall-runoff depth, P is rainfall event depth, S is the Potential Maximum Retention, and CN is the Curve Number. In Eq.1, if Initial abstraction I_a= 0.2S is greater than rainfall event P then effective runoff P_e is taken as zero. The CN varies from 30 to 100, it depends on the Hydrological Soil Group defined by NRCS (A, B, C, and D), Land Cover, Hydrological Condition (Good, Fair, Poor), and Antecedent Moisture Conditions (AMC I, AMC II, AMC III). The higher the curve number, the lower will be the losses. In the present study, with respect to the study area, CN of 98 is selected considering Hydrological Soil Group-D, Impervious Land Cover with Good Hydrological condition, and AMC II condition by consulting standard tables and figures defined by NRCS [13]. By using the selected CN value for the study area in Eq.2 the potential maximum retention is calculated.

$$S = (25400/98)-254 = 5.18 \text{ [mm]} \quad (3)$$

The effective rainfall P_e is then calculated by using Daily rainfall events values of P in Eq.1 and Eq.3 results.

2.5. Run-off Volume Calculation

Rainfall run-off volume is $_{calculated}$ by using the average of the monthly sum of effective rainfall P_e for all the rainfall events from the year 1981 to 2021 and the total measured rooftop area.

$$\text{Runoff Volume} = (P_e/1000)* \text{ Total Rooftop Area } [m^3] \quad (4)$$

Five percent conveying losses are assumed in the calculation of the volume of water that will be conserved in the underground tank as shown in Fig.1.

3. Results

The total rooftop area is calculated to be 4207.6 square meters. Using the calculated Curve number of 98 and potential maximum retention S of 5.18 mm. The runoff depths are calculated for each event of all months of a year for all the years from 1981-2021. The Sum of all rainfall events of each month and their respective runoff is calculated. The average rainfall depth and run-off depth are calculated to be 399.87 mm and 325.4 mm per annum respectively from the year 1981to 2021. The relation of the rainfall depths and their

respective runoff depths per year from 1981 to 2021 is shown in Fig. 3. Using Eq.4 the resulting rainfall runoff volume is 1369.2 cubic meters, if five percent conveying losses are assumed the resulting volume of water that can be conserved is 1300.74 cubic meters, which is about 25 percent of the total water consumption of 5013 cubic meters.

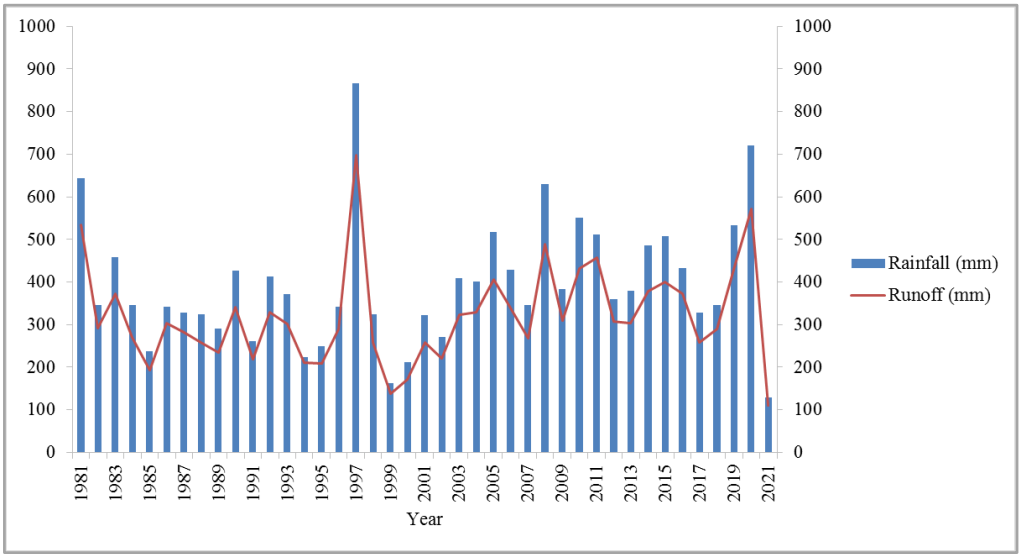

Figure 3. Rainfall and Runoff Depths of the Study Area (1981-2021

The proposed rainwater harvesting system is shown in Fig. 4. It is proposed that harvested water will be conveyed by using already installed rooftop rainfall drainage pipes. These pipes will be connected with underground new pipes which will be installed in a manner that gravity flow may occur. These underground pipes will convey the collected volume of water to the water storage tank. This conserved water can be pumped out from the installed water storage tank for use. The drainage pipes of the OPD building will be connected to the new conveying pipe, this pipe will be then connected to the newly installed conveying pipe of the Main building. Similarly, the conveying pipe of the Main building on the other side will also carry water coming from the rooftops of the Cafeteria, Labs, Bank, and Electric room. This pipe will be then connected to the water storage tank. Therefore, the water conveying system will require new pipes, the mesh at each entrance point of drainage pipes on the rooftop, the elbows to join already installed drain pipes with the underground conveying pipes and the water storage tank.

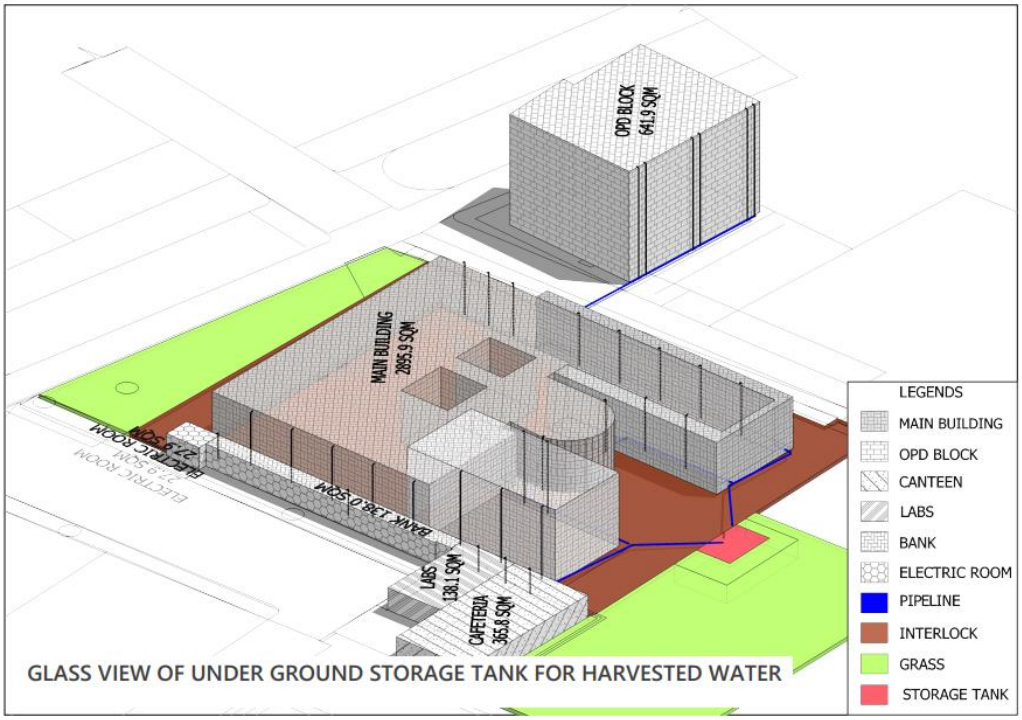

Figure 4. Proposed Rainwater Harvesting System

4. Conclusion & Recommendations

It is concluded that using the Rooftop Rainwater Harvesting technique, the total volume of water that can be conserved is around 1300.74 cubic meters which is 25 percent of the water usage per annum in the University of Faisalabad - Amin Campus. It is concluded that 81 percent of the total rainfall is observed to be the run-off, therefore the run-off coefficient of the study area is 0.81.

The feasibility of all engineering projects also depends on the cost. It is recommended that an economic analysis of the proposed rainwater harvesting systems for water conservation should be done for the optimum design.

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