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RAINWATER HARVESTING: AN OPTION FOR IRRIGATION AND GROUND WATER RECHARGE

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Abstract: *Water scarcity due to global warming is one of the challenging issues of the current day and near future. Pakistan is also one of the victims of this burning issue. Among many alternatives, rain water harvesting (RWH) is one of the convenient, practical and economical solutions to cope with water scarcity. The overall aim of the research program is to encourage society with economy, to reduce the irrigation water requirements from other expensive sources. In this study Gulberg Greens Housing Society Islamabad was selected as a project site and the rainwater harvesting potential of farm houses were evaluated. To estimate the RWH potential of the study site, mean monthly rainfall data of the nearest rain gauge station was obtained from Pakistan Metrological Department (PMD) Islamabad for 31 years (1986-2016). The Runoff Curve Number (RCN) method was used to estimate the RWH potential. The study indicates that, the use of RWH fulfills up to 80% of the total irrigation water demand of farm houses. The installation cost and benefits of RWH were evaluated to compute the savings due to RWH. These outcomes encourage farm houses owners to install the RWH system for sustainable landscape irrigation.*

Keywords: *Water scarcity, Rain water harvesting, Landscape irrigation*

I. INTRODUCTION

Water is the world most important natural resource. It is a vital product for survival and a gift from God for all living things. Human can survive for weeks without food but not for a day without water. Water also play important role in the economy and Agriculture like using water to extract minerals from the earth, refine petroleum and other chemicals, produce other food products and beverages that go to market and produce a chain of business (Compacts, May 2009).
Beside all the importance of water the fresh water has very limited resources. With population growth the demand of water use for different purposes increases, Surface and ground water resources are used rapidly for these purposes rather than recharge of Ground water. The water demand and supply gap increasing day by day. Rainwater harvesting is alternative water resource to compensate the water shortage for irrigation and other house hold purposes after proper treatment (Anderson, 2017). Comparatively rainwater is clean and free from disinfection bi products, salts, minerals and other natural and manmade contaminants. And stored rainwater is suitable for landscape irrigation. (Krishna, 2005)

II. LITRATURE REVIEW

In 2011 International Center for Agriculture Research in the Dry areas (ICARDA) conducted a long term project in the upper Karkheh River Basin in Iran. The project aimed to supplement the irrigation water by RWH to increase the yielding area of the crops within the basin (A. R. Tavakoli, 2010). Cultivation area also increased by adopting RWH and irrigation strategies.
A feasibility study was conducted by *Saour* in 2009 at Texas for RWH to fulfill irrigation water requirement. The study area was divided into different watersheds, like watershed D had 240 buildings with approximate 89 Acers of rooftop area. Similarly 149 RWH storage points were selected throughout the area based on natural slopes, buildings grouping, rooftop area and drains of the watershed. According to their results, one of the watersheds having annual rainfall of 39 inches, 113 buildings were able to collect 60,850,000 gallons of water annually. If this amount of volume is stored, economically it will save approximately $406,000 per year at the rate of $2.44 per 1000 gallons. They opted for three different landscape option having one, two and three storage points; these landscape options will reduce portable water source utilization for irrigation up to 50%, 75% and 100% respectively. The initial cost of the tanks were high but will be repaired from the savings of payments on water in 14 to 20 years (Saour, 2009).
Rain water harvesting (RWH) is a centuries old practice and hence it dates back to 5000 years. In old times RWH was practiced mainly in arid and semi-arid regions, for irrigation and domestic water supply. The main reasons for adopting RWH were, no other reliable source, not getting rainfall when needed for crops and having rainfall only for some part of the year. Currently RWH is used not just for irrigation but also for other various objectives like ground water recharge, flood control strategies, soil erosion control tool etc. with much more develop and accurate technology.

In the literature most of the research are done for household purposes on individual base or used surface water harvesting concept for large catchments. In this study I used both the roof top and surface water harvesting concepts combine for farm houses of Gulberg greens (Housing society) Islamabad to store rainwater and use it for landscape irrigation.

III. RAINWATER HARVESTING

Rainwater harvesting (RWH) is practice of storing and using rainwater on site for different purposes rather than allowing it as surface runoff (Texas development board manual on RWH). RWH is considered as a possible answer to the global water shortage problem especially where rainwater is available in sufficient amount and scope for development of surface and ground water based water supply system is limited or costly. The existing scenario prevailing in both the surface and ground water gives us a signal of intense danger if proper actions are not taken in this regard (world water resource institute).

VI. METHODOLOGY

To estimate the rain water harvesting (RWH) potential of the study site, mean monthly rainfall data of the nearest rain gauge station was obtained from Pakistan Metrological Department (PMD) Islamabad for 31 years (1986-2016). The rainfall data was analyzed to get mean annual rainfall. The catchment area of the farm houses were measured from the site plan of Gulberg Green housing society. Parameters which influence RWH potential like land use; soil type, antecedent moisture content and slope were evaluated for catchment area. The Runoff Curve Number (RCN) method was used to estimate the RWH potential of Farm houses. At the end, the initial cost and benefits of RWH system were evaluated to compute the savings.

4.1. Rainfall Data

Mean monthly rainfall data of the Shams Abad rain gauge station was obtained from Pakistan metrological department Islamabad for the period of 31 years from 1986 to 2016. The data was analyzed to get the mean annual rainfall. Mean annual rainfall and meanmonthly rainfall data are shown in the figure 1 and 2 respectively. The maximum rainfall occurs up to 322 mm in the Monsoon (July to September) while the minimum rainfall occurs in the month of November and December. In the remaining months the rainfall is also occurs in sufficient amount ranging from 50 mm to 120 m.

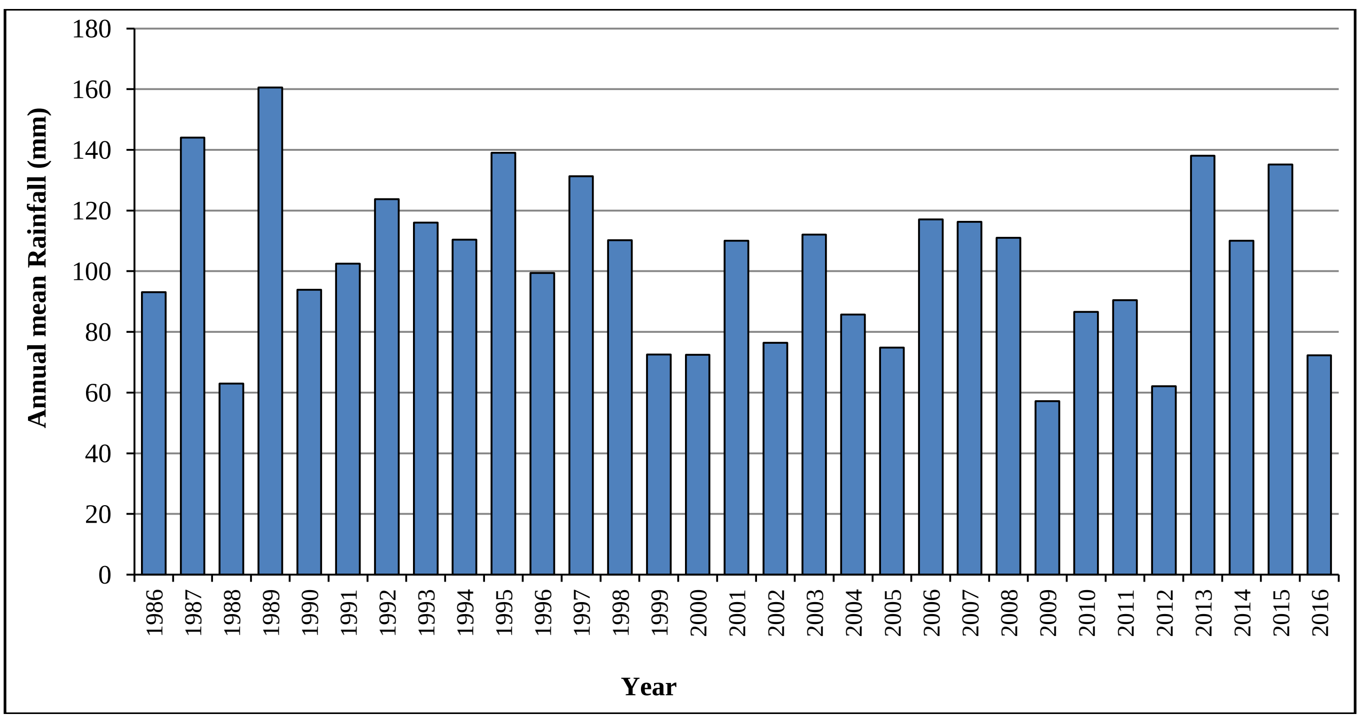

Figure 01 Mean Annual Rainfall Data of Shams Abad Station

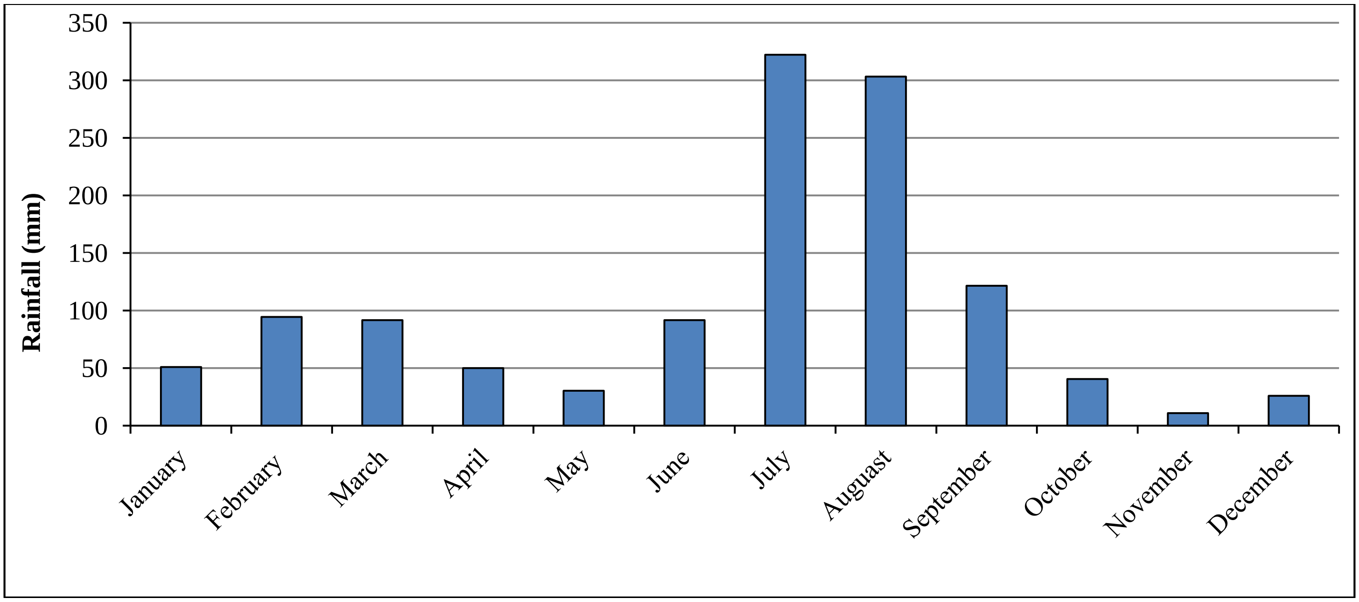

Figure 02 Mean Monthly Rainfall data of Shams Abad Station

4.2. Runoff Curve Number (RCN) Method

This is an empirical method developed by the US Soil Conservation Services (USSCS). It is well-established and reliable method; the required inputs are generally available and easy to compute. RCN method can handle various soil types, land uses and management practices conveniently. The major advantage of using RCN method is, it can gives both runoff volume as well as maximum runoff as compared to other methods like Rational Method which only gives maximum runoff.

Mathematically

$$Q = \frac{(P-0.2S))^2}{(P-0.S)} \text{ -------- (I)}$$

$$S = \frac{1000}{CN} - 10 \ldots \ldots \ldots \text{(II)}$$

Where,

Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins (in)

The S value (specific retention) is related to the soil characteristics and surface cover conditions. These elements are interconnected by a dimensionless number called curve number. It ranges from 0 to 100. For impervious surfaces which will contribute all its water to runoff bears a curve number of 100. For natural surface, which will fist infiltrate the rainwater and will contribute to runoff once their infiltration demand is fulfilled have a CN less than 100. USSCS has provided the established tables and charts for different land use and soil types.

Factors affect the RCN are Hydrologic soil group, Land use and treatment, Ground surface condition and Antecedent moisture condition. The moisture content present already in the soil mass has great effect on its ability to generate runoff after a rainfall event. The RCN method divides the moisture content condition into three types that is AMC I, AMC II and AMC III. The AMC I means, the soil is dry and will saturates itself before generating runoff. The AMC II means the soil mass have average mixture content and will produce runoff quickly as compared to AMC I. The AMC III means the soil is already saturated by a previous rainfall and will yield runoff just after beginning the current rainfall. The USSCS tables and formulas are designed to calculate the curve number (CN) by considering the moisture content in AMC II. On site, if the moisture content is not AMC II, then the fallowing formulas must be applied to get the correct field condition.

$$\mathrm{CN(I)} = \frac{4.2CN(II)}{10 - 0.058CN(II)} \ldots\ldots\ldots\ldots\ldots\ldots.(III)$$

$$\mathrm{CN(III)} = \frac{23CN(II)}{10 + 0.13CN(II)} \ldots\ldots\ldots\ldots\ldots\ldots.(IV)$$

In this study we use the AMC II type of moisture content condition for the study area.

V. RESULTS AND DISCUSION

Rainwater harvesting (RWH) potential by using Runoff Curve Number (RCN) method was calculated from 10, 5 and 4 kanal farm houses separately. The rainwater harvesting potential of total farm houses was calculated. At the end cost analysis were carried out of Rainwater harvesting installation cost and the saving due to RWH systems. The Results are shown in the following figures.

5.1. RWH Potential of Farm Houses

There is large number of farm houses covering area of about 7300 kanals. According to their sizes they are divided to 10, 5 and 4 kanal farm houses. RWH potential were found for each size as shown in figure 3, 4 and 5 respectively. For each size of farm house considering 50 % of the area is covered by the building and footpaths with curve number (CN) of 98 according to USSCS table. The remaining 50% area is green with fair condition having hydrological soil type "B" results in CN of 52.We assumed the AMC II moisture content condition in this study. So no correction to the Curve number (CN) for green area is required.

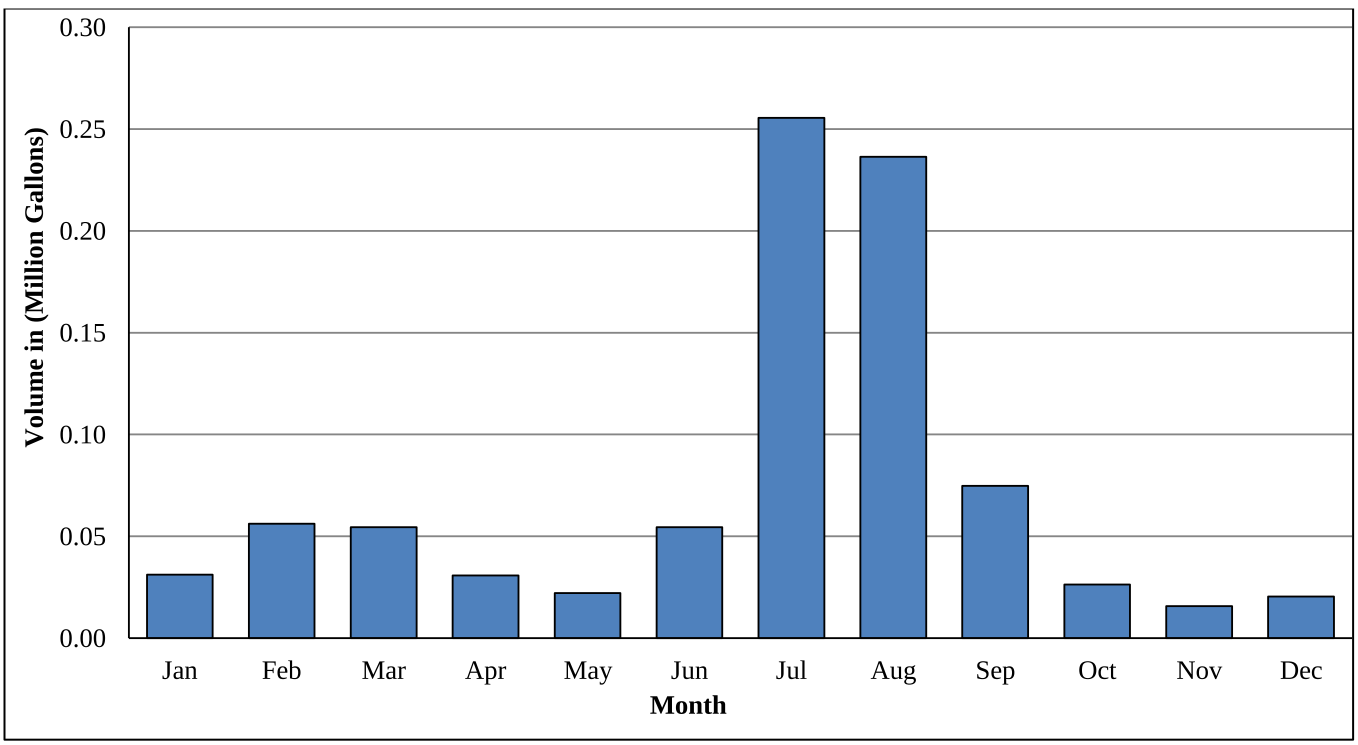

Figure 03 RWH Potential of a 10 Kanal Farm House

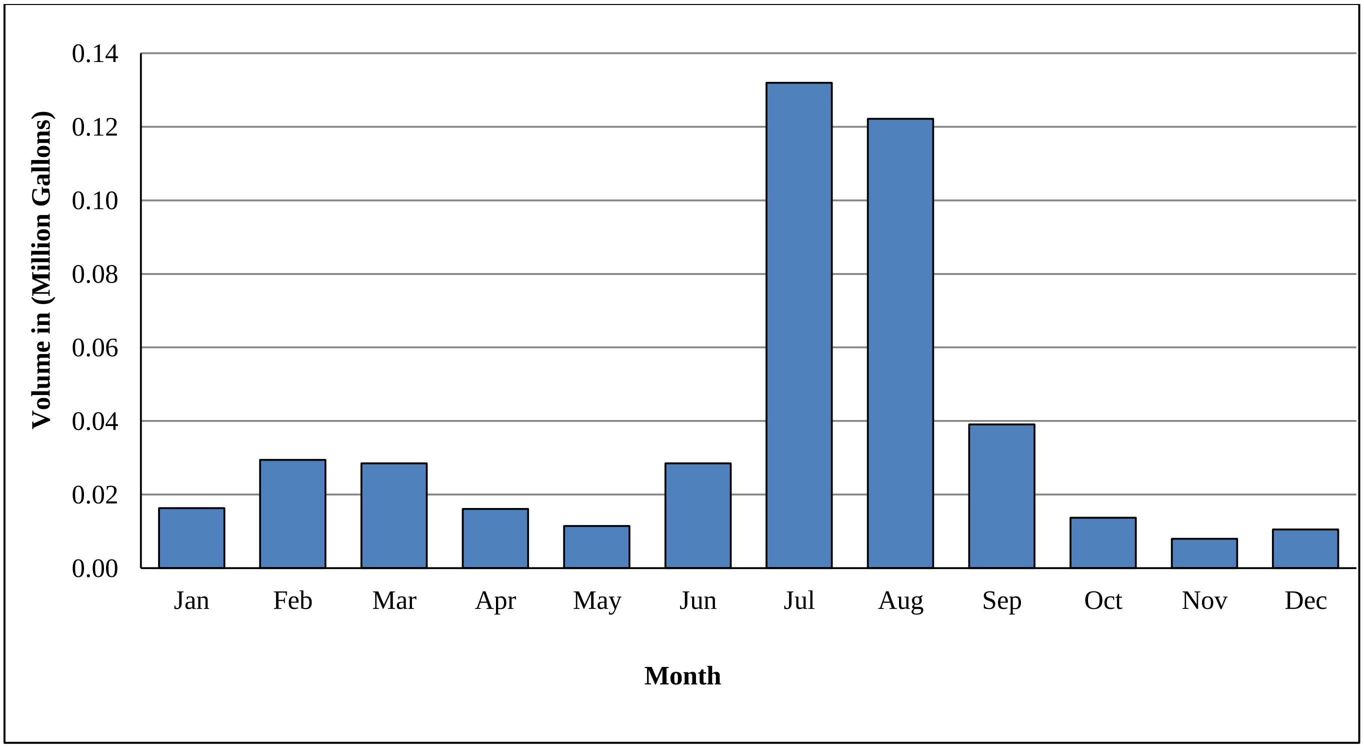

Figure 04 RWH Potential of 5 Kanal Farm House

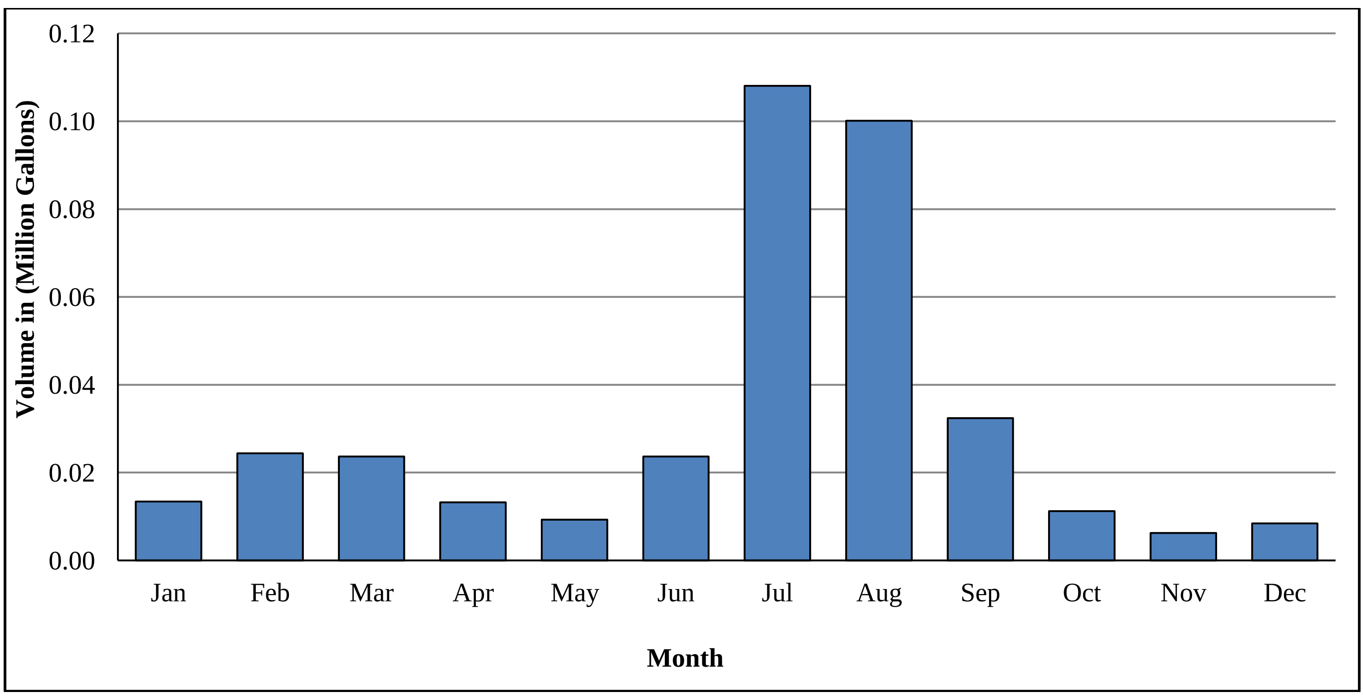

Figure 05 RWH Potential of 4 Kanal Farm House

From the Figures 3, 4 and 5, it is evident that, during the months of July and August the farm houses can yield much more water due to monsoon season as compared to the rest of the year. In these months the water usage for irrigation and other purposes are also on its top due to excessive evaporation. If the volume generated in these months is stored, it will fulfill the water demand in the upcoming low rainfall months. From October to December the water accumulation is on its minimum level due to dry arid climate of the project site.

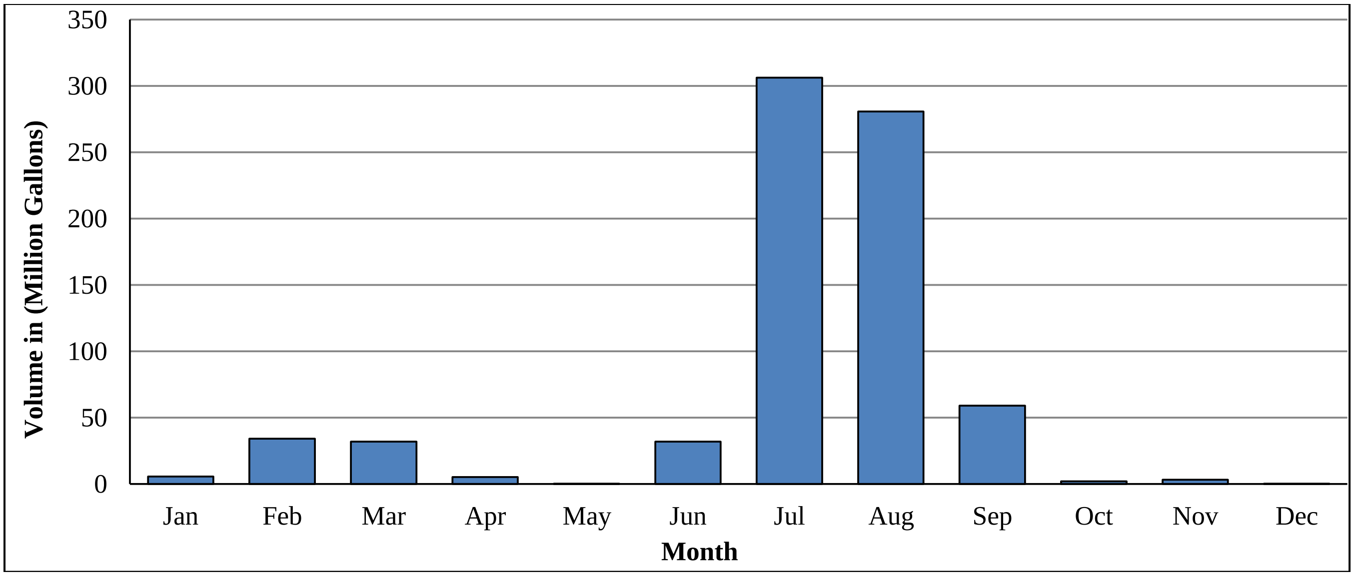

Figure 06 RWH Potential of All Farm Houses

Gulberg greens contain 2059 total farm houses distributed in various blocks from Block A to Block E. This includes 345 farms houses of 10kanals (1.25 acres), 981 of 5kanals (0.625 acres) and 733 of 4kanals (0.5 acres). These farm houses cover a huge area of about 1411 acres. It is enforced by law from Gulberg Greens on all farm house holders that, they can coveronly 20% of the area by building and the remaining 80% area must be open area consisting of landscape, footpaths etc. The rainwater harvesting potential from all the farm houses is graphically shown in figure 6. We can harvest a huge amount of water from farm houses, only in July the harvesting potential is more than 300 million gallons. On yearly basis the rainwater harvesting potential is greater than 760 million gallons.

5.2 Installation of RWH System on Farm Houses

For the farm houses the installation of RWH system is compulsory as per the policy of Gulberg green. In the farm houses, the main components of rainwater harvesting system are underground storage tank, first flash drain, receiving drain and the connecting piping network. The estimated cost for design Rainwater harvesting for 10, 05 and 04 Kanal houses are given Below in Table 01, Table 02 and Table 03.

Table.1 RWH system installation cost (10 Kanal farm houses)

S.Nos	Description	Unit	Quantity	Unit Rate PKR	Total Amount in PKR
1	RWH Tank of (15x15x10) ft^3	PKR	1	636000	636000
Main Drain and Filtration					
2	RCC work of (100x4x4) ft^3	PKR	1	400000	400000
3	Slotted PVC Pipe (10")	feet	100	820	82000
4	Coarse Gravel	ft^3	800	32	25600
5	Sand	ft^3	300	26	7800
6	Screen mesh	ft^2	10	50	500
7	First Flush Drain	PKR	1	10000	10000
8	PVC Drain Pipes (4 inch)	feet	800	185	148000
9	Labor charges	PKR	1	100000	100000
	Total				**1409900**

Table.2 RWH system installation cost (5 Kanal farm houses)

S.Nos	Description	Unit	Quantity	Unit Rate PKR	Total Amount in PKR
1	RWH Tank of (15x10x10) ft^3	PKR	1	495000	495000
Main Drain and Filtration					
2	RCC work of (60x3.5x3.5) ft^3	PKR	1	225000	225000
3	Slotted PVC Pipe (10")	Feet	60	820	49200
4	Coarse Gravel	ft^3	600	32	19200
5	Sand	ft^3	200	26	5200
6	Screen mesh	ft^2	10	50	500
7	First Flush Drain	PKR	1	10000	10000
8	PVC Drain Pipes (4 inch)	Feet	600	185	111000
9	Labor charges	PKR	1	60000	60000
	Total				**975100**

Table.3 RWH system installation cost (4 Kanal farm houses)

S.Nos	Description	Unit	Quantity	Unit Rate PKR	Total Amount in PKR
1	RWH Tank of (15x10x10) ft^3	PKR	1	385000	385000
2	RCC work of (60x3.5x3.5) ft^3	PKR	1	180000	180000
3	Slotted PVC Pipe (10")	Feet	50	820	41000
4	Coarse Gravel	ft^3	500	32	16000
5	Sand	ft^3	180	26	4680
6	Screen mesh	ft^2	10	50	500
7	First Flush Drain	PKR	1	10000	10000
8	PVC Drain Pipes (4 inch)	Feet	500	185	92500
9	Labor charges	PKR	1	50000	50000
	Total				**779680**

VI. COST ANALYSIS

As from the figures 3, 4 and 5 we can harvest annually 0.878, 0.455 and 0.37 Million gallons water from 10, 05 and 04 kanal Farm houses respectively. as per by laws of the society the green area of the Farm houses are almost 50 percent and need huge amount of irrigation water that are not allowed from water supply lines of the society. The only source for irrigation water will be supplied from outside sources on bowser if Rainwater harvesting system is not installed. Per bowser charges are around one thousand rupees having capacity of only 1200 gallons.
The total amount of harvested water on the basis of one bowser charges of 1200 gallons is Rs: 1000/-So the annual amounts of harvested water for 10, 05 and 04 kanal farm houses are Rs: 731374, Rs: 379015 and Rs: 308210 respectively.

VII. CONCLUSION

Comparing the Rainwater harvesting installation cost and the amount of Harvested rain water it is concluded that by installing rainwater harvesting on each size farm house we can save a handsome amount annually on very little initial installation cost of Rainwater harvesting system comparatively.

And beside the economic benefits RWH system is environmental friendly and also conserves water, reduce flood and soil erosion.

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