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Rainwater Harvesting - A Sustainable Approach for Ground Water Recharge

Farrukh Basheer and Izharul Haq Farooqi

Environmental Engineering Section, Department of Civil Engineering,
Aligarh Muslim University, Aligarh-202002 India

Abstract: The scarcity of water is a well-known fact. Most of the rain falling on the surface tends to flow away rapidly, leaving very little for the recharge of groundwater. As a result, most parts of the world experience lack of water even for domestic uses. 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 deterioration of 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. Rain Water Harvesting, is an age-old system of collection of rainwater for future use. But systematic collection and recharging of ground water, is a recent development and is gaining importance as one of the most feasible and easy to implement remedy to restore the hydrological imbalance and prevent a crisis. In scientific terms, water harvesting refers to collection and storage of rainwater and also other activities aimed at harvesting surface and groundwater, prevention of losses through evaporation and seepage and all other hydrological studies and engineering inventions, aimed at conservation and efficient utilization of the limited water endowment of physiographic unit such as a watershed. Rain is a primary source of water for all of us. There are two main techniques of rainwater harvesting:

- Storage of rainwater on surface for future use.
- Recharge to groundwater.

The paper presents thorough overview of the most common rainwater harvesting system such as Roof Rain Water Harvesting, Land based Rain Water Harvesting and Watershed based Rain Water harvesting. The paper also presents the design considerations for the same.

Key words: Rainwater Harvesting • Ground Water Recharge • Artificial recharge • Roof-top Harvesting

INTRODUCTION

Rapid urbanization and industrialization has led to incessant withdrawal of groundwater in recent times, without paying much heed to the hydro geological characteristics of the area, thereby depleting the groundwater level at a fast rate. The water is perhaps the scarcest commodity of the 21st century. On global scale it is assessed that over the next two decades, water use by human beings will increase by 40%. Therfore17% more water will be needed to grow more food for the increasing population. The world water vision commission drew attention to the "gloomy arithmetic of water" as water demand will out strip its availability. India has been blessed with 113 rivers (14 major, 44 medium and 55 minor rivers) Lengthwise, these rivers cover 45,000 km. Three of the major rivers are international and the remaining 11 are national. Together, they contribute approximately 80 percent of India's total water. The average annual rainfall of India works out to about 1.2 meters, (against 0.86 by the entire world) Fig. 1 shows the average mean rainfall and rainy days [1]. Still the scenario of water in India is equally gloomy. Rajasthan, one of India's driest states, relies on groundwater for 90% of its drinking water supply and 60% of its water for irrigation [2].

The reality of water crisis cannot be ignored. India has been notorious of being poor in its management of water resources. The demand for water is already outstripping the supply. [3] Majority of the population in the cities today are groundwater dependent. In spite of the municipal water supply, it is not surprising to find people using private tube wells to supplement their daily water needs. As a result, the groundwater table is falling at an alarming rate.

Corresponding Author: Farrukh Basheer, Environmental Engineering Section, Department of Civil Engineering,
Aligarh Muslim University, Aligarh-202002 India

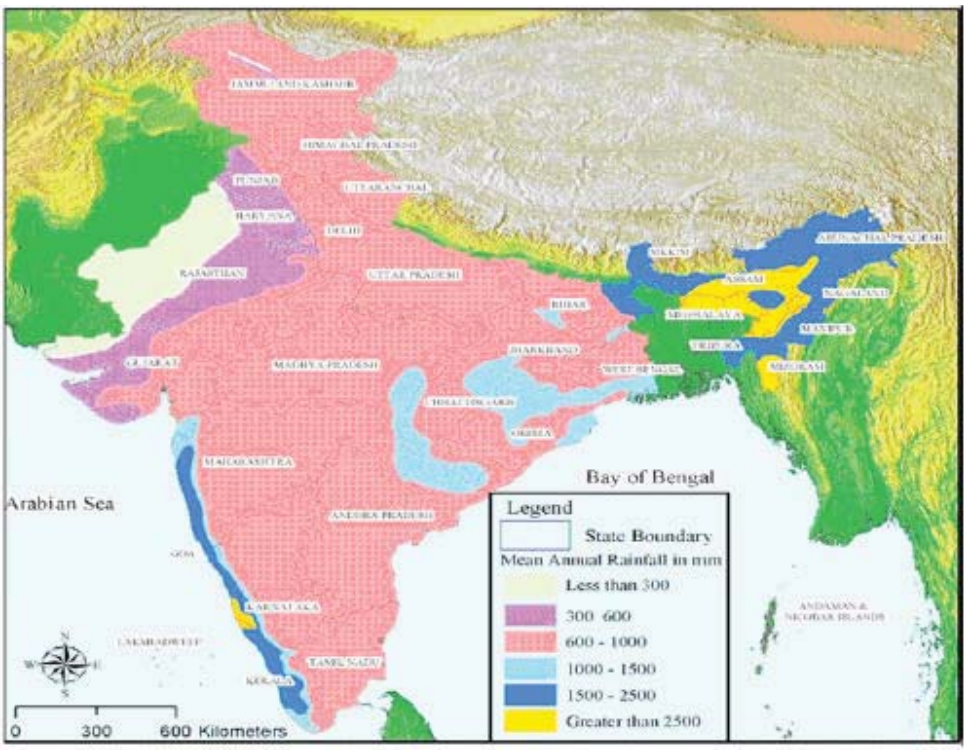

Fig. 1(A): Average annual rainfall

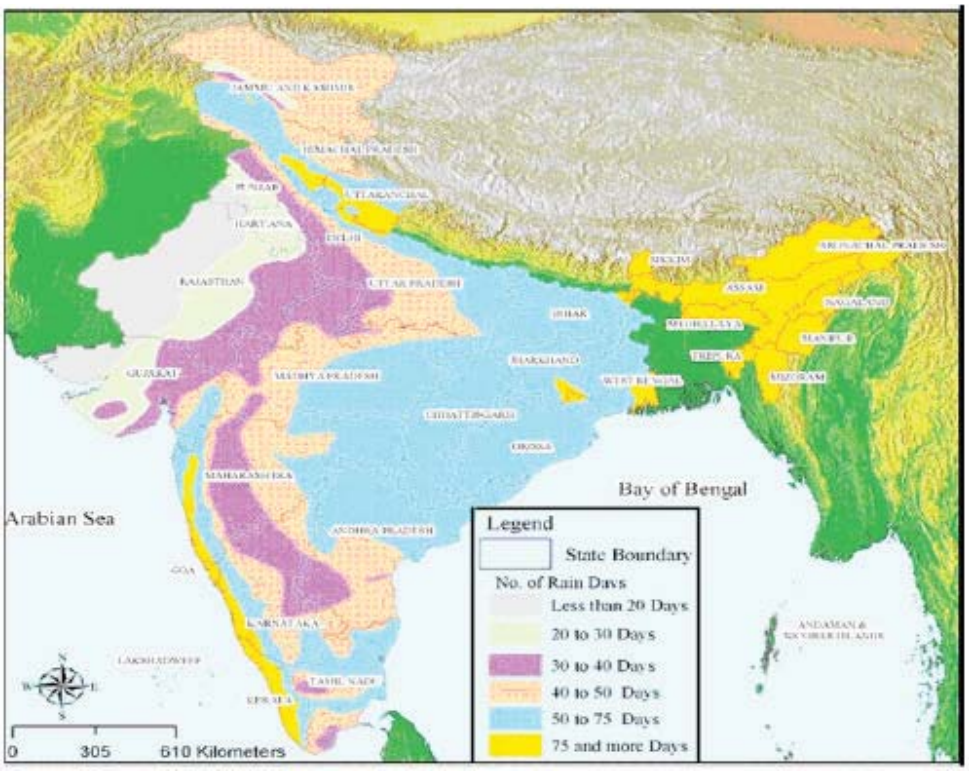

Fig. 1(B): Average number of rainy days

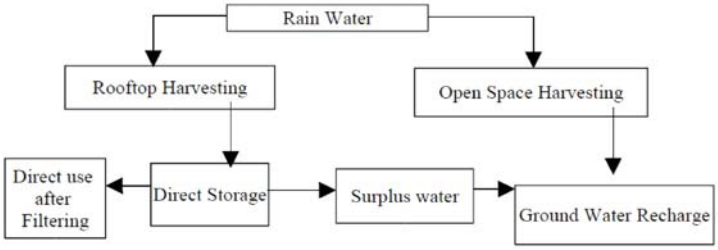

Fig. 2: Rainwater Harvesting Techniques Figure 1(A): Average annual rainfall

Extraction of groundwater is being done unplanned and uncontrolled. This has resulted in:

- Hydrological imbalance
- Deterioration in water quality
- Rise in energy requirements for pumping

For reasons stated above, it is high time to start harvesting rainwater, especially in urban cities and drought-prone areas of the country. The rainwater during the rainy seasons can easily be collected from the rooftop (even in thatched huts). The collected rainwater may either be recharged into the groundwater aquifers or storied for direct use after very simple pre-treatment. Water harvesting refers to collection and storage of rainwater and also other activities aimed at harvesting surface and groundwater, prevention of losses through evaporation and seepage and all other hydrological studies and engineering inventions, aimed at conservation and efficient utilization of the limited water endowment of physiographic unit such as a watershed.

Rain is a primary source of water for all of us. There are two main techniques of rainwater harvesting (Fig. 2).

- Storage of rainwater on surface for future use.
- Recharge to groundwater.

The objective of water harvesting in India differs between urban and rural areas. In urban areas, emphasis is put on increasing groundwater recharge and managing storm water. On the other hand, in rural areas securing water is more crucial. There the aim is to provide water for drinking and farming, especially for life-saving irrigation and to increase groundwater recharge.

Artificial Techniques and Design: wide spectrum of techniques is in vogue to recharge ground water reservoir. Similar to the variations in hydrogeological framework, the artificial recharge techniques too vary widely. The artificial recharge techniques can be broadly categorised as follows:

A: Direct Surface Techniques

- Flooding
- Basins or percolation tanks
- Stream augmentation
- Ditch and furrow system
- Over irrigation

Table 1: Availability of Rain Water through Roof Top Rain Water Harvesting

Rainfall (mm)	100	200	300	400	500	600	800	1000	1200	1400	1600	1800	2000
Roof top area (sqm)	Harvested water from Roof top (cum)												
20	1.6	3.2	4.8	6.4	8	9.6	12.8	16	19.2	22.4	25.6	28.8	32
30	2.4	4.8	7.2	9.6	12	14.4	19.2	24	28.8	33.6	38.4	43.2	48
40	3.2	6.4	9.6	12.8	16	19.2	25.6	32	38.4	44.8`	51.2	57.6	64
50	4	8	12	16	20	24	32	40	48	56	64	72	80
60	4.8	9.6	14.4	19.2	24	28.8	38.4	48	57.6	67.2	76.8	86.4	96
70	5.6	11.2	16.8	22.4	28	33.6	44.8	56	67.2	78.4	89.6	100.8	112
80	6.4	12.8	19.2	25.6	32	38.8	51.2	64	76.8	89.6	102.4	115.2	128
90	7.2	14.4	21.6	28.8	36	43.2	57.6	72	86.4	100.8	115.2	129.6	144
100	8	16	24	32	40	48	64	80	96	112	128	144	160
150	12	24	36	48	60	72	96	120	144	168	192	216	240
200	16	32	48	64	80	96	128	160	192	224	256	288	320
250	20	40	60	80	100	120	160	200	240	280	320`	360	400
300	24	48	72	96	120	144	192	240	288	336	384	432	480
400	32	64	96	128	160	192	256	320	384	448	512	576	640
500	40	80	120	160	200	240	320	400	480	560	640	720	800
1000	80	160	24	320	400	480	640	800	960	1120	1280	1440	1600
2000	160	320	480	640	800	960	1280	1600	1920	2240	2560	2880	3200
3000	240	480	720	960	1200	1440	1920	2400	2880	3360	3840	4320	4800

B: Direct Sub Surface Techniques

- Injection wells or recharge wells
- Recharge pits and shafts
- Dug well recharge
- Bore hole flooding
- Natural openings, cavity fillings.

Rooftop Rainwater Harvesting: Rooftop rainwater harvesting is one of the solutions to the declining water table problem in India. It helps in reducing flood hazard and soil erosion and also improves the quality of existing groundwater through dilution. The urban housing complexes or institutional buildings have large roof area and can be utilising for harvesting roof top rainwater to recharge aquifer in urban areas. Table 1 shows availability of Rainwater through Roof Top Rainwater Harvesting. A typical Roof top Rainwater Harvesting System comprises of (Fig 3, 4 and 5).

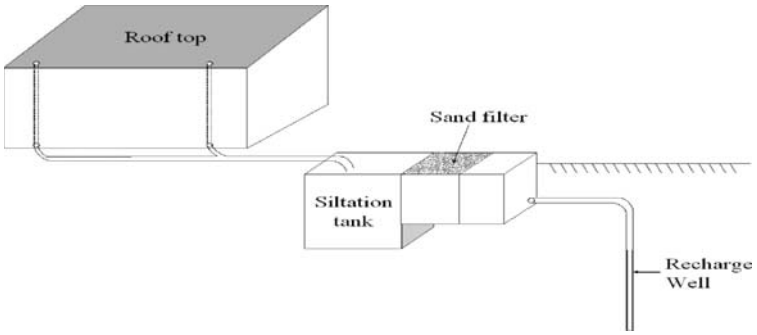

Fig. 3: Filtration units and recharge well for rooftop rainwater harvesting

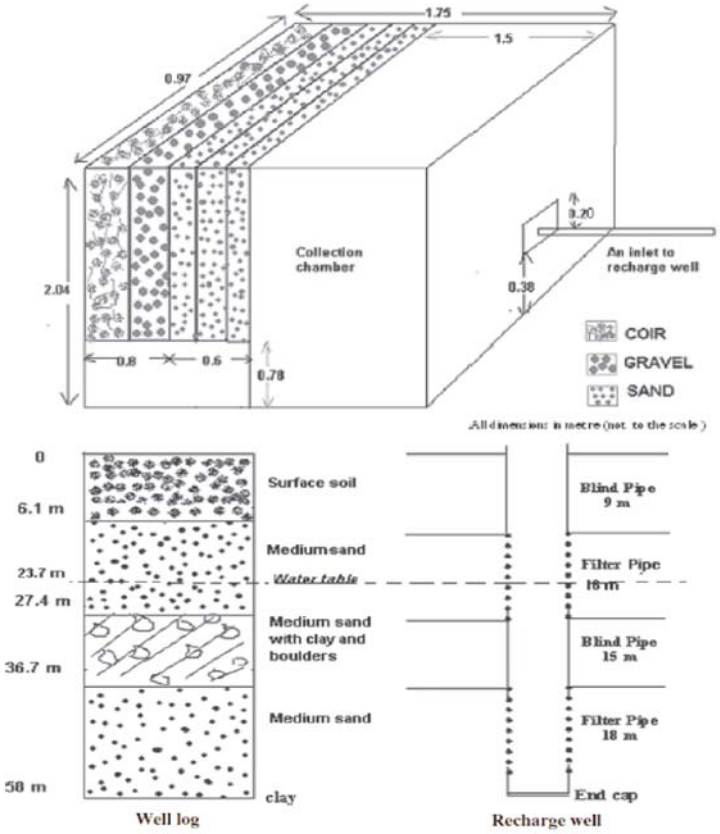

Fig. 4: Dimensions of filtration unit, well log and recharge well

Fig. 5: a) The Rain Barrel - a simple method of rainwater harvesting
b) A recharge well

- Roof catchment
- Gutters
- Down pipes
- Rain water/Storm water drains
- Filter chamber
- Ground water recharge structures like pit, trench, tubewell or combination of above structures (IS 1172 Indian Standard)

The total amount of water that is received in the form of rainfall over an area is called the *rainwater endowment* of that area. Out of this, the amount that can be effectively harvested is called the *water harvesting potential.*
Water Harvesting potential = Rainfall (mm) X Collection efficiency

An example of potential for rainwater harvesting: Consider a building with a flat terrace area of 100m^2. The average annual rainfall in Delhi is approximately 600 mm (24 inches). In simple terms, this means if the terrace floor is assumed impermeable and all the rain that falls on it is retained without evaporation, then, in one year, there will be rainwater on the terrace floor to a height of 600 mm.

Area of the plot	=	100 m^2
Height of annual rainfall	=	0.6 m (600 mm or 24 inches)
Volume of rainfall over the plot	=	Area of plot X Height of rainfall
	=	100 m^2 X 0.6 m
	=	60 m^3 (60,000 litres)
Assuming that only 80 percent of the total rainfall is effectively harvested,		
Volume of water harvested	=	48,000 litres (48m^3) [3]

Design Considerations: Three most important components, which need to be evaluated for designing the rainwater harvesting structure, are:

- Hydrogeology of the area including nature and extent of aquifer, soil cover, topography, depth to water levels and chemical quality of ground water
- Area contributing for runoff i.e. how much area and land use pattern, whether industrial, residential or green belts and general built up pattern of the area
- Hydro-meteorological characters like rainfall duration, general pattern and intensity of rainfall.

Design Criteria of Recharge Structures: Recharge structures should be designed based on availability of space, availability of runoff, depth to water table & lithology of the area.

Assessment of Runoff: The runoff should be assessed accurately for designing the recharge structure and may be assessed by following formula.

Runoff = Catchment area * Runoff Coefficient * Rainfall
Runoff Coefficients: Runoff coefficient plays an important role in assessing the runoff availability and it depends upon catchment characteristics. It is the factor that accounts for the fact that not all rainfall falling on a catchment can be collected. Some rainfall will be lost from the catchment by evaporation and retention on the surface itself.

Fig. 6: Check Dams in Rajasthan, India

General values are tabulated below which may be utilised for assessing the runoff availability [4].

Type of Catchments	Runoff Coefficient
Roof catchments	
• Tiles	0.8 - 0.9
• Corrugated metal sheets	0.7 - 0.9
Ground surface covering	
• Concrete	0.6 - 0.8
• Brick pavement	0.5 - 0.6
Untreated ground catchments	
• Soil on slopes less than 10 %	0.0- 0.3
• Rocky natural catchments	0.2 - 0.5
• Green area	0.05 - 0.10

Rainwater Harvesting in Watershed Management: Watersheds consist of a complex pattern of various ecosystems (forests, farmland, wetlands, soils, etc) which provide a number of important goods and services for human well-being. Rainwater harvesting in the context of a watershed means collecting runoff from within a watershed area, storing it and employing it for different purposes. Runoff collection is generally distinguished as in situ management (Fig 8), when the water is collected within the area of harvesting and *ex situ* when it is diverted outside of the harvesting area. The storage is of crucial importance: for in situ rainwater harvesting the soil acts as the storage, whereas for *ex situ* rainwater harvesting the reservoir can be natural or artificial, where natural generally means groundwater recharge and artificial means surface/subsurface tanks and small dams (Fig.6). Given the fact that rainfall is unevenly distributed between years, as well as within rainy seasons, storing rainwater is a key component of water management. The water can be stored in storages of different construction and dimensions; for example, large reservoirs with large catchments and small tanks and ponds with small catchments, or use of natural or artificial groundwater recharge to store water in the soil. [5]

Groundwater recharge in watershed management can be induced through different structures; for instance, through dug shallow wells and percolation tanks. Percolation tanks are recharge structure which is generally constructed on small streams and used for collecting the surface runoff. Under favourable hydro-geological conditions, percolation rates may be increased by constructing recharge (intake) wells within percolation tanks. Percolation tanks hold a great promise for drought mitigation in regions having impermeable strata beneath a sandy profile, with limited water holding capacity but

Fig. 7: A farm pond next to recharge well and a traditional 'kalyani' to store rainwater

Fig. 8: Dug wells recharged by in situ water harvesting

Fig. 9: UV-resistant, plastic-lined rainwater harvesting tank for irrigation.

high percolation rates. However, the effectiveness of groundwater recharge in any area depends on the technical efficiency of recharging groundwater, the storage potential of the aquifers which are being recharged and the dynamics of interaction between groundwater and surface water [6].

Traditionally water harvesting was done in 'tanks', manmade lakes and 'kalyani' or step well in rural areas. (Figure 7). In the modern context, it is necessary to revive the ancient culture of maintaining these beautiful rain harvesting structures and make them functional. In rural areas farm ponds (Figure 8) are good methods of harvesting rainwater. They can either be used as collection structures or as recharge structures depending on the nature of the soil and the condition of infiltration and percolation at a place. [5]. In North East region of India rainwater are collected in large quantities in lined ponds. Generally, big ponds are constructed and subsequently lined with non-permeable sheets like agrifilm, silpaulin, HDPE or nylon, or with a semi-permeable coating of clay to reduce the seepage losses (Figure 9). [7]

To design a water-harvesting tank for irrigation purposes, the irrigation requirements of the cultivated crops have to be calculated first. Knowledge of factors such as effective rainfall, evapotranspiration, application efficiency and leaching requirements, if any, is essential for calculating the irrigation requirements of the crops. Subsequently, the total seasonal water requirement for the entire area to be irrigated can be found. Water needed for other purposes, such as fishery, may also to be taken into consideration while designing the tank is prepared. Direct evaporation from the water surface in the tank has also to be taken care of and corresponding adjustments can be made in the size of the tank.

CONCLUSIONS

To provide supplemental water for the city's requirement, rainwater harvesting increase soil moisture levels for urban greenery, to increase the ground water table through artificial recharge, to mitigate urban flooding and to improve the quality of groundwater are some of the reasons why rainwater harvesting can be adopted in cities. It can be concluded from above findings that rainwater, if conserved and utilized using the rainwater harvesting technology, can be an effective tool of replenishing ground water resources. It is of utmost importance in the developing countries like India where availability of water scares. Also that rainwater, if conserved and utilized using the rainwater harvesting technology, can be an effective tool of replenishing ground water resources.Rainwater harvesting can be a vital intervention in the rehabilitation of ecosystem services for enhancing human well-being in the context of watershed management. Its appropriate application can influence changes in the well-being of both human-oriented and ecosystem services. The changes are triggered through synergies across sectors; for instance, through interactions between agricultural practices, rainwater recharge, soil conservation and food security needs.

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