Rooftop Rain Water Harvesting as Part of IWRM Plan of Khuskera-Bhiwari Neemrana Investment Region

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***Abstract*— Since water resources are dwindling and water table are going down in many areas, it is essential to follow good water management practices. One of the well know strategies for increasing the water supply is rain water harvesting. Studies were conducted using house sizes and population factors of Khuskera-Bhiwari Neemrana Investment Region (KBNIR) for the rooftop rainwater harvesting. It is estimated that if rain water harvesting is achieved in 50 % of resident houses and all buildings likes hospitals, schools, community halls etc., then 100% of the drinking water requirement of KBNIR could be met from rainwater harvesting alone.**

Keywords—Rooftop Rainwater harvesting, Population, IWRM, water budegting

I. INTRODUCTION

Water plays important role in our daily life. Water is essential for all living beings on the earth for their survival. Not only availability of water but also the quality of water is equally important.

Fresh water depletion is increasingly becoming very critical issue due to over exploitation of ground water at many places. Severe problems are faced in different regions of country due to shortage of water resources, indicating that the country needs to have an optimal water resource utilization strategies and management practices [15]. Water scarcity normally means there is an imbalance between available water and water demand, however could also be due to improper utilization of water resources and/or human activities turning good quality water to poor quality. Population increase and industrialisation have lead to over exploitation of ground water resources resulting in decline in water table in many different parts of the country.

In India most of the rainfall occurs during monsoon (2-3 months). The annual precipitation including snowfall is estimated to be of the order of 4000 billion cubic meters (BCM) in India, which is the main source of water in the country [3]. Rajasthan is one of the driest states of India. The weather of Rajasthan is mostly hot and arid. The entire state receives scanty rainfall and continuous change in the nature of rainfall, characterized by low and erratic rainfall, high air and soil temperature, intense solar radiation and high wind velocity. The state has an area of 342,239 square kilometers, which is 10.4% of the country and 5.5% of its population, however it is estimated that it has only 1.0% of the water resources of the country [24] The total population of the State is about 68 million. The population density of the state was 200.29 per sq. km in the year 2011. Nearly 76% of the state's population resides in rural regions. The state has 49 million livestock mainly cows, buffaloes, and goats comprising 10.13% of the country's livestock population [4]. Rising population and increasing standard of living has been continuously increasing domestic water demand for last few decades. Increasing pressure of population and livestock on the water resources in the north east Rajasthan and depletion of environmental resources particularly, vegetation, soil resources have led to decline of water table [22]. The drinking water crisis with the shortage of water for irrigation and other purposes is being felt very seriously [22].

Therefore it is important to follow best practices in water management in most part of the state, Not only attempts need to made to protect and utilize the existing resources in optimal way but also newer sources of good quality water must be tapped wherever possible. Many methods have been suggested to increase the sources of water supply, out of which one alternative source is rainwater harvesting (RWH) [1]. In present paper attempts have been made to suggest RWH for the study area.

II. OVERVIEW OF RAINWATER HARVESTING

Rainwater harvesting is the accumulation and storage of rainwater for prolonged use. It has been used to provide drinking water, water for livestock, and water for irrigation or to refill aquifers in a process called groundwater recharge (Source Wikipedia). RWH is increasingly recognised as a relatively low-cost intervention which can be employed to improve access to clean water, and which has the potential to better people's livelihoods [12]. Rooftop Rain Water Harvesting is a technique through which rain water is captured from roof catchments and stored in reservoirs [8, 10]. It includes the collecting, storing, and use of rainwater as non-potable and potable water from rooftop and other impermeable surface [16].

Domestic rainwater harvesting system (DRHS) is one of the broad categories of the RWH system. In this system, the rainwater is collected from rooftops and other artificially treated surfaces, and then the water is stored in the underground tanks or aboveground tanks for domestic purpose.

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The purpose of this paper is to find out to rainwater harvesting technology’s potential to provide drinking water and domestic water needs of rural households, this paper highlights rooftop rainwater as a significant water source. Based on analysis presented, it may be conclude that roof top rainwater harvesting may be a good solution for meeting domestic water demand (DWD), especially drinking water requirement (DWR).

III. REVIEW & LITRARTURE

Harvested rainwater is a renewable source of clean water which can be used for domestic purposes, garden watering and small scale productive activities or could be used for augmenting groundwater resources. It also contributes to reducing flood risks and the load on sewer system [10]. Singhal and Goyal [23] developed a GIS based methodology based on the spatial distribution of parameters for understanding the effect of rainfall and vegetation density on groundwater recharge. Kaur [14] analyzed the problem of declining groundwater resources and possible factors responsible for this and suggest suitable strategies for arresting over-exploitation and for sustainable agriculture in Punjab. Giridhar [9] used GPS to identify sites for construction of rainwater harvesting structures using Remote Sensing and GIS techniques.

RWH is a technology where surface runoff is effectively collected during yielding rain periods [11]. RWH can serve the poor by supplying water for domestic use and supplemental irrigation, thus ensuring both water and food security [20] According to Owusu and Teye [19] public education for house owners is required to invest in rainwater harvesting facilities and governmental support will be needed to increase investment in rainwater harvesting, purification and usage.

Rooftop RWH is being widely promoted as a panacea for the growing drinking water crisis in India and many underdeveloped and developing countries [17]. DeBusk. and Hunt [6] describes that runoff from roof surfaces carries a wide variety of pollutants including sediment, heavy metals, nutrients and bacteria. Nzewi [18] discussed about collecting and storing of roof runoff via RWH systems. Rooftop RWH systems can provide a supply of non-potable (‘non-drinking’) water for end uses that do not necessarily require potable water. These can include toilet (WC) and urinal flushing, laundry (washing machines), vehicle washing and gardening[ward].

IV. STUDY AREA

The study area selected for present study is Khushkheda-Bhiwadi-Neemrana Investment Region (KBNIR) Region identified by Delhi-Mumbai industrial corridor (DMIC), located in the Alwar district, Rajasthan state, India. KBNIR region is shown in the Fig. 1. The whole of Alwar District is also part of the National Capital Region (NCR). The District is situated in north-east Rajasthan. It covers an area of 8,380 square kilometres. It is bounded on the north and north-east by Gurgaon District of Haryana and Bharatpur District respectively. On the north-west, Alwar is bounded by Rewari District of Haryana. Jaipur District bounds Alwar on the south-west and south

The climate of the District is semi-arid and very hot in summer and extremely cold in winter. The monsoon season is of very short duration. The cold season starts by the middle of November and continues up to the beginning of March. The summer season follows the winter season and extends up to the end of the June. The south-west monsoon continues from July to mid-September. The period from mid-September to mid-November forms the post-monsoon season. The rainfall during the south-west monsoons constitutes about 80% of the annual rainfall. 577.7 mm is the annual average rainfall [5].

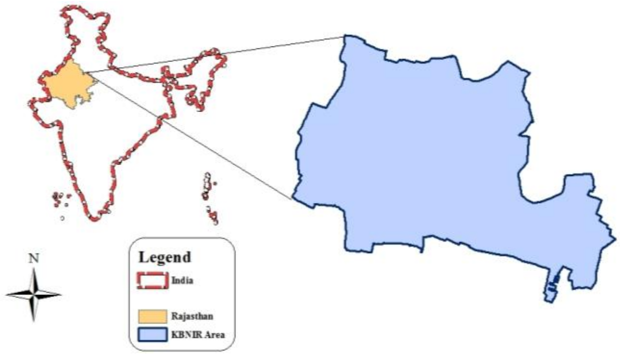

Fig. 1: KBNIR region map

KBNIR area lies between longitude 76^{o}24’6.0’’E to 76^{o}35’40.00’’ and Latitude 27^{o}54’33.00’’ N to 28^{o}03’20.00’’. Total geographic area is approximate 162 Km^2. West part of study area lies in Neemrana block and east in Mandawar block. Out of 162 Km^2 area, 130 Km^2 lies in Neemrana block and rest 32 Km^2 lies in Madawar block. Yearly rainfall data of station surrounding KBNIR region is download from Rajasthan Water Resource website [21]. All nearby stations are illustrated in the Fig 2. The sample table of rain fall data is shown in Table 1. The average annual rainfall based on the complete data between 1993 to 2013 from these stations is 611 mm.

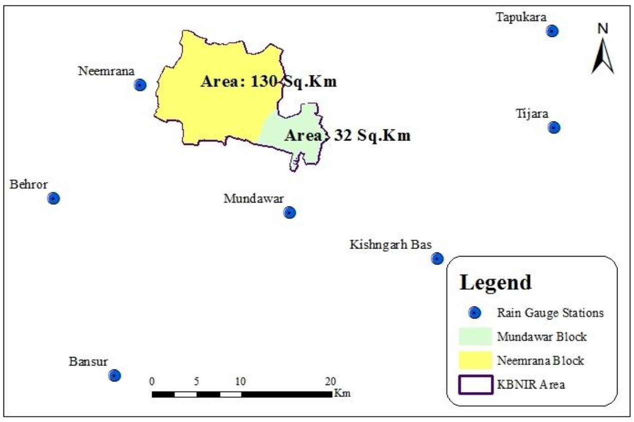

Fig. 2: Rain gauge station map

Fig. 3: sprinkler system and Village farm house

Numbers of field visits were organized between 7/5/2014 to 19/6/2014 dates to collect field data about the farmers, households, water usage, house sizes, agriculture activities, etc. Fig. 3, taken during field visit, shows use of sprinkler system, houses and tube well situated in agriculture field. Based on the field data collected primary assumptions are made about average house sizes, area available for RWH etc.

The major crops grown in study area in rabi (winter) season are wheat and mustard and in kharif (summer) season are bazara, gwar and chara. Other crops grown in this area are chana, kapas and arahar etc. The crops are irrigated only by wells or tube wells situated in field, no other source of irrigation is available here for irrigation. Mostly Farmers are dependent on rainfall for kharif crop. The farmers use submersible pumps for extracting water from ground, which are 10 horse powers on average. Ground water has been declining by about 1 m per year as told by villagers.

Table 1: Sample table of rainfall data

Station	Latitude	Longitude	Year			
			1993	*1994*	*2012*	*2013*
Kishngarh	27.82	76.72	563.5	563.5	490	804
Bansur	27.70	76.35	780.7	580	776	720
Tijara	27.95	76.85	590	645	633	653
Tapukara	28.05	76.85	658	570	485	342
Behror	27.88	76.28	555	401.3	487	746
Neemrana	28.00	76.38	1008	795	566	456
Mundawar	27.87	76.55	1010	931	483	775

V. ANALYSIS FOR RWH

In order to develop plan for RWH, it is essential to first estimate the present and future water demand of the area. One of the main factor on which domestic water demand of any area depends is population. Population data download from Census of India [2] for the year of 1991, 2001 and 2011 respectively for Behror and Mundawar Block are shown in Table 2. From the population of different blocks, population of study area has been estimated assuming that the density of the population is constant throughout the block and therefore estimated according to fraction ratio of area of particular block in KBNIR to total area of that particular block.

Table 2: Population data (1991 to 2011)

Year	Behror		Mundawar		Total KBNIR
	Total	*KBNIR*	*Total*	*KBNIR*	
1991	235376	41927	162010	9164	51091
2001	305688	54451	197582	11176	65627
2011	359248	63991	231628	13102	80093

After 2013-2014, Neemrana block was separated from Behror block and therefore for that prediction of population of Neemrana block fraction ratio is used accordingly. Logistic curve method have been used to predict future population for the years 2021 to 2051 of the study area. Equations, 1 to 4, used for logistic curve method are given below

$$P_s = \frac{2P_0P_1P_2 - P_1^2(P_0 + P_2)}{P_0P_2 - P_1^2} \quad \text{..... 1}$$

$$m = \frac{Ps - P_0}{P_0} \quad \text{..... 2}$$

$$n = \frac{2.3}{t_1}\log_{10}\left(\frac{P_0(P_s - P_1)}{P_1(P_s - P_0)}\right) \quad \text{..... 3}$$

$$P = \frac{P_s}{1 + m\log_e^{-1}(n.t)} \quad \text{......4}$$

Here P is future population, P_s is saturated population , P_o P_1 P_2 are the population of year 1991, 2001 and 2011 respectivly, m and n are cofficient. Here saturated population calculated using equation 1 is 435228 for Behror and 355780 for Mundawar. The values of m are 0.849 and 1.196 and n are -0.070 and -0.040 for Behror and Mundawar blocks respectively.

Using these m, n and Ps values the future population has been predicted for KBNIR region from equation 4. Predicted population is 76521 for Mundawar block and 18168 for Neemrana block for the year 2051. Population predicted using logistic curve method for different years are shown in Table 3.

VI. RESULTS AND DISCUSSIONS

Number of houses data of Alwar district has also been downloaded from Census of India for the year 2011. Number of houses in KBNIR region is then calculated by multiply the area ratio to the total number of houses in Alwar district, assuming that the density per unit area of houses remain same throughout the district. The number of houses in future years are calculated by assuming that population and houses ratio remains the same in future years. Table 3 also shows the number of houses in KBNIR for future years.

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Table 3: Domestic water requirement

Year	Population	Houses	DWR (Litre)	TCW (Litre)
2021	84934	20780	4185122850	167585080
2031	89872	21988	4428442800	177361080
2041	92875	22723	4576415625	183275560
2051	94689	23167	4665800475	186868240

According to estimated population there will be challenge to fulfill Domestic Water Demand or drinking water demand. The daily per capita demand constitution is shown from the Table 4 below as per Indian standard code. The domestic water demand (DWD) and drinking water requirement (DWR) of the area has been calculated by assuming 135 litre per person per day demand for domestic use out of which 5 liter per person per day is water demand for drinking water use [13]. Table 3 also shows the values of DWD and DWR for the future years for KBNIR calculated based on the populations in various years. Fig. 4 shows how the water requirement would grow in coming years.

Table 4: Domestic water requirement per person

S. No.	Description	Amount of water (per person per day in litres)
1	Bathing	55
2	Washing of clothes	20
3	Flushing of W.C.	30
4	Washing the house	10
5	Washing of utensils	10
6	Cooking	5
7	Drinking	5
Total		135

Source: IS 1172 (1993)

In order to estimate potential of RWH from a house, it is assumed that on average 25 square meters of clear roof area would be available per house. This is based on observed average house area during the field visit. These houses may have different type of roof material but majority of houses have either stone or concrete roof and therefore average collection efficiency of 80% could be considered. Now total rainwater collected (TRC) from a single household could be estimated as

$$TRC = RTA * AAR * CF \quad \ldots.. 5$$

Where RTA is rooftop area, AAR is average annual rainfall and CF is collection efficiency.

It is estimated that public buildings likes hospitals, schools, community halls, government building and commercial building (non-residential) are approximately 4% of the total houses in any area. Therefore it is estimated that about 927 such buildings would exist in the year 2051. Average area for RWH of such building could be estimated to be about 100 square meters (approximately 4 times average house area, which seems to be on conservative side). So the additional area available for RWH from such buildings would be 92700 square meter. It may be assumed that in order to plan a strategy for RWH of any area, these buildings must be taken up first and then only households must be taken for RWH. Different scenarios could be generated considering that different ratio of households adopt RWH. Table 5 below, gives how much percentage of domestic or drinking water requirement could be met if different percentage of households are taken up for RWH.

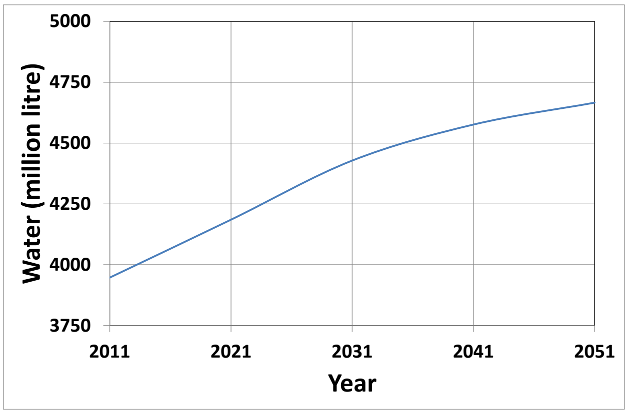

Fig. 4: Domestic water requirment for years 2011 to 2051

It can be seen that if the RWH systems are installed in 50% of total household and all the public buildings, then 100% drinking water requirement of the entire area can be met by RWH alone. Approximate 4.0% domestic water requirement can thus be fulfil by rooftop rain water harvesting.

Table 5: Water requirement fulfill from RWH

Houses with RWH	Percentage demand met from RWH	
	Drinking	Domestic
0 %	26.2 %	1.0 %
10 %	42.6 %	1.6 %
20 %	59.0 %	2.2 %
30 %	75.4 %	2.8 %
40 %	91.8 %	3.4 %
50 %	108.1 %	4.0 %

VII. Conclusions

RWH could be taken up as a water management practice to meet out the ever growing water requirement of an area. During field visits data has been collected to estimate water requirement and potential of water harvesting in KBNIR. It is estimated that besides non-resident buildings, if 50% of the resident houses are taken up for rain water harvesting, then 100% drinking water requirement could be met from RWH alone. This water would be good quality water and therefore cost of water treatment would also be low. Achieving 50% level of RWH is not easy and needs a good awareness building programme and government subsidiaries, Cost benefit analysis can be carried out for any other drinking water supply scheme by estimating the cost of RWH with other schemes.

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