A Study of Rain Water Harvesting in Different Regions of India

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Abstract

India has a lengthy water collecting history. Many of the traditional water harvesting systems have fallen into a disuse either because of a wide variety of physical, social, economic, cultural and political factors, as well as because of the declining institutions that nurtured them and because of a lack of capacity to satisfy the desires of communities, or because they are less relevant today. Although the first component of the decrease in the tradition of water collecting is extensively studied and recorded, the second dimension is considerably less known and appreciated. It is also very apparent that there is no readiness to understand that the origin, development and collapse of new traditions in water reaping are likewise a feature of various eras of history. A surge in water harvesting has defined India's water industry history during the last two decades. They vary significantly from conventional harvest years in two respects, firstly in context and secondly in intent. They are also significantly different. With respect to the setting in question, current progress in soil, geology and hydroscience has been made during the last two decades, as well as contemporary methods and technologies of research, land motions and building. In terms of water technologies for water harvest and water distribution and the volume of water processed, traditional collection years were at most the best engineering features of those times, but modern water harvesting systems were in the best of the cases small variants of the large water resources systems used for advancing civil engineering and hydrology.

Keywords: *Potential and Pitfalls, Rainwater Harvesting, India, water technology, water resource systems*.

1. INTRODUCTION

One of the main fundamental principles in rainwater collecting is that this technology is benign (Bachelor et al. 2002). Initiatives of water harvesting are guided by strong convictions and assumptions, including:

- that there is a large quantity, which remains uncaught in the natural sinks, particularly in the seas and oceans, backed by national macro-hydrology aggregates;
- that there are too little local water demands and there is no need for such foreign water;
- that there are always modest and thus cost-effective local water collecting systems;
- As water's economic, social and environmental values in areas affected by water shortages are extremely high, water collection measures are sustainable, backed by the premise that there is no cost-effective alternative that could provide the same amounts of water;
- Incremental structures provide incremental advantages and rewards;
- They do not have negative implications for downstream usage since they are tiny with limited water storage and diversion capacity.

Modern water collection systems are used as resource management solutions and not as solutions for resource development. In order to improve aquifer storage and groundwater quality various water collecting devices were constructed, for example. The Indian study on rainwater collection and artificial refuelling (RWH) has till now been confined to engineering of different structural aspects (see Muralidharan and Athawale 1998). Although there is a lot of predictable data on social and economic benefits, based on empirical study, there is limited knowledge of:

- the effect on local hydrological regimes of the net water production activity;
- effects of basin level on the total water balance of the basin;

- Long-term economic requirements.

Researchers have late questioned the potential unexpected effects and economic effects of aquatic collection (see Bachelor et al. 2002). (see Kumar 2004). The failure to provide accurate scientific information on different parameters, mostly hydraulic, hydrological and meteorological, governing performance and impact of water harvesting is one of the reasons why there was little or no empirical research on hydraulic and economic aspects of water harvesting systems. The issue comes primarily from the extremely micro-type of these systems, making it impossible to collect data on traditional variables. The study of water collection systems also ignores the 'scale factor' effect.

2. LACK OF EMPHASIS ON LOCAL WATER DEMAND AND POTENTIAL SUPPLIES

Rainwater collections ignore some critical parameters governing the potential of RWHS to meet local water requirements, such as: a) the region/locality hydrological regime; b) the reliability of the supply governing the rainfall reliability; c) the constraints placed upon the recharge capacity of the geological and geo-hydrological local environment; and d) the aggregated harvesting capacity; Some fundamental hydrological processes that make rainwater collection and groundwater rechange extremely essential for the above-mentioned parameters:

- The precipitation must surpass the threshold to create the rivers during harvesting, but the threshold would vary depending on the type of the soil and the area's land cover. The predicted rush based on the regression equation in western India (GOG 1994) indicates that, for rush to 100mm, the minimum rainfall needed is 682mm, based on the measured flows in the Sabarmati Sub-bassin Hathmasti (R=0.00193*X 2.022). When the plummet reaches 366 mm, the rush begins with the Kabani sub basin of the Cauvery Basin. 1 The real river flows would, however, rely on how strong the rainfall-runoff connection in a particular basin is and this relationship diminishes when the rainfall intensity and pattern changes significantly year by year.
- Lower average yearly precipitation regions are more variably subject to and vice versa (Pisharoty 1990). Therefore, the rainwater collection as a reliable water supply is expected to be low in areas with lower average annual precipitation.
- In general, a higher magnitude of yearly rainfall implies a higher number of rainy days and less annual rainfall is less common throughout the rainy season (Pisharoty 1990). Gujarat's examples demonstrate this further (see Kumar 2002b; Kumar 2004). Less wet days also implies more dry periods and therefore higher evaporation losses in the same area. The semi-arid and dry areas of India have high intensity precipitation (Garg 1987; Athawale 2003). Higher rainfall intensity may result in high runoff intensities, which occur over short periods of time and restrict rainwater systems' effective storage capacities to almost the same storage size.
- In the wet season, high evaporation causes surface structure losses. It also implies that soil moisture is depleted quicker, both by evaporation and by evapotranspiration, which increase soil infiltration rate and quantity. The possibility for runoff is reduced. ET0 during monsoon (June to September) ranges from the lower of 543 mm in Vadodara to 714 mm in Rajkot among the seven sites in Gujarat, where statistics on ET0 (evapotranspiration reference) are available. The ET0 as an annual percentage ET0 in semi-humid Sourate ranges from the lowest 33% to the 37.3% in Bhuj, Kachch (source: IMD authors' study, Ahmedabad). The range of ET0 in the monsoon for Rajasthan on the hill Mt Abu station in the Thar Desert varies from 433 mm to 967.7 mm in the jaisalmer. The percentage range in Sawaimadhupur ranges from the lowest 32% of the total yearly ET0 to 49.3% in Anupgarh (GOR 1992). The values vary from 429 mm to 600 mm, with ET0, as a percentage of the total ET0, from 31.3 percent in Betul to 35 percent in Mandla, among the 10 places chosen along the Narmada Basin in Madhya Pradesh (source: GOMP 1972).
- Capacity for soil infiltration may be a recharging factor. In sandy and sandy loam soils, the soil may be continuously removed for the infiltration capacity of the recharge area. But clayy soils are restricted inherently (see Figure 1). In the case of silty loam, infiltration rate stabilises at 129,1 mm/h during the first 25 minutes of sandy loam, while at the case of the sandy loam it stabilises in a rate of 129,1 mm/h after brief infiltration tests conducted in dug wells in Andhra Pradesh in two distinct soil types (NGRI 2000). If the infiltration rate approaches zero quickly, the charge efficiency of percolation ponds would be adversely affected. The scope of the issue is wider in hard rocky regions, with a thin soil covering, because the thin soil cover is low (Muralidharan and Athawale 1998). Dickenson (1994) demonstrates that the penetration rate decreases to a minimal value after 4-5 days of pounding on basis of several infiltration experiments. This will

also negatively affect the performance of buildings in regions with flash floods and high evaporation rates, which may be wetted or dried by regulating inputs.

- The aquifer's storage potential is very significant for artificial recharge. In geological forms and probably the depth of the disinflated area, the storage capacity of an aquifer in relation to the extra recharge is calculated.
- The area available for farming in mountainous watersheds is usually very limited, with little need for agricultural water. At the same time, owing to high rainfall and runoff levels surface water potential for collection is usually high. Conversely, the area accessible for agriculture in the valleys and plains is increasing, increasing demand for agricultural water. At the same time, because of the reduced rainfall and the low runoff coefficients due to moderate slopes, high PE T and deeper ground profiles, the available surface water potential for use is usually limited.

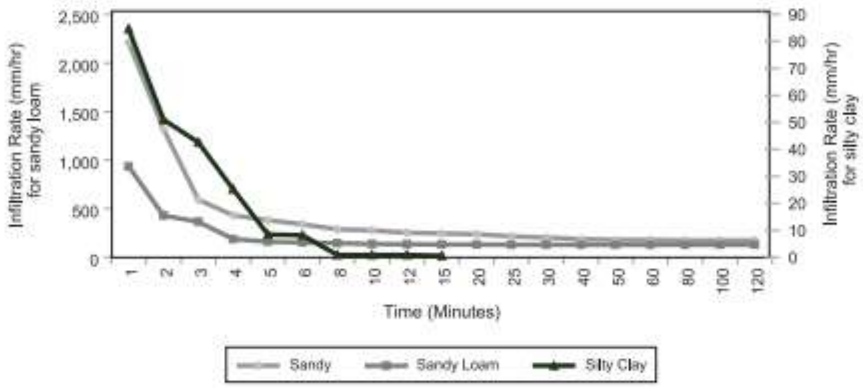

Figure 1. Infiltration rate in the sandy loam and silty clay soil at the bottom of a dug well

3. LIMITATIONS IMPOSED BY HYDROLOGICAL REGIMES

Less knowledge of local hydrological systems governing the prospective supply of water to harvest frequently relies upon local water management actions. They are founded more on the profound conviction that the larger the water structure, the higher the water storage and refuelling hydrological benefits. The participatory effort to save water initiated by the Government of Gujarat is the finest example. The government has undertaken large-scale excavations of thousands of local lakes, regardless of catchment type and size (Kumar 2002a). Part of the reason for this is the absence of access by stream-flux data on inflows and outflows for the tiny rainfall catchment, as indicated by evaporation rates. This is also disregarded, while rinse collection is most appropriate for regions with large "runoff catchment areas" to be "run-on" (Lalljee and Facknath, 1994). The greater the aridity, the bigger the catchment area to the cultivated area needed to produce the same water (Prinz 2002). Often, the intrusion of water collection system catchment for the growth of crops is extremely rapid, decreasing the possibility of runoff. The countries who have been taking up large-scale projects for rainwater collection and groundwater re-enlistment include Gujarat (North Gujarat, Saurashtra and Kachchh), Rajasthan, Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh, Madhya Pradesh, Orissa and Chattisgarh. The six rivers of the river basin systems Sabarmati, the Kachchh and Saurashtra Rivières, Pennar, Cauvery Rivers, the eastern flowing River between Mahanadi and Godavari, the eastern flowing Rivers Pennar and Kanyakumari River cover a major part of these regions with fewer than 1,000 m3 of water per year (Gupta 2000: pp 116). Let us now examine the hydrological system in these areas.

With respect to PE, lions are under high evaporation in Gujarat and the region of Rajastan (2,500-3,000 mm). Almost 35-56 percent of the geographical region of other countries is under high evaporative regimes, with the exception of Orissa and Chattisgarh; the area of medium evaporation (1,500-2,500 mm) of these states falling within the range of 38-65 percent. All Orissa and Chattisgarh regions are covered by medium evaporation. Overall, there are medium and medium to high evaporation in vast areas (out of the nine States included). A large part of the region (in Gujarat and Rajasthan) has very little to low precipitation and considerable evaporation (Table 1).

We evaluate in the following phase the percentage of the geographical area of individual regions/countries that fall into a range of rainfall variability classifications such as > 25%, 25-30%, 30-40%, 40-50% and 50% and above. The greater the quantity of PET during the mountain, the greater the adverse effects on hydrological variables such surface storage and recharge. The greater PET during the monsoon also implies higher agricultural water demand throughout the season and an increased depletion of soil moisture that leads to less rainfall recharging. Higher evaporation rates in steep soles lead to a quicker loss of soil moisture that perpetuates a greater infiltration rate and less runoff.

Table 1. Rainfall and PE regimes of states having water harvesting programs

Name of State	% Area with rainfall in the range of						% of area with evaporation in the range of (PE)			
	<300 mm (very low)	300-600 mm (low)	600-1,000 mm (medium)	1,000-1,500 mm (high)	1,500-2,500 mm (very high)	>2,500 mm (extremely high)	<1,500 mm (low)	1,500-2,500 mm (medium)	2,500-3,500 mm (high)	>3,500 mm (very high)
Gujarat	10.88	39.08	47.27	2.77					88.53	11.47
Rajasthan	41.80	32.45	25.75						100.00	
Maharashtra			85.86	6.93	7.21			37.96	56.23	5.81
Madhya Pradesh			95.71	4.29				56.94	42.89	0.17
Andhra Pradesh			97.83	2.17				52.70	47.30	
Karnataka			88.01	3.65	5.67	2.67		62.82	37.18	
Tamil Nadu			96.52	2.98	0.50			64.56	35.44	
Orissa			54.01	45.99				100.00		
Chattisgarh			59.39	40.61				100.00		

Table 2. Rainfall variability regimes of states having water harvesting programs

Name of State	% area with rainfall variability in the range of				
	<25 % (low)	25 – 30 % (medium)	30 – 40 % (high)	40 – 50 % (very high)	> 50 %
Gujarat	0.24	27.12	44.30	17.11	11.22
Rajasthan	8.33	24.08	23.04	30.71	13.84
Maharashtra	37.67	62.33			
Madhya Pradesh	49.71	50.29			
Andhra Pradesh	62.64	37.36			
Karnataka	29.15	70.85			
Tamil Nadu	7.73	92.27			
Orissa	100.00	0.00			
Chattisgarh	100.00	0.00			

As shown in Table 2, a significant proportion of Gujarat and Rajasthan's entire geographical area (72% and 68%, respectively) have a high to very high variability (30-40% and above). In the three to seven countries, a major portion of the geographical region in Table 1 (37 to 92 percent) has medium rainfall variability; the remainder have low variability. The total rainfall variability in the Orissa and Chattisgarh is minimal. In a nutshell, there is medium variability across 50% of the entire geographic area of all States; about 25% experience "high to very high variability" and almost 20% experience 'low variabilité' in precipitation. They correlate with "medium- to high evaporation rainfall;" low precipitation to extremely heavy evaporation and "high precipitation to medium evaporation."

4. LIMITATIONS IMPOSED BY THE SOCIOECONOMIC SYSTEM

Arguments on water harvesting completely ignore the micro-level viewpoint on water demand availability. The RWHS would ideally function if the region with uncompromised flows had a "unmet demand" or vice versa. In other words, the arrangements for the transfer of water from 'surplus' regions to deficit areas are different in major water resources systems. The water requirements of a given region are dictated by the agro-climate and the current socio-economic system that in reality is adapted through time to the village's natural resources and access technologies. In regions that had previously been extensively irrigated and backed by excellent water supply, institutional backing and favourable regulations, significant amounts of water may be requested for irrigation even when running out of water. This is because communities take a while to develop coping and adaptive methods for dealing with water shortage situations. Studies conducted in Kachchh hamlet in Mandvi Taluka, one of India's most dry regions, demonstrated that an annual recycling in irrigation aquifers amounts to 25.42 MCM. Groundwater, which has serious overdrawing conditions, supplied the whole water demand of the community (Kumar 1997). The town has approximately 10,14 MCM total rainwater dropping (source: based on data provided in Kumar 1997 on geographical area and the mean annual rainfall of Kachchh). The quantity of rush water available for refuelling by natural and artificial recharge from inside the community is just 0.40 MCM with surface water potentially at 0.014 MCM/sq. km (IRMA /UNICEF 2001). Therefore, the runoff is a tiny percentage of the overall consumption. In order to ensure that water is sustainable, the community must thus rely on external supplies of water. It depicts nearly the whole peninsular of India with the exception of Kerala, Central India and western India.

5. ISSUES IN EVALUATING COSTS AND ECONOMICS

Cost and economic factors are essential for the assessment of various choices in the design of major water resources systems. The same does not seem, however, for small systems, while writers like Phadtare (1988) and Kumar expressed concerns about the economics of recharge systems in specific circumstances (2004). Part of the reason why the emphasis on 'cost' is the lack of scientific understanding of the small-scale interventions hydrological aspects such as the amount of flux that is available at the impoundment point, their samples, the quantity that might be deposited or reloaded and the area of influence of the charging system. While there are simulation models for the analysis of catchment hydrology, the generation of critical micro-level data are very difficult, in particular those relating to daily rain, soil infiltration rates, catchment pathways, land cover and PET, which determine the possible inflows, and evaporation rates which determines potential exits. In addition, it is difficult to justify the expense of hydrological studies and planning for small-scale water collection schemes carried out by local agencies and NGOs with modest budgets. In modest water harvesting installations, such provisions are often not provided.

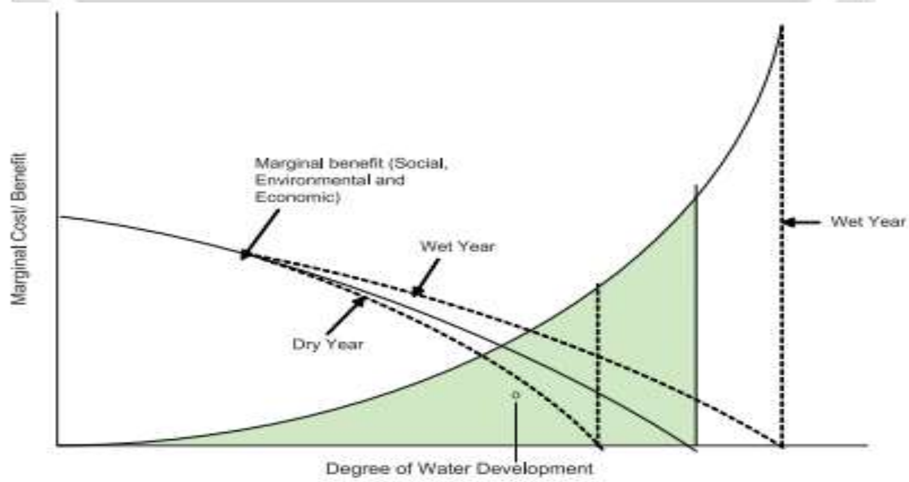

Figure 2. Marginal cost and benefits of water-harvesting with different degrees of basin development.

The marginal benefit of a new watershed would be less for every basin, but the marginal cost would be greater at higher levels of basin development (see Figure 2). The reason for the study is: 1) the higher the degree of development in basins, the lower the chances of obtaining socially and economically viable sites of water structure impoundation, increasing the economic and financial cost of harvesting each water unit; and 2) increasing the social and environmental costs of harvesting any water unit (Freder). The cost and economic assessment should thus be transferred from the water level to the basin level. As shown in Figure 2, the degree at which basin growth may take place will depend on whether we take the flows into consideration in a rainy, dry year or average year. However, there is a development stage (as indicated O on the graph) which leads to an increase in negative social, economic and environmental benefits, thus decreasing total advantages. Here, O is the highest degree of development of water resources.

However, it is essential to bear in mind that a community living in one part of a basin may bear the negative social and environmental impact of overuse of water resources in the basin, while the advantages are derived for a population living in a different part of the basin. Ideally, water development initiatives in a basin should satisfy various stakeholders' demands and interests in different areas. The optimal degree of water development should thus not be aimed at maximising net basin benefit, but should instead optimise the net hydrological and social economic advantages for various stakeholders and communities in the whole basin, which is basin-wide optimisation. That stated, the local economic advantages of the RWH versus economic costs may be dubious in some circumstances itself. But, if there are possible societal advantages in terms of improving water access for poorer farmers with low-capability land holdings, it may be acceptable to change the patterns of water availability and usage. These choices should, however, be founded on the assessment of alternative solutions that address local water requirements of the poor. Now, where the recharged water is finished, relies on the capacity to draw the economic advantages. The patterns of groundwater flow are very complicated in the areas underpinned by hard rock geology. It is often advantageous to extend recharge structures up to several kilometres downstream or upstream depending on how geological features such as lines, cracks and decks arise (source: based on Muralidharan and Athawale 1998). In these circumstances, the tracking of recharge water would need advanced isotopic research. This has been a frequent issue with large-scale water rearing and water refilling measures by means of check dams, ponds and percolation tanks in Saurashtra, Kachchh, North Karnataka and the Tamil Nadu hard-rock regions. Often the communities that invest in charging systems are not benefited (Moench and Kumar 1993). Recharge water may end up in salt aquifers in some other circumstances. The economy of RWH would also depend on the increase in the value of additional water benefits. Besides the recharge volume, the value of the usage of added water to determine the incremental benefits is very essential, a problem which has frequently been neglected in project design. In many instances, the advantages of RWHS are not apparent. Although the expense of water production is substantial, it is important that the additional water be converted to highly valuable usage. Phadtare (1988) said recharge schemes in alluvial North Gujarat would economically be feasible if the water were to be irrigated because buildings are costly. The loss of production due to stress in arid or semi-aride areas is very substantial, and that installing a number of protective irrigation systems may significantly improve rainfed agricultural yield and water productivity, in particular during drought (Rockström et al. 2003). The additional water collected from the monsoon rains should thus be redirected in dry years towards further irrigation.

6. CONCLUSION

RWH provides limited capacity in India's most water-scarce areas. The low groundwater capacity of the hard-rock underlying these regions is a restriction to recharge in many other areas, with medium to high rains but 'medium to highly evaporated.' This is shown by fluctuations in water levels in the wells of the Saurashtra Ghelo basin. The economic assessment of the systems for water harvesting presents many complications as their hydrological effects and different advantages are quantified. The economics of water harvesting cannot be based on individual advantages but on incremental advantages for buildings. The balance between enhancing the hydrological advantages of RWH and making them economical is strong throughout many water-scarce basins. RWH intervention in many water scarcity basins leads not to increase but to distribute hydraulic advantages. The historic flow history of data from the Ghelo basin also showed this. The optimal amount of water harvesting may be achieved by a basin for optimising the product with a gross value in relation to economic, social and environmental production across the basin.

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