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Traditional water harvesting structures and sustainable water management in India: A socio-hydrological review

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ABSTRACT

Water harvesting systems are traditional technologies that have met the needs of local populations for many centuries indicating the systems are clearly sustainable. It is simply defined as a method for inducing, collecting, storing and conserving local surface run-off for future productive use. It is one of the oldest and most commonly used sustainable water management systems in India. There are various types of systems to harvest rainwater in India ranging from very simple to the complex industrial systems. Examples of traditional rainwater systems in India include bamboo pipes and *Apatani* systems of eastern Himalayas, *Ghul* of western Himalayas, *Zabo* and *Cheo-ozihi* of north eastern India, *Dongs, Garh* and *Dara* of Brahmaputra valley, *Kund, Khadin, Talabs, Beri, Johad, Baoli etc. of Thar desert and Gujrat,* the *Havelis* of Jabalpur, *bandh* and *bandhulia* of Satna, *virda* of Gujarat, *ahar-pynes* of Bihar, *Eri* and *Kulam* of eastern coastal plains, *Jackwells* of islands, most of which showed immense structural simplicity and high efficiency. Almost all forts in India, built in different terrains and climatic conditions, had elaborate arrangements for drinking water. Most of the old temples in south India built centuries ago have large tanks in their premises. These tanks are either fed by harvested rain water or by tapping underground springs. The traditional water-wisdom at all levels of the society ensured adequate availability of water for all, which in turn, formed the basis for all round development and prosperity. We should again learn and comprehend the ancient knowledge and apply it in our modern society to get rid of the present water stressed condition.

1. INTRODUCTION:

Water is a compound whose material constitution becomes secondary to its symbolic value because of its reflection in our mind as a symbol of life. The access to water is a basic human right, as because water is a social and cultural good, not merely an economic commodity. The hydrological cycle of the globe can be referred to as water democracy, because it is a system of distributing water for all the living beings. Providing water is absolutely essential for a country's development objectives – job creation, food security, GDP growth and social goals including poverty reduction (UNESCO, 2009).

Global consumption of water is doubling every 20 years, more than twice the rate of human population growth. Mismanagement and unsustainable use of water is making the whole situation environmentally uncomfortable for India. Most of the rain falling on the surface tends to flow away rapidly, leaving very little for the recharge of groundwater. Besides, the ground water availability in the Indian sub-continent is highly complex due to diversified geological formations, complexity in tectonic framework, climatic variations and changing hydro-chemical environments. Natural replenishment of ground water reservoir is slow and is unable to keep pace with the excessive continued exploitation of ground water resources in various parts of the country. This has resulted in declining ground water levels and depleted ground water resources in large areas of the country.In recent times, most of the water resource development projects implemented in India were proved to be ecologically damaging, socially intrusive, capital intensive and unsustainable. In agricultural production, the "classical" sources of irrigation water are often at the break of overuse and therefore untapped sources of irrigation water have to be sought for. The ability of urban areas to increase water supply potential is further limited due to depletion of groundwater resources, falling groundwater levels and deteriorating groundwater quality and pollution of surface water bodies. In such circumstances, urban water utilities are severely strained to maintain the supply levels. People are increasingly coming under pressure to find alternative sources of water supply.

Water harvesting is the deliberate collection and storage of water that runs off on natural or manmade catchment areas. Catchment includes rooftops, compounds, rocky surface or hill slopes or artificially prepared impervious/ semi-pervious land surface. The amount of water harvested depends on the frequency and intensity of rainfall, catchment characteristics, water demands and how much runoff occurs and how quickly or how easy it is for the water to infiltrate through the subsoil and percolate down to recharge the aquifers (Srinivasan and Babu, 2000). It is one of the oldest and most commonly used water management systems in India. There are various types of systems to harvest rainwater in India ranging from very simple to the complex industrial systems.

Water harvesting is especially useful in semi-arid regions where irrigation water is not available regularly. India has a great and long tradition of water harvesting. Water-harvesting systems were significant developed from ancient times in urban areas and rural areas of some of the most arid and water stressed regions of the country such as Kutch and Saurashtra in Gujarat and Western Rajasthan (Agarwal and Narain, 1997). For the people of these regions, water harvesting was not a technique, but a part of their culture and was deep embedded in the socio-cultural frames. According to Li *et al*., 2000, supplemental irrigation provided at critical stages of crop growth is a practice which can generate significant increases in crop yields. The major advantages of rainwater harvesting are that it is simple, cheap, replicable, efficient, sustainable and adaptable (Reiz *et al*., 1988). It can be implemented in small-scale, can be operated easily, highly adaptive, and requires low cost; and therefore, is ideally suited to the socioeconomic and biophysical conditions of semiarid rural areas (Li *et al*., 2000). Rainwater harvesting also has been shown to improve water-use efficiency, reduce soil erosion, improve soil fertility, and increase agricultural productivity (Li *et al*., 2000).

2. TRADITIONAL WATER HARVESTING SYSTEMS OF INDIA: A FEW EXAMPLES:

EASTERN HIMALAYAS:

1. Bamboo pipes:

Water is transported through bamboo pipes for irrigation in this method. Bamboo pipes are used to divert perennial springs on the hilltops to the lower regions by gravity. Bamboos of varying diameters are used for laying the channels. About four to five stages of distribution are involved from the point of the water diversion to the application point (Dhiman and Gupta, 2011). This system is now becoming obsolete and being replaced by iron pipes and channel irrigation (Centre for Science and Environment, 2011). In Meghalaya, the traditional water harvesting system of tapping flowing streams and spring water for use in irrigation is popular in the state. *Umbir* and *Mawlyndep* and many other villages of *Revoi* district of Meghalaya collect flowing stream water through bamboo pads for domestic use. In *Jowai* district, the flowing stream water is stored in small cement plastered pond through bamboo which is used by the whole community, and the overflowing water is used in the catchments areas for farming (Borthakur, 2008).

2. *Apatani*:

It is a wet rice cultivation cum fish farming system practiced in elevated regions of about 1600 meters and gentle sloping valleys, having an average annual rainfall about 1700 mm. *Apatanis* can tap several small streams and springs found in those hill regions by making temporary walls, which act as barriers and can divert the flow of water towards terraced and valley lands. Water harvested from the hilltops is mixed with domestic wastes as it passes through the village through small channels. In *Apatani* system, valleys are terraced into plots separated by 0.6 meters high earthen dams supported by bamboo frames. All plots have inlet and outlet on opposite sides. The inlet of low lying plot functions as an outlet of the high lying plot. Deeper channels connect the inlet point to outlet point. The terraced plot can be flooded or drained off with water by opening and blocking the inlets and outlets as and when required. The stream water is tapped by constructing a wall of 2-4 m. high and 1 m. thick near forested hill slopes. This is conveyed to agricultural fields through a channel network. The local drainage system is thus merged with the irrigation system which, in turn, improves the nutrient content of water required for rice cultivation. It is practiced by *Apatani* tribes of *ziro* in the lower *Subansiri* district of Arunachal Pradesh (Agarwal and Narain, 1997).

WESTERN HIMALAYAS:

Ghul:

In the high altitude of Himalayan region, water is tapped from hill slops known as *ghuls*. These *ghuls* ranges in length from 1-15 km. and carries a discharge of 15-100 liter of water/ sec. In the entire region of Western Himalaya comprising Jammu, Himachal Pradesh and Northern Uttaranchal, *ghul* is a standard harvesting technique. While constructing *ghul*, a cut is made in the stream, which is further extended by stone embankment, generally made of a pile of stones. Often, it goes on till several kilometers to reach the dammed with the help of trees and branches.

NORTH EASTERN HILL RANGES:

1. *Zabo*:

The *zabo* (the word means 'impounding run-off') system is practiced in Nagaland in north-eastern India. Also known as the *ruza* system, it combines water conservation with forestry, agriculture and animal care and promotes soil management, environmental protection and sustainable water management.

Villages such as *Kikruma*, where *zabos* are found even in the modern age, are located at high altitudes. In spite of heavy rainfall, the areas experience water scarcity. The *zabo* system has various components for water management such as: forest land as a catchment area, water harvesting systems like ponds with earthen embankments, cattle sheds and agricultural lands at lower elevations. The rain falls on a patch of protected forest on the hilltop; as the water runs off along the slope, it passes through various terraces. The water is then collected in pond-like structures in the middle terraces; below are cattle yards, and towards the foot of the hill are paddy fields, where the run-off ultimately meanders into collection systems. The maintenance of the whole system along with the catchment area is done every year, usually in the pre-monsoon period (Agarwal and Narain, 1997).

2. *Cheo-ozihi*:

The river *Mezii* flows along the *Angami* village of *Kwigema* in Nagaland and the river water is tapped in seven different places in different elevations by means of channel diversion. The river water is brought down by a long channel from which many branches take off, and water is often diverted to the terraces through bamboo pipes. One of the channels is called *Cheo-oziihi*. *Oziihi* means water and *Cheo* was the person responsible for the laying of this 8-10 km-long channel with its numerous branches. The channels are maintained and cleared each year by the local community. This channel irrigates a large number of terraces in *Kwigwema*, and some terraces in the neighboring village (Agarwal and Narain, 1997).

BRAHMAPUTRA VALLEY:

1. *Dongs*:

Dongs are ponds constructed by the *Bodo* tribes of Assam to harvest water for irrigation. Water was lifted from the ponds and distributed into the fields by an instrument called *lahoni*. The ponds were individually owned and there was no community involvement for digging and maintenance. In Jalpaiguri region, Cultivators make small irrigation channels and watched them carefully as the rivers of the *Duars* changed their courses frequently (Dhiman and Gupta, 2011).

2. *Garh and Dara:*

In Assam, the *garh* is also built to channelize river water to the agricultural field. A *garh* is like big *nala*, where the both sides have big and long embankment and the middle side is left open to flow water. In the paddy field, the whole areas is divided into small pieces in square size, creating small embankment, called *Dara* , where rain water is stored for cultivation. This is also a rain water harvesting techniques practiced in the state from the ancient time (Borthakur, 2008).

INDO-GANGETIC PLAINS:

1. *Ahar Pynes*:

This traditional floodwater harvesting system is indigenous to south Bihar and functions by using the land slope. The terrain in those areas has a marked slope of 1 meter per km. from south to north and the sandy soil does not retain water. Rivers in this region swell only during the monsoon, but the water is swiftly carried away or percolates down into the sand. All these factors make floodwater harvesting the best option here, to which this system is perfectly suited. An *ahar* is a rectangular earth filled catchment basin with three sided embankments, built at the end of a small *pyne* (artificial channels constructed to utilize river water in agricultural fields). Both *ahars* and *pynes* carry water during the rainy season from July to September (Dhiman and Gupta, 2011).

2. Bengal's Inundation Channel:

In Bengal, the system of overflow irrigation was very popular which made full use of the abundant water of the Ganges and Damodar floods, and the monsoon rainfall. The canals were broad and shallow, carrying the crest water of the river floods. Canal beds contained fine clay and free coarse sand. The canals were long, continuous and fairly parallel to each other. Irrigation was done by cuts in the banks of the canals, which was closed when the flood was over. This controlled system enriched the soil and ensured a supply of water to every individual field and also checked malaria. William Willicocks suggested restoration of this ancient system to tackle the modern problems of agriculture and recommended their revival from the public health point of view (Chhabra and Gai, 1981).

THAR DESERTS AND WESTERN INDIA:

1. *Kunds / Kundis*:

Kund is an indigenous water harvesting structure made of local materials or cement which is more prevalent in western arid areas of Rajasthan, where the groundwater availability is limited and the salinity is moderate to high (Ministry of rural development, 2004). *Kunds* have a saucer-shaped catchment area that gently slopes towards the centre where the well is situated. A wire mesh across water-inlets prevents debris from falling into the well-pit. The sides of the well-pit are generally covered with lime and ash. Most pits have a dome-shaped cover or a lid to protect the water. The catchment areas of *kunds* are made by using locally available materials like pond silt, charcoal ash and small gravels. Water is usually drawn out with a bucket. The depth and diameter of *kunds* usually depend on consumption patterns. Most of the *kunds* are privately owned by individual households or by caste groups (Dhiman and Gupta, 2011). It is calculated that a *kund* having 100 square meter catchments area with 100 mm effective annual rainfall could easily collect 10000 liters of water. The rainfall data collected shows that areas with 100 mm rainfall can use the *kund* system very effectively (Bhalge and Bhavsar, 2007).

2. *Kuis / Beris*:

Found in western Rajasthan, *kuis* are 10-12 m deep pits dug in the vicinity of tanks to collect the seepage. *Kuis* can also be used to harvest rainwater in areas with meager rainfall. The mouth of the pit is usually made very narrow which prevents the evaporation of the stored water. The pit gets wider as it burrows under the ground, so that water can seep in into a large surface area. The openings of these earthen structures are generally covered with planks of wood, or put under lock and key. The water is used sparingly, as a last resource in crisis situations (Dhiman and Gupta, 2011).

3. *Khadins*:

The *khadin* system is s runoff agricultural system, in which, the runoff water from the high catchment area is stored with the help of a *khadin* bund where it is impounded during the monsoon season. The system is based on the principle of rainwater harvesting on farmland and subsequent use of this water enriched land for crop production. The *khadin* soils remain moist for a long period because of water storage and chemical weathering, decomposition along with the activities of the microbes which eventually raise the organic matter and other nutrient content of the soil. *Khadin* have functioned efficiently for centuries maintaining the soil fertility. It was first designed by the *Paliwal Bhramins* of Jaisalmer in the 15th century (Mishra, 2001; Bhalge and Bhavsar, 2007). The king gave lands to the *Paliwals* and asked them to develop *khadins* on the land. The ownership of the land would remain with the King. Out of the grains that harvested from the *khadin* land, one forth would have to be given the King. Thus they develop a net work of *khadins* in *Jaislamer* district. *Khadins* are also found in *Jodhpur, Bikner* and *Barmer* district of Rajasthan state of India. There are still 500 big and small *khadins* covering an area of 12000 ha. This system has great similarity with the irrigation methods of the people of Iraq around 4500 BC. A similar system is also reported to be practice in Negave desert, and southwestern Colorado, 500 years ago (Bhalge and Bhavsar, 2007).

4. *Nadis*:

Nadi is the local name of village ponds used for storing rainwater from the adjoining natural catchment areas, found near Jodhpur in Rajasthan. The site was selected by the villagers based on an available natural catchments and its water yielding potential (Ministry of rural development, 2004). In normal rainfall years, most of the *nadis* have the capacity to retain water for four to eight months, while a few can even retain water throughout the year. It is estimated that the recharge from a *nadi* covering 2.25 ha and having a storage capacity of 15 000 m^3 in an alluvial area may induce a groundwater recharge of 10 000 m^3 in one rainy season. The location of the *nadi* had a strong bearing on its storage capacity due to the related catchment and runoff characteristics (CGWB, 2011). Unfortunately, in Jodhpur, many *nadis* have been severely polluted because of poor maintenance and negligence, destruction of catchment areas and uncontrolled urbanization (Mishra, 2001).

5. *Talabs*:

Talab is a local name of a water harvesting structure used as reservoir situated in valleys and natural depressions. Some *talabs* have wells in their beds which are called *beris*. The oldest *talab* found in Rajasthan is *Ranisar* (constructed in 1490 AD). Until now, many of the existing *talabs* in Rajasthan are good sources of potable water and are feeding a large number of wells and *baoris* (Mishra, 2001).

6. *Tankas*/Tanks:

Tankas (small tank) are underground structures and mostly found in the houses of Bikaner. They are built in the main house or in the courtyard. They were circular holes made in the ground, lined with fine polished lime, in which rainwater was collected. *Tankas* were often beautifully decorated with tiles, which helped to keep the water cool. The water was used only for drinking purpose (Ministry of rural development, 2004). In contrast, tanks are generally constructed with large walls on four sides and an almost impermeable floor, with enormous water holding capacity. The tanks are provided with a large catchment area and a system of canals. The oldest tank of Jodhpur is *Fatehsagar*, which was built in 1780 (Dhiman and Gupta, 2011).

7. *Virdas*:

Virdas are shallow holes which are made in the sands of dry riverbeds and lakes for collecting drinking water. They are found all over the *Banni* grasslands, a part of the great *Rann of Kutch* in Gujarat. The topography of the area is undulating, with depressions on the ground. In *virdas*, the sweet freshwater remains in the upper layer from which the water is collected, and the saline water remains below the freshwater zone because of its higher density. The harvesting system depends on the grass cover of the adjacent areas which is essential for free infiltration of groundwater. The *Maldharis* (local nomadic people) first established these unique structures in the *Rann of Kutch* (Centre for Science and Environment, 2011).

8. *Naada / Bandha*:

Naada/bandha are found in the *Mewar* region of the *Thar* desert. It is a stone check dam which is constructed across a stream or gully to capture monsoon runoff on a stretch of land. Because of submergence in water, the land becomes fertile as silt deposits on it and the soil retains substantial amount of nutrients (Agarwal and Narain, 1997).

9. *Johads*:

Some non-governmental organisations have led to the revival of the age old water harvesting system in Rajasthan called Johad. Now, Johad is meeting water needs of more than 700 villages in the state without any hassles. Essentially, Johads are simple stone and mud barriers built across the contour of slope to arrest rain water. They have high embankments on three sides while the fourth side is left open for rain water to enter. In the villages, where Johads have been revived water is shared among the villagers and the farmers are not allowed to grow water intensive crops. A Johad prevent rain water from running off, allowing it to percolate into the ground, recharging water aquifers and improve the water balance of the earth (Borthakur, 2008).

A total of 8600 johad*s* have been built in 1086 villages of Alwar district in Rajasthan, covering 6500 km^2 under the leadership of Tarun Bharat Sangh and its leader Rajendra Singh, the Water Man of Rajasthan. This has resulted in the shallow aquifer recharge in groundwater bringing up the water table from about 100–120 meter depth to 3–13 meter at present. The area under single cropping and double cropping was 11% and 3%, which was increased to 70% and 50%, respectively, resulting in prosperity for the farmers. The forest cover, which used to be around 7%, increased to 40% through agro-forestry and social forestry, providing sufficient fuel wood and sequestering carbon from the atmosphere. It is estimated that for per capita investment of Rs.100 on johad, results in Rs. 400 annual profit by increasing crop production. Fisheries also developed because of *johad*. A significant social impact has been emancipation of the status of women in decision making. The most important achievement is the rejuvenation of the *Arvari* and *Ruparel* rivers through rainwater harvesting and groundwater recharge (Sharma, 2006; Das, 2010).

10. Stepwells or ***baoli:***

These are wells or ponds in which the water may be reached by descending a set of steps. They may be covered and protected and are often of architectural significance. They also may be multi-storied having a bullock which turns the water wheel to raise the water in the well to the first or second floor. The step well can be considered to originate from the need to ensure water during the period of drought, and in the deep relationship of faith in the Water God as conspicuous even in the Vedas of around 1000 BC. They are most common in western India, mainly in Gujrat and Rajasthan. The majority of surviving stepwells originally also served a leisure purpose, as well as providing water (Shekhawat, 2015). This was because the base of the well provided relief from daytime heat, and more of such relief could be obtained if the well was covered. Stepwells also served as a place for social gatherings and religious ceremonies. Usually, women were more associated with these wells because they were the ones who collected the water. Stepwells usually consist of two parts: a vertical shaft from which water is drawn and the surrounding inclined subterranean passageways, chambers and steps which provide access to the well. The galleries and chambers surrounding these wells were often carved profusely with elaborate detail and became cool, quiet retreats during the hot summers (Davies, 1989).

Jhalara is also a local name given to step wells. *Jhalaras* were human made tanks, found in Rajasthan and Gujarat, essentially meant for community use and for religious rites. Often rectangular in design, *jhalaras* have steps on three or four sides. Jhodhpur city has eight *jhalaras*, two of which are inside the town and six are found outs ide the city. The oldest *jhalara* is the Mahamandir *Jhalara,* which dates back to 1660 AD.

3. EASTERN COASTAL PLAINS:

***Eri and Kulams*:**

The southern state of Tamil Nadu in India has a rich water resource heritage. Tamilnadu has no perennial river that can cover the whole state and so people have to depend on the monsoon rains for irrigation and filling the ponds for consumption and other purposes. A system of tanks was made about 1500 years ago to provide enough water for the area. These thousands of these tanks not only recharged the groundwater table after the monsoon rains but also provided the sole source for drinking and irrigation water. Approximately one-third of the irrigated area of Tamil Nadu is watered by *eris* (tanks) (Agarwal and Narain, 1997). *Eris* have played several important roles in maintaining ecological harmony as flood-control systems, preventing soil erosion and wastage of runoff during periods of heavy rainfall, and recharging the groundwater in the surrounding areas (Bhalge and Bhavsar, 2007). Moreover, without the *eri*, the development of rice cultivation, which is the staple diet of the people, would not have been possible. Majority of the irrigation tanks were built from the 6th to the 10th century A.D., during the dynasty of the *Pallavas*. From the beginning of the 16th century, rivers were partially diverted to fill these tanks quickly, which, in turn, ensured food production (Agarwal and Narain, 1997). Until the arrival of the British in 1600 AD, *eris* were maintained by the local communities with resources. Historical data from the *Chegalpattu* district indicates that in 18th century about 4.5% of the gross produce of each village was allocated for the maintenance of the *Eris* and other irrigation structures (Bhalge and Bhavsar, 2007).

Apart from these broad irrigation tanks, the villagers use small ponds or *kulam*, often masonry made, close to a temple. The *oorani* is mainly used for drinking purposes while the *kulam* is temple based and used mainly by the priests for various temple purposes. These were constructed to tap rainwater, act as flood control devices and can also recharge the groundwater. Most the settlements in south India were situated around the temples and the temple tanks are the focal points of all social and cultural activities. The *oorani* is shared among the village people but different sides of the ponds are allotted to the different caste communities (Agarwal and Narain, 1997).

ISLANDS:

Jackwells:

Because of the difference in the physiographic, topography, rock types and rainfall in the islands, the local tribes in the different islands developed different water harvesting structures. For instance, the southern part of the Great Nicobar Island near Shastri Nagar has a relatively rugged topography in comparison to the northern part of the islands. The *Shompen* tribal here made full use of the topography to harvest water. In lower parts of the undulating terrain, bunds were made by using logs of hard bullet wood. They make extensive use of split bamboos in their water harvesting systems. A full length of bamboo is cut longitudinally and placed along a gentle slope with the lower end leading into a shallow pit. These serve as channels for rainwater which is collected drop by drop in pits called *Jackwells* (Agarwal and Narain, 1997). These split bamboos are often placed under trees to harvest the rainwater through the leaves. A series of increasingly bigger *jackwells* is built, connected by split bamboos and ultimately leading to the biggest *jackwell*, with an approximate diameter of 6 m and depth of 7 m so that overflows from one lead to the other (Dhiman and Gupta, 2011).

3. CONCLUSIONS:

Our environment, both physically and culturally has lost its purity over the course of time. The ecological impact in societies caused by human activities is proportional with the development and technological advancement. It is absolutely essential for us to secure the right for saving water resources and environment in general. There are many policies developing in many countries for water resource management, but they are all directly or indirectly dependent on the traditional knowledge developed in the ancient age which teaches us the concept of the value of a simple life. The traditional water-wisdom at all levels of the society ensured adequate availability of water for all, which in turn, formed the basis for all round development and prosperity. We should again learn and comprehend the ancient knowledge and apply it in our modern society to get rid of the present water stressed condition. An endeavour should be encouraged on behalf of the international, national, regional and local authorities to respect and restore and water resources for the betterment of our society. We have to find a new way of understanding our place in the world.

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