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Existing & Novel Methods of Water Harvesting

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Abstract: **- Through ground water utilization has substantially enhanced domestic utility and crop productivity – due to widespread over exploitation, underground water level is going down day by day at an alarming rate in most parts of India especially in Karnataka & Tamil Nadu. Further, the two main sources of irrigation in India are cannels and groundwater – both sources are also facing extreme downward trend. To combat such alarming situation, the urgent need is to explore novel methods of water harvesting especially through rain water harvesting which has been highlighted in the present study.**

Index Terms**: groundwater, rainwater, Runoff, harvesting, Rooftop catchments**

I. INTRODUCTION

Due to deforestation and increasing population, land pressure rises and as land pressure rises, more and more marginal and semi-marginal areas in the world are being used for cultivation. Noteworthy that much of this land is located in the arid or semi-arid belts where rain is less falls irregularly and as a result much of the precious water is soon lost as surface runoff. Recent droughts in India have highlighted the risks to human beings and livestock, which occur when rains falter or fail. Irrigation is the most obvious response to drought and there is now increasing interest in a low cost alternative - generally referred to as "water harvesting". Water harvesting is the collection of runoff for productive purposes usually in irrigation. Instead of runoff being left to cause erosion, it can be harvested and utilized. In the semi-arid drought-prone areas, water harvesting is a directly productive form of soil and water conservation and yields and reliability of production can be significantly improved with this method. Water harvesting can be considered as a rudimentary form of irrigation; the difference is that with water harvesing the farmer (or more usually, the agro-pastoralist) has not much control over timing. Runoff can be harvested only when it rains [1]. Rainwater harvesting is the accumulation and deposition of rainwater for reuse on-site instead of than allowing it to Run-off (Runoff is generated by rainstorms and its occurrence and quantity are dependent on the characteristics of the rainfall event, i.e. intensity, duration and distribution). Hence, it means capturing rain, the run-off in one's own village or town and taking measures for keep that water clean by not allowing polluting activities to take place in the catchment. Rainwater can be collected from rivers or roofs is redirected to a deep pit (well, shaft, or borehole), a reservoir with percolation. Its uses include water for gardens, livestock and irrigation including domestic use with proper treatment, etc. The harvested water can also be used as drinking water, longer-term storage and for other purposes such as groundwater restoring & recharge [1] (Fig. 1).

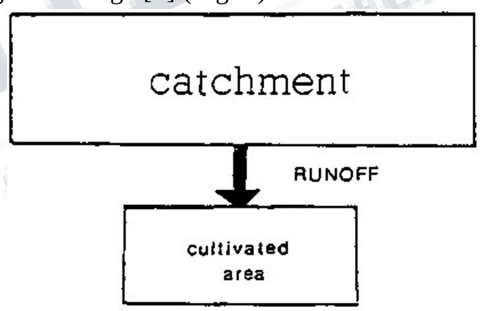

Fig. 1: The principle of Rain water harvesting [1]

Water harvesting techniques which harvest runoff falls under the following terminologies:

Rainwater Harvesting: while all systems which collect discharges from watercourses are grouped under the term [1, 2]:

Floodwater Harvesting: A wide variety of water harvesting techniques for many different applications are known. Productive uses include provision of domestic and stock water, concentration of runoff for crops, fodder and tree production and less frequently water supply for fish and duck ponds. Therefore, water harvesting is undertaken through the following ways

- Capturing runoff from rooftops
- Capturing runoff from local catchments

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- Capturing seasonal floodwaters from local streams
- Conserving water through watershed management
- These techniques can serve the following purposes:
- Provide drinking water
- Provide irrigation water
- Increase groundwater recharge
- Reduce stormwater discharges, urban floods and overloading of sewage treatment plants
- Reduce seawater ingress in coastal areas.

In general, water harvesting is the act of direct collection of rainwater. The rainwater collected can be stored for direct use and be recharged into the groundwater. Rain is the first form of water in the hydrological cycle and hence is a primary source of water for human beings. Rivers, lake, groundwater, etc. are secondary sources of water. In present, we primarily depend on such secondary sources of water. In the process, we forget that rain is the ultimate source that feeds all these secondary sources and remain ignorant of its value. Water harvesting admires us to understand the value of rain, and to make optimum use of the rainwater at the place where it falls, the run-off [2].

Rooftop catchments: In the most basic form of the above technology, rainwater collection in simple vessels from the edge of the roof. Variations happen on this basic approach, which include collection of rainwater in gutters which drain to the collection- vessel through down-pipes constructed for this purpose, and/or the diversion of rainwater from the gutters to containers for settling particulates before being conveyed to the storage container for the domestic use. As the rooftop is the main catchment area, the amount and quality of rainwater collected depends on the area including type of roofing material. Reasonably pure rainwater can be collected from roofs constructed with galvanized corrugated iron, aluminium (or asbestos cement sheets), tiles and/or slates, although thatched roofs tied with bamboo gutters and laid in proper slopes can produce almost the same amount of runoff less expensively. However, the bamboo roofs are least used because of health hazards. Similarly, roofs with metallic paint and/or other coatings are not recommended as they may impart tastes or colour to the collected water. Roof catchments ought to be cleaned regularly to remove dust, leaves and bird droppings so as to maintain the quality of the product water [1, 2] (Fig. 2).

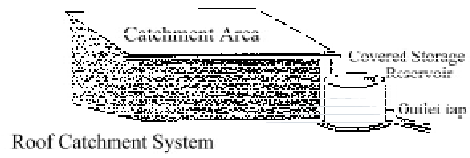

Fig. 2: Rooftop Catchment system [1, 2]

Land surface catchments: Rainwater harvesting using ground/land surface catchment areas is a much less complex way of collecting rainwater. This involves improving the run-off capacity of the land surface through various techniques including collection of run-off with drain pipes and storage of collected water. Compared to rooftop catchment techniques, ground catchment techniques give more opportunity for collecting water from a large surface area. By retaining & capturing the flows (including flood flows) of small creeks and streams in small storage reservoirs (on surface or underground) created by low cost (e.g., earthen) dams, this technology can meet water demands during dry periods. There remains a possibility of high rates of water loss due to infiltration into the ground, and, because of the often marginal quality of the water collected, this technique is mainly suitable for storing water for agricultural purposes. Various techniques available for increasing the runoff within ground catchment areas involve: i) clearing or altering vegetation cover, ii) increasing the land slope with artificial ground cover, and iii) reducing soil permeability by the soil compaction and application of chemicals [1, 2] (Fig. 3).

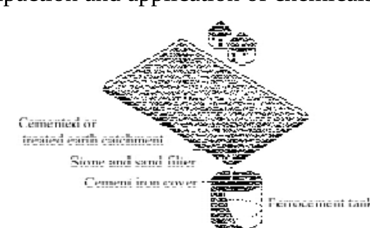

Fig. 3: Ground Catchment system [1, 2]

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II BASIC CATEGORIES OF WATER HARVESTING SYSTEMS FOR PLANT PRODUCTION

1 Microcatchments (rainwater harvesting)
2 External catchment systems (rainwater harvesting)
3 Floodwater farming (floodwater harvesting)

The water harvesting techniques falls under three basic categories whose main characteristics are as follows [3, 4, 5]:

Microcatchments (rainwater harvesting) (Fig. 4) (sometimes referred to as "Within-Field Catchment System")
Main characteristics:
- overland flow harvested from short catchment length
- catchment length usually between 1 and 30 metres
- runoff stored in soil profile
- ratio catchment: cultivated area usually 1:1 to 3:1
- normally no provision for overflow
- plant growth is even

Typical Examples:
Negarim Microcatchments (for trees) Contour Bunds (for trees)
Contour Ridges (for crops)
Semi-Circular Bunds (for range and fodder) External catchment systems (rainwater harvesting) (Fig. 5)
(Long Slope Catchment Technique) Main Characteristics:
- overland flow or rill flow harvested
- runoff stored in soil profile
- catchment usually 30 - 200 metres in length
- ratio catchment: cultivated area usually 2:1 to 10:1
- provision for overflow of excess water
- uneven plant growth unless land leveled [3, 4, 5]

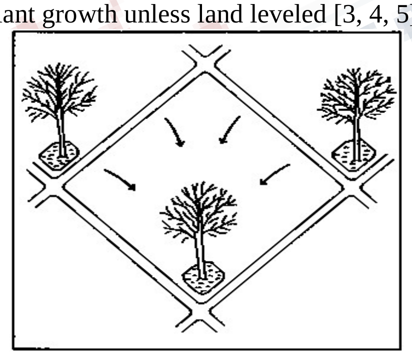

Fig. 4: Microcatchment system: Negarim microcatchment for trees [3, 4, 5]

Typical Examples: Trapezoidal Bunds (for crops) Contour Stone Bunds (for crops)

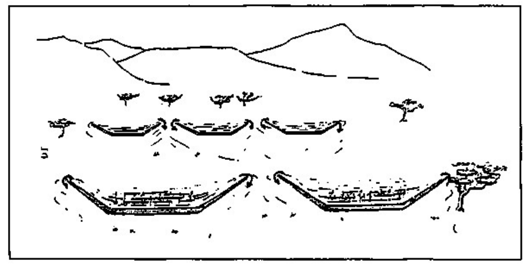

Fig. 5 External catchment system: trapezoidal bunds for crops [3]

Flood water farming (floodwater harvesting) (Fig. 6) (often referred to as "Water Spreading" and sometimes "Spate Irrigation")
Main Characteristics:
- turbulent channel flow harvested either (a) by diversion or (b) by spreading within channel bed/valley floor
- runoff stored in soil profile
- catchment long (may be several kilometers)
- ratio catchment: cultivated area above 10:1
- provision for overflow of excess water

Typical Examples:
Permeable Rock Dams (for crops)
Water Spreading Bunds (for crops) [3, 4, 5]

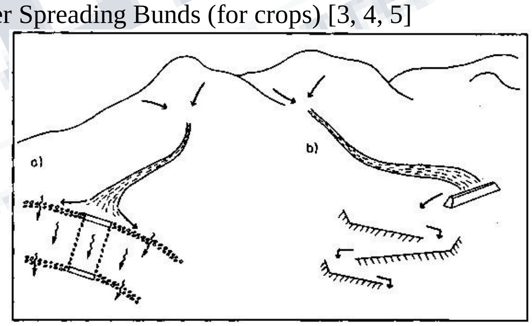

Fig. 6: Floodwater farming systems: (a) spreading within channel bed; (b) diversion system [3, 4, 5]

III HISTORY

The history of rainwater harvesting in South-east Asia can be traced back to about the 9th or 10th Century BC and the small-scale collection of rainwater were reported from roofs and simple brush dam constructions in Asia. Rainwater collection from the eaves of roofs or using simple gutters into traditional jars and pots has been traced back almost 2000 years in India, Myanmar & Thailand. Rainwater harvesting has also been reported in the Loess Plateau regions of China. More recently about 40000 well storage tanks, in a variety of different forms, were constructed between 1970 and 1974 using a technology which stores rain and storm-water runoff in ponds of different sizes. A thin layer of red clay/mud is generally laid on the bottom of the ponds to minimize seepage loss. Trees, planted at the edges of the ponds, help to minimize evaporative losses from the ponds.

Around the 3rd century BC, the farming communities in Balochistan area (now located in Pakistan, Afghanistan and Iran), and Kutch area in India, used rainwater harvesting for agriculture and many uses also. In ancient Tamil Nadu, rainwater harvesting was reported to be done by Chola kings (Rainwater from the Brihadeeswarar temple which is located in Balaganpathy Nagar, Thanjavur, India was collected in Shivaganga tank). During the later Chola period, the Vīrānam tank was built (1011 to 1037 CE) in Cuddalore district of Tamil Nadu to store water for irrigation and drinking purposes. Vīrānam (as reported) is a 16 km (9.9 mi) long tank with a storage capacity of 1,465,000,000 cubic feet (41,500,000 m3) [4, 5, 6, 7, 8].

In the olden days rainwater harvesting was reported to be done in the Indian states of Madhya Pradesh, Maharashtra, and Chhattisgarh. Ratanpur (in Chhattisgarh) had around 150 ponds and most of the tanks or ponds were utilized in agriculture works. Present day [4, 5, 6, 7, 8]

- Currently in China and Brazil rooftop rainwater harvesting is being practiced for providing drinking water, domestic water, water for livestock, water for small irrigation and a way to replenish groundwater levels. Gansu province in China and semi-arid north east Brazil have the largest rooftop rainwater harvesting projects ongoing.
- In Bermuda, the law requires all new construction to include rainwater harvesting adequate for the residents.
- The U.S. Virgin Islands have a similar law.
- In Senegal and Guinea-Bissau, the houses of the Diola-people are frequently equipped with homebrew rainwater harvesters made from local, organic materials.
- In the Irrawaddy Delta of Myanmar, the groundwater is saline and communities rely on mud-lined rainwater ponds to meet their drinking water needs throughout the dry season. Some of these ponds are centuries old and are treated with great reverence and respect. In the United States: until 2009 in Colorado, water rights laws almost completely restricted rainwater harvesting; a property owner who captured rainwater was deemed to be stealing it from those who have rights to take water from the watershed. Now, residential well owners that meet certain criteria may obtain a permit to install a rooftop precipitation collection system (SB 09-080). Up to 10 large scale pilot studies may also be permitted (HB 09-1129). The main factor in persuading the Colorado Legislature to change the law was a 2007 study that found that in an average year, 97% of the precipitation that fell in Douglas County, in the southern suburbs of Denver, never reached a stream—it was used by plants or evaporated on the ground. In Colorado you cannot even drill a water well unless you have at least 35 acres (14 ha). In New Mexico, rainwater catchment is mandatory for new dwellings in Santa Fe. Texas offers a sales tax exemption on the purchase of rainwater harvesting equipment. Both Texas and Ohio allow the practice even for potable purposes. Oklahoma passed the Water for 2060 Act in 2012, to promote pilot projects for rainwater andgraywater use among other water saving techniques.
- In Beijing, some housing societies are now adding rain water in their main water sources after proper treatment.
- In Ireland, Professor Micheal Mcginley established a project to design a rain water harvesting prototype in the Biosystems design Challenge Module at University College Dublin
- Canada: A number of Canadians have started implementing rainwater harvesting systems for use in stormwater reduction, irrigation, laundry, and lavatory plumbing. Substantial reform to Canadian law since the mid 2000s has increased the use of this technology in agricultural, industrial, and residential use; but ambiguity remains amongst legislation in many provinces. Bylaws and local municipal codes often regulate rainwater harvesting.
- India: Karnataka: In Bangalore it is mandatory for adoption of rain water harvesting for every owner or the occupier of a building having the sital area measuring 60 ft (18.3 m) X 40 ft (12.2 m) and above and for newly constructed building measuring 30 ft (9.1 m) X 40 ft (12.2 m) and above dimension. In this regard BWSSB has initiated and constructed "Rain Water Harvesting Theme Park" in the name of Sir. M. Visvesvaraya in 1.2 acres (4,900 m2) land situated at Jayanagar, Bangalore. In this park 26 different type of Rain Water Harvesting models are demonstrated along with the water conservation tips. The Auditorium on the first floor is set up with Green Air conditioning system and the same will be utilized to arrange the meeting and showing the video clip about the rain water harvesting to students as well as general public.

- Tamil Nadu: In the state of Tamil Nadu, rainwater harvesting was made compulsory for every building to avoid groundwater depletion. It gave excellent results within five years, and every state took it as role model. Since its implementation, Chennai saw a 50 percent rise in water level in five years and the water quality significantly improved.
- Rajasthan: In Rajasthan, rainwater harvesting has traditionally been practiced by the people of the Thar Desert. There are many ancient water harvesting systems in Rajasthan, which have now been revived. Water harvesting systems are widely used in other areas of Rajasthan as well, for example the chauka system from the Jaipur district.
- Maharashtra: At present, in Pune, rainwater harvesting is compulsory for any new housing society to be registered.
- In Mumbai city in Maharashtra rain water harvesting is being considered as a good solution to solve water crisis. The Mumbai city council is planning to make rainwater harvesting mandatory for large societies.
- An attempt has been made at the Department of Chemical Engineering, IISc, Bangalore to harvest rainwater using upper surface of a solar still, which was used for water distillation
- Israel: The Southwest Center for the Study of Hospital and Healthcare Systems in cooperation with Rotary International is sponsoring a rainwater harvesting model program across the country. The first rainwater catchment system was installed at an elementary school in Lod, Israel. The project is looking to expand to Haifa

in its third phase. The Southwest Center has also partnered with the Water Resources Action Project (WRAP) of Washington D.C. WRAP currently has rainwater harvesting projects in the West Bank.

- Rainwater harvesting systems are being installed in local schools for the purpose of educating schoolchildren about water conservation principles and bridging divides between people of different religious and ethnic backgrounds all while addressing the water scarcity issue that the Middle East faces.
- Sri Lanka: Rainwater harvesting has been a popular method of obtaining water for agriculture and for drinking purposes in rural homes. The legislation to promote rainwater harvesting was enacted through the Urban Development Authority. Lanka rainwater harvesting forum is leading the Sri Lanka's initiative.
- South Africa: The South African Water Research Commission has supported research into rainwater harvesting. Reports on this research are available on their 'Knowledge Hub'. Studies in arid, semi-arid and humid regions have confirmed that techniques such as mulching, pitting, ridging and modified run-on plots are effective for small-scale crop production.
- United Kingdom: In the United Kingdom, water butts are often found in domestic gardens to collect rainwater, which is then used to water the garden. However, the British government's Code For Sustainable Homes encourages fitting large underground tanks to new-build homes to collect rainwater for flushing toilets, washing clothes, watering the garden, and washing cars. This reduces by 50 percent the amount of mains water used by the home.
- United States: Colorado: Until 2009, water rights laws almost completely restricted rainwater harvesting; a property owner who captured rainwater was deemed to be stealing it from those who have rights to take water from the watershed. Now, residential well owners that meet certain criteria may obtain a permit to install a rooftop precipitation collection system (SB 09-080).Up to 10 large scale pilot studies may also be permitted (HB 09-1129). The main

  factor in persuading the Colorado Legislature to change the law was a 2007 study that found that in an average year, 97% of the precipitation that fell inDouglas County, in the southern suburbs of Denver, never reached a stream—it was used by plants or evaporated on the ground. In Colorado you cannot even drill a water well unless you have at least 35 acres (14 ha)
- New Mexico: In New Mexico, rainwater catchment is mandatory for new dwellings in Santa Fe.
- Texas offers a sales tax exemption on the purchase of rainwater harvesting equipment. Both Texas and Ohio allow the practice even for potable purposes.
- Oklahoma passed the Water for 2060 Act in 2012, to promote pilot projects for rainwater and graywater use among other water saving techniques.

IV HOW MUCH WATER CAN BE HARVESTED?

Urban scenario

The total amount of water received in the form of rainfall over an area is called the rainwater endowment of the area. Out of this, the amount of water that can be effectively harvested is called the water harvesting potential.

Water harvesting potential = Rainfall (mm) x Collection efficiency

The collection efficiency accounts for the fact that all the rainwater falling in an area cannot be effectively harvested, due to loss via evaporation, spillage etc.

Factors like runoff coefficient and the first-flush wastage are taken into consideration when estimated the collection efficiency.

The following is an illustrative theoretical calculation that highlights the potential for water harvesting. The same procedure can be applied to get the potential for a plot of land or roof-top area, using rainfall data for that area..

Consider your own building with a flat terrace area of 100 sq m. Assume the average annual rainfall in your area is approximately 600 mm (24 inches). In simple terms, this means that if the terrace floor is assumed to be impermeable, and all the rain that falls on it is retained without evaporation, then, in one year, there will be

1. Area of plot = 100 sq. m. (120 square yards)
2. Height of the rainfall = 0.6 m (600 mm or 24 inches)
3. Volume of rainfall over the plot = Area of plot x height of rainfall
4. Assuming that only 60 per cent of the total rainfall is effectively harvested
5. Volume of water harvested = 36,000 litres (60,000 litres x 0.6)

This volume is about twice the annual drinking water requirement of a 5-member family. The average daily drinking water requirement per person is 10 litres [9, 10, 11].

Rural scenario

Community based rainwater harvesting in rural areas of India (the paradigm of the past) has in it as much strength present day as it ever did in past. It is, in fact, that only with this rudimentary technology that people are still able to survive in water scarce areas. Recognizing this fact, our ancestors were able to learnt to harvest water in number of ways:

- They harvested the rain-water directly. From rooftops, they collected rain-water and stored it in the tanks built in their courtyards. From open community lands, they collected the rain and stored it in wells made artificially.
- They harvested monsoon runoff by capturing water from swollen streams during the monsoon and stored it various forms of artificial water bodies they made (like lakes).
- They harvested water from directly flooded rivers during monsoon.

Assuming that average Indian population of an Indian village in October 1990 is approximately 1000. India's average rainfall is about 1300 mm. If even only half this water can be captured, though with technology this can be greatly increased, an average Indian village needs 1.12 hectares of land to capture 6.57 million litres of water it will use in a year for cooking and drinking. If there is a drought and rainfall levels dip to half the normal, the land required would rise to a mere 2.24 hectares. The amount of land needed to meet the drinking water needs of an average village will vary from 0.10 hectares in Arunachal Pradesh (average population 236) where villages are small and rainfall high to 8.46 hectares in Delhi where villages are big (average population ~5000) and rainfall is low. In Rajasthan, the land required will vary from 1.68-3.64 hectares in different meterological regions and, in Gujarat, it will vary from 1.72-3.30 hectares. And of course any more water the villagers catch can go for irrigation [12, 13, 14].

Is this an impossible task? Is there a single village that doesn't have this land availability? India's total land area is over 300 million hectares. Let us assume that India's 587,000 villages can harvest the runoff from 200 million hectares of land, excluding inaccessible forest areas, high mountains and other uninhabited terrains, that still gives every village on average access to 340 hectares or a rainfall endowment of 3.75 billion litres of water. These calculations show the potential of rainwater harvesting is enormous and undeniable [15, 16, 17].

What is National Water Harvesters Network

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(NWHN)? National Water Harvesters' Network (NWHN) is a far-reaching network that addresses water issues via people from diverse background in India and abroad.

Their members are primarily professionals, bureaucrats, grassroots functionaries, interested citizens and all those committed in developing or undertaking water harvesting programme. Theis network addresses and highlights the local issues and traditional systems relating to water harvesting to further the cause of community based water management [15, 16, 17].

Table 1 - Naturally Preferred Climatic Zones Of Multipurpose Trees [15, 16, 17]

	Semi-arid/marginal 500-900 mm rain	Arid/semi-arid 150-500 mm rain	Tolerance to temporary waterlogging
Acacia albida	yes	Yes	Yes
A. nilotica	yes	Yes	Yes
A. saligna	no	Yes	Yes
A. Senegal	yes	Yes	No
A. seyal	yes	Yes	Yes
A. tortilis	yes	Yes	No
Albizia lebbeck	yes	No	No
Azadirachta indica	yes	No	Some
Balanites aegyptiaca	yes	Yes	Yes
Cassia siamea	yes	No	No
Casuarina equisetifolia	yes	No	Some
Colophospermum mopane	yes	Yes	Yes
Cordeauxia edulis	no	Yes	?
Cordia sinensis	no	Yes	?
Delonix elata	yes	No	?
Eucalyptus camaldulensis	yes	Yes	Yes
Prosopis chilensis	yes	Yes	Some
Prosopis cineraria	yes	Yes	Yes
Prosopis juliflora	yes	Yes	Yes
Ziziphus mauritiana	yes	Yes	Yes

Cultural acceptability

Rainwater harvesting is a widely accepted freshwater augmentation technology in Asia & India. While the pathological quality of rainwater collected from ground catchments is poor, that from properly maintained rooftop catchment systems, equipped with storage tanks having good covers and taps, which is generally suitable for drinking, and frequently meets WHO drinking water standards. Notwithstanding the fact that such water generally is of higher quality than most traditional, and many of improved, water sources found in the rapidly developing world. Contrary to popular beliefs that rather than becoming stale with extended storage, rainwater quality often improves as bacteria and pathogens gradually die off. Rooftop catchment and rainwater in storage tanks can provide good quality water, suitable enough for drinking, as long as the rooftop is clean, impervious, and made from non toxic materials (materials like lead paints and asbestos roofing materials should be avoided), and located away from over-hanging trees since birds and animals in the trees may defecate on the roof [18, 19, 20].

Advantages & Disadvantages

Rainwater harvesting technologies are quite simple to install and operate. Local people can be trained easily to implement such technologies, and the construction materials are also readily available. Rainwater harvesting is convenient in view that it provides water at the point of consumption by all, and family members have full control of their own systems, which greatly reduces operation and maintenance problems. Running costs, also, are almost negligible. Water collected from roof catchments generally is of acceptable quality for all domestic purposes, as it is collected using existing structures which are not specially constructed for the purpose, rainwater harvesting has few negative environmental impacts compared to other water supply project technologies although regional or other local factors can modify the local climatic conditions, rainwater can be a continuous source of water supply for both the rural and poor. Depending upon household capacity, its needs, both the water collection and storage capacity may be increased as needed within the available catchment area. Disadvantages of rainwater harvesting technologies are mainly due to the limited supply and usual uncertainty of rainfall. Adoption of this technology requires a "bottom up" approach rather than the usual "top down" approach employed in usual other water resources development projects. This makes rainwater harvesting often less attractive to some governmental agencies tasked with providing water supplies in developing countries, but the mobilization of government with NGO resources can serve the same basic role in the development of rested periodically for it to regenerate, so that natural reseeding can take place [25, 26, 27, 28].

REFERENCES

1. Gould, J.E. 1992. Rainwater Catchment Systems for Household Water Supply, Environmental Sanitation Reviews, No. 32, ENSIC, Asian Institute of Technology, Bangkok.

2. Gould, J.E. and H.J. McPherson 1987. Bacteriological Quality of Rainwater in Roof and Groundwater Catchment Systems in Botswana, Water International, 12:135-138.

3. Critchley, W R S and Reij, C. 1989. Water harvesting for mplant production: Part 2. Case studies and conclusions from sub0Sahara Africa.

4. Nissen-Petersen, E. (1982). Rain Catchment and Water Supply in Rural Africa: A Manual. Hodder and Stoughton, Ltd., London.

5. Pacey, A. and A. Cullis 1989. Rainwater Harvesting: The Collection of Rainfall and Runoff in Rural Areas, WBC Print Ltd., London.

6. Schiller, E.J. and B. G. Latham 1987. A Comparison of Commonly Used Hydrologic Design Methods for Rainwater Collectors, Water Resources Development,

7. UNEP [United Nations Environment Programme] 1982. Rain and Storm water Harvesting in Rural Areas, Tycooly International Publishing Ltd., Dublin.

8. Wall, B.H. and R.L. McCown 1989. Designing Roof Catchment Water Supply Systems Using Water Budgeting Methods, Water Resources Development, 5:11-18. Behzadian, k; Kapelan, Z (2015). "Advantages of integrated and sustainability based assessment for metabolism based strategic planning of urban water systems". Science of The Total Environment. Elsevier. 527-528: 220–231.doi:10.1016/j.scitotenv.2015.04.097.
Zhu, Qiang; et al. (2015). Rainwater Harvesting for Agriculture and Water Supply. Beijing: Springer. p. 20. ISBN 978-981-287-964-6.
New Scientist, 3 April 1999 Devkota, Jay (2013). "Development and application of EEAST: A life cycle based model for use of harvested rainwater and composting toilets in buildings". Journal of Environmental Management.
Devkota, Jay (2015). "Life cycle based evaluation of harvested rainwater use in toilets and for irrigation.". Journal of Cleaner Production. Rain water harvesting by fresh water flooded
Forests

15. "Harvesting rainwater for more than greywater". SmartPlanet. Retrieved 13 November 2014.

16. Kumar, Ro. "Collect up to 10 gallons of water per inch of rain with Rainsaucers' latest standalone rainwater catchment".LocalBlu. Retrieved 11 February 2013.

17. "Rainwater Harvesting - Controls in the Cloud". SmartPlanet. Retrieved 11 January 2015.

18. O'Brien, Sara Ashley. "The Tech Behind Smart Cities - Eliminating Water Pollution". CNN Money. Retrieved 13 November2014.

19. Braga, Andrea. "Making Green Work, and Work Harder" (PDF). Geosyntec. p. 5. Retrieved 30 November 2014.

20. "Rain water Harvesting". Tamilnadu State Government, India. Retrieved 23 January 2012.

21. "Believes in past, lives in future". The Hindu. India. 17 July 2010.

22. "Rare Chola inscription found near Big Temple". The Hindu. India. 24 August 2003.

23. "Rainwater Collection in Colorado" (PDF). Colorado water law, notices. Colorado Division of Water Resources. Retrieved2012-03-24.

24. "Criteria and Guidelines for the "Rainwater Harvesting"" (PDF). Pilot Project Program. Colorado Water Conservation Board (CWCB). January 28, 2010. Retrieved 2012-03-24.

25. Johnson, Kirk (June 28, 2009). "It's Now Legal to Catch a Raindrop in Colorado". The New York Times. Retrieved2009-06-30. Precipitation, every last drop or flake, was assigned ownership from the moment it fell in many Western states, making scofflaws of people who scooped rainfall from their own gutters. In some instances, the rights to that water were assigned a century or more ago.

26. 82(R) H.B. No. 3391. Act relating to rainwater harvesting and other water conservation initiatives. † went into effect on September 1,

2011". 82nd Regular Session. Texas Legislature Online. Retrieved 8 February 2013.

27. "State Rainwater Harvesting Statutes, Programs and Legislation". NCSL. Retrieved 7 February 2013.

28. "Rain Water Harvesting BWSSB - Bangalore Water Supply and Sewerage Board". bwssb.gov.in.

