POTENTIAL OF WATER HARVESTING AS A STRATEGIC TOOL FOR DROUGHT MITIGATION

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Abstract

Water harvesting is the process of collecting rainfall as runoff from a larger catchment for use in a smaller target area. Different traditional and innovative techniques are available in different countries for runoff farming water harvesting, surface storage water harvesting and groundwater recharge. Water harvesting is of particular importance in arid and semi-arid regions, which are also drought prone. Rainwater harvesting measures if adopted on a large scale may alleviate water scarcity even during severe drought years. However studies which systematically describe water harvesting measures in different countries and regions, document successful experiences in large scale implementation of such measures and quantify their potential to alleviate the effects of droughts of different extremity are limited. This paper explores the utility of various water harvesting measures in the context of proactive approach to drought management and mitigation with examples primarily from South Asia. The paper suggests that large-scale application of water harvesting measures in drought-prone areas may be seen as a strategic tool for drought mitigation, if it is realized through the adoption of relevant policies and investments at different levels such as user, watershed, urban locality, district, state and a country.

Introduction

Drought is a recurring natural climatic event, which stems from the lack of precipitation over an extended period of time from a season to several years. It is considered to be the most complex, but least understood natural hazard, affecting more people than any other hazard (Hagman, 1984). Being normal feature of climate, its recurrence is inevitable. It occurs in all geographical regions, but its impacts and frequency are more pronounced in arid and semi-arid regions (e.g. Baluchistan and Sindh provinces in Pakistan; western and southern lowlands of Afghanistan; parts of Rajasthan and Gujarat states in India; large parts in Iran, China, Australia and sub-Saharan Africa). Drought extremity is frequently characterized according to the deficiency of rainfall. In India, a severe drought is defined as the condition in which more than 51 per cent of rainfall deficiency prevails in more than 20 per cent of the geographical area under study. Every drought is a meteorological drought, but definitions of various droughts are mainly centered around the demand and supply of water for different sectors.

Droughts impose a serious threat to agricultural production and off-farm economic activities in the affected region. In China, over 50 million tons of agricultural production was lost due to drought of 2000. The monetary losses in Iran during extensive 1999-2000 droughts were estimated at US$ 3500 million. In India, severe droughts affecting more than 40% of the country's geographical area occurred 6 times since 1918 and during pre-Green revolution period, losses in food grain production due to drought used to be as high as 25% of total produce. In southwest Asia as a region, more than 100 million people get affected during extensive droughts.

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The ability of the local communities and governments in developing countries and international relief agencies to deal with droughts is constrained by the absence of reliable data and tools, information networks and the professional and institutional capacities. The important shift is necessary in drought management policies in general – a shift form contingent drought relief to drought preparedness. Countries and communities must be pro-active in their approach to manage the risks as opposed to managing the crisis (Nairizi, 2003). Water harvesting and conservation measures should be seen in this context of proactive drought management approach as a measure of risk control.

Water harvesting and conservation as a strategic tool

Strategies for combating drought include the components of early warning and drought monitoring, contingency crop planning for drought proofing, integrated watershed management, improved agronomic (water saving) practices, alternative land use systems; management of livestock, animal health and feed and fodder resources and socio-economic aspects. All these components are essential and important and help in alleviating the impacts of drought but the most strategic tool for combating and mitigating the drought shall be through enhanced water supplies at the local level. This may be achieved partially through importing water from other less affected regions but more sustainably through water harvesting and conservation in the drought prone region itself. Water harvesting, though an age-old practice, is emerging as a new paradigm in water resources development and management due to recent efforts of both government and non-government organizations and several innovative communities. Several 'bright spots' of successful water harvesting measures for drought proofing can be easily seen in operation in India, Pakistan, Iran, China and some other countries. The water resources generated locally help in meeting domestic and livestock needs, provide water for supplementary/deficit irrigation, enhance groundwater recharge; reduce storm water discharges, urban flood and seawater intrusion in coastal areas. Participatory management of water resources ensures effective utilization, maintenance and sustainable operation of these systems.

Rainfall is the principal source of water, which augments soil moisture, groundwater and surface flows. Agriculture and several of the other economic activities in dry and drought prone areas depend on rain. An annual rainfall of less than 300 mm characterizes most of the drought prone areas but several regions in semi-arid tropics receiving upto 1000 mm annual rainfall also experience frequent droughts. In most regions of water scarcity (except extremely arid tracts), the shortage of water is not caused by low rainfall as is normally perceived but rather by a lack of capacity for sustainable management and use of available rainwater (Sharma, 2001). The most critical challenge is how to deal with the poor distribution of rainwater leading to short periods of too much water and flooding and long periods of too little water. It is estimated that in most semi-arid tropics (SAT), the time when it is actually raining is in total about 100 hours per year, out of the 8,760 hours of the year (Sharma, 2003). However, even in the 'so-called' dry regions, rainwater is often available in abundance during the rainy season.

Potential of water harvesting

Water harvesting is the process of collecting rainfall and/or runoff from a larger catchments area to be used in a smaller target area (Oweis et. al., 1999). It is relevant to areas where rainfall is reasonably distributed in time, but inadequate to balance potential evapo-transpiration (ET) of crops. The process may occur naturally or artificially. The collected runoff water may be either directly applied to an adjacent field or stored in some type of on-farm storage facility for domestic use and as supplemental irrigation of crops. Water harvesting is generally feasible in areas with an average annual rainfall of at least 100 mm in winter rains and 250 mm in summer rains.

Water harvesting and integrated land-water management is not new to the world. The art and science of "collecting water where it falls' is ancient but this 'dying wisdom' needs to be revived to meet modern freshwater needs adequately, equitably and sustainably and modernized with inputs form science and technology (Sen, 1993). Given the increasing frequency and severity of droughts and population growth, it becomes increasingly important to systematically explore the unrealized potential of anti-drought measures including water harvesting, water conservation and efficient water utilization. During the recent (2002) but one of the severest droughts in Rajasthan (India), the government agencies transported drinking water to 10530 villages and 74 towns through deployment of 27001 tankers and 102009 railway wagons. Drought 2002 was also a clear pointer to the fact that droughts now lead to 'water famines' than 'food famines' (Anonymous, 2004). To withstand drought, the national and international focus should be on characteristics features of droughts, present status of water resources and its demand, and strategies to meet future water need for growing population on sustainable basis. Identification of potential rainwater conservation technologies to withstand droughts of different extremities and quantification of this potential at different spatial scales should be an important part of national and international anti-drought research and management programs.

The worldwide potential for introduction of water harvesting has not been fully assessed, but the potential is quite large. A major reason for the growing over exploitation of water resources is the current stress on river water and groundwater to the neglect of rainwater and floodwater, the availability of which is far greater. Several studies have shown that by allocating 1 to 5% of the area of the catchments for water harvesting, adequate resources can be generated for meeting the contingent needs of the water deficit communities. In the drought prone areas of India, such as Deccan Plateau, Central India, the western regions of Rajasthan and Gujarat and Tamilnadu, water harvesting remains an important source of water for agriculture (Kolavalli and Whitaker, 1996).

Water harvesting and conservation techniques

Rainwater harvesting can meet the people's basic water needs and also improve food and livelihood security. The methodology for assessment of the potential of any water harvesting technology may include: i) collection of hydro-geological and hydro-morphological data of an area ii) analysis of long-term climatic data for drought and surplus rainfall years and their frequency to select drought "scenarios" iii) assessment of the present status of water resources and water demands in the area iv) identification of the most promising harvesting methods v) joint analysis of geo-hydrological maps, population maps and rainfall data to establish the most suitable areas for promising technologies, and vi) quantification of possible surplus to water resources (e.g. due to influence of conservation/recharge structures) for a few drought scenarios and feasible scenarios related to possible extent of application of selected technologies. Some of the successful water resource development strategies popular in the water scarce and drought prone regions are briefly enumerated below:

1. *In-situ* rain water harvesting

Extensive research efforts on *in-situ* rainwater harvesting have been made in different parts of the world. Field bunding, contour bunding, ridging, conservation furrows, key line and contour cultivation have given useful leads in the past. The concept of vegetative barriers to replace or supplement earthen bunds that emerged in 1980s has been tried in a number of countries with mixed results. In a study on constructed micro-catchments of 45^o slope, ridge-furrow system (60:40 cm), and flat regular planting were compared with respect to soil moisture storage and yield of pearl millet. The ridge furrow system and micro-catchments resulted in 210% and 120% higher yield, respectively than regular flat planting. In micro-catchment based cropping, rainwater is concentrated in a small portion of the cultivated area. Tree crops being deep rooted can utilize the moisture stored in the sub-stratum and hence form a better option for micro-catchment based farming in sandy soil situations (Sharma et. al., 1986). Arid horticultural plants like dates, pomegranate*, ber, jujube* and several others can be successfully grown with appropriate micro-catchments in the water scarce regions.

2. Cisterns/ *tankas/ kund*

Underground storage cisterns/ *tanka /kund* is the most common rainwater harvesting system in the Indian arid zone, Pakistan, Sri Lanka, China and several other countries, generally constructed for storage of surface runoff. Almost every household, school, religious center in rural areas constructed *tankas/ kund* for meeting drinking water needs. T*anka* is constructed by digging a circular hole of 3.00 to 4.25 m diameters and plastering the base and sides with 6-mm thick lime mortar or 3mm thick cement mortar. The catchment of *tankas* are made in a variety of ways using locally available sealing materials like pond silt, *murram,* wood, coal ash, gravel etc. Improved designs of *tankas* have been developed and adopted under Drinking Water Missions in drought prone developing countries. It is estimated that more than 10,000 such structures are successfully functioning in Indian arid region. There are more than 200 *kunds* in Cholistan desert of Pakistan.

Gansu province in China has attained remarkable achievements by carrying out “121” Project. Under this project, each farm household has built up two cisterns for irrigating one *mu* (~500m^2) of farmland so as to ensure high and stable yield. Pengwa village in Qinan County has solved the drinking water problem of 1820 persons by building 359 cisterns each with a capacity of 20-30 m$^{3.}$ Besides, the village also built up 642 cisterns with a capacity of 45 m^3 for irrigation purposes. It has now been possible to establish 300 *mu* of fruit trees, 1,000 *mu* of food crops and 100 *mu* of sunlight glasshouse. During the severest drought of 2000 when all other neighboring villages had no harvest, this village had almost normal yield of 110 kg wheat*/mu*. The net income per capita rose from 680 to 1020 Yuan after construction of the cisterns. From 1996 to 2000, Shanxi Province built up about 0.4 million cisterns and dry wells, effectively supplementing irrigation water for 5.3 m ha of dry farmland (Wembo, 2002).

3. Run-off water harvesting based farming (*khadin farming*)

Khadin system of water harvesting and moisture conservation is well suited in deep soil plots surrounded by some sort of natural catchment zone. The soils in such pockets have developed from the silt load carried in runoff and hence are fine textured. Such soil situations are available in deep Thar Desert (Rajasthan, India) having rainfall as low as 150-350 mm/ annum. In this system, runoff from upland and rocky surfaces is collected in the adjoining valley by enclosing a segment with an earthen bund. Any excess water in *khadin* bed is passed out through a spillway provided in the bund. The plots are rigorously built and managed to make the entire system a self-contained unit for winter cultivation. The total energy input of rainwater, sand-silt-clay accumulation and cultivators’ own activities are interwoven into a complete production system of winter crops. There is progressive increase in crop yield every year, as more and more fresh silt and clay accumulates in the bed. The ratio of farmland and catchment areas is regulated to be about 1:6 to 1:18, so that a suitable moisture supply is uniformly maintained. A study conducted at Central Arid Zone Research Institute, Jodhpur (India) has shown that even without the use of chemical fertilizers, the average crop yield in *khadin* ranges from 2.5-3.0 t/ha of wheat and 1.5-2.5 t/ha of chickpeas. Even during severe drought years*, khadins* may be used for getting a successful crop on stored soil profile moisture.

4. Village ponds *(Nadis/ tobas*)

Nadis /tobas are small to medium sized excavated or embanked village ponds, for harvesting meager precipitation to mitigate the scarcity of drinking water and domestic needs in water scarcity regions. Pond water is available for periods from two months to a year after rain, depending upon the catchment characteristics and amount and intensity of rainfall. The *nadis* range from 1.5 to 12 m in depth, 400 to 700,000 m^3 in capacity and have drainage basins of various shapes and sizes (8 to 2,000 ha). These *nadis* can also be used for recharging the groundwater through construction of infiltration wells and recharge pits in the bed of the storage area. Under suitable conditions, a recharge pit of 3mx3mx3m was sufficient to divert 6,500m^3/ annum water to ground water reservoir. Recharge from a village pond of 2.25 ha water spread area and storage capacity of 15,000 m^3 in north Gujarat, (India) alluvial area, could be induced to create groundwater recharge of 10,000 m^3 in one rainy season. These structures are however not scientifically designed and constructed and suffer from high seepage and evaporation losses. Pakistan government has constructed more than 1500 *tobas* in Cholistan area for domestic and livestock water supplies. The optimized characteristics of the village ponds for minimizing the storage losses are given by Sharma and Joshi (1983,Table 1). They show that water may still be available in such structures during drought lasting up to 1 year.

Table 1. Optimized village pond characteristics to minimize the storage losses

Physiography	Optimized depth (m)	Optimized surface area (m^2 x 10^3)	Water availability (months)
Dune complex	2.5	29.1	4.8
Sandy plain	2.0	27.1	8.3
Younger alluvial plain	5.0	161.0	12.0
Older alluvial plain	3.0	96.0	12.0
Rocky/ gravel pediment	6.0	126.5	12.0

5. Series of check dams on natural streams

In this system the artificial recharge is made to restrict the surface run off through streams and by making additional water available for percolation. The surface water is impounded during monsoon behind the structure and spread over the entire streambed and thereby increasing the wetted area. The impounded water helps in replenishment of groundwater. A series of check dams can be constructed on a stream to recharge the depleted groundwater aquifers. With the construction of check dams at village Ujalian, district Jodhpur (India), static water level in wells in the zone of influence increased from 1.8 – 2.2 m as compared to increase of only 0.5 m in wells located outside the zone of influence. In another study made in Pali district of Rajasthan it has been observed that the presence of check dams in series have increased aquifer recharge from 5.2 to 38% (Khan, 2001).

6. Percolation tanks

Percolation tanks are generally constructed on the small streams or rivulets with adequate catchment for impounding surface runoff. These tanks are used entirely for recharging the aquifer through percolation. In comparison to ponds, percolation tanks conserve water to a greater extent because the filling and recharge occur mostly during the monsoon when the evaporation rate is about the half of potential rate in summer through which ponds contain water. Selection of suitable site for the construction of percolation tanks and subsequent maintenance is crucial for its effective functioning. Where hydro-geological conditions are favorable, percolation rates may be increased by constructing recharge (intake) wells within percolation tanks (Raju, 1987).

Studies conducted on artificial recharge through percolation tanks constructed in hard rock and alluvium formations revealed that the rate of percolation ranged from 14-52-mm/ day (Table 2). Partitioning of water loss from percolation tanks suggests that percolation loss accounted 65-89% whereas the evaporation loss was only 12-35% of stored water (Khan, 2001). The rate of percolation from a newly constructed percolation tank in deep alluvium formation near Sojat city, (Rajasthan, India) was 2.4 m (77 mm day $^{-1}$) in July when the static water head in tank was 5.4 m and 1.82 m (59 mm/day) in August when the static water head was 3.3 m. The rate of percolation reduced to 4.8 mm day^{-1} in the month of December when the water column in tank was only 0.27 m. The recharge form the percolation tank accounted 88% whereas evaporation accounted only 12% of the stored water in the tank (Khan, 2001).

Table 2. Percolation and evaporation losses from percolation tanks

Location of tank	Basin	Formation	Tank capacity (m^3)	Average rate of percolation (mm/day)	Percolation rate (%)	Evaporation (%)
Sablipura	Guriya	Hard rock	35,400	18	77	23
Dhaneri	Lilri	Hard rock	25,700	14	65	35
Sojat	Sukri	Alluvium	3,80,000	52	88	12
Sheopura	Sukri	Alluvium	64,300	38	83	17
Dhabar	Phunpheriya	Alluvium	29,500	33	89	21
Mev	Guhiya	Hard rock	67,000	27	81	29

7. Sub-surface barriers (SSB)

Sub-surface water harvesting systems exploit water already infiltrated and concentrated through natural hydrological processes into the sand rivers that fill valleys in arid and semi-arid regions. Such barriers are quite suitable structures as they are safe from flood havoc, do not need elaborate overflow arrangement and periodic de-sitting. The construction needs a 30-60 cm wide concrete or brick impermeable basement or compact foundation. Surface barriers may also be constructed with angular pieces arranged in form of dry masonry 100 cm wide wall or with 250-micron polythene sheeting, properly embedded in the soil. Construction of two sub-surface barriers across an ephemeral stream within 300 m from the water supply wells at a site in Jodhpur district (India) have been found to store sufficient water required for a village with a population of 500 persons. Studies conducted for 3 years (1996-98) at Kalawas and Chauri-Kalan village in Jodhpur district revealed that with the construction of SSB, the annual rate of depletion of groundwater has been reduced from 1.0 m to 0.3 m and from 1.0m to 0.23 m for Kalawas and Chauri Kalan, respectively.

8. Recharge tube wells

Excess rainwater collected behind check dams, surface ponds or percolation tanks can be efficiently utilized for recharging groundwater through recharge tubewells. The floodwater, which has to be mixed with groundwater occurring at a deeper depth, should be potable and free from suspended solids. To achieve this, filter bed should be provided on top of the recharge tubewell. Recharge tubewell may be drilled in the area of the dam or percolation tank down to the prevalent depth of exploitation. Diameter of the borehole may be around 50 cm and PVC pipe of 6-kg/m^2 strength having a diameter of 20 cm be used.

The annular space between the borehole and the pipe is filled with gravel and developed with compressor till it gives clear water. On top a 6m x 6m x 6m dimension pit should be dug out keeping the tubewell at the centre and the section is filled with rounded boulders, chips and sand. This recharge tube well can also be used for pumping ground water in case of emergency.

Hundreds of such recharge tubewells have been constructed in Kutchh and Saurashtra (Gujarat, India) for harvesting groundwater. In Rayan Micro watershed in Kutchh 18 check dams, one percolation tank and 2 recharge tubewells were constructed creating the storage of 44,715 m^3. The artificial recharge through rainwater harvesting structure has resulted in the rise of water level varying from 1.2 to 3.65 m and improvement in the water quality by reduction in TDS varying from 10 to 420 ppm. There was an increase of 15% of the cropped area with 30-35% higher yields even in drought years of 1993-94 (Sharma, 2003).

9. Integrated watershed development

Upper catchments and foothills of several regions provide the greatest scope for rainwater harvesting and groundwater recharge because of favorable hydrological formations and heavy rainfall. An integrated watershed development programme in Kandi area of the Indian Punjab (foothills) including (i) forest rehabilitation in 45,000 ha in upper catchments (ii) 19 water harvesting dams (iii) seven medium capacity irrigation dams having cultivable command area of 9,606 ha and (iv) on-farm development by various departments during the last two decades has already paid dividends by reversing the declining water table as well as increasing the ground water recharge in the downstream irrigated area. The water balance has increased from (-) 97,867 ha-m in 1979-80 to (+) 52,075 ha-m during the period 1997-98, thus reversing the falling trend of water table to a rising water table (Khepar 2001). Similar studies/projects undertaken elsewhere suggest that upper catchment of falling water table areas should be taken up on priority basis for watershed management including water conservation/ harvesting structures and low irrigation dams.

10. Rainwater harvesting in urban areas

Efforts should be made to harvest the rainfall runoff and using the same for groundwater recharge in urban areas. Some of the possible sources of water include roof top rainwater, storm water, outflow from households/community buildings etc. The water harvested from these sources can be used for ground water recharge through adoption of site-specific recharge techniques such as recharge wells/shafts/pits etc. Some of the municipal corporations have already introduced building bylaws making roof water harvesting as mandatory for buildings having roof area larger than specified norms. The roof top water harvesting is of special importance in case of institutional buildings, which have large roof area and space for installation of ground water recharge structures. Rain water-harvesting structure installed in the building of Ministry of Water Resources, New Delhi, India having a roof top area of 3110 m^2 was able to collect a recharge of 3000 m^3 during rainy season of 2000.

Some "bright spots" in water harvesting and drought mitigation

Local water management and rainwater harvesting provide the key to the transformation of the ecological and economic base of an agrarian village. Over the last few decades several countries have seen a number of micro-experiences of successful community resource management. These micro-experiences are remarkable as they are testimony to the potential of generating wealth and well being even in the face of severe droughts through rainwater harvesting. Here are few examples from India:

The Sukhomajri Experience: In the 1970s in the foothills of Himalayas, Sukhomajri was sparsely vegetated, with poor agriculture and high levels of soil erosion and runoff. As agriculture was riddled with uncertainty, villagers traditionally kept herds of livestock to minimize risk. In 1979 when the nation was facing a severe drought, the villagers built a small tank to capture the rainwater and agreed to protect their watershed so that the tank did not get silted up. Since then villagers have added a few more tanks and have protected the heavily degraded forest which forms the catchment of these tanks. Significant economic and ecological changes have taken place in the village over the years: wheat production increased from 40.6 to 63.6 tons, maize production increased from 40.9 to 54.3 tons, grass productivity increased from 0.04 to 3.0 t/ha, milk production increased from 334 to 579 l/day and tree density in watershed increased from 13 to 1292/ha. In just five years from 1979-1984, the annual household income went up from INR 10,000 to INR 15,000.There has been no migration from the village even during severe droughts. A village level institution, The Hill Resources Management Society that was specifically created to discuss the local problems, manage the local environment and maintain discipline among its members, played a crucial role in this entire exercise.

The Ralegaon Sidhi Experience: Ralegaon Sidhi is held up today as a model of development. It is a village situated in a drought-prone area of Maharashtra where the annual rainfall ranges from 450-650 mm/ annum and the villagers once were not assured of even one regular crop. In summers they would regularly take to state-sponsored drought relief measures or would migrate to other localities. The village was in grip of chronic poverty, moneylenders and country made liquor. Mr. Anna Hazare-a dedicated retired driver from the army-began work in village by constructing storage ponds, reservoirs and gully plugs. Due to steady percolation of water, the groundwater table began to rise. Simultaneously, government social forestry program was utilized to plant about 400,000 trees. Because of the increased availability of irrigation water, the total area under farming increased from 630 to 950 hectares. The average yield of millets, sorghum and onion increased substantially. To ensure that the limited amount of water available was distributed equitably among all households, only low water-consuming crops were allowed. No farmer will get a second turn of irrigation until all the families have been served and even the interest of landless families were taken care of. Today not a single inhabitant of the village depends upon drought relief and the incomes and prestige have increased substantially. The evolution of village institutions in Ralegaon has been an important part of its development.

The Alwar Experience: Gopalpura is a poor, drought-stricken village, located at the base of Aravalli hills in the state of Rajasthan. The area is semi-arid and over the years deforestation has left it devoid of any vegetation. Water shortages are common and have a deep impact on the lives of the people and their agriculture. In 1986, the villagers with the help of a local NGO (Tarun Bharat Sangh), built three small earthen rainwater harvesting structures, locally called *johads*, on their fields and village grazing lands to store monsoon rains, irrigate their fields and increase percolation in the ground to recharge wells. The effort of Gopalpura has attracted so much attention that within 10 years the communities have been able to build almost 2500 water harvesting structures in over 500 villages of the region. Till 1997-98, water-harvesting structures had cost about USD 3.33 million and the poor villagers in cash or kind contributed more than 73% of this. The direct and most dramatic impact of these structures has been to increase the groundwater as well as surface water availability in the region. Water has increased agricultural productivity of this extremely impoverished land and people do not migrate during even the worst droughts.

Institutions and policies related to water harvesting

Over the years and across the globe, two major discontinuities have emerged in the management of water resources. First, the State has emerged as the major provider of water taking this role from communities and households. Second, there has been growing reliance on the use of surface and groundwater, while the earlier reliance on rainwater and floodwater has declined, even though rainwater and floodwater are available in much greater abundance (Agarwal and Narain, 2002). However, the “bright spot” experiences mentioned in this paper and in other developing countries have clearly demonstrated that innovative paradigms for drought mitigation can be constructed only through effective participation of the communities for rainwater/ floodwater harvesting. The state may ordinarily act as a facilitator and provide seed money for purchase of the inputs which are not available locally. Water harvesting implies re-establishing the relationship between people and their environment. Worldwide, many projects have failed primarily due to lack of people’s participation for mobilizing and utilizing their energies and resources in such programs. The consequences are wastage of public funds invested on construction of these structures, which generally fail after the rains every year and have to be reconstructed. Unless the program stakeholders, i.e. beneficiary and affected people are convinced and own to harvest, store, conserve, repair and maintain the resources by investing their time, energy and money (even partially), water harvesting and conservation projects cannot perform satisfactorily (Samra et al., 2002).

There is a need for a policy framework to develop institutional mechanism to promote water harvesting at different levels such as user, watershed, municipality, district, state and federal level by having representatives from local level people’s institutions, non-governmental organizations and concerned government departments. Social mobilization, more decentralization and community empowerment are needed to be explicitly included in government policies for success of community based water resources development. Village institutions and local level water users’ associations may offer a platform for this to happen. Traditional technologies of water harvesting and conservation can be blended and augmented with modern tools and techniques, in view of the local socio-economic and socio-cultural needs. It is suggested that basin-wise planning and management of water resources should integrate participatory watershed management for sustainable development, and small and micro-water harvesting systems made integral part of the water resources development at the regional and national levels.

Conclusions

Potential of water harvesting in different countries and regions is not yet fully understood, quantified and implemented. Indigenous and innovative technologies in the form of micro-catchments, storage cisterns, run-off water harvesting based farming, embankment ponds, check dams on natural streams, percolation tanks, recharge tube wells, sub-surface barriers, integrated watershed development and rain water harvesting in urban areas offer a large potential even under water scarce regions.

Several village level success stories have demonstrated that water harvesting based development paradigms were able to mitigate drought and positively impact household economy. Indications are that rainwater-harvesting measures when adopted on a large scale may minimize the risk of water scarcity even during severe drought years but such studies are few and scattered. Further research is needed to ascertain to what extent these interventions help to withstand droughts and to what extent shall cover the deficit.

Potential of water harvesting as a strategic tool for drought mitigation can be realized through a policy framework to develop institutional mechanism to water harvesting at different levels such as user, watershed, urban locality, district, state and federal level by having representatives from local level people’s institutions, NGOs and concerned government departments.

Small and micro-water harvesting systems should be made integral part of basin-wise planning and water resource development at the regional and national levels.

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