Indian Journal of Agronomy **54**(1): 90–97 (March 2009)

Rainwater harvesting and water-saving technologies

B. CHANDRASEKHARAN[1] AND B.J. PANDIAN

Tamil Nadu Agricutlural University, Coimbatore, Tamil Nadu 741 003

ABSTRACT

Water is an important life giving natural resource. Yet, human kind not done enough to replenish, conserve and safeguard sources of water supply. On contrary, we face the real prospect of reduced supply of water because of climate change and global warming. Irrigation is the major source of water and it consumes about 80 % of the current water utilization in India. It is estimated that with increasing demand from other competing sectors, the share of water is likely to reduce by 10 to 15 in the next two decades. In addition, shrinking water resources due to falling ground water-tables, silting of reservoirs and pollution of water resources from untreated domestic waste, industrial effluents and agro-chemicals are threatening the sustenance of existing levels of agricultural production. At the national level, the ground water contributes to about 50 % in the irrigated areas and its intensive development has been one of the key-driving elements in ushering the green revolution but over exploitation of ground water has led to several other problems affecting the sustainability of the production base. Its unscientific exploitation is creating problems and leading to many areas in the country being classified as dark and grey blocks. The per caput water availability is declining continuously and likely to reach the stress and even scarcity levels in some regions in the next few years. There are variety of irrigation water saving technologies that can improve the water use efficiency and productivity of water. These include *in-situ* water conservation, water auditing, increasing in irrigation efficiency adoption of improved irrigation methods and conjunctive use. Even a marginal improvement in the water use efficiency in irrigation sector will result in saving of substantial quantity of water which can be utilized either for extending the irrigated area or for diverting the saving to other sectors of water use. It is now widely recognized that water, especially irrigation water is finite and a vulnerable resource. There is also a wide consensus that water development and management should be based on a participatory approach, involving all stakeholders.

Key words **:** Rainwater, Technologies, Water conservation, Water harvesting

Annual precipitation including snow fall in our country has been 4,000 km^3 for centuries and will remain nearly the same for centuries to come. Out of 4,000 km^3, India's average annual run-off generated by rainfall and snowmelt is estimated to be about 1,869 km^3, while the rest is lost in evaporation etc or escapes into sea during the floods. However, the present availability of utilizable annual surface water (690 km^3) and groundwater (432 km^3) of 1,122 km^3 is just sufficient to meet the estimated demand of 1,093 km^3 by 2025 AD. Present utilizable water resources may just sufficient to meet the total water needs for the country by the year 2025 AD. Moreover, the entire replenishable groundwater is assumed to be utilized by 2025. The present population of India is about 101 crores which is projected at 170 crores by 2050 AD. The country is producing today around 200 mt of food which is estimated of the order of 450 mt by 2050 AD. This has to be produced from available net cultivable area which is 143 m ha as of now and is expected to go only to 145 m ha by 2050 AD. So there will be a gap between the water availability and requirement by 2050 AD. In India, the water situation is steadily worsening. The average annual per capita fresh water availability has come down to 1,869 m^3 in 2000, from 5,000 m^3 in 1950. The average water availability though looks comfortable up to 2025 AD, the water scarcity condition (availability less than 1000 m^3/capita/annum) already exists in 8 of the 20 major river basins in the country. Some of these regions suffer absolute water scarcity, with availability below 500 m^3. Many basins are either physically water scarce or have pockets of unsustainable ground water use or have high food dependency ratios (Rao, 2007).

Water harvesting is the activity of direct collection of rainwater, which can be stored for direct use or can be recharged into the groundwater. Water harvesting is the collection of runoff for productive purposes. Rain is the first form of water, which enters into the hydrological cycle and it is a primary source of water for us. Presently rivers, lakes and groundwater are the secondary sources of water in which we depend entirely on them.

***Corresponding address:** (E-mail:drres@tnau.ac.in)

Invited lecture delivered by senior author National Symposium on 'New Paradigms on Agronomic Research' held at Navsari Agricultural University, Navsari, Gujarat during 19-21 November 2008.

Challenges in sustaining the water resources

There are some challenges in sustaining the water resources. The foremost challenge related to water scarcity in developing countries like India is the need to increase the efficiency of water use in agriculture, urban areas, and industry. Irrigated area accounts for over two-thirds of world rice and wheat production, so growth in irrigated output/unit of land and water is essential. Improved efficiency in agricultural water use is required both to maintain productivity growth and to allow reallocation of water from agriculture to urban and industrial uses.

New sources of water are increasingly expensive to exploit. Water to meet growing household and industrial demand may come through water savings from irrigated agriculture, which generally accounts for 80 % of water diverted for use in developing countries. To truly contribute to reduce the water scarcity, improved efficiency in agricultural use should be accompanied by improved efficiency in urban and industrial use. The quality of land and water must be sustained in the face of mounting pressure to degrade these resources through water logging, salinization, groundwater mining, and water pollution.

Experts feel that with the present rate of water consumption, India is poised to have more Cauvery-like disputes among states. Worldwide, the crisis can be so grave as to trigger a Third World War. According to the data presented with the standing sub-committee for assessment of availability and requirement of water for diverse uses, the total demand for water at the start of the millennium stood at 634 BCM, which is likely to soar to 1,447 BCM at the present rate, whereas the total utilizable water is 1,123 BCM. Central Water Commission has stressed on the need of water conservation and judicious use of water. “If India has to sustain its growth rate, it is very imperative that we use water efficiently. Even 10 % of the water saved during the course of irrigation can meet 40 % of the other demands”.

Water use efficiency is presently estimated to be only 38 to 40 % for canal irrigation and about 60 % for groundwater irrigation schemes. On the basis of 1991 census, our country’s per caput water availability/year was estimated at 2,214 m^3 against the global average of 9,231 m^3. In 1990, India was ranked at the 42nd position among 100 countries by per caput water availability. In the total water use in 1990, the share of agriculture was 83 %, followed by domestic (4.5 %), industrial (2.7 %) and energy (1.8%). The remaining 8 % was for other uses including environmental requirements. The projected total water demand by 2025 AD. is around 1,050 km^3 against the country’s utilisable water resources of 1140 km^3. The share of agriculture in total water demand by 2025 AD would be about 74%. Thus, almost the entire utilisable water resources of the country would be required to be put to use by 2025. Irrigation, being the major water user, its share in the total demand is bound to decrease from the present 83% to 74% due to more pressing and competing demands from other sectors by 2025 AD. It is estimated that with 10% increase in the present level of water use efficiency in irrigation projects, an additional 14 m ha area can be brought under irrigation from the existing irrigation capacities which would involve a very moderate investment as compared to the investment that would be required for creating equivalent potential through new schemes. (planningcommission.gov.in/plans/annualplan/1999-00).

Rainwater harvesting

The collection and storage of rainwater for later productive use is defined as rainwater harvesting. Any rainwater harvesting system has three components *viz.*, catchment, conveyance, and storage. The benefits of rainwater harvesting include : (i) Rainwater harvesting (RWH) is the ideal solution for all water requirements; (ii) increase in groundwater level; (iii) mitigates the effects of drought; (iv) reduces the runoff, which other wise flood storm water drains; (v) reduces flooding of roads and low-lying areas; (vi) reduced soil erosion; (vii) improves the groundwater quality; (viii) low cost and easy to maintain; and (ix) reduces water and electricity bills.

The approaches pertaing to rainwater harvesting are: (i) planning houses with rainwater harvesting structures, modification of house, existing house, etc.from rooftops; (ii) government buildings, institutions, hospitals, hotels, shopping malls etc. from rooftops and open areas, (iii) farmlands, public parks, playground, etc. and (iv) paved and unpaved areas of a layout /city/town/village

Rainwater harvesting techniques

There are 2 techniques of rainwater harvesting *viz* rooftop rainwater harvesting and storm water recharging through open drains.

Rooftop rainwater harvesting : The rooftop rainwater harvesting system requires four elements *i.e.* (i) catchment area, (ii) conduits, (iii) settlement tank and (iv) recharge or storage facility. For rainwater harvesting system, a dried bore well, an underground tank or soak pit are required along with conduits or the pipes carrying rainwater from the catchment or roof tops to harvesting/storage system.

Storm water recharging through open drains : In urban areas, natural way rainwater harvesting occurs only in areas left out for open spaces and parks. In the new areas which are being developed by the urban development authorities/civic bodies, the storm water is disposed off through underground channels of sewer lines, thus leaving no scope for recharging of this rainwater into the earth. The old technique of disposal of storm water through open drains is considered more environment friendly as through these open drains storm water charging take place in natural way.

Water harvesting and recycling

Collection of rainwater through check dams, farm ponds and recycling of saved water through application devices (rain gun) increase the productivity of water. In on-farm, overhead sprinkler and rain gun systems are used to give supplemental irrigation under rainfed cultivation through farm ponds to mitigate the intermittent drought.

On-farm RWH and Conservation Technologies

Community-based technologies

Community-based technologies include underground pipe systems, lined-canals and sprinkler systems. In most applications, they have large fixed costs and require collective action or ongoing co-ordination of many house-holds. Sprinkler systems, for example, require substantial water pressure to operate. To attain sufficient pressure, some villages need to construct water towers and elaborate piping networks. Besides, the small size of plots and fragmented nature of most farm-holdings in most of the Indian states mean that operating a sprinkler system requires coordination for use. It is difficult to use a sprinkler that irrigates in a large circular pattern on 1 plot without irrigating the plots of other households around it.

Water conservation through watershed

The watershed approach has been applied for the purpose of arresting rainwater runoff, rainwater harvesting, and *in-situ* soil and moisture conservation. Community based watershed development has become the guiding principal for rejuvenation of natural resources, especially land and water.

The engineering measures for rain water harvesting adopted differ with location, slope of the land, soil type, amount and intensity of rainfall. Depending on these parameters, the methods commonly used are contour trenching, contour stone walls, construction of temporary and permanent check dams and gully plugging structures. Additionally, percolation ponds, silt detention tanks and irrigation tanks are constructed to harvest water and recharge it to the groundwater for use in agriculture (irrigation). Farm ponds can also be constructed for every 4-5 ha in the watershed to provide protective/supplemental irrigation.

Water Harvesting Structures

Contour bunds, contour barriers (vegetative and stone), contour trenches and contour stone walls will not only prevent soil erosion but also obstruct the flow of runoff water. Consequently, the obstructed water will increase the soil moisture and recharge the groundwater in the area.

Check dams

Check dam may be a temporary structure constructed with locally available materials. The main function of the check dam is to impede the soil and water removed from the watershed. This structure is cheap, but lasts for about 2-5 years only. The cost of the structure is about US$ 200 - 400 depending on the materials used, the size of the gully and the height of the dam. A permanent check dam can be constructed using stones, bricks and cement. Small earth work is also needed on both sides. Costs vary from US$ 1 000 - 3 000 depending upon the length and height of the dam. A little water is also stored above the dam. This water recharges the groundwater.

Percolation Pond

The percolation pond is a multipurpose conservation structure. It stores water for livestock and recharges the groundwater. It is constructed by excavating a depression, forming a small reservoir or by constructing an embankment in a natural ravine or gully to form an impounded type of reservoir. The cost of this type of structure is estimated at around US$ 5,000 – 10,000. The capacity of these ponds or tanks varies from 0.3 to 0.5 mcft (10,000–15,000 m^3). Normally 2 or 3 fillings are expected in a year (season) and hence the amount of water available in a year in such a tank is about 1 mcft to 1.5 mcft (30 000-45 000 m^3). The cost for one mcft (30 000 m^3) varies from US$ 5,000 to 15,000. This quantity of water, if it is used for irrigation, is sufficient to 4-6 ha of irrigated dry crops (maize, cotton, pulse, etc.) and 2-3 ha of paddy crop.

Irrigation tank

The main function of this storage structure is irrigating crops. It is constructed below the percolation pond in a watershed. In Tamil Nadu, each tank irrigates 10 to 5,000 ha. In south India, there are about 2,00,0000 tanks, irrigating about 3.5 million ha. Earthen bunds are reinforced with masonary to collect and store rainwater for irrigation. The cost of this tank varies from US$ 1,500–2,500 to irrigate 1 ha of land. Water from the tanks is normally used to grow paddy.

On-farm rainwater harvesting

The farmers of rainfed and dry farming regions are poor because of lower and unstable yield. In addition, it has uneven and erratic distribution which results in moisture stress to the crops. To overcome this acute problem of water scarcity, the natural rainwater is stored in augmented storage structures and being used for domestic and irrigation purposes.

The most efficient and cheapest way of conserving rainwater at the agricultural farm was found to be *in situ* runoff management, which also reduces soil losses and increases the opportunity time for groundwater recharging. The average depth of runoff at 80 % probability level was found to be 14 cm. It is observed that earthen embankment for rainwater harvesting has cost benefit ratio of 1.38:1. Hence it can economically be replicated. It is also observed that earthen check dam/reservoirs which are recommended across the streams to regulate run off for flood control, trapping silt, collecting water for irrigation and fish production and to recharge groundwater has good potential for replication. Excavated dug-out ponds tanks are found most suitable for storing runoff in cultivated lands with inverted truncated pyramid shape having 1:1 side slopes with lining of polyethylene sheet of 200 micron buried under 20 cm thick soil at bottom and pitched with bricks. The rainwater harvesting during monsoon and its use for irrigation during scarcity period was found to increase the crop yield by 20-30% during *rabi* and additional water for population use by 60% in the area. (Sharma *et al.,* 2004)

In-situ soil moisture conservation

Apart from the above, to increase moisture availability to agricultural and tree crops, *in situ* moisture conservation techniques must be adopted in addition to the large-scale soil and moisture conservation and water harvesting structures in the watershed. The following are some of the *in-situ* moisture conservation measures, which can be practised in the watershed to increase the production.

For agricultural crops, the measures adopted are forming ridges and furrows, broad-bed and furrows, basin tie ridging (random tie ridges) and water spreading. For tree crops micro-catchment, saucer basin, semi-circular bund, crescent-shaped bunds, V ditch technology, catch pits and deep pitting can be practised.

The small storage structures with a water storage capacity for an area of about 0.4 to 0.5 ha can be constructed in large numbers for every 10 to 20 ha catchment or watershed at the foot-hills slopes and hilly areas. These storage facilities would attenuate the floods during storms. These measures will also ensure soil moisture for good growth of trees grown down stream recharging the groundwater in the region and making available more water for drinking and irrigation water.

Contour-farming

During intense rain storms, the soil cannot absorb all the rain as it falls. The excess water flows down the slope under the influence of gravity. If farming is done up and down the slope, the flow of water is accelerated, because each furrow serves as a rill. The major part of the rain is drained away without infiltrating into the soil. The top fertile soil, along with plant nutrients and seed is washed off. All this results in a scanty and uneven growth of crop.

A simple practice of farming across the slope keeping the same level as far as possible (which is technically called contour-farming) has many beneficial effects. The ridges and the rows of the plants placed across the slope form a continual series of miniature barriers to the water moving over the soil surface. The barriers are small individually, but as they are large in number, their total effect is great in reducing run-off, soil erosion and loss of plant nutrients.

It has been experimentally proved that contour-farming reduces run-off and prevents soil erosion as compared with the up-and-down cultivation in the major groups of soils in India, *viz*. alluvial soils, black soils and deep lateritic soils. Apart from conserving the water and soil, contour-farming conserves soil fertility and increases crop yields. Contour-farming has also given 490 kg of sorghum grain and 273 kg stalks more than the up-and-down cultivation at Kanpur. Thus 1 mm of rain-water conserved by contour-farming gave 22.5 kg of sorghum grain and 12.5 kg of straw more than the up-and-down cultivation. It has been proved that much less power is required to be exerted by men, animals and machines, if the cultivation is done in the contour instead of up-and-down the slope. There is less wear and tear of the implements and the same job is done in less time in contour-farming.

Broad Bed Furrow (BBF)

The BBF system consists of a relatively raised flat bed or ridge approximately 95 cm wide and shallow furrow about 55 cm wide and 15 cm deep. The BBF system is laid out on a grade of 0.4–0.8 % for optimum performance. It is important to attain a uniform shape without sudden and sharp edges because of the need in many crops and cropping systems to plant rows also on the shoulder of the broadbed. This BBF system is most effectively implemented in several operations.

Benefits

- The raised bed portion acts as an *in-situ* ‘bund’to conserve more moisture and ensures soil stability; the shallow furrows provides good surface drainage to promote aeration in the seedbed and root zone; prevents water-logging of crops on the bed.

- BBFdesign is quite flexible for accommodating crops and cropping systems with widely differing row spacing requirements.
- Precision operations *viz.*, seed, fertilizer placement and mechanical weeding are facilitated by the defined traffic zone (furrows), which saves energy, time, cost of operation and inputs.
- Facilitates double cropping and increases crop yields.
- It can be adopted for groundnut crop in red soils with a reduced gradient along the bed (0.2–0.4%).

The BBF formed during the first year can be maintained for the long term (25-30 years). This will save considerable cost as well as improve the soil health. The increase in yield in improved system is shown in Table 1.

Table 1. Crop yields in improved and traditional system in Vertisols Watersheds, ICRISAT Patancheru (1976-2006)

Crop	Mean crop yield (t/ha)
Broad Bed Furrow system with double cropping (Maize or sorghum - Chickpea or pigeonpea	3.9 - 1.3
Traditional flat system (*rabi crop)* Sorghum or chickpea	1.1

Mulching

Surface mulches are used to prevent soil from blowing and being washed away, to reduce evaporation, to increase infiltration, to keep down weeds, to improve soil structure and eventually to increase crop yields. Inter-culture kills weeds and produces 5-7 cm thick soil mulch which helps to reduce evaporation from the top soil. It also breaks the surface crust which forms after each downpour. Studies on mulching carried out in India under rainfed agriculture have concentrated on the measurement of crop responses rather than on the manner in which crop responses are influenced.

Mulching with maize residues did not significantly influence the yield of the succeeding crop. Mulching, in general gave a higher yield of wheat grain and stalk than no mulching. At Bellary, mulching with different materials (*e.g.* paddy husk, grass mulch, jowar stubble) did not give encouraging results in increasing the yields of cotton and jowar. Mulching with straw on Encap Esso mulch increased the infiltration rate, improved soil moisture and increased the yields of wheat, barley, gram and linseed, succeeding the maize crop on eroded soils at Ranchi.

Growing of crops which provide the maximum cover, reduce run-off

Cultivated legumes in general furnish a better cover and hence better protection to cultivated land against erosion than ordinary cultivated crops. The crops and the cropping systems will naturally vary from region to region, depending on the soil and climatic conditions. At Dehra Dun, cowpeas provided the maximum canopy with or without the application of phosphate fertilizer. This was followed by *mung*, *urd* and *dhaincha*. At Vasad, cowpeas provided the best vegetative cover for the soils. Sunnhemp was the next best; *mung* and groundnut were effective to some extent.

At Kota, velvet bean formed the canopy effective to the maximum extent. Cowpea was the next best. At Kanpur, *mung* served as the most effective canopy, followed by *urd* and clusterbean. The application of phosphorus increased the canopy. At Rehmankhera, cowpea formed the best canopy, followed by *Styzolobium*, *mung*, groundnut, *urd*, *moth* and soybean. Sunnhemp, *mung* and *Styzolobium* helped to conserve soil moisture well, leading to a higher yield in the succeeding barley crop. All the legumes were equally effective in reducing the loss of soil and nutrients. Thus among the legumes, cowpea and *mung* proved to be important crops for providing a good cover for the land during the rainy season.

Vetiver

Vetiver grass, or khus khus (*Vetiveria zizanioides* L.), roots and tops have also been harvested. Traditionally, these roots were woven into mats, fans and fragrant screens, while the tops of the grass were used for handicraft, thatch, mulch, fodder and animal bedding. In the last 50 years, attention has been focussed on vetiver's unique soil conservation properties. When planted in single lines along the contour, hedges of vetiver grass are found to be very effective in soil and moisture conservation. The stiff stems of the thick hedge slow the movement of runoff water and spread it out, trapping silt behind the hedge. This allows more water to be absorbed into the soil, thus reducing runoff and erosion.

Vetiver hedgerows will bring soil losses down to reasonable and acceptable levels, will prevent organic matter loss (i.e. FYM and soil organic matter), and will reduce rainfall runoff resulting in improved soil moisture, increased groundwater, and better yields. Because of its deep root system vetiver can recycle nutrients, not normally available to crops, by treating the vetiver leaves as a crop residue and incorporating them in the soil.

The water used by crops accounted for 33-67%, soil-water storage accounted for 0-14% of rainfall and runoff accounted for 3-13% of rainfall. Amount of rainfall drained to groundwater recharge was quite high (31-65

%) due to the recharge season (rainy season) that rainfall amount was input to the study sites and infiltrated into the soils while the excess water run off. However, rainfall is found to be far exceeding evapotranspiration during this period which may cause more excessive soil-water content than the soil can store. Soil-water would subsequently be drained freely from the soil profile through gravity. In particular, sandy soils may be capable of draining soil-water within a few hours compared to few days in fine texture soils.

Comparing to the control plots, the maize plots where vetiver hedgerows were applied showed higher recharge values with 20 % increased groundwater recharge (Table 2). Meanwhile, there were no differences in recharge values found between control and vetiver hedgerows applied plots at Longan and soybean cultivation sites. Vetiver hedgerows planted across cultivated slopes at Yom Watershed, Northern, Thailand were found to increase water stored in soil profile while reducing 19-56% of water loss by runoff. Vetiver can reduce surplus runoff by diverting it perpendicularly along the contour hedgerows and allowing smaller amounts to pass through, while other amounts are seeped through the soil and retained by soil profile. In the cropping season, the major proportion of rainfall amount was used by crops and evapotranspiration has greatly affected the water balance. Vetiver hedgerows acted as intercrops that withdrew more water compared to the sole crop. Thus, the water output as deep drainage was not obviously enhanced at high evapotranspiration field. The finding is brought to the conclusion that with fine soils, low soil hydraulic conductivity, and high runoff, vetiver hedgerows could increase groundwater recharge up to 20 %.

Recommendation deriving from this study is that, within the headwater areas which are normally high slope, vetiver hedgerows can be used as an effective conservation treatment in agricultural practices. The potentials of vetiver hedgerows in holding water, reducing runoff and increasing groundwater recharge are, therefore, the ability to help watershed to store and provide water properly in quantity and timing. This may be an alternative way in watershed conservation that is similar to the function as provided by natural forest.

Water saving in farms

Field level water savings and real, basin-wide water savings may differ due to several agronomic and hydrologic factors. Water saving technology adoption will increase in response to water shortage only if (farmers) perceive that adoption will lead to water-savings or generate other benefits. Micro- irrigation is suitable for all row crops and especially for wide-spaced high value crops. The required quantity of water is provided to each plant at the root zone through a pipe net work. Hence there is little loss of water from the soil surface. Micro-irrigation is well adapted for undulating terrain, shallow soils, porus soils and water scarce areas. Saline/brackish water can also be used since water is applied daily, which keeps the moisture and salt stress at a minimum. Water use efficiency in crops can be increased by using water saving irrigation methods. The modern improved irrigation methods give overall efficiency as high as 90 % as against only 30-40 % under the conventional methods. Pressurized irrigation systems (sprinkler, surface and sub-surface drip) have the potential to increase irrigation water use efficiency by providing water to match crop requirements, reducing runoff and deep drainage losses, and generally keeping the soil drier reducing soil evaporation and increasing the capacity to capture rainfall. Agronomic practices for water conservation help to intercept rain drops and reduce the splash effect, help to obtain a better intake of water rate by the soil by improving the content of organic matter and soil structure, help to retard and reduce the overland run-off through the use of contour cultivation, mulches, dense-growing crops, strip-cropping and mixed cropping.

Micro irrigation

The decade of 1990-2000 witnessed a quantum leap in expansion of micro-irrigation technology (Table 3), both

Table 2. Soil water recharge calculated through water balance equation

Sites	plots	Rainfall (mm)	Evapotranspiration (mm)	Evapotranspiration (%)	Runoff (mm)	Runoff (%)	Change in soil moisture (mm)	Change in soil moisture (%)	Recharge (mm)	Recharge (%)
Longan	Control	1043.2	666.9	63.9	57.7	5.5	-30.0	-	348.6	33.4
	Vetiver		697.7	66.9	34.2	3.3	136.3	-	347.7	33.3
Maize	Control	967.4	404.7	41.8	125.3	12.9	139.4	14.4	298.0	30.8
	Vetiver		437.3	45.2	55.2	5.7	116.9	12.1	357.9	37.0
Soybean	Control	1242.2	408.1	32.9	38.9	3.1	-9.0	-	804.2	64.7
	Vetiver		442.3	35.6	31.4	2.5	-29.4	-	798.0	64.2

Sources: http://www.vetiver.com/ICV4pdfs/DAS01.pdf in developed and developing countries. In micro irrigation, the highest coverage is in America (1.9 m ha) followed by Europe and Asia (1.8 m ha each), Africa (0.4 m ha), and Oceania (0.2 m ha). The area under micro-irrigation increased almost 6 fold during last 20 years i.e. from1.1 m ha in 1986 to 6.1 m ha at present.

Drip irrigation

A new technology of drip irrigation was then introduced in Israel by Simcha Blass and his son Yeshayahu. Instead of releasing water through tiny holes, blocked easily by tiny particles, water was released through larger and longer passage ways by using friction to slow the water flow rate inside a plastic emitter. The first experimental system of this type was established in 1959 in Israel by Blass, where he developed and patented the first practical surface drip irrigation emitter.

Drip irrigation is an effective tool for conserving water resources and studies have revealed significant water saving ranging between 40 and 70% by drip irrigation compared with surface irrigation, with yield increases as high as 100% in some crops in specific locations (Table 4). Drip irrigation is very popular in wide spaced horticultural crops *viz.*, coconut, mango, guava, sapota, pomegranate, lime, oranges, grapes, banana, tapioca, turmeric; close spaced crops like vegetables, potato; and flowers such as jasmine, rose, and commercial crops like sugarcane and cotton. In view of its higher water use efficiency, wider adaptability to diversity of soils, crops, climate etc. and other benefits, the Government of India is providing high subsidy to its large-scale adoption. Increased efficiency in drip irrigation mainly due to maintaining optimum soil moisture for plant growth throughout the crop period. Relative soil moisture varies most in furrow irrigation and least in drip irrigation system.

Sprinkler irrigation

Sprinkler Irrigation is a method of applying irrigation water, which is similar to rainfall. Water is distributed through a system of pipes usually by pumping. It is then sprayed into the air and irrigated entire soil surface through spray heads so that it breaks up into small water drops, which fall to the ground. Sprinklers provide efficient coverage for small to large areas and are suitable for use on all types of properties. It is also adaptable to nearly all-irrigable soils since sprinklers are available in a wide range of discharge capacity. Sprinkler system is an unique irrigation system. It is designed to ensure maximum water saving, combining high quality, affordability and ease of installation. All the products are made out of high strength and chemical resistance engineering plastics to achieve functional satisfaction and to maintain cost economics. All sprinklers undergo extensive quality testing in our well-equipped state of the art lab. Moreover, performance of the products is also tested in the field to ensure uniform water distribution and higher efficiency.

It is suitable for almost all field crops like wheat, gram, groundnut, pulses as well as vegetables, soyabean, tea, coffee, and other fodder crops.

Some unique benefit of sprinkler irrigation include : (i) good control of water application, which can reduce vegetative growth and improve the product quality (eg. onion bulbs and taproot quality of carrots), (ii) can be used to cool the crop during heat waves, to protect against frost and to manage plant Health (eg reduces the impact of *As-*

Table 4. Water requirement (WR), yield and water use efficiency (WUE) of crops in micro-and conventional irrigation methods

Crops	Irrigation methods	WR (cm)	Yield (t/ha)	WUE (kg/ha/mm)
Banana	Surface	176.0 57.5	32.7	
	Drip	97.0 (45.0)	87.5 (52.0)	90.2
Sugarcane	Furrow	215.0	128.0	59.5
	Drip	94.0 (56.0)	170.0 (33.0)	180.9
Grapes	Surface	53.2	26.4	49.6
	Drip	27.8 (48.0)	32.5 (23.)0	116.9
Cotton	Furrow	83.0	26.4	31.3
	Drip	28.0 (66.3)	32.5 (25.0)	116.1
Sugarbeet	Furrow	49.5	41.8	850.0
	Drip	37.1 (25.0)	49.0 (17.1)	1,320.0
Sweet pepper	Furrow	49.0	11.9	242.0
	Drip	48.0 (2.0)	12.0 (0.8)	249.0
Sweet potato	Surface	63.1	4.2	67.3
	Drip	25.2 (60.1)	5.9 (38.7)	233.7
Beetroot	Surface	85.7	0.6	6.7
	Drip	17.7 (79.3)	0.9 (55.3)	50.1
Radish	Surface	46.4	1.1	22.5
	Drip	10.8 (75.7)	1.2 (13.5)	109.8
Papaya	Surface	225.8	13.9	0.06
	Drip	73.8 (67.8)	23.5 (69.5)	0.32
Mulberry	Surface	50.0	69.3	1386.0
	Drip	20.0 (60.0)	71.4 (3.0)	3,570.0
Tomato	Surface	30.0	32.0	106.7
	Drip	18.4 (39.0)	48.0 (50.0)	260.9

Sources: WTC Annual Reports 1985-2003
*Figure in parenthesis are increase over conventional irrigation

Table 3. Utilization of micro-irrigation in world

Year	1981	1986	1991	2000	2006
Area (ha)	4,36,590	10,30,578	18,26,287	32,01,300	60,89,534
% increase		136.1	77.2	75.3	90.2

pergillus black mould near harvest in onions), (iii) has the ability to keep soil soft for emerging seedlings with frequent short irrigations, (iv) with proper drainage, sprinklers can be used efficiently to flush accumulated salts down the profile.

Collection of rainwater through check dams, farm ponds and recycling of saved water through application devices (rain gun) increase the productivity of water. In on-farm, overhead sprinkler irrigation and rain gun systems are used to give supplemental irrigation under rainfed cultivation through farm ponds to mitigate the intermittent drought.

It is concluded that water is likely to become an increasingly scarce resource in future. Therefore, its conservation and utilization has necessarily to achieved through water harvesting and recycling technologies on one side and reducing losses and wastages on the other. People at large who are the users of water realize the scarcity of water and treat it as a precious resource and participate in the water conservation process by avoiding wastage of water. The Government has to play a major role in water conservation along with the stakeholders to achieve the best results.

REFERENCES

http:iiwww.vetiver.com/icv4pdfs/DASO.1pdf

PlanningCommission.gov.in/plans/annualplan/1999-00

Rao, P.C.M., 2007.Water is Too Precious – Conserve it. *Proceedings 12th National Water Convention* at Podicherry from 1st to 3rd November, 2007.

Sharma, I., Rohitashw Kumar, P. and Kumar, P. 2004. Traditional and new techniques of On- farm Rainwater Harvesting in North-West Himalayan Region of India, International Workshop on 'Water Harvesting and Sustainable Agriculture'.