Concerted rainwater harvesting technologies suitable for hilly agro-ecosystems of Northeast India

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Much of the enormous water resources in India's North-Eastern region remain unutilized and the efficient utilization and management of available rainwater is the core issue if the cropping intensity and production is to be enhanced. The rainwater harvesting can be implemented as a viable alternative to conventional water supply or on-farm irrigation projects. Storing of rainwater can be done in two ways: (i) storing in an artificial storage and (ii) storing in the soil media as groundwater. The rainwater or run-off can be harvested using eco-friendly low-cost technologies such as uv-resistant plastic lined ponds, ferro-cement tanks, etc. and used for multiple purposes.

Keywords: Artificial storage, ferro-cement tank, multiple uses, plastic lining, rainwater harvesting.

NORTHEAST India is endowed with a bounty of water resources, accounting for about 40% of the total water resources in the country, i.e. about 60 million hectare-metre. The region is in the highest rainfall zone of the country and enjoys typical monsoon climate, with conditions ranging from tropical to temperate. The rapid changes in topography result in climatic changes within short distances. For example, the average annual rainfall reaches a peak of 13,390 mm in the Cherrapunji–Mawsynram region in the Meghalaya plateau, while the northern and adjoining central areas in the same plateau that fall in the rain-shadow region need irrigation during most part of the year[1]. The pre-monsoon showers (March–May) accounts for 25% of annual rainfall, while bulk of the rainfall (67%) occurs during June–September, which constitutes the monsoon season. The monsoon withdraws from the Northeast almost abruptly by the last week of September; post-monsoon rainfall (October–December) and winter season rainfall are scanty, limiting the scope for agricultural activities during the rabi season[2].

Delay in pre-monsoon showers and slow onset of monsoon along with skewed distribution of rainfall not only lead to serious dislocations, but also cause damage to the crops and also severe water shortage. On the other hand, excessive precipitation causes rapid run-off on steep slopes, resulting in heavy soil loss as well as siltation of riverbeds. It may also lead to catastrophic flood hazards in the plains, excessive leaching losses and also dangerous landslides. All this only underscores the need for a scientific and technical approach towards water management, with focus on harvesting and multiple uses of water.

In this context, it has been observed that rainwater harvesting can be implemented as a viable alternative to conventional water-supply schemes in the region, considering the fact that any land anywhere can be used to harvest rainwater.

Rainwater harvesting besides helping meet the ever-increasing demand for water, helps reduce run-off which is choking storm drains, reduce flood hazards, augment the groundwater storage and control the decline in the water level, improve quality of groundwater and reduce soil erosion. This is considered to be an ideal solution for water problem, where there is inadequate groundwater supply or where surface resources are either not available or insufficient. Rainwater is bacteriologically pure, free from organic matter and soft in nature. The suggested structures for harvesting rainwater are simple, economical and eco-friendly. Previous studies have shown that subsistence agriculture in the hilly northeastern region could be successfully transformed into a profit-earning enterprise by tapping and utilizing rainwater in limited quantities[3,4].

Rainwater harvesting, irrespective of the technology used, essentially means harvesting and storing rainwater in days of abundance, for use during the lean days. Storing of rainwater can be done in two ways: (i) in an artificial storage and (ii) in the soil media as groundwater.

A demand–supply analysis is required while designing water-collection tanks. Factors such as amount and frequency of rainfall, run-off coefficient of the collecting surface, number of users, daily requirement and dearth period are important for calculating the size and capacity of the storage tank.

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In domestic rooftop rainwater harvesting systems, rainwater from the roof of a house is collected in a storage vessel or tank for use during the periods of scarcity[5]. Usually these systems are designed to support the drinking and cooking needs of the family at the doorstep. Such a system usually comprises a roof, a storage tank and guttering arrangement to transport water from the roof to the storage tank. In addition, a first flush system to divert the dirty water during the first rains and a filter unit to remove debris and contaminants before water enters the storage tank are also provided.

Rainwater can be collected in large quantities in lined ponds. Generally, big ponds are constructed and subsequently lined with non-permeable sheets like agrifilm, silpaulin, HDPE or nylon, or with a semi-permeable coating of clay to reduce the seepage losses (Figure 1).

The roof water, run-off water (after filtration, for potable/household purposes) or spring water may be diverted to the pond. A large quantity of water, generally 50,000–20,00,000 l, can be harvested using such ponds, which in turn may be used for irrigation or household purposes. The cost of construction will be less than Rs 0.20/l. Moreover, it is durable and easy to construct with less maintenance cost.

To design a water-harvesting tank for irrigation purposes, the irrigation requirements of the cultivated crops have to be calculated first. Knowledge of factors such as effective rainfall, evapotranspiration, application efficiency and leaching requirements, if any, is essential for calculating the irrigation requirements of the crops. Subsequently, the total seasonal water requirement for the entire area to be irrigated can be found. Water needed for other purposes, such as fishery, may also to be taken into consideration while designing the tank. Direct evaporation from the water surface in the tank has also to be taken care of and corresponding adjustments can be made in the size of the tank.

Normally three types of ponds, viz. embankment type, excavated (dugout) and dugout-cum-embankment type are constructed for collection of excess run-off. Embankment type and dugout-cum-embankment type of ponds are feasible in hilly and undulating topography. Embankment type of ponds are made by constructing a small length of dam across a water course, whereas dugout-cum-embankment type of ponds are made by excavating a site surrounded by hillocks from two or three sides and making the embankment from the excavated soil on the remaining sides. In flat areas, where these two types of ponds are not feasible, dugout ponds are constructed.

Figure 1. UV-resistant, plastic-lined rainwater harvesting tank for irrigation.

Three steps are to be followed while designing of a water-harvesting pond. These are hydrologic design, hydraulic design and structural design. Hydrologic design involves the estimation of peak rate of run-off to be passed safely through the pond and run-off volume from the catchment of the pond. The run-off is estimated[6] for a design frequency of 25 yrs.

The hydraulic design includes determination of storage capacity and storage dimensions (length, width and height) of the pond and dimensions of spillway for safe disposal of excess inflow to the pond. Water should flow through the structure safely without overtopping the embankment, and when water leaves the structure its energy should be dissipated. Standard Weir formula for determining the crest length is used.

According to a study at the ICAR Research Complex for NEH Region, Barapani, Meghalaya, India, seepage losses could be as high as about 55 $l/m^2/day$. Owing to the high rate of seepage loss and evaporation, harvested water will be lost within 1–2 months after recession of rain. Therefore, lining of the pond with non-permeable film is essential for retention of harvested water in the pond for the entire dry season, i.e. from November to March. LDPE (low density polyethylene) plastic sheets, popularly known as Agrifilm, are found to be a low-cost and durable lining material. The following method can be adopted for lining of the pond with agrifilm.

After the pond is dug according to the design, the pond bed and sides are made weed and stone-free. Steps at 50 cm vertical intervals are made on the sides of the pond to hold the agrifilm at place (Figure 2). On top of the sides, a continuous trench of 50 × 50 cm is dug for the purpose of anchoring the agrifilm, to prevent it from sliding

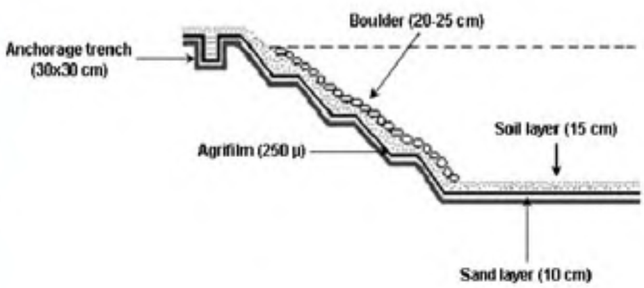

Figure 2. Schematic diagram of agrifilm lining of a water-harvesting pond.

down. After the sides and bed are dressed properly, 10 cm thick layer of sieved sand is spread uniformly on the bed and sides to provide a cushion to the agrifilm. Then the agrifilm (preferably 250 μm LDPE) is laid properly on the pond. For joining the film to suit the size and shape of the pond, bitumen of 85/25 and 80/100 grade in the ratio 2 : 1 is used. Soil cover of 30 cm is provided over the agrifilm. Stone pitching is done on the sides only, to safeguard the sides of the pond against erosion and any other external forces.

A study of storage behaviour of the pond revealed that seepage loss from agrifilm-lined ponds reduced from 55 to 2.9 l/m^2/day, i.e. by 94.7%.

To prevent seepage and percolation losses, the dug-out tanks can also be lined using UV-resistant polyethylene films such as Silpaulin (200 GSM or more) or nylon (500 GSM). These sheets are made up of waterproof, UV-stabilized, heat-sealed, multi-layered and cross-laminated plastic materials and hence ensure high tensile strength, long life and high resistance to external pressure. Generally trapezoidal-shaped storage tanks are constructed by excavating soil and dumping the removed soil along the four sides of the tank. After this, plastic sheets are made into the shape of the pond according to the final dimensions of the constructed pond by a process called thermal welding. Then the pond-shaped plastic sheet is inserted into the pond and the sides are stabilized by burying it into the soil or shoulder bunds, or by riveting through the metal rings provided along the sides of the pond-shaped plastic sheet. The shoulder bunds can be further stabilized with rubble pitching and vegetative fencing. Soil cover or rubble pitching over the plastic lining is generally not needed in case of tanks lined with UV-stabilized sheets.

It is found that silpaulin or nylon-lined ponds are more stable and have a longer and useful life. It can be made in any size and is also suitable for multiple uses of harvested water.

The storage behaviour of an unlined pond with similar soil characteristics showed an average rate of seepage loss up to 0.11 m^3/m^2 wetted perimeter/day. However, it was found that the maximum percolation rate through the silpaulin-lined pond was nearly zero, and the storage hydrographs of the unlined and lined ponds clearly showed increase in water-saving efficiency of the ponds after lining, in terms of both quantity and duration of storage.

Costs involved in different works while digging out and lining of the ponds with plastic sheets were also calculated. Detailed analysis revealed that the cost of construction of the plastic-lined ponds/m^3 of water storage capacity was only Rs 150.23. The cost of construction includes the cost involved in land preparation, digging of the pond, lining and other finishing works.

It is also observed that the cost/l for collecting rainwater/spring water in UV-resistant plastic sheets is significantly less compared to other methods such as concrete (Rs 400–500/m^3), brick masonry (Rs 300–400/m^3), ferro-cement (Rs 150–200/m^3), fibre-glass (Rs 400–500/m^3), etc.

The water harvested in lined ponds can be utilized for multiple uses, such as irrigation, drinking water for cattle and other livestock, fishery, duckery, etc. thereby increasing its use efficiency.

With reference to a study carried out in the hilly terrain, based on the estimated annual costs and returns, all the financial viability criteria such as IRR, NPV and BCR were found favourable for investment on plastic-lined water-harvesting tanks (capacity >40 m^3 integrated with micro-irrigation system and fish farming. The analysis indicated that establishment of such an integrated system is not only financially viable, but also a highly attractive proposition for low-cost harvesting and effective use of rainwater/run-off. Moreover, the studies suggested that these technologies are sustainable, locally adoptable, cost-effective, applicable and affordable to the farmers.

1. Anon., Basic Statistics of the North–East, N.E.C., Ministry of Home Affairs, Govt of India, 1995, p. 40.
2. Sharma, U. C., Yield sustainability and strategies in North Eastern states. *Productivity*, 1996, **36**, 682–690.
3. Singh, R. K., Lama, T. D., Saikia, U. S. and Satapathy, K. K., Economics of rainwater harvesting and recycling for winter vegetable production in mid hills of Meghalaya. *J. Agric. Eng.*, 2006, **143**, 33–36.
4. Saha, R., Ghosh, P. K., Mishra, V. K. and Bujarbaruah, K. M., Low-cost micro-rainwater harvesting technology (Jalkund) for new livelihood of rural hill farmers. *Curr. Sci.*, 2007, **92**, 1258–1265.
5. Anon., *Hand Book on Rainwater Harvesting*, Kerala Rural Water Supply and Sanitation Agency, Govt of Kerala, 2004, pp. 31–33.
6. Schwab, G. O., Fangmeir, D. D., Elliot, W. J. and Frevert, R. K., *Soil and Water Conservation Engineering*, John Wiley, NY, 1993, 4th edn, pp. 212–213.

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