Low-cost micro-rainwater harvesting technology (*Jalkund*) for new livelihood of rural hill farmers

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It is an irony that an area like the Northeast known for its high precipitation rate, suffers from water scarcity during post-rainy season (November to April). In the absence of major and medium irrigation potential/ facilities, the alternative method is to explore minor irrigation potential through effective water-conservation measures. A low-cost rainwater harvesting structure called *Jalkund* of varying capacity (6000–30,000 l of water) has been developed for the hilltops at the ICAR Research Complex for NEH Region, Umiam, Meghalaya. However, farmers may have option for the capacity according to their water requirement for the crop intended to be cultivated and also for diversified use of stored water in various farm activities like crop, livestock and fish production during post-rainy season (stress period). The *Jalkund* was made up of clay and cow-dung plastering followed by 3–5 cm cushioning with dry pine leaf, laying down of 250 μm LDPE black agri-film and covering with 5–8 cm bamboo thatch. The study revealed that the cost/l of stored water was Rs 0.14 during the first year considering Rs 4205 of total cost which came down to Rs 0.046/l of stored water during the third year owing to negligible maintenance cost. Feedback from beneficiaries envisages that 30,000 l of stored water in *Jalkund* could support 200 tomato plants, rear five piglets or two ducks or 50 poultry birds along with reasonable amount of fish seedling from November to April. Using stored water economically in various farm activities is the most acceptable and profitable one particularly to those in the hilltops, who are the worst sufferers due to water scarcity. This economically viable and easily adoptable technology needs to be popularized among large sectors of farmers.

Keywords: Low-cost, micro-rainwater harvesting, Northeast India, rural livelihood security.

Northeast at a glance

THE northeastern region of India comprising eight states, viz. Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, Tripura and Sikkim, has a total geographical area of 262,180 sq. km, which is nearly 8% of the total area of the country with more than 39.0 million population. The region is characterized by different terrain, wide variations in slope and altitude, land tenure systems and cultivation practices. The agriculture in the region is mostly rainfed and monocropped[1]. Economic development of this region is highly dependent on the judicious use of its natural resources, mainly soil and water. Crop productivity through efficient water management and suitable agronomic practices enhances the rural economy, quality of life and creates more job opportunities through development of agro-based industries.

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Water resources and potentiality

Water is considered to be the key input for augmenting agricultural production all over the world. With respect to water resources and potential, the region is endowed with a bounty of water resources accounting for about 46% of those in the country. The region experiences a paradoxical hydro-climate environment and represents a typical hydrological entity in the world atlas. The annual average rainfall of the region is 2000 mm, accounting for 10% (42.0 Mha m) of the country's total water of 420 Mha m. It can till date utilize only 0.88 Mha m of water[2]. The remaining more than 41.0 M ha m water is lost annually particularly due to its major portion being hilly. Though the region receives high rainfall, lack of appropriate rainwater management conditions coupled with lack of suitable soil and water conservation measures lead to severe water scarcity, particularly during post-monsoon season and affect crop productivity as well. May to October is the major part of the water surplus period, while November to April is mainly categorized under the water-deficit period (Figure 1). The mean values of water surplus (1596.6 mm) and water deficit (240.1 mm) also indicate that net water surplus (1356.5 mm) in this region supercedes water deficit[3,4]. It is opined by experts that if water use in the region could even be increased to 2.0 Mha m from the present level of 0.88 Mha m, irrigation potential of the region could be explored for optimizing agricultural production.

Why micro-rainwater harvesting structures?

Rainwater harvesting has tremendous potential of being an irrigation water resource for domestic use as well as for agricultural purposes for the resource-poor farmers in this vulnerable environment. One of the major constraints for water-harvesting structures in this hilly region is high seepage loss from storage tanks. Further, seepage losses are quite high as the soil is coarse-textured and lower strata are made of fractured stones. Seepage loss from small tanks has been reported to be in the range of 300–400 l/m^2 wetted area per day[5]. Gradual siltation and clogging of soil pores has resulted in the development of layers of low hydraulic conductivity on the wetted perimeter.

In this region, around 56% of the area is under low altitude (valley), 33% under mid altitude and the rest under high altitude (upland terrace)[1]. In the valley, collection of run-off water in macro-water harvesting structures (macro ponds) having reasonably large catchment area has been proved successful, provided due attention is given to check seepage loss. However, in case of upland terrace at the hilltop, where land available for constructing a pond is less with limited catchment area and there is severe water scarcity during off-season as most of the rainwater goes waste by run-off through terrace land, construction of cost-effective micro-rainwater harvesting structures is the right option. If subsistent farmers of this region invest in micro-water harvesting structure with suitable lining materials which completely check seepage loss, this can increase productivity and they can diversify their homestead farming by growing highly remunerable crops and rearing of livestock (pig, poultry, duck, etc.) against their conventional practice of remaining idle or workless for want of water during post-rainy season. With this backdrop, a low-cost rainwater harvesting structure called *Jalkund* for the hilltops has been developed. All aspects, including cost of preparation, size and capacity of *Jalkund*, water loss, longevity of lining material used, water productivity, and diversified use of stored water have been dealt with. Also, a thorough and comprehensive assessment has been made during 2003–06 followed by field demonstration (2004 onwards). An account of this technology is discussed here.

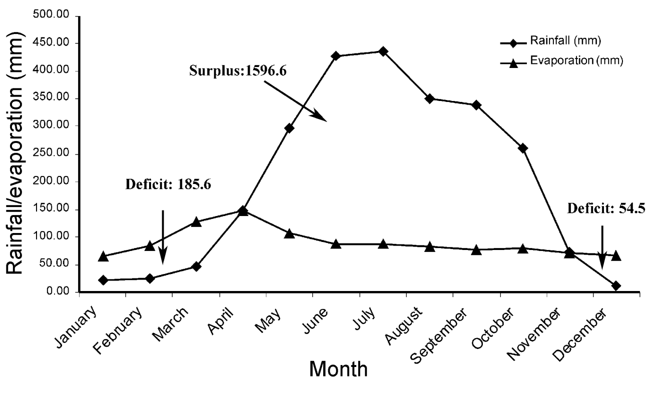

Figure 1. Climatic water balance of Meghalaya.

About *Jalkund*

- Excavation of the *kund* on selected site was completed before the onset of monsoon.
- The bed and sides of the *kund* were levelled by removing rocks, stones or other projections, which otherwise might damage the lining material (Figure 2 *a*).
- Spraying of insecticide like endosulphon 35EC on the surface of the inner walls and the bottom, and application of aluminum phosphide (@ 1 tablet/live hole) around 5 m of the *kund* was done before the lining process.
- The inner walls, including the bottom of the *kund*, were properly smoothened by plastering with a mixture of clay and cow dung in the ratio of 5 : 1 (Figure 2 *b*).
- After clay-plastering, about 3–5 cm thick cushioning was done with locally and easily available dry pine leaf (@ 2–3 kg/sq. m) on the walls and bottom, to avoid any kind of damage to the lining material from any sharp or conical gravel, etc. (Figure 2 *c*).
- This was followed by laying down of 250 μm LDPE black agri-film. Seepage loss was completely checked throughout the year. The agri-film sheet was laid down in the *kund* in such a way that it touches the bottom and walls loosely and uniformly, and stretches out to a width of about 50 cm all around the length and width of the *kund* (Figure 2 *d*). A 25 × 25 cm trench was dug out all around the *kund* and 25 cm outer edge of agri-film was buried in the soil, so that the film was tightly bound from all around. At the same time, side channels all along the periphery of the *kund*, helps to divert the surface run-off and drain out excess rainwater flow. This is to minimize siltation effect in the *kund* by allowing only direct precipitation.
- *Jalkund* was covered with thatch (5–8 cm thick) made of locally available bamboo and grass. Neem oil (@ 10 ml/sq. m) is also advocated to reduce evaporation during off-season (Figure 2 *f*).

Benefits/advantages from *Jalkund*

Actual beneficiaries

It has been recommended to construct the *Jalkund* at high ridges of crop catchment areas so that water could be recycled through gravitational force without any extra energy application. About 44% area is under high and medium altitudinal condition[2]. Hence, farmers residing at the hilltop are considered to be the beneficiaries of this technology.

Figure 2. Different stages of *Jalkund* preparation. ***a***, Excavation of *Jalkund*. ***b***, Plastering with clay. ***c***, Cushioning with pine leaf. ***d***, Lining with LDPE black agri-film. ***e***, Rainwater collected in *Jalkund*. ***f***, Thatch cover to prevent evaporation.

Water loss

Seepage: There was no seepage loss of water from poly-lined *Jalkunds* of all sizes (6000 to 30,000 l), except from a 40,000 l capacity where the joint of the LDPE agri-film *Jalkund*, had opened probably due to more water load during heavy rains. During the rainy season, water load in the big-sized *Jalkund* also damaged the bottom of the embankment.

Evaporation: The evaporation rate of water was maximum in February (9.2 mm/day) and minimum (1.8 mm/day) in October in the control *Jalkund*[6]. Use of neem oil as anti-evaporate on the water surface and *Jalkund* covered with thatch were found effective to minimize evaporation. It was recorded that application of neem oil (@ 10 ml/sq. m) on the water surface after each watering reduced 43.25% evaporation rate, whereas use of thatch reduced up to 80% in comparison to the control (without neem oil or thatch)[6,7].

Low preparation and maintenance cost

The cost/l-harvested water, which was calculated on the basis of aging, duration of lined LDPE agri-film, total expenditure under different materials and capacity of *Jalkund* is given in Table 1. It was observed that during the first year, cost/l of stored water was Rs 0.14, considering the total expenditure of Rs 4205 for preparing a 30,000 l capacity *Jalkund*. At the end of the third year, the cost came down to Rs 0.046/l of stored water, owing to negligible maintenance cost during the second and third years (Table 1).

Capacity

Farmers have the option to go in for size and capacity of the *Jalkund* according to the water requirement for crops intended to be cultivated. Preparation cost is reflected accordingly. However, considering the seepage loss of

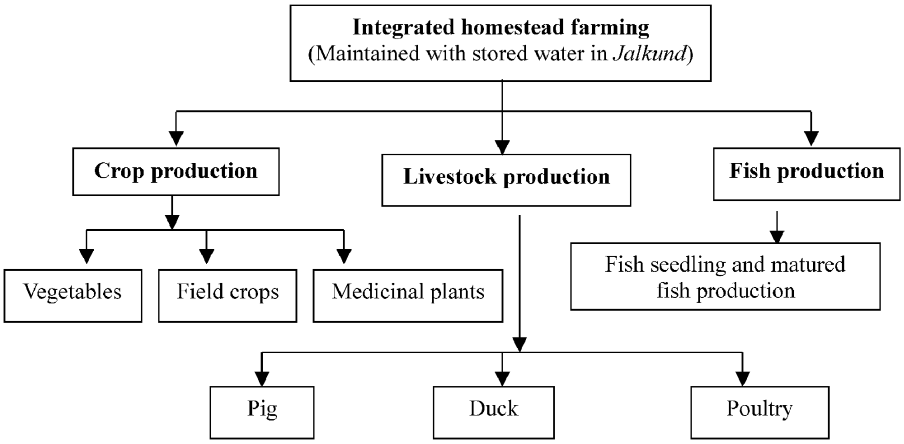

Figure 3. Flow chart showing diversified use of stored water during off-season.

Table 1. Cost of making a *Jalkund* (capacity 30,000 l)

Particulars	Unit price (Rs)	Total price (Rs)
Digging expenses	30/m^3	900
Plastering with clay	2.50/m^2	120
Cushioning with pine leaf	2.50/m^2	120
Lining with LDPE black agri film (250 µm)	40/m^2	2880
Thatching	2/m^2	60
Fencing	2/m	75
Insecticide, etc.	–	50
Total	–	4205
First year cost/l stored water	–	0.14
Second year cost/l stored water	–	Nil
Third year cost/l stored water	–	Nil
Average cost/l stored water	–	0.046

Figure 4. Tomato crops grown in upper ridges at ICAR farm using stored water from *Jalkund*.

water, the size was restricted from 6000 to 30,000 l with respective dimensions of 3 m × 2 m × 1 m, 3 m × 2 m × 1.5 m, 4 m × 3 m × 1 m, 4 m × 3 m × 1.5 m and 5 m × 4m × 1.5 m. The size of lining material of the corresponding dimension was 6 m × 4 m, 7 m × 6 m, 7 m × 6 m, 8 m × 7 m and 9 m × 8 m respectively.

Use of stored water

The diversified use of stored water during off-season is presented in Figure 3.

Crop production

At the hilltop, crop is grown only during rainy season. Due to the unavailability of water during November to April, most of the hill areas remain barren. Tomato is one of the important vegetable crops during the summer season. The crop was planted during dry season at the upper ridges of the research farm at our institution, where stored water from the *Jalkund* was used for irrigation (Figure 4). Siphon technique was used for supplying water to the plants through a polypipe. The results (Table 2) revealed that maximum crop yield (1.24 kg/plant) was recorded when frequency and amount of irrigation to plant was 1 l/day followed by 1.5 l/day (Rs 1.09 kg/plant), 750 ml/day (0.69 kg/plant), 500 ml/day (0.57 kg/plant) and control (0.24 kg/plant)[8]. The other yield attributes also showed that 1 l water/day to tomato plant produced reasonably good yield during the stress period.

Medicinal plants (*Alpina galanga*, local name Kulanjan) are grown all along the periphery of the *Jalkund* to increase farm income as a whole. This does not require direct watering for growth, as the required soil moisture is maintained throughout the periphery of the *Jalkund*. The rhizomes of the plant yield essential oil containing methyl cinnamate, cineole and oleoresin used for rheumatism, bronchitis and as carminative, and having high market value for pharmaceutical/clinical industries.

Livestock and fish production

The stored water in the *Jalkund* could partly be used for crop production and partly for livestock or fish production

Table 2. Yield attributes of tomato under various amount of irrigation water from *Jalkund*

Frequency and amount of irrigation (ml/day)	Plant height (cm)	No. of fruits/plant	Fruit weight (g)	Fruit length (cm)	Per cent fruit set	Yield/ plant (kg)
Control	26.65	6.32	36.85	3.10	22.35	0.24
500	30.18	11.83	48.13	3.22	27.83	0.57
750	34.84	12.20	56.44	3.47	32.50	0.69
1000	39.05	17.14	72.36	4.12	45.44	1.24
1500	39.11	15.25	71.50	4.06	43.56	1.09
SD (±)	5.50	4.12	15.26	0.47	9.97	0.40

or integration of both livestock and fish. Use of stored water for the dual purpose of crop production and livestock/fish production was a complementary system, where none of the enterprise was practised at the cost of the other as far as water use was concerned. Various options of farmers' choice were tested for diversification and economic use of stored water in the *Jalkund*. Farmers can opt for these farming system according to resources available with them.

Pig-based activity: Based on three years of study at the research farm, per unit water requirement of *rabi* crop and piglet has been standardized, which envisaged that 30,000 l of stored water could support 200 tomato plants in 250 sq. m area and five piglets for 200 days during dry spell periods (November to April) of the year.

Poultry-based activity: Based on per unit water requirement, 30,000 l of stored water can support 200 tomato plants in 250 sq. m area along with 50 poultry birds for 200 days during water-stress periods (November to April) of the year.

Fish and duck-based activity: The stored water in the *Jalkund* could be partly used for crop production and partly for integration of fish-cum-duck culture, where Azolla is used as feed for fish production (Figure 5). In duck–fish integration, the duck variety selected was the Indian runner, which was found to survive well in the mid-hill conditions. Excreta of duck reared in the *Jalkund* was also used as fish feed. The water was used for vegetable production during December to February, and fish and duck lived together in the *Jalkund* during the whole post-rainy season without affecting water supply to the vegetable crops. The fish culture was with grass carp, *Ctenopharyngodon idella* and golden hybrid tilapia. These two species were selected considering their compatibility in the culture system, utilization of unwanted weeds and Azolla for raising grass carp and the effective utilization of decomposed feed materials and faecal matter of grass carp by golden hybrid tilapia. Grass carp was stocked @ 1 no./sq. m and golden hybrid tilapia @ 3 nos/sq. m. Golden hybrid tilapia being a natural breeder, bred in the pond during the culture period and the young ones were allowed to grow even after the harvest of main stock (table-size fish) in November. The study revealed that apart from meeting water requirement of *rabi* crops, 30,000 l of water could also support 1000 fish seedling of one month age, 25 fish of five months age and two ducks. By doing so, the water quality of stored water not only improved, but also farm income had increased.

Impact analysis based on economics

It was observed that with 30,000 l of stored water in the *Jalkund*, farmers can opt for three complementary diversified farm activities, viz. (i) crop production and duck-cum-fish culture, (ii) crop production and pig rearing, and (iii) crop production and poultry rearing. However, selection and adoption of a particular farm activity depended on resources available with them to bear initial expenditure and preferential food habit, and the income so generated should also improve their standard of living. Economic analysis of each activity was made with the aim to select or recommend a profitable activity for farmers, which they should adopt for properly utilizing stored water in the *Jalkund* as well as for maintaining their livelihood. Details of economic analysis are presented in Table 3. Expenditure on seed/seedling, feed, cage and maintenance cost was also included in the analysis. Water requirement of 90 days (December to February) for tomato and 200 days (November to April) for livestock/fish was considered in the analysis. Since the *Jalkund* is usually filled up directly with rainwater during May–October, water use during this period was not included in the calculation. Local market price of each input was also taken into consideration. If a farmer utilizes 30,000 l of water distributed in various farm activities, the profit from each system would be as follows:

Tomato–pig based activity: Water application to tomato @ 1 l/day and for pig 10 l/day has been standardized. Based on this, it was estimated that to grow 200 plants, 18,000 l of water was needed for 90 days, while 10,000 l was needed for pig rearing for 200 days. The rest 2000 l could be used for miscellaneous purposes, including loss

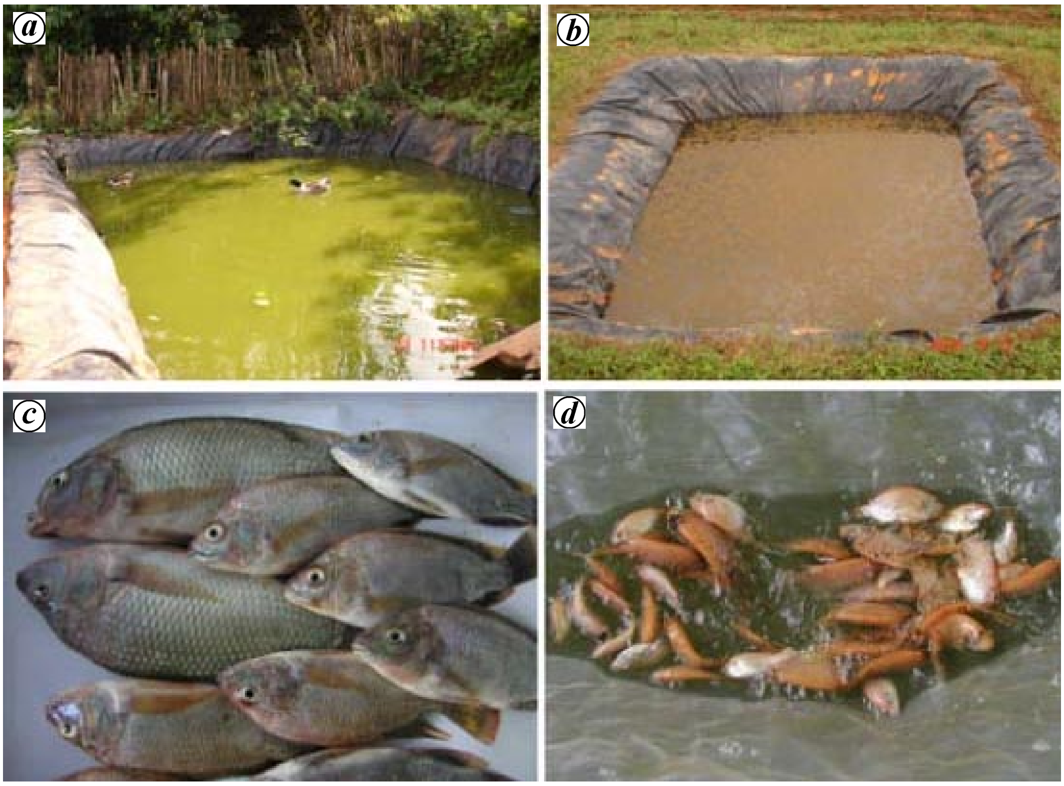

Figure 5. ***a***, Duck rearing in *Jalkund*. ***b***, Azolla is being used as fish feed. ***c***, Good harvest of tilapia fish during July–November. ***d***, Seed of Red tilapia raised during post-rainy season (December–April).

Table 3. Utilization of stored water in *Jalkund* (30,000 l capacity) during dry spell periods in diversified farm activities and its economic analysis

Farming activity	Total water requirement (l)			Expenditure (Rs)				Income (Rs)			Net profit (Rs)	Benefit : cost ratio
Tomato–pig	Tomato	Pig	Misc. use	Tomato	Pig	*Jalkund*	Total	Tomato	Pig	Total		
	18,000	10,000	2000	Hybrid seed – 500 Other inputs – 250	Piglets – 5000 Feed – 4000	Making – 4205 Polypipe – 250	14,205	3700	20,000	23,700	9495	1.67
Tomato–poultry	Tomato	Poultry	Misc. use	Tomato	Poultry	*Jalkund*	Total	Tomato	Poultry	Total		
	18,000	5000	7000	Hybrid seed – 500 Other inputs – 250	Chicks – 750 Feed – 5000	Making – 4205 Polypipe – 250	10,955	3700	15,000 (egg) 12,000 (meat)	18,700 (egg) 15,700 (meat)	7745 (egg) 4745 (meat)	1.71 (egg) 1.43 (meat)
Tomato–duck–fish	Tomato	Duck–fish	Misc. use	Tomato	Duck–fish	*Jalkund*	Total	Tomato	Duck–fish	Total		
	18,000	*	–	Hybrid seed – 500 Other inputs – 250	Ducklings – 30 Fish seed – 100 Feed – 500	Making – 4205 Polypipe – 250	5835	3700	1600 (egg) 2000 (fingerling) 1500 (mature fish)	8800	2965	1.51

*Not calculated.

of water by various means. Growing 200 tomato plants and rearing five piglets could provide a net profit of Rs 9495, with benefit : cost (B : C) ratio of 1.67.

Tomato–poultry based activity: Water requirement of poultry @ 500 ml/day for 200 days has been standardized and total 5000 l of water was needed for 200 days. The rest 7000 l of water may be used for other purposes. Water requirement for tomato was similar to that of the pig-based activity. Growing 200 tomato plants and rearing 50 chicks with the use of stored water could provide a net profit of Rs 7745 with B : C ratio of 1.71 when egg production was taken into account, but it was Rs 4745 with the lowest B : C ratio (1.43) in the case of meat production.

Tomato–fish-cum-duck-based activity: A *Jalkund* of 30,000 l capacity can support 200 tomato plants, two ducks and about 1000 fingerlings, where 18,000 l of water was needed for tomato. The rest 12,000 l was utilized by duck and fish for survival during the stress period. In this case, 12,000 l of water was not considered as actual consumption *per se*, unlike other livestock. Therefore, calculation of water requirement per unit was not done for fish and duck. Since the *kund* was small, maintenance cost, including water treatment was negligible and was not considered in the calculation. Though the total expenditure incurred in this system was much less, net profit and B : C ratio was also less (Rs 2965 and 1.51 respectively) compared to pig- and poultry-based activities.

If net profits and B : C ratio of all three systems are compared, it is clear that tomato–pig-based activity provided 22.6 and 220% higher profit than poultry- and fish-cum-duck-based activity respectively. Though B : C ratio of poultry-based activity was marginally higher than pig-based activity, farmers of this region having preferential food habit toward pig meat, prefer to adopt tomato–pig-based activity for their livelihood. Further, rearing of pigs has an added advantage because they do not require sophisticated cage/chamber and quality food or concentrate. Pigs can survive on rubbish food or food of moderate quality.

Field demonstration in participatory mode

The technology was demonstrated at five farmers' field in the villages of Ri-Bhoi District, Meghalaya on participatory mode. The capacity of the *Jalkund* was 18,000–30,000 l of water. The stored water was used for maintaining a kitchen garden and also for pig, duck and poultry-rearing. Judicious use of stored water was made for growing crops by the siphon method during the stress period. For economic use of stored water, this method of applying water to the crops with the help of polypipes was also demonstrated to the farmers. Drip/micro-sprinkler can also be used for economic utilization of stored water so as to cover a large area. The micro-sprinkler system developed by Kerala Agricultural University (KAU micro-sprinkler system), is a simple clogs-free design with discharge rate of 35–45 l/h and involves low cost. This has been installed in the research farm for demonstration purpose to the local farmers. The Krishi Vighyan Kendra located at Umiam, Meghalaya also initiated the extension work to disseminate the technology to other nearby villages. In a recent National Agricultural Innovation Project (institute-based), action is being taken to disseminate the technology in all the NEH States.

Feedback from beneficiaries

To popularize the technology and create awareness among the farmers of Meghalaya, NABARD in Shillong region has come forward and conducted a sensitization meeting, where many beneficiaries from nearby villages of Ri-Bhoi District were present, including officials from other financial institutes. According to some of the beneficiaries, 30,000 l of stored water in the *Jalkund*, which is otherwise being lost through run-off, can cover 250 sq. m area for crop production and rear five piglets or two ducks and 50 poultry birds along with reasonable amount of fish production during off-season (November to April). Thus the technology provides new livelihood to the farmers, particularly those residing at the hilltop and who are the worst sufferers from water scarcity in the NEH region. The outcome of the sensitization meeting envisages that the technology is beneficial to them. However, farmers being rural resource-poor, some financial assistance in the form of subsidy to bear the initial cost, may help the technology reach up to the expected level.

Future strategies

- A sensitization programme in each state is necessary to disseminate and popularize the proven technology among farmers of all states of the NE region. In this context, linkage is needed among the research institutes, financial institutes, state departments and farmers to channelize the technology from the technology-producing centre to farmers in a partnership mode. Having successfully implemented the technology to the farmers' field at 25 locations in each state with two *Jalkunds* of 30,000 l capacity, about 1.2 ha m rainwater may be stored in this region, which otherwise goes waste. It is also estimated that with 1.2 ha m water, 100 ha area can be covered along with rearing of 2000 piglets or 20,000 poultry birds and 800 ducks.
- The technology may open options for farmers who can afford a greenhouse/polyhouse for cultivation of vegetables/flowers/medicinal plants/orchids, not only for fetching high market value during off-season, but also for providing employment opportunities to rural youth.
- Usually at the hilltop, area available with farmers for cultivation is limited and their homes are situated within the cultivated field. Therefore, to store water in a *Jalkund* for longer periods during off-season, roof water collection may be linked up wherever possible.

- Feasibility of various organic materials other than pine leaf and needles for cushioning may be explored.
- For longevity of the agri-film, efforts may be made to test thicker films, preferably with 400 or 500 μm thickness.
- A village knowledge centre in each district may be set up to disseminate the technology among a number of farmer families of the state.
- Benefit of the proven technology may also reach other hill farmers facing the problem of water scarcity for crop production.

1. Anon., Agro-climatic planning for agricultural development in Meghalaya. Working group, Zonal Planning team, Eastern Himalayan Region, AAU, Jorhat, 1992.
2. Vision 2020. ICAR Research Complex for NEH Region, Umiam.
3. Saha, R. and Mishra, V. K., Probability analysis of rainfall at Meghalaya for crop planning. *Indian J. Soil Conserv*., 2005, **33**, 86–87.
4. Saha, R. and Mishra, V. K., Estimation of profile moisture status from surface moisture in hilly slopes of Meghalaya. *J. Agrometeorol.*, 2006, **8**, 81–86.
5. Laig, I. A. F., Sealing leaking excavated tanks on farms in Western Australia. In Proceedings of the Water Harvesting Symposium, Phoenix, AZ, USA, 1974, pp. 159–166.
6. Annual report of AICRP on water management in high rainfall areas and temperate hill zones. Division of Water Management, ICAR Research Complex for NEH Region, Umiam, 2004–05, pp. 34–38.
7. Mishra, V. K., Saha, R. and Bujarbaruah, K. M., *Jalkund* – An approach of rain-water harvesting and recycling in hilly ecosystem. ICAR Research Complex for NEH Region, Umiam, 2005.
8. Annual report of AICRP on water management in high rainfall areas and temperate hill zones. Division of Water Management, ICAR Research Complex for NEH Region, Umiam, 2005–06, pp. 36–37.

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