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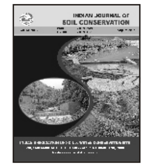

Rainwater harvesting using plastics lined ponds and its efficient utilization strategies

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ABSTRACT

Rainwater harvesting is one of the important aspects which has been emphasized again and again at all levels. For agricultural growth, water is a crucial factor. However, only 44% cultivable land has been brought under irrigation and rest has to depend on rainfall only. In uplands of hilly or plateau regions, which is horticultural potential area, mainly suffers due to lack of irrigation water, even though occurrence of good amount of rainfall that is restricted to monsoon season. Rainwater harvesting in small ponds and then providing irrigation using some efficient system is one of the answers to the problem. But, higher seepage from such ponds limits use of such water resources. Plastics lining (may be with LDPE, HDPE or silpauline) has become popular now-a-days. Method of lining with such material differs from one place to another as well as requirement. Proper method of lining, life of such lining, protection from damages, *etc.* are some of the issues which are being researched upon at several places and recommended based on need of the location. Secondly, appropriate strategy for utilization of such costly water resources in upland or mid-land areas needs to be evolved for realizing maximum benefits. It includes water conveyance, irrigation method, water delivery and application devices, irrigation scheduling, and dynamic command area as per availability of harvested water in a particular season/period, economics, *etc.* The paper enumerates various achievements obtained in experimental farm as well as in farmer's field in participatory mode at different locations under the AICRP on Application of plastics in Agriculture as well as elsewhere.

1. INTRODUCTION

India has been characterized under monsoon region where it gets rainfall during a period of 3-4 months, while rest of the period remains more or less dry with scanty rainfall that is not enough to meet any type of water demand. However, the water demand occurs throughout the year and it is more during dry period of summers when higher temperature and evaporative demand increases as compared to other part of year. Hence, to meet the water demand for dry period, it is emphasized again and again to conserve the water obtained during rainy season. Rainwater harvesting was emphasized as one of important aspect of water resource planning in National Water Policy, 2007 as well as in the consultative meeting proceedings for framing new National Water Policy, 2012. In India, the rainfall occurs mostly due to south west monsoon which starts in mid-June and end in end of September in most part of the country. However, its distribution is widely varying between 150 mm in Jaisalmer to more than 11,000 mm in Mausinram near Cherrapunji with an average annual rainfall of 1060 mm in the country (Kumar *et al.,* 2005). But, most of the rainwater goes un-utilised as runoff and adds to the sea.

Water is a crucial input in all type agricultural production systems, whether it is food grain production, horticulture, fishery, livestock, forestry, piggery, poultry, and so on. However, paucity of water during dry periods reduces the productivity of all the agricultural commodities especially during summer periods. Rainwater harvesting and efficient utilization for such production systems are very important to sustain such production systems which can provide water on a limited scale, though not meeting the full demand. About 56% of the Indian agriculture has to survive on rainfall as only 44% area could be getting irrigation water from one source or the other. The production level is too low under rainfed condition, mostly because of uncertain rainfall. Rainwater harvesting may improve the production level of such areas by providing supplementary irrigation, may be on a limited level, but it can improve the overall scenario, if the water used judiciously with proper strategy.

Harvesting of rainwater in upland areas is most crucial, as they are water scarce areas, poor productivity due to lack of water, and needs diversification to realize the actual potential using climatic and other resources available. If water is stored, seepage and evaporation are major constraints which limit quantity of usable water out of stored water. Storing water in small ponds is a viable technique, but the ponds need lining to protect water from seepage. Several methods of ponds lining are being practiced during the past periods including cement concrete. Cement concrete or cement mortar lining are very costly, and once the walls develop cracks then they become almost irreparable. A plastic film lining has become more popular now-a-days, but, not much success is obtained in propagating the technology among the small and marginal farmers. Even after successful construction of ponds, water utilization strategies are weak link to realize the real benefits. Efforts have been made at several places to prepare an appropriate technology to construct the effective Plastics lined ponds and their efficient utilization pattern. The paper discusses the rainwater harvesting in small plastics line ponds along with the strategies for its efficient utilization based on the achievements made under AICRP on Application of Plastics and in other projects.

2. RAINWATER HARVESTING

Rainwater harvesting means capturing the rain water where it falls, or capturing the runoff in small ponds or suitable structure from where it can be used for beneficial purpose. Technically, rainwater harvesting has three components *viz.,* (i) source or catchment from where the water is collected, (ii) pond or reservoir where the water is stored, and (iii) command area where the water is used.

Designing an effective rainwater harvesting system, it is important to consider all the three components individually and then design the system that can be sustainable to provide water at a reasonable probability. Source of the system may be direct rainfall, runoff from overlying catchments, seasonal or perennial streams or springs, in few cased lifted subsurface water in uplands where it is supposed to vanish soon due to lateral seepage, or combination of these.

In order to design a system the steps to be followed are: assessment of temporal water availability from the source or catchment; assessment of water requirement in the command area; and deciding water storage requirement which may be minimum of the above two factors or depending on water storage site configuration which can limit size of pond.

Assessment of water availability from catchment may be done using hydrologic soil cover complex method (Bhatnagar *et al.,* 1996) using appropriate curve numbers relevant to topography and land use pattern. The temporal and spatial water requirement in available command area where the water application using gravity is feasible. In some cases, water may be lifted for use in catchment area itself for irrigation. Catchment command area ratio is to be worked out to decide actual water availability at different probability periods. Water available through direct rainfall and runoff is stored in a pond for its further use in command area. Lining of ponds is required to save water from seepage losses which are huge. Unlined ponds are very poor in storing water for longer periods. In uplands of eastern plateau region having lateritic soil, the water stored in ponds disappears in few days only due to seepage losses.

Plastic Pond Lining

Among the various methods of lining available, plastics film lining has been found very effective in preventing seepage losses, cheap and relatively more sustainable. However, it requires skill and care while film laying and protecting it from damages. Three types of plastics film being used for lining of ponds are: Geo membrane high density polyethylene (HDPE) film (1.5-4.0 mm thick); Multi-layered cross laminated (MLCL) or Silpaulin (150- 200 gsm); and Low density polyethylene (LDPE) film (150-250 micron or 600-1000 gauge).

HDPE and silpaulin are UV stabilized and do not need to be covered. HDPE may last for a life varying from 5-10 years depending upon thickness and other factors, while silpaulin is relatively stronger in mechanical strength but get deteriorated in sunlight. The life of the silpaulin may also be 5-8 years depending upon condition in which it is used. LDPE is relatively cheaper than the two materials, but needs covering as it is not UV stabilized and has fast strength deterioration in sunlight. However, if the film is protected from the sunlight, it can have life more than 20 years (Srivastava and Bhatnagar, 1991). Covering of the film not only protects from chemical deterioration in the sunlight, but it protects from damage due to human or animal activities also. The plastic lined water harvesting tanks helped to reduce seepage loss to the minimum (Singh *et al.,* 2005, Samuel and Satapathy, 2008 and Samuel *et al.,* 2013).

Construction Technique for Plastics Lined Ponds

In order to construct the plastic film lined ponds, the ponds needs to dug out with appropriate dimensions and side slopes. The sides and bottom needs to be cleaned properly by removing stones and roots of the plants. If there are some roots of nearby trees, it should be cut properly. Use some herbicides to prevent further plant/root growth. Then plastic is laid on the surface in one sheet and folded in corners. If LDPE is used, then it needs to be covered. Covering may be provided using brick pitching, stone pitching or soil layer. Almora Centre has found coal tar felt sheet as an effective material to cover the LDPE film to protect it from sunlight. If the film is to be covered using soil layer then side sloped are required to be made in the form of stairs and film is laid properly such that it penetrates inner corner of the steps and then soil is spread on the sides so that it gets anchored and does not slide down.

Construction Technique Standardized for Meghalaya

At ICAR RC for NEH, Barapani Centre, technology was standardized for construction of LDPE lined pond. The water harvesting pond lined with LDPE sheet (250 micron) were constructed: first in research farm (480 m^3), and second in the farmers' field (1000 m^3). The pond was dug as per the design, and bed and sides was made weed and stone free. Steps at 50 cm vertical interval were made on sides of the pond to hold the agrifilm at its place. On top sides, continuous trench of 30 x 30 cm was dug for the purpose of anchoring the agrifilm to prevent it from sliding down. Pre-emergence weedicide was also sprayed on sides and bed to arrest the weed growth. After the sides and bed were dressed properly, 10 cm thick layer of sieved sand was spread uniformly on bed and sides to provide cushion to the agrifilm. After that, agrifim (250 µ) was laid properly in the pond. For joining, bitumen of 85/25 and 80/100 grade in the ratio of 2:1 was used. While laying too much stretching or tightness of the agrifilm was avoided, particularly on sides. Over agrifilm, soil cover of 15 cm was provided. Stone pitching on sides was done in the research field pond to safeguard the sides of the pond against erosion and any other external forces (Fig. 1).

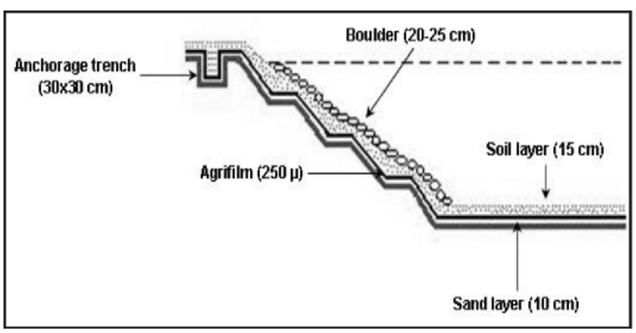

Fig.1. Cross section of LDPE lined pond

Safety of Lining from Seepage Water Pressure

A technology to protect the polythene lining against the uplift pressure due to overland flow of water on sloppy terrains was developed, which was tested again with new water pond at Barapani Centre. Perforated plastic pipes of 2" diameter were laid in trenches made in bottom of the pond (Fig. 2). All the pipes (06 nos.) were made to converge to an outlet which led the water outside pond. Pipes were wrapped with coir rope to prevent choking of the perforations in the pipe. Then pipes were covered with sand. Above that plastic film was laid. Due to this arrangement seepage water was disposed out of pond safely and hydraulic pressure was released. Hence the damage to the lining was avoided.

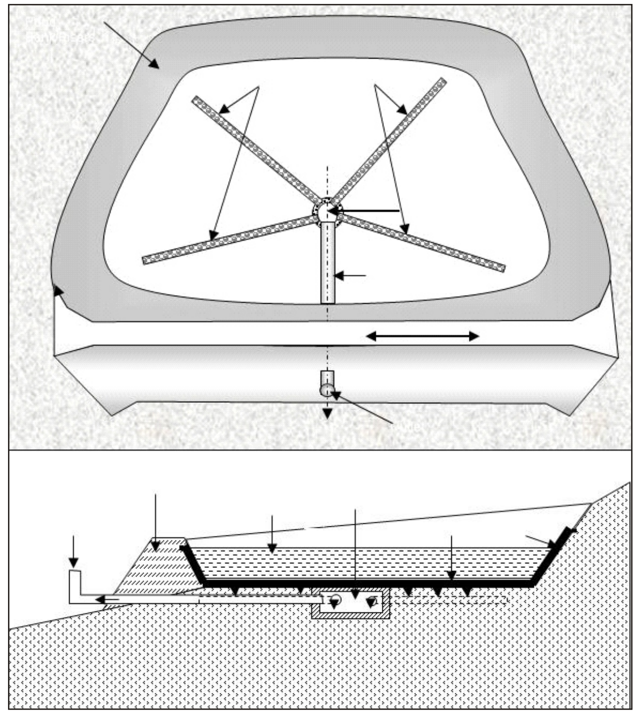

Fig. 2. Schematic diagram of safety mechanism for LDPE lined ponds against uplift pressure from overland water flow

3. MULTIPLE USES OF HARVESTED RAINWATER

A study was conducted in ICAR RCER Research Centre, Ranchi on multiple uses of harvested rainwater in a small pond. The region gets a rainfall of 1200-1400 mm. In order to harvest the direct rainwater and runoff from a small overlying catchment of about 2.5 ha, a pond was constructed having capacity of of about 1200 m^3. The dug out pond had side slopes in the form of stairs, which was covered with LDPE sheet of 250 micron and then covered by soil layer. A 15 cm thick soil layer was provided at the bottom. This provided soil environment all around the pond which is congenial for plankton growth and fish production can effectively be done.

The pond was used for multiple uses *viz.,* fish, irrigation to multi-tier horticulture in command, supplemental irrigation to cereal production in area between outlet and pond, pulse/vegetable production on bunds or outer side slopes (Fig. 3). As per assessment of the water requirement in the command area comprising of 70 x 100 m for multi-tier horticulture, the water available in the pond is enough to meet the water demand up to mid-June for the plantation of 60 plants of Litchi (1^{st} tier), 180 plants of Guava (2^{nd} tier) and vegetable cultivation on 1000 m^2 in two seasons (Oct.-Feb. and Feb.-mid May) considering the daily surface evaporation (Pan E x 0.7). The fish to be stocked when level was more than 25cm (in mid July) and to be harvested gradually after February when it attains weight of 100 g or more. By mid-May the water level goes down to 25 cm and all the fishes needs to be harvested by that time. A small amount (50 mm) of water may be used to irrigate rice crop grown in 50 x 70 m land when rainfall fails during grain filling stage in late September, which will boost the yield level substantially. As the tress plants grow, their water requirement increases, and the area under vegetable goes on reducing. Till they attain fully matured, no vegetables can be grown as the harvested rainwater is enough to meet the water demand of trees only. However, if we plan to grow only vegetables, an area of 1500 m^2 can be cultivated for two seasons with the water available in the pond.

The outlet of the reservoir was connected to water conveyance pipe such that irrigation may be provided gravitationally in the command area. Gravity fed drip irrigation system has been laid out in the command to irrigate the fruit and vegetable plants which had emission uniformity of 89% with pressure head varying between 1.0 to 2.5 m for emitters lay on sloppy land. Average discharge was 3.02 L/s with 89% uniformity and 13.57% CV. The variation was due to head loss in the lateral as the discharge was reduced along the lateral and increase in discharge along the slope.

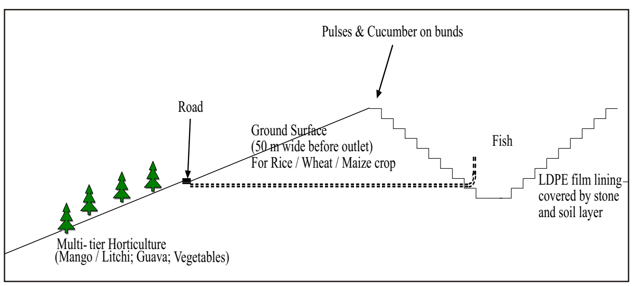

Fig. 3. Sketch diagram for multiple uses of rainwater harvesting pond in eastern plateau region

Small Water Tank for Direct Rainfall Collection in Upland Areas

Small water tanks (named as Jalkunds) were recommended for collection of direct rainwater to establish plantations or irrigate them subsequently based on the research conducted at Dapoli, Barapani and Ranchi under different projects. At Ranchi, the rainwater occurring 1200-1400 mm annually was considered to be collected in the Jalkunds (later on named as *"doba"* as per local name) of 3.0 x 1.5 x 1.0 m depth. The Jalkunds were full by the end of September. In order to sustain the plantations, the water needs to be applied till June, otherwise they will get die in summer. To sustain the water availability in plateau region is challenge in view of higher evaporation. Assessment of temporal availability indicated that even without taking a drop of water for irrigation, the all the water will gets evaporated by the end of mid June considering pan factor 0.8. With a structured irrigation application as per evaporative demand in particular months, if 10 plants are irrigated, then all the Jalkund get emptied by 25th April and no water is available subsequently. However, if the pan factor is reduced to 0.25 then 10 plants can be sustained up to 30th June. An experimental study was carried out to work out strategies to reduce the pan factor at ICAR RCER Research Centre, Ranchi and found that if the Jalkund is kept covered using a thatch cover made from bamboo frame and grass netting, the pan factor can be reduced to 0.35-0.47 when the cover is lifted all the time for removal of water for irrigation (weekly). However, if a small hole of 50 x 50 cm is created in a corner and water lifter using a bucket and rope from it and again closed with small cover, then pan factor can be reduced to 0.26-0.28. This was the desired level and hence it is recommended. However, the pan factor was further reduced to 0.07 to 0.18 when a black polythene cover was provided below the grass thatch which reduced the evaporation loss to minimum. Such Jalkunds can be used for providing irrigation to small plants up to 3 years to have them established. Afterwards, the plants may survive rainfed as the plants choosen for this are hardy in nature like *Aonla, etc.* However, if irrigation is needed subsequently, more Jalkund may be needed to meet the demand. An analysis was made and recommendations were made in this respect. For example, for a litchi plant having canopy diameter of 5 m, pan factor 0.25, 2.5 Jalkunds will be required for each plant to irrigate at IW/CPE = 0.5.

Growing Transplanted Paddy in Upland Using Surplus Harvested Water

A study was conducted at VPKAS, Almora to use surplus run-off water received during monsoon period for growing transplanted rice having higher productivity then prevalent direct sown rice under rainfed conditions in upland areas of mid-hills (Bhatnagar *et al.,* 1996). The transplanted rice was recommended to be transplanted in the first fortnight of July when the rainwater enough for puddling could not be accumulated. Hence, the water obtained as runoff in the pond between 1-20 July can be utilized for puddling and keeping one week ponding following the transplanting. This treatment showed very encouraging results as it enhanced the yield substantially as compared to rainfed. However, without surety of water for puddling, no farmer can think even for going for transplanted rice in upland areas. The rainfall-runoff analysis conducted and obtained catchment command area ratio for different curve numbers which directly gives information on amount of command to be covered using the technique for a given catchment area with defined topography and land use (Fig. 4).

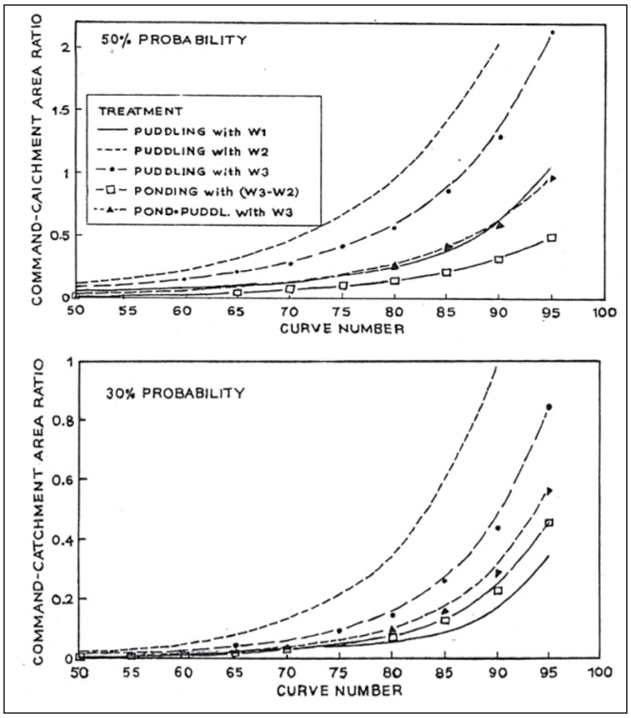

Fig. 4. Command-catchment area ratio and runoff curve number for different treatments used for using surplus runoff during 1 June-20 July at 50 and 80% probability

Runoff Water Harvesting for Irrigation in Hilly Terraces

Efforts have been made to design runoff water harvesting system using LDPE lined tanks with strategies for its utilization and economics at VPKAS, Almora centre of AICRP on APA under a consultancy project given by Dept of Agriculture, Uttarakhand (Anonymous, 2008). Details regarding site selection, excavation, treatment to the pit, preparation of flim with proper dimension, laying of film and covering was worked out (Fig. 5). The water storage dynamics with respect to different alternative irrigation scheduling to probable cropping pattern has been worked out considering the water availability in different meteorological weeks. Construction cost of the LDPE film lined tanks with tarfelt covering for 80 m^3 capacity is estimated at ₹ 15,220 with desilting needs once in five years and replacement of film once in ten years. It can irrigate 16 nalis (1 nali = 200 m^2) of field with different combination of cereals, pulses, and vegetables in *rabi* and *kharif.* The return from such combinations were worked out assuming farmers get minimum support price for cereals and average farm gate price for vegetables with assured market. When rice (10 nalis) and horse gram (6 nalis) in *kharif*; wheat (10 nalies) and lentil (6 nalis) were considered, the total cost of cultivation and returns comes out to be ₹ 17,122 and ₹ 21,798, respectively with an income of ₹ 4,767 only. It provided payback period of 3 yr 4 months with IRR of 32.8% and B-C ratio 1.47. If tomato and capsicum is introduced in *kharif* in 2 nalis each followed by garden pea in *rabi*, the income enhanced to ₹ 21,762 with B-C ratio of 2.2 and payback period of only 4 months. The third scenario has diversification of 10 nalis to vegetables (tomato 5 nalis; capsicum 5 nalies in *kharif;* and garden pea-6 nalis and lentil 4 nalis in *rabi*), the income enhanced to ₹ 44,085 with B-C ratio 2.7 and payback period less than 4 months.

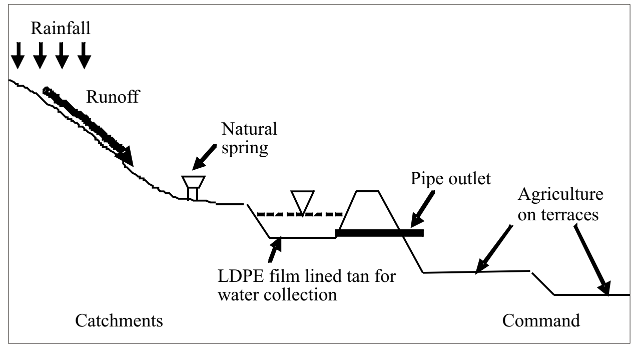

Fig. 5. Schematic diagram of water harvesting

Functional Evaluation of LDPE Lined Ponds in Farmer's Field

VPKAS, Almora Centre has done the functional evaluation of the already developed LDPE (low density poly ethylene) film lined ponds in the farmer's field in villages Darim (District Nainital) and Bhagartola (District Almora). Low density polyethylene lined small ponds were found quite effective in providing supplemental irrigation to horticultural/ vegetable production in hilly areas where cement concrete ponds or lift irrigation with 40-80 m of lift is quite expensive and difficult to operate. Keeping this in view, water resources of 2417 m^3 capacity were developed at the farmers' field under the outreach activities of the project with funding from National Horticultural Board. The water resources were developed in two clusters *i.e.,* in village Bhagartola in Almora District and village Darim in Nainital District through the series of tanks and a total of 26 and 52 tanks were constructed in the two villages, respectively. The length, width and depth of these tanks varied from 2.4 to 33 m, 1.5 to 7 m and 0.7 to 2.6 m, respectively. The capacity of the tanks ranged from 10 to 289 m^3. Nearly one third LDPE tanks were having the

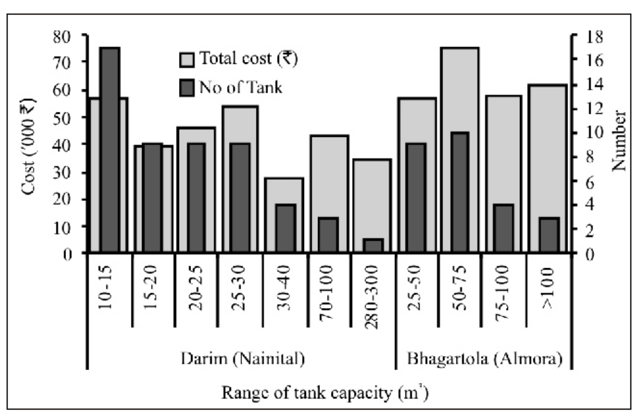

Fig. 6. Number of LDPE tanks constructed and total cost involved in different range of capacity

capacity of 10 to 15 m^3 because of the available small terrace size and land holdings of the farmers. Nearly half (27) of the polytanks were of 15 to 30 m^3 size and only 15.4% of tanks constructed were above 30m^3 capacity (Fig. 6). The source of water for these tanks was runoff and low discharge natural springs.

The construction of the tanks involve cost in earthwork, LDPE film and coal tar felt sheet as covering material. As input sharing, the farmer born the cost of earthwork, while institute contributed for polythene and covering material. The share of farmer was only 37% for tank having capacity in 10-15 m^3 range, while it increased to 84% for tanks of 280-300 m^3 capacity (Fig 7). The cost per m^3 was also found to reduce from ₹ 271 for the tanks in 10-15 m^3 capacity range to ₹ 120 for tanks of 280-300 m^3 capacity. The cost (R, ₹ m^{-3}) may be correlated with the capacity (C, m^3) using the following regression equation (Fig. 8):

$$R = \frac{500}{C^{0.25}} \quad ...(1)$$

However, due to smaller land holdings and terrace sizes, the scope for large polytank (more than 100 m^3) is limited. It is evident in the cluster of polytanks at Darim where only one tank out of 52 was having more than 100 m^3 capacity. Secondly, due to lack of land consolidation farmers had limited option to go for big size polytanks.

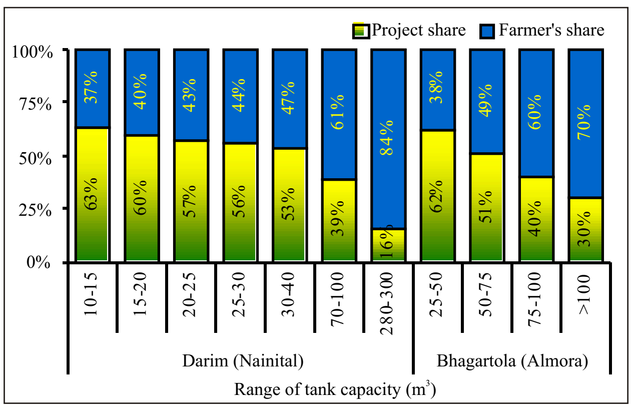

Fig. 7. Cost shared by institute and farmers in the construction of LDPE tanks in different range of capacity

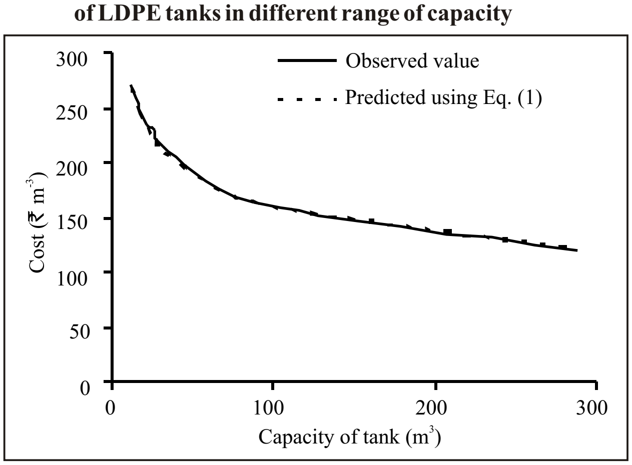

Fig. 8. Unit cost of LDPE lined tanks constructed at farmer's field

A total of 20 tanks out of 78 constructed at the farmers' field, were evaluated for irrigation in different vegetable production. It was observed the supplemental irrigation (in the form of check basin) from such developed tanks helped in 14.7 to 27.8% increase in the productivity of different vegetables (Table 1).

Table: 1
Yield of vegetables in the command of the tanks

Vegetable*	Yield (q ha^{-1})	
	Irrigation from tanks	Hand watering
Frenchbean (18/6/2007-26/8/2007)	96.7	84.3
Tomato (17/7/2007-13/10/2007)	207.8	163.2
Vegetable pea (12/11/2006-3/5/2007)	126.3	104.3
Cabbage (28/10/2007-19/3/2007)	152.4	119.2
Capsicum (4/4/2007-19/72007)	176.8	151.5

*Figures in parenthesis are mean date of sowing/transplanting and final harvesting, respectively

4. CONCLUSIONS

Rainwater harvesting is one of the techniques which can provide irrigation water at every place including the uplands. However, the strategies for water collection and storage needs to be worked out for each region separately considering rainfall amount and pattern and opportunity for their use in various agricultural production systems. Few strategies have been discussed above with a view to enhancing the overall productivity and income of the farmers especially those who cannot afford costly systems of water storage and surface water is not available due to topographical constraints. However, the strategies may change from case to case and effective system has to be worked out to realize maximum benefits.

REFERENCES

Anonymous. 2008. Annual Report, 2007-08. All India Coordinated Research Project on Application of Plastic in Agriculture. Coordinating Unit, CIPHET, Ludhiana.

Agrawal, A, and Narain, S. 1999. Making water management everybody's business: Water harvesting and rural development. *Gatekeept Series,* no. 87, International Institute for Environment and Development, London. 20 p.

Bhatnagar, P.R., Srivastava, R.C. and Bhatnagar, V.K. 1996. Management of runoff stored in small tanks for transplanted rice production in mid-hills of Northwest Himalaya. *Agric. Water Manag.,* 30: 107-118.

Kumar, R., Singh, R.D. and Sharma, K.D. 2005. Water Resources of India. *Curr. Sci.,* 89(5): 794-811.

Samuel, M.P. and Satapathy, K.K. 2008. Concerted rainwater harvesting technologies suitable for hilly agro-ecosystems of Northeast India. *Curr. Sci.,* 95(9): 1130-1132.

Samuel, M.P., Sarangi, S.K., Singh, R.K., Ngachan, S.V. and Chowdhury, P. 2013. Enhancing productivity of micro watershed based farming systems through lined water harvesting tanks in north eastern hills. *Ind. J. Soil Cons.,* 41(1): 36-40.

Singh, R.K., Lama, T.D., Saikia, U.S. and Satapathy, K.K. 2006. Economics of rainwater harvesting and recycling for winter vegetable production in mid hills of Meghalaya. *J. Agril. Engg.*, 43(2): 33-36.

Srivastava, R.C. and Bhatnagar, P.R. 1991. Assessment of strength deterioration of L.D.P.E. film in L.D.P.E. lined tank in hills. *Ind. J. Soil Cons.*, 19(3): 87-88.