Harvesting Water Resources to Meet the Demands for Drinking, Sanitation and Irrigation in Hilly Areas of Uttarakhand, India

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ABSTRACT

About 70 % population living in mountainous regions of Uttarakhand State mostly depend on agriculture for their livelihood, but various climatic, geographical and socio-economic constraints have led to a dismal low agricultural productivity in the region. Agriculture is largely (about 90 %) rainfed, and the farmers generally face severe soil-moisture stress at germination stage and large dry-spells during the subsequent growing period of winter (Rabi) and pre-monsoon crops due to erratic distribution of rainfall amount and intensity. Though the average annual rainfall in Uttarakhand is about 1000 mm, the agricultural productivity is adversely affected by non-availability of sufficient water at critical stages of crop growth. Therefore, the only option is to collect and store total water resources available in three forms namely, direct surface runoff, runoff through roof-tops of houses, and the discharge from natural water springs. The spring water in low quantity goes waste, but its collection in the storage tanks can be developed into a huge water resource to solve the problem of drinking water and irrigation in the region. The field studies conducted at the locations in Garhwal region about 2000 m above mean sea level, have revealed that construction of a brick-lined cemented tank to store spring-water for drinking purpose, in combination with a dug-out farm pond lined with 0.25 mm thick Low Density Poly-Ethylene (LDPE) sheet to collect the overflow from this tank and the surface runoff, is a technically feasible and economically viable option to develop water resources and to enhance the irrigation potential in the region. This integrated approach must be spread to the far-off places in mid and high hills, which is a challenge for the developmental agencies in the undulating, rugged and inaccessible terrain.

Introduction

About 30 % of the total geographical area of India is drought prone, primarily, due to erratic pattern of rainfall distribution. Out of about 148 M ha total cultivable land, about 72% is categorized as rainfed or drought prone. It is evident from Table 1 that there exists a wide scope to beneficially utilize the available rain water in the zone of 1000-2500 mm rainfall. The mid and high hills of Uttarakhand fall under this category. Water is the single most important key element for sustaining mountain agro-ecosystems. Mountains are the major sources of all the natural resources including forest, land, water, animal, mineral etc. and they are called life giver to the biotic means not only to the inhabitants residing in this region but also to the inhabitants downstream. The Himalayas have given birth to many perennial rivers and streams for the survival of living beings in the downstream regions of most of the northern States of India, but the inhabitants of the mid- and upper-reaches in Himalayan region keep struggling for their own survival for want of adequate water resources at their disposal, food security and sustainable livelihood due to various topographical and socio-economical constraints.

Since generations, the inhabitants of Himalayan region have been depending on the natural water springs and streams to meet their daily water needs for drinking and domestic uses, irrigation, animal consumption etc. During recent times, most of the perennial springs and streams have become seasonal or have dried-up for want of adequate recharge due to various natural and man-made hazards. The women have to walk several kilometers daily to fetch a head-load of water for drinking and domestic uses. Though about 90% population in the hilly areas of Uttarakhand earn their livelihood from agriculture and animal husbandry, they are still in the subsistence class characterized by extremely limited capital resources and consistent use of traditional means of crop production. Various climatic, geographical and socio-economical constraints have led to a dismal low agricultural productivity from unconsolidated, small and scattered land holdings in the region. About 90% agricultural lands, mostly in mid and high hills, are rainfed and vulnerable to severe soil erosion and degradation due to erratic rainfall, cloud-bursts and large dry spells during crop growth. Ever increasing population of humans and cattle has resulted into inappropriate cultivation practices on marginal lands and intense use of water resources, which causes considerable surface runoff and soil erosion on one hand, and reduces the infiltration and discharge of natural water springs on the other.

Though most areas receive good annual rainfall, its intensity and distribution is quite erratic and causes severe drought spells to hamper the growth of timely sown winter crops, and subsequent planting of spring crops due to lack of soil moisture. This situation forces the farmers to risk their winter (Rabi) crops at the germination and ripening stages of growth. Frequent and long dry spells retard the growth, size and yield of important fruit crops like apple, plum, peach, apricot etc. If proper irrigation facilities are assured, vegetable crop production has a great potential to raise the economic standard of hill farmers. Off-seasonal vegetables (pea, potato, cauliflower, cabbage etc.) can be produced on a large scale and can be sold at high prices in plain areas. Assured irrigation can also promise cultivation of pea and potato crops twice a year.

Considering all these points, there remains no option but to appropriately harvest the available water resources at suitable locations. In hilly areas, water is available in three forms namely, direct surface runoff, runoff through roof-tops of houses, and the discharge from natural water-springs. Several authors have emphasized runoff harvesting to eliminate the ill-effects of droughts and low productivity in the arid semi- arid and foothill areas in the country (Chitranjan and Rao, 1986; Grewal *et al.*1989 and Oswal, 1994). The studies conducted by Kumar (1992) suggested the feasibility of cost-effective low-density poly-ethylene (LDPE) lined dug-out small ponds for irrigation purpose in mid-Himalayan region. In order to minimize the adverse effects of water stress particularly at the productive stages of crop growth, the conservation of rainfall in soil profiles and providing irrigation through runoff /spring flow harvesting in ponds or tanks at suitable locations, are the only ways out to solve drinking water problems as well as enhance productivity of rainfed agriculture on high and medium hills in Uttarakhand. This study also analyses socio-economic aspects of water resources planning and management in terms of resource sharing and maintenance of storage structures.

Study area

The study was conducted at the Hill Campus of G.B. Pant University of Agriculture & Technology**,** Ranichauri located at the longitude of $78^0\ 2'$ E and latitude $30^0\ 15'$ N with an altitude of about 1900 m above the mean sea level. The mean annual rainfall of this region is about 1176 mm, of which about 75 % is received during the monsoon months of June to September. The soil of the region is generally sandy-loam type. The surface runoff tends to be high due to high slopes and low water holding capacity of the soils. Coarse soil texture and high seepage losses through the soil do not permit sufficient moisture retention in the surface soil and upper horizons of the sub-soil. Because of this phenomenon, the crops suffer badly due to moisture stresses at different critical stages of crop growth during pre- and post-monsoon periods and long dry spells during rainy season.

Hydrologic Analysis

In hills, the water is available in three forms viz. surface runoff, runoff through roof-tops, and flow from natural water-springs. The surface runoff, which can be estimated using various methods on the basis of past rainfall data and landuse, is suitable for irrigation only. Runoff through roof-tops can be estimated using a reasonable value of runoff coefficient for different type of roofs, can be utilized for domestic uses after proper filtration. The flows from water-springs can also be estimated using past records and it can be used for drinking purpose. The optimum size of a lined pond depends on the amount of runoff expected, crops to be irrigated and benefit-cost ratio for the harvesting system. The probability analysis of rainfall data reveal that at 80 % probability (assured level), the expected rainfall during pre- and post-monsoon periods is almost negligible for the germination of Rabi (winter) crops creating large moisture stress at the germination and reproductive stages of Rabi crops and timely sowing of summer crops. Under these circumstances, rainfall and/or runoff harvesting during rainy season along with spring-water harvesting at suitable locations seems to be the only way out.

Though water requirements of the farmers are more, the size of storage structures has to be restricted according to water availability and topography of the location. The capacity of the storage structures depends mainly on the availability of relatively flatter land on which these structures could be made, and the runoff passing through that point. The small and scattered land holdings on different terrains permit the construction of small water storage tanks at the upstream end of a cluster of fields to facilitate irrigation through gravity flow. The experiments were conducted at the research station and nearby areas to evaluate the feasibility and economic viability of lining materials. Out of the existing options viz. cement-concrete, brick/stone masonry, and Low Density Poly Ethylene (LDPE) sheet, for lining the dug-out pond, the LDPE lining has proved to be technically feasible and economically viable for the hill farmers. This technique is the most appropriate for poor farmers as it can be implemented and maintained by the farmers themselves using their own labour and locally available resources.

Design of the Farm-pond

The construction of dug-out pond includes digging of a truncated reverse-pyramid shaped pit with 1:1 side slopes. The depth of the pond was restricted to 1 to 1.5 m only to avoid upward movement of the bottom soil due to buoyant force of water. At the locations where stones are available near the site, the depth of pond may be increased to 2 m by doing the stone pitching all around the surface of the pond. As shown in Fig. 1 a single piece LDPE sheet (0.25 mm thick) of required size is placed with properly folded corners and buried ends on all sides. Before placing the sheet the inner surfaces of the pond were plastered with 5 cm thick mud plaster so that the sheet is properly stuck to the surfaces. Another 10 cm layer of mud mixture of soil and wheat straw or chopped dry pine-needles (4:1) is placed on the sides, and a 15 cm thick layer is placed at the bottom. In case of harvesting the surface runoff, a small silt retention trench of 1x 0.5 x 0.5 m size is dug at the entry point to the main pond so that debris and suspended particles along with overland runoff could settle down and relatively clean runoff water may enter the main pond. The silt retention trench is not required when harvesting the runoff through roof-tops or water-springs. Evaporation losses from the pond can be minimized by spreading on water surface a small quantity of burnt engine oil or by broadcasting polyethylene granules of about 3 mm size. Being relatively free from dust or foreign materials, the runoff from roof-tops and the flows from water-springs can be stored in closed brick-cemented tanks for drinking, domestic uses and cattle feeding after proper treatment or filtration.

The cost analysis of the pond is shown in Appendix 1. The construction cost of this pond comes out to be Rs. 150 per cubic meter storage of water, which is much less than the brick-masonry cement plastered tanks of the same capacity costing more than Rs. 1000 per cubic meter. Another advantage of LDPE lined pond is that this system can be constructed, repaired and maintained by the farmers themselves at a reasonably low cost, as the only material to be purchased is the LDPE sheet which may be available from local markets. As a precautionary measure, the LDPE sheet should not be exposed to the sun light for longer duration as Sun's ultra-violet rays can damage the sheet. The useful life of such ponds is normally 20 years which can be further extended if special care and maintenance is ensured. Water from these tanks is taken by siphoning through rubber pipes to irrigate the crops at lower elevations through gravity.

As an integrated approach, all the available water resources can be combined in such a way that a cemented tank is used to store spring-water and runoff from roof-tops for drinking and domestic uses, while the over flow this tank and overland surface runoff may be stored in the LDPE-lined dugout ponds at lower elevations (Fig. 2). In this way the water resources are utilized to the maximum extent and all the needs of the farming communities are also met simultaneously.

Utilization of Water

The harvested water must be judiciously and efficiently used for irrigating the high value cash crops in the region. It has been found that the off-seasonal vegetable production is one such option where farmers can fetch high returns for their investments. Important vegetables like potato, pea, cabbage, capsicum etc. along with ginger, garlic etc. have shown significant increase in their productivity with the application of life saving irrigation at the right and the earliest opportunity. This water has also been successfully and beneficially used in raising other crops such as medicinal and aromatic plants, orchards, and forest nurseries which are the major sources of income for hill farmers. Efforts have also been made to use this water through more advanced and efficient methods of irrigation such as drip and sprinkler in the orchards and other cash crops.

Experiments were conducted to utilize the stored water for supplemental irrigation in wheat at the critical stages (pre-sowing, crown-root-initiation, and flowering) and their combinations. The results indicate that a supplemental irrigation of 2 cm at CRI stage alone increased the wheat yield by 44 %; whereas, two irrigations at pre-sowing and CRI stages increased the yield by 53 % as compared to the control. Therefore, it is very clear that proper planning and management of available water resources can solve the problem of drinking water shortage and greatly enhance the crop productivity of large rainfed areas of Uttarakhand State.

Summary and Conclusions

The farmers of Uttarakhand, being mostly dependent on rainfed agriculture for their livelihood, face a great difficulty due to lack of water availability for drinking and domestic uses and for irrigation at crucial times of crop growth. Though the region receives good rainfall, the farmers still face serious problem of moisture stress during pre- and post-monsoon periods. As the farm holdings are small and scattered on different terrains, the storage of runoff from land surface and roof-tops, and flows from natural water-springs in the cemented and/or LDPE-lined dugout ponds is the only viable and feasible option to stabilize the rainfed farming in the hilly areas. Such ponds can be constructed and maintained by the farmers themselves at affordable costs. The stored water has to be judiciously utilized for cultivation of high value off-seasonal vegetables, medicinal and aromatic plants, forest nurseries and orchards using the most efficient methods of irrigation like drip and sprinkler irrigation. Dissemination of this approach to the far-off places is being carried out through government agencies and the NGOs. Since the number of available resources (natural water-springs and streams) is limited, sharing and maintenance of these resources/schemes by local communities poses some difficulties. As drinking water is the most vital requirement of all the people of an area, the development, conservation and management of spring water gets the top priority followed by water needs for house hold activities, which can be met by roof water harvesting. The irrigation requirements can be met by surface water harvesting as per the needs and availability of runoff at a location. Since the farmers of the area are poor, some incentives from government in terms of supply of raw materials (LDPE sheet, tin sheet etc.) at subsidized rates will ensure quick acceptance of the technology. Also, the overall water resource planning on small watershed basis has to be done by the scientists, planners and managers together with the beneficiaries and governmental/non-governmental organizations.

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Table 1. Distribution of area and rain water availability in the country

Rainfall zone (mm)	Geographical area (M ha)	Rainwater available (M ha-m)	Net sown area (M ha)	Volume of rain water received	
				(M ha-m)	(%)
100 - 500	52.07	15.62	29	8.70	55.7
500 - 750	40.26	25.16	22	13.75	54.6
750 - 1000	65.86	57.63	24	29.75	51.6
1000 - 2500	137.24	205.86	44	66.00	32.1
> 2500	82.57	95.73	14	41.15	43.0

Table 2. Observed mean and expected lowest assured rainfall at various probability levels

Period	Observed mean rainfall (mm)	Probability level	
		80 %	50 %
Jan	58.2	7	59.8
Feb	83.3	28.7	80.9
Mar	77.9	33.9	66.5
Apr	52	14.3	39.5
May	83	33.8	77.2
Jun	114	89.1	129.2
Jul	274	163.9	289.3
Aug	263.1	200.1	284.6
Sep	136.9	60.2	133.5
Oct	33.3	-	5
Nov	21.4	-	4.3
Dec	58.5	-	51.9
Spring (Feb-May)	296.4	177.3	296.2
Summer (Jun-Sep)	788	659.6	759.8
Winter (Oct-Jan)	171.4	82.8	135.9
Annual	1255.6	1019.5	1299.8

Appendix 1

Cost of construction of LDPE lined pond at Hill Campus (G. B .Pant University), Ranichauri, Tehri Garhwal (Uttaranchal) in the year 1996.

A. Excavation of pit

Total earth work = 20 .30 m^3

Rate of excavation = Rs. 25 per m^3

Cost of digging = Rs. 507.50

B. Weight of LDPE sheet (0.25 mm) = 13.15 Kg

Rate of sheet = Rs. 55 /Kg

Cost of sheet = Rs.723.25

C. Plastering the pond

Weight of wheat straw = 80 Kg

Rate of straw = Rs. 1.50 /Kg

Cost of straw = Rs. 120

Labour involved in mixing the soil with straw /pine needle and plastering below and above the sheet were 4 man-days @ Rs. 35 per day

Labour cost = Rs. 140.00

Total cost involved in A, B and C above = Rs. 1490.00

Storage capacity of the pond = 15 m^3

Cost of pond per cubic meter of water stored = Rs. 99.38, say **Rs. 100.00**

Assuming a price hike by 50 % for 2008, the cost = **Rs. 150 per m^3 water stored**

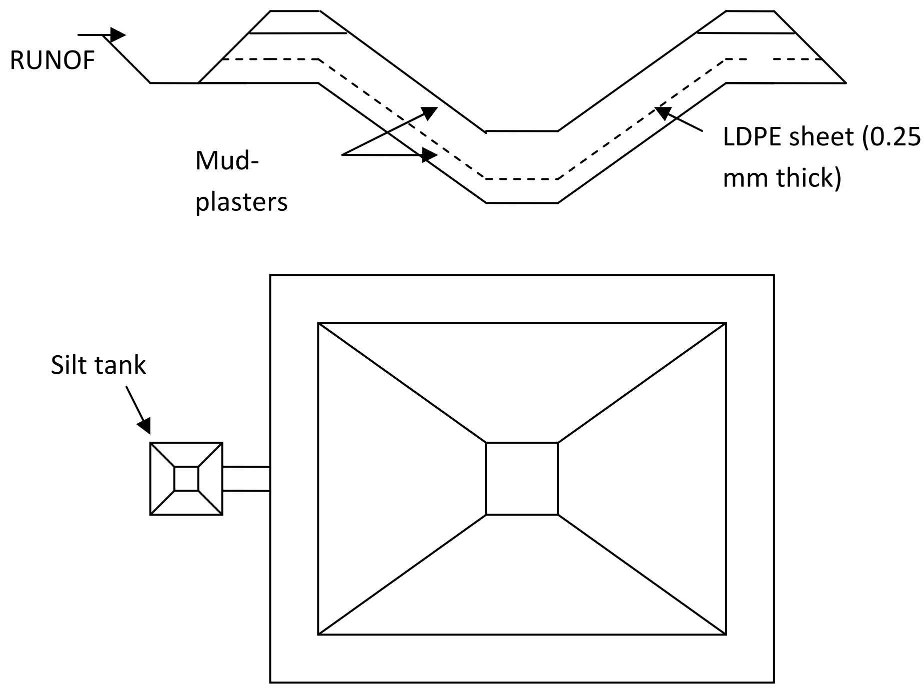

Fig.1. Details of LDPE lined tank suitable for hilly areas.

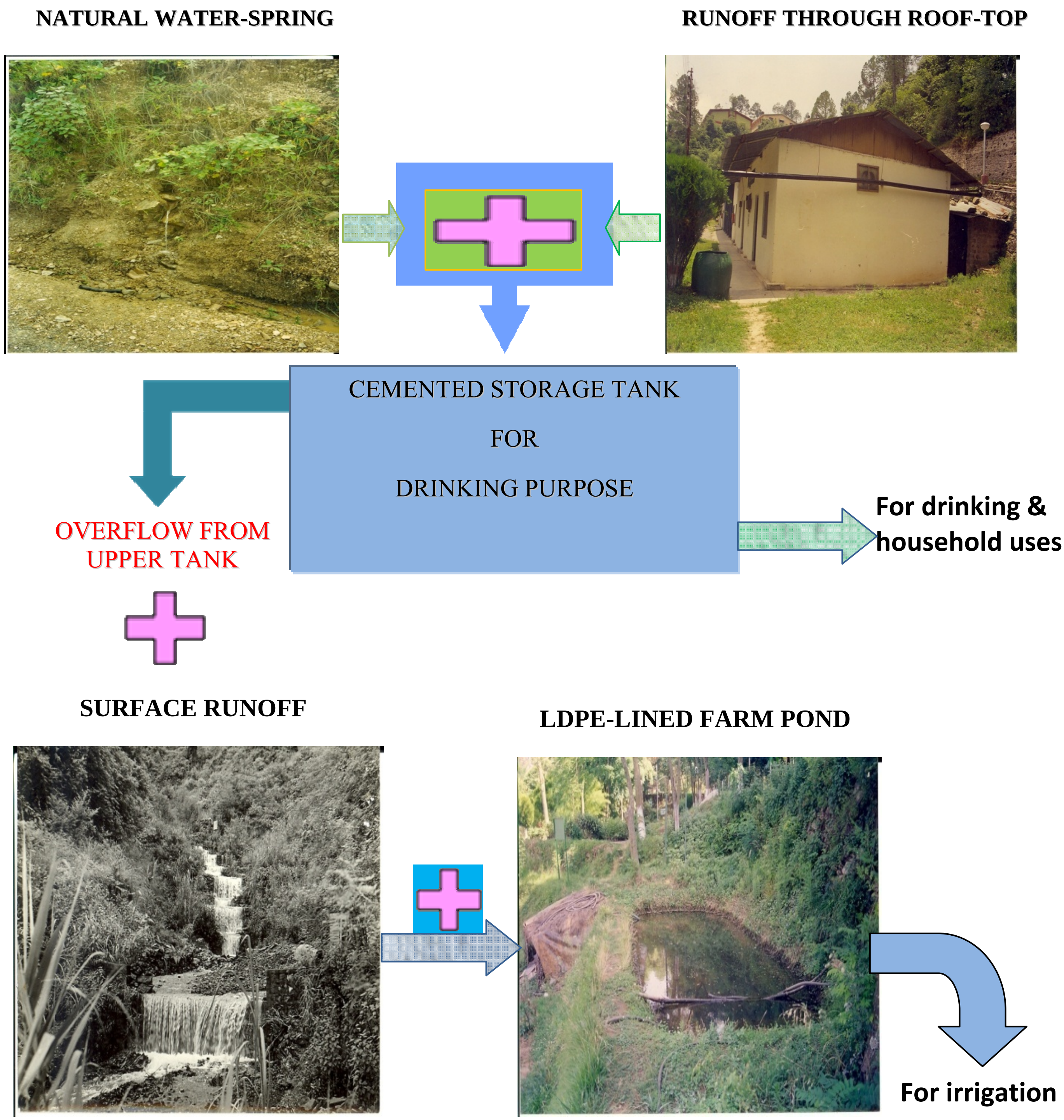

Fig. 2. An Appropriate Water Harvesting Model for Hilly Areas