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Rain-Water Harvesting Structures as an Alternative Water Resource under Rain-Fed Conditions of District Hamirpur, Himachal Pradesh, India

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ABSTRACT: The results of the investigations on rainwater harvesting (RWH) under rain-fed conditions of Hamirpur district of Himachal Pradesh are being described. On the basis of hydrological and technical as well as social and cultural conditions, appropriate techniques for RWH are developed, discussed and evaluated. The main objective is to analyze their technical and economical feasibility as well as their affordability for future users. The top most priority of the present study was to way out the source of water for meeting minimum critical water needs of vegetable crops and maintenance of nutritional gardens. In detail, two small-scale RWH systems are examined. First one is roof rain water harvesting structure (RCC-Tanks) which are having dimensions as 3x3x3m^3 and water holding capacity of 12,000 liters using corrugated iron roofs or terrace catchments as rain collection areas. Second one is poly-lined tank structure having dimensions at the bottom as 6x10x1.5m^3 and water holding capacity of 65,000 liters using 1-1.2 hectare area under catchment. Rainwater harvesting impact on cropping pattern have been enhanced (11.6 ha) as area under conventional cereals (Wheat & Maize) shifted toward cash crops under crop-diversification. The current status of local water supply and water use was investigated in Mann villages of district Hamirpur (Himachal Pradesh). Concepts and techniques of RWH were discussed with the local populations. The feasibility of the RWH systems was assessed in relation to local socio-economic conditions of small and marginal farmers. The present study reveals that it is economically feasible to apply decentralized techniques of RWH in terms of the roof catchment systems at individual levels. The ground catchment system, however, needs moderate subsidies and implementation at community farm level. Moreover, the proposed technologies provide comparable benefits to the irrigation and public water supply.

Keywords: Rain water harvesting; poly-lined tank; crop diversification; rain-fed; water resources

INTRODUCTION

The climate change issue is global, long term and involves complex interaction between demographic, climatic, environmental, economic, health, political, institutional, social, and technological processes. It has significant international and intergenerational implications in context of equity and sustainable development. Climatic change will impact social, economic, and environmental systems and shape prospects for food, water, and health security. Socioeconomic and Resource development technological characteristics of populations strongly affect emissions, explaining the pace and capacity of societies to adapt to and mitigate climate change. In addition, extreme climate events are registering an increasing trend. For a long time, climate of the Holocene epoch (~ 11 kyr BP to present), compared to last glacial period (widely accepted dates for the Last Glacial are ~ 74 kyr and 14 kyr ago as given by the Intergovernmental Panel on Climate Change), was considered to be stable.[1] Indeed, pace of the Holocene events and of abrupt climate shifts during the last glaciations has been suggested to be statistically the same; together, they make up a series of climate shifts with a cyclicity close to 1470 ± 500 years.[2] Some proxies representing local climate at different places across the world reveal that the 20th century is probably neither the warmest nor a uniquely extreme climatic period of the last millennium.[3] A variable sun through changes in solar irradiance and processes such as biological regime shifts may have caused the observed climate variability and climate fluctuations over much of the Holocene.[4, 5, 6] Indeed, geophysical, archaeological and historical evidences support a solar- output model for climate change during a large part of the Holocene.[7] The major advantages of rainwater harvesting are that it is simple, cheap, replicable, efficient, sustainable and adaptable.[8] Eris (Tanks) have played several important roles in maintaining ecological harmony as flood-control systems, preventing soil erosion and wastage of runoff during periods of heavy rainfall, and recharging the groundwater in the surrounding areas.[9] Climate fluctuations are not necessarily anthropogenic as inferred from biological and geological proxies, terrestrial palaeo-temperature may have been higher due to natural variability.[10] Himachal Pradesh is comparatively a small state in north-west Himalayas. The population of Himachal Pradesh has grown from 23.86 lakh in 1951 to 60.78 lakh in 2001. Thus, the population has grown more than 2.5 times in a period of 50 years. The state of Himachal Pradesh is located between 30°22’ to 30°12’ north latitude and 75°47’ to

79°4' east longitude. The mountainous state has altitude ranging from 350 m to 7000 m above mean sea leve.[11] Taking the present growth trend into consideration, the population is expected to further rise to 98.61 lakh in 2031.[12] In many villages these systems have now fallen into disuse with the spread of piped water supply.[13] The size of catchments limits the quantity of water collected. The water demand has risen many times. Most of these water sources are highly polluted.[14] Hydrologic design involves the estimation of peak rate of run-off volume from the catchments of the pond. The run-off is estimated for a design frequency of 25 years.[15]

Himachal Pradesh is a hilly state and majority of the people are engaged in farming profession. Hamirpur district is the smallest district and situated in the center of the state .it falls in the sub-tropical zone of Himachal Pradesh. There is great diversity of climate in the zone due to variation in altitude, topography and geographical location. In general the district is endowed with a wide variety of agro climatic conditions and soil types that enable the cultivation of various field vegetables and fruit crops. Total geographical area of Hamirpur district is 1, 11,800 ha, out of which mere 5% is under irrigation rest is under rain fed areas. Hamirpur district normally receives 1,100 mm/annum rainfall of which about 80% is received during monsoon months i.e. July to mid-September. Majority of farmers in this hill district have marginal and small land holdings averaging 0.40 ha consequently having a poor socio economic status. Irrigation through canals, tubewells is not feasible due to mountainous terrains and monsoon rainfall goes waste as runoff due to sloppy terrain of district Hamirpur. After launching of an ambitious ICAR Funded NICRA project in Hamirpur District, rain-fed agriculture is one of the serious constraints in hill agriculture for sustainable agricultural production and climatic resilient agriculture. Sustainable management of natural resources of land, water and vegetation is essential in providing livelihood and environment security. Ever increasing demographic pressure coupled with developmental activities are causing tremendous pressure in the utilization of these resources, leading to various kinds of problems such as droughts siltation of reservoirs, deterioration of water bodies and mainly loss of biodiversity. Resource conservation therefore, is an issue which concerns not only researchers and scientists but also planners and policy makers.

In this district, conventional irrigation methods like canals tube wells are not feasible due to mountainous terrains. Most of monsoon rainfall goes waste as runoff due to uneven and sloppy terrain of the region. The months of October, November and December are generally dry, due to which Rabi crops fail frequently and yield levels are very low. Under such circumstances, rain water harvesting remains only feasible option for meeting minimal irrigation needs of the crops, especially in upland areas. Because rain is the first and the ultimate source that feeds all rivers, lakes and ground water which are all secondary sources of water and hence remains ignorant of its value ,so it is necessary to understand the value of rainwater at the place where it falls. Mittal and Sharma proposed watershed management plans in Shivalik foothills to avoid drought situations.[16] Tied ridging had been found beneficial for moisture conservation and in increasing yield of cotton.[17] Approximately one-third of the irrigated area of Tamil Nadu is watered by eris (tanks).[18] Previous studies have shown that substance agriculture in hilly region could be successfully transformed into a profit- earning enterprise by tapping and utilizing rainwater in limited quantities.[19] Hence, World Development Report (2008) emphasized that the potential of agriculture to contribute to growth and poverty reduction depends on the productivity of smallholder farmers.[20] And raising that productivity will require a much higher level of adoption of new agricultural practices and technologies than presently observed in the smallholder farming population.[21] Certified organic agriculture and polylined tank techniques must meet certain standards in the production, processing and handling which developed in accordance with basic standards established by the International Federation of Organic Agriculture Movements.[22, 23] It would be useful investing in decentralized facilities, efficient technologies and policies, and human capital to improve overall productivity rather than to find new sources of water supply.[24, 25] Traditionally, such systems have been integrated with agroforestry and ethno-forestry practices, and remain useful in contemporary conservation and ecological restoration of degraded ecosystems.[26, 27] The low external input and sustainable agriculture (LEISA) approaches involve limiting the use of external inputs such as inorganic fertilizers and pesticides as well as rain harvested water through polylined tanks relying more on local and naturally available resources and a combination of traditional and improved methods to manage soil fertility, water, pests and other agronomic needs.[28, 29]

Organic agriculture through rain harvested water is based on minimizing the use of external inputs and avoiding the use of synthetic fertilizers and pesticides.[30] Based on certification, price premiums of 10 to 50 per cent are common for developing country exports of organic products.[31, 32] Based on this fundamental principal we should strive to collect and conserve the rain water falling on farm land, village, state and the country locally.[33, 34, 35] In this way, we can improve our socio- economic status and conserve our environment sustainably.[36, 37, 38, 39] Different water harvesting structures viz. tied ridging or basin listing (formation of small basin) had been used at many places and found to be very effective in conserving rainwater in soil profiles and in increasing crop yields in Himalayan hills.[40] There is significant concern about the impacts of climate change and its variability on agricultural production and productivity World-wide. Scientific assessment of the causes and consequences of climate change is important, but the real need at the local and national level is adaptation and NRM technological development as well as mitigation measures. Rainfed agriculture is one of the serious constraints in district Hamirpur for sustainable agricultural production and climatic resilient agriculture. It is found that silpauline or nylon-lined ponds and roof-rain water harvesting tanks 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. It has been observed that the cost/litre for collecting rainwater/spring water in UV-resistant plastic sheets is significantly less compared to other methods such as concrete, brick masonry, ferro cement, fibreglass.[41] Rain water harvesting refers to collection and storage of rain- water ,activities of in situ soil water conservation, prevention of unproductive losses through evaporation and seepage including hydrologic and engineering interventions, aimed at conserving and efficient utilization of the limited water received from a physiographic unit called water shed.

MATERIAL NAD METHODS

The comprehensive study has been conducted in the 5 villages of Hamirpur district, Himachal Pradesh and is based on the primary and secondary data. To select the sample households, random sampling procedure was followed. To begin with, 5 villages, namely Mann, Tareti, Jangloo, Ghumaharatsa and kutherah were selected to represent different micro-climatic niches and cropping patterns. A sample of households was selected randomly from these villages through proportional allocation method. The data on different aspects of agricultural development, livestock rearing and natural resource management specially water and land, were collected through personal interview and semi-structured questionnaire method during March 2011 to February 2017. The data were analyzed using simple statistical tools like averages and percentages.

Problem: Very severe water scarcity persists in these villages and district also during summer period i.e. mid-April to mid-June (Table 1). Farmers have to carry water from far off places for domestic as well as for meeting the minimum critical water needs of agricultural cash crops like tomato, cucurbits, capsicum etc. thus water scarcity emerged as the major problem of the natives of Mann panchayat and Hamirpur district as well. The top most priority of the natives of study area was to have some irrigation water for meeting minimum critical water needs of vegetable crops.

Table1: Prerequisite rainfall data (mm) previous three years (2009-2011) through which researchers approach rain water harvesting silpauline bricks lined tank for rain off water

Month	Year			Average Rainfall (mm)
	2009	2010	2011	
January	17.5	15.25	33	21.91
February	12	46.5	132.5	63.67
March	5	22	40.5	22.5
April	53	-	38.75	30.59
May	34	27.75	35.25	32.34
June	28.5	134	133.25	98.59
July	206	202.25	221.75	210.0
August	374.25	441.25	317.5	377.67
September	165.25	214.5	102.5	160.75
October	13	14.5	-	9.17
November	-	12.5	-	4.17
December	-	77.5	-	25.84
Total	908.5	1208	1055.4	1057.2

Approach: Six nos. silpauline brick lined tanks as well as twelve nos. of Roof-rain water harvesting tanks were constructed in NICRA villages i.e. Mann, Tareti, Jangloo, Ghumaharata and kuthera, Nadaun district Hamirpur during project period in session 2011-17 years. These silpauline brick lined tanks were constructed on farmer's field whereas roof rain water harvesting tanks were constructed as among their houses to harvest the run off meeting the critical need of irrigation of off season vegetables and major crops (i.e maize and wheat of marginal and small farmers also). Polylined tanks were owned by individual farmer but managed by group of beneficiary farmers. Trapezoidal shaped Polylined tanks having depth of 1.5 m, length of 10 m and width of 6 m ,at bottom each and side slope of 1:1 were constructed for lining the tanks, a blue colored UV stabilized, multilayered cross- laminated sheets were used. Since, the class I bricks 4800 no. of each tank were provided for lining the silpauline sheets. The silpauline sheets and bricks were provided to farmers from the project funds where as other jobs such as pond digging smoothening weedicide spray, sheet laying and bricks lining (completely loose, without any cementing material) have been done by the hard workers farmers by themselves. The storage capacity of silpauline lined tanks is approximately between 70000-75000 liters in each.

Whereas, roof rain water harvesting tanks have dimensions as 3m x 3m x 3m as well as 12000 liters of harvested rain water capacity. After digging the tank in trapezoidal shape, smoothen and level the four walls and base of the tank. For making the four walls and the base of the tank weed free, spray either glyphosate @ of 4 liters /ha or atrazine @ of 4kg/ ha. If small pebbles are present on the walls and bottom, try to remove them completely, otherwise there are chances of the sheet getting damaged. If the need be, the walls and the base may be leveled by spreading the fine screened soil. After this spray the weedicide on the four walls and base of the tank. The size of the sheet should be obtained by actually measuring the cross dimension i.e length and width of the already dug out trapezoidal tank including 85 cm of sheets which needs to buried at the top outer ends of the tanks (Figure 1, Figure 2, Figure 3, Figure 4).

Figure 1: Preparation of polylined tank

Figure 2: Rain water harvested in polylined tank

Figure 3: Preparation and demarcation of roof rainwater harvesting tank

Figure 4: Rising of nutritional garden

Main objectives: Rain water harvesting tanks: if, runoff is collected locally at appropriate locations in water harvesting tanks, not only it can be gainfully utilized subsequently, but it will also help in reducing the volume of runoff in streams or rivers during monsoons and subsequently reduce the curse of floods or droughts and soil erosion. Since time immemorial, the tanks have been used in our villages for drinking needs of human and cattle population as well as for meeting out the irrigation needs. Due to ever increasing demand of water for huge human and cattle population, there is urgent need for the planning, construction and maintenance of water harvesting tanks.

Uses of water harvesting tanks

1. Irrigation
2. Drinking water and other domestic aspects
3. Fish production and fish farming
4. Wild – life recreation
5. Forest fire protection etc.

Types of tanks

1. **Check dam type tanks:** This type of agricultural tanks is constructed by erecting concrete

dam against small seasonal or perennial water streams.

2. **Dug out tanks:** Such type of agricultural tanks is constructed on relatively flat lands. The construction cost of such tanks is relatively higher and is suitable for only those kinds of situations where relatively less amount of water is needed to be stored.

RESULTS AND DISCUSSION

In the study area, most of the farmers are small and marginal holders with small production only for 2-3 months self consumption. The over-exploitation of natural resources with the population growth affects the quality of rural life in the rural areas. Hence, it is necessary to develop a suitable strategy to improve the economy of the rural households through agricultural development and sustainable use of natural resources. To achieve the goal of rural prosperity in this region, it is necessary that the development strategy should focus on improved agricultural production which provides gainful self-employment to the farmers. As agriculture and allied activities is the main source of rural employment, but being deprived of irrigation facilities, a majority of the small and marginal farmers are heavily under-employed in a year in this region while now scheme of government provide an alternative for short time. Even under well established irrigated conditions of the area, the growth of the agriculture sector itself has been almost stagnant from the last 15-20 years. Therefore, the policy makers and agriculture experts have been urging to accelerate growth in the agriculture sector.

Water is an important input required to enhance agricultural production. The soil profile stays moist for a longer time, which stimulates soil life so that the formation of stable humus, the nutrient availability and the water holding capacity are improved. The hilly region is deprived of irrigation facilities but the sustainable use of all the available water resources should be ensured to improve the crop yields. In the absence of adequate water conservation measures, water scarcity is likely to be a serious bottleneck in the future. With increasing exploitation of natural resources and environmental pollution, the atmospheric temperature is expected to rise. If it happens, most of the rivers originating from the Himalayas may dry up and cause severe shortage of water for irrigation, suppressing agricultural production by 40-50%.[42] Rainfall is expected to be erratic and the water requirement for crops is likely to increase due to a significant increase in evaporation and transpiration losses. Therefore, greater awareness needs to be created to make efficient use of water resources and to prevent global warming through environmental protection. In the study area poly-lined and Roof-rain water harvesting type of structures were observed, but these structures were present in very small number only (18 tanks were observed in all the 5 villages). And all the structure supported by government under NICRA schemes.[43, 44, 45, 46] Low adoption may be due to lack of awareness among the people about water harvesting and sustainable use of water resources and high construction cost as farmers are poor. Rainwater harvesting impact on cropping pattern have been enhanced (11.6 ha) as conversional cereals (Wheat & Maize) changes toward Cash crops under crop-diversification (Table 2).

Table 2: Water storage capacity created and irrigated potential generated under crop-diversification

Types of Tanks	Nos	Capacity (Litre/Tank)	Impact of rainwater harvesting [Total area in watershed (ha)]			
			Crops	Before	After	Change
Poly-lined Tank (10x6x1.5) m^3	06	60,000-65,000	Wheat	9.0	7.5	-1.5
			Maize	8.5	6.5	-2.0
			Vegetables (Cucurbits, Garlic, Elephant foot yam, Ginger & Colocasia)	0.5	3.5	3.0
RRC Tanks (3x3x3)m^3	12	12,000	Wheat	-	1.5	1.5
			Maize	-	1.2	1.2
			Vegetables (Cucurbits, Garlic, Elephant foot yam, Ginger & Colocasia)	0.2	9.6	9.4
Total	18	Total area (ha) under crop-diversification in study area		18.6	29.8	11.6

There is a scope for introducing new technologies in the following areas for efficient management of water resources in the region:

1. Efficient rain water harvesting and storage of rain water through polylined tanks.
2. Reducing loss of water by evaporation in reservoirs and tanks
3. Development of alternate and renewable sources of energy for rural uses.
4. Technologies for low water consumption by crops and trees.

Irrigation should be provided through siphon technique. Initially the water from the silpauline lined tank should be sucking in small length pipe and subsequently relatively longer pipe can be attached to it for irrigation the whole field by gravity method. Hence this irrigation technique will further enhance the life of the tank. Whereas roof-rain water structures provide better option to raise nutritional gardens.

Water Conservation for Irrigation:

1. Rain water harvesting and conservation through poly lined rain water harvesting tank should provide a better option for enhancing irrigated area.
2. Sustainable utilization of water for irrigation by using drip and sprinkler irrigation and reduce the water requirement of crops by using poly mulching.
3. Use of proper technologies for improving the quality of land and irrigation water.

Crop Protection:

1. Improving crop yields and quality through genetic modification
2. Use of bio-compost, bio-fungicide, bio-pesticides, disinfectants
3. Drying and storage of seeds and food grains by using low cost techniques
4. Techniques for long shelf life of fruits, vegetables and other food product Post- harvest Management.

Water harvesting tanks should be constructed on that piece of land where all type of waste water such as rainwater, runoff water channel can be collected easily. The catchment area of such tanks should be sufficient enough to have sufficient amount of runoff including rainfall. The catchment area should not be large enough as compared to the tank capacity, otherwise there is every possibility of excessive soil entering the tank, and more over the tank may be completely damaged through huge runoff volume resulting from large catchment area. The construction site should be well above the land to be irrigated, so that irrigation can be easily provided through gravity system without the use of any power source. The capacity of tank depends upon the volume of water to be stored and the physical conditions of the catchment area. The rain fall amount, intensity and time also govern the run off volume from the catchments.

CONCLUSIONS

This observation has clearly shown that rain water harvesting offers a viable solution to the irrigation problems of the farmers of rain fed district Hamirpur under this ambitious project NIRCA. This can lead to sustainable management of biodiversity i.e the fauna and flora of Hamirpur district and also lead to substantial improvement in the socio-economic condition of the small and marginal farmers of NICRA villages district Hamirpur also. Poverty and lack of employment is a serious problem in the study region, to overcome this situation it is a necessary to enhance agricultural production through promotion of irrigation through poly-lined and RRWH tanks techniques as people gain more cash crops, development of agroforestry system on wastelands and livestock development with a special focus on generation of productive self-employment for the rural poor. These activities should enhance the economy of rural poor by providing them gainful self employment opportunity in seasonal and off seasonal vegetables especially in protective cultivation year around. The remote areas are also deprived of basic infrastructural facilities so they should be the target areas of current development programmers. There is also a need to develop low cost economically viable agriculture technologies as the target population is poor these technologies enhances the capacities of rural poor and enable them to take active part in the process of strengthening the regional economy.

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