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Runoff Rainwater Harvesting for the Development of Arid Areas: Some Experiences from Dry Zone of Sri Lanka

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Abstract: Water scarcity in the dry zone areas of Sri Lanka is one of the crucial factors constraining the development. The government of Sri Lanka and various NGOs have implemented Runoff Rainwater Harvesting (RRWH) projects in the rain fed agricultural areas of dry zone. The paper is based on the research conducted in the poverty stricken dry zone districts of Moneragala, Hambantota and Puttalam Districts on the recent interventions on promoting RRWH techniques in the area. The major objective of the paper is to discuss the effects and impacts of RRWH interventions with special focus on agricultural development. The study findings shows that the usefulness of harvested rainwater is multifaceted including annual crop cultivation, perennial crop cultivation, livestock rearing, aquaculture, meet the domestic household needs and different combination of the above requirements. About 62% of the beneficiaries have utilized the systems for cultivation purposes, 40% are using to fulfill the various needs of livestock and 49% of the beneficiaries have utilized the water for various household water needs other than drinking. About 31% of sample beneficiaries have used the RRWH systems for aquaculture, while performing crop cultivation activities. Only 9% of the RRWH systems have been abandoned due to various reasons. Farm level data indicates that, the number of farmers involved in seasonal crops cultivation has increased significantly after introduction of RRWH systems. About 91% and 28% of farmers who under take seasonal crops cultivation are using runoff rainwater stored as a supplementary water source during wet (*maha)* and Dry (*yala)* seasons respectively while about 72% of *yala* cultivators are using runoff rainwater as a sole source or main water source for their cultivation, which indicate the water scarcity condition in the area during dry seasons. About 68% of perennial crop cultivators use the RRWH systems as a supplementary source of water, while rest of the people depends on them as a main or exclusive water source. According to the beneficiary perceptions, 85% have realized the changes in the surrounding micro environment after construction of RRWH tanks mainly in the form of the survival of vegetation in the surrounding environment of RRWH system during dry spells, which were severally effected prior to the project. The rainwater harvesting intervention experiences shows that it has a great potential in developing the rain fed marginal areas of the dry areas and mitigates the effects of drought disaster.

Key words: Runoff • Rainwater harvesting • Agriculture • Drought • Dry zone

INTRODUCTION

Sri Lanka receives rainfall with an annual average of 1200mm. However variability of rainfall temporally and spatially complicates the water availability situation in the country. Precipitation is mainly confined to about five to six months in a year and varies from less than 1000mm to more than 5,500mm per annum within the country. In the dry zone rivers, nearly 80percent of the annual flow occurs in the four month period from October to January [1].

The predicted climate change also poses severe challenge to the current water availability situation. Sri Lanka as a small island has been identified by UNFCC and IPCC as a nation under serious threats from climate change impacts, such as sea level rise, severe floods and droughts [2, 3]. According to [4], "Global warming is expected to lead to a rise in sea level, higher temperature, more frequent and prolonged droughts, high intensity rainfall and increased thunder activity". The increase of ambient temperature leads to an increase in the atmospheric water demand and subsequently increases

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Fig. 1: Picture of a Runoff Rainwater Harvesting Pond

the potential evapo-transpiration. Therefore, crop water requirements also have to increase to compensate the increase in atmospheric water demand which will substantially affect irrigation water withdrawals. Although droughts in Sri Lanka used to occur once in a decade since 1930s, droughts have occurred three times after year 2000 indicating increase of drought frequency [5]. It has been predicted that, rainfall to be received from North-east monsoon will be reduced in the future and the reduction will be around 26-34 percent, especially in the dry zone districts. Similarly rainfall to be received from southwest monsoon has been predicted to be increased by around 38 percent especially in the wet zone districts [6]. With the change of future rainfall pattern, wet areas become wetter and dry areas become drier. The increase intensity of rainfall will not be much useful for crop cultivation or groundwater re charge, as it will be mainly in the form of high intensity erosive rains due to enhanced convection.

Increased climatic variability and the greater frequencies of droughts and floodsmake the role of rainwater harvesting systems even more important as sources of supplementary, back-up, or emergency water supply. The water crisis today is not about having too little water to satisfy the needs, but it is collecting, storing and managing the available water captured through precipitation throughout the year.

Sri Lanka has centuries of old wisdom in rainwater harvesting techniques. Historical evidences show that ancient kings have developed rainwater harvesting systems to cope up the water scarcity conditions. There are mainly four different kinds of surface water storage structures in Sri Lanka namely large reservoirs, major, minor irrigation tanks and micro storage facilities (farm pond). They differs each other based on capacity, type of management and irrigated command areas. However, due to economic costs, environmental impacts, social side effects and technical complexities the construction of large dams, reservoirs and river basin transfers have not been promoted or encouraged very much though storage of water is still a must. Therefore, micro storage facilities/farm ponds have a significant role to play in harvesting and storing the water. This is indeed describes the small scale concentration, collection, storage and use of rainwater runoff for both domestic and other purposes.

Micro storage facilities are the water storage structure owned and maintained by individual beneficiaries. The command area under micro storage facilities is very small and often sufficient to provide supplementary irrigation for about 1-2 ha of land. The micro storage devices are known as farm pond. The capacity of the farm pond is very small and the source of water is limited. The main sources of water are direct fall of rainfall and surface relief of water from surrounding areas. Generally farm ponds are built at the lower elevation of the farm land in order to enable maximum collection of surface runoff.This paper based on the findings of rainwater harvesting activities for agriculture under the micro storage facilities (farm pond).

Objectives: The major objective of this study is to find out prospects of introducing runoff rainwater harvesting system in Sri Lanka with special reference to drier parts of the country. The specific objective is to discuss the effects and impacts of RRWH interventions with special focus on agricultural development.

MATERIALS AND METHODS

Study Sites: The dry zone area covers around 65% of the total land area of the country. The dry zone annual average rainfall varies from 1250mm to 2000mm in which about 65% of the rainfall received during the four month period of October to January. This paper is based on the research conducted in three dry zone districts viz. Moneragala, Puttalam and Hambanthota districts, which are vulnerable for drought incidents compare to other areas in Sri Lanka. Three districts consisted of different kind of RRWH systems implemented in different context.The rainfall patterns of these study areas are illustrated in Figure 1.

The average values of annual rainfall, rainfall distribution and temperature of all the selected areas have characteristic features of the dry/arid conditions, where lack of sufficient water or water scarcity is the crucial factor hindering the development of the area in general and agriculture in particular. However, agriculture is the main source of livelihood for majority of the peoples living in these areas. Therefore various development agencies promoted RRWH systems aiming to enhance the income and social and economic conditions of the people living in dry and marginal areas primarily through improving the water availability in the area to develop agricultural activities.

Methods of Data Collection: The study was mainly based on quantitative data and qualitative data collected from primary and secondary sources such as questionnaire survey, key informant interviews, focus group discussions with the stakeholders of the projects and review of literature. The sample survey was conducted during the period of October to November, 2007.

The beneficiaries who received RRWH systems before the year 2005 were selected for the sample survey. The total sample size of the study is 161 randomly selected households. Sample size represents more than 10% of the total population selected from six different locations of the three districts.

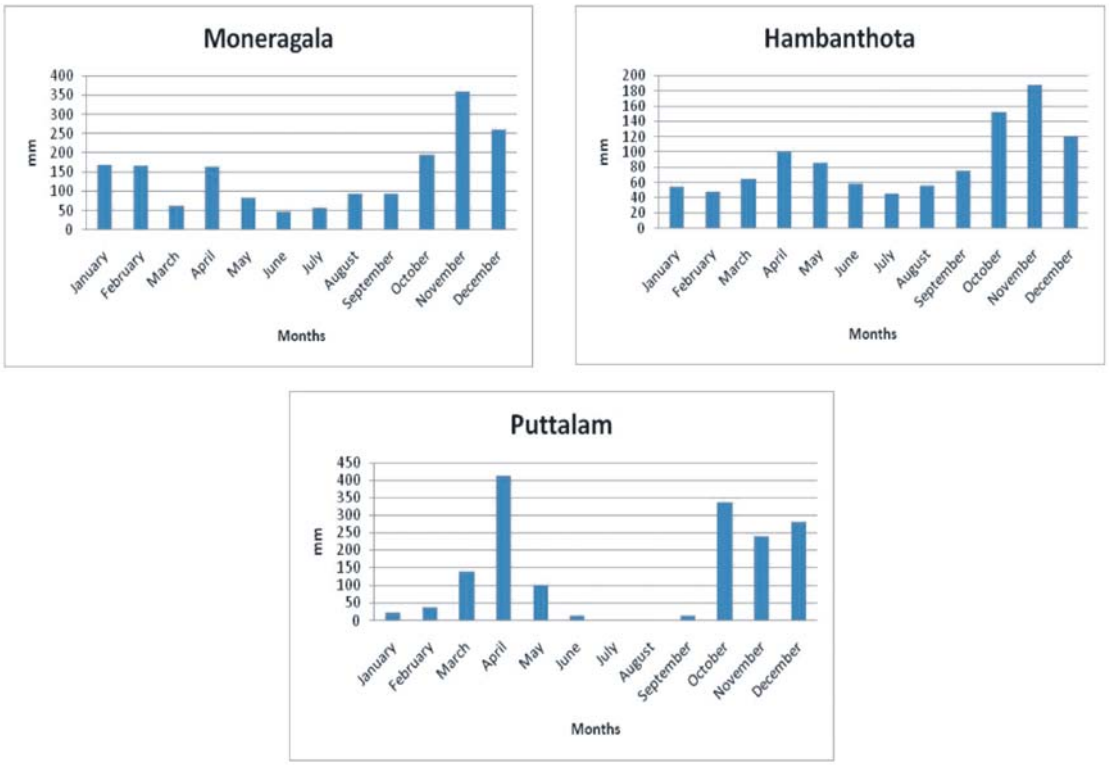


Fig. 1: Average Monthly Rainfall in Hambanthota, Puttalam and Moneragala Districts
Source: Department of Meteorology, Sri Lanka, (1961-1990 average monthly rainfall)

RESULTS AND DISCUSSION

Use of Land and Water Resources in the Area: As in other parts of water scarcity dry areas in the country, people are dependent on multiple sources of water for their agricultural and other water needs. Farmers have one or more plots of land under one or more land categories viz. low land, highland and home garden. Irrigation channel, drainage channel, agro-well (large diameter shallow dug well) and RRWH systems are the major water source used for the cultivation.

Table 1 shows the degree of dependency on different water sources under different land categories in the study areas. The findings show that 23% of sample farmers have some access to irrigation water.Irrigation water received from irrigation channel is mostly used for lowland cultivation (mainly water intensive rice cultivation). RRWH systems are mainly popular for highland and homegarden cultivation while 35 percent of lowland cultivators use RRWH systems for some of their lowland plots as a supplementary water source. About 80 percent of the RRWH water users for low land cultivation primarily use it as a source of supplementary source to undertake rice cultivation.

Utilization of Rrwh Systems for Agriculture: Runoff water collected in the RRWH systems has been used to cultivate annual crops or perennial crops or both types of cultivation. The cultivation of crops has been taken place in all three major land categories viz. lowland, highland and homegarden. Large numbers of farmers have increased their extent of cultivation especially during *yala* (dry) season and introduced number of new crops to their farming system after construction of RRWH systems. Table 2 describes the use of RRWH systems for various purposes. In addition to the uses listed in Table 2, about 37 percent of farmers reported that, the RRWH systems are also used by their neighbours time to time during the periods of water scarcities for various household purposes.

Findings show that, the number of farmers involved in seasonal crops cultivation has increased significantly after introduction of RRWH systems. The increase is very much significant during dry seasons.

In addition to the increase in numbers of cultivators, there is a change in cropping pattern and increase in extent of cultivation. A considerable numbers of farmers have introduced new crops to their farming system.

Table 1: Use of different Water Source for Agriculture

	Type of land					
	Lowland(N=71)		Highland(N=65)		Home garden (N=161)	
Type of water source	No.	%	No.	%	No.	%
Irrigation channel	37	52	2	3	3	2
RRWH systems	25	35	23	35	117	73
Agro-well	3	4	4	6	15	9
Other water sources	-	-	-	-	2	1
Rainfed cultivation	7	10	37	57	39	24

Source: Authors' survey data, 2007

Table 2: Use of RRWH Systems for Various Activities

Purpose of use	% of respondents
Only seasonal crop cultivation	6
Only perennial crops cultivation	3
Both seasonal and perennial crops cultivation only	9
Crop cultivation+ livestock only	12
Crop cultivation + Aquaculture only	32
Crop cultivation+livestock+Aquaculture	25
Livestock only	2
Aquaculture only	1
Livestock+ aquaculture only	1
Use for household needs	49
No activities/abandoned pond	9

Source: Authors' survey data, 2007

Table 3: Changes in Cropping Pattern of Annual Crops in *yala* (dry) seasons (before Vs after the project)

	Before project	After project	
Name of crop	No. of farmers cultivated	No. of farmers cultivated	% change
Cowpea	11	32	+65
Green gram	7	19	+63
Rice	1	15	+93
Ground nut	4	12	+66
Maize	1	7	+86
Ginger	10	2	-80
Other traditional cereals*	4	3	-25

Source: Authors' survey data, 2007

* Other traditional cereals includes Finger millet, Millet and Italian millet

Table 4: Changes on Cropping Pattern of Seasonal Crops during *maha* (wet) seasons (before and after the project)

	Before the project	After the project	
Name of crop	No. of farmers cultivated	No. of farmers cultivated	% change
Cowpea	50	52	+4
Rice	26	52	+50
Green gram	45	45	0
Ground nut	26	40	+35
Maize	30	43	+30
Ginger	6	4	-33
Other traditional cereals	23	10	-56

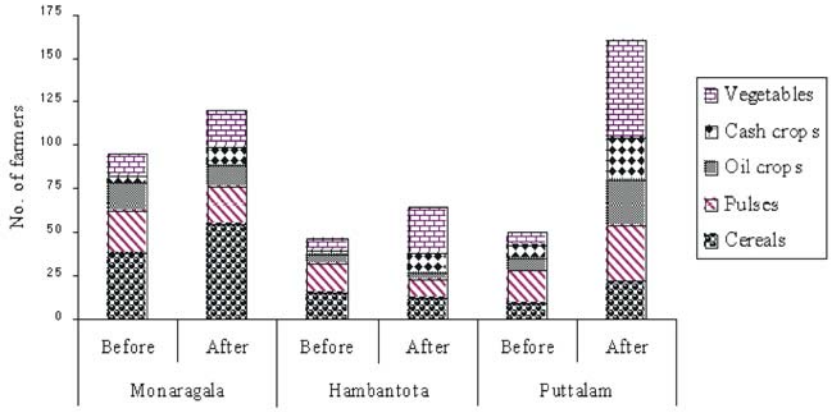
Source: Authors' survey data, 2007

The noteworthy change is number of farmers involved in staple rice crop cultivation has increased dramatically after the project as shown in Table 3 and 4. Another feature related to the change of cropping pattern is decreased in number of farmers involved in low input, less return rainfed traditional cereal crops such as finger millet (*Eleusine coracana*), Millet (*Panicum millaceum*) and Italian millet (*Setaria Italica*) and increased in irrigated crops such as cowpea (V*igna catiang*), Green gram (*Phaseolus aureus*) and Ground nut (*Arachis hypogaea*).

Cereals, pulses, oil crops, vegetables and cash crops (chillie and onion) are the main groups of annual crops cultivated in the study areas. As illustrated in Figure 2 the numbers of farmers involved in various categories of annual crops cultivation have increased after the introduction of RRWH systems to the beneficiaries' farming system. Figure 3 shows that the involvement of farmers in perennial crops cultivation such as timber trees (Teak, *Halmilla* etc), fruit trees (Mango, orange, papaya, guava, coconut, pomegranate, banana, cashew, Lime etc) and food crops (Coconut, Jack, bread fruit, drumstick etc) have increased tremendously after the project.Farmers have been very successful in safeguarding these trees during dry periods with the help of water available in runoff tanks. In the long run farmers are expect to receive better income from perennial trees at their maturity.

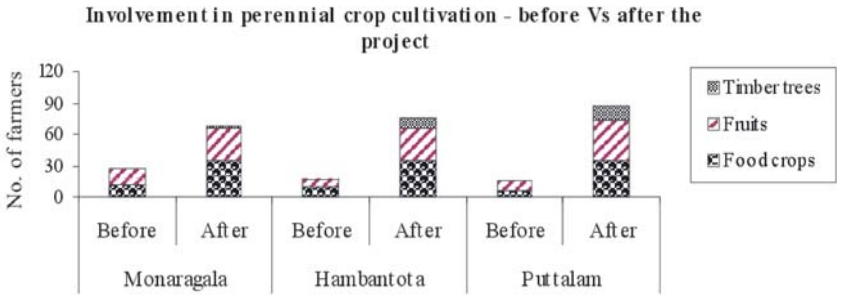
The main causative factors for the changes in cropping pattern after introduction of RRWH systems are introduction of vegetable cultivation, commencement of perennial crops cultivation, introduction of new perennial crops, shift towards the cultivation of high water consuming crops, increase extent of cultivation during dry seasons, commencement of cultivation by new farmers and expansion in extent of cultivation by already cultivating farmers.

Effectiveness of Rrwh in Agriculture: The study experiences clearly demonstrate that RRWH interventions have been effective in enhancing agriculture production and household income, especially in dry (*yala)* seasons. About 91 percent and 28 percent of farmers who under take seasonal crops cultivation are using runoff rainwater stored in the RRWH systems as a supplementary water source during *maha* and *yala* respectively. This is a positive aspect and proactive reaction of farmers in utilizing limited available water source to acquire optimum results. In the mean time, about 72 percent of *yala* cultivators are using runoff rainwater as a sole source or main water source for their cultivation, which indicate the water scarcity condition in the area during dry seasons.



Source: Authors' survey data, 2007

Fig. 2: Involvements of Farmers in Annual Crop Cultivation by District (Before Vs after the Project)



Source: Authors' survey data, 2007

Fig. 3: Involvement Farmers in Perennial Crop Cultivation - before Vs after the Project

About 68 percent of perennial crop cultivators use the RRWH systems as a supplementary source of water, while rest of the people depends on them as a main or exclusive water source.

Use of Rrwh Systems for Animal Husbandry: Availability of RRWH systems have greatly influence the water security situation of the domesticated animals in the area. Cattle and poultry are the main livestock reared by the 86% and 25% of sample households with some linkages on RRWH systems. About 9% of livestock farmers are also having buffaloes and goats. About 6 percent of livestock farmers are utilizing the RRWH systems solely for livestock rearing.

About 40 percent of the sample beneficiaries are using RRWH systems to fulfill the various needs of livestock. The various uses of RRWH systems related to livestock rearing as perceived by the beneficiaries are listed in Table 5. The findings show that, the systems are used for multiple purposes in the livestock industry, while 98 percent of beneficiaries using the ponds for drinking water needs of animals mainly during water scarcity periods. About 69% of livestock entrepreneurs have accepted that there is an improvement in livestock related income after introduction of RRWH systems to their farming system.

About 71 percent of users of RRWH system for animal rearing claimed that, there is no problem of using RRWH systems in the livestock enterprises, while 18 percent of beneficiaries mentioned about insufficient water available in the pond to undertake both agriculture and livestock enterprises together. However, only 3 percent of farmers have some concerns about the inadequate quality of water for livestock.

Use of Rrwh Systems for Aquaculture: About 31 percent of beneficiaries have some experience of using the RRWH systems for aquaculture, while performing crop cultivation activities. Number of seasons practiced aquaculture by these farmers is varied from 1 to 4. About 34 percent of practitioners have use the RRWH systems for aquaculture only one season in the past,

Table 5: Various uses of RRWH Systems for Livestock Enterprise

Uses	No. of responses(N=65)	% of responses
Drinking needs of animals	64	98
Wallowing for buffaloes	5	5
Water for bathing and sanitation	20	20
Water for cooling effect of animal sheds	2	2

Source: HARTI survey data, 2007.

Note: N denotes total number of livestock farmers and percentages are based on N

Table 6: Use of RRW Collected for Household Needs

Purpose	No. of responses(N=79)	% of responses
Bathing	54	68
Other Sanitary Requirements	50	63
Washing cloths	50	63
Washing Kitchen utensils	43	54
Watering Ornamental plants	39	49
Cooking	6	8
Drinking	3	4

Source: Authors' survey data, 2007

while 42 percent and 21 percent of practitioners have used twice and four times respectively. Another 24 percent of the beneficiaries have the experience of performing integrated farming activities of crop cultivation, livestock rearing and aquaculture using the water resource available in the RRWH system.

Non availability of water in the RRWH systems throughout the season, low level of growth of fish fingerlings within the recommended time period and lack of adequate knowledge on aquaculture are major problems hindering the practice of aquaculture. However, about 16 percent of respondents mentioned as no problem of undertaking fish culture in the given RRWH systems.

Although marketing of surplus agricultural production has been one of the biggest challenges in the remote rural areas, it was not the case among the aquaculture farmers. Fish culture has contributed very much in improving food security of the households as well as neighbors while improving the nutritional values of food. The farmers have made linkages with local traders to market their excess fish harvest at reasonable price. Farmers have earned an income of Rs. 5,000[1] to 20,000 per season from marketing of surplus fish production without much effort. The prawn culture farmers (about 4% of total aquaculture farmers) have earned income of up to Rs 20,000 per month.

Use of RRWH for Domestic Needs and Other Indirect Impacts: About 48 percent of sample households are utilizing the harvested runoff water for various household needs except for drinking. Bathing during dry periods, sanitation, washing cloths and washing kitchen utensils are the major uses of the runoff water at household level (Table 6). Only few families have utilized the water for drinking and cooking.

RRWH systems have been constructed in the water scarce and marginal rainfed areas. Therefore it was expected the construction of ponds have an impact on local micro environment around the ponds through evaporation, infiltration and seepage of water. According to the beneficiary perceptions, 85 percent have realized the changes in the surrounding micro environment after construction of RRWH tanks. The beneficiaries have listed multiple indicators to prove their perception. The most important impact perceived by the 88 percent of respondents is the survival of vegetation in the surrounding environment of RRWH system during dry spells, which were severely effected before construction of the RRWH tank. Some of the other impacts realized by the beneficiaries are Greener homestead environment and scenic beauty (54%), increased water levels in the domestic wells (35%), increased water levels in the neighbours wells and increased the yield level of perennial crops (15%).

It has been reported by 37% of beneficiaries that, large number of neighbours living around RRWH systems are also using the water for the various household and on-farm activities during dry periods. It is interesting to note that, even in the drier environment about 22% on non owners of the tanks (neighbours) have been allowed to use the RRWH systems to save their crop and various other household needs, which has indeed helped to build up the social relations in the village environment.

1US $= Rs. 110 inMay 2009.

Concluding Remarks: RRWH ponds are most popular for highland and home garden cultivation in the water dry areas of the country. Further about 35 percent of farmers use RRWH pond water for some of their lowland plots as a supplementary water source mainly to cultivate rice.

Runoff water collected in the pond has been used to cultivate annual crops or perennial crops or both types of cultivation. Large numbers of farmers have increased their extent of cultivation especially during *yala* season and introduced number of new crops after construction of RRWH ponds. The number of farmers involved in seasonal crops cultivation has increased significantly after introduction of RRWH systems especially during *yala* seasons. RRWH ponds are also used by the neighbours time to time during water scarcities for various purposes. The majority of annual crop cultivators in the areas uses the RRW as the main source during yala seasons, while perennial crop cultivators mainly utilizing the source as supplementary resource. RRWH interventions have been effective in enhancing agriculture production and household income, especially in *yala* seasons.

Farmers are utilizing the harvested water very carefully as majority of them are not practicing water intensive flood or furrow irrigation method for both annual and perennial crops cultivation. Farmers have adopted good water management practices such as use of hosepipe and buckets/cans to irrigate the crops in order to avoid the water wastages. However, the progress of adoption of micro irrigation technology to use the available water more efficiently is very less. The financial, technical and social capacities to adopt high tech irrigation technologies need to be developed parallel to the RRWH interventions.

Availability of RRWH systems have greatly influence the water security situation of the domesticated animals in the area. Cattle and poultry are the main livestock reared by the households with some linkages on RRWH systems mainly to fulfill the drinking water needs of the animals during water scarcities. Majority of livestock entrepreneurs have accepted that there is an improvement in livestock related income after introduction of RRWH systems to their farming system.

Fish culture has contributed very much in improving food security of the households as well as neighbors while improving the nutritional values of food and level of household income without much effort. However, non-availability of water in the RRWH systems throughout the season, low level of growth of fish fingerlings within the recommended time period and lack of adequate knowledge on aquaculture are major constraints hindering the promotion of aquaculture. However no beneficiaries have mentioned the marketing of surplus fish as a problem though marketing is a common problem for most of the agricultural produces in the remote villages.

Almost half of the sample households are partially utilizing the harvested runoff water for various household needs such as bathing during dry periods, sanitation, washing cloths and washing kitchen utensils at household level. RRWH systems are constructed in the water scarce and marginal rainfed areas have an indirect impact on local micro environment around the system. The most important impacts are the survival of vegetation during dry spells, which were severely affected before construction of the tank, groundwater recharge as indicated by the water levels of domestic wells and increased productivity of perennial crops.

Intervention made in the marginal areas in developing RRWH has proved as success strategy in developing the areas and minimize the effects of water scarcity, droughts and flash floods. However it is very important to consider the suitability of location and soil type of the area to collect and store sufficient water for considerable period of time, unless it will be futile due to loss of retention of water. Integrated farming with crops, livestock and aquaculture under the runoff harvesting practice in dry areas in the country has yielded higher return in a short period of time with a small investment and also has resulted significant benefit to the environment.

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