RUNOFF RAINWATER HARVESTING INTERVENTIONS IN SRI LANKA

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FOREWORD

History of practicing Rain Water Harvesting (RWH) techniques to meet the requiments of water in Sri Lanka goes beyond the 5th century B.C. Today rainwater harvesting is being used worldwide to meet the water demand for drinking and agricultural purposes. Water shortage is still a major problem facing a large number of people engaged in agriculture in dry zone areas and also a major factor that hinders the economic development. It is estimated that 28 million m^3 of rainfall is lost in the form of runoff in each year, which could be harvested to irrigate a sizable areas. Even in places with less water shortages, demand for additional water is significant. As rainwater harvesting techniques in general are not fully utilized, there is a grate need to focus and expand the runoff rainwater harvesting practices in a systematic manner.

The findings of this report highlights the possibility of promoting runoff rainwater harvesting systems to generate additional income for rural folks through agricultural intensification and enhanced livestock and aquaculture activities. The effects of runoff rainwater harvesting interventions on rural agricultural sector are two-fold. Firstly, the increased use of rainwater harvesting provides additional or secured water supply and consistency of the water source and reduces pressures on surrounding surface and groundwater resources. Secondly, rainwater harvesting can reduce erosive storm flow, decreasing incidence of flooding and short peak flows and also control soil erosion. In addition, the environmental benefits of runoff water harvesting and construction of micro storages are enormous. They help to maintain greener micro environment and reduce vulnerability in the event of prolong drought especially in the context of climate change.

The report highlights that future interventions aimed to promote runoff rainwater harvesting technologies must pay greater attention to suitability of the technology in a given context and acceptability of the system by beneficiaries. Stakeholder consultation and public participation are key factors in balancing the positive and negative trade-offs that may emerge.

Lalith Kantha Jayasekara
Director

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The success of the entire study rested on the runoff rainwater harvesting farmers in the study areas. The research team is extremely grateful to them and the officials of Agrarian Service Centers for sharing their experiences and valuable time in conducting this study.

M. A.C. S. Bandara
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EXECUTIVE SUMMARY

This study was conducted to assess the performance of Runoff Rainwater Harvesting (RRWH) systems intervention, in improving the livelihoods of the marginal farmers in the rainfed areas of dry zone of Sri Lanka. Government and non governmental organizations (NGOs) have introduced homestead level RRWH systems in some of the dry areas of the country to minimize the negative effects of drought. Two major approaches were adopted by the implementing organizations, and those are namely; full subsidy for the construction and partial subsidy for construction, with a farmer participation and contribution. However, the performance of these systems and the intervention approaches were not systematically assessed up to now. Considering the forecasted climate change impacts and the consequent increasing water scarcity conditions specially in the dry areas, it is important to asses the intervention and performance of the existing RRWH systems to use the RRWH systems as a tool to minimize the effect of drought disaster.

Findings of the present study are based on the data collected from field survey of randomly selected 161 RRWH farmers. Sample households were selected from the three districts namely Moneragala, Hambanthota, and Puttalam.

The findings show that 75 percent of RRWH systems beneficiaries have received their systems under fully subsidized approach without any beneficiary contribution. Over 88 percent of the partially subsidized recipients have shared 50 percent of the cost of construction of the RRWH system and the rest of the beneficiaries have shared only 25 percent of the total cost. About 9 percent of RRWH units were found abandoned due to various reasons. The main reasons for the failure of the systems are technical errors that have occurred during the construction phase, and the construction of RRWH unit at unsuitable locations (improper soil condition to store harvested rainwater etc.). Out of the total failed RRWH systems, 93 percent of them have been granted under the fully subsidized scheme. This clearly indicates the importance of farmer participation and contribution in construction of RRWH system. The findings also indicate that, the system failure was minimal where site selection for the RRWH system was done jointly by both farmers and project officials. The site selection for about 93 percent of failed systems has been done by either farmers or project officials alone. However, only 5 percent of the systems have failed primarily due to construction errors, where site selection was done by consultation with both parties (viz) i.e. project officials and farmers.

The findings of the study showed that, farmers utilized the harvested rainwater stored in the RRWH units for various purposes such as agriculture, livestock rearing, aquaculture and various domestic needs. The RRWH units are most popular for highland and home garden cultivation but, about 35 percent of farmers use runoff water for some of their lowland plots as a supplementary water source. The number of farmers involved in seasonal crop cultivation has increased significantly after introduction of RRWH units. The increase is very much significant during *yala* seasons. The cropping pattern and increase in extent of cultivation has increased among RRWH farmers. A considerable numbers of farmers have introduced new crops to their farming system. The noteworthy change is number of farmers involved in paddy cultivation has increased dramatically after the implementation of project

even in the rainfed areas located in the drier part of the country. A majority of the *yala* cultivators are using harvested rainwater as a sole or main water source for their cultivation, which indicates the water scarcity condition in the area during dry seasons.

Cattle and poultry are the main livestock reared by the beneficiaries with some linkages on RRWH systems. About 6 percent of livestock farmers use the RRWH units purely for livestock rearing. About 70 percent of livestock entrepreneurs have accepted that there is an improvement in livestock related income after introduction of RRWH units to their farming system.

About 31 percent of sample beneficiaries have used the RRWH units for aquaculture, while performing crop cultivation activities. Non availability of water in the RRWH units throughout the season, low level of growth of fish fingerlings within the recommended time period, and lack of adequate knowledge on aquaculture are the major problems specified by the farmers in performing aquaculture.

Almost half of the sample households are utilizing the harvested runoff water for various household needs except for drinking while utilizing for cultivation and other purposes. Around 85 percent of beneficiaries have realized the positive changes in the surrounding micro environment after construction of RRWH units. Rainwater harvesting is a guaranteed source of water for multiple uses, with low institutional and almost no operational and maintenances cost for the government.

The sensitivity analysis of the economic analysis under different scenarios indicated that the investment on RRWH units remain economically viable. Siltation of ponds was the main problem experienced by farmers when they are using the RRWH units. Loss of water through the cracks formed in the ponds, evaporation and percolation losses and damage created to bunds by wild and domestic animals are the other main problems encountered by farmers at the later stage of the system operation

Integration of crops with livestock and aquaculture into the farming system under the RRWH units in dry areas in the country can make higher return in short term period. The farm pond concept also has increased the household food security at a considerable level among the poorest rain fed farmers living in the more vulnerable and marginal areas. It is recommended to provide subsidies or credits to needy farmers after proper assessment. The location and soil type of farm pond must be suitable to collect and store sufficient water to use it for considerable period of time. The adoption of micro irrigation technologies to increase water use efficiency, cultivation of shade plants around the RRWH systems to reduce evaporation losses and introducing techniques like lining with cement/ sand mixtures or plastic sheeting to reduce seepage can maximize the use of harvested water. The study strongly recommends that any future interventions aimed to promote RWH technologies must provide greater attention on the appropriate approach to be adopted in the project implementation and suitability and need of the system into the given locality, rather than focusing on numbers.

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ABBREVIATIONS

ADB	-	Asian Development Bank
ADRA	-	Adventist Development & Relief Agency Sri Lanka
ASIA ONLUS	-	ASIA ONLUS
Aus Aid	-	Australian Aid
BLIA	-	Buddha's Light International Association
CI	-	Care International
CWSSP	-	Community Water Supply & Sanitation Project
DS Division	-	Divisional Secretariat Division
EC	-	Ekamuthu Cultivators
IMF	-	International Monetary Fund
IOM	-	International Organization for Migration
KORBMO	-	Kala Oya River Basin Management Office
LRWHF	-	Lanka Rain Water Harvesting Forum
NGOWSSDS	-	NGO Water Supply and Sanitation Decade Service
NWSDB	-	National Water Supply & Drainage Board
ORDE	-	Organization for Resource Development and Environment
PALM	-	PALM Foundation
Plan SL	-	Plan Sri Lanka
PRDA	-	People's Rural Development Association
RRW	-	Runoff Rainwater
RRWH	-	Runoff Rainwater Harvesting
WV	-	World Vision

CHAPTER ONE

Introduction

1.1 Background

Sri Lanka, like other South Asian countries, has an agrarian economy, with a small industrial sector. Agricultural production is highly dependent on the vagaries of nature with significant variability in production. The agricultural sector, on average, accounts for about 11.9 percent of the GDP, 33 percent of employment (Department of Census and Statistics, 2007) , over 19 percent of the total foreign exchange earnings, and major supplier of food stuff for consumers in the country (Central Bank of Sri Lanka, 2007).

Rural community in Sri Lanka comprises nearly 80 percent of the population of 20 million (DCS, Censes of Population and Housing, 2001). Predominantly, the rural population is engaged in farming as the main occupation. Majority of these farmers are paddy farmers since rice is the staple food of Sri Lanka (Mahrouf, 2006).

From the total land area, 27 percent is used for agricultural purposes and 30 percent is covered with forest (Water Statistic, 2003). Most of the land used for agriculture is rainfed land where cultivation is mostly done without using surface or groundwater for cultivation. In the dry zone 20 percent of the rain fed land is used as *chena*[1] cultivation. Irrigated land occupies 24 percent of agricultural land and paddy is the main crop cultivated under irrigation, which accounts for 41 percent of agriculture lands. Village settlements in the dry zone are mostly located near or around reservoirs mainly due to the availability of irrigation water for the livelihood and assured availability of water to meet domestic requirements.

One of the major development challenges in the country is how to promote food production to meet the ever-increasing demand of the growing population. According to the water statistics in the country ample amount of rainfall has been received during the rainy periods, but due to temporal and spatial variability of rainfall, water scarcity condition for crop cultivation is reported in many instances, especially in the drier part of the country and during *yala*[2] seasons. Most of the precipitation received to the country is not fully captured in many areas due to poor vegetation cover and poor soil condition and lost through direct evaporation or uncontrolled runoff. Thus, there is need for appropriate strategies to harvest the runoff using suitable technologies to address the water scarcity condition in drier areas.

Annually through two major monsoons, country is receives ample amount of rain, 43 Million Cubic Meters (MCM) flows as runoff, out of which 28 MCM (65 percent) escape into the sea (Water Statistics, 2003). Sri Lanka has made remarkable efforts since ancient time to harvest monsoonal rain through construction of large and small

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[1] *Chena* is a traditional form of cultivation carried out in jungle using seasonal rainwater under slash and burn method. Under this method farmers clears bushes in the jungle and burn it but do not destroy the larger trees.

[2] *Yala* is the dry season in Sri Lanka mainly extending from April to September and receives rainfall from South west monsoon.

tanks and reservoirs. However, still there is a potential of harvesting some more runoff for the use of agricultural and domestic purposes in water scarce areas.

Use of rainwater harvesting for agriculture in Sri Lanka has a long history and still widely practiced in areas where there is a failure of the seasonal rains or drier climatic conditions. Large number of surface runoff collection tanks known as '*Wewa*' had been constructed and operated mostly in drier parts of the country to serve the agriculture and other water related activities. These tanks were constructed during the ancient king's era, mainly to cultivate paddy and Other Field Crops (OFC's).

There are large numbers of evidences to describe the water scarcity situation in dry zone areas for cultivation purposes and other needs. Available water in the tanks (*Wewa*) was not enough for full scale cultivation in some seasons due to low water availability (Sunday Observer, 1999/09/05). According to the accepted norms of the village people on water allocations, the priorities have given mostly to domestic needs and fishing industry during water scarcity periods (Lakbima, 2002/12/04). During water scare periods most of the agricultural production systems are interrupted or failed and farmers have to seek alternative water sources available to safeguard their cultivation. During past few years, farmers had to experience water scarcity problems for both domestic needs and cultivation practices due to low rainfall or drought condition occurred, especially, in Hambanthota, Moneragala and Puttalam districts (Divaina, 2002/08/04, 27).

With regard to irrigated agricultural development, small scale irrigation schemes seems to be more preferred than large scale schemes due to varies reasons, namely requirement of high capital cost for constructing large scale irrigation scheme which can only benefit a fortunate few, risk of system failures due to uncertainty of the rainy condition and need high cost of maintenance. Small scale irrigation systems are easily adoptable to land condition.

There is new increasing interest among development planners to the low cost alternative, generally referred as 'water harvesting', focusing on small-scale farming systems. Runoff, instead of being considered as a problem, it can be harvested and used for different purposes, which is lost otherwise causes flash floods and soil erosion. Various methods of rainwater harvesting, which rainwater is captured, stored and used at times of water scarcity are available. Rainwater harvesting can be broadly defined as a collection and concentration of runoff for productive purposes like crop, fodder, pasture or trees production, livestock and domestic water supply (Gould, 1999).

The annual average rainfall multiplied by the surface area of the country gives the total runoff, and it amounts to large volume of water. Rainfall constitutes a major water source of the country but, it is lost almost completely through direct evaporation or through uncontrolled runoff. With the present climate change (increasing rainfall intensity and expanded dry period) the situation can be worsen in the future. So, there is an urgent need to explore the possibility of supplementing the irrigation water with alternative supply such as rainwater harvesting to minimize the problem of water deficit.

The concept of rainwater harvesting is not a new technique to Asian region in general and for Sri Lanka in particular. Ancient's kings have developed Rainwater harvesting systems to capture and store seasonal rainwater to use it during water scarcity periods for supplemental irrigation, animal rearing and domestic purposes while preserving the environmental sustainability.

1.2 Problem Statement

Despite agriculture is an integral part of rural livelihood of Sri Lanka, farmers in water scare areas are unable to succeed in their agricultural ventures due to the unreliable water supply. The situation creates two interrelated problems for farmers in marginal rainfed areas. Firstly, as rainfall is highly unreliable; farmers adopt risk aversion approach via minimizing their investments in labour, seeds and planting materials, fertilizer and other cash investment in order to minimize anticipated losses due to drought or water scarcity. The lack of investments in production inputs means that even when good rainfall occurs, the yield is not as large as it should be. Secondly, food price are tend to rise dramatically in times of drought or off seasons, when there is low supply. In periods of good rainfall, when harvests exceed subsistence needs and there is a lot to sell. To minimize this kind of situations farmer need reliable water source at farm levels in order to select suitable crops and optimum extent of cultivation in line with the market demand forecast. Therefore, runoff rainwater harvesting, can be effectively use by resource poor farming households, to overcome hardships of this nature.

Small-scale privately owned and managed RRWH systems (farm ponds) are constructed and dispersed among several districts in Sri Lanka to improve the income level of poor households via developing supplementary irrigation. This kind of systems was initially introduced by NGO's such as World Vision, Practical Action (formerly known as ITDG), Janashakkathi Development Centre, Canadian Development Fund, CARE International, Australian Aid etc, and later government organizations also involved in promotion of RRWH systems. RRWH projects incurred huge amount of money in the past. For instance, one of the above mentioned NGO's has invested Rs.2.5 million from year 2003 to 2004 for construction of RRWH systems in Moneragala district alone.

The investment on RRWH systems is still continuing in various drier areas of the country. Although RRWH systems is considered to be one of the appropriate strategies to minimize the drought disaster risk as experienced in many other countries like China, Iran, India, Tanzania etc; the present RRWH systems implemented in Sri Lanka are not comprehensively assessed to find out the prospects and constraints of on going projects. It is also important to understand the economical, environmental and social issues of RRWH project, which need to be addressed in the future development path.

1.3 Need of RRWH in the Present Context

Sri Lanka is a country blessed with ample water resources in aggregate terms and wisdom of traditional water management practices of the country are dating back to 5th century BC. However the seasonal and geographical rainfall patterns indicate the high degree of variation in the availability of water temporally and spatially in different parts of the country. Sri Lanka has the second highest annual variability of rainfall out of 22 Asian and Pacific countries (De Silva, 2004).

Although Sri Lanka is located in tropical climate region with heavy monsoonal rain, and having large number of water storage structures, dry zone of Sri Lanka experienced some kind of drought almost every years mainly due to delayed or shortened monsoon rain. Successive droughts were experienced in 2001, 2002 and 2004 in the dry zone of Sri Lanka, and have lead to many hardships to the people in the drought affected areas; mainly loss of livelihoods and lack of access to water for drinking and domestic purposes. Drought of 2004 realized in 7 districts and caused damages to 52,651 ha of crops while affecting 231,076 families (Ariyabandu, 2005).

Change of climate is expected to trigger more water scarcity and water management problem in the country. The past rainfall records indicates that, daily rainfall intensities and the lengths of dry spells are increasing, while the lengths of wet spells are decreasing (Ratnayake and Herath, 2005). At the meantime, it has been predicted that, by 2050, the amount of rainfall received from North West monsoon which is the major source of water for dry zone of Sri Lanka is to be reduced by 34 percent and the rainfall received from South-West monsoon is to be increased by 38 percent (de Silva, 2006). The predicted condition had the ability to create more drought prone condition in dry zone districts and more floods and landslide problems in the wet zone districts.

Therefore, the country needs more viable strategies to face envisaged water crises and the management of available water resources. One of the solutions to address the condition of excessive runoff and intensive short spell of rainfall is storage of runoff water. Construction and popularization of farm pond was seen as one of the feasible mechanisms to harvest runoff water and store it for use in water scarce period.

Large-scale dam and irrigation projects had been implemented in Sri Lanka. But, they have often proved to be too expensive and demanding more resources for construction and maintenance. Therefore, micro scale water harvesting ponds at the village or household level are seen as a practical and effective alternative to improve the lives of rural people at little cost and with minimal outside inputs. In theory, household water harvesting can be done mainly through the effort of the individual farmer. Use of stored rainwater could supplement natural rainfall and make farming families less vulnerable to drought and therefore less dependent on outside help in harder times (Gould, 1999).

1.4 Objectives

The major objective of the study is to find out prospects of introducing runoff rainwater harvesting system in Sri Lanka and to identify the existing problems and constraints experienced by farmers in order to understand the potential of promoting the runoff rainwater harvesting technology in the Sri Lanka with special reference to drier parts of the country.

The specific objectives of the study are following;

1. To asses the implementing strategy and level of success of runoff rainwater harvesting systems implemented by various organizations in several part of the country in minimizing effects of water scarcity.
2. To examine the usefulness of runoff rainwater harvesting systems in enhancement of household income and fulfilling various water needs.

3. To study the changes in cultivation pattern and other livelihood activities after intervention.
4. To identify problems and constraints in using existing runoff rainwater harvesting technologies to minimize the difficulties of water scarcity.
5. To find out economic feasibility of individually owned and operated runoff rainwater harvesting systems in agriculture production.
6. To make necessary recommendations for the future interventions in similar nature of runoff rainwater harvesting to minimize the impacts of drought disasters.

1.5 Research Methodology

The study was mainly based on quantitative and qualitative data collected from primary and secondary sources. The data was collected using several methods and approaches including a questionnaire based empirical field survey, interviews of field level officers and implementers of RRWH projects under the various NGO's, informal discussion with key informants in the study villages, and focus group discussions with the stakeholders of the projects. Secondary data were gathered from literature available on RRWH for agriculture and project documents maintained by the implementers. Three districts were selected to study the different kind of RRWH systems implemented in different context. The sample survey was undertaken during the period from October to November, 2007.

1.5.1 Description of the Study Sites

Moneragala, Puttalam and Hambanthota districts were selected for the study, which are vulnerable for drought incidents compare to other areas in Sri Lanka. These districts have comparatively higher percentage (Hambanthota 95.6%, Puttalam 90.5% and Moneragala 97.7%) of rural population. (Department of Censes Statistics, 2001). The rural people are mostly depending on agriculture for their livelihood. However, farming activities of rural people have been interrupted due to unexpected drought. Therefore, various organizations implemented large RRWH systems in the selected districts. The details of study sites are given in table 1.1.

Table 1.1: Sample Size and Study Locations

District	DS division	Beneficiary population	Sample size (Households)
Puttalam	Karuwalagaswewa	122	29
	Wanathavilluwa	116	13
Moneragala	Siyambalanduwa	267	25
	Thanamalwila	188	42
	Wellawaya	20	10
Hambanthota	Lunugamwehera	125	42
Total		838	161

Source: HARTI survey data, 2007

1.5.2 Sampling Procedure and Methods of Data Collection

The sample frame was prepared using the beneficiary list maintained by the RRWH systems implementers in the study areas. The beneficiaries who received RRWH systems before the year 2005 were selected for the study. The total sample size of the study is 161 detailed out in table 1.1 and selected randomly using stratified random sample technique. Sample size represents more than 10 percent of the total population which was selected in six different locations from three districts (Table 1.1). The questionnaire survey was focused on general socio-economic status of farmers, the extent of cultivation, cropping pattern, cropping intensity, household income, and use of water application systems, possibilities of using RRWH ponds for non agricultural uses and merits and demerits of present RRWH systems.

The research team visited the line agencies relevant to the implementation of RRWH systems, agriculture officials, farmer leaders and selected RRWH farmers, in order to understand the prospects and issues in using RRWH systems.

Case studies were conducted to generate necessary data to perform the economic analysis of RRWH systems. The required data such as cost of production, yield, and farm gate price of the produces were collected from case studies. Case study locations were selected after a reconnaissance visits to the selected districts.

1.5.3 Data Analysis

The fist part of the data analysis mainly focuses on analyzing the descriptive statistics of the data mainly regarding household's socioeconomic characteristics. The second part is mainly focused the perception of farmers on the constraints and opportunities of RWH technologies.

The third part of data analysis is based on case studies conducted among the purposively selected two farmers from Puttalam and Moneragala districts. The selected farmers are using unlined open runoff harvesting ponds for cultivation purposes. Farm records maintained by the selected farmers and the secondary information maintained by the line agencies were used to calculate the Benefit Cost Ratio (BCR), Net Present Value (NPV) and pay back period of the investment made.

NPV and BCR are calculated as follows.

$$NPV = \sum_{i=1}^{t=n} \frac{B_t - C}{(l+i)^t}$$

$$BCR = \sum_{i=1}^{t=n} \frac{C_t}{(l+i)^t}$$

B_t	=	Benefit in year t
C_t	=	Cost in year t
t	=	1,2,3, ... n
n	=	life time of the farm pond in years
i	=	opportunity cost of capital/ rate of interest

The benefit item identified was the income earned from the cultivation under farm pond and cost items were the capital cost of farm pond, maintenance cost of farm pond and cost of cultivation. All costs and benefits were calculated at the present values at the interest rate of 10 percent, 12 percent, 15 percent and 20 percent. In terms of NPV criterion, the investment of farm ponds can be treated as economically viable if the present value of benefit is greater than the present value of cost. Similarly, if the BCR is greater than 1, the project is considered economically viable. The duration of time when the net revenue compensates for the total investment is the capital recovery period.

1.6 Significance of the Study

The study is expected to study the experiences and the problems encountered in the past interventions on RRWH, so that possible corrective measures could be taken into account when these interventions are replicated in other parts of the country or to improve the existing systems as well. Besides, understanding the impact of the RWH technologies on agricultural productivity with the use of rainwater harvesting systems, factors affecting the productivity or level of yield, is a vital issue for designing appropriate agricultural development policies and strategies, as well as technology interventions. Therefore, the outcome of this study may serve as a source of information for policy makers and planners in designing and implementing RRWH technology as a drought coping strategy in the future.

1.7 Scope and Limitations of the Study

The findings are based on a one-time field survey of 161 farm households and data gathered from qualitative methods and secondary sources. However, the study has the following limitations.

One of the limitations is the unavailability of base line data on project sites for proper assessment. Such data would reflect the condition of the farm household's agricultural production process in the pre-project situation, and would have been useful to conduct more comprehensive analysis. The other limitation of this study is omission of the environmental benefits and costs that accrue from the RRWH technology intervention due to lack of data on environmental benefits.

CHAPTER TWO

Runoff Rainwater Harvesting Systems

2.1 Types of Surface Water Storage Systems in Sri Lanka

There are different kinds of surface water storage structures in Sri Lanka. They differs each other based on capacity, type of management and irrigated command areas.

I. Large Reservoirs
There are number of large dams in Sri Lanka, which were mostly constructed after gaining independence in 1948. These dams are used to store water in large surface areas. Generally most of the large reservoirs are multi purpose and managed by the line agency or agencies Ex. Irrigation, hydropower and domestic water supply. The irrigation command area is generally far away from point of water storage. Therefore, conflicts in demand of water from multiple sectors complicating the operation of large reservoirs with the involvement of many parties and stakeholders under various institutional arrangements. Due to the greater depth of large reservoirs, the evaporation loss of large reservoirs is lesser and they have the ability to store water for multi years.

II. Major Irrigation Tanks
Major irrigation tanks are generally single purpose but sometime it is dual or multi purpose. The command area under a major tanks is over 200 ac (80 ha) located closer to the storage point. The major tanks are jointly managed by beneficiary farmers (farmer organization) and the irrigation agency. The evaporation loss is little higher than large reservoirs due to high surface area to volume ratio.

III. Minor Tanks
Minor tanks are also called as village tanks. They are defined in the present context a tank which has a command area of less than 80 ha. The primary source of tanks water supply is locally occurring rainfall i.e. direct rainfall on the tank surface and rainfall runoff from its own catchment (Somasiri, 2000). The number of minor tanks in working order at present is around 12,120 with a total command area of 168,788 ha and about 320,090 farmer families are benefitting from those tanks (Department of Agrarian Development, 2000).

Minor tanks are managed by farming community or Farmer Organizations with the technical support of the line agency as required. Therefore, the management of minor tanks is comparatively easier and with lesser institutional complexities. In most of the village environment, minor tanks serves for multiple needs such as irrigation, domestic water needs, aquaculture and livestock rearing. One of the major disadvantages of minor tanks is high evaporation loss due to high ratio of surface area to volume. The seepage and percolation "losses" from minor tanks in Sri Lanka is around 20 percent of tank volume (Tasumi, 1999) against 5 percent of storage volume in large reservoirs (Keller *et-al*, 2000).

IV. Micro Storage Facilities (Farm Ponds)

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 and locally designated as Pokuna /Pathaha. 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 to maximize the collection of surface runoff.

Although farm ponds were existed in the dry land farming for various purposes from ancient times, they were systematically incorporated as one of the components in dry land development in Muthukandiya dry farm development project implemented by an Aus Aid project in early 1980s. The project introduced about 500 farm ponds to the area to promote perennial crop cultivation such as cashew, mango and citrus crops while cultivating suitable seasonal crops. Later several international NGOs introduced farm pond as one of the strategies to develop dry lands and improve the food security condition of marginal dry land farmers.

2.2 RRWH Systems in the Sri Lankan Context

Sri Lanka has an average annual rainfall of 2,400 mm with a range of 900mm in the dry zone and 5000 mm in the wet zone. According to the water statistic of Sri Lanka, the total volume of water received from the annual rainfall is estimated as 118,015 MCM. The total runoff to the sea has been estimated as 28,000 MCM. Annually 6 percent of water is used for both domestic and industrial uses which are about 2,500 MCM. Therefore, the amount of available surface water can be estimated as 43,000 MCM by adding the water usage and the runoff to the sea.

Hence, the percentage of water utilization from available surface water is about at 35 percent and annually 65 percent of the water running to the sea without much direct use (Water Statistics, 2003). In this background, it is necessary to emphasize the importance of rehabilitation of existing water storage schemes and provision of infrastructures facilities to capture at least proportion of runoff water that flows to sea.

To Sri Lanka, Runoff rainwater harvesting is not a novel technology. Similar systems of runoff rain water harvesting were developed about 2000 years back during the Sinhalese kings and most of these tanks are functional even today. According to the history of Sri Lanka, traditional rain water collecting methods such as collecting rainwater from trees, using banana leaves or stems as temporary gutters has been reported. Some reports explain up to 200 liters of rainwater may be collected from a large tree in a single storm (Ariyabandu, 1998).

The system of minor tank cascades is a common feature in dry zone of Sri Lanka. There are about 12,500 minor tanks scattered throughout the dry zone and some reports indicated that they have an irrigation potential of about 100,000 ha (Gunasena, 2001). Other than irrigation, minor tanks are also used to supply water for drinking, fishing and environmental needs.

Institutionalized rainwater harvesting has started to receive significant attention from Sri Lankan government in the recent past. It has been regarded as one of the decisive tools to achieve household water security and food self-sufficiency, and is being promoted in various parts of the country particularly in water scarce areas. Large numbers of studies have been undertaken by various persons and institutions about domestic roof rainwater harvesting systems. However, regarding the RRWH systems no such systematic research has been undertaken so far. But, some preliminary studies have been made on some parts of the country which are specific to the site and institutions.

According to the Lanka Rain Water Harvesting Forum (LRWHF) information 22,543 RWH units have been built in Sri Lanka by Individuals, organizations and institutions till December 2007. Majority of these tanks were constructed under subsidy programmes of both the Government and NGO's funded by international funding agencies such as Asian Development Bank (ADB), IMF, USAID, etc. and local and international NGOs such as World Vision, Practical Action (Former ITDG), National Christian Council, PALM Foundation, Lanka Rainwater Harvesting Forum (LRWHF), Wayamba Farmers Development Foundation, Community Resource Development Organization, Care International.

2.3 Experiences of RRWH in Other Countries

China: The provinces of Gansu, Sichuan, Guangxi, Guizhou and Yunnan of China has developed and implemented rainwater harvesting techniques at field level since 1980's,. Gansu province is one of the driest and poorest regions of China; rainfall is low and so is the groundwater reserve, thus making life quite hard for the residents of the region. The Gansu Research Institute for Water Conservancy in collaboration with the local government of the province introduced a water-catchments project called '121' project, where the government supported the local people to prepare catchment areas, water storage facilities and catchments basin or planting area. The people of the region not only managed to put an end to the drinking water scarcity for themselves and their estimated 1.18 million livestock, but also managed, for the first time in history, to use their green houses for production of cash crops such as vegetables, herbal medicines, flowers and fruit trees and as well as nurseries using newly introduced rainwater harvesting structures (Gnadlinger 2000; Gould 1999).

Kenya: A study on rainwater harvesting conducted at Mwala division, Kenya indicates that harvesting runoff water for supplemental irrigation has proven as one of the risk-averting strategies. By using underground spherical tanks having a combined capacity of 60 m^3, seasonal water for supplemental irrigation for an area of about 400 m^2 was guaranteed. With rainwater harvesting, farmers have diversified to include horticultural cash crops and keeping of dairy animals. For instance households with supplemental irrigation earn US$735(per ha) from cash crop compared with US$146 normally earned from rainfed maize. This has contributed to food security; better nutrition and higher family income (RELMA-in-ICRAF, 2004).

Egypt: In Middle East, rainwater harvesting is thought to have existed about 9000 years ago in Jordan, and about 4000 years ago the Negev Desert of Israel (Nasr, 1999). A study by Nasr (1999) in Egypt showed that rainwater harvesting if systematically implemented not only helps in producing crops in areas where it otherwise wouldn't have been possible, but also helps in reducing or halting environmental degradation. Two types of storage facilities are common in the

Bedouin area. One is dams, constructed in channels either of earth or of stone depending on the slope of the soil. The water can then be applied either in the form of flood farming or by storing and using as a supplemental irrigation. The second is building earthen reservoir in depression. Most of the water harvesting systems are developed and utilized as a single-family business and are seldom owned communally, and almost all the household practice water harvesting of one or another form.

Zambia: Over 12% of the farm households in the southern province of Zambia were estimated to have adopted conservation agriculture technologies during the 2002/2003 season which has a component of the use of rainwater harvesting. The project area is estimated to have an extent of over 50,000 hectares. The experience of Zambia shows that crop yields have on the minimum doubled. Maize yield rose from under 0.5t/ha to above 2t/ha and cotton from 1.5t/ha to 3t/ha under conventional as compared to conservation agriculture respectively. This has been attributed to improved rainwater harvesting made possible by the planting stations and surface cover. Most farmers have diversified their cropping system to include crops such as maize, beans and sunflower. Increased production at the household level in the last five years has introduced the rapid re-birth of a cash economy among the communities. This has propelled private entrepreneurship in agricultural related trading. Large and small private entrepreneurs have emerged in the area and are selling agricultural inputs and other household commodities as well as buying off the crop. Most households are able to put up for sale 20-30% of their produce. The ultimate effect is enhanced livelihoods (UNEP, 2005).

Tanzania: Hatibu *et.al,* (1999) studied types and prevalence of rainwater harvesting technologies in Dodoma, Kilimanjaro and Mwanza areas of Tanzania. They have recorded the prevalence of agronomic practices like mulching and adding manure so as to raise the water holding capacity of soil; runoff utilizations that is used mainly for growing maize, rice and other high water demanding crops; diversion and utilizations of ephemeral streams and the use of rainwater harvesting with storage in the area. Farmers in the area are well aware of the importance of rainwater harvesting and water conservation in general, and are ready to accept technologies with proven yield increasing capacity; where such is found, farmers do all they can to acquire the necessary technology. Rainwater harvesting has played decisive role in reducing poverty and increasing income of the farmers where it is successfully adopted and implemented (Ibid).

India: India has a long tradition of rainwater harvesting so much so that it is regarded as one of the dying tradition of the country[3]. However, it has been spreading rapidly in many parts of the country, particularly in rain scarce areas. For instance, 'Derwadi', a village in the central state of Maharashtra, is one of such dry villages of India. It is a remote village with no assurance to drinking water, farming being mainly rain fed based and agricultural production can not meet more than three-month food need of the village. The villagers established a link with an Indo-German watershed Development NGO called Watershed Organization Trust (WOTR), which later assisted them to construct contour trenches, farm and contour bunds, and check dams

[3] Source of the India's experience is from www.rainwaterharvesting.org/rural, which describes the experience of rainwater harvesting in more than 20 Indian villages.

to collect rainwater. A degraded land then stared to provide adequate water both for drinking and for irrigation, thus paving the way for transformation of the lives of the villagers.

Gandhigram village of Gujarati state is another remote, water scarce village of India. This village is constantly suffering from acute water scarcity both for consumption and production. Assisted by a local NGO called Shri Vivekanand Research and Training Institute, the community started to build communal dams- small and big- in 1995 so as to store rainwater and use it during dry season. A committee was formed from among the beneficiaries to oversee the distribution of the water and maintenance of the dams. They evolved an interesting management mechanism where each household was asked to pay Rs 3 (equivalent of $0.067) per month for water supply for consumption purpose, and Rs 250 (equivalent to $5.56) per ha for irrigation purpose. The community managed not only to secure sustained supplies of water for domestic consumption, but also was able to get on upon producing high value crops like ground nuts, wheat, onion etc. They managed to increase their agricultural yield and work availability has also increased for land less laboures. As it has become beneficial, the momentum for rainwater harvesting continued in the village as is evident from community's interest to increase the number of dams by constructing new ones.

Ethiopia: The history of rainwater harvesting in Ethiopia is dated back to 560 BC in the tip Northern Parts of the country and to 15th to 16th century in Gonder area. It has been regarded as one of the crucial tools to achieve food self-sufficiency, and is being implemented on a large scale particularly in water scarce areas of the country. A study by Rami (2003), mainly on rainwater harvesting implementation related problems in the regions and the prospects of using it for the stated objective of attaining food self-sufficiency. It has been found that RWH is top of the agenda in the two regions, as is the case at national level, with some times over ambitious plans of constructing wells and ponds. The success in achieving the planed amounts of tanks and ponds to be constructed and the perceptions of the beneficiaries are found mixed. Shortages of required construction raw materials, lack of timely dispersal of finance and shortage of skilled labor have been among the factors inhibiting the attainments of the stated goals. This is evident from Amhara region where it was planned to construct 29,005 tanks made of cement and plastic but only 12,614 tanks were constructed and 27,955 wells were excavated.

CHAPTER THREE

Demographic and Socio Economic Characteristics

3.1 Population Composition

The total population of the sample comprised 698 individuals belonging to 161 households. Sex wise distribution of population indicates female dominance in most of the areas. The muscularity ratio[4] of the study population (male/female) is 93 percent, which is notably lower than the average country ratio of 98 percent (Department of Censes and Statistics, 2001).

Table 3.1: Population Composition among the Districts

District	DS Division	Sex (%)	
		Male	Female
Puttalam	Karuwalagaswewa	45.05	54.95
	Wanathavilluwa	52.54	47.46
Moneragala	Siyambalanduwa	47.57	52.43
	Thanamalwila	47.09	52.91
	Wellawaya	51.28	48.72
Hambanthota	Lunugamwehera	49.24	50.76
Total		48.14	51.86

Source: HARTI survey data, 2007.

3.2 Age Distribution

The analysis of the age structure indicates a predominantly youthful population in the study areas (Figure 3.1). The sex wise age distribution pattern with respect to age levels in the study population is illustrated in figure 3.1.

About 23.5 percent of the total population constitutes the "less than 14 years" age category (Table 3.2). 74 percent of the population is in the ages range between 15-64 years (Work force); where as 2.5 percent of the total population belong to age category of over 65 years.

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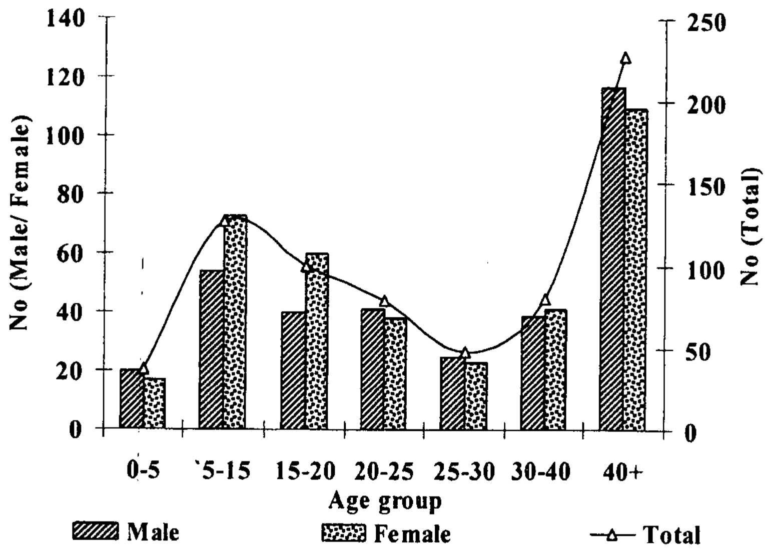
[4] Muscularity ratio is number of males per 100 females

Figure 3.1: Age Distribution by Sex



Source: HARTI Survey data, 2007

Table 3.2: Distribution of Labour Force by Age Group and Sex

Age Group	Sex				Total	
	Male		Female			
	No.	%	No.	%	No.	%
< 15	74	10.6	90	12.9	164	23.5
15 - 65	249	35.7	267	38.2	516	73.9
> 65	13	1.9	5	0.7	18	2.6
Total	336	48.1	362	51.9	698	100

Source: HARTI survey data, 2007

3.3 Family Size Distribution

According to the survey data average family size of the sample population is around 4.32. About 27 percent of the families have less than 4 members, 53 percent of the families have 4-5 members and rest have, 6 and more members. District wise average family size of the sample households is shown in table 3.3.

Table 3.3: Average Family Size by DS Division

District	Average Family Size
Moneragala	4.30
Hambanthota	4.69
Puttalam	4.05

Source: HARTI survey data, 2007

3.4 Educational Status

Table 3.4 shows the level of education in the selected districts. Nearly 4 percent of the population has not received formal education (The literacy rate of the study population is around 97 percent). About, 20 percent of population passed the GCE (O/L) and 8 percent of population has received education up to GCE (A/L).

Table 3.4: Level of Education by District

Levels	Moneragala %	Hambanthota %	Puttalam %	Total %
Infants (Not qualify for schooling)	2.60	2.40	1.70	6.70
Primary (0-5 years)	11.60	6.00	6.20	23.80
Secondary (6-10 years)	17.0	12.20	8.30	37.50
Passed GCE (O/L)	10.0	4.70	5.00	19.80
Passed GCE (A/L)	3.70	2.10	2.10	8.00
Graduates	0.15	0.15	-	0.30
No schooling (Can read & write)	0.40	0.10	0.30	0.90
No schooling (Illiterate)	1.90	0.40	0.70	3.00

Source: HARTI survey data, 2007

3.5 Labour Force and Land Utilization

According to the findings, the labour force represents 84 percent of the total population which comprises both economically active and inactive population. The economically active population comprises all the individuals between 15-64 years of age, both employed and unemployed during the period under review. The economically inactive population includes students, housewives, the sick and the old. The estimated age dependency ratio of the selected population is nearly 17 percent, which means 17 dependents for every 100 individuals in the production age group of 15-64 years. However, the estimated age dependency ratio varies considerably across the study locations (Table 3.5).

$$\textit{Age Dependency Ratio} = \frac{\textit{Age group (10-14)} + \textit{Age group 65 \& more}}{\textit{Age group (15-64)}}$$

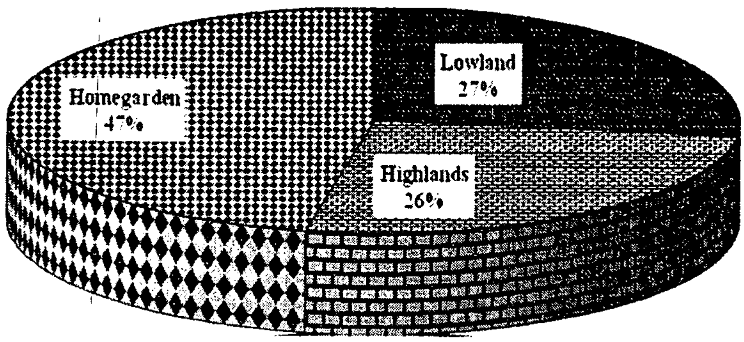
Table 3.5: Age Dependency Ratio by District

District	Age Dependency Ratio
Puttalam	14.06
Moneragala	15.56
Hambanthota	22.13

Source: HARTI survey data, 2007

In terms of land utilization, lands are categorized into three categories, namely low lands, highlands and home gardens. According to the findings most prominent land category is home gardens consisting of 47 percent of the total land holdings. Figure 3.2 illustrates the land utilization pattern in the sample population. The findings illustrate the prominent nature of upland cultivation (highlands and home gardens) in the economy of the selected areas.

Figure 3.2: Land Utilization Pattern (% of No. of Land Holdings)



Source: HARTI survey data, 2007

Table 3.6 shows the land size distribution in accordance with the different land size classes. Nearly 50 percent of lowland holdings are under 1.5 ac, while around 50 percent of agricultural holdings belong to both highland and home garden categories are in the range of 1.5-3ac. Table 3.7 gives an idea about the land extent distribution in the area.

Table 3.6: Land size distribution based on No. of Land Holdings

Range of land extent (ac)	% of No. of Land Holdings		
	Lowlands	Highlands	Home gardens
1.5	49.3	27.7	19.9
1.5 ≤ 3	32.4	49.2	46.6
3 ≤ 4.5	14.1	15.4	17.4
4.5 ≤ 6	4.2	4.6	13
>6	0	3.1	3.1
Total	100	100	100

Source: HARTI survey data, 2007

Table 3.7: Land Size Distribution Based on Total Land Extent

Range of Land Extent (ac)	Land Extent							
	Low Land		Highland		Home Garden		Total	
	Extent (ac)	%	Extent (ac)	%	Extent (ac)	%	Extent (ac)	%
< 1.5	32.25	26.5	14.55	9.6	29.25	7	76.05	10.98
1.5 ≤ 3.0	65	53.4	69	45.4	147	35.1	281	40.56
3.0 ≤ 4.5	19.5	16	40.5	26.6	99.5	23.7	159.5	23.02
4.5 ≤ 6	5	4.1	13	8.5	113.25	27	131.25	18.94
>6	0	0	15	9.9	30	7.2	45	6.50
Total	121.75	100	152.05	100	419	100	692.8	100

Source: HARTI survey data, 2007

Around 60 percent of the total land extents are under home gardens and 22 percent represents highlands. However, according to the findings low lands extent is very limited in the study areas indicating the importance of promoting highland cultivation which is mainly rainfed.

3.6 Economic Features

The percentage of the employed (37.7 percent) in the study area is higher than the national average (35.19 percent) (Central Bank of Sri Lanka, 2007). Majority of the households (73 percent) in the sample population are involved in the farming activities (Table 3.8).

Table 3.8: Status of the Sample Population (Employed)

District	DS Division	Main occupation				
		Farming %	Govt. jobs %	Private Sec. jobs %	Self Employee %	Total %
Moneragala	Siyambalanduwa	10	1	2	1	14
	Thanamalwila	22	1	2	2	27
	Wellawaya	4	0	1	1	6
	Sub total	**36**	**2**	**5**	**4**	**47**
Hambanthota	Lunugamwehera	20	0	4	2	26
	Sub total	**20**	**0**	**4**	**2**	**26**
Puttalam	Karuwalagaswewa	12	2	6	0	20
	Wanathavilluwa	5	0	1	1	7
	Sub total	**17**	**2**	**7**	**1**	**27**
All districts	**Grand total**	**73**	**4**	**16**	**7**	**100**

Source: HARTI survey data, 2007

Out of the total number of "household heads" of the study area, around 82.5 percent are involved in agriculture as the primary employment. The household income is varies from Rs. 1,500 to 98,000. According to the findings (Table 3.9) only 8 percent of sample households are in the income range over Rs. 48,000; while in Hambanthota district no households belong to this income category. About 5 percents of sample households are in the income range of less than Rs. 3,000; while in Puttalam district no households belong to this income category.

Table 3.9: Distribution of Monthly Income (Both Agriculture and Non Agriculture)

Income group (Rs.)	District						Total (N=161)	
	Moneragala (N=77)		Hambanthota (N=42)		Puttalam (N=42)			
	No	%	No	%	No	%	No	%
<3000	6	8	2	5	-	-	8	5
3000 - 6000	22	29	4	10	2	5	28	17
6000 - 12000	18	23	16	38	6	14	40	25
12000 - 24000	12	16	11	26	10	24	33	20
24000 - 48000	13	17	9	21	17	40	39	24
>48000	6	8	-	-	7	17	13	8
Total	77	100	42	100	42	100	161	100

Source: HARTI survey data, 2007

Household's income levels in Puttalam district is higher compared to other two districts, where 40 percent of households belong to income range of Rs. 24, 000 to 48,000. Among the three districts selected, highest numbers of low income households are in Moneragala. The contribution to household income from agriculture activities is given in table 3.10. About, 94 percent of households receives over half of their household income from agricultural activities and around 50 percent of households are almost totally depend on agriculture for their livelihood (Table 3.9), indicating the vital importance of agriculture development in the areas.

Table 3.10: Level of Contribution of Agricultural Income to Household Income

Level of contribution of total HH Income	% of Households						Total	
	Moneragala		Hambanthota		Puttalam			
	No	%	No	%	No	%	No	%
26 – 50	9	12	1	2	0	0	10	6
51 – 75	24	31	16	38	25	60	65	40
76 – 90	1	1	3	7	5	12	9	6
91 – 100	43	56	22	52	12	29	77	48
Total	77	100	42	100	42	100	161	100

Source: HARTI survey data, 2007

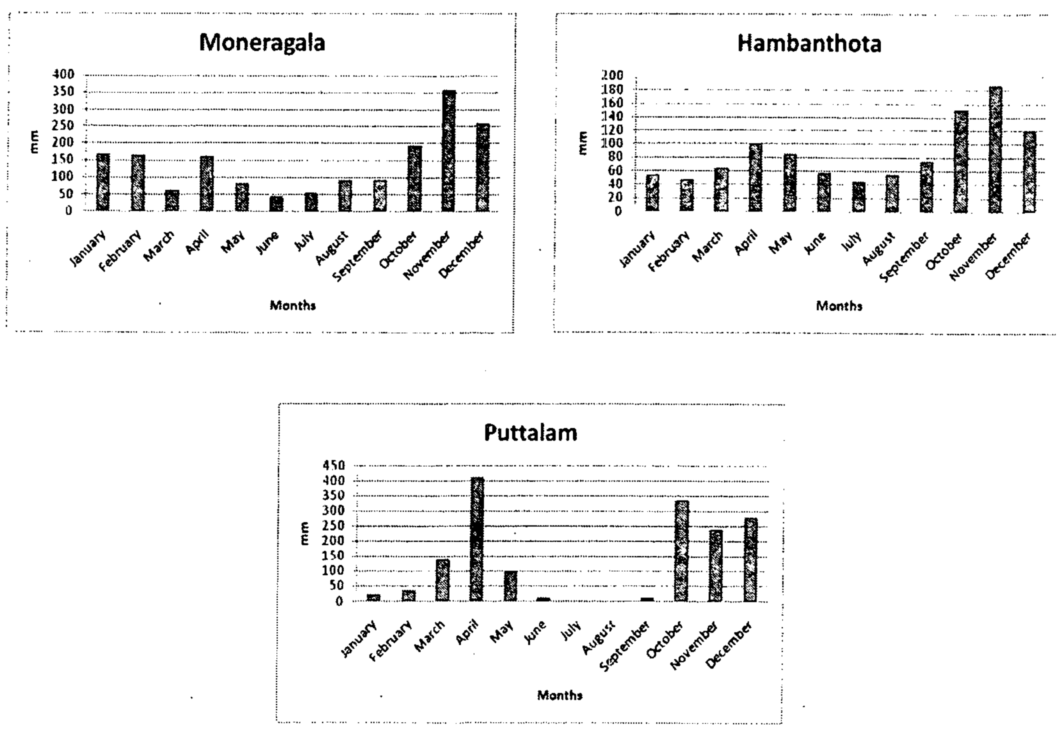
CHAPTER FOUR

Diffusion and Adoption of Runoff Rainwater Harvesting Technologies

4.1 Water Availability and Climatic Zones

Based on the rainfall availability, the country could be broadly divided into wet zone, intermediate zone and dry zone. The wet zone comprises the south - west part of the country covering around 23 percent of the total land extent i.e. around 1.5 million ha. The intermediate zone covers about 13 percent of the country i.e. around 0.8 million ha and includes most parts of the Kurunegala, Matale and Badulla districts and some parts of Kandy and Nuwara Eliya districts. The remaining portion of the country, covering nearly 64 percent of the land is categorized as the dry zone, which gets most of the north- east monsoonal rains (Dry zone covers a land area of about 4.5 million ha). The availability of rainfall in the selected dry zone districts and the variability of rainfall throughout the year are clearly illustrated in the figure 4.1.

Figure 4.1: Average Monthly Rainfall in Hambanthota, Puttalam and Moneragala Districts



Source: Department of Meteorology, Sri Lanka, (1961-1990 average monthly rainfall)

The average annual rainfall of dry zone is 1,250-2,000 mm and about 65 percent of the annual rainfall is received during *Maha* season (October- January) as indicated in fig. 4.1. dry zone is the main food crop cultivation area of the country. Of the 4.5 million ha in the dry zone, only about 2 million ha are effectively used for cultivation. Thus, there is a large extent of potentially cultivable land in the dry zone where most of the soils are relatively higher fertile than those in the wet zone. Non-availability of adequate rainfall during the *Yala* season is one of the limiting factors of crop production in the dry zone. Although numerous irrigation projects provide irrigation for around 200,000 ha in the dry zone a large extent of land in the dry zone still does not get adequate water for crop production.

4.2 Features of RRWH Practices in Sri Lanka

Rainwater collected from rooftops and surface runoff is being utilized in Sri Lanka for domestic use, agricultural activities and industrial uses from ancient times. Basically, rainwater harvested from roof tops is commonly used for domestic purposes in Sri Lanka and rainwater harvested from ground surface is mostly utilized for agricultural purposes.

The table 4.1 provides information on district wise distribution of rainwater harvesting systems and the implementing agencies. According to the information given by LRWHF majority of the units given in this table are used to harvest rainfall form roof catchments to use for domestic purposes.

Table 4.1: Data Base on Rainwater Harvesting Systems in Sri Lanka

District	No of Units	Units Built Organizations
Ampara	683	CI, LRWHF
Anuradhapura	3,496	Plan, KOPBMO, BLIA, NWSDB, Practical Action, LRWHF
Badulla	5489	CWSSP, LRWHF
Batticaloa	47	Asia onlus, LRWHF
Colombo	46	USIP, LRWHF
Galle	1,397	LRWHF
Gampaha	24	EC, LRWHF, CWSSP
Hambanthota	3,918	Sarvodaya, WV, ADRA, OXFAM, NWSDB, SDA, LRWHF, Practical Action
Jaffna	14	LRWHF
Kalutara	1,443	NGOWSSDS, Asia onlus, NWSDB
Kegalle	1,672	NWSDB, LRWHF
Kandy	2,673	CWSSP, LRWHF
Kilinochchi	9	LRWHF
Kurunegala	628	Sarvodaya, Plan, LRWHF, GTZ,
Mannar	109	IOM, LRWHF
Matara	1718	LRWHF, CWSSP
Matale	994	CWSSP
Moneragala	1,944	Sarvodaya,NWSDB, RWHF,SDA, Practical Action
Mullativu	3	LRWHF
Nuwara Eliya	969	PALM, CWSSP, LRWHF
Puttlam	1,666	ORDE, PRDA, NWSDB, LRWHF
Polonnaruwa	1,096	NWSDB,NCC
Ratnapura	111	EC
Trincomalee	19	LRWHF
Vavunia	114	WV, IOM, LRWHF
Total	30,282	

Source: Lanka Rainwater Harvesting Forum (Database updated on 17/03/2009)

Note on Abbreviations:

ADRA	- Adventist Development & Relief Agency Sri Lanka
BLIA	- Buddha's Light International Association
CI	- Care International
CWSSP	- Community Water Supply & Sanitation Project
EC	- Ekamuthu Cultivators
IOM	- International Organization for Migration
KOPBMO	- Kala Oya River Basin Management Office
LRWHF	- Lanka Rain Water Harvesting Forum
NCC	- National Christian Council
NGOWSSDS	- GO Water Supply and Sanitation Decade Service
NWS&DB	- National Water Supply & Drainage Board
ORDE	- Organization for Resource Development and Environment
PALM	- PALM Foundation
Plan	- Plan Sri Lanka
PRDA	- People's Rural Development Association
SDA	- Southern Development Authority
USIP	- Urban settlement Improvement Project
WV	- World Vision

4.3 Types of RRWH Systems

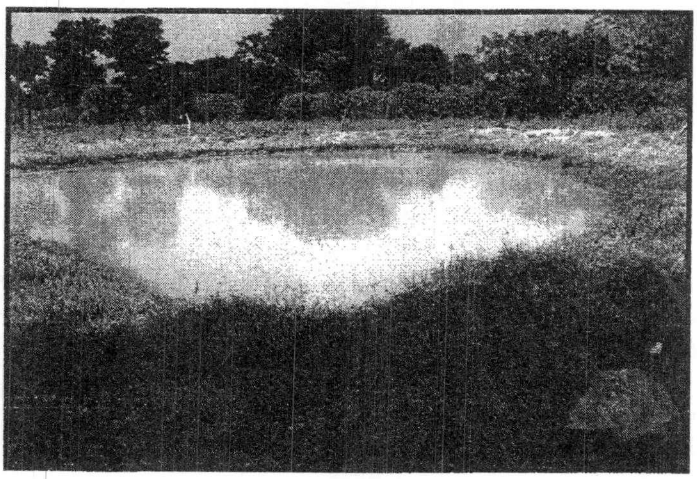
There are two types of RRWH systems available in Sri Lanka.

1. Unlined RRWH ponds (*Pathaha*)
2. Lined RRWH ponds

Unlined RRWH Ponds:

Unlined RRWH ponds are made out of soil bunds (Figure 4.2). The technology used for construction of RRWH systems is very simple and less costly. Unlined RRWH ponds are excavated using soil excavators and the excavated soil is use to construct earth bunds. To prevent the soil erosion of bunds around the unlined RRWH ponds grass cover is applied. Spillway is available to prevent collapse of earth bunds by high water pressure, alleviating heavy rains. Soil trap is used to trap the silt coming with the runoff water to control siltation of pond. The capacities of the unlined RRWH ponds are differ due to uneven shapes but, approximately it varies from 300 m^3 to 500 m^3. Usually, ponds are constructed at the valley, bottom of the cultivated land to facilitate the gravitational flow of runoff water via contour drains towards the pond for collection. It was observed that farmers generally lift harvested water by manual methods such as use of buckets but some farmers also uses peddle pumps, hand pumps and Kerosene pumps.

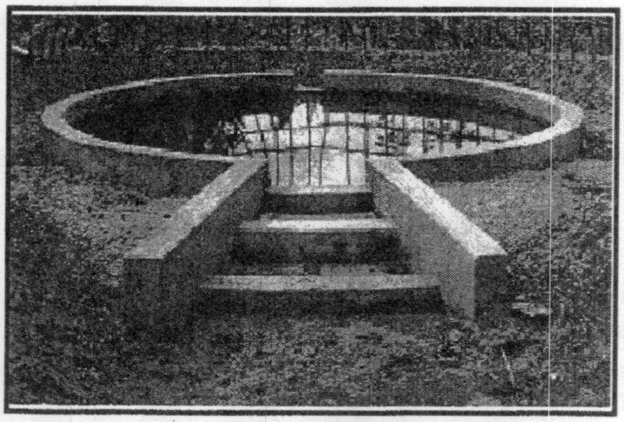
Figure 4.2: Unlined Runoff Rainwater Harvesting Pond in Karuwalagaswewa.



Lined RRWH Ponds:

Lined RRWH ponds available in the study areas are cylindrical in shape. The dimension of the ponds varies from 3 to 4.5 m diameter and 3 to 3.6 m depth. The ponds are completely lined with bricks and cement mortar (Figure 4.3). Both silt trap and spill are two supplementary components available with lined RRWH ponds systems. Capacities of the ponds are generally vary from 120 m^3 to 150 m^3, but there are limited numbers of lined ponds with the capacity of 500 to 1500m^3. Farmers are provided hand pumps or peddle pumps to lift the water. Some of the farmers use improved water application technologies (Drip irrigation systems) to minimize water losses.

Figure 4.3: Lined Runoff Rainwater Harvesting Pond in Wellawaya



4.3.1 Runoff Rainwater Harvesting Interventions in Puttalam District

Surface runoff collection for agriculture has been initiated in Puttalam district with the support of various organizations. World Vision has played a significant role in constructing of RRWH systems in Puttalam district. There are two types of runoff rainwater harvesting systems that are common in Puttalam district; cement lined ponds provided by the Coconut Cultivation Board which are commonly called as "*Pol-tanki*[5]" and unlined ponds ("*Pathaha*[6]"). The "*Pol-tanki*" is used to collect rainwater in coconut cultivation lands to use as the source of supplementary irrigation during the water scarce periods.

In Puttalam, unlined RRWH ponds (*Pathaha*) are generally used for agricultural activities, mostly in the dry season and sometimes non rainy days of the rainy season. However, use of horse pipes is a common practice for water application in the area. Nevertheless, use of water efficient irrigation for perennials is reported occasionally in some locations.

Capacities of the unlined RRWH ponds vary according to the shape and the depth. However, capacity may change over time due to siltation and collapse of bunds. People are aware about the soil conservation methods to overcome the bund collapsing and minimizing the siltation by trapping eroded soil. But, only few of them have applied the knowledge into practice.

In the absence of other permanent water sources, unlined RRWH ponds have become a source of drinking water for domestic animals and supplementary irrigation for crop cultivation during the dry season. In addition, pond water is used for household purposes as well. The irrigable land area of farm ponds (RRWH ponds) varies from ¼ to 2 ac extent. It is important to protect the irrigated area and farm pond from stray cattle by erecting fences around them with thorny branches, barbed wire or stone or brick walls, but only few of the beneficiary have erected fence around the pond.

[5] *Pol-Tanki* is completely lined pond and constructed in coconut plantations. It has the capacity of around 15,000 liters which is sufficient to irrigate 25 coconut plants.
[6] Unlined tank created by damming the small stream or excavating the soil surface

NGOs have implemented RRWH projects in Vanathavilluwa, Karuwalagaswewa, and Mahakumbukkadawla DS divisions. According to the statistics maintained by the World Vision (INGO), around 350 unlined RRWH ponds have been constructed in Puttalam district until 2007 under the Sustainable Agricultural Development Project funded by US Department of Agriculture (USDA).

4.3.2 Runoff Rainwater Harvesting Interventions in Moneragala District

In Moneragala district, a large number of ponds are constructed in Siyambalanduwa DS division (under Muthukandiya dry farm project) followed by Thanamalwila DS division. In these areas it is very common construction of earth bunds across the small streams which have water only in rainy season and store the water to use in dry seasons. In Moneragala, unlined RRWH ponds that are used for agricultural activities commonly called as "Pokuna" by the people in the area. These structures are similar to the *Pathaha* (RRWH ponds), commonly found in a Puttalam district.

A large number of "Pokuna" (RRWH pond) are found throughout the Thanamalwila DS Division. Under World Vision programme, around 171 'Pokuna' were constructed targeting marginal farmers in the area. In some occasions, RRWH units are utilized to collect the water to recharge the aquifer. RRWH systems found in Siyambalanduwa DS division are constructed under the Muthukandiya dry farm project. According to the statistics of the Department of Agrarian Development, about 275 unlined RRWH ponds were excavated under the Siyambalanduwa dry farm project during 1980's.

Nongovernmental organization like Practical Action also has involved in popularizing of RRWH techniques in Moneragala district. The lined ponds are constructed under a partial subsidy programme with farmers' labour contribution. The capacities of the lined ponds were 15,000 liters and 150,000 liters. The total cost of up to Rs.150, 000 was provided by the funding agency. In addition to the construction of lined ponds, the programme has provided water application system (Drip irrigation unit), over head storage tanks and a hand pump. According to the Practical Action, around 35 lined RRWH ponds were constructed for agricultural purposes under the programme implemented in Moneragala district.

4.3.3 Runoff Rainwater Harvesting Interventions in Hambanthota District

RRWH ponds in Hambanthota district are mostly found in Lunugamwehera, Ambalantota and Tissamaharma DS divisions. There are lined and unlined ponds within the district. There are about 35 lined ponds in the Hambantota district constructed by Practical Action which are mostly 15,000 liter capacity. Under World Vision programme around 125 unlined RRWH ponds were constructed in Lunugamwehara DS division for cultivation and recharge of groundwater. Other than crop cultivation unlined RRWH ponds are used for livestock rearing, inland fishing and sometime for human needs. In Lunugamwehera, 70 percent of the cultivated land extents under unlined RRWH ponds are in between 1.5 to 3 acre. Irrigated land extent under RRWH ponds of Hambanthota was bigger in extent compared to Moneragala and Puttalam district. Usually, farmers used the harvested rainwater as a supplementary source of irrigation as practiced in other areas. Other than RRWH ponds, most of the beneficiaries also have received peddle pumps, mammoty and other farming equipments under the World Vision project. Some of the unlined

RRWH ponds are provided as a full subsidy scheme while some other beneficiary received them as partial subsidy with some kind of farmer contribution.

4.4 Approaches of Interventions

The study made an attempt to analyze the successfulness of the different development approaches adopted in promoting RRWH by different organizations. Those approaches can be broadly classified into two;

1. **Development of RRWH Systems under Fully Subsidized Approach**

Under this approach the total cost of construction of RRWH system was granted by the funding agency and the beneficiaries were passive recipients of the system. But they have to be maintained the system at their own cost. In addition to the RRWH unit, some supplementary components such as water pumps, over head storage tanks and micro irrigation kits and agricultural equipment were also provided in some locations under this fully subsidy approach by the funding agencies.

Muthukandiya irrigation scheme (located in Siyambalanduwa DS division) was initiated in the early 1970s, but failed to provide sufficient water for entire settlers of the project due to dry weather pattern in the area. Therefore, the government was initiated Muthukandiya dry farm development project targeting 267 farmer families who failed to receive gravity irrigation water from the irrigation project. Initially, each farmer was provided an unlined RRWH pond and a lump sum of money to construct a house or shelter. This project is one of the examples of fully subsidized rainwater harvesting intervention under the government programme.

Under this project, farmer families were given 4 acre of upland for cultivation and settlement purposes and the families were settled in 1986. The main short-term income of the settlers was cultivation of seasonal crops and the project strongly promoted cultivation of perennial crops such as cashew, mango, brinjal, papaw, banana, guava, coconut and sugarcane. The average capacity of these unlined RRWH ponds ranges from one hundred to three hundred m^3. The tanks were constructed completely using earth bunds. Majority of the farm unit had individual unlined RRWH pond, but some farm unit had to share the pond with a neighboring farmer. The main feature of this dry farm development project was top down approach of development. The beneficiaries seldom involved in the project planning and designing stage. The wisdom and traditional knowledge of the local community was not incorporated into the project implementation process. The major drawback was selection of non appropriate site for the construction of RRWH pond. The project officers selected the sites which are suited to share by two neighboring farmers rather than considering land topography, runoff direction and soil permeability. Therefore considerable numbers of ponds have failed to function due to insufficient water collection and storage.

There are number of NGOs also implemented RRWH interventions under fully subsidized approach. The major difference of the NGO intervention is the approach adopted for beneficiary selection and mobilization of farmers towards the project. At the first step, farmers who are willing to practice RRWH technology were identified and they were mobilized to form an organization paying a specific membership fee.

Only the members of the farmer organization were eligible to submit an application to receive a RRWH pond in their farming system. Participatory development approach was adopted with the participation of all stakeholders including a representative from the funding agency, beneficiary farmer and the social mobilizer of the project in selection of suitable location of the project and determining the design and capacity of the RRWH system.

2. **Development of RRWH Systems under Partially Subsidized Approach**

The funding agencies have granted the part of the capital investment cost of constructing the RRWH system and the balance have to be contributed by the beneficiary farmer mainly via providing the unskilled labour and sometime locally available materials such as river sand and bricks. In this approach, the system cost is calculated by the technical officer in collaboration with funding agency and the farmer. Subsequently, the farmer share and the funding agency share were decided after the stakeholder discussion. According to the past records funding agencies have contributed 50 - 75 percent share of total cost of RRWH systems and the rest by the beneficiary farmer. As discussed in the fully subsidized approach, suitable farmers who are willing to bear the partial cost of the project were identified by the project officials. Then they were asked to form an organization at each local area (DS division) paying a membership fee of Rs. 1000 to the organization. The members had to prepare a proposal to the funding agency requesting RRWH system which was evaluated by the representative of the funding agency, Farmer leader of the respective organization and the social mobilizer of the area. After the evaluation, cost estimations of the systems were conducted by the technical officer of the agency and decided the share of both the agency and the beneficiary farmer.

Generally, funding agencies provided half of construction cost, but sometimes it was up to 75 percent of the total cost depending on the economic hardship of the farmer. Generally, the cost of construction varies form Rs. 15,000 to Rs. 30, 000 it varies with number of hours were used for excavating machine to dig the pond. However farmers have the liberty to expand the size of the pond depending on their own financial capability. For instance some farmers have spent over Rs. 50,000 to construct their expanded RRWH systems.

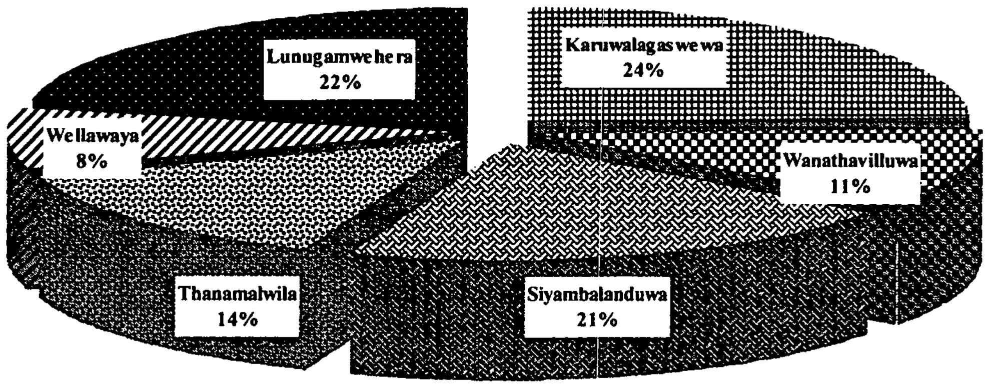
The selection of specific location for the RRWH system and size of the unit was mainly decided by the head of the household with expert opinion of technical officer and social mobilizer. However, capacity of the RRWH unit determines based on available land extent and the farmer's capacity to contribute. In general, capacities of the systems varies from hundred to three hundred m^3. However, according to field observations, water storage capacities of some RRWH units can not be exactly determined as they are irregular in shape.

4.5 Features of Different Approaches

According to the findings about 75 percent of the RRWH systems in the study locations are constructed under fully subsidized approach. Partial subsidized approach has been practiced only in two DS divisions namely, Thanamalwila (39%) and Lunugamwehera (61%). Figure 4.4 shows distribution pattern of fully subsidized RRWH systems in the study areas. However, fully subsidized approach was implemented in early part of this programme and most of those units are located in

Puttalam district and Lunugamwehera DS division. The programme introduced partially subsidized units at later part, especially in Moneragala and part of the Hambanthota district.

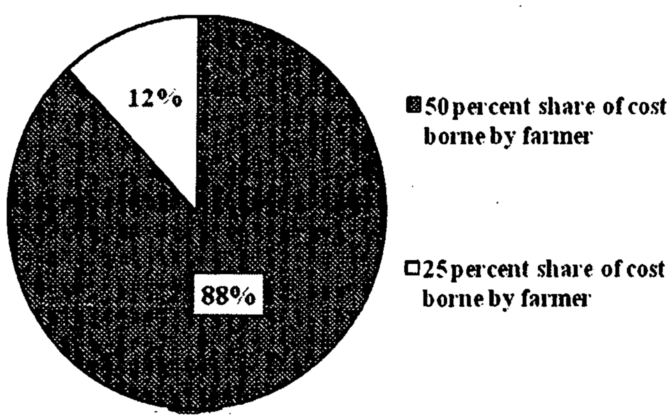
Figure 4.4: Distribution of Fully Subsidized RRWH Systems in the Study Areas



Source: HARTI survey data, 2007
Note: Percentages are based on each approach separately

Figure 4.5 shows the degree of farmer contribution under partially subsidized RRWH system development programme. More than 88 percent of the farmers have contributed over 50 percent of cost of construction of the RRWH system under partially subsidized RRWH systems development.

Figure 4.5: Level of Farmer Contribution under the Partially Subsidized RRWH System Approach



Source: HARTI survey data, 2007
Note: Percentages are based on number of partially subsidized RRWH systems (N=41)

As discussed earlier, some of the farmers also have received some supplementary components with their RRWH systems such as drip irrigation systems, overhead tanks, water pumps and farm implements. Table 4.2 shows the detail description of the level of utilization of these supplementary components. However it is noteworthy that majority of these components are never being used by the beneficiaries except some of the farm implements.

Table 4.2: Equipments Granted Under the Project other than RRWH System

Received equipment	No. of item received	Percentage of farmers utilized the item*
Drip irrigation system	06	33.3 (2)
Overhead water storage tank	06	33.3 (2)
Hand pump	07	14.3 (1)
Mammaty and other instruments	91	95.6 (87)
Peddle pump	15	66.7 (10)

Source: HARTI survey data, 2007

Note: Percentages are based on number of farmers received the item, No. in the parenthesis indicates number of farmers utilized

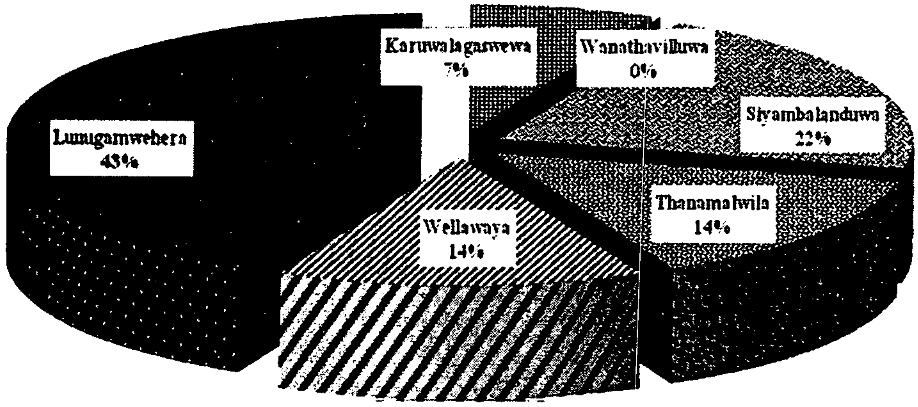
One of the reasons for not using drip irrigation kits as perceived by the farmers was the poor quality of stored rainwater in the RRWH systems causing clogging of drippers and also lack of knowledge among farmers to rectify this problem. Further, farmers complained that manual operation of hand pumps is very laborious and therefore most of the hand pumps granted were unutilized.

4.6 Performance of the RRWH Systems

The research results reveal that, 9 percent (14) of RRWH units are abandoned at the time of survey due to various reasons. The main reasons for the systems failure are technical errors occurred during construction, selection of suitable land site (sandy nature of soil), and poor quality of construction. Technical errors and poor quality construction have caused cracks in the system and leading to leakage of stored water within a short period of time.

Out of total abandoned RRWH systems, 93 percent of the RRWH units were constructed under fully subsidized development approach. The findings clearly indicate that the beneficiary contribution for RRWH system construction has a positive relationship for the successfulness of the RRWH systems. The highest number of abandoned systems was found in Lunugamwehera DS division (Figure 4.6).

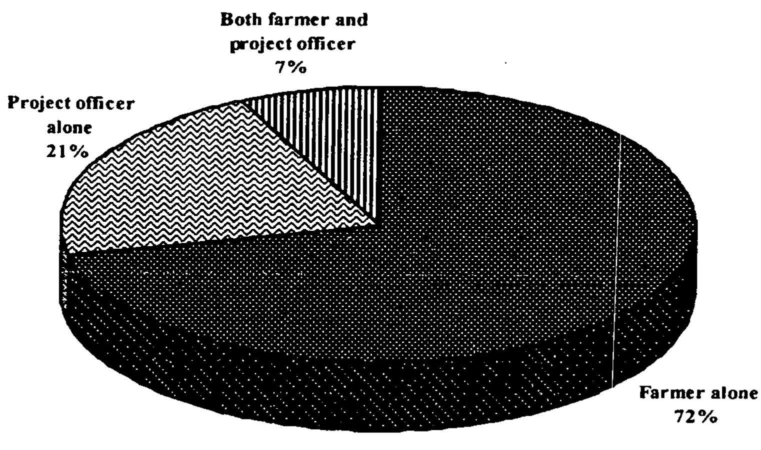
Figure 4.6: Distribution of Abandoned RRWH Systems



Source: HARTI survey data, 2007
Note: Percentages are based on total number of abandoned RRWH systems

One of the reasons for the poor performances or system failure of RRWH system is no application of participatory techniques in selecting appropriate site for the project. As illustrated in figure 4.7, site selections for 72 percent of abandoned systems were solely done by farmers, and 21 percent of the abandoned RRWH systems were selected by project officer alone. However, the site selected jointly by both beneficiary farmers and the project officers have accounts only 7 percent of abandoned systems. This is an outcome of blending of local knowledge of beneficiary people and the expert technical knowledge of project officials.

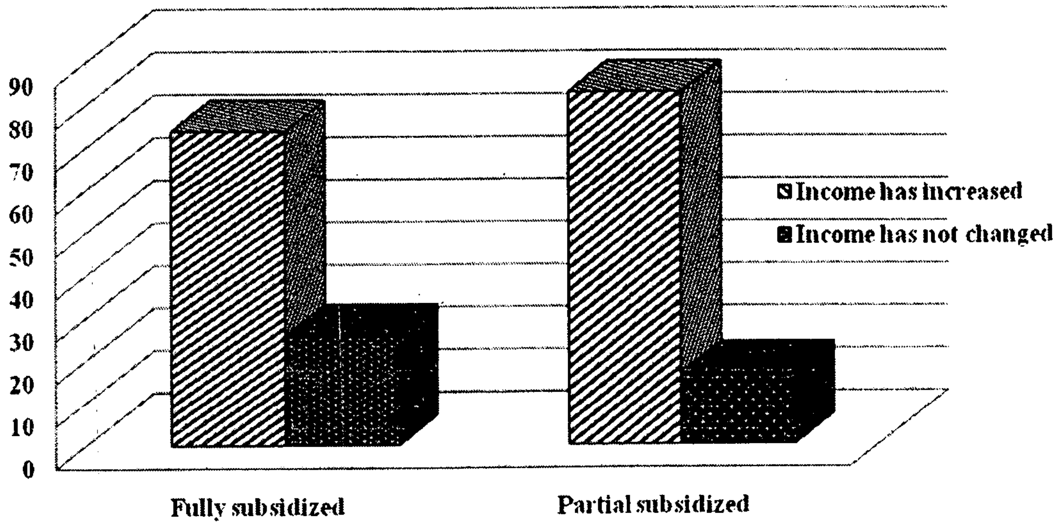
Figure 4.7: Abandoned RRWH Systems based on the Approach Adopted in Site Selection



Source: HARTI survey data, 2007
Note: Percentages are based on the total number of abandoned RRWH systems

Beneficiary farmers were asked about the impact of RRWH system on their farm income. The responses are given in figure 4.8. The majority of farmers (90% who were financially contributed to the RRWH system construction have reported an income increase after introduction of the system compared to fully subsidized farmers (80%).

Figure 4.8: Response to Income Change after Introduction of RRWH System



Source: HARTI survey data, 2007

4.7 Role of Farmers in Maintaining and Improving the RRWH Systems

The survey finding shows that the primary reason for the failures occurred in the RRWH systems in the past is due to low water availability in the system or harvested water is lost within short period of time. Poor targeting is the other reason for systems abandonment. The study made an attempt to elicit information on the role played by farmers in expanding or maintaining granted systems in order to understand their dependency on the RRWH systems. Expansion of the systems is possible for unlined RRWH ponds. Some of the beneficiaries wanted to enlarge the capacity of RRWH systems. However, only about 12 percent has already expanded the RRWH system by now (Table 4.3). Survey results also showed that around 89 percent of beneficiaries are willing to expand the RRWH system, but, they have not done yet due to financial difficulties as heavy machines are needed for excavation and construction of bund. The beneficiary farmers were asked about their willingness to invest on de-silting of RRWH system at their own cost, but only 25 percent of the beneficiaries express their willingness to de-silt the RRWH system at their own cost.

Table 4.3: Expansion of RRWH Systems by DS Divisions

DS division	Expanded of RRWH systems % (N*=151)
Karuwalagaswewa	0.7 (1)
Wanathavilluwa	0.7(1)
Siyambalanduwa	0 (0)
Thanamalwila	9.2 (14)
Lunugamwehera	1.32 (2)
Wellawaya	0 (0)
Total	11.9(18)

Source: HARTI survey data, 2007

*Note: Percentages are based on the number of expandable ponds

The main reason behind the RRWH system capacity expansion was to store additional amount of water during rainy period. By increasing the capacity of the RRWH system they have intention to increase the cultivable land area and ensure reliable irrigation water supply.

CHAPTER FIVE

Effects and Impacts of Runoff Rainwater Harvesting Systems

5.1 Application of RRWH Systems in Agriculture

The average values of annual rainfall, rainfall distribution and temperature of all the selected areas are characteristic features of the dry/arid conditions, where lack of sufficient water or water scarcity is the critical factor hindering the development of 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, major objective of the agencies promoting RRWH systems was 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.

5.1.1 Land Use under Different Water Sources

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- low land, highland and home garden. Irrigation tank, irrigation channel, drainage channel, agro-well and RRWH systems are the major water sources used for the cultivation.

Table 5.1 shows the level of utilization of different water sources under different land categories in the study areas. Irrigation water received from irrigation channel is mostly used for lowland cultivation and followed by runoff rainwater collected in the RRWH systems. The findings shows that, out of 161 sample farmers, only 37 of them (23%) have some access to irrigation water. RRWH systems are mainly popular for highland and home garden cultivation. The interesting feature of water use in lowland is that about 35 percent of farmers use RRWH systems water for some of their lowland plots as a supplementary water source. About 80 percent of the RRWH water users primarily use the RRWH system as a source of supplementary source to undertake paddy cultivation in low lands.

Table 5.1: Use of Different Water Source for Agriculture

Type of water source	Type of land					
	Lowland (N=71)		Highland (N=65)		Home garden (N=161)	
	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: HARTI survey data, 2007

5.1.2 Crops Cultivation under RRWH Systems

Runoff water collected in the ponds 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 home garden. Large numbers of farmers have increased their extent of cultivation especially during *yala* season and introduced number of new crops to their farming system after construction of RRWH system. Table 5.2 describes the use of RRWH system for various purposes. In addition to the uses listed in table 5.2, about 37 percent of farmers perceived that, the RRWH systems are also used by their neighbors time to time during the periods of water scarcities for various purposes.

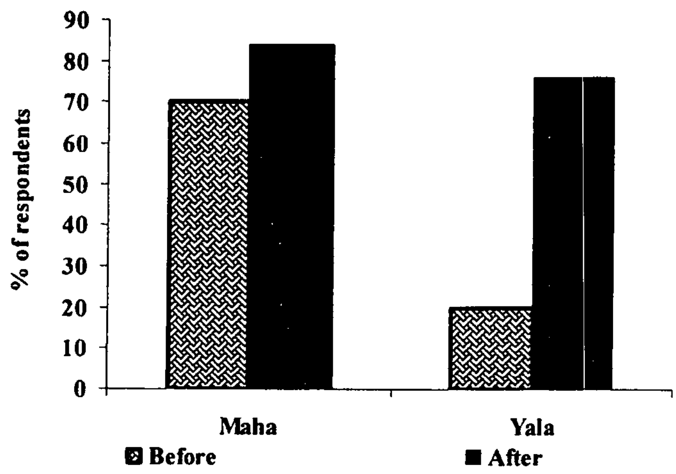
Table 5.2: Use of RRWH Systems for Various Activities

Purpose of use	No. of respondents (N=161)	% of respondents
Only seasonal crop cultivation	9	6
Only perennial crops cultivation	5	3
Both seasonal and perennial crops cultivation only	15	9
Crop cultivation+ livestock only	20	12
Crop cultivation + Aquaculture only	52	32
Crop cultivation + livestock + Aquaculture	40	25
Livestock only	4	2
Aquaculture only	2	1
Livestock+ aquaculture only	1	1
Use for household needs	79	49
No activities/abandoned pond	14	9

Source: HARTI survey data, 2007

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 *yala* seasons (Figure 5.1)

Figure 5.1: Progress in Seasonal Crop Cultivation – Before Vs After the Project (% of people involved in cultivation)



Source: HARTI survey data, 2007

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. The noteworthy change, as shown in table 5.3 and 5.4 is number of farmers involved in paddy cultivation has increased dramatically after the project. 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 Thanahal/Italian millet (*Setaria Italica*) and increased in irrigated crops such as Cowpea (*Vigna catiang*), Green gram (*Phaseolus aureus*) and Ground nut (*Arachis hypogaea*).

Cereals, pulses, oil crops, vegetables and cash crops (chili and onion) are the main groups of annual crops cultivated in the study areas. As illustrated in figure 5.2, 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 5.3 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 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 results from perennial trees with their maturity.

Table 5.3: Changes in Cropping Pattern of Annual Crops in *yala* Seasons (before and after the project)

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

Source: HARTI survey data, 2007

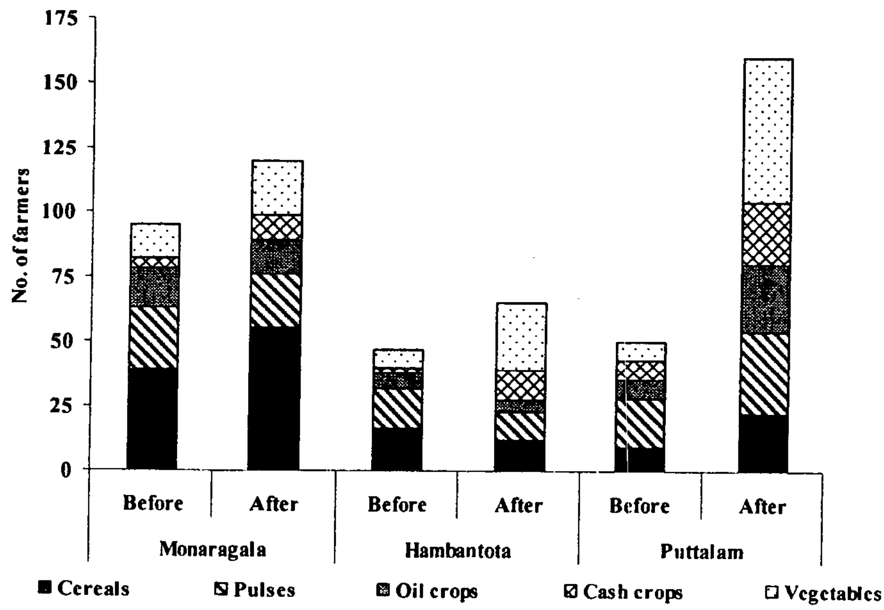
* Other traditional cereals includes Finger millet, Millet and Italian millet

Table 5.4: Changes on Cropping Pattern of Seasonal Crops during *maha* Seasons (before and after the project)

Name of crop	Before the project	After the project	% change
	No. of farmers cultivated	No. of farmers cultivated	
Cowpea	50	52	+4
Paddy	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

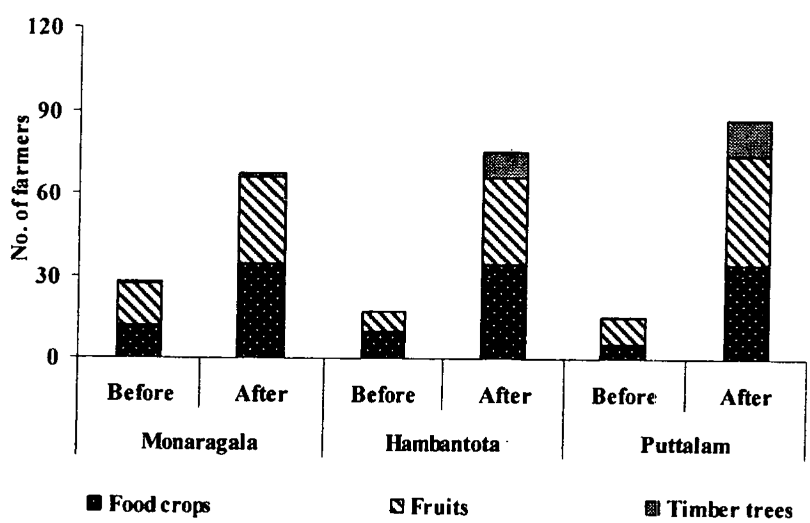
Source: HARTI survey data, 2007

Figure 5.2: Involvements of Farmers in Annual Crop Cultivation by District (before Vs after the project)



Source: HARTI survey data, 2007

Figure 5.3: Involvement Farmers in Perennial Crop Cultivation – before Vs after the project



Source: HARTI survey data, 2007

Attempts were made to analyze the causative factors for the changes in cropping pattern after introduction of RRWH systems. The main reasons are introduction of vegetable cultivation, commencement of perennial crops cultivation, introduction of new perennial crops, shift towards the cultivation of high water consuming crops, commencement of cultivation by new farmers and expansion in extent of cultivation by already cultivating farmers (Table 5.5).

Table 5.5: Reasons for the Differences in Cropping Pattern after the Project

Reasons	No. of responses (N=139)	% of responses
Introduction of vegetables after assured water	44	32
Commencement of perennial crop cultivation	40	29
New cultivation	32	23
Expansion in area of cultivation	22	16
Shift to high water consuming crops	20	14
Cultivation of vegetables in *yala* season	21	15
Cultivation of paddy in *yala* season	7	5
No changes in cropping pattern	14	10

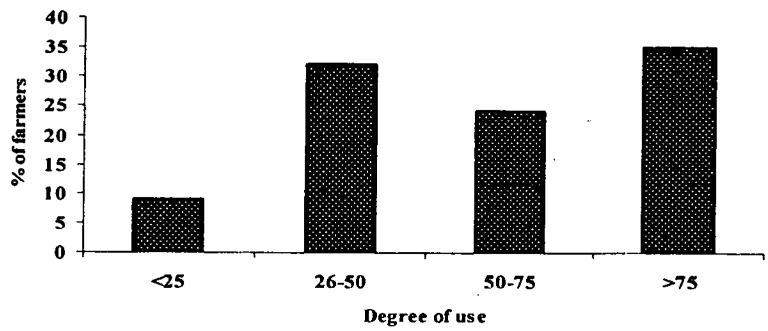
Source: HARTI survey data, 2007
Note: N denotes total number of crop cultivators and percentages are based on N

5.1.3 Level of Utilization of RRWH System for Crop Production

The interventions for promoting RRWH technology was largely backed by subsidies attached to the programme. The level of contribution made by farmers was mainly limited to in-kind support and sometime no contribution at all. Therefore, it is meaningful to study the acceptability of the technology among farmers after withdrawal of the project interventions.

The level of adoption of RRWH technology is the percentage of number of seasons cultivated using RRWH systems and the numbers of seasons were available for cultivation until 2007 *maha* from the introduction of technology to farmers' field. An assumption was made as the number of seasons available for cultivation per year is two. The findings are illustrated in figure 5.4. About 60 percent of beneficiaries have utilized the RRWH ponds for more than 50 percent of seasons they have come across after introduction of the systems.

Figure 5.4: Progress of Utilizing RRWH Systems for Agriculture until 2007 *Yala*



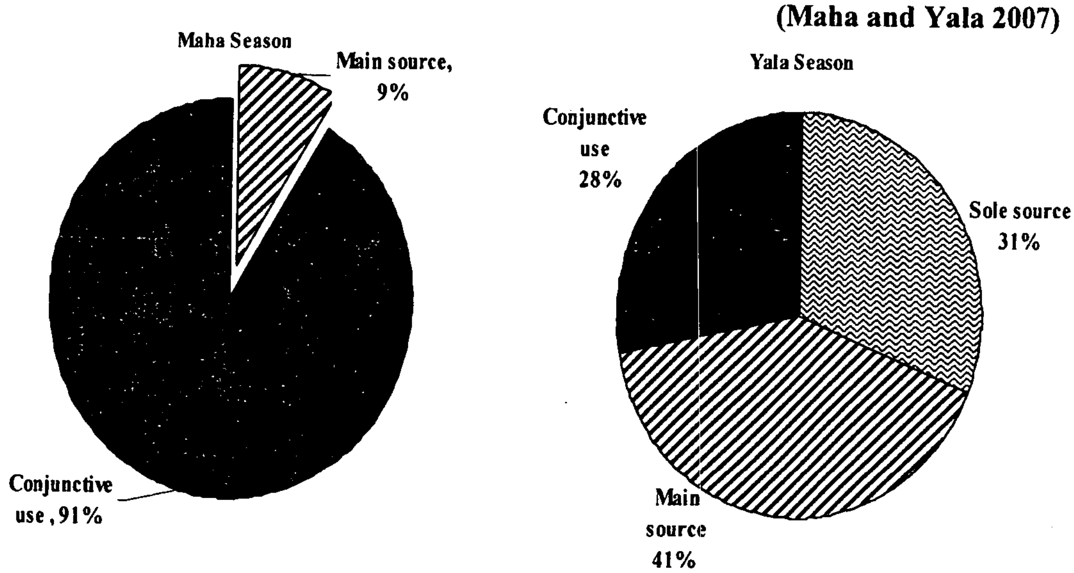
Source: HARTI survey data, 2007

Note: Figure excludes the information about 9 percent of the beneficiaries who have abandoned the use of RRWH systems.

5.2 Effectiveness of RRWH in Agriculture

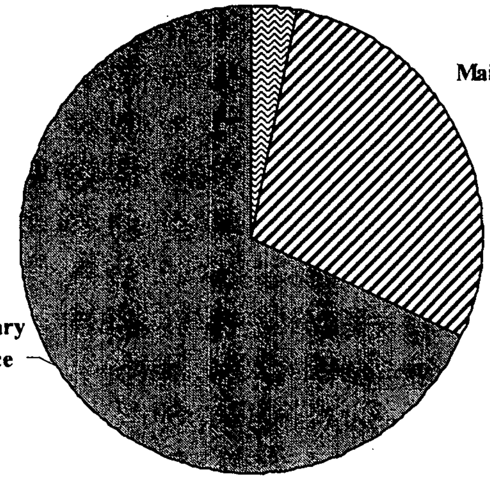
The present field research findings clearly show that RRWH interventions have been effective in enhancing agriculture production and household income, especially in *yala* seasons. About 91 percent and 28 percent of farmers who under take seasonal crops cultivation are using runoff rainwater stored in the RRWH ponds 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 (Figure 5.5). About 68 percent of perennial crop cultivators use the RRWH ponds as a supplementary source of water, while rest of the people depends on them as a main or exclusive water source (Figure 5.6).

Figure 5.5: Dependency on RRWH Systems for Seasonal Crop Cultivation (Maha and Yala 2007)



Source: HARTI survey data, 2007

Figure 5.6: Use of RRWH Systems for Perennial Crop Cultivation



Source: HARTI survey data, 2007

Since the available water in the RRWH pond is limited and need to be used throughout the season to safeguard the crop, the methods of management adopted by farmers in utilizing available water in the pond was studied. Inquiries were made about the irrigation method practiced by farmers during *maha* and *yala* seasons for annual and perennial crop cultivation separately (Table 5.6 and 5.7). Findings show that, the number of farmers using water intensive flood or furrow irrigation method is very less in 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. As the farmers in the sample areas are resource poor, marginal farmers are not in economic position to purchase the micro irrigation technologies. The awareness on the technology and the availability of necessary support services in the area to use the technology are also very less.

Table 5.6: Water Application Methods for Seasonal Crops

Method of application	*Yala* season		*Maha* season	
	No. of responses (N=106)	% of responses	No. of responses (N=106)	% of responses
Use of hosepipe	39	48	32	30
Carrying water by pots/cans/buckets	27	33	43	41
Flood irrigation	11	14	28	26
Furrow irrigation	2	2.5	2	2
Drip irrigation	2	2.5	1	1

Source: HARTI survey data, 2007

Table 5.7: Water Application Methods for Perennial Crops

Method of application	No. of responses (N=104)	% of responses
Carrying water by pots/cans/buckets	71	68
Use of hosepipe	30	29
Flood irrigation	2	2
Drip irrigation	1	1

Source: HARTI survey data, 2007

5.3 Use of RRWH Systems to Perform 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 percent and 25 percent of sample households with some linkages on RRWH systems. About 9 percent of livestock farmers are also having buffaloes and goats. Two farmers have introduced ducks to their pond environment. About 6 percent of livestock farmers use 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 5.8. 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 percent of livestock entrepreneurs have accepted that there is an improvement in livestock related income after introduction of RRWH systems to their farming system.

Table 5.8: Various Uses of RRWH Systems for Livestock Enterprises

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

About 71 percent of users of RRWH system for animal rearing claimed that, there is no any 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 perceived about the lack of adequate quality of water for livestock (Table 5.9).

Table 5.9: Constraints in using RRWH Ponds for Animal Rearing

Problem experienced	No. of responses (N=65)	% of responses
No any problem	46	71
Available water is not sufficient	12	18
Quality of available water is not satisfactory for livestock	2	3
Others	5	8

Source: HARTI survey data, 2007

5.4 Use of RRWH Systems for Aquaculture

About 2 percent of beneficiaries have utilized the RRWH systems solely for the aquaculture activities. However 31 percent of sample beneficiaries have used 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, 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.

Farmer's perceptions on the problems in using RRWH systems in fish culture is given in table 5.10. 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 specified by the farmers. About 16 percent of respondents mentioned no problem in 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 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.

Table 5.10: Problems in Practicing Aquaculture in RRWH Systems

Type of problem	No. of respondents (N=95)	% of respondents
Low growth rate of fish	25	26
Lack of water throughout the season	26	27
Lack of knowledge on fish culture	23	24
Non availability of fingerlings/low quality of available fingerlings	19	20
No problem	15	8
Quality of water is not suitable for fish	8	16
Theft of fish before harvest	7	7
Damage by wild animals and birds	10	11
Loss of fish during spilling time of pond/tank	3	3
Obstruction due to water weeds	2	2
Religious and cultural barriers	1	1

Source: HARTI survey data, 2007

5.5 Use of RRWH for Domestic Needs

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 5.11). Only few families have utilized the water for drinking and cooking.

Table 5.11: 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: HARTI survey data, 2007

5.6 Other Impacts of RRWH

RRWH systems are 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 and seepage of water. According to the beneficiary perceptions, 85 percent have realized the changes in the surrounding micro environment after construction of unlined RRWH ponds. The beneficiaries have listed multiple indicators to prove their perception (Table 5.12). 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 severally affected before construction of the RRWH pond.

Table 5.12: Impacts of RRWH Ponds on the Micro Environment

Impacts	No. of responses (N=137)	% of responses
Survival of vegetation around the homestead during dry seasons which were died/effected earlier	121	88
Greener homestead environment	74	54
Scenic beauty of micro environment	71	52
Increased water level in the domestic wells	48	35
Increased water levels in the neighbours' well	36	26
Increased in the yield of perennial crops	20	15

Source: HARTI survey data, 2007

It has been reported by 37 percent 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 percent on non owners of the ponds (neighbours) have been allowed to use the RRWH systems to save their crop, which has indeed helped to build up the social cohesions within the village environment (Table 5.13).

Table 5.13: Purposes of Using RRWH Systems by Neighbours

Purposes	No. of responses (N=60)	% of responses
Bathing	21	35
Washing Kitchen utensils	19	32
Drinking water for animals	19	32
Washing cloths	18	30
Crop Cultivation (few Irrigation rotations)	13	22
Watering Ornamental plants	9	15
Cooking	4	7
Drinking	3	3

Source: HARTI survey data, 2007

5.7 Problems and Constrains in using RRWH Systems

Problems and constraints experienced in using RRWH systems were analyzed in two folds, firstly, problems encountered during the construction phase of the pond and secondly problems encountered after the construction and/or during the usage of pond. The main problems faced at the initial period were inadequate capacity of the pond and uncertainty about water retention period to make the cultivation plan (Table

5.14). However, about 43 percent of beneficiaries perceived no problem experienced at initial development stage.

Table 5.14: Problems Encountered During the Initial Construction Phase

Problem	No. of responses (N=161)	% of response
No problem	69	43
Inadequate capacity of pond	60	37
Uncertainly about water retention period	34	21
Financial constraints to contribute construction	8	5
Unsuitable site selection for pond/tank construction	6	4
Other	3	2

Source: HARTI survey data, 2007

Siltation of RRWH systems was the main problem experienced by farmers when they are using the ponds. Loss of water through leaks created in the ponds, loss of water through evaporation and percolation and damage created to bunds by wild and domestic animals are the other main problems encountered by farmers at the later stage of the pond operation (Table 5.15).

Table 5.15: Problems Encountered During the Usage of RRWH Systems

Problem	No. of responses (N=161)	% of responses
Siltation	77	48
Leaks created in the pond/tank	37	23
No problem	30	19
Damaged to ponds by animals	18	11
Collapse of bunds	14	9
Loss of water through evaporation	11	7
Insufficient runoff	1	0.5
Other	4	2

Source: HARTI survey data, 2007

5.8 Economics of RRWH Ponds for Agriculture

The economic analysis is based on case studies conducted among the two entrepreneur farmers purposively selected from Tabbowa area in Puttalam district (Farmer A) and Thanamalwila area in Moneragala district (Farmer B). The selected farmers are using unlined open RRWH ponds ('pathaha') for cultivation purposes. Farm records maintained by the selected farmers and the secondary information maintained by the line agencies were used to calculate the Benefit Cost Ratio (BCR) of the investment made on unlined RRWH ponds, Net Present Value (NPV) and payback period of the investment made.
The required cost and return data were obtained from the farm records maintained by the given farmers. Farmer 'A' cultivates two and half acre and Farmer 'B' cultivates

two acre extends of land using the water from unlined RRWH ponds. Out of this land, Farmer 'A' utilize about one and half acre for the cultivation of perennials crops and rest have been kept for seasonal crops like vegetables, cereals and oil crops while Farmer 'B' utilizes 1.75 ac extent for seasonal crop cultivation and rest for perennial crops. The areas cultivated under farm pond by both farmers were not used for any cultivation before introduction of unlined RRWH pond.

Farmer 'A' has grown perennial crops like mango (10 plants), cashew (15 plants), papaw (13 plants) and orange (12 plants). The remaining land extent (1 ac) was used to grow seasonal crops like tomato, groundnut, green gram, chili, capsicum, maize, brinjal, etc.

Farmer 'B' has cultivated 20 plants of mango, 50 banana plants as the perennial crops and cultivated seasonal crops are maize, cowpea, luffa, bitter guard and brinjal. Farmer 'B' is also using the pond for aquaculture and part-time brick making industry, which provides annual income of Rs. 8500 and Rs 7000 respectively.

Benefit-Cost Analysis

One of the problems encountered in doing Cash flow analysis was difficulty in quantifying all the costs and benefits. Therefore, the analysis was carried out with the following assumptions.

I. The life period of runoff harvesting pond was considered as 10 years
II. The future income stream from the unlined RRWH pond was uniform and constant as current year during its entire life period
III. Crop cultivation practices/farming systems are uniform over the period
IV. Differential discount rates of interest rates (10%, 12%, 15%, and 20%) were assumed to represent the opportunity cost of capital

According to the table 5.16, sensitivity analysis of NPV and BCR shows that, the project is viable even at 20% discount rate, if there is no change in the cost of production and gross income during the life period. One of the important investment issues which can be verified from the cash flow analysis of the adoption of runoff harvesting system is that, farmer 'A' and 'B' can recover the full capital cost within two and five year periods respectively. In addition farmers have the opportunity to maximize the economic returns by starting the cultivation prior to commencement of regular season with use of tank water which leads to get yields in off seasons and higher market price.

Although present analysis not aimed to assess the extended environmental and social benefits of RRWH ponds, it has been reveled that farm ponds have increased well water level and more greenish and cooler environment in vicinity as discussed in section 5.6. Integration of crops with, livestock and aquaculture in to the farming system under the runoff harvesting pond in dry areas in the country can make higher return in short term period. The unlined RRWH pond concept also has increased the household food security at a considerable level among the poorest rainfed farmers living in the more vulnerable and marginal areas.

Table 5.16: Sensitivity Analysis of NPV and BCR for Unlined RRWH Ponds

Description	Values	
	Farmer A	Farmer B
Net Present Value		
At 10 percent discount rate	414885.54	309170.11
At 12 percent discount rate	372199.55	272099.74
At 15 percent discount rate	318168.51	224958.86
At 20 percent discount rate	249100.36	164173.73
Benefit Cost Ratio		
At 10 percent discount rate	1.70	1.72
At 12 percent discount rate	1.67	1.67
At 15 percent discount rate	1.64	1.60
At 20 percent discount rate	1.59	1.50

Source: HARTI survey data, 2007.

The results of the sensitivity analysis show that (Table 5.17), BCR and NPV decrease with a decrease of interest rate but the change is marginal. The lowest BCR observed is 1.30 with discount rate of 20 percent under scenario iii, where cost of production is increased by 10 percent while benefits derived is decreased by 10 percent. In addition, it is evident from the analysis that the reduction in NPV and BCR is much higher when expected benefits decrease by 10 percent than the increase in cost of cultivation by 10 percent. In general, the sensitivity analysis under various scenarios indicate that the unlined RRWH ponds investment remain economically viable in all the given circumstances.

Table 5.17: Sensitivity Analysis of NPV and BCR under Different Scenarios for Unlined RRWH Ponds

Description	Farmer A			Farmer B		
	Scenario I	Scenario II	Scenario III	Scenario I	Scenario II	Scenario III
Net Present Value						
At 10 % discount rate	360108	314396	259618	294820	250558	221259
At 12 % discount rate	321553	280241	229594	258546	218266	197193
At 15 % discount rate	272831	237092	191755	212430	177217	153002
At 20 % discount rate	210740	182128	143768	152999	124324	103855
Benefits Cost Ratio						
At 10 % discount rate	1.55	1.53	1.40	1.67	1.61	1.50
At 12 % discount rate	1.53	1.51	1.38	1.62	1.56	1.46
At 15 % discount rate	1.50	1.48	1.35	1.55	1.49	1.40
At 20 % discount rate	1.45	1.43	1.31	1.45	1.39	1.30

Source: HARTI survey data, 2007.

Note

Scenario I : 10 percent increase in cost of cultivation

Scenario II: 10 percent decrease in benefits

Scenario III: 10 percent increase in cost and 10 percent decrease in benefits

CHAPTER SIX

Conclusions and Recommendations

6.1 Major Findings

6.1.1 Demographic and Socio-economic Features

Sex wise distribution of population of the study areas indicates female dominance in most of the areas. The muscularity ratio of the study population is (male/female) 93 percent. The analysis of the age structure indicates a predominantly youth population in the study areas. 74 percent of the population is in the age range between 15-64 years (work force); where as 2.5 percent of the total population belong to age category of over 65 years.

Nearly 4 percent of the population has not received formal education (The literacy rate of the study population is around 97 percent). Average family size of the sample population is around 4.32. About 27 percent of the families have less than 4 members, 53 percent of the families have 4-5 members and rest consists of 6 or more members. According to the findings, the labour force represents 84 percent of the total population which comprises both economically active and inactive population. The estimated age dependency ratio of the selected population is nearly 17 percent.

The most prominent land category in the areas is home gardens consisting of 47 percent of the total land holdings. In line with the land size distribution, nearly 50 percent of agricultural land holdings in highlands and lowlands are under the class size of 1.5 to 3 and less than 1.5 acre extent respectively. However, highest percentage (46.6) of home garden holding are belongs to 1.5 to 3 acre class. Around 60 percent of the total land extents are under home gardens and 22 percent represents high lands. However, according to the survey data low lands extent is very low in selected areas indicating the importance of promoting highland cultivation.

Out of the total number of "household heads" of the sample population, around 82.5 percent are involved in agriculture as a primary employment. The household income is varies from Rs. 1,500 to 98,000. Household's income levels in Puttalam district is higher compared to other two districts involved in this survey. About, 94 percent of households received over half of their household income from agricultural activities and this is more prominent in Hambanthota and Moneragala districts, indicating the vital importance of agriculture development in the areas Because, RRWH farmers especially in those two districts have more concern about the continuous supply of water and consistent water source for their agricultural activities. This is clearly indicated in the "wiliness to expansion" of the RRWH system.

6.1.2 Approaches of Interventions

RRWH has been regarded as one of the important tools to achieve household water security and food self-sufficiency, and is being implemented on a large scale particularly in water scarce areas of the country. According to the Lanka Rain Water Harvesting Forum (LRWHF) information 22,543 RWH units have been built in Sri

Lanka by Individuals, organizations and institutions till December 2007. Those tanks are implemented under subsidy programmers through Government and NGO's.

There are two types of RRWH systems generally practiced in Sri Lanka. Those are lined RRWH ponds and unlined RRWH ponds. Normally, unlined RRWH ponds are excavated using heavy machinery and by using excavated soils, bunds are made. The capacities of the unlined RRWH ponds are differ due to uneven shapes but, approximately it varies from 300 m^3 to 500 m^3.

Lined RRWH ponds mostly available in the country are cylindrical in shape. The dimension of the tanks varies from 3 to 4.5 m in diameter and 3 to 3.6 m depth. There are completely lined with bricks and cement mortar. Capacities of the lined ponds vary from 120 m^3 to 150 m^3. The beneficiaries of the lined RRWH ponds normally use either hand pumps or peddle pumps to lift the water. Some of the farmers use improved irrigation technologies (Drip irrigation systems) to apply water to field to minimize the water losses.

Two types of approaches have been adopted by the implementing agencies to promote RRWH systems namely full and partial subsidy with farmer contribution development methods. In the partially subsidized RRWH system development approach, the agencies have granted the part of the cost of constructing the RRWH system and the remaining cost have been contributed by the beneficiary farmers via mobilization of both cost and un skill labour. However about 75 percent of RRWH systems in the study areas have been provided under the full subsidy approach. All the beneficiaries in Karuwalagaswewa, Wanathavilluwa, Siyambalanduwa and Wellawaya DS divisions have benefited under full subsidy programme. In other words, partially subsidized RRWH systems are available only in Thanamalwila and Lunugamwehera DS divisions. More than 88 percent of the farmers under partial subsidy approach have contributed over 50 percent of the total cost of construction of the RRWH system.

Agriculture equipments such as drip irrigation kits and hand pumps provided with RRWH systems in some locations, but those were provided under the top down approach without proper consultation of all the stakeholders therefore, those are largely not utilized by majority of the farmers. The main reason for not to use the drip irrigation kits was the poor quality of stored rainwater in the RRWH systems which caused clogging of drippers. The hand pumps given by the project is seem to be very laborious in operation and therefore most of the hand pumps granted are not in use.

According to the findings 9 percent of RRWH units are abandoned at the time of survey due to technical errors of construction, selection of un suitable land site for the RRWH system (sandy soil), and poor quality of construction. The main reason for the system failure was insufficient water stored in the systems due to high soil permeability and/or leaks occurred in the system due to poor construction or technical errors occurred in the construction.

Introduction of RRWH systems has helped to increase the income levels of 90 percent of partially subsidized and 80 percent of the fully subsidized beneficiaries. Out of total abandoned RRWH systems, 93 percent of the RRWH units were constructed under full subsidy development approach. These findings clearly indicate that the beneficiary contribution for RRWH system construction has a positive relationship for the success of the RRWH systems.

The finding indicates that the beneficiary investment for the expansion of granted RRWH system is very minimal. Only 12 percent of the beneficiaries have already expanded the RRWH system by now at their own cost showing their dependency on external agencies. The main reason behind the RRWH system capacity expansion was to store additional amount of water for expanded cultivation. Survey results also showed that around 89 percent and 25 percent of beneficiaries are willing to expand and de-silt the RRWH systems respectively. However lack of capital availability among these marginal farmers has curtailed to implement their interest in system expansion.

6.1.3 RRWH Systems in Agriculture

As in other parts of water scarcity dry areas in the country, peoples are dependent on multiple sources of water for their agricultural and other water needs. Farmers have one or more plots of land in a one or more land categories- low land, highland and home garden. RRWH units are most popular for highland and home garden cultivation. The interesting feature of water use in lowland is that about 35 percent of farmers use RRWH units' water for some of their lowland plots as a supplementary water source mainly to cultivate paddy.

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 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 86 percent and 25 percent of sample households respectively with some linkages on RRWH systems mainly to fulfill the drinking water needs of the animals during water scarcities. Only 3 percent of farmers perceived about the lack of adequate quality of water available in the system for the use of livestock, while 18 percent of beneficiaries mentioned about insufficient water available in the RRWH system to undertake integrated agriculture and livestock enterprise activities. About 9 percent of livestock farmers are also having buffaloes and goats. About 6 percent of livestock farmers use the RRWH systems purely for livestock rearing. About 69 percent of livestock entrepreneurs have accepted that there is an improvement in livestock related income after introduction of RRWH systems to their farming system.

About 31 percent of beneficiaries have utilized the RRWH systems for integrated crop cultivation and aquaculture activities. 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 in promoting aquaculture, though 16 percent of the respondents had not any problem in undertaking fish culture in the given RRWH system including the marketing of surplus fish harvest. Fish culture has contributed very much in improving food security of the households as well as neighbors while improving the nutritional values of food.

About 48 percent of sample households are utilizing the harvested runoff water for various household needs such as bathing during dry periods, sanitation, washing cloths and washing kitchen utensils are the major uses of the runoff water 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 as perceived by the 85 percent of beneficiaries. One of the most important impacts is the survival of vegetation during dry spells, which were severally effected before construction of the tank. Another direct social impact is that large number of neighbours living around RRWH systems is also using the water for the various household needs, and on farming activities during dry periods. It is interesting to note that, even in the drier environment about 22 percent of non owners of the RRWH systems (neighbours) have been allowed to use the RRWH systems to save their crop, which has helped to build up the social cohesions and integration in the village environment.

6.1.4 Problems Associated with the RRWH Systems

There are several problems associated with runoff water harvesting for agriculture. These problems are mostly associated with the system itself and sometimes it may be due to external factors. In the semi-arid or dry tropics with potential evaporation rates of 5-8 mm per day, water losses through open water evaporation is very significant. Over a 6-month dry season the water loss due to evaporation can amount to 0.9 - 1.4 m (SIWI, 2001). This will affect the water in RRWH systems. Strong winds also increase the evaporation losses during dry periods.

Typically, harvested runoff water consists of higher percentage silt and debris which can be accumulated in the pond if proper traps are not available. As a result, the pond gets enriched with nutrients providing a suitable medium for algal growth. Soil conservation methods available in lands determine the sedimentation rate of the pond. Moreover, irrigation with harvested rainwater helps to disseminate weed seeds thought out the crop field.

Lined RRWH ponds are generally constructed using single layer of bricks. The walls of these ponds are susceptible to cracking when the water level of the pond is at maximum due to high pressure as reported in some locations. Further, after construction of the pond wall, the packing of soil around the wall should be done carefully to minimize the damages to the wall.

Collapsing of earth bunds is frequently found in unlined RRWH ponds which were constructed long time ago (especially in Muthukandiya dry farm project) mainly due to technical errors of construction. The construction of bunds should be undertaken considering the soil type of the locality, topography of the land etc.

Capacities of the RRWH systems are mostly determined by the funding agency under the full subsidy development approach. However, under the partial subsidy development approach, capacity determining factors are size of the land, financial capability of the farmer, crop type, etc. Depth of the hard pan also limits the excavation of the RRWH system and thereby limiting the overall capacity. Due to these reasons, some farmers tend to go for small systems though they have a high runoff potential.

Water harvesting systems depend on runoff production from either state/communal land or from private land owned by neighbors. As long as water harvesting is an exception in a rural community, there may not be any problems with the ownership of runoff producing land. However, no sooner the demand for runoff water rises, and especially when upstream farmers tap runoff that otherwise would reach downstream water harvesters, there can be a crisis. As far as the study areas are concerned, this has not developed into a serious problem yet.

6.1.5 Economics of RRWH Ponds for Agriculture

According to the sensitivity analysis of NPV and BCR shows that, the project is viable even at 20 percent discount rate, if there is no change in the cost of production and gross income during the life period. However, BCR and NPV decrease with a decrease of interest rate but the change is marginal. The lowest BCR observed is 1.30 with discount rate 20 percent under the scenario of cost of production is increased by 10 percent while benefit derived is decreased by 10 percent. In addition, it is evident from the analysis that the reduction in NPV and BCR is much higher when expected benefits decrease by 10 percent than the increase in cost of cultivation by 10 percent.

One of the important investment issues which can be verified from the cash flow analysis of the adoption of runoff harvesting pond is that, an entrepreneur farmer as the potential of recovering the full capital cost within two to five year periods as found in the case studies. In addition farmers have the opportunity to maximize the economic returns by starting the cultivation prior to commencement of regular season with use of pond water which leads to get yields in off seasons and higher market price and integrating the livestock and aquaculture with the farming system

Although present analysis not aimed to assess the extended environmental and social benefits of RRWH systems, it has been reveled that the systems has pave the way to increase well water level and helped to develop more greenish and cooler environment in vicinity. The farm pond concept also has increased the household food security at a considerable level among the poorest rainfed farmers living in the more vulnerable and marginal areas. In general, the sensitivity analysis under various scenarios indicate that the RRWH ponds investment remain economically viable in all the given circumstances.

The small tanks have served the community as a whole and they shared and managed it jointly. This sharing and management method was ideally fitting with the existed relationships to the means of production of those times. Land, water, forest, wild life all were commonly owned by the community and government did maintain that ownership. Even when granted/donated to a few for various reasons, this particular relationship remained intact. It was a 'bulk transaction' but not a 'piece meal' deal. Hence, the community has to get together for shared management under the eye of the "feudal guardians". However, now this relationship to the means of production has been replaced by the market economy to a smaller, individually owned 'privately managed' system. The concept of each 'individual' having his/her own source of water, be it a tap, well or a pond for own and multiple use seems the way forward in this new era. This is happening around us in all other sectors: transport, health care, education, supply of food, etc. The "we" and "our" has being effectively replaced by "I" and "mine'. This is slowly coming into the 'access to water' as well. The current need is s/he should be able to use water independently for whatever his/her use at any desired time. The RRWH systems discussed in this report owned and run by individuals independently of others is an ideal case. This kind of irrigation system is increasingly termed as "atomized irrigation" or "private irrigation, and is something similar to have a private well with a pump or tap. Therefore, one of the major advantage this development approach, which need attention of the policy makers is providing 'everyone a guaranteed source of water for multiple uses, with low institutional and almost no O&M cost for the government.

6.2 Recommendations

1. It is important to identify the feasibility of rainwater harvesting (for domestic or agriculture) in the area prior to introduce the systems. A detailed rainfall analysis should be conducted to estimate the acceptable 75 percent rainfall probability value for each DS division based on the agro-ecological zones covered of each DS divisions and districts.
2. It is recommended to provide subsidies or credits to needy farmers who are in lack financial capacity to invest on RRWH systems after proper assessment. The Government organizations and NGO's should develop some criteria in this regard.
3. The location and soil type of RRWH system must be suitable to collect and store sufficient water for considerable period, unless it will be a failure due to loss of retention of water. Sandy nature of soils has less ability to store and retain water due to high loss of infiltration and percolation. In such situation, construction of cement tank or use of sealing material for pond is a suitable strategy, but the cost will be higher. On the other hand collapsing of bunds must be avoided by managing proper gradient of the walls of ponds as well as compaction of walls at the initial construction stage are recommended.
4. The study proposes the implementers to seriously consider the proportion of surface area to depth in order to reduce water losses. One or two rings of vegetation around the water body are recommended as a measure to create a

favorable micro environment and minimize the evapo-transpiration losses. In addition, adoption of micro irrigation technologies has the ability to improve water use efficiency of harvested limited water.

5. The study recommends promoting the user organizations to undertake expansion and de-silting of RRWH systems in a collective basis via community labour participation, which will minimize the machinery hiring cost than hiring on individual basis and ease the labour mobilization. The partner organization could play a crucial role in this direction.
6. Integration of crops with, livestock and aquaculture into the farming system under the runoff harvesting practice in dry areas in the country has proven higher return in short term period.
7. The study strongly recommends that any future interventions aimed to promote RWH technologies must provide greater attention to implementing approach and suitability and a real need of the system in the given environment, rather than focusing on the number of RRWH systems.
8. It is important that the all the agencies already involved or to be involved in rainwater harvesting have an understanding and consensus on the developed strategies for rainwater harvesting in the country. It is recommended that a knowledge sharing workshop be organized inviting district level decision making authorities in each stakeholder institution.

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