ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

CONSTRAINTS TO UTILIZATION OF RAINWATER HARVESTING PONDS BY FARMERS IN DERRA WOREDA, CENTRAL ETHIOPIA

BY

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A THESIS SUBMITTED TO SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF ARTS IN GEOGRAPHY AND ENVIRONMENTAL STUDIES

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APROVAL PAGE

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ABBREVIATIONS

ARDO – Agriculture and Rural Development Office

ASA – Arid and Semi-arid Areas

CTO – Culture and Tourism Office

DAs – Development Agents

FGD – Focus Group Discussion

GDP - Gross Domestic Product

ha – hectares

HH – House Hold

IPRO – Information and Public Relation Office

IWMI - International Water Management Institute

MoARD - Ministry of Agriculture and Rural Development

ND - No Date

NGO - Non Governmental Organizations

PAs - Peasant Associations

RWH – Rainwater Harvesting

Sear NET – Southern and Eastern Africa Rainwater Network

SNNP – Southern Nations Nationalities and People

SPSS – Statistical Package for Social Science

UNFCCC – United Nations Framework Convention on Climate Change

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ABSTRACT

The purpose of this study was to assess the constraints to the utilization of rainwater harvesting ponds by farmers in Derra woreda, Oromia region. To achieve the objectives of the study, the researcher collected primary data through household questionnaires, interviews with various officials and key farmers as well as group discussions with PA level administrators; and secondary data from written materials. The collected data were analyzed through both quantitative methods like frequencies, percentages and significance tests; and through qualitative methods.

The results of the study disclosed that most farmers have good perceptions for the technology and have gained enough awareness about the benefits obtained from the ponds. But, the utilization of the technology is surrounded by various constraints. The major constraints include: the low quality of the constructed and hence short service duration of the ponds; inferior utilization of the stored water resulted mainly from low involvement and from limited training of stakeholders during the implementation of the program, and from the wrong site of the ponds. Furthermore, high cost of construction has hindered farmers not to have additional ponds; and limited financial power of farmers has resulted in low maintenance of old ponds and also decreased the capacity of farmers of purchasing materials and equipments to utilize the technology. Low investigation of soil types and ground slope by experts during the construction periods have contributed to the existence of unutilized ponds. The results of the study also identified that the incidence of local disputes among the society and reducing cultivation land as a major negative impacts that the unutilized ponds have exerted on the community. From the results of the study it is also known that households with large family labor, better land size and oxen, and better income have better possibility of utilizing the technology than their counterparts.

On the basis of the findings, it is recommended that the government shall give due attention for the construction of quality and long lasting ponds; facilitate ways for the involvement of NGOs in the technology; create financial institutions assist technology users; and repairing or closing of unutilized ponds through mobilizing the community.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

The base for Ethiopian economy is agriculture (Woldeamlak, 2006). The agricultural sector plays an important role in the national economy, livelihood, social and cultural systems of the country. The sector supports employment of over 80% of the population, accounts for 45-50% of the national GDP and makes the largest contribution to raw materials for agro-industries and food security (Berhanu, 2006). One of the major factors contributing to food insecurity in Ethiopia, particularly to transitory food insecurity, is the dependence of the agriculture on the highly variable and unreliable rainfall (Woldeamlak, 2007). The country's agriculture production is aimed at self-subsistence and dependent on forces of nature. As such rain-fed agriculture is severely affected by forces of nature like climatic variability (Mitiku et al, 2002).

In addition, the rainfall pattern of the country also shows high level of variations (Daniel, 2006). In the semi-arid areas rainwater is available in abundance during the rainy season and surpasses the evapotranspiration during a few months (July, August and September in most cases, and March and April for selected Ethiopian conditions) (Rockstrom, 2000). The main reason is the practical difficulty posed by the nature of rainfall. The rain is very poorly distributed in both spatial and temporal terms. Often there is too much water during a few days of the year, while water supply is insufficient during most of the year. As a consequence, the moisture stress between rainfall events (dry spells) is responsible for most crop yield reductions and sometimes even for total crop failures (Abebe et al, 2003). These events have challenged agricultural activities especially rain-fed agriculture.

On the otherhand, Ethiopia like other developing countries is the most vulnerable to climate change impacts because the country has fewer resources to adapt: socially, technologically and financially. Climate change is anticipated to have far reaching effects on the sustainable development. Thus, overcoming the limitations of these arid and semi-arid areas and making good use of the vast agricultural potential under the Ethiopian context is a necessity rather than a choice. To this end, there is a great need for appropriate intervention to address the prevailing constraints of agriculture using rain water harvesting (RWH) technologies for improved and sustainable agricultural production. (UNFCCC, 2006; Rebeka, 2006)

In addition to the above mentioned factors, due to population increase in the highland areas of Ethiopia, more and more marginal areas are being used for agriculture. The situation challenges agricultural productivity (Nega, 2004). Accordingly, one of the major challenges to rural development in the country is how to promote food production to meet the over increasing demand of the growing human population. Rainfall in the arid and semi-arid areas is generally insufficient to meet the basic needs of crop production for the increasing human population (Rebeka, 2006).

For many of smallholder farmers, reliable access to water is the difference between plenty and famine (IWMI, 2009). The classic response is to store water behind dams or in tanks or ponds when it is abundant and where it can be used for times of shortage. Water storage spurs economic growth and helps alleviate poverty by making water available when and where it is needed (IWMI, 2009).

Thus, as witnessed in several parts of the country, complications due to the amount and distribution of rainfall could be averted through the expansion of RWH practices (Daniel, 2006). Hence, rainwater harvesting and buffering through times of rainfall scarcity through the application of supplemental or protective irrigation might be a good option to protect loss of crop yields, or even complete crop failure (Woldeamlak, 2006).

1.2 Statement of the problem

There is a growing interest in the large range of low cost agricultural water management technologies in the arid and semi-arid developing countries. This is in response to the observation that unreliable water supply is one of the biggest threats to the food security of poor small farmers. The vast majority of the rural people rely on rain-fed land for their survival, making them vulnerable to the highly variable and unpredictable rainfall. Thus, periodic drought and famine are the result, especially in many Sub Saharan Africa (SSA) countries (Salas, 2006).

Following this, focusing on low cost rain water harvesting technologies to tackle the pressure of fresh water scarcity of rain-fed agriculture is often identified as one of the possible responses to this problem (Ngigi, 2003).

Diverting rivers and building small dams in order to increase small scale irrigation system are the major areas of emphasis of Ethiopian water policy (Daniel, 2006). Since 2003, the government of Ethiopia had been engaged in massive expansion of RWH structures. In the four major Regional States of the country (Amhara, Oromia, Tigray and SNNP), about 952,120 pond of various RWH types were constructed between 2002 and 2005, and about 20,000 hectares of agricultural land was cultivated (Daniel, 2006).

According to Gezahegn et al (2006), much of the money allocated for food security program in the country was invested for the implementation of RWH programs, many of which are based on construction of ponds planned and implemented by the Ministry of Agriculture and Rural Development (MoARD). The merit and compatibility of RWH ponds with the rural livelihoods have been debated, though not widely, among various scholars and politicians. While the government promotes RWH technologies as "magic bullet" to fight food security problems, some critics have minimized its role in the context of acute land scarcity, absolute poverty, vulnerability to malaria, and abundance of rivers in the country (Daniel, 2006; Nega, 2004; Emishaw, 2009).

The Agriculture and Rural Development Office of Derra *Woreda* was engaged in the implementation of on farm RWH ponds in the *Woreda* in 2003 and 2004. Accordingly, thousands of ponds were dug in the entire 33 rural *kebeles* of the *Woreda* during *Bega* 2003 and *Bega* 2004. The project was carried out with the government budget through *'Migib Lesira' or* food for work. It was rural poor farmers who were given priority in the digging of the ponds under the supervision of the ARDO experts. Starting from the year 2005, the NGO called Menschen fiir Menschen has engaged in the construction of ponds for selected farmers of the woreda. Ponds made with help of this organization have better quality and most of them are productive.

Like other areas in Ethiopia, the implementation of onfarm RWH ponds in Derra *Woreda* was a diffuse 'quota system' as many as without location condition, geological structure, soil and pond types as well as practical awareness of users. Even at the time of implementation, many farmers did not have information whether or not the ponds were dug on their plots.

Irrespective of huge financial, labor and time resources invested upon the implementation of RWH ponds in the *Woreda*, today majority of these ponds are unutilized due to various constraining reasons. Furthermore, the existing useless ponds on plots are becoming additional constraints to the local farmers. Therefore, investigating on the constraints to utilization of rainwater harvesting ponds by farmers in Derra *Woreda*, by addressing the following objectives is useful.

1.3 Objectives of the study

The overall aim of this study was to assess the constraints to utilization of rainwater harvesting ponds for agriculture by farmers of Derra Woreda.

The study tried to address the following specific objectives:

- To assess the perception of farmers towards RWH ponds in the study area;
- To examine the constraints to the utilization of RWH ponds in the *Woreda*;
- To explore the socio-economic impacts of unutilized RWH ponds in the community; and
- To investigate the determinants of households' decision whether or not to utilize RWH ponds

1.4 Research Questions

To address the above mentioned objectives, the study was focused on answering the following research questions:

- What is the perception of the farmers towards RWH ponds?
- What are the constraints to the utilization of RWH ponds in the *Woreda*?
- What are the socio-economic impacts of unutilized RWH ponds in the community?
- What are the determinants of households' decision whether or not to utilize RWH ponds?

1.5 Significance of the study

Various efforts have been exerted in the past decades to promote the effectiveness of implementation of RWH technologies in various parts of the country to enhance food security. However, constraints remain unsolved in Derra *Woreda* and perhaps in many other similar areas. Accordingly, the findings of this study will initiate the concerned bodies like government officials, non-governmental organizations, development agents and farmers to give due attention for the solutions of the existing constraints related with the utilization of RWH technologies.

In addition to this, the study may serve as a base for further research investigations in the study area. Furthermore, the study will give general and specific recommendations for the improvement of RWH technologies.

1.6 Delimitation of the study

The study was conducted in Oromia Regional State, Derra *Woreda* focusing on the constraints to utilization of RWH ponds by famers in general and assessing the perception of farmers to RWH ponds; exploring the effects of unutilized ponds on the local people; and examining the determinants of farm HH decision whether or not to utilize RWH ponds in particular.

1.7 Limitations of the study

Undertaking research without any limitation is difficult. In addition to the shortages of time and finance, limitations such as shortage of reliable secondary data from various offices of the woreda, difficulty of representing the study area with 120 farm household respondents were the challenges of the study. However the researcher tried to minimize these constraints through increasing working hours; self covering some expenditures of the study; and boosting the response rate of the respondents so as to make his research more effective.

1.8 Methodology of the Study

1.8.1 Research Design

To gather adequate information that meets the stated general and specific objectives of the research, both qualitative and quantitative methods were employed in this study.

1.8.2 The Study Area and Sampling Procedures

Among the Oromia Regional State *Woredas*, Derra is selected purposively giving due attention to criteria such as the majority of RWH ponds constructed in this *Woreda* are becoming out of use due to various reasons which were tried to be identified through this study. Moreover, the researcher's long time living experience in the area made him understand well the problem understudy.

The study *Woreda* comprises a total of 34 *kebeles* of which 33 are rural and the remaining one urban. In all 33 rural PAs of the *Woreda* on farm RWH ponds has been implemented.

Firstly, these 33 rural PAs were grouped to three strata depending on their local climatic characteristics as *Dega, Woina-dega* and *Kolla*. From the 33 rural PAs, *Addis Alemyaya* from *Dega*, *Ilu Godechefe* from *Woina-Dega*, and *Harbu Deso* from *Kolla* were selected to represent the study area.

Secondly, 120 farm HH heads of half pond users and the remaining half non users of ponds were selected proportionally from the three PAs as follows:

Table 1.1 Sample size of farm HH heads.

Sample Kebeles/Pas	No of households	No of sample households		
		Users	Non users	Total
Addis Alemyaya	1789	33	32	65
Illu Godechefe	862	15	16	31
Harbu Deso	670	12	12	24
Total	3321	60	60	120

Source: Own table

Finally, applying simple random sampling method, farm HH heads were selected to be included in the survey.

1.8.3 Data and Methods of Collection

The sources of data for this research were both primary and secondary which were gathered through the following instruments.

1.8.3.1 Primary data sources

A. Household survey: Structured survey questionnaires, with closed-ended and open-ended questions were used to gather primary household data at village level. Efforts have been made through handling all survey questions by the researcher to each village so as to increase the response rates. Accordingly data needed over: demographic characteristics of farm households; farmers' perception and awareness about RWH ponds and households' participation in various phases of RWH; constraints to the utilization of RWH ponds; and the socio-economic impacts of unutilized RWH ponds in the community were gathered.

B. Key Informant Interviews: through pre-prepared unstructured interviews, staff members from the Agriculture and Rural Development Office of the *woreda*, DAs and purposively selected RWH pond user and non-user farm HH heads from each of the sample PAs were included in this study as key informant interviewees.

C. Focus Group Discussion: the other method of gathering primary data was FGD. The focus group was composed of six PA leaders selected from the sample kebeles. The in-depth discussion which was led by the researcher to have the thoughts, perceptions and constraints over the utilization of RWH ponds was carried out.

D. Field Observation: the researcher's field visit aiming at cross checking the data found through other instruments was the other important tool of primary data collection.

1.8.3.2 Secondary Data Sources

Published and unpublished materials including reports, journals, articles, books, master theses and doctoral dissertations that were collected from libraries, offices and websites were used in this study as a supplement of the primary data.

1.8.4 Methods of Data Analysis

Since the research is descriptive in nature, descriptive data analysis methods were employed. Furthermore, the quantitative data collected from close-ended questions were analyzed using SPSS (statistical Package for Social Science) version 16.0 to compute correlation analyses; and presented using means, percentages, frequencies and tables.

Concerning data from open-ended questions, key informant interviews, field observation and FGD, the analysis was performed through qualitative description.

1.9 Organization of the thesis

The thesis has five chapters. Chapter one is about the introductory part of the study followed by chapter two which is the review of related literature part. Background of the study area is discussed in chapter three of the paper. Chapter four is all about the results and discussions part of the thesis. In this chapter the findings of the study are included with their in-depth analysis. The last chapter composes of the conclusion and recommendations parts of the study.

1.10 Definition of basic terms and concepts

The following terms and concepts are used in this paper according to the definitions given as follows:

- *Rainwater harvesting technology user households* = households engaged in the utilization of the stored water in the ponds for various productive purposes.
- *Rainwater harvesting technology non-user households* = households having ponds but could not utilize the stored water for productive uses due to various reasons.
- *Woreda* = District.
- *Kebele* = Peasant association that consists of some villages.
- *Ekub* = Local saving system.
- *Dega = Highland*
- *Woina-dega* = Mid-highland
- *Kolla* = Lowland

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Definition and Concepts of Rainwater Harvesting

According to Manoj et al (2008), rainwater harvesting, irrespective of the technology used, means harvesting and storing rainwater in days of abundance for use during the lean days. Storing of rainwater can be done in two ways: (i) in artificial storage and (ii) in the soil media as soil moisture.

Rainwater harvesting is a broad definition including all methods for concentrating, collecting and storing surface runoff water in different mediums, for domestic or agricultural uses (Rockstrom, 2000). A common straight forward definition of water harvesting is the collection of runoff for productive use (Siegert, 1994; cited Rockstrom, 2000). Runoff can be collected from roofs or ground surfaces (rainwater harvesting) as well as from seasonal streams (floodwater harvesting) (Agromisa, 1997; cited in Rockstrom, 2000). The harvested runoff can involve different forms surface runoff (sheet, rill, gully and stream flows) and the storage is either done above ground, in different systems of tanks, reservoirs or dams or below ground in the soil. Methods for harvesting runoff water can be distinguished after (i) source of the surface water (external or within field catchment), (ii) the method of managing the water and (iii) the use of water (livestock, household, crop production and erosion management) (Rockstrom, 2000).

However, the most short and precise definition of rainwater harvesting, is the definition given by Boers et al (1982); cited in Dietes et al (1999),: the method of inducing, collecting, storing and conserving local surface runoff for agricultural use in arid and semi-arid regions.

The definitions given by Manoj et al (2008) and Boers et al (1982) fit the scope of this study while the remaining definitions are out of the scope of this research.

Rainwater harvesting techniques can be applicable in all agro-climatic zones. However, it is more suitable in arid and semi arid areas. These are areas of average annual rainfall of 200mm-800mm (rarely exceeding 800mm); the average temperature is above 18^0c. The rainfall may come in one or two seasons. In such environment, rain-fed crop production is usually difficult without some form of RWH (Rebeka, 2006).

The same author generalized that the RWH technologies can be applicable in the following circumstances:

- In ASA areas, where the potential for crop production is diminishing, due to environmental degradation. Providing water to these areas through RWH can improve the vegetative cover and enhance resource conservation;
- In the area where other permanent water resources like rivers, springs etc are not available or uneconomical to develop and to use them;
- In dry environment, where low and poorly distributed rainfall, normally makes agricultural production impossible;
- In rain-fed areas where crops can be produced, but with low yield and with high risk of failure; and
- Where water supply, for domestic, agriculture and animals is not sufficient.

Moreover, the technology could be more effective in environments where the slope of the area is not exceeding 5%. This is due to uneven distribution of runoff and large quantities of earthwork required which will not be economical. Soil of the area also needs to be suitable for irrigation: they should be deep, not saline or sodic, and ideally be naturally fertile. Rainwater will not work on soils with sandy texture because the infiltration rate will be too high. If the water soaks in as fast as it falls from the sky, no runoff will occur (SearNET, ND, *www.searnet.org*, accessed 14th August, 2010).

2.2 Classification of Rainwater Harvesting Technology Systems

Water harvesting pertains to any practice that collects runoff for productive purposes. A distinction is often made between in-situ water harvesting, i.e., the capture of local rainfall on farmland, and ex-situ water harvesting, i.e., the capture of rainfall that falls outside the farmland (Oweis et al, 1999)

However, the classification is further complicated by the fact that a number of RWH technologies are integrated or combined by land users, for instance, In-situ water conservation is combined with runoff farming on farm with terraces, in which terrace channel collects and stores runoff from small external catchments while the crop-land between the channels harvest and conserve direct rainfall (Ngigi, 2003).

Generally, Rainwater harvesting technology systems can be classified as it is summarized below:

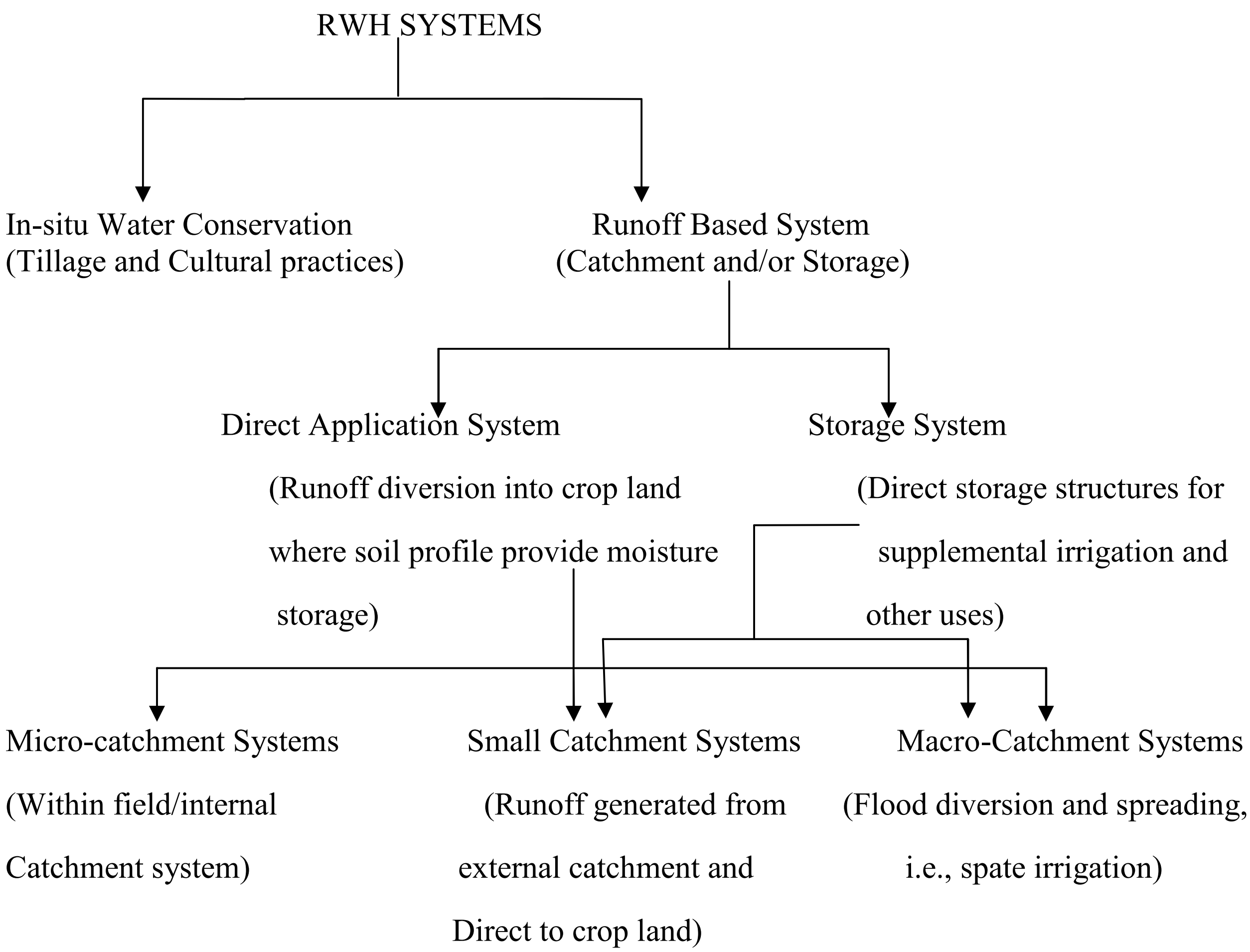

Figure 2.1: Classification of RWH technologies and systems (Adopted from Ngigi, 2003)

The classification shown in the figure 2.1 above is based on runoff generation process and type of storage/use and size of catchments adopted. Accordingly, rainwater harvesting system can be classified as in-situ rainwater conservation system and runoff based system (The classification is according to Ngigi, 2003; Oweis et al, 1999).

2.2.1 In-situ rainwater conservation system

Unlike run off farming system, in-situ rainwater conservation system does not include a run off generation area, but instead aims at conserving the rainfall where it falls in the cropped area or pasture. Under this category, the most common technology is conservation tillage that maximizes the amount of soil moisture with in the root zone. Conservation tillage is defined as any tillage sequence having the objective to maximize the loss of soil, and water and having an operational threshold of leaving at least 30% mulch or crop residue cover on the surface through out the year (Rockstrom, 2000 cited in Ngigi, 2003). However for small scale farmers' conservation tillage is any tillage system that conserves water and soil while saving labor and traction needs.

Enhancing infiltration and moisture conservation, enabling improved timing of tillage operations, improving crop yield are some among several attractive effects that conservation tillage has compared to the traditional soil and water conservation systems like funya juu terracing. In addition to conservation tillage, a number of cultural moisture practices such as ridging, mulching, addition of manure, etc could fall under in-situ rainwater harvesting conservation system. The other positive effect of in-situ water conservation technique is to concentrate with in-field rainfall to cropped area. On the otherhand, although soil improvements such as addition of manure would enhance realization of better yield, the technique may offer little or no protection against poor rainfall distribution (Ngigi, 2003).

2.2.2 Run off farming

The run off farming systems, which entail run off generation either with in field or from external catchments and subsequent application either directly in the soil profile or periodic storage for supplemental irrigation, are further classified according to two criteria as storage rainwater harvesting systems and direct run off application system (Ngigi, 2003).

Storage RWH systems are aim at storing rainwater in various types of storage dams. These systems are implemented in Ethiopia in various parts of Amhara, Oromia and Tigray regions (Daniel, 2006). This system, although it is simple to design, has challenges such as high cost of lifting water, cracking and hence abandoned, and loss of water through seepage has been identified as drawbacks. In contrary, since the system enables to store large quantities of water in ponds at the times of abundance rainfall, has advantages like conserving water for livestock watering small scale irrigation.

On the otherhand, direct run off application systems are characterized by run off generation, diversion and spreading with in the crop land, where the soil profile acts as the moisture reservoir (Oweis et al, 1999).

According to the size of catchments, run off generation rainwater conservation system is further divided in to macro-catchment system which large external catchments providing massive run off (floods) that is diverted from gullies and ephemeral streams and spread in to crop land, i.e, spate irrigation; small external catchments in which run off is diverted to crop lands from adjacent roads, fields, etc ; and small external catchments normally with in crop land that generate small quantities of run off for single crop, group of crops or row crops (Ngigi, 2003).

2.3 Rainwater Harvesting in Developing Countries

As to Falkenmark et al (2005), 70% of the world's poor live in rural areas and are often at the mercy of rainfall based sources of income (rain-fed agriculture). In developing countries there is an increasing competition for limited water resources. As a result, food production is water constrained and the degree of freedom is constantly shrinking. Therefore, water is increasingly understood as a key factor in socio-economic development.

To cite some examples, in Tanzania, poverty is higher in areas with no dependable cash crop, a situation that is more common in arid and semi-arid areas. However, there are potential benefits that can be derived from application of rainwater harvesting technologies. Wider adoption of rice and onion production, and other similar high valued crops will assist in poverty reduction. This together with improved maize yields under RWH can considerably improve food security in arid and semi-arid areas of the country. However, it is important to note that RWH alone may not be a solution to poverty reduction if other complementary inputs, markets and infrastructure are not in place (Senkondo et al, 2004).

The over five million water catchment system of China supports the domestic water supply for 21 million people and irrigation water for over one million hectares of land. As a result, farmers have changed their traditional cultivation of only one harvest of corn in a year in to one or two harvest of rice and one of corn. Despite all those contributions, like happened in Tanzania, RWH is not taken as the only way out of the complex problems in China. A development strategy, which comprises “terracing + plastic sheeting + rainwater harvesting + agriculture structure modification,” is a prominent approach in Northwest China. RWH still occupies a central place in China and therefore land productivity is enhanced (Zhu and Li, 2004; cited in Daniel, 2006).

A study conducted in Rajasthan district of India has illustrated that the water from RWH has improved the income of poor people, education, as well as social and cultural well being. Increased water availability through small scale water harvesting structures in Mayagaon, Jamun and Nala villages of the district, has increased the productivity of crops, fodder and milk production (Sharma, ND).

In southwestern part of Uganda, where banana production constitutes the backbone of rural food security, efforts have been made, especially in Mbarara district to develop water harvesting methods for banana fields. Bananas are cultivated on the relatively steep foot hills, and have over the year been submitted to water erosion caused by runoff produced from upstream soils. This has resulted in fertility depletion and a shift in the water balance, with lowered infiltration and higher runoff losses, causing recurrent soil-water scarcity. To tackle this problem water infiltration schemes have been developed, which are dug along the contour, at specific interval according to the slope. Through these farmers harvested runoff produced from paths and roads and established sustainably increased banana yields (Rockstrom, 2000).

Farmers in the Yatenga province in Burkina Fasso provide an example where water harvesting is used to improve production and increase income. As early as 1989, farmers in 8,000ha in 400 Yatenga villages were using an improved version of their traditional water harvesting techniques that involved building simple stone bund across the slopes of their fields (Postel, 1992; Tiffen et al, 1994, cited in IWMI, 2003).

With all these empirical examples, it is important to notice that with proper implementation of RWH technologies in conjunction with other infrastructural and market improvements, poverty reduction in general and proving food self sufficiency in particular is possible.

2.4 Rainwater Harvesting Technologies in Ethiopia

In Ethiopia, rainwater harvesting dates back to the pre- Axumite period (560 BC) (Fattovich, 1990: cited in Daniel, 2006). However, it has not been filtered through modernization. While direct diversion of overland surface water on to the field has been commonly practiced in many parts of Ethiopia, digging holes to collect water is rather a new practice in highland parts (Getachew, 1999). Hune (2004) reported that, in the food security strategy of Ethiopia, RWH is aimed to meet two goals: to cultivate horticulture during dry period and to provide water as supplementary irrigation in wet season.

Rainwater harvesting had been practiced in Ethiopia for the last 10 years in various parts of the country. In response researchers have conducted studies on various issues of rainwater harvesting technologies in various parts of the country.

To state some of them, for instance, introduction of RWH structures in the drought prone Wukro district of Tigray Region was found to be important both in terms of harvesting enough water needed to meet both the domestic and the irrigation needs. A significant number of farmers of the *Woreda* started to obtain higher yields after they adopted the technologies and their annual income had become higher (Nigussie, 2008). Some farmers have still mixed feelings about this technology and all its advantages, the adoption rate of the technologies by all farmers is still low and this is due to the fact that the technology is surrounded with a lot of constraints. Furthermore, the study revealed that poor capital and human resource endowments, lack of access to credit, involvement in off farm activities, a negative perception, gender issues, sedimentation, inaccessibility of the construction materials, lack of technical know-how are among the factors negatively influence the adoption of RWH technologies (Nigussie, 2008).

Site selection is an important factor in the adoption and utilization of rainwater harvesting. For example, Meket in north Wollo of Amhara Region is just one of many *Woredas as* that experienced problems with site selection for the implementation of rainwater harvesting technologies. The *Woreda* has three agro-ecological zones and receives on average 700-800mm of rainfall. The lowland suffers from the most chronic water shortages, but is difficult to access for transport of cements and heavy plastic linings. Ponds and tanks therefore are constructed mainly in the midland (*Woina- Dega*). But mid and highlands with their swampy black cotton soil have a very good ground water potential and often a very high water table which makes them much less suitable for ponds and tanks than the lowland kola areas (Rami, 2003).

Concerning materials and machines of rainwater harvesting, the choice of technology should consider the capacity of the beneficiaries to operate equipment on their own (example, mechanized pumps) and to maintain the pumps and obtain spare parts. There is a classical example of the Meki-Zeway scheme in Oromia which failed particularly because farmers could not get spares for the imported pumps, afford the electricity fees to run the pumps. There is a need to provide periodic training in the field of rainwater harvesting technology, agricultural input supplies, marketing and employees engaged in the implementation of the program (Sileshi et al, 2006).

Responding to constraints of RWH technologies, it is possible to increase the use of the technology. For instance, a conclusion from a research on rainwater harvesting in Ethiopian level including Boset and Dugda Bora *Woredas* of Oromia Region and Tehule Dere, Kalu and Bati *Woredas* of Amhara Region indicated that to avert the potential limitations and maximize the benefits of RWH as a strategy for poverty reduction, new policies are needed. By resolving the biophysical, socioeconomic and policy constraints of RWH, it is possible to improve the situation of millions of poor farmers through reduction of vulnerability to crop failure, malnutrition and seasonal food deficits (Daniel, 2006).

The lessons of rainwater harvesting vary from one part of the country to the other, while huge opportunities exist for supporting RWH on sustainable basis. Some of these opportunities include several NGOs and regional bureaus have assessed the water potential in their areas of operation to be huge. This potential, especially if utilized along with high value crops; and communities' willingness to participate in any form water harvesting interventions that will improve the rural poor current livelihoods. This willingness should be taken advantage of especially during the planning and implementation of RWH projects (Silesh et al, 2006).

In summary, regardless of various studies carried on so far, the constraints in the utilization of rainwater harvesting technologies in some parts of the country are still there. The situation in Derra *Woreda*, which is different from the other parts of the country in the majority failure of the

RWH ponds, is surprising. To this end, there is a need of focusing on the constraints to utilization of rainwater harvesting ponds and why the project failed in the study area.

2.5 The roles of rainwater harvesting

Most of the famine stricken areas of Ethiopia experience moisture stress either at the growing season or dry spell periods. Thus, many of them could tremendously improve food security through rainwater harvesting, which aims at supply the deficit rainfall and evapotranspiration during the growing season or dry spell periods (Emishaw, 2009). In case of rainwater harvesting for supplemental irrigation, the deficit is maintained by supplying water to the crops during the critical periods (Ngigi, 2003). Therefore, the technology has led to improved food security and living standard through provision of water for domestic, livestock and agricultural purposes.

The other role of rainwater harvesting is the diversification of crops grown. For instance, as Nigussie (2008) stated, farmers in Wukro district of Tigray region, have grown new crops which were not grown before the technology adoption through rainwater harvesting technology. Furthermore, the stored water in the RWH ponds used for growing of various fruits and vegetables through small scale supplemental irrigation. In the study area, RWH user farmers have informed that they are growing fruits such as papaya, lemon, orange, banana and vegetables like onions, potatoes, cabbage, and sugar cane. Some of them also used the stored water for the growing of nursery in the dry spell periods. Diversification of foods in the daily diets is also the other interesting role of RWH in the study area.

Low technology rainwater harvesting serves not only as a water supply system, but also as a conflict resolution mechanism. For example, according to Ngigi (2003), different clans especially with in pastoral communities in arid and semi-arid land areas have been engaged in increasing conflicts over the control and use of communal water sources. Hence, one of the logical ways to contain the situation is to provide adequate water supply. This can be done by assisting in the construction of water pans to store rainwater for different clans. This shows that rainwater harvesting could play a major role in conflict resolutions, especially in drier areas.

The other important role of rainwater harvesting technology is related with gender. Since women are affected by any situation that happens in the community, it is important to look the impact of RWH structures in relation to gender. According to Nigussie (2008), although the income of both men and women is important to meet the basic needs of the family, since women purchase most of their income on family expenditures, their income will be affected more than men do. As RWH is concerned, women are more benefited a lot from income generated from the sale of fruits and vegetables produced by rainwater harvesting technologies. In addition to this, RWH provides women with job opportunity even at the dry spell periods and diversifies their income source through the sale of RWH products every week.

2.6 Conceptual Framework

As shown in Figure 2.2, the major constraints and determinants of farm households' decision whether or not to utilize rainwater harvesting technologies are technical problems with the ponds, institutional constraints, financial constraints and environmental constraints.

The technical problems related with the pond include absence of fence and roof covers to ponds and absence of silt-trap of ponds. These problems are constraining factors of utilizing rainwater harvesting and hence could result directly in low utilization of the technology and indirectly in low yield of agricultural production.

The other most important constraint in utilization and determinant households' decision whether or not to utilize rainwater harvesting technology is institutional constraint. Such constraints are involvement of stakeholders in implementation of the technology, site and household selection to adopt the technology, provision of education and training to utiliers and fragmented administration coordination in implementation of the program. Furthermore, good participation of stakeholders in implementation, appropriate location of ponds and provision of continuous education and training to utilize the stored water can result in high agricultural production.

In addition, financial constraints including high construction and maintenance costs and low supply and provision of equipments to utilize rainwater harvesting technologies are additional constraints and household decision factors in the utilization of the technology. If construction and maintenance costs are lowered, materials and equipments are provided to farmers with low price, it is possible to increase the utilization rate of the technology and also increase agricultural production.

The environmental factors include: soil type, cracking of the walls of the ponds, plot slope, plot size and rainfall conditions could directly affect agricultural production and the utilization of

RWH technologies. Farm households having medium land slope type, shallow soil plot depth, and large plot size near their resident have high probability to utilize RWH technologies and also they could increase the amount of yield that could be produced.

The technology utilization decision could increase the farm households' agricultural production by improving the availability of water during the dry spell periods, and it has also the potential to increase the moisture of the soil and thereby improve soil fertility, which in turn can increase the agricultural yield harvested.

Finally, as can be depicted from the figure, agricultural productivity can be affected by utilization of RWH technologies which in turn affected by farm households' decision to utilize rainwater harvesting technologies.

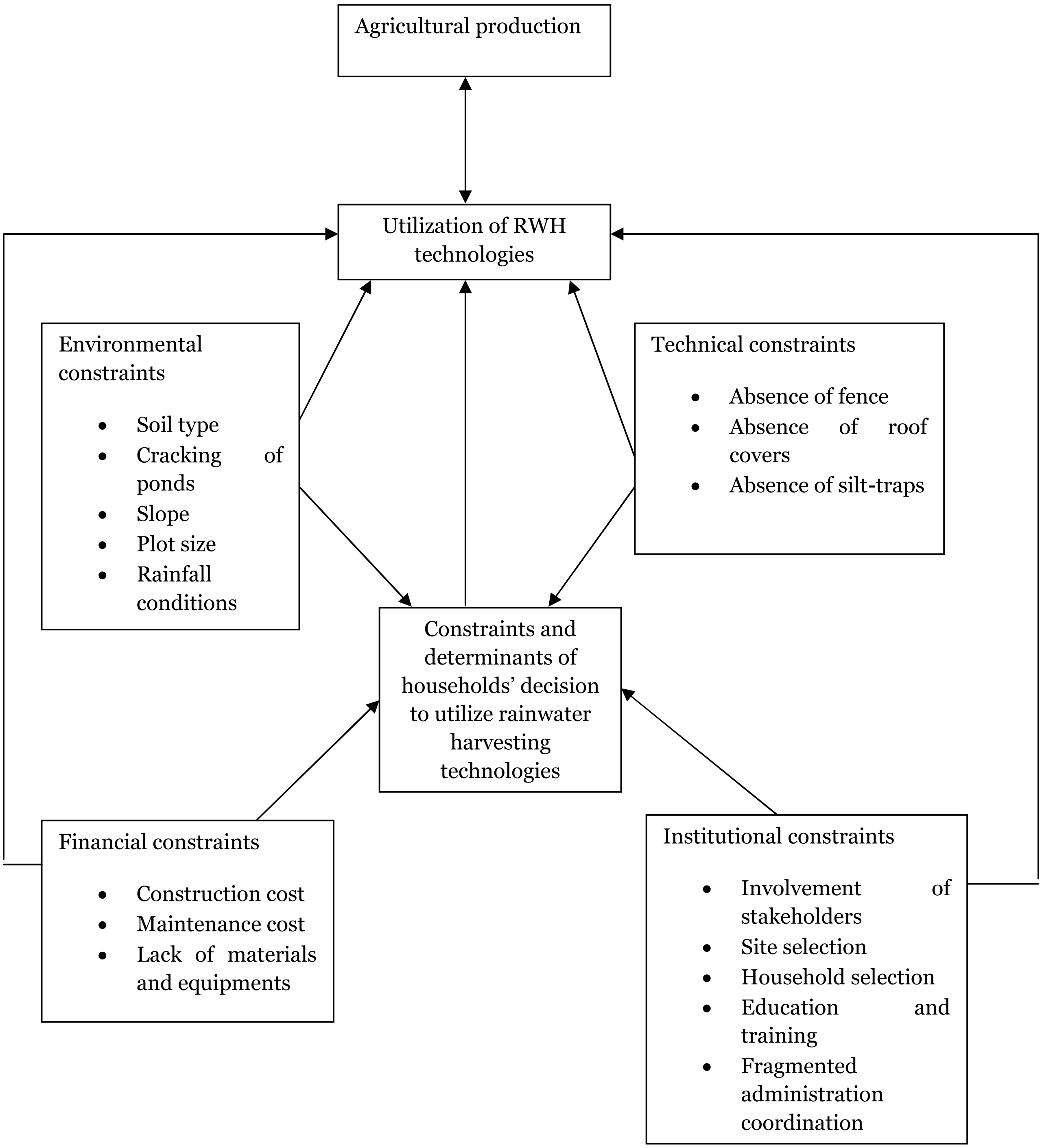

Figure 2.2: Schematic presentation of Constraints and utilization decision factors of RWH technologies

CHAPTER THREE

THE STUDY AREA

3.1 Physical Background

3.1.1 Location and topography

Derra woreda is among 17 woredas that are currently found in North Shewa zone of Oromia Regional State. The woreda is situated 220 kilometer north of Addis Ababa and 105 kilometer from the zone capital-Fitche. It lies is between latitudes $10^{0}00'48''$N up to $10^{0}22'26''$N and longitudes $33^{0}09'58''$E and $33^{0}51'48''$E.

Derra woreda is surrounded by rivers such as Beto in North, Jema in South, Wenchit in East and Abay river in West.

Currently the woreda comprises a total of 34 kebeles in which 33 are rural and one urban kebele-Gundo Meskel town (Figure 3.1).

The topography of the woreda is mainly characterized by plain which accounts to the 65% of the total area. Other features include hills (20%), gorges and uplands (10%) and mountainous features (around 5%). The altitude of the woreda is between 500meters and 2800 meters above sea level (Derra woreda IPRO, 2010).

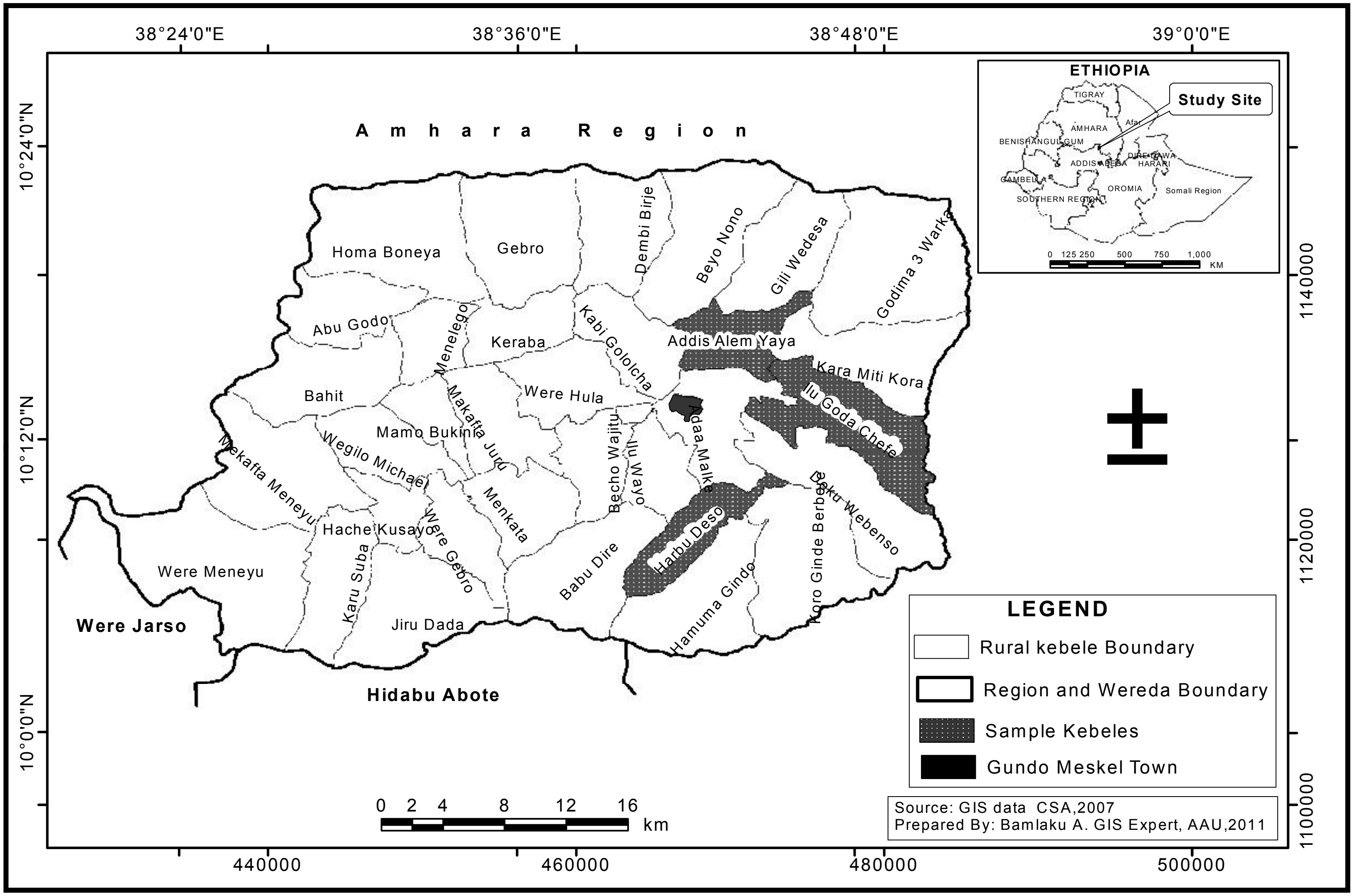

Figure 3.1 Location of the study area

3.1.2 Climate and land use

Dega, Woina-Dega and Kolla are the three local agro-climatic regions in Derra woreda. Around half of the woreda's climatic condition is covered by the Kolla climate followed by Woina-Dega (30%) and Dega (20%). The annual rainfall of the woreda ranges between 800milimeter and 1500 milimeter and its temperature is between 18 and 25 degree Celsius (Derra woreda CTO, 2010).

Derra woreda covers a total area of 152,714 hactares. The total area of agricultural potential which accounts for 75,462 hectares is the largest land use/cover of the woreda. Forest area covers 50,397 hectares from the total area in which 11.96% of it is indigenous trees. Grazing land accounts for 18,208 hectares. The remaining 8,647 hectares of the woreda is covered by settlement areas (Derra woreda CTO, 2010).

3.2 Socio-economic Background

3.2.1 Population

According to the 2007 census, the total population of Derra woreda is about 181,661. Out of this 50.3% is females' proportion while the rest 49.7 % is male (Derra woreda CTO, 2010).

Around 69.1% of the population belongs to Oromo nation; and Amhara nation accounts for about 29.4% of the total population. The remaining 1.5% belongs to other nations found in the woreda (Derra woreda CTO, 2010). At kebele level, 14 rural kebeles are Afan Oromo speakers while 9 rural kebeles speak Amharic as their major language. The remaining one urban kebele belongs to both Afan Oromo and Amharic speakers.

3.2.2 Agriculture

Agriculture plays a vital role in the economy of Derra woreda. More than 85% of the population of the woreda is engaged in agriculture. The woreda is endowed with 75, hectares of agricultural suitable land in which most of it is utilized. Derra is known for teff production. In addition to this, for instance, major crop productions of the woreda in the three climatic conditions are summarized below.

Table 3.1: Leading produced crops of Derra woreda in the three agro-climatic regions.

Climatic Regions	Leading produced crops		
	First	Second	Third
Dega	Teff (*Eragrostic tef*)	Guaya (*Castilia guaya*)	Wheat
Woina-Dega	Teff	Zengada(*Sorghum bicolor*)	Teff
Kolla	Sorghum	Teff	Selit (*Sesamum indicum*)

Source: Derra woreda ARDO, 2010

Derra woreda is also known for high potential of domestic animals. In the year 2010 there were 174,000 cattle, 98,000 goats, 21,000 sheep, 60,000 hens, 14,856 traditional and 689 modern beehives, 21,000 donkeys, 192 horses and 400 mules (Derra woreda ARDO, 2010).

3.2.3 Infrastructure

Derra is among the developing districts of North Shewa zone. Its capital town is called Gundo Meskel. The Woreda possesses 518.6 kilometer rural and 10.5 kilometer urban roads (Derra woreda IPRO, 2010).

The woreda was suffering from the shortage of potable clean water for a long time. But at present the clean water supply of the woreda reaches to 65.1% (Derra woreda IPRO, 2010).

As far as health is concerned, there are 33 health stations in all rural kebeles of the woreda and 5 health centers with pharmacies (Derra woreda IPRO, 2010).

On the other hand, the woreda has 4 kindergartens, 45 first cycle primary (1-4 grades), 36 second cycle primary (1-8 grades) schools and one high school and one preparatory school (Derra woreda IPRO, 2010).

Other infrastructures such as 24 hours hydroelectric service, mobile and landline telephone services and one commercial bank are also found in the woreda (Derra woreda IPRO, 2010).

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Demographic and socio-economic characteristics of sample households

The study included a total of 120 sample households. As can be observed in Table 4.1, 93.3% of the rainwater harvesting users was headed with male and 6.7% of them with female. More than 83% and about 16.7% of rainwater harvesting non-user households have male and female heads respectively. The slight difference observed between user and non-user households on female headed is due to the labor intensive nature of rainwater harvesting technology construction and practice.

Average age of household heads is the other characteristics of sample respondents. Accordingly, as per the survey, the years 40.8 and 46.7 represent the average age of user and non-user sample household heads respectively. The average age of rainwater harvesting user household heads is lower.

In traditional agriculture in general and rainwater harvesting practices in particular family labor which is expressed by family size plays a vital role. For instance, family labor is important for pond construction and watering of the products in rainwater harvesting. As it is seen in Table 4.1, the average family size of farm households of who use rainwater harvesting is found to be 6.6. On the other hand, non-users of rainwater harvesting farm households have an average of 5.4 family sizes. With the existence of working age and male members in a family, it is easy to construct and utilize RWH ponds to farm households with large family size.

Concerning the educational levels, as it is presented in Table 4.1, the educational level of rainwater harvesting user household heads is found to be 25% illiterate, 25% read and write and 50% primary educations. Beside, 46.7% illiterate, 40% read and write and 13.3% primary educations is the educational level of household heads that do not use rainwater harvesting. Since low level of education attained limits farmers' access to have information from different sources it could result in the reluctance to adopt and utilize new technologies.

Table 4.1 also revealed the spouse educational level of sample households. And about 43.3% of the wives or husbands of RWH user and 29.2% of the wives or husbands of RWH non-user households either can read and write or have attended primary educations.

Table 4.1 Demographic characteristics of sample households

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Sex:			
Male	56(93.3)	50(83.3)	106(88.3)
Female	4(6.7)	10(16.7)	14(11.7)
Average age:	40.8	46.7	43.75
Average family size:	6.6	5.8	6.2
HH head educational status:			
Illiterate	15(25)	28(46.7)	43(35.8)
Read and write	15(25)	24(40)	39(32.5)
Primary	30(50)	8(13.3)	38(31.7)
Spouse educational status:			
Illiterate	34(56.7)	51(85)	85(70.8)
Read and write	19(31.6)	7(11.7)	26(21.7)
Primary	7(11.7)	2(3.3)	9(7.5)

Source: Own survey, 2011

Asset ownership is the other important factor in rainwater harvesting technology adoption and utilization. Particularly land, since it is necessary for both pond construction and agricultural activities, is the most important asset in practice of RWH. As it is seen in Table 4.2, 83.3% of both RWH user and non-user sample households have their own cultivation land. Parallel to this, it is also tried to calculate the average land size of sample households and found to be 1.8 hectares.

Similarly, oxen ownership of sample respondents was assessed because oxen are important means of production in traditional agriculture. Most of the subjects of the study have oxen. From Table 4.2, 84.2% of sample households have their own oxen. Furthermore, in average a household has 2.1 numbers of oxen.

Table 4.2 Land holding and oxen ownership of sample households

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Land ownership:			
Yes	50(83.3)	48(80)	98(81.7)
No	10(16.7)	12(20)	22(18.3)
Average land size	2 hectares	1.6 hectares	1.8 hectares
Oxen ownership:			
Yes	53(88.3)	48(80)	101(84.2)
No	7(11.7)	12(20)	19(15.8)
Average oxen number	2.5	1.7	2.1

Source: Own survey, 2011

4.2. The implementation and utilization of rainwater harvesting technology

A total number of 78 operational ponds were surveyed out of which 69 are individual and the remaining 9 are community. Rainwater harvesting technology began to be disseminated in the study area in the years 2003/04 by the woreda office of agriculture and rural development. As time went, non governmental organization called Menschen fiir Menschen started participation in the construction of rainwater harvesting ponds in the year 2005/06. The primary purpose of the expansion of the technology in the woreda was to use as an alternative use for supplemental irrigation of horticulture production and for crop water supply in time of moisture stress. As shown in Table 4.3 below, 37.5% of the ponds were constructed in 2003/04 and 25% of them in 2005/06. The remaining 21.6% and 15.9% of the sample ponds were constructed in 2007/08 and 2009/10 respectively.

Table 4.3 Years of construction of RWH ponds

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Years of construction			
2003/04	13(21.7)	32(53.3)	45(37.5)
2005/06	10(16.7)	20(33.3)	30(25)
2007/08	20(33.3)	6(10)	26(21.6)
2009/10	17(28.3)	2(3.4)	19(15.9)

Source: Own survey, 2011

As stated in the above section the woreda agriculture and rural development office through participating poor farmers in food for work and NGO Meschen fiir Meschen Derra Integrated rural Development Project has took part in the construction of the structures. Some self-initiated farmers have also constructed a number of ponds. As presented in the Table 4.4, 50.8% of sample households informed that their ponds were constructed by the government by mobilizing the community while 30% of the households said the ponds were constructed by Meschen fiir Menschen project. The remaining 19.2% of the households have constructed the ponds by themselves.

Table 4.4 Responsible body for the construction of RWH ponds

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Who have constructed the ponds?			
Government	12(20)	49(81.7)	61(50.8)
Individual farmers	20(33.3)	3(5)	23(19.2)
Menschen fiir Meschen	28(46.7)	8(13.3)	36(30)

Source: Own survey, 2011

The major pond types constructed in the study area are excavated only type and cement lined type. As it is seen in table 4.5 below, 70.8% of sample households possess excavated only pond types while the remaining 29.2% of them have cement lined pond types.

Table 4.5 Pond types of the sample households

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Types of pond?			
Excavated only type	28(46.7)	57(95)	85(70.8)
Cement lined type	32(53.3)	3(5)	35(29.2)

Source: Own survey, 2011

Regarding utilization, half of the sample households use the stored water to produce vegetables and fruits such as onion, tomatoes, cabbages, potatoes, papaya, sugar cane, banana, etc when the rain stops, but the remaining half of the households does not utilize the harvested water mainly due to the decrease of water after some weeks and shortage of labour lifting equipments. Furthermore, as per the field observation, most unutilized RWH structures are the oldest government constructed ponds while utilized ones are recent ponds constructed by Menschen fiir Menschen and some self-initiated farmers. Unlike government constructed ponds, these ponds have constructed with high storage capacity, better quality and long service duration. This can depict that involvement of NGOs in implementation and utilization of RWH is important.

Information on RWH contributes positively on the utilization of rainwater harvesting technology. This is because the initiation to get involved in rainwater harvesting can be motivated by the awareness households have before the utilization of the technology and information before utilization has better chance to successfully utilize the technology. As Table 4.6 reveals, 71.7% of the sample households have information about rainwater harvesting before get involved in the technology.

Table 4.6 Households' information about RWH before get involved in the technology

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Have information either from the government or neighbors before get involved in RWH :			
Yes	47(78.3)	39(65)	86(71.7)
No	13(21.7)	21(35)	34(28.3)

Source: Own survey, 2011

The participation of RWH beneficiaries in the various phases of the implementation of the RWH activity is crucial. The chances for the success are much greater if they are involved from the early planning stages (Oweis et al, 1999). Hence, in addition to the adopters, it needs the participation of different governmental and non-governmental organizations. For instance, the main actors in expansion and adoption of the technology in the study area are the local government and Meschen fiir Menschen. As Table 4.7 depicts, 56.7% of the sample households stated that they get assistances like advices on how to utilize stored water and some inputs and equipment from the government and Meschen fiir Menschen.

Interview data from ARDO experts of the woreda also revealed that their office is assisting farm households in guidance and supervision through the respective development agents. Furthermore, FGD data showed that kebele officials also assist some RWH users by promoting them as model farmers. DAs also mentioned that they give weekly super vision for RWH user households in extension services.

Daniel (2006) stated that due to the labor intensive venture of RWH practice it is difficult for single household heads to utilize ponds. Similarly, as can be seen from Table 4.7, 85% of sample households said that male headed household is more effective in the practice of RWH while 15%

of them said female headed households are more effective. This could show taking the advantage of highly participating in construction and practice of the RWH; male headed households are more effective than their counter parts.

Table 4.7 Assistance of government and effectiveness of households in RWH

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Is there government assistance in RWH?			
Yes	40(66.7)	28(46.7)	68(56.7)
No	20(33.3)	32(53.3)	52(43.3)
Who is more effective in the utilization of RWH?			
Male headed household	45(75)	57(95)	102(85)
Female headed household	15(25)	3(5)	18(15)

Source: Own survey, 2011

4.3 Perception of farmers towards RWH ponds

Participation of stakeholders during initial stage of design and implementation as well as utilization is one of the major factors that determine the success of new technology adoption and utilization. The top-down approach of implementation coupled with the lack of adaptation of the technology to the local situation led to considerable resistance by farmers to accept the intervention (Melete, 2007).

According to Desalegn (2007), the failure or success of any rainwater harvesting technology will ultimately depend on the degree of acceptance of the technology by the adopters. Ngigi (2003) also added that despite the benefits of the rainwater harvesting technology, their successful adoption and utilization will depend on the knowledge, socio-economic and cultural dynamics, and the perceptions of the farmer/community. Thus, all stakeholders in the technology adoption shall have clear awareness on the advantages and drawbacks that a specific technology has.

According to the interview data from the woreda agriculture and rural development office staff members and development agents, full labor force was provided for pond construction through mobilizing community in food for work programs. This was done in order to reduce the reluctance and maximize the acceptance of the technology. After 2005/06 the provision was stopped and farmers are supposed to use their own cost for the construction. This resulted in the considerable decline in constructed pond construction. In fact some farmers were assisted by Meschen fiir Menschen to construct ponds since 2005/06. The organization provided construction inputs for some volunteer farmers in long term loan.

Almost all farmers have good awareness about the benefits that can be obtained from utilizing ponds as supplementary water sources for agricultural activities. As it is presented in Table 4.8, 95% of the sample households are aware of the benefits obtained from the utilizing pond water. But interviewed RWH non-user farmers were asked that if they are aware of the benefits why they failed to use and expressed that they better focus on cereal production rather than wasting time on production of plenty of fruits and vegetables through stored water. In addition, households were also asked their opinion on whether or not RWH could be a good means of tackling impacts of droughts and as it is seen in Table 4.8, 97.5% of them expressed RWH could help to mitigate severity of impacts of drought on people and livestock but the remaining 2.5%

of them believed that it would be not helpful in times of drought due to the problems of the technology.

Table 4.8 Perceptions of farmers on the benefits of RWH structures

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Do you think that RWH has benefits?			
Yes	57(95)	57(95)	114(95)
No	3(5)	3(5)	6(5)
Do you think that RWH could be a good means of tackling the impacts of droughts?			
Yes	60(100)	57(95)	117(97.5)
No	0	3(5)	3(2.5)

Source: Own survey, 2011

At the household level, the benefits of rainwater harvesting structures include income gain from the sale of vegetables and fruits; getting diversified diets for the household and at community level the stored water serves for livestock watering. For instance, RWH user farmers have either additional income or diversified diets in their meal compared with their counterpart RWH non-user farmers. Interviewed RWH non-user farmers also indicated that the users are economically better off due to the additional income they obtain from sale of RWH products. In addition, FGD participant PA officials discussed that RWH help farm households in that it make all household members participate in agricultural activities.

Farmers engaged in rainwater harvesting were asked their perception about the success of the program and as expressed in Table 4.9, 46.7% of the sample farmers have rated the construction of ponds as moderately successful while 18.3% of them rated it as successful. The remaining 35% of the participants have rated ponds as failed structures in their villages.

Table 4.9 Farmers perceptions about the success of RWH ponds

	RWH technology users N (%)	Total N (%)
How do you rate the success of RWH ponds in your village?		
Successful	11(18.3)	11(18.3)
Moderately successful	28(46.7)	28(46.7)
Failed	21(35)	21(35)

Source: Own survey, 2011

Finally, the opinion of farmers on the impact of expansion of rainwater harvesting structures on their plots was assessed. As presented in Table 4.10 below, 86.7% of respondents do not think the expansion of the structures has narrowed down their plots but 13.3% of them believe their plots are narrowed by the expansion of RWH structures.

Table 4.10 Perception of farmers on the expansion of RWH ponds

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Do you think that expansion of RWH ponds has narrowed down your plots?			
Yes	2(3.3)	14(23.3)	16(13.3)
No	58(96.7)	46(76.7)	104(86.7)

Source: Own survey, 2011

4.4 Constraints to utilization of rainwater harvesting ponds

Rainwater harvesting is a cross-cutting issue. It has complex interfaces with the environment, economy, social, health and policy (Daniel, 2006). In addition, since rainwater harvesting is relatively new technology in Ethiopia, it is surrounded by constraints that have the nature of varying from place to place and from time to time.

Four categories of constraints were identified in the study area. These are technical problems related with the ponds, institutional constraints, financial constraints and environmental constraints.

4.4.1 Technical problems related with the ponds

The identified technical problems with the pond affecting utilization of the technology in the study area include absence of fences and roof covers of the ponds, accidents on animals and kids and absence of the silt-trap of the ponds.

The major problem with ponds is the absence of fences and roof covers to the rainwater harvesting ponds. The survey disclosed that more than 88% of the ponds in the study area have no fences and the same is true for roof covers. Almost all rainwater harvesting onfarm ponds have no roof covers. Focus group discussion data depicted that farmers were used corrugated iron to make roofs for their ponds. But through time these kinds of roofs were stolen and pond roofs were forced to left without roof covers. As it is seen in Table 4.11, only 11.7% and 4.2% of sample farm households replied that their ponds have fences and roof covers made up of locally available woods and grasses respectively. But the remaining 88.3% of the respondents reported as their ponds have no fences and about 96% of the sample households said that their ponds lack roof covers. The absence of fences and roof covers of the ponds has further implication on the utilization of the technology. Such ponds are known with their trap of death for animals and kids. In addition, in the absence of roof covers, the stored water decreases in short period of time. This is because the uncovered ponds loose a significant portion of their water through evapotranspiration. Uncovered ponds are also responsible for the breeding of mosquitoes that transmit malaria.

Table 4.11 Fences and roof covers of ponds

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Do your ponds have fences?			
Yes	11(18.3)	3(5)	14(11.7)
No	49(81.7)	57(95)	106(88.3)
Do your ponds have roof covers?			
Yes	5(8.3)	0	5(4.2)
No	55(91.7)	60(100)	115(95.8)

Source: Own survey, 2011

Siltation of sediments due to transportation of sediments generated from the runoff area is identified as a major constraint in the study area. Interviewed ARDO experts disclosed that from the limitation of knowhow of their development agents at the initial years of dissemination most ponds are constructed without a silt trap. The magnitude of the problem is prevailed on the excavated only pond types and oldest ponds. Through time the accumulated siltation could sustainably shrink the capacity of the ponds to accumulate water (Plate 4.1).

Plate 4.1**:** Pond constructed with out silt-trap

Source: own picture, December: 2010

4.4.2 Institutional constraints

At the initial stage of RWH implementation, almost all major regions adopted a "quota system" to diffuse the technology. In order to meet the quota, the authorities were pushing local experts to dig as many ponds as possible. Such activities were undertaken irrespective of the location conditions, geological structure, soil type, pond type and the like. It was often the installation of those ponds that many constraints cropped up (Daniel, 2006). Lakew (2004) also added that there is a need to systematically collect data on soil, natural vegetation, cropping pattern, rainfall amount, intensity and probability to adopt a technology to the farmers. The same was true in the study area during initial years of dissemination of the structures. The expansion of the rainwater harvesting ponds in the study area was held in all 33 rural kebeles of the woreda. Interviewed ARDO experts were asked how they have expanded the technology in all kebeles of the woreda without considering environmental and social differences. In response, they informed that they are ordered from the regional government to afford food grain to poor farmers through participating them in development activities. So they have assigned farmers to dig and construct ponds for rainwater harvesting and rewarded them with the food grain.

A cross checking question saying what reasons necessitates you to construct the technology was raised to sample households and as can be seen in Table 4.12, 47.5% of them replied that they constructed the technology to produce more while 14.2% of the households constructed the technology to get food grain and because of water shortage. The remaining 24.1% of the respondents constructed the technology due to soil infertility.

It is important to know more about the willingness of adoption or refusal of rainwater harvesting technology by local community. The surprising dilemma found in the study area is that some households were not asked their willingness to adopt the technology. As presented in Table 4.12, 10.9% of the sample households expressed that they have not asked their willingness to construct the ponds. They only have seen ponds constructed on their plots. The reason told them from the agricultural experts and development agents was that their farm lands are suitable for the construction of the structures. How much the plots are suitable for construction, would the structures be productive without the interest of the owner? Therefore, willingness of the adopters has a positive impact on the utilization of the stored water for the intended use.

Table 4.12 Reasons and willingness of households to construct the ponds

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Were you asked your willingness to construct the pond?			
Yes	57(95)	50(83.3)	107(89.2)
No	3(5)	10(16.7)	13(10.9)
What reasons necessitates you to construct the pond?			
Water shortage	10(16.7)	7(11.7)	17(14.2)
Soil infertility	14(23.3)	15(25)	29(24.2)
To produce more	31(51.7)	26(43.3)	57(47.5)
Food grain paid out	5(8.3)	12(20)	17(14.2)

Source: Own survey, 2011

Involvement in rainwater harvesting technology is also expressed by the equal participation of all stakeholders in various stages of implementation. Sample farmers were asked whether they have participated or not in the implementation of the technology in their villages and as shown in Table 4.13, more than 73% of the households expressed that they have participated in the implementation through labor, money and materials while about 26.7% of them informed that they have not participated in the implementation activities. Participation of farmers in the implementation of the technology could increase the sense of ownership and hence the chance of utilizing the implemented structures.

Table 4.13 Participation of households in the implementation of RWH

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Have you participated in the implementation of RWH ponds?			
Yes	48(80)	40(66.7)	88(73.3)
No	12(20)	20(33.3)	32(26.7)
What was your contribution in the construction of the ponds?			
Labor	32(53.3)	41(68.3)	73(60.8)
Money	8(13.3)	4(6.7)	12(10)
Materials	20(33.4)	15(25)	35(29.2)

Source: Own survey, 2011

Household and site selections are important issues that have to be carefully considered in rainwater harvesting adoption and utilization. In the study area, there was a plan to construct the technology for poor and food insecure farmers but most of the pond owners were found to be relatively rich, educated and food secured. Majority of rainwater harvesting users are model farmers who are known in the community with their wealth and new technology adoption capacity. Table 4.14 revealed that 85.8% of the sample households informed as there was household selection to construct the structures while 14.2% of them said that there was no household selection to construct the technology. Sample farmers said there was no household selection have further informed that they have got involved in the technology learning from neighbors; and from the pressure that development agents exerted on them to use. Appropriate and criteria based involvement of well informed experts in the selection of households to adopt the technology have important role in the effectiveness of the technology utilization.

Table 4.14 Selection of households to construct ponds

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Was there HH selection to construct RWH ponds?			
Yes	50(83.3)	53(88.3)	103(85.8)
No	10(6.7)	7(11.7)	17(14.2)
Who have participated in the HH selection?			
ARDO experts	12(20)	10(16.7)	22(18.3)
DAs	10(16.7)	38(63.3)	48(40)
PA leaders	8(13.3)	4(6.7)	12(10)
MFM experts	30(50)	8(13.3)	38(31.7)
How you involved in the technology?			
DAs' pressure	7(5.8)	29(48.3)	36(30)
Self initiation	30(60)	2(3.4)	32(26.7)
Learning from neighbors	23(38.3)	29(48.3)	52(43.3)

Source: Own survey, 2011

Inappropriate location of rainwater harvesting ponds is the other constraining factor in the utilization of the technology in the study area. Planting RWH ponds at a particular place needs careful assessment of local variability (Daniel, 2006). This is because location of ponds has important implication for management, utilization and maintenance. As Rami (2003) reported mistakes in site selection are responsible for most of failures of the technology. In the study area, site selection of ponds was made by development agents in collaboration with kebele administrative officials and beneficiary farmers. Inappropriate pond location was resulted from the limited knowledge over site selection that DAs and farmers have. Most observed unutilized ponds have no stored water that emanated from their wrong location. The failure of farmers to prepare runoff canal to the ponds has exaggerated the problem.

Location of ponds has many implications in the utilization of the stored water. Majority of survey participants informed that their rainwater harvesting ponds are constructed on their farm plots. Teff and sorghum are the leading crops produced in the study woreda. But, the stored water is not serving to produce such crops because these crops need large quantity of water. Watering of vast plots also demands large labor force. Large number of farmers expressed that they failed to utilize the RWH structures due to reduction of stored water which directly related with wrong pond location. Most stored water is used for animal watering in most case and for household domestic use in some villages as long as it stayed stored (Plate 4.2).

Plate 4.2: Community pond used for animal watering

Source: own picture, December: 2010

The other issue has to be raised in site selection is the distance of ponds from the homesteads of farmers. Since most ponds in the study area are constructed on the plots, large numbers of farmers have to travel more than half an hour on foot to reach their onfarm ponds. This has lowered farmers' commitment of utilization after such long distance traveled. Interviewed farmers also told that the appearance of ponds near their residential areas made them utilize the technology more efficiently as it is easy to all household members to participate in the utilization activities.

Plate 4.3: Women fetching pond water for vegetable growing

Source: own picture, December: 2010

Training over how to use the stored water and how to maintain ponds is important to maximize the return obtained from the technology. Shortage of training given to farmers is another problem observed in the study area. As revealed in Table 4.15, while 65.8% of the households obtained training, the remaining 34.2% of them did not get training over any of construction, usage and maintenance of rainwater harvesting.

Table 4.15 Training of households in RWH

	RWH technology users	RWH technology non-users	Total
	N (%)	N (%)	N (%)
Have you got training in rainwater harvesting pond construction, usage and maintenance?			
Yes	47(78.3)	32(53.3)	79(65.8)
No	13(21.7)	28(46.7)	41(34.2)

Source: Own survey, 2011

4.4.3 Financial constraints

In the study area, at the beginning years of rainwater harvesting implementation, the full cost of construction of the ponds was covered by the government. This was made through participating poor farmers in food for work. Most constructed ponds were excavated and adopting farmers were contributing only plot of land to be constructed on. Such ponds, although afforded freely for the purpose of rainwater harvesting demonstration, were not long lasting and most of them became unutilized ponds these days. From 2005/06, Menschen fiir Meschen started constructing cement lined pond for voluntary farmers by covering all construction costs to be paid by beneficiary farmers in long term credit. This process of pond construction has initiated many farmers to participate in rainwater harvesting. Interviewed rainwater harvesting non-user farmers disclosed that the way Menschen fiir Menschen is constructing ponds has increased their needs to participate in the technology. As mentioned in Table 4.16, about 80% of the farmers showed their willingness to have additional and new ponds in future. This is a good indicator to that if a technology is adopted to farmers in a viable cost; the chance to yield return will be meaningful.

Table 4.16 Shows households' willingness to have RWH ponds in future

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Do you want to have additional/new RWH ponds in future?			
Yes	56(93.3)	40(66.7)	96(80)
No	4(6.7)	20(33.3)	24(20)

Source: Own survey, 2011

The other important financial constraint identified in the study area is lack of materials and equipments in the utilization of stored water. As known, the stored water in the ponds needs to be lifted to be used. Most farmers use buckets to lift water. Interview data from ARDO experts indicated that for the early adopters, water lifting buckets were supplied in lower price for some farmers. The remaining non-supplied farmers were also bought the buckets from the market. But the problem is when the stored water decreases. At this time lifting of stored water becomes difficult especially for handicap and female farmers. The alternative lifting mechanism is using motor pumps but most farmers said their purchasing power is too low to buy or rent from other farmers. Furthermore, due to the increasing price of fuel, it is difficult to use such lifting mechanism.

Fail to cover maintenance cost of ponds is also the other financial constraint in the study area. Development agents also depicted that due to low commitment and willingness of farmers to maintain structures many ponds became useless (Plate 4.4).

Plate 4.4: Vegetated pond due to lack of maintenance
Source: own picture, December: 2010

4.4.4 Environment Related Constraints

In rainwater harvesting pond construction, environmental factors such as soil type and land slope have to be considered carefully. In the study area, soil type ranges from black Verti to Clay soil. Black verti soils are very common in dega and woina-dega parts of the study area. As to Daniel (2006), such soil types have the characteristics of expanding after rains and contracting and cracking during dry times and are not suitable for pond construction. But to fulfill the quota, incredible numbers of ponds were constructed on plots with such soil type. In addition to their short life span, ponds constructed on such soil type demanded high cost of maintenance.

As per the field observation, the sides of some concrete and excavated only ponds were cracked. According to Woldeamlak (2007), cracking of concrete tanks is the occurrence of cracks on the sides that causes leakage of stored water. In some cases in the study area, the detached part of the wall has filled the pond and hence decreased the amount of water stored in the ponds (Plate 4.5). Since moisture aggravated the degree of the detachment of the pond sides, the severity of the problem could be increased during the rainy seasons. Due to this problem majority of such ponds became out of use.

Plat 4. 5: Failure of sides made pond shrink

Source: own picture, December: 2010

The other important environmental factor that should be considered in rainwater harvesting design is ground slope. Data from the development agents' interview and the researcher's personal observation revealed that the study area has ground slope ranging between gentle and steep. As Rebeka (2006) stated, medium ground slope as the best slope for rainwater harvesting technology. But, if the ground slope is steep, the probability of the pond to be filled by silts at the time of rainy season is high. Hence, such slope types are not recommended for rainwater harvesting technology. Gentle slope is also not preferred for pond location unless the source for runoff is roof tops. Interviewed RWH non-user farm households raised the unsuitability of their plot for the rainwater harvesting due to its slope as a reason not to adopt the technology. Thus, soil type and ground slopes are the main environmental constraints to adopt and utilize rainwater harvesting technology are the idea that the researcher reasonably conclude.

4.5 The socio-economic impacts of unutilized ponds

In the study area, the quota system expansion of rainwater harvesting ponds in the year 2003/04 has resulted in the construction of many excavated ponds in all kebeles of the woreda. Now days most of these ponds became useless because most of them fail to store enough water for agricultural activities. Due to this these ponds are named unutilized ponds for the purpose of this study. Assessing the socio-economic impacts of these ponds is found to be important to sight some tackling means to the problems emanated from these ponds. As it is recognized from the field observation in various kebeles of the woreda, most of such ponds are constructed on the farm plots of the farmers. First and for most, sample households were asked whether or not they have unutilized onfarm ponds. As Table 4.17 depicts, 81.7% of the households replied as they have unutilized ponds. These ponds are relatively wider in their size that's why farmers could not close them. FGD participants discussed that narrow sized unutilized ponds were closed up by farmers because they fail to utilize them due to the previously mentioned constraints.

As it can be seen from Table 4.17 below, 53.4% of the unutilized ponds are found at the middle of the plot while 32.8% and 13.8% of them are situated at the side and out side of the farm plots respectively. The specific locations of unutilized ponds have strong implication on their negative impacts. For instance, mid and side plot ponds trap livestock and wild animals for drinking the stored water that led the onfarm crop to be grazed and destructed. About 88% of the respondents also informed that these ponds are challenged either by domestic or wild animals. As the result of this, onfarm crop destruction and stored water reduction are encountered. Furthermore, FGD data depicted that on market days, livestock traders and people who use pack animals for transportation are causing great destruction of onfarm crops while they let their livestock drink. The impact is usually intensive especially for road side plots.

The decision of adopting a new technology to the receiving farmers should consider the interest of adopters so as to increase the chance of being successful (Rami, 2003). In the study area, the choose of sites for onfarm ponds was largely carried on by DAs to be in the middle of the plots. Asked why they decided to dug ponds in the middle of the plots, interviewed DAs expressed that they did so considering the mean place to use the stored water and decrease large labor requirement.

Table 4.17 Shows preference, location decision and damage of unutilized onfarm ponds

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Have you unutilized onfarm ponds?			
Yes	47(78.3)	51(85)	98(81.7)
No	13(21.7)	9(15)	22(18.3)
Specific location of unutilized ponds?			
At the middle of the plot	23(41)	39(65)	62(53.4)
At the side of the plot	20(35.7)	16(30)	38(32.8)
Out side the plot	13(23.3)	3(5)	16(13.8)
Who decided over the location of ponds?			
DAs	42(70)	50(83.3)	92(76.7)
Farmers	18(30)	7(16.7)	28(23.3)
Are your ponds challenged by domestic and wild animals?			
Yes	53(83.3)	53(88.3)	106(88.3)
No	7(11.7)	7(11.7)	14(11.7)
What are these challenges?			
Onfarm crop destruction	27(51)	40(75.5)	67(63.2)
Water storage reduction	26(49)	13(24.5)	39(36.8)

Source: Own survey, 2011

The incidence and rise of local disputes in the community is the other social impact emerged due to unutilized ponds. This may seem unreal theoretically, but majority of the respondents pointed out the impact. As presented in Table 4.18, more than 62% of the sample households replied these unutilized ponds are causing local conflicts in their community. The reason behind is the trap of livestock by these ponds which in turn causes the destruction of onfarm crops. Due to this, disputes are arising between farmers with destructed crops and those farmers who could not keep their livestock thoroughly. There is a problem of keeping domestic animals thoroughly in the study area (Plate 4.6).

Plate 4.6: Sheep grazing onfarm crops

Source: own picture, December: 2010

Furthermore, PA officials also discussed that due to the livestock watering of stored water in the unutilized onfarm ponds, significant number of farmers quarrel each other. The magnitude of this problem is high over the onfarm ponds which have no fences and cover roofs.

Table 4.18 Unutilized onfarm ponds and conflicts in the community

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Do you think that there are conflicts in the community due to unutilized ponds?			
Yes	30(50)	45(75)	75(62.5)
No	30(50)	15(25)	45(37.5)

Source: Own survey, 2011

The study area is characterized by high population density and serious farm land shortage. Even most of the marginal areas of the dega and woina-dega parts of the woreda are being cultivated because of the agricultural land shortage. In this situation, a small portion of unutilized land will have a great value. As shown in Table 4.19, 86.7% of the sample households responded that they do think the existence of unutilized ponds has reduced their plots while 13.3% of them do not think. Interview data with RWH non-user household heads depicted that unutilized onfarm ponds have narrowed down their plots especially for farm households with small land size. In strengthening this idea, a farmer having half hectares of land said " ንዲሁ ከሚቀመጥ ጉድጓዱ ያረፈበትን መሬት ባርሰው አንድ ልጅ ይመግብልኝ ነበር" to say "if I used to cultivate the land occupied by the idle pond, I would produce food crop for a child". The farmer might be right because unless these ponds are utilized, they may cause land shortage since they are significant in number in the study area.

Table 4.19 Unutilized onfarm ponds and cultivation land shortage

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Do you think that the existence of unutilized ponds on your plot have narrowed down your land?			
Yes	49(81.7)	55(91.7)	104(86.7)
No	11(18.3)	5(8.3)	16(13.3)

Source: Own survey, 2011

Health of beneficiary stakeholders and the local people is one of the most important issues that have to be addressed during design and implementation of any intervention. Stored water can be a place for malaria breeding and use of water from uncovered ponds can lead to water born diseases (Melete, 2007). Since the stored water is not used for drinking purposes in most parts of the study area, no water borne disease was witnessed. The study woreda is characterized by the incidence of malaria mainly due to its kolla climatic condition. Table 4.20 also shows that 67.5% of the respondents do think that the existence of unutilized ponds will aggravate the threat of malaria. Interviewed DAs informed during the months September and October, there is always the fear of malaria epidemics especially in lowland kolla kebeles. But, with the preliminary protection measures by health extensions and supply of mosquito protecting nets, they are trying to control the problem. PA officials also informed that they have mobilized the community to close unutilized ponds found in malaria incidence villages.

Table 4.20 Unutilized RWH ponds and malaria incidence

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Is there malaria epidemic in your kebele?			
Yes	34(56.7)	41(68.3)	75(62.5)
No	26(43.3)	19(31.7)	45(37.5)
Do you think that malaria is aggravated by unutilized RWH ponds?			
Yes	42(70)	39(65)	81(67.5)
No	18(30)	21(35)	39(32.5)

Source: Own survey, 2011

Death trapping is the other socio-economic impact of RWH ponds in the community. Uncovered and unfenced ponds cause accident on animals and kids. The problem is usually high over garden ponds. Since majority of ponds in the study area are onfarm and constructed far from the residential areas of the farmers, there has not been seen significant problems of accidental life loss. But, interviewed ARDO experts informed that two kids died in the year 2003/04 in two different kebeles while they are trying to swim in the ponds.

Finally, farm households were asked to cite if they are using unutilized ponds for any other purposes and as it is shown in Table 4.21, 80% of the respondents inform that they are not using the existing unutilized ponds for any other purposes while 20% of them said they are using unutilized near by ponds which have no stored water for compost preparation as well as for accumulation and burning of solid wastes in their villages.

Table 4.21 Usage of unutilized RWH ponds for other purposes

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Do you use unutilized ponds for any other purposes?			
Yes	15(25)	9(15)	24(20)
No	45(75)	51(85)	96(80)

Source: Own survey, 2011

4.6 Determinants of households' decision whether or not to utilize RWH

Based on the data obtained from sample households, determinants of households' decision whether or not to utilize the technology were identified. To test the strength of variables' dependence, Pearson's correlation at various significance levels was employed. Accordingly, each determinants of households' decision to utilize the ponds are discussed below.

4.6.1 Labor

Labor is an important factor in rainwater harvesting activities. In construction of structures, utilizing the stored water and making use of the products, labor is necessary. In farm household, labor is highly depending on family size. Family size is an important factor in determining the extent to which labor is available for agricultural work in rainwater harvesting. It is identified that the larger the size of the household, the more is the availability of labor for peak period rainwater harvesting activities.

Table 4.22 illustrate that RWH user households have large family size than those households of RWH non-user farm households. Hence RWH user farm households have more probability to get enough labor for the activities of rainwater harvesting.

Table 4.22 Labor and RWH pond utilization

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Family size of sample households			
1-3	1(1.7)	11(18.3)	12(10)
4-6	29(48.3)	30(50)	59(49.2)
7-10	29(48.3)	19(31.7)	48(40)
>10	1(1.7)	0	1(.8)
Do you think that your family size is enough for RWH operation?			
Yes	48(80)	35(58.3)	83(69.2)
No	12(20)	25(41.7)	37(30.8)

Source: Own survey, 2011

In addition, as can be seen in Table 4.23, household family size is positively correlated with the utilization of rainwater harvesting ponds at 0.01 levels of significance. This means households with large family size are more likely to utilize the technology since they can compensate costs that the technology demands. Furthermore, a Pearson correlation between family size and probability to get enough labor for the activity revealed that there is a positive correlation between households' family size and the probability of getting enough labor for RWH operation. This implies that households with large family size have more chance of getting enough labor for rainwater harvesting activities. Some interviewed RWH non-user farmers also stated that they did not use the technology due to the labor shortage in their family to utilize the stored water.

Table 4.23 Pearson correlation between family size and RWH utilization

		RWH utilization		Pearson correlation	Significant (2-tailed)
		Yes	No		
Family size	1-3	1	11	.321	.000
	4-6	29	30		
	7-10	29	19		
	>10	1	0		
Total		60	60		

Source: Own survey and computations, 2011
**. Correlation is significant at the 0.01 level (2-tailed).

4.6.2 Land

Access to land and land ownership are the other important determinants of household decision whether or not to utilize rainwater harvesting technology. Land is essential in rainwater harvesting in that it is required for both pond construction and production of agricultural outputs using the stored water. As it is seen in Table 4.24, more than 83% of the sample households have their own cultivation land while 16.7% of them do not have their own land. These farmers produce by rented land, land given from parents and/or share cropping. More specifically, 28.3% of the respondents have land size up to one hectare and about 45.8% of them have land sizes ranging between 1.25 hectares and 2.25 hectares. While 15.8% of the households have land size between 2.5 hectares and 3.5 hectares, the remaining 9.9% of them have cultivation land size greater than 3.5 hectares. There is meaningful variation in total cultivation land size between rainwater harvesting user and non-user households.

Table 4.24 Land and RWH utilization

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Do you have your own cultivation land?			
Yes	50(83.3)	50(83.3)	100(83.3)
No	10(16.7)	10(16.7)	20(16.7)
What is the total size of your land?			
0-1 ha	14(23.3)	20(33.3)	34(28.3)
1.25-2.25ha	26(43.3)	29(48.3)	55(45.8)
2.5-3.5ha	12(20)	7(11.7)	19(15.8)
3.75-4.75ha	4(6.7)	3(5)	7(5.8)
5-6ha	3(5)	1(1.7)	4(3.3)
>6ha	1(1.7)	0	1(0.8)

Source: Own survey, 2011

As it is presented in Table 4.25, though not statistically significant due to the presence of more land owner RWH non-user households in the sample, there is a positive Pearson association (.151) between land size and RWH utilization. This can implies that not only farmers with own land, but also farmers who have large land size, are more likely to utilize the technology than farmers who do not have own cultivation land as well than as those who have small land size.

Table 4.25 Pearson correlation between land size and RWH utilization

		RWH utilization		Pearson correlation	Significant (2-tailed)
		Yes	No		
Land size(hectares)	0-1	14	20	.151	.000
	1.25-2.25	26	29		
	2.5-3.5	12	7		
	3.75-4.75	4	3		
	5-6	3	1		
	>6	1	0		
Total		60	60		

Source: Own survey and computations, 2011

Tenure security is the other important issue in rural cultivation land. As Daniel (2006) stated most rainwater harvesting users in the past preferred ponds to be located very close to their homesteads. Such preference could be linked to the problem of land tenure insecurity. As rural land re-distribution had been repeatedly practiced in most high land parts of the country, farmers were hesitant to dig ponds at outlying plots where there was the chance of loosing it in the re-distribution process. In the study area almost all farmers have got land ownership certificate and most of them feel there is tenure security in the woreda. As can be seen in Table 4.26 below, more than 47%% of the respondents said that they have to travel up to 5 minutes to reach their nearest pond on their foot and 17.5% of them travel from 6 to 10 minutes. The remaining 36% of the households said they have to travel more than 10 minutes to reach their nearest ponds on foot. There is also significant variation in distance traveled to reach the nearest plot pond between RWH user and non-user farm households. Since farm households with nearest pond to homestead have the chance to harness labor and time of the household members including house wives and probability of producing high value crops at the same time protecting these crops from thieves, are found to be rainwater harvesting user households. Interview data from RWH non-user households also revealed that robbery of onfarm crops is one reason not to use rainwater harvesting technologies in the woreda.

Table 4.26 Distance of pond from homesteads and RWH utilization

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
How long you travel to reach nearest pond in on your foot (minutes)?			
0-5	36(60)	21(35)	57(47.5)
6-10	11(18.3)	10(16.7)	21(17.5)
11-15	5(8.3)	3(5)	8(6.7)
16-20	0	6(10)	6(5)
>20	9(15)	20(33.3)	29(24.3)

Source: own survey, 2011

4.6.3 Oxen Availability

In subsistence farming system oxen power contributes a vital role. In most parts of the study area, availability of oxen is one among the necessary determinants make or not farmers engage in agriculture. Table 4.27 disclosed that 85% of the households responded as they have ox while 15% of the farmers replied that they do not have ox and they produce crops using either hired oxen or borrow from friends and neighbors. Similarly, more than 62% of the sample households reported as they have 2 oxen while more than 20.6% of them have only one ox. The rest 16.7% of the farmers have three oxen and more than it.

Table 4.27 Oxen availability and RWH utilization

	RWH users N (%)	RWH non-users N (%)	Total N (%)
Do you have oxen?			
Yes	54(90)	48(80)	102(85)
No	6(10)	12(20)	18(15)
How many oxen do you have?			
1	10(18.5)	11(22.9)	21(20.6)
2	33(61.1)	31(64.6)	64(62.7)
3	3(5.6)	2(4.2)	5(4.9)
4	6(11.1)	4(8.3)	10(9.8)
>4	2(3.7)	0	2(2)

Source: own survey, 2011

Table4.28 reveals that there is a positive Pearson association (.304) between oxen number of the households and rainwater harvesting pond utilization. This means that farm households having large number of oxen are more likely to utilize RWH ponds than farm households having small number of oxen. This is due to that farmers use oxen power to cultivate their plot using stored water in the study area. But, since most RWH non-user households in the survey have oxen availability, there has not been statistically significant association between oxen availability and RWH technology utilization.

Table 4.28 Pearson correlation between oxen number and RWH utilization

		RWH utilization		Pearson Correlation	Significant (2-tailed)
		Yes	No	.304**	.001
How many oxen do you have?	1	10	11		
	2	33	31		
	3	3	2		
	4	6	4		
	>4	2	0		
Total		54	48		

Source: own survey and computations, 2011
**.Correlation is significant at 0.01 levels (2-tailed)

4.6.3 Agricultural Inputs

A. Credit access

As Fitsum et al (2002) cited in Nigussie (2008), one of the potential constraints to farmers adopting and utilizing modern technologies and inputs is the shortage of capital. It is difficult to increase the productivity of the agricultural sector in the absence of credit facility, given the fact that majority of farmers are resource-poor. As ARDO experts of the woreda informed, in the study area farmers were endowed with credit subsidies either from the woreda agriculture office or Menschen fiir Menschen for construction and utilization of RWH technology. From Table 4.29, 90% of farm households responded that there is credit access in their localities. But, there are variations between households in the obtaining credits facility. More than 28% of the sample households have got credits either from the woreda agriculture office or from Menschen fiir Menschen while the remaining 71.7% of the households have not got the facility mainly due to the insufficiency of the amount given.

Table 4.29 Credit access and RWH utilization

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Is there any credit access in your locality?			
Yes	56(93.3)	52(86.7)	108(90)
No	4(6.7)	8(13.3)	12(10)
Have you had credits?			
Yes	25(41.7)	9(15)	34(28.3)
No	35(58.3)	51(85)	86(71.7)

Source: own survey, 2011

Table 4.30 shows that there is positive Pearson association (.296) between RWH utilization and credits obtained at 0.01% level of significance. As far as the finance obtained from credits assists farmers to purchase agricultural inputs like oxen, fertilizers, modern seeds and labor, households having credits are more found to be rainwater harvesting users. This implies that households, who obtained credits, taking the high possibility to purchase inputs through the money given, are more likely RWH utilizers than their counter parts who did not obtained the credits.

Table 4.30 Pearson Correlation between credits obtained and RWH utilization

		RWH utilization		Pearson Correlation	Significant (2-tailed)
		Yes	No	.296**	.001
Have you had credits?	Yes	25	9		
	No	35	51		
Total		60	60		

Source*:* own survey and computations, 2011
**.Correlation is significant at 0.01 levels (2-tailed)

B. Saving

Saving is the other determinant of households' decision whether or not to utilize rainwater harvesting ponds. As presented in Table 4.31, about 45.8% of the households are engaged in saving activity in the form of *ekubs*, banks and buying livestock. Furthermore, Pearson's correlation revealed that there is statistically significant negative association (-.184) between RWH utilization and saving. This means, since farm households engaged in saving are less likely to purchase on labor, oxen, fertilizers and some other inputs, have less probability to utilize rainwater harvesting technologies. In addition, saver farmers probably might prefer to be involved in off farm activities. Thus, farm households with more saving habits are found to be more likely RWH non-users.

Table 4.31 Pearson correlation between saving and RWH utilization

		RWH utilization		Pearson Correlation	Significance(2-tailed)
		Yes	No	-.184**	.044
Do you save?	Yes	19	36		
	No	41	24		
Total		60	60		

Source: Own survey and computations, 2011
**. Correlation is significant at 0.01 levels (2-tailed)

C. Fertilizer and manure/compost

The study area is one among the highly degraded central highlands of Ethiopia. Thus, usage of chemical fertilizers is common. As can be depicted from Table 4.32, 89.2% of the households use chemical fertilizers. Since large number of RWH non-user farmers use chemical fertilizers, there is no statistically significant Pearson association found between RWH utilization and use of fertilizers. On the other hand, 62.5% 0f the households use manure/compost for their plots while only 37.5% of them do not use it. Interviewed RWH user farmers further informed that they use manure/compost more highly than chemical fertilizer since they take using manure as an indigenous practice for horticulture production.

Table 4.32 Fertilizers and manure/compost and RWH utilization

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
Do you use chemical fertilizers?			
Yes	54(90)	53(88.3)	107(89.2)
No	6(10)	7(11.7)	13(10.8)
Do you use manure/compost?			
Yes	54(90)	21(35)	75(62.5)
No	6(10)	39(65)	45(37.5)

Source: Own survey, 2011

As it is seen in Table 4.33, there is positive Pearson association (.568) between RWH utilization and manure/compost use at 0.01 significant levels. This implies that manure/compost using farmers are more likely to utilize rainwater harvesting ponds for various productive purposes.

Table 4.33 Pearson correlation between manure/compost using and RWH utilization

		RWH utilization		Pearson Correlation	Significance(2-tailed)
		Yes	No	.568**	.000
Do you use manure/compost?	Yes	54	21		
	No	6	39		
Total		60	60		

Source: Own survey and computations, 2011
**. Correlation is significant at 0.01 levels (2-tailed)

4.6.5 Household Income

The financial, human and land resources endowment of a household plays an important role in the decision of the household on whether to utilize any newly introduced agricultural technology or not (Nigussie, 2008). Household income is essential in the households' decision whether or not to utilize rainwater harvesting ponds so as income boosts up household's power to purchase all the needs that the technology demands. Even households income source determines the decision to utilize the ponds. In Table 4.34, 95.8% of the households mentioned on farm source as the major households' income source while only 4.2% of them put off farm as their major income source. Furthermore, 31.7% of the households have at least a family member engaged in off farm activities such as sale of goods, local drink and fire wood as well as daily labor. Since the probability of engaging in agricultural activities is high for on farm income source households, they are found to be better RWH pond utilizers than those households who have off farm income source and the same is true for those households who less engaged in off farm activities.

Table 4.34 Major income sources and RWH utilization

	RWH technology users N (%)	RWH technology non-users N (%)	Total N (%)
What is your households' major income source?			
On farm income source	60(100)	55(91.7)	115(95.8)
Off farm income source	0	5(8.3)	5(4.2)
Is there any family member engaged in off farm activities?			
Yes	11(18.3)	27(45)	38(31.7)
No	49(81.7)	33(55)	82(68.3)

Source: Own survey, 2011

As shown in Table 4.35, Pearson correlation also revealed that there is a statistically significant positive association between households' major income source and RWH technology utilization. Thus, households having on farm income source are more RWH pond utilizers than their counter parts.

Table 4.35 Pearson correlation between households' major income source and RWH utilization

		RWH utilization		Pearson Correlation	Significance(2-tailed)
		Yes	No	.209**	.022
What is your households' major income source?	On farm	60	55		
	Off farm	0	5		
Total		60	60		

Source: Own survey and computations, 2011
**. Correlation is significant at 0.01 levels (2-tailed)

The study also assessed the annual income of the sample households in terms of Ethiopian Birr. Usually due to the mysterious nature of farmers, it is difficult to determine farm HH annual income. But tries were made to estimate annual income by subtracting their annual crop consumption from annual production and change to monetary value with current price. As presented in table 4.36 below, 67.5% of the respondent households earn annual income up to 500 Birr while 20% of them have annual income between 500 and 1000 Birr. And only 12.5% of the respondent households earn annual income more than 1000 Birr. In addition to this, although not statistically significant due to the presence of large number of RWH non-user farmers with high annual income in the sample, there is positive Pearson association (.104) between annual household income and rainwater harvesting pond utilization.

Table 4.36 Estimated annual household income and RWH utilization

	RWH users N (%)	RWH non-users N (%)	Total N (%)
What is your household's annual income in terms of Ethiopian Birr?			
0-500	34(56.7)	47(78.3)	81(67.5)
501-1000	15(25)	9(15)	24(20)
1001-1500	7(11.7)	4(6.7)	11(9.1)
1501-2000	2(3.3)	0	2(1.7)
>2000	2(3.3)	0	2(1.7)

Source: own survey, 2011

Wealth status in the society has positive impacts in the participation of farmers in newly introduced technologies. This is due to that any technology demands cost and purchasing such technologies needs better financial capacity. In the study area, wealth of farmers is determined by possession of large agricultural land size, large number of livestock and large annual crop production. Considering such qualifications, Table 4.37 revealed that 62.5% of the households said they have medium wealth status as per to the local standard while 19.2% of them are rich in wealth. The remaining 18.3% of the respondents ranked them selves as poor in wealth according to the local standard. Pearson correlation also depicted that there is a positive association (.204) between wealth standard and RWH utilization. From this it is possible to say that farm households with better wealth rank are more eager to utilize RWH ponds.

Table 4.37 Pearson correlation between households' wealth rank and RWH utilization

		RWH utilization		Pearson Correlation	Significance(2-tailed)
		Yes	No	.204**	.025
How do you rate your wealth ranking according to the local standard?	Rich	16	7		
	Medium	36	39		
	Poor	8	14		
Total		60	60		

Source: Own survey and computations, 2011

**. Correlation is significant at 0.01 levels (2-tailed)

On the other hand, purchasing on agricultural inputs could be determined by the income of the household. This means households with better income have better probability of purchasing this income on agricultural inputs like fertilizers, labor, oxen, modern seeds, etc. As can be seen from Table 4.38, 52.5% of the sample households rate their amount purchased on agricultural inputs as fair. While 23.3% of the households purchased poor on agricultural inputs, 20.9% of them purchase good. Only the remaining 3.3% of the respondents purchase very good amount of their income on agricultural inputs.

Table 4.38 Income purchased on agricultural inputs and RWH utilization

	RWH users	RWH non-users	Total
	N (%)	N (%)	N (%)
How do you rate your income amount purchased on agricultural inputs?			
Very good	3(5)	1(1.6)	4(3.3)
Good	18(30)	7(11.7)	25(20.9)
Fair	30(50)	33(55)	63(52.5)
Poor	9(15)	19(31.7)	28(23.3)

Source: own survey, 2011

Finally as shown in Table 4.39, Pearson correlation depicted that there is positive association (.275) between amount purchased on agricultural inputs and rainwater harvesting technology utilization. This means, households purchasing better on agricultural inputs are found to be better RWH utilizers.

Table 4.39 Pearson correlation between amounts purchased on agricultural inputs and RWH utilization

		RWH utilization		Pearson Correlation	Significance
How do you rate your income amount purchased on agricultural inputs?		Yes	No	.204**	(2-tailed)
	Very good	3	1		.002
	Good	18	7		
	Fair	30	33		
	Poor	9	19		
Total		60	60		

Source: Own survey and computations, 2011
**. Correlation is significant at 0.01 levels (2-tailed)

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The characteristics of agriculture in Derra woreda is predominantly small scale rain-fed farming. This farming system resulted in fluctuating food crop productivity mainly due to moisture stress emanated from rainfall variability in many parts of the woreda that led to food insecurity at household level. Recognizing the correlation between rainfall variability and fluctuations in food crop production, the woreda started implementing rainwater harvesting technology from 2003 in all rural kebeles of the woreda. Later on, in 2005, the non governmental organization called Menschen fiir Meschen has took part in the construction of the ponds for some selected farmers. Accordingly, there are hundreds of rainwater harvesting ponds constructed in the woreda. Currently, large numbers of the ponds are not meeting the purpose they were constructed due to various constraints.

Therefore, the purpose of this study was to assess these constraints of the utilization of rainwater harvesting ponds in some selected kebeles of the woreda; and the major findings of the study are summarized as follow:

The implementation of the technology in the woreda was a quota system in all rural kebeles of the woreda that resulted in inferior large numbers of excavated only ponds. This was made by the Woreda Office of Agriculture through participation of the poor farmers in the construction process in food for work program. In addition, while disseminating the ponds in all kebeles, even the woreda did not conduct a pilot survey. Resulting from these factors, these ponds have no stayed longer and most of them fail to store water for agricultural activities.

On the otherhand, the recent Menschen fiir Menschen constructed rainwater harvesting ponds that centered the specific needs of the farmers and having better quality, has found to be better than the target-less government constructed ponds. Large numbers of farmers expressed that the way the NGO construct ponds have increased their motivation to have additional ponds because utilization of ponds has enabled them to grow vegetables and fruits such as onions, tomatoes, cabbages, sugar canes, oranges, bananas and the like. These crops are additional sources of income and are used for household consumption.

Most of the oldest rainwater harvesting ponds (ponds constructed before 2005) was constructed on the plots that are far away from the homesteads of the farmers. This was done to achieve one of the major objectives of expanding ponds in the study area; that was to use the stored water as a supplementary irrigation for grain crops production and mitigate the problem of crop failure when the rain stops during the critical crop maturity period. However, most farmers reluctant to use the stored water for such purpose mainly it is time taking and tedious to irrigate the plots due to the high water requirement of the crops.

The utilization of the ponds in the woreda is surrounded by some technical problems of the pond like low quality and the resulted short duration services; institutional constraints such as low participation of farmers during the implementation periods, limited assessment of the needs of the society before adoption, in-appropriate location of ponds and lack of sustained training over how to maintain the ponds; financial constraints including high costs for construction and maintenance of the ponds; and environmental constraints like in-appropriate soil and slope types to construct ponds. These constraints have minimized the utilization of the technology in the study area.

These constraints, on the otherhand, have resulted in the existence of large numbers of unutilized rainwater harvesting ponds on the plots of the farmers. These unutilized ponds have brought socio-economic impacts in the community. Major impacts include: the destruction of onfarm crops by the wild and domestic animals that are attracted by the stored water in the ponds; narrow down of the plots due to the portion of land occupied by the idle ponds, and the incidence of conflict among the local community due to the quarrel emanated from watering livestock from the ponds that are located at the middle of the plot. Here also the reason of quarrel is the destruction of onfarm crops.

Finally, the study also identified that family labor of the household; land size; oxen availability; financial power to purchase agricultural inputs; and household income as the determinants of households' decision weather or not to utilize rainwater harvesting ponds. Furthermore, households having large family labor, large cultivation land size and numbers of oxen, as well as better income have high possibility to utilize for productive purposes ponds than their counter parts.

5.2 Recommendations

From the results, discussions and conclusions of the study, it is reasonable to forward the following recommendations to be considered by the concerned body to improve the performance and utilization of rainwater harvesting technologies:

- Expanding rainwater harvesting ponds in all rural kebeles of the woreda has led to inferior low quality ponds. Therefore, the government shall focus on the construction of better quality structures in specific areas rather than expanding low quality ponds in all rural kebeles of the woreda.

- Survey based assessments aimed at identifying the interest of the local community has to be investigated before adopting the technology. In addition, the participation of beneficiary farmers and other stakeholders is important during the planning, implementation and utilization stages of the program to increase the productivity of the ponds.

- The Meschen fiir Meschen constructed ponds were found to be better in quality and long lasting than the government constructed ponds in the study area. Since the role of NGOs in the adoption and utilization of the technology is important, government should facilitate ways that the NGOs take part in the adoption and utilization of the technology to farmers.

- The objective of expanding onfarm ponds for supplemental irrigation had not been achieved in the study area due to the mismatch between low storage of water and high water requirement for the grain crops production. So future dissemination of the technology has to focus on the construction of ponds for the production of vegetables and fruits that require less amount of water.

- Financial power of the farmers is important for the construction, maintenance and utilization of the rainwater harvesting. Hence, governmental and non governmental organizations promoting the technology shall create financial institutions that can provide long term credits to farmers for the utilization of the technology.

- Finally, there were found many unutilized rainwater harvesting ponds that are causing various social and economic impacts on the community. Therefore, the local administrative officials have to organize and mobilize the society at large either for repairing and thereby made them utilize by the farmers or for clogging/eliminating them and hence minimize their adverse negative impacts.

REFERENCES

Abebe, Y. and Gete, Z., 2003. Can Integrated Watershed Management bring Greater Food Security in Ethiopia? IFAC, Department of Biological and Environmental Engineering, Cornell University, USA

Agromissa, 1997. Water Harvesting and soil moisture retention. Agrodoc-series No. 13, Technical Centre for Agricultural and Rural Cooperation, Wageningen, The Netherlands.

Berhanu, A., 2006. Effective aid for Small Farmers in Sub-Saharan Africa: Ethiopian case study. Southern Civil Society Perspectives, For Canadian Food Security Policy Group, Addis Ababa

Boers, T.M., and Ben, J. 1982. A review of Rainwater Harvesting. Agricultural Water Management, 5

Daniel, K., 2006. Rainwater Harvesting in Ethiopia: Capturing the Realities and Exploring Opportunities. Forum for Social Studies (FSS), Research Report 1, Addis Ababa.

Dessalegn, Y., 2007. The Significance of Water Harvesting in Augmenting Household Agricultural Productivity in Awi Zone. Unpublished MA Thesis presented at School of Graduate Studies of AAU, Department of Geography and Environmental Studies. Addis Ababa

Diets, P .and Singh, A., 1999. Technological Potential for Improvements of Water Harvesting, Assessment of Irrigation Options. Thematic review IV, 2. *(http://www.dams.org/)*

Emishaw, G., 2009. Practices and Challenges of the agricultural use Rainwater Harvesting in Amhara Region, Menz Mama Mider Woreda. Unpublished MA Thesis presented at School of Graduate Studies of Addis Ababa University, Department of Environment and Development, Institute of Developmental Research (IDR).

Falkenmark, M., Rockstrom, J., and Rain, 2005. The Neglected Resource. Swedish Water House, policy brief No.2. Stockholm International Water Institute (SIWI). *(http://www.siwi.org/documents/Resources/Policy_Briefs/PB2_Rain_the_neglected_resource_2005.pdf)*

Fattovich, R., 1990. Remarks on the Pre-Axumite period in Northern Ethiopia. Journal of Ethiopian Studies, 23.

Fitsum, H.; Pender, J. and Nega G., 2002. Land degradation and strategies for sustainable land management in the Ethiopian highlands: *Tigray Region.* Socio economics and Policy Research Working Paper 25. International Livestock Research Institute (ILRI), Nairobi, Kenya.

Getachew, H., 1999. Rainwater Harvesting Concepts and Issues. Paper presented at the founding conference of the Ethiopian Rainwater Harvesting Institute. December 17, 1999, Addis Ababa.

Gezahegn, A., Gemechu, A., Kiflu, G.M., Tilahun, H., and Kidane, G., 2006. Water harvesting practices and impacts on livelihood outcomes in Ethiopia. Research Report No. 6

Hune, N., 2004. Water Harvesting and household water management towards household food security in Ethiopia. Paper presented at the National Stakeholders'workshop on Conservation of Agriculture and Rainwater Harvesting in Ethiopia, November 17-19/2004, Addis Ababa.

International Water Management Institute (IWMI), 2003. Innovative Approaches to Agricultural Water use for Improving Food Security in Sub-Saharan Africa. Working paper No. 55. *(http://www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR55.pdf)*

International Water Management Institute (IWMI), 2009. Irrigation Methods: Surface Irrigation-Options for smallholders. Module 5, part I. *(http://www.ilri.org/InfoServ/Webpub/fulldocs/IWMI_IPMSmodules/Module5_Part1.pdf)*

Manoj, P., Samuel, and Satapathy, K., 2008. Concerted Rainwater Harvesting Technologies sustainable for hilly agro-ecosystems of Northeast India. Article of Current Science Vol. 95, No. 9. (*http://www.ias.ac.in/currsci/nov102008/1130.pdf*)

Melete,G., 2007. An Assessment of Benefits and Challenges of Household Rainwater Harvesting Ponds in Kilte Ewlaelo Woreda, Eeastern Tigray. Unpublished MA Thesis presented at School of Graduate Studies of Addis Ababa Universiry, Department of Regional and Local Development Studies (RLDS).

Mitiku, H. and Sorssa N. M., 2002. Workshop on The Experiences of Water Harvesting in the Dry lands of Ethiopia: Principles and Practices. Conference Proceedings held December 28-30, 2001, Mekelle, Ethiopia.

Nega, H., 2004. Managing Rainwater in dry land areas of Ethiopia for improved agricultural development: The Ministry of Agriculture Experience. Paper presented on the Second General Assembly proceedings of Ethiopian Rainwater Harvesting Association (ERWHA).

Ngigi, S. N., 2003. What is the Limit of up-scaling rainwater harvesting in a river basin? Department of Agricultural Engineering of Nairobi, Kenya. Physics and chemistry of the earth, 28.

Nigussie, H., 2008. Rainwater Harvesting in Ethiopia: Technical and Socio-economic Potentials and constraints for adoption In Wukro District, Tigray. A Thesis Submitted to Wageningen University, the Netherlands.

Oweis, T.; Hachum, A., and Kijne, J., 1999. Water Harvesting and Supplemental Irrigation for Improved Water Use Efficiency in Dry Areas. System-Wide Initiative on Water Management (SWIM) paper 7. Colombo, Sri Lanka: International Water Management Institute (IWMI) (http://www.iwmi.cgiar.org/Publications/SWIM_Papers/PDFs/Swim07.pdf)

Postel, S. 1992. Last oasis: Facing water scarcity. W.W. Norton and Company, New York

Rami, H., 2003. Ponds Filled with Challenges. Water Harvesting Experiences in Amhara and Tigray. Assessment Mission Report. United Nations Office for Coordination of Humanitarian Affairs (UN OCHA) Ethiopia. Addis Ababa.

Rebeka, A., 2006. Impact Assessment of Rainwater Harvesting Ponds: A Case of Alaba Woreda, Ethiopia. A Thesis presented at School of Graduate Studies of Addis Ababa University, Faculty of Business and Economics, Addis Ababa.

Rockstrom, J., 2000. Water Resources Management in smallholder Farms in Eastern and Southern Africa. Paper 3, Section 7. Physics and chemistry of the earth (B) vol. 25(3)

Salas, J.C, 2006. Rainwater Harvesting: A Community's Technology for coping with Climate Change. International Rainwater Catchment Systems Association (IRCSA), Philippines. (http://www.igemportal.org/Resim/Rainwater_Harvesting_A_Communitys_Technoly for_Coping_with_Climate_Change.pdf)

Sear NET, ND, (http//www.searnet.org).

Senkondo, M., Msangi, A., Xavery, P., Lazaro, E., and Hatibu, N., 2004. Profitability of Rainwater Harvesting for Agricultural Production in selected Semi-arid areas of Tanzania. Journal of Applied Irrigation Science Vol. 39, No.1. (http://www.vlirrigation.org/cms/fileadmin/content/zfb/2004_01/senkondo_et_al_2004_p rofitability_of_rainwater_harvesting_for_ag_prod_semi_arid tanzania_etc.pdf)

Sharma, O.P., ND. Holistic Approach to Rainwater Harvesting in the Aravali hills, Rajasthan, India. (http://www.sahra.arizona.edu/unesco/allepo/RegionalOmPrakashSharma.p df)

Siegert, K., 1994. Introduction to water harvesting some basic principles for planning and monitoring. In: Water Harvesting for Improved Agricultural production. Proceedings of FAO Expert consultation, Cairo, Egypt, 21-25 November, 1993. FAO, Rome

Sileshi, B. and Merrey, D. J., 2006. Assessment of Small Scale Irrigation and Water Harvesting in Ethiopian Agricultural Development. International Water Management Institute (IWMI), Addis Ababa.

Tiffen, M., Mortimore, M. and Gichuki, F., 1994. More people, less erosion- Environmental Recovery in Kenya., African Centre for Technology Studies. Nairobi, Kenya.

United Nations Framework Convention on Climate Change (UNFCCC), 2006. Climate Change: Impacts, Vulnerability and Adaptation in Developing Countries. Climate Change Secretariat, Bonn, Germany. (*http://unfccc.int/resource/docs/publications/impacts.pdf*)

Woldeamlak, B., 2006. Adapting to Rainfall Variability in Drought Prone areas of the Amhara Region of Ethiopia. Rainwater Harvesting as a Livelihood Strategy. Abstract of Organization for Social Science Research in Eastern and Southern Africa (OSSREA) publication. (*http://publications.ossrea.net/index.php?option=com_content&view=article& id=19*)

Woldeamlak, B., 2007. Rainwater Harvesting in Drought Prone areas of the Ethiopian Highlands. A Journal of Organization for Social Science Research in Eastern and Southern Africa (OSSREA). Volume XXIII. Addis Ababa. Pp. 2-14

Zhu, Q. and Li, Y., 2004. Rainwater Harvesting: An alternative for securing food production under climate variability. Water Science and Technology, 49(7).

_____(2010). Agriculture and Rural development Office of Derra woreda, Gundo Meskel.

_____(2010). Culture and Tourism Office of Derra woreda, Gundo Meskel.

_____(2010). Information and Public Relation Office of Derra woreda, Gundo Meskel.

APPENDIX I

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

Questionnaire Prepared for sample households

This questionnaire is prepared to assess the constraints to the utilization of rainwater harvesting ponds by farmers in Derra *Woreda.*

Dear respondents, you are kindly requested to respond to all the necessary questions and give genuine information to the following items. I would like to assure you that this is fully academic research and your responses are confidentially kept.

Thank you for your willingness!

1. Background information of respondent households

1.1. Kebele ____________________

1.2. Age of the household head _______ years.

1.3. Sex: 1=Male 2=Female

1.4. Educational level of the household head

1=illiterate 2=read and write 3=primary 4=secondary

1.5. Family size (in no.)_____

1.6. Is your wife/husband educated? 1=yes 2=no

1.7. If yes, what is her/his educational level?

1=illiterate 2=read and write 3=primary 4=secondary

2. Perception of farmers towards rainwater harvesting technologies

2.1. Do you think that RWH has benefits? 1=yes 2=no

2.2. If yes, what are these benefits? ____

____

2.3. Do you think that RWH could be a good means of tackling the impacts of droughts? 1=yes 2=no

2.4. If yes, how? _______________________________________

2.5. If no, how? _______________________________________

2.6. Can you say that RWH has disadvantages? 1=yes 2=no

2.7. If yes, what are these disadvantages? (you can mark more than one) 1=health impact 2=sudden human life loss 3=sudden livestock life loss 4=others (specify)____________________________________

2.8. Do you think that expansion of RWH ponds will narrow down your cultivated land? 1=yes 2=no

2.9. If yes, how? _______________________________________

2.10. If no, why? ____

____

2.11. Who is more effective in utilizing household RWH ponds? 1=male headed household 2=female headed household

2.12. How you rate the success of RWH pond construction? 1=successful 2=moderately successful 3=failed scheme 4=I can't say

3. Constraints to utilization of rainwater harvesting ponds

3.1. Have heard about rainwater harvesting technologies before it is implemented on your plot? 1=yes 2=no

3.2. Do you have your own RWH pond? 1=yes 2=no

3.3. If yes, when you have started? ___________

3.4. Which type of RWH pond do you have? 1=excavated only 2=plastic lined 3=cement lined 4=others (specify) ___________________________

3.5. Who has constructed the pond? 1=government 2=community 3=individual household 4=others (specify) ____________________

3.6. Have you participated in the construction of RWH ponds? 1=yes 2=no

3.7. If yes, in what way you have participated? 1=simply attending meetings and discussions 2=attending meetings and decide over the implementation 3=decide over site selection 4=others (specify) _____________

3.8. What was your contribution in the time of pond construction? 1=material 2=money 3=labor 4=others (specify) ________________________

3.9. Is there selection of households to adopt RWH ponds? 1=yes 2=no

3.10. If yes, who is directly involved in the selection of households for the adoption of the pond? 1=ARDO experts 2=DAs 3=kebele officials 4=others (specify) __

3.11. If no, how you get involved in the technology? 1=DAs' pressure 2=personal initiative 3=learning from neighbors 4=others (specify) ____

3.12. Have you been asked your willingness when RWH pond is constructed on your plot? 1=yes 2=no

3.13. If yes, which type of pond was your preference? 1=communal pond 2=individual pond

3.14. Do you utilize the stored water in your ponds? 1=yes 2=no

3.15. If no, why? 1=decrease in water storage 2=don't know how to use 3=don't will 4=others (specify) _______________________

3.16. If yes, what types of crops you grow using stored water? ____
____

3.17. Are there problems during use of the stored water? 1= yes 2=no

3.18. If yes, what are these problems? (Tick as many as you can)
1=lack of operational skills 2=poor maintenance 3=poor water quality 4=lack of lifting tools 5=seepage 6=disease prevalence

3.19. Does your pond have fence? 1=yes 2=no

3.20. Does your pond have roof cover? 1=yes 2=no

1.21. If no, what constraints you have faced due to absence of fence?

Specify ____
____

1.22. What are your reasons to construct RWH pond?

1=water shortage 2=soil infertility 3=to produce more
4=others (specify) _______________________________________

3.23. Indicate the following constraints to utilize RWH ponds in your kebele.

1=land shortage 2=financial problem 3=absence of guidance 4=material shortage 5=high cost of construction
6=others (specify) ________________________________

3.24. Is there any assistance given from government or other else organizations for the construction and utilization of RWH technologies? 1=yes 2=no

3.25. If yes, what are these assistances? ____
____

3.26. Where your pond is constructed? 1=in garden 2=on cultivation plot
3=others (specify) ____________________________________

3.27. If it is constructed on your cultivation plot, how many hours did you travel to your nearest plot? (in minutes) ___________________

3.28. Have you got any training how to perform with RWH technology?
1=yes 2=no

3.29. If yes, on which of the following did you have training? 1=how to construct pond
2=site selection 3=how to use the stored water
4=for what purpose to use the stored water 4=others (specify) __________

3.30. What is your major crop production? 1=teff 2=sorghum 3=maize
4=wheat 5=barley 6='guaya' 7=vegetables 8=fruits
9=others (specify) ____

3.31. Do you think that water stored in your pond is suitable for your major crop production?
1=yes 2=no

3.32. If no, for what purpose you use the stored water? 1=for human drink
2=for animal drink 3=for nothing 4=others (specify) ______________

3.33. What is the rate of utilizing RWH ponds in your kebele?

1=increasing 2=decreasing 3=no change 4=stopped

3.34. Can you reason out for your replay of question number 3.33? 1=financial constraints 2=lack of skilled labor 3=quota system expansion
4=others (specify) ____

4. Socio-economic impacts of unutilized ponds

4.1. Do you have unutilized ponds? 1=yes 2=no

4.2. If yes, where is your pond constructed? 1=at the centre of the plot 2=outside of the plot 3=at the edge of the plot 4=others (specify) ____

4.3. For your replay of question no. 4.2, was that your preference? 1=yes 2=no

4.4. If no, who have influenced you to do so? 1=DAs 2=community leaders 3=kebele officials 4=others (specify) _____________________________

4.5. Do you think that your pond is damaged by animals? 1=yes 2=no

4.6. If yes, what are these damages? (You can mark more than one) 1=storage reduction of ponds 2= damage of onfarm crops 3=others (specify) ____

4.7. Is there any conflict with the surrounding community due to these damages? 1=yes 2=no

4.8. Do you think that the existence of unutilized ponds on your plot have narrowed down your land? 1=yes 2=no

4.9. If yes, what would be your measures? 1=eliminating the pond 2=compensating via expansion 3=others (specify) ____

4.10. Is there malaria epidemic in your kebele? 1=yes 2=no

4.11. If yes, do you think that the epidemic is aggravated by the RWH ponds? 1=yes 2=no

4.12. Is there any animal or human life loss you heard due to the ponds? 1=yes 2=no

4.13. If yes, how many life losses? Animals__________ Human____________

4.14. Have you observed any usage of unutilized ponds for other purposes? 1=yes 2=no

4.15. If yes, what are these purposes? (Specify) ____

4.16. Can you suggest me how you are going to react with unutilized ponds? ____

5. Determinants of households' decision whether or not to utilize rainwater harvesting ponds

5.1. Labor

5.1.1. What is your family size? ___________

5.1.2. Do you think that your family members enough for RWH operations? 1=yes 2=no

5.1.3. If no, how do you operate? 1=exchange (wonfel) 2=neighbor 3=hired labor 4=relative 5=others (specify)___________________________________

5.1.4. How many sons/daughters you have in your household? _________________

5.1.5. How many of them go school? _____________________________________

5.2. Land

5.2.1. Do you have your own cultivation land at present? 1=yes 2=no

5.2.2. If no, how you produce crops? 1=by share cropping 2=by renting 3=given from parents 4=others (specify) _________________________

5.2.3. If yes, what is the total size of your cultivation land? ______________ha/timaj

5.2.4. Do you feel tenure security? 1=yes 2=no

5.2.5. If yes, do you have land ownership certificate? 1=yes 2=no

5.2.6. Do you think that your cultivation land is suitable for RWH? 1=yes 2=no

5.2.7. How long you travel from your home to your nearest plot? (in minutes) ______

5.3. Livestock

5.3.1. Do you have oxen? 1=yes 2=no

5.3.2. If yes, how many? ______________

5.3.3. If no, how you operate your cultivation? 1=coupling with others 2=hire from someone 3=borrow from friends 4=others (specify) _____

5.3.4. Is there fodder shortage in your village? 1=yes 2=no

5.3.5. If yes, what are your sources of fodder? 1=own grazing land 2=communal grazing land 3=crop residue 4=others (specify) ______

5.3.6. Is there communal grazing land in your village? 1=yes 2=no

5.6.7. Do you think that there is a problem of keeping thoroughly the livestock in your kebele? 1=yes 2=no

5.4. Agricultural inputs

5.4.1. Is there any credit access in your area? 1=yes 2=no

5.4.2. If yes, have had credit? 1=yes 2=no

5.4.3. If no, what are your reasons not to take credit? 1=its insufficiency 2=fear of the debt 3=high interest rate 4=others (specify) ____________

5.4.4. Do you have credit for the operation of RWH? 1=yes 2=no

5.4.5. If yes, who provide the credit? 1=government 2=NGO 3=private credit association 4=others (specify) ___________________

5.4.6. Do you save? 1=yes 2=no

5.4.7. If yes, in what form? 1=banks 2=ekub 3=buying livestock 4=others (specify) ____

5.4.8. Do you use chemical fertilizer? 1=yes 2=no

5.4.9. If no, why? 1=no soil fertility problem 2=difficulty of purchasing 3=supply shortage in markets 4=others (specify) ________________

5.4.10. Do you use manure? 1=yes 2=no

5.5. Household income

5.5.1. What is your major source of income? 1=onfarm income source 2=off farm income sources 3=remittance

5.5.2. What is your annual crop production? _________quintals

5.5.3. From this annual production, how much of it is used for your household consumption (in quintals)? ___________

5.5.4. What is the annual income of your household (Birr) ____________

5.5.5. Is there any family member engaged in off farm activities? 1=yes 2=no

5.5.6. If yes, what are these activities? 1=sale of goods 2=sale of local drink 3=sale of fire wood 4=daily labor 5= others (specify) ________________

5.5.7. How do you your income amount purchased on agricultural inputs? 1=very good 2=good 3=fair 4=poor

5.5.8. How do you rate wealth ranking of your household according to local standard? 1=rich 2=medium 3=poor

APPENDIX II

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

Interview check list prepared for Agriculture and Rural Development Office staff members

- Have you conducted studies before the expansion of RWH in the woreda?
- Have you examined the willingness of households for the construction of RWH ponds?
- For what reasons you expand the technology in the woreda?
- How do you see the awareness and participation of farm households in RWH?
- How you choose farm households to adopt the ponds?
- What materials, machines and trainings you supply to the practice of the technology?
- What major constraints you face to construct the ponds for farmers?
- How you expand ponds to all rural kebeles of the woreda without considering climatic conditions, soil type and distance of plots from farmers' residence?
- Do you have enough agricultural experts to assist farmers in their endeavor to utilize RWH?
- How do you see the socio-economic impacts of unutilized ponds in the woreda? What will be your actions to the problem?
- Do you think that expanding RWH ponds in the woreda profitable?

Interview check list prepared for Development Agents

- What were your contributions during expansion of rainwater harvesting in the woreda?
- How you explain the awareness of farmers to RWH?
- Do you think that RWH ponds be crucial for the farm households' well being in the woreda?
- What constraints you have observed over the construction and utilization of RWH ponds in your kebele?
- In what ways you help farmers in their endeavor to utilize the technology?
- What guidance you gave to non-user farmers to utilize their ponds?

Interview check list prepared for farmers with RWH ponds

- What reasons necessitates you to construct rainwater harvesting ponds?
- Can you tell me about your participation during the expansion of the technology?
- What is your perception towards the benefits of ponds on your plot?
- What great constraints you observe of utilizing the technology?
- Would you tell me about the current practice concerning ponds?
- What your income looks like before and after the technology adoption?
- Can you say that RWH ponds are supporting your action of food self sufficiency?
- How you see the socio-economic impacts of the current unutilized ponds on your farm lands?
- What suggestions do you have regarding the futurity of the ponds?

Interview check list prepared for RWH non-user farmers

- What are your main reasons not to utilize RWH ponds?
- How you evaluate the utilization of those farmers who adopted the technology?
- Can you say that RWH ponds are challenges to you and the society? How?
- What is your future plan concerning the utilization of ponds?
- How you see the socio-economic impacts of the current unutilized ponds on the farm lands?
- Can you say that you are unlucky of not utilizing the technology?
- What suggestions do you have regarding the futurity of the ponds?

APPENDIX III

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

Focus Group Discussion guide for PA level Administrative Officials

- Does your kebele community have good awareness towards the benefits obtained from RWH?
- What are the constraints to utilization of the technology in your kebele?
- As a kebele leader what assistances you give farmers to utilize RWH ponds?
- Are there financial, moral and equipment assistances given to farmers to utilize the ponds?
- How do you see the relationship between development agents and farmers in your PA?
- Would you tell me about the welfare difference between user and non-user farmers in your locality?
- What are the social and economic impacts on the community due to unutilized ponds in your kebele?
- What measures you have taken to minimize these impacts?
- What can you conclude about the utilization of RWH ponds in your kebele?

Declaration

I, the under signed, declare that the thesis is my original work, has not been presented for a degree in any other university and that all sources of materials used for the thesis have been duly acknowledged.

Name: Husen Maru Ahmed

Signature ________________

Date ____________________