ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
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AN ASSESSMENT OF BENEFITS AND CHALLENGES OF HOUSEHOLD RAINWATER HARVESTING PONDS IN KILTE AWLAELO WOREDA, EASTERN TIGRAY

By
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A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Arts in Regional and Local Development Studies (RLDS)

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May God bless you and be with you all!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS and ACRONYMS

CCHABA	Comprehensive Community and Household Asset Building Approach
DA	Development Agent
EGS	Employment Generation Schemes
HVH	High Value Horticulture
REST	Relief Society of Tigray
TFSCO	Tigray Food Security Coordination Office
FDRE	Federal Democratic Republic of Ethiopia
TWRDB	Tigray Water Resources Development Bureau
RWH	Rainwater Harvesting
PA	Peasant Association
USD	United States Dollars
IFSP-DPA	Integrated Food Security Programme for Drought Prone Areas
FFW	Food for Work
BC	Before Christ
Masl	Meters Above Sea Level

MM	Millimeter
Hectares Ha	
PSNP	Productive Safety Net Program
SSA	Sub Saharan Africa
CA	Catchment Area
CB	Cropped Basin
FGD	Focus Group Discussion
SPSS	Statistical Package for Social Science
ERHA	Ethiopian Rainwater Harvesting Association

GLOSSARY OF LOCAL TERMS

Woina –Dega	Mid- altitude
Meher	Main production season
Woreda	District
Kushet	Village
Kebele/Tabia	Peasant Association that consists of 4-5 villages
Gesho	Alcholic ingredient used to make local beer (Tella)

ABSTRACT

Agriculture in Tigray is characterized by small scale subsistence rain- fed farming with low productivity emanated from poor resource base, high spatial and temporal variability of rainfall; and severe environmental degradation that resulted in high level of food insecurity in the region. The regional government of Tigray has designed an integrated food security program to improve agricultural productivity and tackle the prevailing food insecurity. Construction of household rainwater harvesting ponds was one of the interventions designed to address the problem of low productivity and enhance household food security.

The paper examines the benefits and challenges of adopting household rainwater harvesting ponds in Kilte Awolaelo woreda, Eastern Tigray. The main focus of the study is to assess the contribution of pond water utilization towards increasing agricultural productivity, household income and the potential to reduce household food insecurity. The study also aims at exploring the major issues and challenges related to household ponds.

To attain the objectives of the study, household survey, focus group discussion, and key informant interview were employed to collect data at household and individual levels. The results reveal that adoption and utilization of household ponds have a positive impact in improving and diversification of agricultural production. Ponds also enable farmers to generate income from the sale of crops grown by using the stored water as supplementary irrigation which improves their access to food and hence reduce household food insecurity.

The results of the study also show that the program has faced problems related to the design, lack of training, wrong site selection of ponds, lack of construction materials, high labour demand and so on. The study concludes by suggesting measures that may be taken for better implementation of the technology.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Agriculture is the main economic activity in most Sub Saharan Africa (SSA) countries including Ethiopia. Majority of the population in these countries make their living from rainfed agriculture and depend to a large extent on smallholder, subsistence farming for their livelihood security (e.g. Ethiopia 85%, Malawi 90%, Botswana 76%, Kenya 85%, and Zimbabwe 70-80% of the population). As a result, the communities involved are experiencing a combination of short term, often acute food crisis, and long term or chronic food shortages (Rockstrom, 2000; Ngigi, 2003).

Ethiopia is one of the most food insecure SSA countries that have faced continuous drought and famines. The first recorded famine goes back to the ninth century and there were more than ten major famines between 1540 and 1742. The years 1984/85, 1993/94, and 1999/2000 were drought years in the recent Ethiopian history. In general, in the years 1981 to 1995, averages of 4.9 million people have been affected by droughts, with this part of the population ranging from 46 percent in Tigray to 9.5 percent in Bale. Moreover, 14 million people needed immediate food assistance during the year 2002/03 (Alem, 1999; Sen, 1981).

The major features of food security in Ethiopia are persistent deficit in aggregate food supply, a down ward trend in per capita food production and large variability in output of food items. Different studies indicate that about 52% of the country's population is food insecure. The causes of food insecurity in the country include inadequate and variable rainfall, fragile natural resource base, improper farming practices, lack of access to productive resources, land tenure insecurity, poor storage technology, poor transport and infrastructure, heavy workload on women, and civil war and ethnic conflicts. However, the major cause of food insecurity at household level results from the nature of the rainfall, which is characterized by high spatial and temporal variability (Alem, 1999; FDRE, 1996; Ngigi, 2003).

Tigray is the northernmost region of Ethiopia covering an area of approximately 53,386 Km^2. It has an estimated population of 4.335 million in July 2006, 81% of whom live in rural areas. The total arable land is 1,082,959 hectares (ha) of which 1,023,246 ha is cultivated. More than 99% of the cultivated land is rain-fed (TFSCO, 2006).

The mean annual rainfall varies from less than 400mm in the east to 1600 mm in the west with high spatial and temporal variability. According to Amare cited in Fitsum et al (2002), the coefficient of variation in annual rainfall for the region is about 28% which is far higher than the national figure of 8%. The Eastern zone and bigger portion of the Southern zone have bimodal type of rainfall and the rest of the region has monomodal rainfall pattern. Late beginning and/ or early ending of the rainy season is a typical feature of rainfall in many parts of the region. Moreover, the phenomenon of rainless situation for consecutive days between rains is common (TWRDB, 2002).

The main means of livelihood for the population is agriculture dominated by small scale subsistence producers and high farmland fragmentation which resulted in declining of agricultural production. Erratic nature of rainfall combined with intermittent dry spells is the main climatic limitations that threaten crop production. Moreover, environmental degradation such as desertification, soil erosion and loss of soil fertility are some of the reasons for low agricultural productivity. Only 16% of the population is self-supporting while the vast majority, 84%, is food insecure. The average production of cereals, the major agricultural output, is 4-7 quintals per household in the drought prone areas that can only feed a family for 5-8 months a year at best. Most farmers in the region face food deficits even in the years of good harvest and adequate rainfall. For instance, during 1994/95 when rainfall was considered to be adequate and there was little crop loss due to insect infestation, only 17.9% of the population had enough harvest to support themselves and the remaining 82.1% had faced food shortages (Tigray Regional State, 2000; Middlebrook and Mengesha, 2000; Rami, 2003).

In addition to low agricultural productivity, lack of purchasing power is one of the major problems in the region which contributes to low access to food. Households are unable to acquire their food needs from markets because of inadequate incomes (Kiros, 2003).

To mitigate the problem of food insecurity, the Ethiopian government has developed a national food security strategy in 1996.The strategy focuses on agriculture and gives priority to rural development. The main components of the strategy were increasing agricultural production and reduction of marketing costs through provision of infrastructure and promotion of competition. Furthermore, maintaining sound macro-economic policies, encouraging small scale business enterprises and creating supplementary income generation schemes are some of the focuses of the strategy. It also focuses on developing different mitigating measures for the regions with less reliable rainfall such as diffusion of simple technology packages and promotion of irrigation development (FDRE, 1996).

In line with the overall national food security strategy, the regional government has designed an integrated food security program for drought prone areas (IFSP-DPA) in 16 highly food insecure woredas. The program was designed to solve the key problems constraining achievement of household food security. These problems are severe environmental degradation, low level of agricultural production, poor water supply coverage, poor health and education services, poor accessibility of the woredas, lack of capital, gaps in training and low off-farm activities, poor agricultural research support and lack of alternative fuel wood/energy sources (Tigray Regional State ,2000).

The regional food security program focuses on undertaking integrated household focused activities. The activities are being implemented using a new approach called Comprehensive Community and Household Asset Building Approach (CCHABA) that aims at improving production and income through provision of household asset building packages and implementation of household support and community wide interventions. CCHABA is a holistic approach to improve and develop economic and natural resource base of the economically disadvantaged and ecologically fragile areas and people in the region. The integrated food security program enables to improve agricultural production, income and household food security through development of micro-watershed based program and hence linking of conservation to production (Kiros, 2003; Tigray Regional State, 2000).

Water harvesting is one of the activities designed to improve cereal, fruit and vegetable crops production and animal products that enables to irrigate large area of land which in turn improves agricultural productivity. Such water harvesting schemes include construction of ponds and tankers, stream development and river diversion (Kiros, 2003). Due to the local availability of construction materials, relatively low cost of construction and simplicity of the design to construct by unskilled labour force; household level rainwater harvesting ponds were given high priority. The stored water is aimed at providing supplementary water for crop production during the rainy season to reduce the risk of moisture stress and increase agricultural productivity (Mills, 2004).

Construction of ponds started in January 2003 with the intention of constructing 500,000 ponds in five years so as to improve agricultural productivity and mitigate the problem of high food insecurity prevailing in the region.

1.2 Statement of the Problem

Kilte Awlaelo woreda is one of the 16 food insecure vulnerable woredas in Tigray included in the IFSP-DPA. As a result, large scale construction of rainwater harvesting (RWH) ponds has been undertaken since 2002/03 so as to enhance agricultural productivity by using the stored water as supplementary source for crops production and improve the food security status of the population.

The initial plan was to construct 30,000 ponds in 2002/03 which was based on the number of identified vulnerable households in the region. A target of around 2000 ponds per woreda was passed to the respective woredas for implementation. However, due to shortage of time for implementation, little flexibility was available to select the beneficiary Peasant Associations (PAs) based on needs and community willingness (Mills, 2004). In addition, low quality ponds were constructed so as to fulfill the quota imposed by the region (Rami, 2003).

Even though ponds are one of the viable options of water storage for agricultural and other purposes, many problems have been encountered during construction of the ponds and utilization of the stored water. Lack of skilled experts and labour, lack of construction materials, threat of malaria and death by drowning are some of the problems related to the ongoing practice (ibid). Moreover, enough study has not been made to identify the side effects of ponds and their potential contribution towards agricultural productivity and mitigate household food insecurity. Therefore, the study will assess the major benefits and challenges of household ponds in Kilte Awlaelo woreda.

1.3 Objectives of the Study

The main function of ponds is the provision of supplementary water source for productive activities. Pond water can be used for agricultural production, drinking water for livestock and domestic purposes. The general objective of the study is to assess the overall socio-economic impact of household ponds and their contribution in enhancing agricultural productivity in Kilte Awlaelo woreda, Eastern Tigray. The specific objectives are:

- To examine the role of ponds in enhancing agricultural productivity, household income and their potential contribution towards household food security
- To assess the perception of farmers towards ponds
- To explore the major issues and problems related to construction and utilization of ponds

1.4 Research Questions

In order to fulfill the objective of the study, a number of questions have been raised and an attempt was made to address the issues. The major research questions are:

- How did beneficiary farmers and other stakeholders participate during introduction of the technology?

- Is there any change in agricultural productivity and diversification of crops grown due to adoption of ponds?
- How has the issue of food security been addressed through ponds?
- What are the major constraints during construction and utilization of ponds?
- What is the perception of farmers towards the technology?

1.5 Significance of the Study

The program of construction of household ponds was implemented in many drought prone areas of Ethiopia as part of the national food security strategy in order to enhance the food security status of the people. Due to the urgent and large scale implementation of the program, enough discussion and participation of stakeholders was not made during design and implementation. As a result, many beneficiaries and other stakeholders were not convinced about the objectives of the program.

According to Daniel (2007), some of the critics are resulted from the prevailing context of acute land scarcity, absolute poverty, vulnerability to malaria and abundance of rivers in the country which are not research based. However, such generalizations cannot be made because the stated issues are location specific. As a result, the information obtained via this study will narrow the information gaps regarding the benefits and challenges of pond adoption. The study will also provide insight for better implementation of the program. Furthermore, it will be used as a base for further research.

1.6 Research Methodology

1.6.1 Selection of Survey Sites

In order to address the objectives of the research Negash and Mai-Quiha were purposively selected out of the 16 PAs in Kilte Awlaelo woreda. Before selecting the target PAs, different areas of the woreda were visited. Discussions were also made with regional and woreda agricultural experts. Based on the information obtained during the visits and discussions, Negash was selected due to its good performance in utilization of ponds and Mai-Quiha was selected as it is one of the PAs that have shown moderate performance in using the stored water from ponds for productive activities. In addition to the reason stated above, the PAs were also selected due to their accessibility.

1.6.2 Sampling Method

The sample population consists of pond –user and non- user households. The list of farmers who own operational ponds and those who did not adopt the technology was obtained from the respective PAs. The sample size of pond user households is 96 and was drawn from a total of 635 operational ponds constructed from 2002/03 to 2005/06. The sample size of non users is 31 which accounts for one third of the sample size of the pond users. Non pond users were included in the study in order to assess their perception towards the technology and the reasons for not adopting ponds.

In Negash 50 pond user households were selected out of the total 331 operational ponds and 46 households were included in Mai-Quiha from a total of 304 operational ponds. The sample size of non pond user households is 16 and 15 for Negash and Mai-Quiha respectively. All sample households were drawn using simple random sampling.

1.6.3 Methods of Data Collection

Primary and secondary data sources have been gathered and analyzed in the research work. Thus, the following data collection methods were employed during data collection for the study.

i. Primary Data Collection

Primary data was collected using various instruments such as household survey, key informant interview, focus group discussions (FGD); and personal observation of the constructed structures and participation in events related to the technology.

Household survey was the main method used to obtain quantitative information. Structured questionnaire with open and close ended questions was designed and used. Sample household heads were the unit of analysis from whom the survey information was collected. Three enumerators in each PA were employed to administer the questionnaire under close supervision of the researcher. The enumerators were development agents (DAs) and students who stationed in the PAs for practical training. The enumerators were briefed about the survey and familiarized with the questionnaire. The questionnaire was translated to the local language, Tigrigna, and given to the enumerators which helped to fill the questionnaire properly.

Key informant interview and FGDs were useful sources of detailed information that could not be obtained through survey method. Key informant interview was conducted to generate information about the general situation of the program implementation, problems related to pond adoption, cost of pond construction and so on. The Key informants include elderly people, model farmers, administration officials, development agents (DAs), regional and woreda experts.

FGD was one of the methods employed to generate qualitative information in the study such as perception of the farmers towards the technology and benefits obtained from ponds. Two FGDs were conducted in each PA one with pond users and one with non users which comprised with in the range of 6 to 8 individuals.

ii. Secondary Data Collection

In addition to primary data, secondary data from different sources were also used in the study. Published and unpublished documents were obtained mainly from institutions such as the Ethiopian Rainwater Harvesting Association (ERHA), Tigray Water Resources Development Bureau (TWRDB), Kilte Awlaelo Woreda Agriculture Office and Local Government Units.

1.6.4 Data Analysis

Both qualitative assessment and descriptive analysis techniques were used for data analysis. The data obtained through household survey was analyzed by employing statistical package for social science (SPSS) software. Relevant statistical methods such as frequency, percentage and mean were used for analyzing the quantitative data. The findings of the survey are discussed together with the qualitative information

1.7 Scope and Limitations of the Study

Many types of water harvesting have been constructed in order to reduce the problem of crop failure and improve agricultural productivity in the study area. These structures include tankers, wells, and community ponds and so on. The research has focused only on the assessment of the socio-economic impact of household rainwater harvesting ponds in Kilte Awlaelo woreda and the study has some limitations during data collection.

The major problem faced during data collection was related to the information gathered through household survey especially on the issues that have close economic implications such as volume of production, number of livestock, income level and so on. Farmers were reluctant to provide proper information and tend to under-state what they actually owned because they have a fear of being excluded from the ongoing productive safety net program (PSNP) if they are economically better off. However, different methods such as informal interviews, FGDs and discussions with DAs were used to crosscheck the data obtained through household survey.

Another problem faced during data gathering was lack of well recorded time series data on production using pond water in the woreda agriculture office. Aggregate data on crops produced using various water harvesting technologies was obtained which created difficulty in assessing the contribution of ponds towards agricultural productivity at woreda level.

1.8 Organization of the Paper

The paper is organized as follows. Chapter one is an introduction of the study that contains statement of the problem, research objective and methodology. The second chapter deals with the review of related literature and conceptual framework of the study. Chapter three gives general background overview of the study area. The major results and discussion are presented in chapter four. In chapter five summary and conclusion is made by addressing the major issues and findings of the study.

CHAPTER TWO

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1 The Basis of Rainwater Harvesting

Water is one of the most important elements of life used for drinking, sanitation and maintaining ecological systems. It is also an input in the production of food which maintains livelihoods. About 95% of the planet's water in oceans and 1.7% is trapped in glaciers. Only less than 1% is currently readily available in the form of ground water, rivers, lakes and swamps in order to be shard by human beings, plants and animals (Mesfin, 2004).

Rainfall is the major source of water in food production. Rain fed agriculture is globally practiced on 80% of the cultivated lands and provides about 60% of the world's food production (FAO, 2001). In Sub-Saharan Africa (SSA) countries rain fed agriculture covers more than 95% of the crop lands (Rockstrom, 1999). Due to the high dependence on rain fall, many of these countries are unable to feed their ever increasing population which leads to transitory and chronic food insecurity (Ngigi, 2003).

According to McCalla cited in Rockstrom (2000), there is little new land to put under the plough in SSA. Thus, the large increase in food production and household income needed in these countries has to be achieved through an increase in productivity per unit of land and per unit of water. However, this is a challenge in the dry lands of SSA where annual rainfall is low which varies from 400-600 mm in semi arid zones and concentrated to one or two short rainy seasons.

Even though rain fall is considered to be low in the dry lands of SSA, the main source of water shortage in these countries is attributed to the high spatial and temporal variability of the rainfall that results in a very high risk of annual droughts and intra-seasonal dry spells. Thus, smallholder producers face food shortages and livelihood losses resulting from inter-seasonal droughts or floods (Hatibu et al, 2004).

Studies show that in a semi-arid region, severe crop reductions caused by a dry spell occur 1-2 times out of 5 years, and total crop failure caused by annual droughts once every 10 years which indicates that the poor distribution of rainfall over time often constitutes a more common cause for crop failure than absolute water scarcity due to low cumulative annual rainfall (Rockstrom, 2000).

The large proportion of non-productive water flows in the water balance also causes water scarcity in rain fed agriculture. Often only a small fraction of the rainwater reaches and remains in the soil long enough to be useful. Up to 80% of the rainfall can be lost as evaporation, or runoff that causes erosion and flooding downstream (Hatibu etal, 2004).

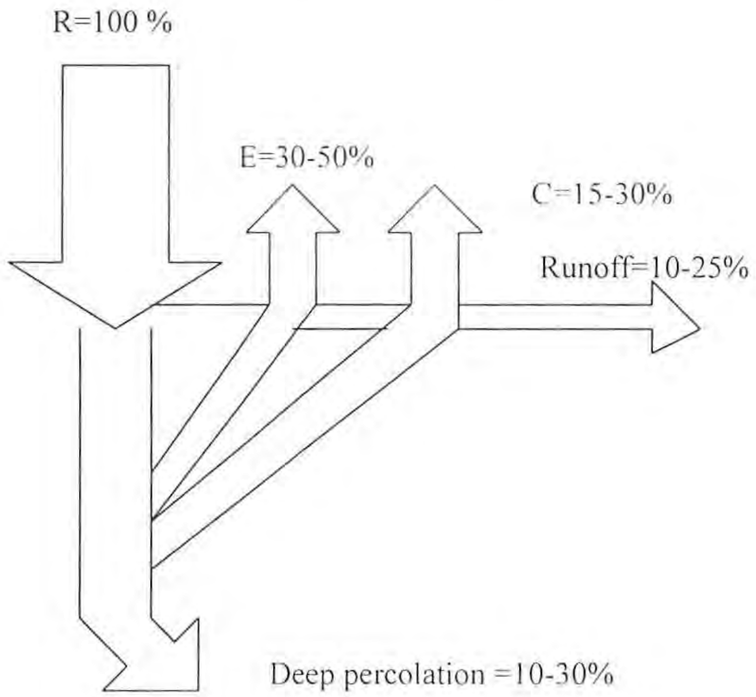

Figure 2.1: Schematic representation of rainfall partitioning in the semi-arid tropics of SSA (Adopted from Rockstrom, 2000).

The above figure indicates the partitioning of rain fall into different water flow components in rain fed agriculture in Sub-Saharan dry lands. Run off accounts to 10-25% of the rainfall and 10-30 goes to deep percolation. The majority, 30-50%, of the rainfall is lost as evaporation and only 15-30% of the total rainfall is used for crop production.

Agriculture in Ethiopia is predominantly rain fed with a potential of nearly 3.5 million hectares (ha) of land suitable for irrigation (Getachew, 1999). The yearly available surface water and ground water resource is about 2000m3 per capita (Mesfin, 2004). The annual rainfall ranges between 2200 mm in the south-western highlands and less than 200 mm in some parts of the northern and south-eastern lowlands while the total annual runoff is estimated at 122 billion m3, and only less than 5 percent is used for productive purposes (Moges, 2004). The country is endowed with enormous land and water resources potential that can be transformed into a dependable source of energy and food (Getachew, 2003).

According to Fallenmark cited in Moges (2004), Ethiopia is still economically water scarce country that cannot make use of available water resources despite the sufficient availability of water for productive activities. The studies show the availability of untapped and abundant water resources in the country that should be managed properly so as to improve food production and reduce food insecurity.

To overcome the problem of low agricultural productivity different technologies such as increasing groundwater withdrawal, irrigation development and rainwater harvesting are used. Increasing withdrawal of groundwater might lead to over exhaustion of the resource if not managed properly. Even though irrigation is most obvious response to drought, it requires high investment costs (Hatibu and Mahoo, 1999).

Currently there is an increasing interest to manage and sustainably use rainfall through rainwater harvesting technologies.

Rainwater harvesting is a relatively low cost alternative. It is believed to be an appropriate and viable option to address the moisture stress problems in dry lands of Ethiopia (Hune, 2004a). Rainwater harvesting technologies are preferred because rain water is more available in moisture stress areas when compared to the permanent water sources. In addition, they are simple to manage, maintain and can also be implemented with family labor using locally available materials (ibid).

2.2 Rainwater Harvesting: An Overview

Rain water harvesting refers to the collection of rainwater from direct rainfall or in the form of surface runoff and its concentration in the soil profile or artificial reservoir from which it can be directed to various uses, ranging from supplementary irrigation to water supply for domestic uses, animals and other productive purposes (Hune, 2004a). More precisely, RWH can be defined as the process of concentrating rainfall as runoff from a larger catchments area to be used in a smaller target area (Oweis et al, 1999). Runoff is collected mainly from ground catchments, as well as ephemeral streams (flood water harvesting) and road/footpath drainage (Ngigi, 2003).The collected runoff water is either directly applied to an agricultural field or stored in some type of storage facility such as tanks, reservoirs, dams, water pans, etc for domestic use and as supplemental irrigation for crops (Oweis et al, 1999).

RWH is practiced in arid and semi-arid regions where surface runoff has an intermittent character and it requires a runoff producing area and runoff receiving area. Moreover, due to the intermittent nature of runoff, storage is an integral part of RWH system in which water can be stored directly in the soil profile or in small reservoirs, tanks and aquifers (Oweis et al, 1999).

In general, the major components of RWH systems are catchment area, storage facility or runoff conveyance and target area/crop land. Catchment area is a runoff area that contributes some or its entire share of rain water to a target area outside its boundaries. The area can be natural surfaces, roads/foot paths, gullies, rills, ephemeral streams, croplands, etc (Ngigi, 2003). Storage facility is a place where runoff water is held from the time that it is collected until it is used. The storage facility can be either soil profile in cropland or distinct structure such as farm ponds, tanks, water pans, earth dams, sand dams and subsurface dams. Target area is a place where the harvested water is used which could be plants or animals in agricultural production (Lakew, 2003).

2.3. Classification of Rainwater Harvesting Technologies and Systems

There is no distinct way of classifying RWH technologies because different experts use various criteria for classifying them. According to Hatibu and Mahoo (1999), RWH systems are divided into three different categories based on the distance between catchment area (CA) and target area /cropped basin (CB). These categories are in-situ, internal (micro) catchment and external (macro) catchment RWH systems.

i .In-Situ Rainwater Harvesting

In-situ RWH or within- field catchment system involves capturing rainwater where it falls and storing it in the root zone. It is one of the practices used for water and soil conservation (Hatibu et al, 2004). The catchment area and target area is the same which is either the crop land or grazing land. The system is useful in prevention of net runoff from a given cropped area by holding rainwater and prolonging the time for infiltration (Hatibu and Mahoo, 1999).

The most commonly practiced technologies include conservation tillage, deep tillage, contour farming and ridging. Conservation tillage is defined as any tillage sequence with an operational threshold of leaving more than 30% mulch or crop residue cover on the surface throughout the year so as to minimize the loss of soil and water (Rockstorm, 2000).

Deep tillage improves soil moisture capacity by increasing soil porosity. In addition, runoff is reduced through increased roughness at the soil surface which increases the time available for water to infiltrate the soil (Rosegrant et al, 2002).

Contour farming is a technique in which tilling and weeding are done along the contours to form cross-slope barrier to the flow of water which is complemented with ridges in order to create roughness and enhance infiltration. In addition to increasing soil water holding capacity, contour farming reduces evaporation and improve the quality of the soil when mulching or other organic materials are added. (Hatibu and Mahoo, 1999; Rosegrant et al, 2002).

In-situ rain water conservation technology is one of the simplest and cheapest methods of water management systems that can be practiced in almost all land use systems (Ngigi, 2003). However, it offers little or no protection against the poor rainfall distribution. As a result, the risk of crop failure is only slightly lower than without any measures (Rockstrom, 2000).

ii. Internal (Micro) Catchment Rainwater Harvesting

In micro catchment system there is a distinct division between catchment area and target area but they are adjacent to each other (Hatibu and Mahoo, 1999). It involves runoff generation within the field and subsequent concentration on either a single crop especially fruit trees, a group of crops or row crops with alternating catchments area and target area mainly along the contours (Ngigi, 2003). Micro catchments systems improve the in-situ management with provisions for supplying extra water from adjacent catchments (Hatibu et al, 2004).

Some of the examples of land-based micro catchments technologies include, strip catchments tillage, contour bunds and semi-circular bunds. The non land- based micro catchments systems are roof tops of buildings and other impermeable structures (Lakew, 2003).

Strip catchments tillage involves tilling strips of land along crop rows and leaving appropriate sections of the inter-rows and leaving appropriate sections of the inter-row space uncultivated so as to release runoff while contour bunds are earth, stone trash embankments placed along the contours of the hillside in order to trap rainwater behind them and allow for greater infiltration (Rosegrant et al, 2002).

***iii.* External (Macro) Catchments Rainwater Harvesting**

It involves the collection of runoff from large area ranging from 0.1 ha to thousands of hectares which are located at an appreciable distance from where it is being used. The system is sometimes used with intermediate storage of water outside the cropped basin for later use as supplementary irrigation. Macro catchments systems are designed to provide more water for crop growth through the diversion of storm floods from gullies and ephemeral stream, into crop or pasture land. Some types of external catchments include hillside sheet/rill runoff utilization, floodwater harvesting within the stream bed, ephemeral stream diversion and storage based rainwater harvesting (Hatibu et al, 2004; Hatibu and Mahoo, 1999).

In hillside runoff utilization runoff from hill tops, sloping grounds, grazing lands or other compacted places are collected in flat areas where it is used for cultivation. Hillside conduit systems are beneficial in areas where the runoff travels long distance before reaching the cultivated area (Rosegrant et al, 2002).

Flood water harvesting within the stream bed is a system that uses barriers such as permeable stone dams to block the water flow and it on the adjacent plain to enhance infiltration while ephemeral stream diversion involves diverting water from its natural ephemeral stream and conveying it to arable cropping areas (Hatibu and Mahoo, 1999).

When high volume of runoff that cannot be stored in the soil profile is produced, storage based systems are used to store the runoff. Water is collected and stored in ponds, underground water tanks, rock catchments, sand dams and sub surface dams. The system requires methods for controlling siltation especially if the area is prone to soil erosion, evaporation, and seepage losses. The stored water is used as supplementary irrigation for crops during stress periods and for the production of vegetables and fruits. In addition, it is also used for livestock and different household uses (Hatibu and Mahoo, 1999; Rockstrom, 2000).

Supplementary irrigation is a temporal intervention designed to support crop growth during periods of water shortage when the crop would die or yields would be substantially reduced by moisture shortage. According to Oweis et al (1999), supplementary irrigation is defined as the application of a limited amount of water to the crop when rainfall fails to provide sufficient water for plant growth, to increase and stabilize yield.

During selection of the rainwater harvesting systems social, economic, technical and demand assessments of the specific area should be made. Social assessment includes the existing rainwater harvesting practices in the locality, the opinion of local people on the technology and the cultural aspects prevailing in the area under consideration. Technical and demand assessments include detailed information on rainfall, existing water sources , availability of materials and harvesting surface, required quantity of water and the willingness to pay of the population (Mitiku and Sorssa, 2001).

Physical structure of the soil has also an impact on the effectiveness of the rainwater harvesting systems. In addition, consideration of risk is very important before adopting the technology in order to make sure that the expected return from the adoption of the new technique be greater than the costs of implementing it (Rosegrant et al, 2002).

2.4 The Role of Rainwater Harvesting

Rainwater harvesting can help mitigate the effects of the temporal and spatial variability of rainfall and the high risks of intra-seasonal dry spells that characterize the water-scarce regions of SSA which can improve the people's livelihoods (Inocencio, 2003). The following are some of the benefits that can be obtained from RWH.

2.4.1 Socio-Economic Benefits

The main objective of most RWH technologies is to increase soil moisture and hence supplement direct rainfall in order to improve crop productivity and diversification that enhances household income and food security (Ngigi, 2003). When combined with appropriate land management practices, RWH can enhance water security in rain-fed areas bringing food security and the potential for diversification into small scale market production (UNDP, 2006). Studies indicate that there is a significant use of harvested rainwater for the production and sale of crops such as maize, paddy rice and vegetables in Dodoma which resulted in increased farmers' income and poverty reduction (Hatibu and Mahoo, 1999).

RWH systems have been found to improve agricultural productivity and returns. According to Ngigi (2003), farm gross income was found to increase by up to United States Dollars (USD) 500 per season as a result of the utilization of the stored water in parts of Laikipia, Kitui and Machakos districts of Kenya. Farmers in Laikipia earned USD 192 in three months from the sale of vegetables grown using stored water from ponds and underground tanks. On the other hand, conservation tillage realized percentage yield increase of 100-150% for maize, wheat and beans while potatoes yields increased by 50-200%.

In Ethiopia many households have started growing high value horticulture (HVH) crops that have improved household food security through increase in income and nutrition diversification. Moreover, water availability at the homestead has encouraged farmers to involve in livestock and poultry keeping hereby increasing agricultural yields and incomes and thus improving food security (Hune, 2004a).

Construction of RWH has created rural employment opportunities for unskilled members of the community. In addition, adoption of the technology has reported to greatly improve the quality of life resulted from improved health and better personal hygiene by providing safe water for domestic use and livestock (RAIN, 2005).

Adoption of RWH systems also the burden of women and children in fetching water for household needs. Before introduction of rainwater storage tanks in Sri Lanka, women were unable to leave their households for social and religious functions due to pre occupation in fetching water. Furthermore, fetching water effected children's education (Ariyabandu, 1999). When water sources are found around the homesteads the burden of carrying water by women and children are reduced which enables women to spend their time for productive activities.

As per the study made by Ngigi (2003), in Kitui children school performance has improved due to the availability of more time to study since the children no longer fetch water from distant sources. Improved health and availability of school fees have also led to better academic performance.

2.4.2 Environmental Benefits

Besides for agriculture and domestic uses, rainwater is also harvested to recharge groundwater aquifers. According to Kariuki (2005), water pans/ponds constructed at the path of water flow not only helps in water storage but also break the water flow path and mitigate soil erosion and the resulting gully formation. Moreover, construction of terraces and retention ditches help to control soil erosion as well as conserve water for crop production.

When collected rainwater is used instead of groundwater, the ground water potential can recover which mitigates the problem of overexploitation of water resources. The environmental impact of RWH have been witnessed in central Tanzania where contour bunds/ trenches incorporate agro forestry and fodder production which has played a major role in afforestation of formerly forested hill slopes. This has led to availability of firewood, fodder, building material, fruits and overall improvements in land productivity that can improve agricultural production and hence attain household food security (Ngigi, 2003; RAIN, 2005).

2.5 Rainwater Harvesting in Ethiopia

Rainwater harvesting is believed to have originated in Iraq over 5000 years ago in the so-called Fertile Crescent while it was in use in India and China for more than 4000 years. The major techniques used were in-situ rainwater harvesting and collecting runoff originating from rainfall over a surface elsewhere, external rainwater harvesting (FAO, 2001).

The history of RWH in Ethiopia dates back to the pre Axumite period (560 BC) when rainwater was harvested and stored in ponds for agricultural and water supply purposes (Getachew, 1999). Studies indicate that there are documented literatures and visual observations on the ponds that were once used for irrigation during that period and a roof water harvesting set up still exists in the remains of the oldest palaces in Axum. Moreover, ponds and underground water storage tanks were found in the remains of one of the old castles in Gondar constructed in the 15-16 century while ponds and underground water tanks constructed by King Lalibela over 800 years ago to be used for drinking and religious rituals are still found in the rock hewn churches of Lalibela (Ephraim and Berhanu, 2003).

In Southern Ethiopia the Konso people have a long and well established tradition of building level terraces to harvest rainwater to produce sorghum under extremely harsh environment and unreliable rainfall. In addition, construction of birkas, ponds and embankments for agriculture and domestic use are some of the traditional water harvesting practices in Ethiopia (Getachew, 1999; Yohannes, 2005).

Promotion and application of rainwater harvesting techniques as alternative interventions to address water scarcity were started through government initiated soil and water conservation programs to construct farm ponds and micro dams so as to respond to the 1971-74 drought in Tigray, Wollo and Hararge with a limited coverage due to low community participation (Hune, 2004b).

According to Belay cited in Ngigi (2003), in recent years water management particularly promotion of rainwater harvesting technologies in moisture stressed areas are included as one of the main package components in the national agricultural extension program that has been designed to enable attainment of food self sufficiency.

Rainwater harvesting is one of the major components of food security strategy designed in 1996 to address the problem of household food insecurity in Ethiopia. The primary focus is mitigating water shortages to enhance agricultural productivity through construction of farmers oriented small scale low cost water resource development such as rainwater harvesting, spring development, shallow wells extraction and various soil moisture retention techniques. As a result, in the year 2003 a total of 118, 559 RWH tanks and farm ponds were constructed at household level in Amhara, Southern, Oromia and Tigray Regions. Some of the techniques are based on local experience while others are based on innovative practices of land users of other countries in their efforts to cope with persistent food insecurity and famine. In many places of the country benefits have been observed from promoting and adoption of rainwater harvesting technologies and systems (Hune, 2004a and 2004b).

2.6 Conceptual Framework

Water is part of the natural capital base that sustain livelihoods and access to reliable supply of water makes it possible for people to diversify their livelihoods, increase productivity and reduce the risks associated with drought (UNDP, 2006). Close to 85% of the Ethiopian population live in rural areas and agricultural sector accounts for 57% of gross domestic product (GDP) and 90% of export earnings (Senait, 2000). However, the sector is characterized by low productivity and the country faces frequent drought and crop failure due to the variable nature of rainfall, environmental degradation, lack of access to productive resources and so on that resulted in high food insecurity (Figure 2.2).

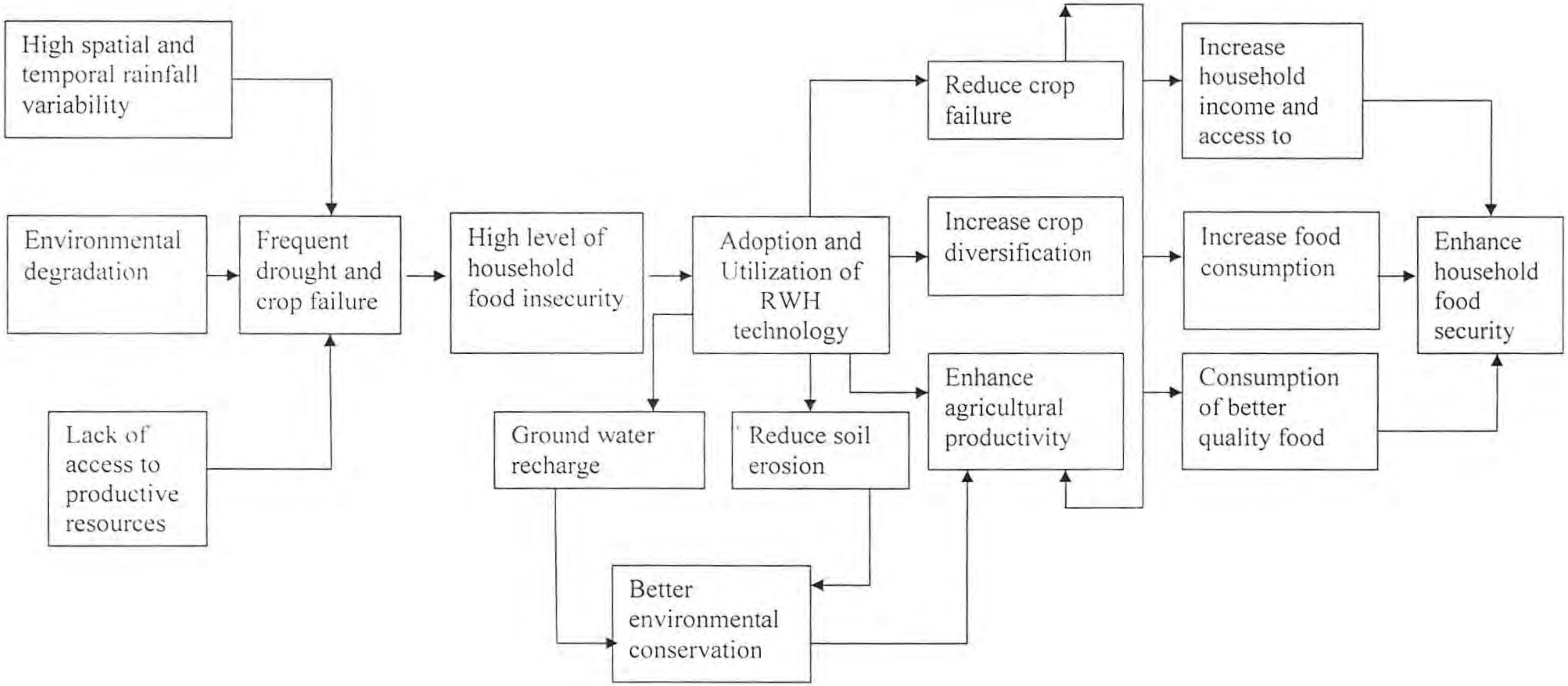

Figure 2.2: A conceptual framework for assessment of the contributions of RWH ponds

Rainwater harvesting is one of the interventions undertaken by the government of Ethiopia to improve agricultural productivity and reduce the prevailing food insecurity in the country. Adoption of RWH can be used as a supplementary irrigation for crops production which can enhance production and improve the food security status of the beneficiaries. Moreover, it helps in reducing soil erosion and recharges the ground water potential that in turn contributes to enhancing agricultural productivity.

CHAPTER THREE

BACKGROUND OF THE STUDY AREA

3.1 Location and Physical Setting

Tigray National Regional State is located in northern Ethiopia and is bordered to the north by Eritrea, to the west by the Sudan, to the south by Amhara region and to the east by Afar region. It extends from $12^015'$ to 14^057N latitude and from $36^027'$ to $39^059'E$ longitude. The region is divided into five administrative zones, 35 woredas and 600 tabias or peasant associations (PAs).

Kilte Awlaelo woreda is found in Eastern zone of Tigray region at about 45 kilometers north of the regional capital, Mekelle with area coverage of 101,028 hectares.The altitude of the woreda varies from 1800 to 2300 meters above sea level (masl) and is agro-ecologically characterized as Woina-Dega (Mid- altitude). The mean annual temperature in the area ranges from 15^0c to 28^0c and annual rainfall ranges from 350 to 550mm. The following table shows mean monthly rainfall for the rainy season in the woreda.

Table 3.1: Mean Monthly Rainfall (in millimeter)

Year	March	April	May	June	July	August	Total
2002/03	-	-	-	42	151	159	352
2003/04	-	-	-	34	205.5	126.5	366
2004/05	38	45	23.2	49.4	77.5	143.7	376.8
2005/06	66.5	41	-	48	138	262	555.5

Source: Kilte Awlaelo Woreda Agriculture and Rural Development, 2006/07

Rainfall in the woreda is characterized by high variability in amount and distribution from year to year. The highest amount of rainfall was recorded during the months of July and August. As can be seen from the above table, there was no rainfall between the months of September and February in the years under consideration. This indicates that the late season rain in September and October which is required for crops during their maturity stage is absent in all years except in 2006/07 production year. Lack of rainfall in the critical time for crop development has been contributing to the prevailing low productivity in the woreda.

Kilte Awlaelo woreda has 16 PAs and 60 kushets (villages) of which Negash and Mai-Quiha are the two sample PAs selected for the study purpose. Negash is located at 11 kilometers from Wukro, the woreda town while the distance from Mai-Quiha to Wukro is 23 kilometers. The physical characteristics of the two PAs are summarized in the table below.

Table 3.2: Physical characteristics of Negash and Mai-Quiha

Description	Negash	Mai-Quiha
Average Temperature (^{0}c)	17	23
Average Annual Rainfall (mm)	350-400	350-450
Altitude(masl)	1900-2150	1900-2300
Area Coverage (ha)	5,868	5,240

Source: PA Agricultural Office

As is indicated in the above table the average temperature and rainfall in Mai-Quiha is higher than that of Negash while area coverage of Negash is higher than Mai-Quiha. Agro ecologically both PAs are categorized as Woina-Dega.

3.2 Population

The estimated total population of the woreda in 2005/06 was 116,014 of whom 56,847 are males and 59,167 are females with an average family size of 5 people. The estimated population of Negash and Mai-Quiha was 9,315 and 7,327 respectively. According to the information obtained from Finance and Economic Development Office, the crude population density in Negash and Mai- Quiha is 154 and 136 respectively. The result indicates that there is higher population density in Negash than Mai-Quiha.

3.3. Land Use Pattern

As per the information obtained from the woreda agricultural office, most of the land is non-utilizable for agricultural purpose because it is characterized by mountains and steep slopes.

Table 3.3: Land Use Pattern in Kilte Awlaelo woreda

Land Type	Kilte Awlaelo woreda		Negash		Mai-Quiha	
	Area(ha)	% Share	Area(ha)	% Share	Area(ha)	% Share
Cultivated land	19,183	18.99	1,202.43	20.49	1,002	19.12
Currently non-utilized	21,089.5	20.87	1,008.62	17.19	1,360.75	25.97
Forest Land	11,258.5	11.14	720	12.27	569	10.86
Grazing Land	4,795.75	4.75	574	9.78	73	1.39
Non-Utilizable	44,701.75	44.25	2,362.95	40.27	2235.25	42.66
Total	**101,028**	**100.00**	**5,868**	**100.00**	**5,240**	**100.00**

Source: Kilte Awlaelo Department of Agriculture.

As can be seen from the above table, about 20.87% of the total land in the woreda is available for agricultural purposes. This shows that even though there is land shortage and availability of landless farmers, there is still unutilized land that can be used to increase agricultural production. On the other hand, 44.25% of the total land is not suitable for agricultural purposes. Unsuitability of the majority of the land coupled with the existing population pressure has resulted in low land holding size in the woreda. The average land holding in the woreda is 0.73 hectares and that of Negash and Mai-Quiha is 0.75 hectares which in all cases is above the average land holding size of 0.5 ha in the region.

3.4 Production System

Rain fed agriculture is the major production system and the woreda is dependent on production of crops with the main rainy season (Meher) once a year. The major crops cultivated include barley, wheat, teff, maize, sorghum, pulses, lentil and chick peas. The woreda is also benefited from irrigation crop production although the area cultivated is small when compared to the rain fed farms. Maize beans and barely cover the largest proportion of cultivated crops under irrigation.

As per the data obtained from the woreda agriculture office, total area cultivated for grain crops during 2005/06 production year was 19,311 hectares and total production was 178,430.45 quintals. On the other hand, total area cultivated and total production under irrigation was 340.16 hectares and 8,851.90 quintals respectively. In addition to cereal crops production, HVH crops are also grown in the woreda. The major vegetables cultivated are onion, tomato, pepper, cabbage and beetroot.

Livestock is an important part of the farming system in the woreda and are used as a wealth indicator. The following table shows livestock availability by type of animals.

Table 3.4: Livestock availability in 2005/06

Description	Kilte Awlaelo	Negash	Mai-Quiha
Cattle	59,236	3,570	4,913
Sheep	26,360	7,765	560
Goat	20,058	1,781	1,345
Equines	13,036	837	954
Beehive	9,525	1,797	178
Chicken	42,733	2,805	4160
Total	**170,948**	**18,555**	**12,110**

Source: Woreda Agricultural Office

As can be seen from the above table, farmers in Negash have better performance in sheep rearing and bee hiving while poultry production is higher in Mai-Quiha.

3.5 Engagement in Off-Farm Activities

Off -farm activities are important source of income to supplement household income and farmers in the woreda employ themselves in different activities such as daily labour, petty trading, sale of firewood and charcoal and so on. However, the major off-farm activity that fills the food gap in the woreda in particular and Tigray region in general is participation in food for work activities. Productive Safety Net Program

(PSNP) and other Employment Generation Schemes (EGS) are undertaken as part of the food security package.

According to the woreda Food Security and Disaster Prevention and Preparedness Coordination Office, about 63.31% of the total population in the woreda is beneficiary of safety net program by participating in different community works while 5.5% of the total population is direct beneficiary from the program. The beneficiaries in Negash and Mai-Quiha are 69.91% and 71.15% of the total population in the respective PAs.

3.6 An Overview of Rainwater Harvesting Ponds

Agriculture in the woreda is characterized by small scale subsistence rain-fed farming with low productivity resulted mainly from moisture stress. As a result, majority farmers are unable to meet their food needs which led to high level of food insecurity. In line with the national Food Security Strategy, the regional government of Tigray has designed an Integrated Food Security Programme for Drought Prone Areas (IFSP-DPA) so as to mitigate the problem of food insecurity in the region.

The program focused on 16 highly food insecure vulnerable woredas. According to the program document, 20% of the households in these woredas are found to have food that lasts for less than 1-2 months and

44% of the households have food for 3-4 months. Only 8% of the households have been able to produce food that lasts for more than 7 months (Tigray Regional State, 2000).

Kilte Awlaelo Woreda is one of the chronically food insecure woredas included in the program. The major constraints towards attaining household food security and issues to be addressed through this program include low level of agricultural production, severe environmental degradation, poor health and education service, lack of capital and so on (ibid).

Since one of the major problems of agriculture in the region in general and Kilte Awlaelo Woreda is shortage of rainfall and its erratic distribution which threatens crop production and hence food security of the people, various water harvesting techniques were designed as part of the food security package. Such techniques are construction of household and community rainwater harvesting structures, spring development, extraction of wells, river diversion, and other water augmenting mechanisms.

Construction and utilization of household ponds is widely practiced in order to solve the problems of crop failure and improve household food security. The areas targeted for the construction of these ponds were the

16 highly food insecure woredas in the region. As per the study made by Mills (2004), six other woredas were included in the construction of ponds since the difference between highly vulnerable and vulnerable woredas is small in Tigray.

Construction of ponds started in 2002/03 with the plan of constructing 2000 ponds in each woreda. The following table indicates a summary of rainwater harvesting structures constructed in Kilte Awlaelo woreda.

Table 3.5: Rainwater harvesting structures in Kilte Awlaelo woreda

Description	2002/03	2003/04	2004/05	2005/06	Total
Communal Pond	118	-	-	43	161
Household Pond	1,945	1,252	1,411	411	5,019
Underground Tanker	-	52	637	335	1,024

Source: Woreda Agricultural Office, Natural Resources Department

About 62 % of the total ponds constructed in the study area are operational in which the stored water is used for productive activities. The above table shows that there is a decline in the construction of all structures in 2005/06. Information obtained from experts in the woreda indicate that the plan for 2006/07 fiscal year is to construct 200 household ponds and 900 underground tankers. Though it is more expensive, farmers nowadays prefer to construct underground tankers due to its better water retention capacity if constructed properly and its lower plot requirement.

Even though there are different types of rainwater harvesting structures in the study area, the study focuses on household rainwater harvesting ponds commonly referred as ponds. Out of the 5,019 ponds constructed from 2002/03 to 2005/06 in Kilte Awlaelo woreda, 20.66% are found in Negash and Mai- Quiha. The following table shows a summary of ponds constructed in the two PAs by type of lining.

Table 3.6: Types of ponds in Negash and Mai- Quiha

Types of ponds	Negash	Mai – Quiha	Total
Plastic lined	240	114	354
Clay lined	5	328	33
Cement lined	18	0	18
Excavated only	322	10	332
Total	585	452	1037
Number of operational ponds	379	320	699
% of operational ponds	**64.79**	**70.80**	**67.41**

Source: From respective PAs

Operational ponds which constitute for 67.4% of the total constructed in the two PAs are those ponds which were filled with water and utilized for different purposes during the last rainy season. The remaining 32.59% of the ponds are non- operational. These ponds are either filled with silt due to lack of silt traps or collapsed as a result of technical problems during construction.

As can be seen from the above table, 55% of the total ponds constructed in Negash are excavated only and 41% are plastic lined. Due to the sandy nature of the soil and shortage of clay soil in the area, only 0.8% of the ponds are clay lined. On the other hand, as a result of availability of clay soil, 72.5% of the total ponds in Mai - Quiha are clay lined and 25% are covered with plastic lining.

The pond water is utilized as a supplementary irrigation for HVH crops production and as source of drinking water for livestock and for household needs. In addition, some farmers in the woreda use the stored water as supplementary irrigation for cereal crops production when the rain stops during the maturity stage of the crops so as to mitigate the problem of crop failure and improve agricultural productivity.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Demographic and Socio-Economic Characteristics of Sample Households

The average family size of the sample households is 6.6 out of which 52.6% are males and the remaining 47.4% are females. About 41.6% of the sample population is found to be below the age of 15. The economically active population that ranges within the age group of 15 to 64 is 56.5%.

Table 4.1: Demographic characteristics of sample households

Description	Negash	Mai-Quiha	Total
Proportion of total population by age:			
0-14	38.2	45.9	41.6
15-64	60.1	51.9	56.5
≥ 65	1.7	2.2	1.9
Average family size	7.24	6.00	6.65

Source: Household Survey, April 2007

In traditional agriculture family labour has strong relation with participation in agricultural activities and increasing income through non-farm activities. Households with larger family size have better opportunity of construction of household ponds in the study area. Survey results indicate that the average family size of pond user households is 7.1 while that of the non- users who participated in the study is 5.1. This shows that family labour is one of the determinant factors in the adoption and utilization of labour intensive technologies.

Having larger family labour has also shown a tendency of earning better income from off-farm activities such as petty trading, daily labour and wage labour. About 72% of households that have two and below economically active members earned annual income less than birr 1000 while 17% of them have earned income that ranges from birr 1000 to 2000. On the other hand, annual income for 71% of the households with active age group people more than two ranges between birr 1000 and 2000 while the remaining 16% of them earned below birr 1000.

Regarding the level of education, about 37.9% of the sample population is found to be illiterate and 33.1% of them have reached from grades 1 to 6. Only 5% of the sample has reached grades 11 to 12. The reluctance of farmers towards adoption of new technology could emanate from the low level of education attained which in turn limits their access to information from different sources.

Since crop production is the main occupation of the farmers in the study area, farm size is one of the basic assets that determine the level of production and the general well being of households. Survey results indicate that the average land holding size of the total sample households is 0.84 hectares. The majority of households that accounts for 38.1% of the total sample population have 0.75 hectars of land which is in line with the average land holding of the two PAs. However, there are also farmers who either own 0.25 hectares or are landless at all. Wide variation in land holding has been observed between the two study sites. The average plot size for Negash and Mai- Quiha is 0.66 and 0.94 hectares respectively.

In addition to crop production, livestock rearing is also an important economic activity in the area. It has a multiple purpose of serving as draft power, source of food and income. It also provides manure for crop production and fuel. The average cattle ownership of the survey participants is 4.5 and 4.2 for Negash and Mai- Quiha respectively. When the farmers were asked about the availability of oxen in their household, 54.8% of them responded that the oxen they possess are enough for their farm operation while the remaining 45.2% informed that they use different ways such as oxen sharing, exchanging with labour or hiring from others in order to perform their agricultural activities. The following table depicts the average livestock ownership among the sample households.

Table 4.2: Average livestock ownership of sample households

Type of livestock	Negash	Mai-Quiha
Cattle	4.50	4.15
Sheep	5.6	4.9
Goat	3.4	3.6
Donkey	1.2	1.25
Camel	0	0.3
Chicken	6.5	6.8

Source: Household survey, April 2007

Availability of livestock determines the economic standard of farmers and those without livestock are considered to be poor. According to the local wealth ranking standards, 32.3% are poor and 1.6% are very poor. About 59.8% of the sample households are medium while the remaining 6.3% of them are rich economically. Even though the majority of households are in the middle, the result shows that economic standard has no significant role in adoption of household ponds in the study area.

About 80% of the households included in the survey indicated that they have additional source of income apart from crop and livestock production. Some of these activities are petty trading, daily labour and remittance from family members or relatives abroad. However, 53.2% of the respondents indicated that participation in Food for Work/Safety Net is the main activity that supplements their major occupation.

4.2. General Features of Sample Household Ponds

A total number of 96 operational ponds were surveyed out of which 50 are from Negash and the remaining 46 are located in Mai- Quiha. About 59.8% of the ponds were constructed in 2002/03 while the year of construction for the remaining 28.3% and 12% of the sample ponds is 2003/04 and 2004/05 respectively. Out of the total households included in the survey, 9% of them are female headed. This indicates that due to the labour intensive nature of construction and utilization of ponds women do not participate equal to their male counterparts in adoption of the technology. According to administration officials and DAs, some assistance has started to be given to female headed households and other elderly people who are unable to construct ponds by mobilizing labor in the form of food for work.

As in many parts of Tigray region, all sample ponds are standard trapezoidal shaped that cover 0.0169 hectares of land (13mx13mx3m) with water storage capacity of $182m^3$. The trapezoidal shaped pond is designed and widely implemented as it can easily be constructed by unskilled labor.

Table 4.3: Percentage of sample ponds by type of lining

Types of pond	Negash	Mai - Quiha
Plastic lined	76.00	76.10
Clay lined	2.00	21.70
Cement lined	8.00	0.00
Excavated only	14.00	2.20

Source: Household survey, April 2007

As shown in the above table the majority ponds are constructed with plastic lining in both sites. Most of the farmers prefer to construct the ponds with plastic lining due to the better water retention capacity. However, study results show that the rate of pond construction with plastic linings has shown a declining trend because plastic linings are provided on credit basis starting from 2003/04 and farmers are afraid of taking the risk of being in debt. Moreover, the demand for plastic lined ponds has also decreased due to the susceptibility of the lining to damage which lowers the life span of the ponds.

Although the prime objective of pond construction is to mitigate the problem of crop failure and improve productivity through supplementary irrigation for food crops production, most of the stored water is used for vegetable production. According to the survey results, 45.3% of the respondents use the stored rainwater to supplement vegetable production when the rain stops during the month of September. In addition, the water is also used for domestic purposes, as drinking water for livestock, fruit production and in rare cases as supplementary irrigation for grain production.

Information obtained from the FGD shows that, the stored water from a pond with good water retention capacity can be used till the month of December if managed and utilized properly. However, most farmers use the stored water for the months of September and October. Some of the participants complained that the water lasts only a week as a result of deep percolation of water into the ground particularly in clay lined ponds and those ponds which are only excavated. Results of the survey indicate that 88.4% of the sample households utilize all the harvested water for agricultural and other household needs while 11.6% of the respondents could not use all the stored water due to shortage of labour and lack of lifting tools.

4.3. Ponds and Cereal Crops Production

Small scale subsistence farming is the main economic activity in the study area. Most of the farmers grow almost the same kinds of cereals with limited tendency for diversification. The major crops grown under rain-fed agriculture are barley, wheat, teff and maize. In addition, pulses, sorghum and spices are grown to some extent. The following table shows average grain production of the major cereal crops grown by the sample households under rain-fed agriculture.

Table 4.4: Average annual grain production per household

Type of grain	Average yield obtained(in Quintals)								
	2003/04			2004/05			2005/06		
	Negash	Mai-Quiha	Total	Negash	Mai-Quiha	Total	Negash	Mai-Quiha	Total
Barley	1.41	1.52	1.46	1.35	1.69	1.51	2.01	2.19	2.13
Wheat	1.78	1.78	1.78	1.43	1.76	1.59	2.32	2.78	2.56
Teff	1.13	1.62	1.46	0.98	1.22	1.13	1.70	1.34	1.47
Maize	1.50	1.67	1.60	1.00	1.70	1.32	1.76	1.81	1.79
Total	**5.82**	**6.59**	**6.30**	**4.76**	**6.37**	**5.55**	**7.79**	**8.12**	**7.95**

Source: Household Survey, April 2007

As can be seen from the above table, average grain production is higher in Mai-Quiha due to the larger farm size farmers have when compared to those in Negash. As a result of shortage of rainfall in 2004/05, average grain production has shown a decline and it has improved during 2005/06 production year. According to the discussions held with DAs, the rise in productivity has resulted from the adequate rainfall during that specific year. In addition, the farmers have increased the use of modern inputs such as improved seeds and fertilizers that led to better production.

About 34.1% of the farmers in the survey have indicated their grain production serves for annual household consumption during adequate rainfall. The remaining 31% and 32.5% of them have informed that the production is enough for nine months and six months consumption respectively. On the other hand, 56.7% of the households informed that during inadequate rainfall own production is sufficient only for three months of consumption while 15.6% and 22.7% have revealed that it is enough for nine months and six months consumption respectively.

Study results indicate that there has been subsequent crop failure due to the erratic nature of rainfall distribution. The rain stops during the month of September which is the maturity stage of crops and leads to significant reduction in production or total crop failure. In order to solve the problems related to shortage and poor distribution of rainfall different water harvesting technologies are used in the study area in addition to growing crops that require short maturity period.

Construction of household ponds in line with other projects was undertaken to a large extent in Tigray region in general and the study

area in particular as part of the food security package in order to tackle the prevailing food insecurity in the area mainly emanated from low productivity. Apart from the production of high value vegetables and fruits, the main objective of pond construction was to use the stored water as source of supplementary irrigation for cereal production during the dry months of September and October.

In the study area the majority of the ponds are constructed in order to attain the above objective. Results of the discussion with DAs indicate that there are few farmers who utilize the stored water for supplementary irrigation when the rain stops before the crop matures by using either treadle pump or motor pumps. However, the number of users is insignificant when compared with the total ponds constructed in the study sites. According to the information obtained from the DAs office, only around 1.74% of the total farmers who own ponds in the two PAs utilized the stored water as supplementary irrigation for cereal crops during 2005/06 production year.

Survey results show that only 1.1% of the pond users have used the stored water from their ponds as supplementary irrigation for cereal crops production and the total production in the two sites in three years is 20 quintals.

Table 4.5: Total grain produced using pond water as supplementary water source

Production year	Total grain production(in quintals)		
	Wheat	**Teff**	**Maize**
2003/04	3.00	1.50	1.25
2004/05	3.50	2.50	1.50
2005/06	2.25	2.00	2.50
Total	**8.75**	**6.00**	**5.25**

Source: Household Survey, April 2007

As can be seen from the above table, there is low level of pond utilization for cereal production. There are different reasons for not using the stored water for the above objective. FGD participants stated that they cannot use stored water because grain crops require larger amount of water and it is time taking and tedious to irrigate the plots using buckets to lift water. In addition, most farmers are reluctant to accept the possibility of using stored water to reduce crop failure.

The study results show that one of the main objectives of pond construction to enhance grain productivity is not achieved as a result of inadequate preparation made before design and implementation of the program. Discussions with woreda experts indicate that since the ponds were constructed in quota system, farmers did not participate during the early stage of the project and much effort was not made to create awareness in the farming community which resulted in inefficient utilization of the stored water for the intended use. This indicates that before introduction of any technology, it should be adapted to the social setting of the beneficiary stakeholders.

4.4. Vegetable Production and Marketing

One of the major advantages of ponds is the possibility of adopting high value vegetables and fruits by using the stored water as supplementary irrigation. These crops are additional sources of income and are used for household consumption. Information obtained from farmers indicates that vegetable and fruits production was not widely practiced before introduction of ponds. The technology has enabled them to grow vegetables mainly around their backyard. About 45.3% of the pond users have informed that ponds are used for vegetable and fruits production.

According to the survey results, the HVH crops grown in the study area in general and the sample households in particular include vegetables such as onion, tomato, cabbage, garlic, pepper, spinach, lettuce, potato and beetroot. In addition, spices are also grown by the pond users. The following table indicates the average production of vegetables, and spices by using ponds as supplementary water source.

Table 4.6: Average annual vegetable and spices production of sample households

Type of crop	Average yield obtained(in kilograms)								
	2003/04			2004/05			2005/06		
	Negash	Mai-Quiha	Total	Negash	Mai-Quiha	Total	Negash	Mai-Quiha	Total
Onion	8.75	11.85	9.25	38.9	9.28	28.76	15.67	25.8	21.00
Tomato	22.86	32.00	25.90	50.00	12.6	34.92	47.22	13.00	43.30
Cabbage	41.67	11.33	31.55	37.5	12.00	32.4	58.74	22.17	45.6
Garlic	5.00	13.78	12.18	3.07	11.17	7.93	5.73	22.08	13.91
Pepper	8.48	8.44	8.46	22.50	6.60	19.93	8.55	19.11	11.19
Spinach	3.36	9.0	6.18	10.0	17.6	15.43	9.00	10.4	9.64
Lettuce	2.50	10.00	5.65	1.50	9.00	5.25	3.25	10.00	6.39
Potato	26.33	3.03	13.02	23.5	10.03	15.42	39.4	14.04	22.49
Vegetable sub-total	118.95	99.43	112.19	186.97	88.28	160.04	187.56	136.60	173.52
Spices	5.20	4.45	4.98	6.76	10.33	8.00	12.56	9.45	10.20
Grand Total	**124.15**	**103.88**	**117.17**	**193.73**	**98.61**	**172.21**	**200.12**	**146.05**	**183.72**

Source: Household Survey, April 2007

As can be seen from the above table, the major vegetables grown in Negash are tomato, cabbage and potato. Most farmers prefer to grow these vegetables due to the high demand in the market. In addition, survey results indicate that 54.2% of the respondents prefer to grow the crops due to their better price while 33.3% informed that they prefer the produce for household consumption. On the other hand, farmers in Mai-Quiha prefer to plant garlic, tomato and onion. About 70.6% of the farmers who participated in the survey indicated that they grow the above vegetables because they are preferred for own consumption and 17.6% of them prefer the produce due to their better price in the market. This indicates that farmers in Negash are market oriented when compared to the farmers in Mai-Quiha.

The above table shows that average production of vegetables has decreased in Mai-Quiha during 2004/05 production year. According to the discussions held with DAs the decline was attributed to the shortage of rainfall during the year. When the total average productivity is considered, productivity has increased over the years under consideration. Information obtained from FGD shows that most farmers' awareness about the benefit of the technology has been improving from time to time by seeing some of the farmers who are successful in utilizing the pond water. As per the discussions with the administration officials, incentive is being provided to model farmers who are committed to improve their agricultural production by utilizing the ponds so as to motivate the farmers to increase their efforts in enhancing their productivity and hence improve their food security status.

The perennial crops grown by sample households include guava, papaya, orange and *gesho*. The average fruits production in 2005/06 was 20 kilograms in Negash and 15.35 kilograms in Mai-Quiha. The average income from the above fruits is birr 75 and birr 57 for Negash and Mai-Quiha respectively. The average *gesho* production was 20 kilograms in 2005/06 and most of the survey participants indicated it is only used for household consumption. As per the information obtained from FGD participants, growing *gesho* is considered as one of the major benefits obtained from ponds because its price ranges from birr 7 to birr 9 per kilogram depending on the demand in the market.

When we compare the two PAs based on the result obtained from the study, the average production of HVH is higher in Negash in all years under consideration. One of the main reasons for better performance observed in Negash is the location of the ponds. According to the FGDs, most of the plots farmers have in Negash are near their homestead which makes production of vegetables possible. On the other hand, plots in Mai-Quiha are far from the homestead and most of the ponds are constructed around their plots which led to lower performance in production of HVH crops.

Discussions with DAs indicate that the lower land availability in Negash has also made the farmers utilize the available land more efficiently. Moreover, there is lower ground water potential in Negash which makes the area more water deficit than Mai-Quiha. As a result, farmers in Negash tend to use pond water efficiently. However, there are also farmers in Mai-Quiha who use the stored water for intended uses. Since rainwater harvesting is the only alternative water source in Debre-Birhan which is one of the villages in Mai-Quiha, most farmers in this area utilize the stored water more efficiently when compared to the farmers who live in other villages of the PA.

The difference in the performance of the two sites shows that construction of ponds in quota system in all places is not the best option to solve the problem of water scarcity. An assessment of alternative water sources should have been made before implementation of large scale construction of household ponds which showed to be a source of wastage of resources in some cases. If there is a ground water potential or flowing water in a specific area, alternative water harvesting technology should be developed apart from pond construction which takes the local situation under consideration.

Apart from differences in utilization of ponds for HVH crops production, the two sites have shown variation in marketing of these produces. Most farmers in Negash tend to sell their vegetable production while farmers in Mai-Quiha use most of their produce for household consumption.

Table 4.7: Average income from sale of vegetables in 2005/06

Type of vegetable	Average income(in Birr)	
	Negash	Mai-quiha
Onion	47.01	33.00
Tomato	59.03	16.25
Cabbage	102.80	38.80
Garlic	28.65	50.00
Pepper	32.06	33.75
Spinach	9.00	10.40
Lettuce	2.44	7.50
Potato	68.95	17.57
Average Total	**349.94**	**207.27**

Source: Household survey, April 2007

The above table shows that sample households in Negash have sold large quantity of cabbage which constitutes about 29.38% of the total income earned from vegetables. On the other hand, sale of garlic comprises 24.15 % of the income in Mai-Quiha which has resulted from the better price of garlic in the market. In addition to the sale of vegetables, spices are good source of income for the farmers in both sites. The average income from the sale of spices is birr 376.80 and 236.25 for Negash and Mai-quiha respectively. This is because the price of spice ranges between 25.00 and 30.00 which is far better than the prices of the other produces.

When farmers were asked about the effect of ponds on their income, 64.2% indicated that their household income has slightly improved while 23.2% said it has moderately improved. About 11.6% informed that introduction of ponds has no contribution to their income and the income of the remaining 1.1% of pond users has highly improved due to utilization of pond water for HVH crops production.

The average distance to the nearby market of the PAs is 3.05 and 3.42 kilometers from Negash and Mai-quiha respectively. About 43.2% of the respondents transport their produce by pack animals while 56.8% of them carry the products by themselves. Study results indicate that low price of vegetables in the market is one of the major problems farmers face during marketing of their produce. About 50.7% of the households in the survey informed that low price is one of the main constraints when they sell their product while low demand for vegetables is the major problem for 38.7% of the respondents. The remaining 10.7% have rated lack of transport for their produce as a constraint for marketing. Diversification of crops produced by farmers and increasing the production of those crops that have better market price are some of the alternative ways that can minimize the problem of low price and lack of demand for the produce. Therefore, during construction of any water harvesting structure the issue of marketing of the produce should be given due attention.

Since HVH products are perishable in nature proper storage should be prepared so as to reduce the risk of damage to the produce. Even though there are some storage facilities prepared by cooperatives in other areas of the woreda, no storage facility was arranged for the farmers in the study sites. As per the information obtained from the DAs, since the production of HVH is at its low stage, the farmers did not face problems due to lack of storage facilities. However, lack of storage facilities could be a problem if the farmers started producing in large quantity. In addition, setting up of such kinds of facilities can be an incentive to the local farmers to utilize the pond water efficiently.

Even though there are some problems observed during implementation, introduction of ponds has enabled farmers to grow HVH crops that can be a source of additional income and used for household consumption. Moreover, pond water has improved crop diversification in the study sites. Study result found that the non- pond user households participated in the survey did not grow vegetables with rain-fed agriculture. As a result, the level of crop diversification is lower for households that did not adopt ponds.

4.5. The Role of Ponds in Enhancing Household Food Security

The main objective behind construction of ponds and other water harvesting structures so as to mitigate the problem of crop failure and increase agricultural productivity is to reduce the prevailing food insecurity in the study area .Even though household ponds did not fully attain the prime objective of water storage as supplementary irrigation for crop production, the results of the study show that rainwater stored in ponds has indirect benefit towards enhancing household food security through production and sale of HVH crops.

According to the survey results, 93.6% of the respondents informed that using stored water from ponds have improved food availability in the household. The increment in food availability has resulted from the increase in household income from sale of HVH crops. Having additional source of income enables farmers to improve their purchasing power which is one of the major reasons for the existing food insecurity in the region in general. If the purchasing power is increased, the farmers will have access to purchase additional food or other demands of the household.

Using ponds as supplementary irrigation has improved the number of meals eaten by the farmers. Study results showed that 10.4 % of the respondents used to eat once a day before introduction of ponds while 72.9% and 16.7% of the respondents used to eat twice and three times per day respectively. However, 42.7% and 57.3% of the farmers have started eating twice and three times a day respectively after the intervention.

Non pond user participants of the FGD informed that they spend an average of birr 40.00 to 50.00 per month on vegetables. The pond users can buy grain or other food complements with the money that could have been spent on vegetables which in turn increases the households' access to food that is one of the major determinants of attaining household food security.

The contribution of HVH crops production to household food security is not only through generating income to purchase other food items but can also diversify the diet composition and improve nutritional status of the pond users. Since the farmers in the study area use part of their produce for household consumption, the variety of food consumed by the sample households has improved due to the utilization of pond water for vegetable production. About 88.5% of pond users have informed that the variety of food available for consumption has improved after introduction of ponds. According to the qualitative findings of the study, their eating habit has improved as vegetables are most of the time part of their diet apart from the most commonly used food supplement in the study area.

Based on the information obtained from discussions with DAs, farmers are expected to have an alternative water source in order to be part of the food security package. As a result, owning ponds enables the farmers to be part of the package. Once the farmers are registered they can borrow money to buy production assets they lack in their household or engage in livestock fattening, dairy production or beehiving which can improve their economic status and hence enhance food security in the household. Although there is an improvement in the food security status of the farmers, when asked of their perception about their food security situation 65.3% of them informed that they are still food insecure.

4.6. Other Benefits Obtained from Ponds

In addition to the positive impacts shown in production of HVH crops and its contribution towards reducing household food insecurity, farmers who own ponds have gained other benefits in the study area. FGD participants stated that growing vegetables has reduced the burden of buying learning materials to their children because most of the students sell vegetables whenever they needed money for school expenses.

Most of the farmers in the study area travel long distance from their homesteads to water their livestock and fetch water for their household needs. As per the survey results, the average time taken by the sample households to reach the water source is 45 minutes in Negash and 51 minutes in Mai-Quiha. Information obtained from the study reveals that the condition is improved to some extent due to introduction of ponds.

Discussion results reveal that most farmers use pond water for livestock watering and household consumption for at least an average of two months after the ponds are filled with water. Moreover, there are some farmers in the study area who use the stored water for livestock fattening and bee hiving as part of the integrated food security package.

Availability of water around the homestead saves time of water fetching for women and they can participate in more productive activities. Most survey participants who constructed their ponds near their homestead showed that their hygiene and sanitation of the household members has improved due to availability of pond water.

According to the discussions with the DAs, ponds are also useful in protecting soil erosion. When rainwater is collected from different catchments, the soil that could have been washed away by the runoff is stored in the silt trap and put back to plots by the farmers during the time of desilting after cleaning the silt trap. This helps to improve the fertility of land and hence improve agricultural productivity. Moreover, water collected in clay lined ponds or only excavated ponds recharges the ground water potential.

4.7. Major Issues Related to Construction and Utilization of Ponds

In Tigray reigion in general and the study area in particular large scale construction of household ponds has been undertaken starting from 2002/03. The goal of the regional government was to construct 500,000 ponds in five years. Due to the ambitious plan and urgent nature of the program, there was no pilot construction that can show the problems that can be faced during implementation. As a result, farmers in the study area have faced problems during construction of ponds and utilization of the stored water. The constraints have emanated from poor design, high labour demand of ponds, lack of skilled experts and training, shortage of construction materials and so on. The major issues observed related to construction and utilization of ponds in the study area are discussed below.

4.7.1. Site Selection and Training

Detailed design and technical specification for pond construction was prepared by REST and TWRDB in collaboration with the regional Bureau of Agriculture and Rural Development. The manual served as a base for training and implementation of the program. A training of trainers was given to Woreda experts for ten days. Foremen were recruited to undertake the implementation at village level and the woreda experts provided training to the foremen and DAs. However, there was short time before implementation of the program and the foremen and DAs did not get enough training that can enable them to undertake the construction as per the technical specification.

Site selection is mostly made by the foremen and sometimes by DAs in collaboration with the beneficiary farmers. Sometimes the farmers are reluctant to accept the advice given by foremen where to locate the ponds and the foremen lack experience to convince the farmers about the proper location of the pond which results in construction of pond that cannot collect enough runoff. Wrong site selection also results from lack of skill and experience of the foremen and DAs in construction of ponds. About 25.9% of the survey participants informed that wrong site selection is one of the problems they faced during construction that led to low water storage capacity of ponds. As per the information obtained from the discussions with DAs, apart from the wrong site selection, lack of commitment by farmers to prepare canal for the runoff is also one of the problems that results in poor water storage in ponds.

Location of ponds has many implications in the utilization of the stored water. Since most of the farmers do not use the pond as supplementary water source for cereal production, the ponds could serve better in HVH crops production, livestock watering and as source of water for household needs if located around homesteads. FGD participants in

Negash indicated that one of the main sources of success of ponds in their PA is due to the location of ponds near their homesteads.

Shortage of training given to farmers is another problem observed in the study area. About 54.2% of the respondents informed that they were given training on the construction of ponds while the remaining 45.8% were not given any kind of training when they constructed their ponds. Most farmers do not construct the ponds as per the instruction given by DAs and foremen. As a result, ponds are constructed without a silt trap which reduces the storage capacity of ponds (plate 4.1). In other cases even though silt traps are constructed, regular desilting and maintenance is required by the users in order to protect the ponds from being filled with silt and maintain the water retention capacity of the ponds.

Plate 4.1: Plastic lined pond constructed without a silt trap (Negash)

Due to the low awareness provision to the stakeholders, there is a tendency of viewing construction of ponds as an end by itself while it should be considered as a means of enhancing agricultural productivity by utilizing the stored water. As a result, there is lack of commitment from the field foremen, DAs and administration officials to guide and follow up the farmers during construction and utilization of ponds.

4.7.2 Technical Aspect and Implementation

Problems related with poor implementation of pond construction occur in all types of ponds that are clay lined, cement lined or plastic lined. When a pond is constructed using cement lining, the ratio of cement to sand is 3 to 1. However, due to lack of awareness of the side effects and with the intention of getting immediate benefit, some farmers exchange the ratio and use one- third cement and two- third sand so as to minimize the cost of construction and use the remaining cement for other purposes. This indicates that there is no proper follow up during implementation by the responsible experts. Moreover, most farmers tend to use less quality sand from the surrounding which is free of charge because they cannot afford to buy better quality sand.

After the construction is completed the cement lined pond should be watered for seven consecutive days which is most of the time not implemented by the beneficiary farmers. Participants of the FGD informed that some farmers do not water the pond due to shortage of water they face during construction of ponds. The above problems combined with lack of skill in construction make the ponds susceptible to crack which in turn leads to seepage.

The major problem of plastic lined ponds is puncture of the plastic lining due to many reasons. Wild animals get into the pond in search of water and tear the plastic with their nails when they try to get out of it. According to the information obtained from FGD participants, farmers were told to cover the plastic lining with flat stones so as to avoid the risk of damage to the plastic lining. However, the stones created more puncture when stepped by livestock when they drink water and by humans during water lifting. This has resulted from lack of caution during selection of flat stones and covering of the plastic with the stones.

Drowning of livestock and people is another problem observed in the study area. Due to the slippery nature of plastic linings that are not covered with flat stones, people and livestock are unable to get out of the pond. Even though major damage has not occurred in the two PAs, farmers have a fear that their children might drown. According to the FGD participants, two brothers have died in the woreda. Some farmers prefer to construct the ponds away from their homestead in order to minimize the risk to people and livestock.

The risk of drowning has resulted from lack of coverage of all the ponds and lack of fences in most of the ponds. Shortage of money to buy fencing materials is their major reason not to fence the ponds. FGD participants informed that they have been trying to get permission for cutting trees so as to fence their ponds but were not allowed by the DAs and administration officials for environmental protection purposes. The DAs in turn advise the farmers to use stones as fencing material. In addition, fodder plants could also be planted around the pond that can serve double purpose of using as source of animal feed and fence to the ponds. However, many farmers are not committed during implementation because most of them are not convinced during the first stages of construction and have constructed the ponds to fulfill the quota of ponds to be constructed in the area. It has been observed that the farmers prefer to work at safety net programs because it is source of food for their immediate requirements.

However, some properly constructed plastic lined ponds covered with flat stones were observed during the study. Since stairs are constructed with stones, the ponds are suitable for water lifting and minimize the risk to human lives and livestock.

Plate 4.2: Stone covered plastic lined pond with stairs (Mai-Quiha)

Clay lined ponds are preferred to plastic lined ponds and cement lined ponds due to their longer life span and lower cost of construction with locally available materials. However, construction of these ponds is highly labour intensive because the clay soil should be properly compacted in order to maintain the water retention capacity of ponds and some of the ponds are found to be poorly compacted which resulted in seepage which led to low storage capacity of ponds.

4.7.3 Labour Availability

Construction and utilization of ponds is highly labour intensive activity. Availability of labour affects vegetable production especially when the timing coincides with other farming activities related to cereal production. According to Mills (2004), farmers with labour constraints would not plant vegetable until late July when they have available spare labour.

High labour demand nature of the technology and labour shortage is one of the major challenges observed in the study area. About 51.7% of the respondents informed that shortage of labour is one of the main problems they faced during pond construction. When the stored water is used for agricultural purposes or other household needs, buckets are mostly used to lift the water which makes utilizing ponds inefficient with labour shortage. The survey results show that 40.6% of the total pond users have rated labour demand of the technology as a high problem while 26% and 12.5% of them have considered it as medium and low problem respectively. For the remaining 20.9% of the respondents high labour demand of the technology is not a problem in their households.

Survey and FGD results from the non pond users indicate that labour shortage is one of the constraining factors for not adopting RWH ponds. The results indicate that alternative mitigating measures should be taken when implementing labor intensive technologies particularly to the households that have labour shortage.

4.7.4 Material Availability

One of the advantages of pond construction is the availability of raw materials at local level except for plastic lining and cement which can be obtained from agricultural offices. The type of pond to be constructed is decided based on the nature of the soil in the area and availability of materials. In areas where clay soil is available, clay lined pond is preferable due to its durability and lower cost of construction. When the soil is sandy, plastic or cement lined pond is constructed so as to minimize the risk of deep percolation.

Once the type of pond to be constructed is decided, cement or plastic lining can be obtained from the administration office or ordered from the woreda agricultural office through the PA administration officials or DAs. However, FGD participants informed that these materials are sometimes delayed or totally unavailable at woreda level when request is made by the farmers. Accordingly, lots of the dug only ponds available in the area are not finished partly due to shortage of materials.

About 58.3% of pond users in the survey consider shortage of plastic lining as one of the major problems observed in the study area. Discussions with DAs and woreda experts reveal that there is long and delayed procedure in purchasing and transporting of these materials to the respective PAs. Some unfinished ponds and underground tankers were observed during the study time because of cement shortage (plate 4.3).

Plate 4.3: Unfinished pond due to lack of cement (Mai-Quiha)

Even though the DAs and administration officials have indicated that there is shortage of supply of the materials, some damaged plastic linings were found in the administration office as a result of lack of proper management. The plastic linings were stored outside the office for a long time and damaged due to wind and radiation. Moreover, some of them are eaten by wild rats (plate 4.3).

Plate 4.4: Lack of proper storage damaged the plastic linings

Most of the households have also faced shortage of other construction materials such as sand which can be found in their area. Information obtained from the FGD shows that the sand soil found in most areas free of charge is of low quality and they cannot afford to buy the ones with better quality. About 72.9% of the households have indicated that shortage of construction materials is one of the major problems observed during pond construction. As a result, low quality ponds are constructed which either can collapse or crack.

Lack of lifting tools is another problem observed in the study area that led to inefficient utilization of the pond water. Survey results indicated that 96.7% of the participants use buckets to lift water. The alternative lifting mechanism is using treadle pump which is available on group credit basis. However, farmers tend to averse the risk of taking additional credit because most of them are already users of credit services under the food security package. On the other hand, farmers can also rent motor pumps from other farmers at the rate of 30 birr per day. Some FGD participants informed that they rent motor pumps to irrigate their vegetable but most farmers stick to using buckets due to lack of purchasing power.

4.7.5. Health Issues

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. Water stored can be a place for malaria breeding and use of water from uncovered ponds can lead to waterborne diseases. Since the stored water is not used for drinking purposes, no waterborne disease was witnessed in the study area. Moreover, the ponds are not a threat to malaria infestation as the area is not malarious.

Other studies made in Tigray and other regions found that there is a positive correlation between malaria and pond ownership. According to Mills, in the lowland areas of Alamata and Raya Azebo ponds were found to be a place for mosquito breeding and the administrations sprayed the ponds with oil. Moreover, mosquito nets were distributed to the nearby households so as to protect the people from malaria (Mills, 2004).

The different results show that health issues received no attention during the initial designing of the program which could cost peoples' lives. As a result, proper measures should be taken to overcome the problem of malaria incidents in the areas where the disease is a threat and precaution should be made to avoid the possibility of occurrence of the disease in the already constructed ponds.

4.7.6. Construction Cost

During the early stage of implementation of the program in 2002/03 some chosen farmers were provided with all the construction inputs including labour through food for work, plastic lining and cement. These farmers did not incur any cost except for their own labour. Starting from 2003/04 farmers were told that they have to cover the cost of cement and plastic lining and were still provided with the labour force. Starting from 2004/05 the government stopped providing any construction input.

Most of the inputs used for construction of ponds are obtained free of charge. All the farmers use family labour and collect the other inputs such as stones, sand and clay from their homesteads or any place where they can be found nearby. The only inputs that can be obtained with payment in the study area are plastic lining and cement.

Since the cost of cement and plastic lining is unaffordable to farmers, the government subsidizes the cost significantly. The initial cost of plastic lining was birr 1,500 and the government subsidizes 70% of the cost. The beneficiary farmers cover birr 600 which is 30% of the total cost. The plastic lining is provided on credit basis to be paid in four years and birr 30 service fee is paid by the farmers to cooperatives when they are supplied with the plastic lining.

The cement required to construct 0.0169 hectares trapezoidal shaped pond is 17.5 quintals. The cost covered by the farmers and subsidized by the government is the same as the plastic lining. The amount paid to the cooperatives is 5% of the amount of the cost of cement covered by the farmers. However, the price of the cement is not fixed as that of the plastic as it depends on the price available in the market. At present cement is not provided to farmers due to its high market price. FGD participants who constructed cement lined pond in 2004/05 informed that the cost to be covered by farmers was birr 24 per quintal which comes to birr 420 and they paid birr 21 for cooperatives.

The average life span of ponds is estimated to be ten years and the annual cost of plastic lined pond construction is birr 63.00 if major damage has not occurred to the pond which might need additional cost. Till the time the survey was undertaken, no farmer has started paying the debt of the materials they obtained and they do not know when they are supposed to pay. This might create inconvenience to farmers if they are required to repay the debt once at the end of the fourth year. Therefore, a mechanism should be designed to collect the money on annual basis which can reduce the burden to the beneficiary farmers and can be an incentive to those who did not adopt the ponds.

High cost of construction is considered by the users as one of the major constraints of pond construction. About 70.5% of survey participants indicated that cost of construction is high problem while 23.2% of them considered it as a medium problem. The remaining 6.4% did not consider cost of construction as a problem at all.

According to TWRDB/REST design manual, when all inputs are taken into account, total cost for plastic lined pond covered with stones is about birr 8098.00 and those not covered with stones cost birr 6131. On the other hand, clay lined pond costs birr 5753 which is not affordable to farmers.

In order to minimize the cost of construction, most farmers use low quality construction inputs which adversely affects the quality of ponds. This shows that the program did not take the purchasing power of farmers into consideration.

4.8. Perception of Farmers Towards Ponds

Participation of stakeholders during initial stages of design and implementation is one of the major factors that determine the success of new technology adoption. The study shows that when the program was implemented, the beneficiary farmers were attending meetings with administration officials and experts so as to get information about the technology with low participation of the farmers. 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.

According to administration officials and DAs, when the program was initially implemented in 2002/03, the government provided construction materials including plastic lining free of charge in a form of incentive and motivated farmers to construct ponds. However, the provision of the lining stopped in 2003/04 and the farmers were informed they will pay 30% of the cost in the future.

In order to reduce the reluctance of farmers and gain acceptance to the technology, labour force was provided in construction of the ponds in 2002/03 and 2003/04 by mobilizing farmers in the form of food for work by paying food grains. During those years 20 quintals of wheat used to be provided as remuneration upon completion of one pond to the farmers who participated during construction including the owner of the pond. Even though there were few farmers who constructed ponds to use the stored water for productive purposes, most of the farmers became willing to construct the ponds so as to get the remuneration of food grain. The provision of incentive in the form of labour mobilization and food grain was stopped starting from 2004/05 and farmers are supposed to use their own labour for construction. This resulted in a considerable decline of the rate of pond adoption in the study area. For example, a plan was made to construct 200 ponds in the woreda during the 2006/07 fiscal year. However, construction of a single pond was not completed till the time the research was conducted in April 2007.

Though most farmers were not convinced about the benefits that can be obtained from utilizing ponds as supplementary water source for agricultural activities, awareness is now improved as there are some committed farmers whose efforts in using pond water has brought change in their living standard. In addition, the government is trying to motivate the farmers to utilize ponds by providing incentive to the model farmers which created acceptance of the technology. Most farmers accept the technology because they are convinced about its benefits in mitigating the problem of water scarcity while some of them are willing to use the stored water for the production of HVH crops so as to get the incentive provided to the farmers who utilize ponds for productive purposes.

Farmers who own ponds were asked about their perception about the success of the program. Survey results show that 52% of the participants have rated construction of ponds as moderately successful while 38% of them rated it as successful. The remaining 10% of the surveyed households have rated ponds as failed water harvesting structure in the study area.

Non-users of ponds have participated in the survey and FGD in order to know their perception about the technology and their reason not to construct ponds. FGD participants have informed that the main constraint for adoption of ponds is labour shortage in their family. As per the results of the survey, 6.7% of the participants do not need ponds because they have enough water supply.

Labour shortage is one of the main reasons for not adopting ponds for 44.3% of the non users participated in the survey while 40.3% of them have land shortages. The remaining 8.7% have stated that high cost of pond construction is the major constraint for adopting ponds. In addition, location of the plot from their homestead was indicated as one of the limiting factors in construction of ponds.

All the farmers who participated in the FGD are aware of the benefits that can be obtained from utilization of ponds. However, as per the information obtained from various discussions, there are still farmers who can afford to construct ponds but are reluctant because they are not convinced about the benefits that can be obtained from the small scale RWH schemes.

When the non users were asked about their economic status compared to the users, 54.8% indicated that the users are economically better off due to the income they obtain from the sale of HVH crops while 45.2% stated that there is no difference in the well being of users of the technology with non users due to low water storage capacity of ponds.

About 80.6% of the non- user households are interested to construct ponds if they get financial and labour support while the remaining 19.4% of them prefer to construct underground tankers which requires smaller space .This indicates that grass roots level participation is crucial before introducing any type of technology in order to explore the constraints at the local level and adapt the technology accordingly which in turn is one of the key factors to the success of any development endeavour.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

Agriculture in Tigray is characterized by small scale subsistence rain-fed farming with low productivity resulted mainly from moisture stress which led to high level of household food insecurity. In line with the national food security strategy, the regional government has designed an integrated food security program for drought prone areas (IFSP-DPA) that focused on 16 highly food insecure vulnerable woredas.

Kilte Awlaelo woreda is one of the chronically food insecure woredas included in the program. Different techniques of water harvesting have been designed and adopted to improve agricultural productivity and reduce food insecurity. Due to the local availability of construction materials, relatively low cost of construction and simplicity of the design to construct by unskilled labour; large scale construction of household ponds was given high priority. As a result, 5,019 ponds were constructed during 2002/03 to 2005/06.The purpose of the study is to assess the benefits and challenges of household ponds in selected kebles of the woreda. The major results of the study are summarized as follows.

Adoption of ponds has enabled farmers to grow HVH crops by using the stored water as supplementary irrigation. These crops are additional sources of income and are used for household consumption. The main crops grown are vegetables, fruits, *gesho* and spices. Before introduction of the technology most farmers used to grow cereal crops and growing of HVH crops was not widely practiced. Even though the major crops grown are still cereal crops, farmers are able to diversify their crop production by growing HVH crops.

The study revealed that utilizing the stored water for HVH crops production has increased food availability in the households. Income obtained from sale of these crops has enabled to enhance the purchasing power of farmers which can improve the households' access to food and improve their food security status. The contribution of HVH crops production in enhancing household food security is not only through generation of income to purchase other food items but also through diversifying the diet composition of households which improved the nutritional status of pond users.

One of the major objectives of pond construction is to use the stored water as supplementary irrigation for grain crops production and mitigate the problem of crop failure. However, the study results indicate that only few farmers have used the pond as supplementary water source for cereal crops production when the rain stops during the critical crop maturity period. Most farmers are reluctant to accept the possibility of using the stored water to reduce crop failure. Furthermore, it is time taking and tedious to irrigate the plots due to high water requirement of the crops.

Apart from agricultural production, pond water is also used as drinking water for livestock and for domestic purposes which has to some extent minimized the burden of water fetching and livestock watering. Moreover, rainwater storage in ponds is useful in reducing soil erosion and recharging ground water potential.

Even though adoption of ponds has brought improvements in agricultural productivity, income and household food security; its implementation has faced many problems. The main problems are related to low attention given to adaptation of the technology to the local situation, poor design, wrong site selection, lack of training to DAs and field foremen, lack of awareness creation to the beneficiary farmers, high labour demand, shortage of supply of construction of materials, high cost of construction, and so on.

Based on the results of the study, the following issues are suggested for future consideration to improve the performance of rainwater harvesting technologies.

- The design of the pond should be revised in order to mitigate the problems faced during adoption of the technology
- Coordination and participation of beneficiary farmers and other stakeholders is important during planning and implementation stages of the program

- The capacity of woreda and PA level experts should be improved through training so as to provide the farmers proper technical assistance which can improve the quality of ponds
- An assessment of alternative water sources should be undertaken before construction of ponds and rainwater harvesting should be an integrated part of other water harvesting schemes. In addition, socio- economic situation of the local community should be given due consideration
- Users of the technology should be trained during adoption of the structure. Moreover, farmers should be supervised how to utilize the stored water for enhanced productivity and income
- Adoption of any technology should be started on pilot basis and it can be extended if the intended benefits are obtained from the pilot structures. Furthermore, solutions can be sought for the problems that might be faced during adoption of the technology without incurring significant cost

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Annex I
Questionnaire prepared for RWH pond users

I. Household Characteristics

1.1 Indicate the household size 1= Male____ 2= Female____ 3=Total______

1.2 Fill the following household characteristics

No	Name of family members	Relationship to the respondent(1)	Sex(2)	Age	Marital status(3)	Educat -ion(4)

Code(1)	Code(2)	Code(3)	Code(4)
1=husband	1=male	1=never married	1=illiterate
2=wife	2=female	2=currently married	2=read & write
3=daughter		3=widowed	3=1-6 grade
4=son		4=divorced	4=7-8 grade
5=mother		5=separated	5=9-10 grade
6=father			6=11-12 grade
7=grandson			7=others (specify)
8=granddaughter			
9=others (specify)			

1.3 Who is the main economic provider for the household? (Put in order of importance) 1=husband____ 2=wife_____ 3=son or daughter____ 4=relatives in the household___ 5=relatives somewhere else_____ 6=others (specify)_________

1.4 What are the wealth indicators in the community? (indicate as many as possible)

1=Livestock 2= Mule and donkey 3=corrugated iron roofed house

3=Radio 4=sending children to school 5=others (specify)_______

1.5 Wealth ranking of the household according to local standards

1=rich 2=medium 3=poor 4=very poor 5=others (specify)_______

II. Household Resources and Means of Livelihood

2.1 Total Land size _________(you can use hectare or local measurement)

2.2 Land under cultivation______________

2.3 Fallow land ____________

2.4 Grazing land ___________

2.5 How do you evaluate the condition of rainfall of the area for crop production?

1=excess 2=sufficient 3=insufficient 4=very low

2.6 Is there any record of crop failure in the area due to shortage of rainfall?

1=yes 2=no

2.7 If yes, indicate the year/s__________

2.8 What kind of crops do you produce? (put in order of importance)

1=teff____ 2=wheat____ 3=Sorghum___ 4=Barley____

5=pulses____ 6=Potato____ 7=Onion___ 8=Tomato___

9=Pepper____ 10=Cabbage 11=Others(specify)_______

2.9 What is the major occupation of the household?

1=crop production 2=mixed farming 3=livestock production

4=others (specify)_______________

2.10 Do you have additional income that supplements your major occupation?

1=yes 2=no

2.11 If yes, state in order of their importance

1=sale of crop production_ 2=sale of vegetables 3=sale of livestock___ 4=sale of livestock products___ 5=earnings from daily laboring___ 6=petty trading____ 7=sale of local drinks____ 8=sale of honey____ 9=sale of chicken and eggs____ 10=sales of pottery____ 11=sale of fuel wood and charcoal______ 12=remittance/gift____ 13=others (specify) ________

2.12 How is your agricultural production in times of adequate rainfall?

1=excess for annual household consumption 2=sufficient for annual household consumption 3= sufficient for nine months consumption 4=sufficient for six months consumption 5= sufficient for three months consumption

6=others (specify)_________

2.13. How is your agricultural production in times of inadequate rainfall?

1=sufficient for annual household consumption 2= sufficient for nine months consumption 3=sufficient for six months consumption 4= sufficient for three months consumption 5=others(specify)___________

2.14 Have you ever faced food shortage? 1=yes 2=no

2.15 If yes, indicate the year/s___________________

2.16 If yes to question 2.14, what was the reason? 1=land shortage 2=oxen shortage 3=labor shortage 4=poor land productivity 5= shortage of manure & fertilizer 6=erratic rainfall pattern 7=others (specify) ______________________________

2.17 What did you do to cope with the problem of food shortage?

1=rent farm land 2=borrow money 3=borrow cereals 4=assets sale 5=engage in daily laboring 6=engage in food for word/safety net

7=others (specify) ____________________________

2.18 Which crops are the major sources of food (staple food) for your household?

1=teff 2=wheat 3=barely 4=sorghum 5=maize 6=others(specify)_____

2.19 Indicate the average number of meals per day in your household? _________

2.20 Annual Grain production

Crop Item	Rain fed						Water from ponds used as supplementary					
	Area cultivated			Total Production			Area Cultivated			Total production(quintal)		
	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998
Wheat												
Maize												
Sorghum												
Teff												
Barley												
Pulses												
Oilseeds												
Millet												
Oats												
Spices												
Others												
Total												

2.20 Annual Grain production

Crop Item	Rain fed						Water from ponds used as supplementary					
	Area cultivated			Total Production			Area Cultivated			Total production(quintal)		
	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998
Wheat												
Maize												
Sorghum												
Teff												
Barley												
Pulses												
Oilseeds												
Millet												
Oats												
Spices												
Others												
Total												

2.21 Annual income from vegetable, fruits and *Gesho* production

Crop Item	Using Rainwater Harvesting Ponds						Rain fed					
	Total production(in Kg)			Total Income (in birr)			Total production			Total Income(in birr)		
	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998
Onion												
Tomato												
Potato												
Pepper												
Cabbage												
Garlic												
Lettuce												
Spinach												
Beetroot												
Orange												
Mango												
Papaya												
Guava												
Banana												
Gesho												
Others												
Total												

2.22 Annual income from Non- Agricultural Sources in 1998

Item	Annual Income
Petty trading	
Pottery	
Sale of local beverages	
Sale of firewood/charcoal	
Assistance from relatives	
Food for work/safety net	
Wage labour	
Oxen hired	
Others	
Sub-total	

2.23 Do you own livestock at present? 1=yes 2=no

2.24 If yes, indicate the type and number

		Number
Cattle	Oxen	
	Cows	
	Heifers	
	Bulls	
	Calves	
Sub Total		
Sheep and Goat	Sheep	
	Goat	
Sub total		
Equines	Horses	
	Mules	
	Donkeys	
Sub total		
Grand total		

2.25. How many chicken do you own?__________________

2.26. What are the sources of your animal feed? (indicate as many as possible)

1=communal grazing 2=around the backyard 3=own grazing land 4=crop residue 5=weeding plant 6=fodder plant 7=hay 8=others(specify)______

2.27 Do you face shortage of animal feed? 1=yes 2=no

2.28 If yes. what do you do to cope with the problem? 1=limit the number of livestock 2=purchase additional fodder from other sources 3=use cactus 4=others (specify) ______

2.29 Are the oxen you possess enough for your farm operation? 1=yes 2=no

2.30 If no. means to get additional oxen 1=exchange with labor 2=hire 3=oxen sharing 4=others (specify) ____________

III Issues Related to Rainwater Harvesting Technology

3.1 Do you have your own rainwater harvesting pond? 1=yes 2=no

3.2 When was the structure constructed? ____________

3.3. What is the base of the pond? 1=cement lining 2=plastic lining (geomembrane) 3=clay lining 4=excavated only 5=others(specify)______________

3.4 who introduced the technology to you?

1=Development Agents 2=Neighbors 3=Researchers 4=Extension Agents 5=Non government organizations 6=others(specify)______________

3.5 For what purpose are you using rainwater harvesting structures? (indicate as many as possible)

1=Domestic water supply 2=livestock watering 3=vegetable production 4=fruit production 5=grain crops production 6=others (specify)________

3.6 Do you have any specialized training on rainwater harvesting technology? 1=yes 2=no

3.7 If yes, who provide you the training? 1=Development Agents 2=Neighbors 3=Extension Agents 4=others (specify)___________

3.8 Is the pond constructed with your full consent? 1=yes 2=no

3.9 Did you participate during construction of the pond? 1=yes 2=no

3.10 If yes, in what way did you participate?

1=simply attending discussion/meetings 2=attending meetings and actively expressing feelings, ideas, views etc- 3 acting as an informant 4=site selection 5=others (specify) ______________________

3.11. What contribution did you make during pond construction?(indicate as many as possible) 1=labor 2=material 3=money 4=others(specify)__________

3.12. How many hectares of your land is used for pond construction? ______________

3.13. How do you evaluate the land used for pond with the remaining land you have? 1=most fertile 2=less fertile 3=no difference 4=others(specify)_____

3.14. Do you use all the harvested rainwater? 1=yes 2=no

3.15. If yes, is the stored water enough for your household and agricultural needs? 1=yes 2=no

3.16. If no to question 3.11, what is the reason? (indicate as many as possible) 1=shortage of water 2=poor water quality 3=risky 4=labor shortage 5=others (specify___________

3.17 What mechanism do you use to lift water? 1=treadle pump 2=buckets 3=motor pump 4=others(specify)____________

3.18 What type of crops do you grow by using the stored water? (indicate as many as possible)

1=wheat 2=barely 3=teff 4=sorghum 5=onions 6=tomato 7=cabbage 8=garlic 9=pepper 10=spices 11=others (specify)_______

3.19 Why do you prefer to grow such produce?

1=better price 2=good production 3=preferred for own consumption 4=high disease resistance 5=needs short time 6=others (specify) _________

3.20 Which of the produce have you adopted through the use of rainwater harvesting structures? 1=wheat 2=barely 3=teff 4=sorghum 5=spices 6=onions 7=tomato 8=cabbage 9=garlic 10=pepper 11=others (specify)_____

3.21 If there are any new produce adopted with ponds, why do you choose them?

1=household demand 2=requires less labor 3=appropriate for the climate 4=easy to apply the stored water 5=others (specify) _________

3.22. Are there any problems during construction of rainwater harvesting structures? 1=yes 2=no

3.23. If yes, what are the problems? 1=wrong site selection 2=shortage of labor 3=shortage of plastic lining 4=others(specify)_________

3.24 Are there any problems during use of the stored rainwater? 1=yes 2=no

3.25 If yes, what are the problems? (rank them in order of importance)

1=poor water quality___ 2=lack of operational skill/training____ 3=poor maintenance___ 4=lack of lifting tools___ 5=high disease prevalence_____ 6=drowning___ 7=seepage____ 8=labor shortage___9=others(specify)_______

3.26. Have rainwater harvesting ponds brought any significant change in relation to fodder availability? 1=yes 2=no

3.27 If no, what is the reason? 1=poor water quality 2=insufficient water 3=inefficient management 4=others (specify)_______________

3.28 How has your household income changed due to the use or rainwater harvesting structures? 1=slightly improved 2=moderately improved 3=highly improved 4=slightly decreased 5=highly decreased 6=no change 7=others(specify)_____

3.29 How many hours did you use to travel to fetch water for household uses and for livestock before introducing ponds?_____

3.30 Do you still travel to fetch water for household uses and livestock? 1=yes 2=no

3.31 What positive impacts of rainwater harvesting ponds have you observed? (rank in order of importance)

1=increase in number of meals eaten per day

2=improve in the type and variety of food eaten

3=increase in the amount of money spent on education, health, clothing, housing,etc

4=improve in the ability to cope with drought

5=increase in agricultural productivity

6=increase in income

7=diversification of crops grown

8=better hygiene and sanitation

9=short distance traveled for water

10=improve the availability of animal feed

11= others (specify) ______________

3.32 Rank the following problems related to rainwater harvesting ponds

Indicators	Extent of the problem high=1 Medium=2 low=3 4=not a problem
High cost of construction	
Low water stored	
Drowning of livestock	
Shortage of land	
Demand labor	
Malaria infestation	
Management difficulty	
Lack of market for the produce	
Low price for the produce	
Shortage of finance	
Shortage of plastic lining	
Shortage of construction materials	
Seepage	
Others(specify)	

3.33 How do you rate rainwater harvesting ponds? 1=successful 2= moderately successful 3=failed scheme 4=can't say

IV. Issues related to food security

4.1 How many months per year do you use to consume from your own production before introducing rainwater harvesting technology?_______________

4.2 How many months per year do you consume from your own production after introducing rainwater harvesting technology?_______________

4.3 Has using rainwater harvesting technology improved food availability in the household? 1=yes 2=no

4.4 If no, why?____

4.5. How many meals per day do you use to eat before introducing RWH structures?

1=once 2=twice 3=three times 4= others (specify) _______________

4.6 How many meals per day do you eat after introducing RWH structures?

1=once 2=twice 3=three times 4= others (specify

4.7 How do you view the variety of your food after using rainwater harvesting technology?

1=better 2=worse 3=no change 4=others(specify)_________

4.8 How do you view the health condition after introducing rainwater harvesting technology? 1=better 2=worse 3=no difference 4=others (specify)________

4.9 If worse, why?_______________________________________

4.10 How do you rate your food security status after using rainwater harvesting technology?

1=better 2=worse 3=no change 4=others (specify)_______________

4.11 Do you feel you are food secure? 1=yes 2=no

4.12. If no, why?____

V. Market

5.1 Do you go to market? 1=yes 2=no

5.2 If yes, why?(indicate as many as possible) 1=to buy grain 2=to buy industrial supplies(eg. salt, sugar, etc) 3=to sell grain 4=to sell vegetables

5=to sell fuel wood/charcoal 6=to sell egg and chicken 7=to sell livestock products (milk, butter, etc) 8=others (specify)____________

5.3 How do you sell your produce? (indicate as many as possible)

1=take produce to the nearby market 2=traders buy from the field

3=contract with institution 4=others (specify) _______

5.4 How far is the nearby market from your plot__________Kms.

5.5 How do you transport your produce to the nearby market? 1=using pack animals

2=carry it myself 3=public transport 4=others (specify)____________

5.6 How long does it take you to the nearby market on foot? __________ hrs.

5.7 How often do you go to the market to sell your produce? 1=once a week

2=once in two weeks 3=once a month 4=others (specify) ______

5.8 Do you face a problem in selling your produce? 1=yes 2=no

5.9 If yes, what type of problems? 1=low price 2=lack of transport

3=low demand for the produce 4=others (specify)________

VI Credit Facilities

6.1. Is there micro-finance institution in your area? 1=yes 2=no

6.2. Have you borrowed money for the last four years? 1=yes 2=no

6.3. If yes, why? 1=to purchase livestock 2=to purchase farm tools

3=to buy modern farm inputs like fertilizers 4=others (specify) _____

6.4 Have you faced failure to repay the loan? 1=yes 2=no

6.5 What other credit source do you use? 1=individual lender 2=relatives

3=friends 4=cooperatives 5=others (specify)_________

6.6 If you do not borrow at all, what is the reason? (indicate as many as possible)

1=fear of being in debt 2=high interest rate 3=fear of failure to repay

4=don't need credit 5=others (specify)___________

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

6.8. If yes, in what form do you save? 1=ikub 2=in the form of jewelry

4=save in a bank 5=others (specify)_________

Annex II

Questionnaire prepared for non-users of RWH ponds

I. Household Characteristics

1.1 Indicate the household size 1= Male____ 2= Female____ 3=Total______

1.2 Fill the following household characteristics

No	Name of family members	Relationship to the respondent(1)	Sex(2)	Age	Marital status(3)	Educat -ion(4)

Code (1)	**Code(2)**	**Code(3)**	**Code(4)**
1=husband	1=male	1=never married	1=illiterate
2=wife	2=female	2=currently married	2=read & write
3=daughter		3=widowed	3=1-6 grade
4=son		4=divorced	4=7-8 grade
5=mother		5=separated	5=9-10 grade
6=father			6=11-12 grade
7=grandson			7=others (specify)
8=granddaughter			
9=others (specify)			

1.3 Who is the main economic provider for the household? (Put in order of importance) 1=husband____ 2=wife_____ 3=son or daughter____ 4=relatives in the household_____ 5=relatives somewhere else_____ 6=others (specify)_________

1.4 What are the wealth indicators in the community? (indicate as many as possible)

1=Livestock 2= Mule and donkey 3=corrugated iron roofed house 3=Radio

4=sending children to school 5=others (specify) ______________

1.5 Wealth ranking of the household according to local standards

1=rich 2=medium 3=poor 4=very poor 5=others (specify)________

II. Household Resources and Means of Livelihood

2.5 Total Land size _________(you can use hectare or local measurement)

2.6 Land under cultivation______________

2.7 Fallow land ____________

2.8 Grazing land ___________

2.5 How do you evaluate the condition of rainfall of the area for crop production?

1=excess 2=sufficient 3=insufficient 4=very low

2.6 Is there any record of crop failure in the area due to shortage of rainfall?

1=yes 2=no

2.7 If yes, indicate the year/s__________

2.8 What kind of crops do you produce? (put in order of importance)

1=teff____ 2=wheat____ 3=Sorghum____ 4=Barley___ 5=pulses____

6=Potato___ 7=Onion_____ 8=Tomato______ 9=Pepper____

10=Cabbage___ 11=Others(specify)_______

2.9 What is the major occupation of the household?

1=crop production 2=mixed farming 3=animal husbandry

4=others (specify)_________________

2.10 Do you have additional income that supplements your major occupation?

1=yes 2=no

2.11 If yes, state in order of their importance

1=sale of crop production___ 2=sale of vegetables___ 3= sale of livestock___

4=sale of livestock products___ 5=earnings from daily labour____ 6=petty trading____ 7=sale of local drinks_____ 8=sale of honey____ 9=sale of chicken and eggs____ 10=sale of pottery____ 11=sale of fuel wood and charcoal____ 12=remittance/gift____ 13=others (specify) _______

2.12 How is your agricultural production in times of adequate rainfall?

1=excess for annual household consumption 2=sufficient for annual household consumption 3= sufficient for nine months consumption 4=sufficient for six months consumption 5= sufficient for three months consumption 6=others (specify)_______________

2.13. How is your agricultural production in times of inadequate rainfall?

1=sufficient for annual household consumption 2= sufficient for nine months consumption 3=sufficient for six months consumption 4= sufficient for three months consumption 5=others (specify) ___________

2.14 Have you ever faced food shortage? 1=yes 2=no

2.15 If yes, indicate the year/s___________________

2.16 If yes to question 2.14, what was the reason? 1=land shortage 2=oxen shortage 3=labor shortage 4=poor land productivity 5= shortage of manure & fertilizer 6=erratic rainfall pattern 7=others (specify) __________

2.17 What did you do to cope with the problem of food shortage?

1=rent farm land 2=borrow money 3=borrow cereals 4=assets sale 5=engage in daily laboring 6=engage in food for word/safety net 7=others (specify) ________

2.18 Which crops are the major sources of food (staple food) for your household?

1=teff 2=wheat 3=barely 4=sorghum 5=others(specify)____

2.19 Indicate the average number of meals per day in your household? ___________

2.20 Annual Grain production

Crop Item	Rain fed Production							
	Area cultivated				Total Production(quintals)			
	1995	1996	1997	1998	1995	1996	1997	1998
Wheat								
Maize								
Sorghum								
Teff								
Barley								
Pulses								
Oilseeds								
Millet								
Oats								
Spices								
Others								
Total								

2.21 Annual income from vegetable, fruits and *Gesho* production

Crop Item	Rainfed production					
	Total production (in Kg)			Total income (in birr)		
	1996	1997	1998	1996	1997	1998
Onion						
Tomato						
Potato						
Pepper						
Cabbage						
Garlic						
Lettuce						
Spinach						
Beetroot						
Orange						
Mango						
Papaya						
Guava						
Banana						
Others						
Total						

2.22 Annual income from Non- Agricultural Sources in 1998

Item	Annual Income(in birr)
Petty trading	
Pottery	
Sale of local beverages	
Sale of firewood/charcoal	
Assistance from relatives	
Food for work/safety net	
Wage labour	
Oxen hired	
Others	
Sub-total	

2.23 Do you own livestock at present? 1=yes 2=no

2.24 If yes, indicate the type and number

		Number
Cattle	Oxen	
	Cows	
	Heifers	
	Bulls	
	Calves	
Sub Total		
Sheep and Goat	Sheep	
	Goat	
Sub total		
Equines	Horses	
	Mules	
	Donkeys	
Sub total		
Grand total		

2.25. How many chicken do you own?___________________

2.26. What are the sources of your animal feed? (indicate as many as possible)

1=communal grazing 2=around the backyard 3=own grazing land

4=crop residue 5=weeding plant 6=fodder plant 7=hay 8=others(specify)

2.27 Do you face shortage of animal feed? 1=yes 2=no

2.28 If yes, what do you do to cope with the problem? 1=limit the number of livestock

2=purchase additional fodder from other sources 3=use cactus

4=others (specify) ___

2.29 Are the oxen you possess enough for your farm operation? 1=yes 2=no

2.30 If no, means to get additional oxen 1=exchange with labor 2=hire

3=oxen sharing 4=others (specify) ____________

III Issues Related to Rainwater Harvesting Technology

3.1 Do you have your own rainwater harvesting ponds? 1=yes 2=no

3.2 If no, do you apply any rainwater harvesting technology? 1=yes 2=no

3.3 If yes, what type of technology are you applying? 1=roof water harvesting

2=community pond 3=flood diversion 4=others(specify)___________

3.4 If no to question 3.1, what is the reason? (Put in order of importance)

1=risky____ 2=costly____ 3= have enough water supply_____

4=labor shortage____ 5=shortage of land_____ 6= Lack of awareness_______

7=others (specify) _____________

3.5 How do you evaluate your economic status with those who use household ponds?

1=better off 2=worse off 3=no difference 4=others(specify)________

3.6 Are you willing to apply household ponds if you get some financial assistance?

1=yes 2=no

3.7 If no, why? ___________________________

IV. Market

4.1 Do you go to market? 1=yes 2=no

4.2 If yes, why?(indicate as many as possible) 1=to buy grain 2=to buy industrial supplies(eg. salt, sugar, etc) 3=to sell grain 4=to sell vegetables

5=to sell fuel wood/charcoal 6=to sell egg and chicken 7=to sell livestock products (milk, butter, etc) 8=others (specify)_____________

4.3 How do you sell your produce? (indicate as many as possible)

1=take produce to the nearby market 2=traders buy from the field

3=contract with institution 4=others (specify) _______

4.4 How far is the nearby market from your plot___________Kms.

4.5 How do you transport your produce to the nearby market? 1=using pack animals

2=carry it myself 3=public transport 4=others (specify)_____________

4.6 How long does it take you to the nearby market on foot? __________ hrs.

4.7 How often do you go to the market to sell your produce? 1=once a week

2=once in two weeks 3=once a month 4=others (specify) ______

4.8 Do you face a problem in selling your produce? 1=yes 2=no

4.9 If yes, what type of problems? 1=low price 2=lack of transport

3=low demand for the produce 4=others (specify)________

V Credit Facilities

5.1. Is there micro-finance institution in your area? 1=yes 2=no

5.2. Have you borrowed money for the last four years? 1=yes 2=no

5.3. If yes, why? 1=to purchase livestock 2=to purchase farm tools

3=to buy modern farm inputs like fertilizers 4=others (specify) _____

5.4 Have you faced failure to repay the loan? 1=yes 2=no

5.5 What other credit source do you use? 1=individual lender 2=relatives

3=friends 4=cooperatives 5=others (specify)________

5.6 If you do not borrow at all, what is the reason? (indicate as many as possible)

1=fear of being in debt 2=high interest rate 3=fear of failure to repay

4=don't need credit 5=others (specify)___________

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

5.8. If yes, in what form do you save? 1=ikub 2=in the form of jewelry

4=save in a bank 5=others (specify)__________

Annex III

Checklist used for Interview and Focus Group Discussion

1. Checklist for interview with Development Agents

- How do you explain the relationship between Development Agents and farmers?
- How do you help the RWH technology users?
- To what extent are the farmers aware of rainwater harvesting technology?
- What relations have you observed between users and non-users of RWH technology?
- What are the reasons for not adopting RWH technology?
- What are the benefits of RWH ponds?
- What are the major constraints in adopting and utilization of ponds?

2. Checklist for interview with PA level Administrative officials

- What are the major problems of your kebele?
- How do you explain the level of awareness of farmers about RWH technologies?
- What assistance is your office giving to farmers in the area of rainwater harvesting?
- What are the problems related to RWH technology adoption?
- What are the measures taken to solve the problem?

3. Checklist for focus group discussion (pond users)

- What are the major constraints for crop and livestock production?
- How do you evaluate community participation in RWH technology adoption?
- How does the agricultural office assist farmers?

- What are the impacts of rainwater harvesting technologies on crop production? Livestock production?
- For what purpose do farmers utilize water stored in ponds?
- What are the major problems associated with ponds?
- How do you evaluate your well being before and after the intervention?

4. Checklist for focus group discussion (non users of RWH ponds)

- What are the reasons for not adopting RWH ponds?
- What mechanisms are you using to augment your water needs
- What are the benefits of ponds?
- How do you compare your welfare with that of pond users?
- How does the agricultural office assist the farmers?

DECLARATION

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

Melete Gebregiorgis

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July 2007

Addis Ababa University

This thesis has been submitted for examination with my approval as a university advisor.

Woldeamlak Bewket

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July 2007