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IMPACT ASSESSMENT OF RAINWATER HARVESTING PONDS:

THE CASE OF ALABA WOREDA, ETHIOPIA

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Dedicated

To
Mom and Dad
With Love

ACRONYMS

ADLI	Agricultural Development Led Industrialization
ASA	Arid and semi-arid areas.
asl	above sea level
CA	Catchment Area.
CB	Cropped basin
FAO	Food and Agricultural organization
FDRE	Federal Democratic Republic of Ethiopia
FFW	Food for Work
GHA	Greater Horn of Africa
GHARP	Greater Horn of Africa Rainwater Partnership
GWH	Global Water Harvesting
ICRAF	International center for Research in Agro forestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IPMS	Improving Productivity and Market Success
NAEP	National Agricultural Extension Program
NGO	Non-governmental organization
NRM	Natural Resource Management
OLS	Ordinary Least Square
PA	Peasant Association
RELMU	Regional land management unit
RWH	Rain Water Harvesting
SNNPR	Southern Nations Nationalities and Peoples Regions
SWC	Soil and Water Conservation
UNEP	United Nation Environmental Protection
UN OCHA	United Nation Office for the Coordination of Humanitarian Affairs

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ABSTRACT

This study assesses the determinants of households' adoption of rainwater harvesting ponds, and its impact on agricultural intensification and yield in Alaba Woreda, southern Ethiopia. Results are based on data collected from a survey of 152 households and 1036 plots operated by the households. Households were stratified into those with rain water harvesting ponds and those without from which equal number of sample households ware drawn. Analysis of descriptive information and econometric methods are used. Analysis of qualitative information supplemented the econometric results.

The finding in the cropping pattern shows that, farm households have started to grow new crops (vegetables and perennial crops) as a result of water availability from the water harvesting ponds. Results of Probit analysis on the determinants of adoption of rainwater harvesting ponds shows that household size, education status of household head, ownership of livestock (cattle, oxen and pack animals), homestead plots and type of pond explained adoption statistically significantly. Results of analysis of qualitative information, consistent, with the Probit model results, also showed that labor requirement, economic problem to use simpler water lifting and watering equipments, inability to easily understand the benefit of the technology and problems related with the structure of the RWH technology adopted were some of the major problems faced by households, and have a negative impact on the technology adoption rate.

The Ordinary Least Square estimation of the determinants of the value of crop production shows that adoption of RWH has a positive and statistically significant effect on value of crop production, after controlling for input use and other factors. This shows that RWH ponds have direct and significant impact on value of crop production. We also find that households with RWH technology use more labor and seed but less oxen power compared with those households who have not adopted the technology. Moreover, labor and seed inputs have positively significant impact on yield while the effect of oxen power is insignificant. These results show that in addition to its direct impact, RWH has significant indirect impact on value of crop production through its effect on intensity of input use.

Labor requirements and cost considerations appear to be important factors that influence household's adoption of RWH technology. This implies that research and development interventions need to take account of the labor and cost demands of the technology. The effectiveness of the technology adoption is mainly constrained by problems related to water lifting and watering equipments, and accidents occurring due to absence of roof cover and fence to the ponds. This implies that support will be needed to provide affordable but improved water lifting and watering equipments, and give training to farm households on construction and use of roof covers and fences to the ponds. As households shift to high value but perishable commodities due to the

RWH, emphasis needs to be given to marketing extension, especially in facilitating markets and market linkages to farmers.

Future intervention to promote RWH technologies need to provide due attention to quality, rather than focusing on the number of adopters. Households appear to neglect the community ponds since they focus on using cleaner water obtained from household ponds and other sources of clean water. In this process the community ponds are becoming a cause of health problems. Thus, it is important that appropriate attention be given to the community ponds as well.

CHAPTER ONE: INTRODUCTION

1.1. Background of the Study

Ethiopia, like other Sub-Saharan African (SSA) countries, is an agrarian economy, with a very small industrial sector. The agricultural sector, on average, accounts for about 45% of the GDP, 90% of merchandise export earnings, 80% of employment, more than 90% of the total foreign exchange earnings, 70% of the raw material supplies for agro-industries, and is also a major supplier of food stuff for consumers in the country. Smallholders who produce more than 90% of the total agricultural output and cultivate close to 95% of the total cropped land dominate the sector. Agricultural production is highly dependent on the vagaries of nature with significant variability in production and actual production patterns (Demeke et al, 2005).

Due to population increase in the highland areas, more and more marginal areas are being used for agriculture which led to the degradation of the natural resources .One of the major challenges to rural development in the country is how to promote food production to meet the ever-increasing demand of the growing population. Rainfall in the arid and semi-arid areas is generally insufficient to meet the basic needs of crop production. In degraded areas with poor vegetation cover and infertile soil, rainfall is lost almost completely through direct evaporation or uncontrolled runoff. Thus, overcoming the limitations of these arid and semi-arid areas and making good use of the vast agricultural potential under the Ethiopian context, is a necessity rather than a choice. Thus, there is need for appropriate interventions to address the prevailing constraints using suitable technologies for improved and sustainable agricultural production.

With regard to agricultural water development, small scale irrigation seems to be preferred to large scale schemes. The reason for the preference of small-scale irrigation to large scale irrigation includes the high capital requirement and cost of constructing large scale scheme which can only benefit a fortunate few but easy adaptability of small scale irrigation (Turner, 1994).

There is now increasing interest to the low cost alternative generally referred to as ‘water harvesting’ especially for small scale farming systems. Runoff, instead of being considered as a problem, can be harvested and used for different purposes, which otherwise is lost and causes soil erosion. Various methods of rainwater harvesting are available, through which rainwater is captured, stored and used at times of water scarcity. Rainwater harvesting can be broadly defined as a collection and concentration of runoff for productive purposes like crop, fodder, pasture or trees production, livestock and domestic water supply (Ngigi, 2003).

Collection and storage of rainwater for different purposes has been a common practice since ancient times. The system was used thousand years ago in many parts of the world. There are also evidences indicating ancient churches, monasteries and castles in Ethiopia used to collect rainwater from rooftops and ground catchments. Birkas in Somalia region and different runoff basins in Konso are good examples of the traditional rainwater harvesting practices in Ethiopia. Moreover embankment and excavated ponds[1] for agriculture use and water supply, runoff farming and various types of soil moisture conservation techniques for crop production could be mentioned as examples (Nega, 2004)

In Ethiopia, promotion and application of rainwater harvesting techniques as alternative interventions to address water scarcity were started through government initiated soil and water conservation programmes. It was started as a response to the 1971-1974 drought in Tigray, Wollo and Hararge regions with the introduction of food-for-work (FFW) programme which were intended to generate employment opportunities to the people affected by the drought. Since then, however, the interventions have been extended to the other parts of the country with very limited coverage. The low level of community participation and declining attention were some of the major reasons for the limited coverage (Ngigi, 2003).

After the fall of the military government, both the Transitional Government of Ethiopia (TGE), established in 1991, and the Federal Democratic Republic of Ethiopia (FDRE), established in 1995, have adopted an economic development policy to achieve food self sufficiency and sustainable development, based on a strategy called Agricultural Development-led Industrialization (ADLI) , which gives more emphasis to improvement in agricultural productivity. Besides, recognizing the problem of variability in the rainfall

[1]*According to (Nega, 2005) they are defined as follows.*
Pond: is small tank or reservoir and is constructed for the purpose of storing the surface runoff
Excavated pond: is a pond type constructed by digging the soil from the ground
Embankment pond: type of pond constructed across stream or water course consisting of an earthen dam.

distribution in the country, the 1995 strategy advocates for water centered sustainable rural development (Desta, 2004). Based on this, several rain water harvesting technologies have been constructed by regional states, NGOs, communities, and individual farmers through out the country.

To mitigate the erratic nature of rain fall in the arid and semi-arid parts of the country, which threatens the lives of millions of people, a national food security strategy based on the development and implementation of rainwater harvesting technologies either at a village or household level was adopted after 1991. The Federal Government had allocated a budget for food security programs in the regions, an amount equal to ETB 100 million and ETB one billion during the 2002 and 2003 fiscal years, respectively. Of the total budget, most of it was used by regional states for the construction of rainwater harvesting technologies including household ponds, in collaboration with the Federal Ministry of Agriculture and Rural Development (Rami, 2003).

1.2. Statement of the Problem

As a result of long history of agriculture and high population in Alaba Woreda, vegetable cover is very low .Consequently erosion hazards in the sloppy areas are enormous. Huge gullies are observed towards the southern end of the Woreda, where soils are totally removed beyond recovery. This is believed to have been aggravated due to the easily detachable nature of the soil. Even though there were some efforts of soil and water conservation (SWC) over the last twenty years, these efforts were limited. Many NGOs were involved in soil and water conservation efforts in the Woreda. Around Blate River (south of Alaba Kulito town), there were some trees planted even though none seem to exist now (IPMS, 2005).

Cropping patterns in the area follows rainfall, as cropping is totally depend on rainfall. The biggest river crossing the Woreda is Blate which is a perennial river, although the volume of water decreases substantially during the dry season. This River is the source of livelihood for many farming families and commercial farms south of Alaba Woreda.

The current government effort of household level water harvesting scheme is wide spread in Alaba. Prior to this, community managed ponds were common in the area. Over twenty years ago, domestic and livestock sources of drinking water were scarce. This is aggravated during drought periods. Owning to these, the community managed water ponds are wide spread in the Woreda currently. The topography of the area is suitable for irrigation. If appropriate water harvesting mechanisms are put in place, Alaba could have a substantial amount of irrigable land. However, unlike other districts, the water table for Alaba is very deep with an average depth of 200 meters and use of underground water as source of alternative irrigation is limited (IPMS, 2005).

Even if government efforts of household level water harvesting schemes are wide spread in Alaba, the performance obtained was not assessed. Due to this reason, there was a need to asses the impact of the existing rainwater harvesting systems in Alaba Woreda to determine their effectiveness and sustainability. In addition, there was a need to assess the condition of indigenous rainwater harvesting technologies and practices in Alaba. Hence, this study is aimed to fill this gap of knowledge in the region.

The purpose of impact assessment is to determine the welfare changes from a given intervention on individual, households and institutions and whether those changes are attributable to the project, programme, or policy intervention. Impact assessments are often undertaken ex ante, evaluating the impact of current and future interventions, or ex post, evaluating the impact of past intervention. It can also be made concurrently within the project cycle (Shiferaw et.al, 2005). Our focus in this study is the ex post impact assessment. Ex post assessment attempts to understand the pathway through which observed impacts have occurred and why interventions fail or succeed in attaining stated objectives. Hence, ex post assessments can inform policy choices as to whether related planned programme interventions should be discontinued, modified, improved or sustained in the future (Ibde)

1.3. Objective of the Study

The general objective of the study is to assess the impact of rainwater harvesting ponds on crop yield using a quantitative approach supplemented by a qualitative approach. In particular the study focuses on:

- Identifying the determinants of household decision to adopt rainwater harvesting ponds.

- Examining the impact of rainwater harvesting ponds on crop yield, input use and cropping pattern.
- Assess the constraints and options to improve rainwater harvesting ponds
- Assess the differential impact of the technology by gender
- Assess indigenous rainwater harvesting technologies and practices in Alaba.
- Derive policy implications to improve the performance of the rainwater harvesting ponds.

1.4. Significance of the Study

The study is expected to identify problems encountered, so that possible measures are taken when these interventions are replicated in other parts of the Woreda or the country. Besides, being an empirical study it will help to add to the empirical literature that uses the combination of both quantitative and qualitative approach in assessing the impact of RWH technology interventions on agricultural production. Finally, understanding the impact of the RWH technologies on agricultural productivity and the determinant factors of rainwater harvesting ponds, which affect productivity or level of yield, is a vital issue for designing appropriate agricultural development policies and strategies, as well as technology interventions. Therefore, the outcome of this study may serve as a source of additional information which may be of significant use to policy makers and planners during the designing and implementation of RWH technology strategies.

1.5. Scope and Limitation of the Study

The case study was based on a one-time field survey of 152 farm households, half of them using rainwater harvesting ponds in their agricultural production process. Substantial qualitative and quantitative information were gathered on agricultural production, the different aspects of the RWH technologies adopted, problems related with the technology intervention and potential solutions, and reason not to adopt by non-users of the technology. However, the study has the following limitations.

One of the limitations is the unavailability of base line data. Such data would reflect the condition of the farm household's agricultural production process pre-technology intervention, and would have been helpful to compare more comprehensively and evaluate the relative effect of the technology intervention on agricultural productivity overtime. The other limitation of this study is related to the lack of accurate measures and valuation techniques to include the environmental benefits and costs that accrue from the RWH technology intervention.

1.6. Organization of the Study

The study comprises ten chapters. Chapter two deals with the principles and technologies of rainwater harvesting. Chapter three presents the literature review. Chapter four presents the conceptual framework, research hypothesis and the methodology used in the study. Chapters five and six present the analysis of socio-economic characteristics and cropping patterns, and community indigenous water harvesting technologies and practices, respectively. Gender and RWH technologies are discussed in chapter seven. The analysis of the perceptions of constraints and opportunities in adoption and use of RWH technologies is included in chapter eight. The Analysis of the determinants of adoption of RWH pond, input use and crop yield are dealt in chapter nine. Chapter ten concludes the thesis and presents recommendation.

CHAPTER TWO: PRINCIPLES AND TECHNOLOGIES OF RAINWATER HARVESTING

2.1 Principle and Definition of Rainwater Harvesting

Rain, forms the most important natural source of water (Nega, 2005). Rain that falls on the earth's surface can do one of the three things:

I. It may evaporate quickly

II. It may seep into the soil, or

III. May run, as surface runoff

If the water evaporates, it is lost into the atmosphere (though it may fall again somewhere else as rain).If the water *seeps in*, it may stay in the soil where plant roots can reach it. Or it may filter further down in to the ground to recharge ground water. This water maybe reached by deep-rooted plants, or it may reappear at a lower surface down as a spring or people can tap it by digging wells. Too much rainfall can result in excess runoff or flood. Water that runs off the surface may remove small soil particles and carry them away, causing erosion. Rainwater harvesting is a concept of utilizing this runoff water for any productive uses. Rainwater harvesting technique, therefore, serves the dual purpose of preserving the environment and providing water, the most needed input.

2.2 Where to use Rainwater Harvesting?

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

Generally, the technique can be applicable in the following circumstances:

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

2.3 Components of Rainwater Harvesting

Some of the main components of water harvesting systems are:

Catchment area: the part of the land that contributes some or its entire share of rainwater to the target area outside its boundary. Catchment surfaces can be either natural or treated (runoff inducement). It is a runoff producing area which may include agricultural, rocky or marginal land, rooftop, paved road etc (Desta, 2004).

Silt trap/sediment pond: it is a small pit used to catch sediment carried by the water. It prevents the tank from becoming clogged. The size of the trap depends on the amount of runoff (heavier runoff means a bigger trap) and the amount of sediment it carries. If there is a lot of sediment, it is preferred to make two-chamber trap- one chamber to catch sand and the second one to trap finer silt. We can add filter mesh to trap leaves and other debris. Mostly we dig the silt trap at least 3 meters away from the storage tank. This is to prevent water from overtopping during heavy rains and damaging the tank (Nega, 2005)

Diversion channels: it leads water from the catchment area to the silt trap and then to the tank. It should be made of compacted earth, or lined with cement. It should have a very gentle gradient to prevent it from being damaged.

Storage facility: the place where runoff water is held from the time that it is collected until it is used.

Target area: where the harvested water is used. In agricultural production, the target is the plant or the animal, while in domestic use, it is human being or the enterprise and its needs.

2.4 Classification of RWH Technologies and Systems.

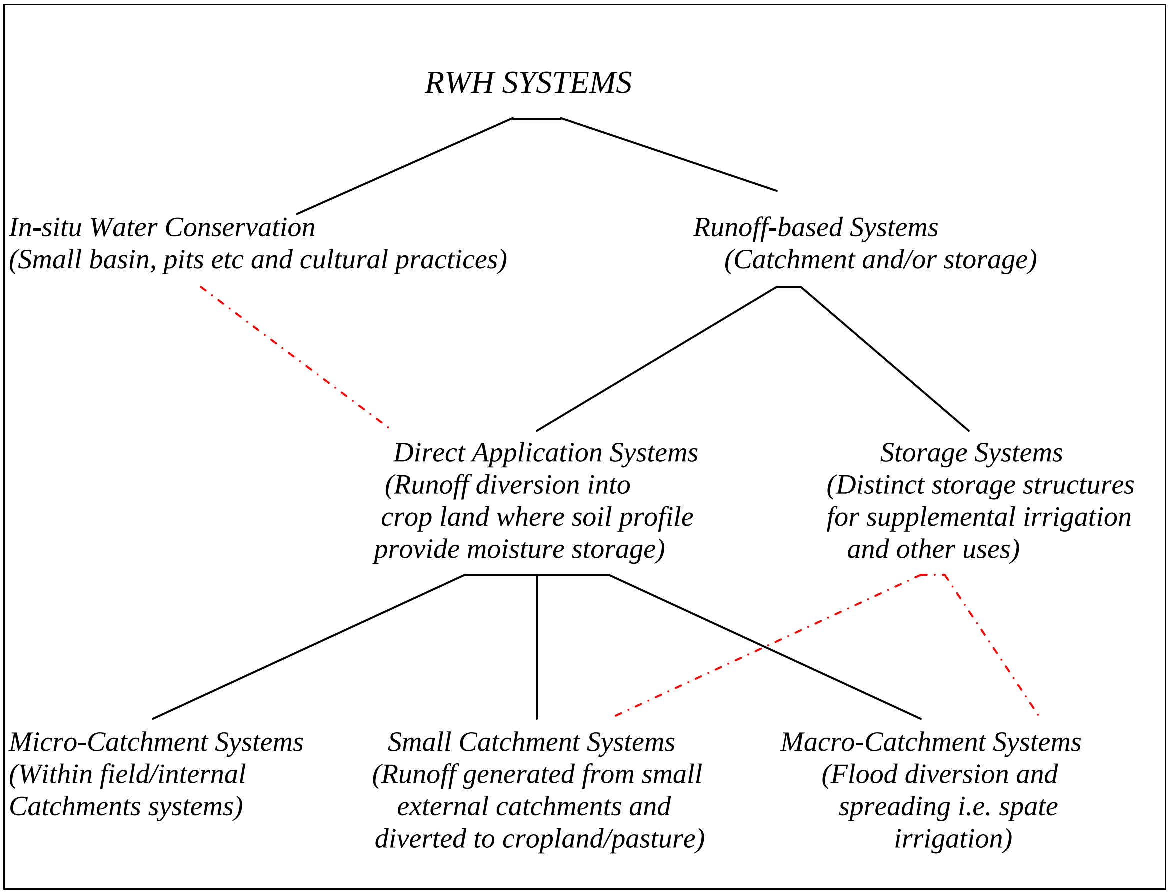


Figure2.1: Classification of RWH technologies and systems in GHA (Ngigi, 2002)

As shown in the figure above the classification is based on runoff generation process, type of storage/use and size of catchments is adopted. Each will be discussed in detail below.

I. Runoff generation criteria:

These criteria of classifying RWH system yield two categories- runoff based systems and in-situ water conservation.

In situ rainwater harvesting is distinct from runoff farming in that they don't include a runoff generation area, but instead aims at conserving the rainfall where it falls in the cropped area or pasture (Ngigi, 2003).

Runoff-based systems entail runoff generation .It has further division based on type of storage and size of catchment adopted.

II. Runoff storage criteria

The runoff based system yields two types of storage categories- direct runoff application (where the soil profile acts as the moisture storage reservoir within cropland) and the storage system (which has distinct storage structures like ponds, tanks etc. to store water to be used for different productive uses). As shown in figure 2.1, we should note that in-site water conservation could also be considered under soil profile storage systems, except that direct rainfall is stored, but not surface runoff.

III. Size of catchment criteria

As can be seen in figure 2.1, within the runoff based system the direct runoff application yields three categories based on the size of catchment system that is –micro catchments (Within field / internal/on farm), macro catchments and small external catchments(sometimes we put it as non-land micro catchment).Note that in the case of storage system we have two categories -the small external catchments (the dominant one especially for small scale land users) and macro catchments with large storage structures (which could be used for large scale or community based project).

A. Micro-catchment (land based water harvesting)

This is a system where there is a distinct division of catchement area and cropped basin (storage area) but the areas are adjacent to each other. It is a method of collecting surface runoff from a small catchment area and storing it in the root zone of an adjacent infiltration basin. This system is mainly used for growing medium water demanding crops such as maize, sorghum, groundnuts and millet (Hatibu et.al, 1999)

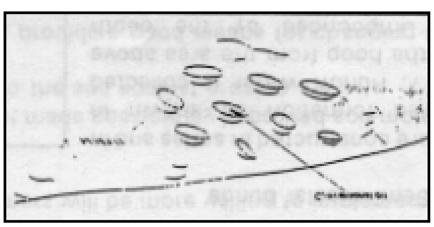
According to Desta (2004) some of the most important land-based microcatchment or on-farm water-harvesting systems known over the world may include:

Table2.1. The different techniques in micro-catchement

N°	Name of the technique	N°	Name of the technique
1	Zay pits	5	Meskats
2	Runoff strips	6	Contour ridges
3	Contour bunds	7	Negarims
4	Semi-circular bunds		

Source: Different techniques in micro catchement (Desta, 2004)

The different techniques in the table will be discussed following Hatibu et.al (1999).



. Figure2.2: Layout of pitting RWH

Pitting**:** These are small semi-circular pits dug to break the thick soil surface (Figure 2.2). In West Africa where they are called ‘Zay’, the pits are about 30 cm in diameter and 20 cm deep

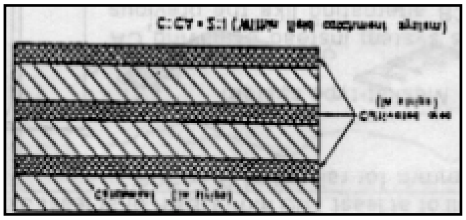
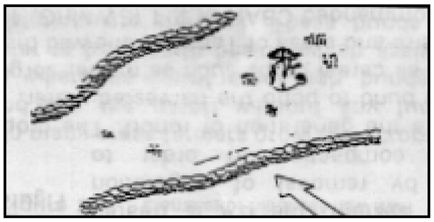


Figure2.3: RWH with strip catchment tillage

Strip catchment tillage**:** This involves tilling strips of land along crop rows and leaving appropriate sections of the inter-row space uncultivated so as to release runoff. It is normally used where the slopes are gentle and the runoffs from the uncultivated parts add water to the cropped strips.



Figur2.4: RWH with Contour bunding

Contour bunds**:** This system consists of small trash, earth or stone embankments, constructed along the contour lines. The embankments strap the water flow behind the bunds allowing deeper infiltration into the soil. The height of the bund determines the net storage of the structure. The water is stored in the soil profile and above ground to the elevation of the bund or overflow structure. This is a versatile system for crop production in a variety of situations. They can be easily constructed but they are limited to availability of power (for earthmoving), stones and trash.

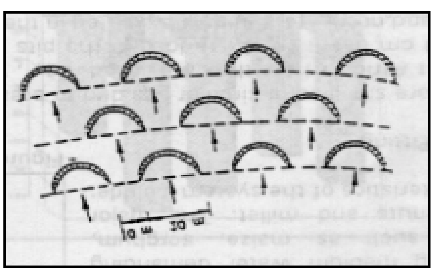


Figure2.5: Semi-circular bund

Semi-circular bunds**:** These are constructed in series in staggered formation as shown in Figure 2.5. Runoff water is collected within the hoop from the area above it and impounded by the depth decided by the height of the bund and the position of the tips. Excess water is discharged around the tips and is intercepted by the second row.

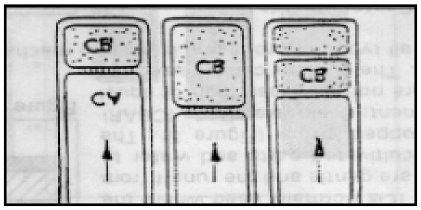


Figure2.6: Meskat-type bunding

Meskat-type system**:** In this system instead of having CA and CB alternating like the previous methods, the field is divided into two distinct parts, the CA and CB, whereby the CB is immediately below the CA. In this system, the CA is treated by removal of vegetation in order to increase the generation of runoff. The cropped basin (CB) is enclosed by a U-shaped bund to pond the harvested water. It can be used for almost all cereal crops such as maize, sorghum and millet.

Contour farming and Ridging**:** This is important where cultivation is done on slopes ranging from 3% and above. All farm husbandry practices such as tilling and weeding are done along the contours so as to form cross-slope barrier to the flow of water. Where this is not enough, it is complemented with ridges, which are sometimes tied to create high degree of surface roughness to enhance the infiltration of water into the soil.

Negarims**:** are regular squares made of soil bunds turned by 45^0 from the contour to concentrate runoff water at the lowest corner of the square. At the corner, an infiltration basin is made. At the center of the basin a planting pit is made. The whole square consists of a catchement area and a cropped area. Runoff collected from the catchement area and flows into the cropped area (Nega, 2005).

B. Macro-catchments and flood water systems

Macro catchment and floodwater harvesting systems are characterized by having runoff water collected from a relatively large catchment, which is at an appreciable distance from where it is being used. The macro catchment system consists of upland runoff harvesting and farming before water reaches natural drainage channels. Also called harvesting from external catchments, is the case where runoff from hill-slope catchments is conveyed to the cropping area located at hill foot on flat terrain (Desta, 2004)

Generally, runoff capture is much lower than for micro catchments, ranging from a low percentage to 50% of annual rainfall. Water is often stored in soil profile for direct use by crops, but may also be stored in surface or subsurface reservoirs, for later use. Sometimes water is stored down as a ground water recharge system. The cropping area is either terraced on gentle slopes or located on flat terrain (Ibde).

Floodwater harvesting can be defined as the collection and storage of creek flow for irrigation use. It is also known as 'large catchment water harvesting' or 'Spate Irrigation' (Prinze et.al, 1999).

According to the location of target area, **two types** of macro catchment and floodwater systems exist - Streambed systems and off-stream-bed system. These practices are traditionally practiced in Ethiopia, in areas like Konso, Raya valley, Dire Dawa, and Godie (Desta, 2004).

Stream-bed systems

In this system, the streambed is used to store the water, either on the surface by blocking the water flow or in the soil profile by slowing down the flow and allowing it to infiltrate the soil for crop production or groundwater recharge. The following are the main streambed techniques (Ibde).

1. Jassour or sediment storage dams (big as well as small)
2. Spongy (permeable) rock dams - streambed cultivation:

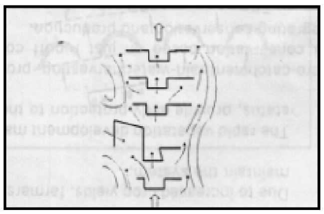


Figure2.7: Flood water harvesting with the stream bed

This is a system that uses barriers such as permeable stone dams to block the water flow and spread it on the adjacent plain and enhance infiltration (Hatibu et.al, 1999).

3. Small farm reservoirs: the need of having reservoirs arises when sometimes macro catchment RWH produces high volumes of runoff that can not be stored in the soil profile. In such circumstances, the harvested water is stored in small dams[2] or water holes[3].
4. A final way of using river floods where it spreads out over a wide river bed or flood plain is simply to wait until floodwater is subsiding and then plant crops on the area which is inundated. This approach is used in Ethiopia along the watercourses in the low lands.

[2]*They are normally constructed in rolling topography where creeks can be found and the dams are constructed across them (Hatibu et.al, 1999)*

[3] *Water holes are storage ponds dug in a flat terrain and they are normally referred to in their Spanish name "Charco dams". In India they are called 'tanks'. They are normally used to store runoff generated from hillside catchments with sheet or rill flow. The system requires methods for controlling siltation especially if the area is prone to soil erosion, evaporation, and seepage losses especially if the subsoil is sandy (Hatibu et.al, 1999).*

Off-streambed systems

The rainwater harvested in off-streambed systems is applied outside the streambed. Structures may be used to force the stream water to leave its natural course and flow to nearby areas suitable for agriculture. Similar structures may also be used to collect rainwater from catchments outside the streambed. The following are the most important off-stream techniques (Hatibu et.al, 1999).

1. Water spreading bunds[4]
2. Hillside conduits-hillside sheet/rill runoff utilization:

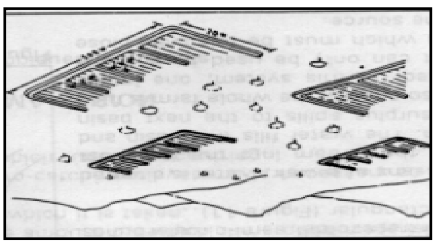


Figure 2.8: Examples of hill sheet flow RWH

In this system, runoff which occurs on hill-tops (with stone outcrops), sloping grounds, grazing lands or other compacted areas flow and naturally collect on low lying flat areas. In many areas farmers grow their crops on the wetted part of the landscape and use the runoff without any further manipulation or management. However, where the runoff is not high, bunds reconstructed on the cropped area in order to form earth basins, which assist in holding the water and increasing infiltration into the soil. These bunds are important when the cropped area is not at the bottom of the landscape. However earth basins are used to facilitate the distribution of the water even if the cultivated area is on flat land. Several designs of these earth basins are used and sometimes are mentioned as types of RWH systems by themselves. These include, for

[4] *It is a floodwater farming technique where earth bunds set at a gradient, with a "dogleg" shape, spreading diverted floodwater*

example the rectangular basins bunded on three sides e.g.Teras as shown in figure 2.8(Hatibu et.al, 1999).

3. Large bunds (could take the different shaped bunds)
4. Runoff harvesting from the road or small waterways
5. Cisterns (reservoirs) of various shapes and geometry that will be explained under rooftop systems as one of the small catchment.

Table 2.2.Differences between micro and macro catchment systems

No	Microcatchment systems	Macro catchment systems
1	Rain locally	Rainfall can be out of the locality
2	Runoff source local	Runoff source primarily channel
3	Short slope length	Long slope length
4	High runoff coefficient, frequent runoff	Low runoff coefficient, runoff less frequent
5	Spillway/control requirement for overflow may not be required	Spillway/control structure required for overflow
6	Steady flow(stable or orderly)	Turbulent flow(unstable or disorderly)
7	Designer controlled	Not designer controlled – amount of runoff
8	Predetermined area ratio (small area) i.e. catchement to cultivated area C:CA - 1:1 to 10:1	Difficult to fix area ratio (could be very large) C:CA - 10:1 to 100:1, 100:1 to 10,000:1 in the case of floodwater harvesting
9	Primarily only for soil storage	Structural storage possible (supplementary irrigation – earth dam, pond, cistern)
10	Saturation is up to field capacity	Saturation is up to inundation(flood)
11	Less crop choice	High crop choice
12	Favors perennial/forage/tree crops	Favors annual and perennial crops
13	Individual ownership	Primarily communal ownership – flood irrigation
14	No upstream/downstream issue	There could be upstream/downstream issue
15	Individual involvement	Organization group/community involvement
16	Only local rainfall water balance study	Basin wide water balance study required
17	Require less effort	Require more effort
18	Macro can not be part of micro	Micro can be part and parcel of macro (IWM)

Source: Differences between micro and macro catchment systems (Desta, 2004)

C. Small Catchment Systems

Under microcatchment systems non-land catchment surfaces include the rooftops of buildings, courtyard and similar impermeable structures used for domestic purpose or garden crops. They are sometimes called borrowed catchments (Desta, 2004).

Table 2.3. Different design of water tanks based on their shapes

N°	***Name of the technique***	**N°**	***Name of the technique***
1	Cylindrical (usually above ground)	6	Dome cap (under ground)
2	Jars (above ground	7	Brick cap (under ground)
3	Rectangular (above ground)	8	Bottle shape (under ground)
4	Hemispherical (under ground)	9	Ferro cement
5	Spherical (under ground)	10	Trapezoidal farm ponds

Source: Different design of water tanks based on their shapes (Nega, 2005)

2.5 Site and Technique Selection

Setting priorities; the people's choice:

Before selecting a specific technique, due consideration must be given to the social and cultural aspects prevailing in the area of concern as they are paramount and will affect the success or failure of the technique implemented. This is particularly important in the arid and semi-arid regions and may help to explain the failure of so many projects that did not take into account the people's priorities. In arid and semi-arid areas, most of the population has experienced basic subsistence regimes which resulted over the centuries in setting priorities for survival. Until all higher priorities have been satisfied, no lower priority activities can be effectively undertaken (Hatibu et.al, 1999)

Technical know-how and criteria:

In addition to the socio-economic considerations, a water harvesting scheme will be sustainable if it also fulfils a number of basic technical criteria as shown in the following figure. The chart shows the basic technical selection criteria for the different water harvesting techniques (Ibid).

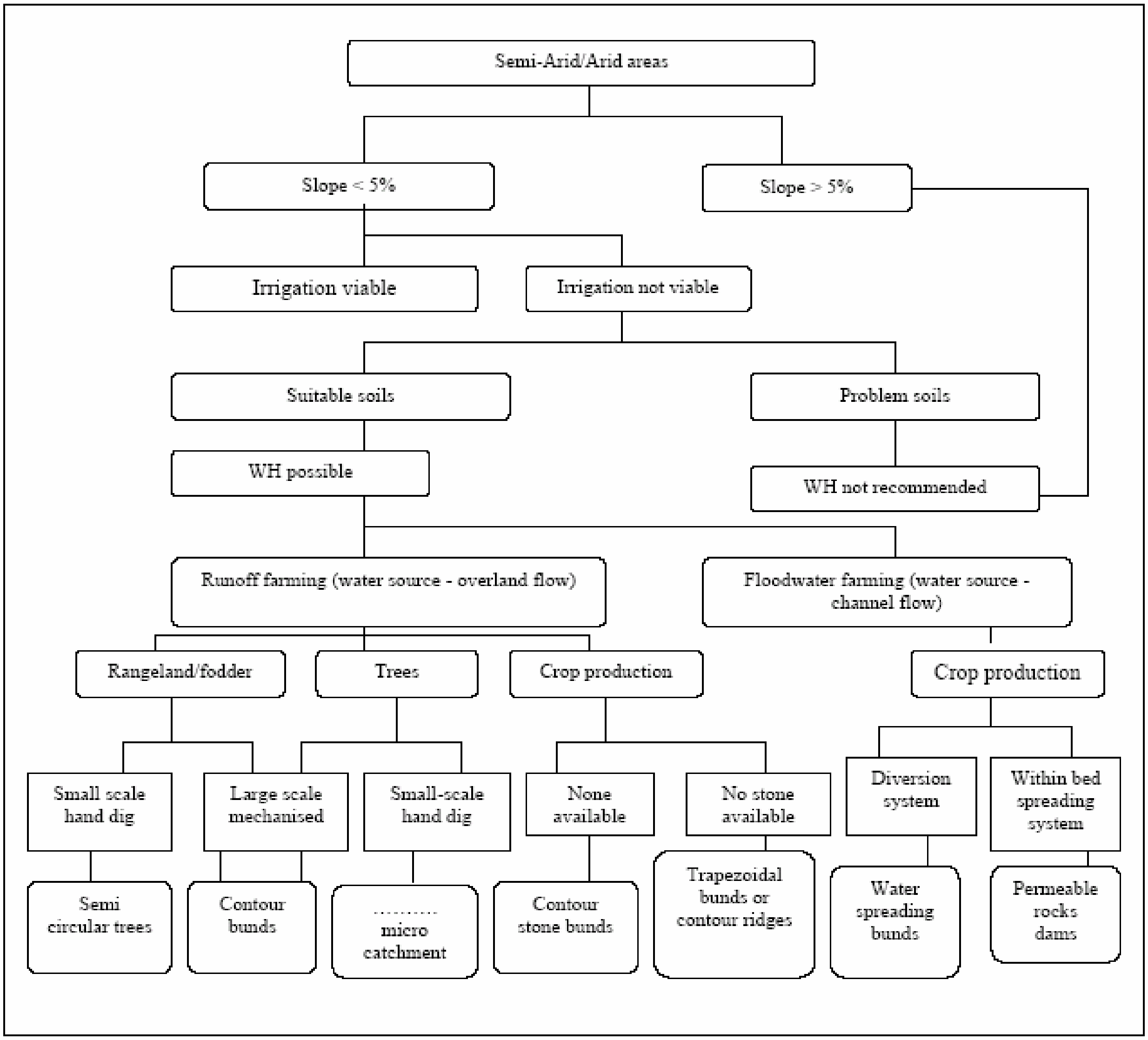


Figure2.9. System Selection or technical selection criteria (Hatibu et.al, 1999)

As can be seen from the figure, water harvesting is recommended in areas where the slope is <5%and where irrigation is not possible .If the soil is suitable, WH is possible for runoff farming which include the fodder, trees and crop production. In addition floodwater farming will be used for crop production.

CHAPTER THREE: LITERATURE REVIEW

Agriculture is the most water-demanding sector, in addition to being a major source of employment and a major contributor of the national gross domestic product (GDP) of many developing countries in Africa. Agriculture in Ethiopia provides 86 percent of the country's employment and 57 percent of its GDP. Rain fed crop cultivation is the principal activity and is practiced over an area of 27.9 million hectares (ha) of land (Gebeyehu, 2006).

Some empirical studies suggest that irrigation has shown some positive impacts in increasing agricultural productivity and thereby increase the income of farm households, who participate in the irrigation schemes (FAO, 1993). In the context of farm households living in the Sub-Saharan African countries, irrigation has, however, proved costly and can only benefit farm households with large plots in addition to concerns related with the environmental and health side effects of the schemes.

Large-scale dam and irrigation projects have not been widely implemented in Ethiopia as they have often proved to be too expensive and demanding in construction and maintenance. Therefore, water harvesting tanks and ponds at the village or household level are proposed as a practical and effective alternative to improve the lives of rural people at little cost and with minimal outside inputs. In theory, household water harvesting can be done mainly through the effort of the individual farmer. Use of stored rainwater could supplement natural rainfall and make farming families less vulnerable to drought and therefore less dependent on outside help in harder times (Takele, 2002)

The role of small scale water harvesting systems in Sub-Saharan Africa has still to be realized. Large scale irrigation has been seen to be the solution to all food deficit and water shortages, but the considerable problems, both technical and more important social, related to them have shown that many could not realize their full potential. A number of rainwater harvesting projects were set up in Sub-Saharan Africa during the last two decades, to combat the effects of drought by improving plant production (usually annual food crops), but few have succeeded in combining technical efficiency with low cost technology and acceptability to the local farmers or agro-pastoralists. This is partially due to the lack of technical “know how” but also due to an inappropriate selection of the prevailing socio-economic conditions (Ibid).

The experience in China on the development of rainwater harvesting shows that since the 1980’s , Gansu, Sichuan, Guangxi, Guizhou and Yunnan provinces adopted rainwater harvesting techniques. To date, rainwater harvesting projects have been carried out in about 700 counties of 15 provinces in semi-arid and humid areas covering two million km^2 and with a total population of 0.36 billion. By the end of 2001, about 12 million water cellars, tanks and small ponds were built with a total storage capacity of 16 billion m^3, supplying water for domestic use for 36 million people and supplemental irrigation for 2.6 million m^2 of dry farming land. This has helped the people access water and engages in agricultural production hence improving food security and alleviating poverty. Rainwater harvesting has also been known to benefit ecological and environmental conservation (UNEP, 2005).

Gansu province of central China is one of the driest and poorest parts of China; rainfall is low and so is the groundwater reserve, thus making life quite hard for the residents of the region. This region, which used to suffer from water scarcity both for production and consumption, was hit by the worst drought in 1995. In response to this the Gansu Research Institute for Water Conservancy in collaboration with the local government of the province introduced a water-catchments project called ‘121’ project, where the government supported the local people to prepare catchments area, water storage facility and catchments basin or planting area. The people of the region not only managed to bring to end the drinking water scarcity for themselves and their estimated 1.18 million livestock, but also managed, for the first time in history, to use their green houses for production of cash crops such as vegetables, herbal medicines, flowers and fruit trees and as well as nurseries (Gnadlinger 2000; Gould 1999). Rainwater, thus, has become a strategic measure for social and economic development in this semi-arid region.

Impact of rainwater harvesting as shown in a case study of Mwala division, Kenya indicates that harvesting runoff water for supplemental irrigation is a risk-averting strategy, pre-empting situations where crops have to depend on rainfall that is highly variable both in distribution and amounts. By using underground spherical tanks having a combined capacity of 60 m^3, seasonal water for supplemental irrigation for an area about 400 m^2 was guaranteed. With rainwater harvesting, farmers have diversified to include horticultural cash crops and the keeping of dairy animals. For instance households with supplemental irrigation earn US$735(per ha) from cash crop compared with US$146 normally earned from rain fed maize. This has contributed to food security; better nutrition and higher family income (RELMA-in-ICRAF, 2004).

A study by Nasr (1999) on the Bedouin tribe of Egypt showed that rainwater harvesting if systematically implemented not only helps in producing crops in areas where it otherwise wouldn't have been possible, but also helps in reducing or halting environmental degradation. As usual, crucial elements in rainwater harvesting are the catchments area, storage media and the catchments basin. The Bedouins decide on these all elements mainly based on their experience of the precipitation rate, water and soil requirements of crops to be grown and the like. Two types of storage facilities are common in the area. One is dams, constructed in 'wadi' channels either of earth or of stone depending on the slope of the soil. The water can then be applied either in the form of flood farming or by storing and using as a supplemental irrigation. The second is building earthen reservoir in 'wadi' depression. Most of the water harvesting systems are developed and utilized as a single-family business and are seldom owned communally, and almost all the household surveyed practice water harvesting of one or another form.

The result is that farmers who used to raise sheep and goats alone have become able to produce crops like barley, with high potency of improving land quality, fruits and others (Ibid). Interestingly enough, the study area also started to experience increased yield with diminishing use of chemical fertilizer, perhaps indicating the use of improved agricultural practice in the form of using organic materials. The other observation is that farmers tend to shun the high cost storage facilities as is evidenced by low prevalence rate of earthen reservoir, whose construction needs such items as concrete and metals, as compared to other storage medias like “Nashou”, which is more of labor, and less of “external” inputs, intensive (Ibid).

The one million cisterns programme which aims to create awareness on rainwater harvesting in Brazil present the impact of rainwater harvesting. The provision of safe drinking water supply during the dry season makes women’s daily lives much easier. The cisterns liberate women from the chore of fetching water daily. At the same time, they liberate their community from dependency on the water trucks provided by politicians. For this reason, it is understandable that there are groups of women who construct cisterns for themselves or for poor colleagues normally marginalized in projects managed by men. Other women plant vegetables with water drawn from subsurface reservoirs, and produce jam and juice from native fruits for commercial purposes. By resolving the family water problems and creating proper income, women become empowered and escape from poverty, thus enabling them to play a strategic role in sustainable development (UNEP, 2005).

By the 1990’s, Zambia’s southern province was recording unprecedented levels of food insecurity, hunger and general poverty. Government food, seed and fertilizer relief support become the norm rather than the exception for many households. During the 2002/2003 season, over 12% of the farm households were estimated to have adopted conservation agriculture technologies which included the use of rainwater harvesting. This was estimated to involve at least 50,000 hectares. The experience of Zambia shows that crop yields have on the minimum doubled. Maize yield rose from under 0.5t/ha to above 2t/ha and cotton from 1.5t/ha to 3t/ha under conventional as compared to conservation agriculture respectively. This has been attributed to improved rainwater harvesting made possible by the planting stations and surface cover. Most farmers have diversified their cropping system to include crops such as maize, beans and sunflower. Increased production at the household level in the last five years has introduced the rapid re-birth of a cash economy among the communities. This has propelled private entrepreneurship in agricultural related trading. Large and small private entrepreneurs have emerged and are selling agricultural inputs and other household commodities as well as buying off the crop. Most households are able to put up for sale 20-30% of their produce. The ultimate effect is enhanced livelihoods (UNEP, 2005).

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

Hatibu et al (2004) tried to quantify the effect on farmers' income and living standards of different rainwater harvesting methods, taking two districts, Maswa from north and Same districts from Eastern parts, of Tanzania. All types, viz. in-situ, micro and macro catchments and rainwater harvesting with storage are all practiced in the two regions in descending order of prevalence; in-situ is more prevalent in both regions followed by micro and macro catchments, with rainwater harvesting with storage being the least. The harvested rainwater is used mainly to grow maize in *Same* area while it is used for rice in *Maswa* region. Good rainwater harvesting increases yield of maize (in Same area) by four fold of rain fed yield level, and two fold for rice (in Maswa area)(Ibid).

India has a long tradition of rainwater harvesting so much so that it is regarded as one of the dying tradition of the country[5]. However, it has been reviving apace in many parts of the country, particularly in rain scarce areas. Derwadi village, a village in the central state of Maharashtra, is one of such dry villages of India. A remote village with no assurance to drinking water, with farming being mainly rain fed based and agricultural production can't meet more than three-month food of the village, Derwadi used to be a desperate village with no employment opportunity for the community and where schooling is a distant dream for the kids of the community. The villagers established a link with an

[5] *This document on India's experience is obtained from website www.rainwaterharvesting.org/rural, where an interesting account of experience with rainwater harvesting in more than 20 Indian villages is presented.*

Indo-German watershed Development NGO called Watershed Organization Trust (WOTR), which later assisted them to construct contour trenches, farm and contour bunds, and check dams. A degraded land then stared to provide adequate water both for drinking and for irrigation, thus paving the way for transformation of the lives of the villagers.

They not only managed to diversify from traditional pearl millet to other host of crops ranging from various vegetables to cotton, but also managed to produce the crops in surplus and be able to sell, perhaps for the first time, to big towns. They managed to send their kids to school. With the help of the NGO they also managed to form self help association that enabled them to organize and carry out such activities as construction of toilet, kitchen garden and improved cocking devices.

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

In Middle East, rainwater harvesting is thought to have existed about 9000 years ago in Jordan, and about 4000 years ago the Negev Desert of Israel (Nasr, 1999). Coming to Ethiopia, the history of rainwater harvesting is dated back to 560 BC in the tip Northern Parts of the country and to 15th to 16th century in Gonder area. In the south of the country, the Konso people "have had long and well established tradition of building level terraces to harvest rain water to produce sorghum successfully under extremely harsh condition"(Getachew ,1999).

Though it has long history in the country, it is only recently that rainwater harvesting has started to receive significant attention from Ethiopian government. It has been regarded as one of the crucial tools to achieve food self-sufficiency, and is being implemented on a large scale particularly in water scarce areas of the country. As the phenomenon is quite recent, detailed study hasn't been made. However, some preliminary studies have been made on some parts of the country. Rami (2003) is one of such studies, and is basically an account of two weeks field visit in Amhara and Tigray regions. The emphasis is mainly on rainwater harvesting implementation related problems in the regions and the prospects of using it for the stated objective of attaining food self-sufficiency. It has been found that RWH is top of the agenda in the two regions, as is the case at national level, with some times over ambitious plans of constructing wells and ponds.

The success in attaining the planed amounts of tanks and ponds to be constructed and the perceptions of the beneficiaries are found mixed. Shortages of required construction raw materials, lack of timely dispersal of finance and shortage of skilled labor have been among the factors inhibiting the attainments of the stated goals. This is evident from Amhara region where it once was planned to construct 29005 tanks made of cement and plastic and 27955 wells were excavated for the purpose but only 12614 tanks were constructed. Furthermore, the tanks constructed so far are found to be substandard, many collapsed and majority leak and seep water, the main factor being lack of experienced masons and supervisors and mismatch between the type of soil in the area and the tank construction method. The tanks were first tested in Adama area and implemented in the two regions, with basically different soil structures from Adama area, without-taking into account the specificities of the two regions (Rami, 2003). In addition, most of the construction was assigned to each Woreda as a quota resulting in less attention being paid to quality as compared to number. Further, the implementation tended to be top-down approach, particularly in Amhara region, and this has also contributed its share to the problems (Ibid).

Besides, rainwater harvesting is found to have undesirable, but not unexpected, health side effects. For instance many people and livestock have been drowned into the tanks and ponds, with often no fences and live saving mechanisms like ladder and ropes (Ibid). It is also cited by people living near the ponds as a source of malaria out break. However, it doesn't mean that rainwater harvesting didn't have any positive effects on the community. It has enabled them to grow crops of short growing periods like vegetables. And some have had good experience, as is the case in Tigray region where, for instance, "a farmer and his wife were able within a single season to pay their old extension credit of more than 1000 Birr through the planting and sale of vegetables (cabbages, tomatoes, beans and peppers) (Ibid). The upshot is that rainwater harvesting is beset with challenges and can be an utter failure and end up in undesirable negative consequences if not cautiously approached. However, it can play immense role in helping attain food security if implemented with thorough consultations with the beneficiaries and is accompanied with other activities like afforestation and soil conservation and fertility enhancing practices.

The econometric approach has some limitations in accurately and fully measuring the changes resulting from NRM interventions, especially those changes which are non-quantifiable. Hence, as a remedy to the shortcomings of the econometric approach, at present ,researchers like Kerr et.al (2005) are advocating that better results could be obtained using an integrated quantitative and qualitative approach in assessing the impact of NRM interventions.

Kerr et.al (2005) employed quantitative analysis (as with and without design mainly employing instrumental variable approach) and also qualitative information to better understand interest in relation to relevant research questions, and to identify the projects' unintended consequences in evaluating the performance of watershed projects in India. Specifically, the study tries to identify: the successful projects, the approaches adopted which lead to the success and additional characteristics of particular villages' contribution to achieve improved natural resource management, higher agricultural productivity, and reduced poverty. The results of the study show that in both of the states, participatory projects combined with sound technical inputs performed better as compared to technocratic, top-down counterpart. Evidence also found on the existence of potential poverty alleviation trade-off during an effort to increase agricultural productivity and conserve natural resources through watershed development. Particularly, the empirical result indicates the existence of strong evidence on the skewed distribution of benefits towards largest land holders in projects, which are more successful in both conservation and productivity .The short-term costs imposed on 'losers' (i.e. the poor) may be substantial and projects would gain from a greater focus on mechanisms to share projects benefits (Shiferaw et.al, 2003).

Apart from the qualitative analysis approach used in the early periods, the literature on quantitative analysis approaches for assessing the impact of natural resource management policy or technology interventions can include the econometric approach, and bio-economic model (link economic behavioral models with biophysical data to evaluate potential effects of new technologies, policies an market incentives on human welfare and the environment) (Shiferaw et.al, 2003).

The commonly applied method in natural resource management intervention impact assessment, i.e., the econometric approach, is developed by linking the measures of current output, cost or profits directly to past research investments. In this approach, either a primal function, based on estimated production function, or a dual function, using a profit or cost function and their related system of supply and factor demand functions are employed. In general, once the econometric approach is adopted, the impact of the natural resource management technology or policy intervention is obtained by translating the parameter estimates of the function used, into economic benefit value (Shiferaw et.al, 2003).

For instance, Pender et al. (200l) employed a structural econometric approach, to explore the impact of land management and investment on the value of crop production in Uganda .The data for the analysis obtained from a survey of 451 households. Selected regressors include several variables at the village, household and plot levels. The study has shown that improvement in land management can lead to higher productivity and lower land degradation. Participation in technical assistance programs, pursuit of certain livelihood strategies, investment in irrigation, and promotion of more specialized production of cereals or export crops are found to achieve “Win-Win” outcomes, increasing agricultural productivity while reducing land degradation. The results of the study don’t support the optimistic ‘more people-less erosion’ hypothesis, though the results are consistent with population induced agricultural intensification', as hypothesized by Boserup. In addition it indicates the need to make further research to identify profitable as well as sustainable land management options, as no land management practices except irrigation were found to be very profitable in the short-run (Shiferaw et.al, 2003).

Gebremedhin et al.(2002, 2000), have applied an econometric analysis to examine the nature and impact of community woodlot and grazing land management's respectively; and identify the determinant factors of collective action and its effectiveness, in Tigray, Ethiopia. Empirical results of the analysis indicated that, more collective action exists manage community woodlots in areas with intermediate population density. In relation to community grazing land management, results from the regression analysis depict that, while population pressure has resulted in reduction of violations of use restrictions of grazing land in areas with low and intermediate level of population density, intermediate population pressure has the tendency to reduce the development of use restrictions and the enforcement of penalties (Gebremedhin et.al, 2000). Besides, while negative relationship has been observed between communities access to market and household's contribution to collective action, tree planting, and the survival rate of trees (Gebremedhin et.al, 2002). However, the result from both studies reveal that, the presence of external organizations is negatively associated with the probability of community payment to guard, survival rate of trees, and collective action for grazing land management Gebremedhin et. al (2002, 2000).

Holden et. al (2004) have applied a bio economic model to assess the potential of food-for-work programs to contribute to poverty reduction and natural resource conservation in the long run, in northern Ethiopia, particularly Tigray, using household level data. Specifically, the study had tried to explore how the out comes of food-for-work programs depend on the design of the program, market, and technology characteristics. Besides, it tries to indicate how such programs may crowed out or crowed in private investments and reveal factors that may pull in different directions. Two bio economic models were employed in the study. The first one a simple static model of a farm household, is developed to examine the effects of FFW participation on household labor allocation to farming activities in an environment of missing markets for labor and land. The second one which is the dynamic, non separable household bio-economic model was developed to explore the dynamics of household welfare, land use patterns, and investment in soil conservation. Specially, the latter model is developed to assess the impact of FFW under three distinct scenarios such as when FFW employment is directed outside agriculture, when FFW employment is provided for conservation investment within agriculture, where in both cases it is assumed that access to off-farm employment is constrained and that conservation investment does not reduce initial yields. Finally, the third scenario is like the second scenario, but with no constraint to off-farm employment and with conservation investment reducing initial yields.

The results of the study indicate that although FFW programs have the potential to contribute for long-run development in an environment with imperfect or missing markets, poor design and implementation may easily reverse the results. In addition to this, the simulation results from the dynamic model depict that FFW programs targeted outside agriculture may reduce incentives for agricultural production and land conservation and therefore have negative crowding out effects. However, the study reveals that if FFW program is targeted at investment in land conservation, it may improve agricultural production in the long-run and lead to more sustainable production. Besides, it shows that conservation effect of FFW may be higher when the private incentives for conservation are lower (Ibid).

Thus linkage can be seen between the method that is applied in the study and the revised literature review related to methodology. The linkage is related to the application of both quantitative and qualitative analysis which will help to increase the validity ad reliability of impact assessment.

CHAPTER FOUR

CONCEPTUAL FRAMEWORK, RESEARCH HYPOTHESIS AND METHODOLOGY

4.1 Conceptual Framework

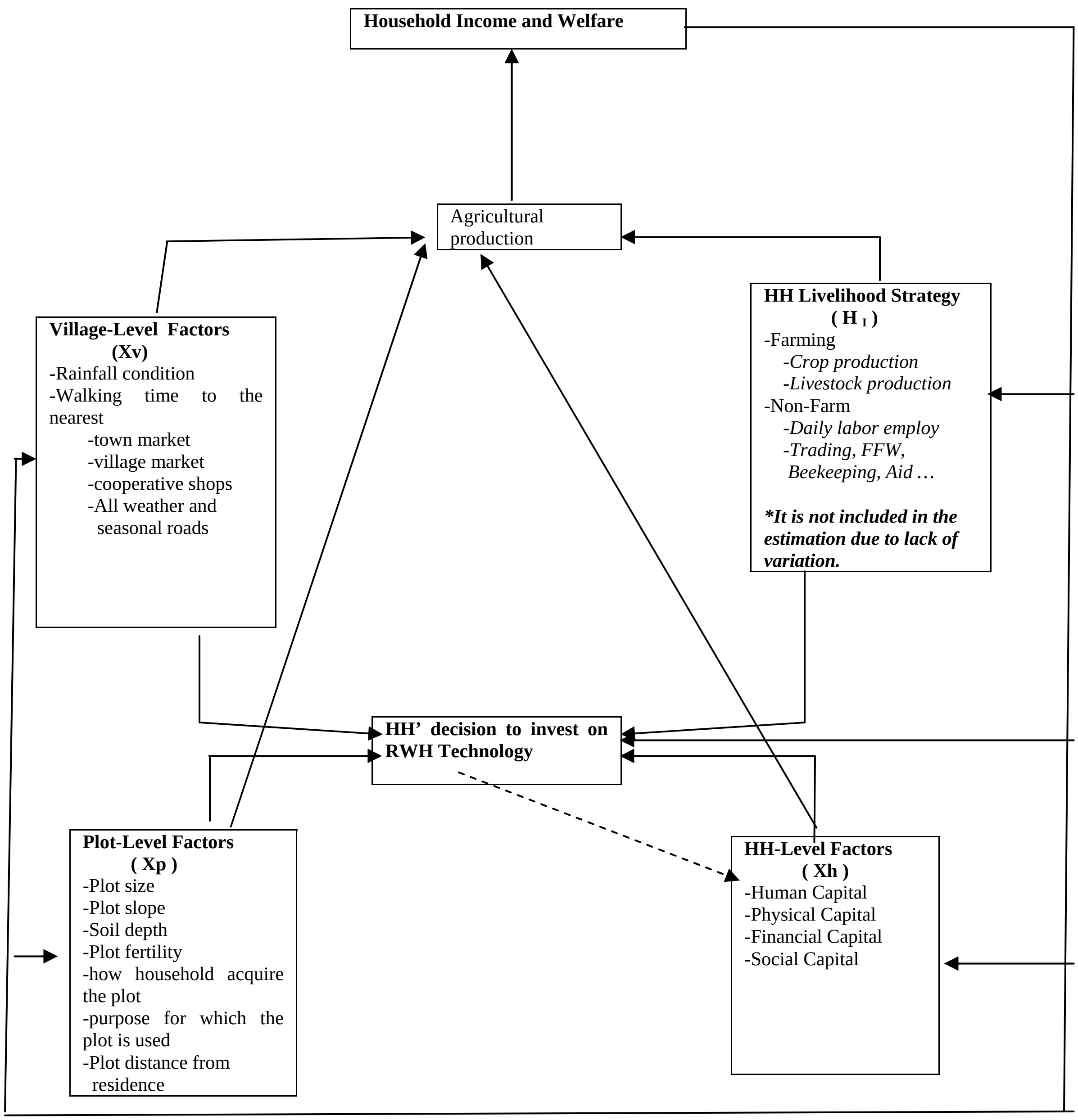


Figure 4.1 Schematic presentations of the relationships and interdependence among the various factors, agricultural output, and household income and welfare.

Key: Dashed line represent indirect impacts of factors on yield.
Solid lines show direct impact of factors on yield and RWH technology adoption decision.

The conceptual framework is illustrated in figure 4.1. It shows the interrelationship among the various household-level, plot-level, village-level factors, the farm household's livelihood strategy, the farm household's production decision, and the decision to invest on RWH ponds. A farm household's decision on agricultural input use and adoption of RWH ponds could be influenced directly by the household-level characteristics, plot and village level characteristics. Adoption decision is also affected by the pond type. The type could be of plastic covered or concrete basement. The agricultural input use is affected by the decision to adopt RWH ponds. Agricultural production decision is affected not only by the household, plot and village level characteristics but also by the agricultural input use and the decision to adopt RWH technology.

The household factors, which could influence the farm household's decision on input use, agricultural production decision and adoption of RWH technology includes human capital (sex of household head, household size and educational status), physical capital (land ownership, livestock and asset endowment), social capital (type of local organization and type of association that the household head is involved in), and financial capital (household's saving and credit need, access and obtained).

The household's decision could also be affected by plot-level factors. Plot level factor includes (how the household acquire the plot, purpose for which plot is used, slope category of each plot, land quality or soil fertility, soil depth of each plot, plot size in hectare and walking time from home to plot in hours). In addition to this, there are also village level factors, which could influence the farm household's investment decision (the rainfall condition and access of the village to town market, village market, transportation facility, and roads).

The technology adoption decision could increase the farm household's agricultural yield by improving the availability of water during the dry spell periods. It has also the potential to increase the moisture of the soil and thereby improve the fertility of the soil, which in turn has an impact to increase the agricultural yield harvested.

Agricultural productivity can be directly affected by farm household's decision to adopt rainwater harvesting technology, or can be indirectly affected by the technology through the use of inputs. The existing land tenure system in the country may influence agricultural productivity indirectly through its effect on the farm household's decision to invest on RWH technology and use of inputs such as fertilizer and improved seed. Moreover, as can be depicted from the figure, household-level factors could affect agricultural productivity indirectly through farm household's decision on the use of inputs and adoption of RWH technology.

Generally, all household, plot and village level factors can directly be affected by household income and welfare condition. And the household income can be affected by the agricultural production.

4.2 Research Hypotheses

In this study hypothesis concerning the linkages among household, village and plot level factors with the technology adoption decision of households is considered. In addition, hypothesis on the linkage between farm household's decision to invest on RWH ponds and its impact on agricultural yield is included.

<u>Household level factors</u>

1. Household Human Capital

The adoption of RWH ponds require large amount of labor especially during construction. Thus, household size is expected to have positive relationship with a decision to invest on the intervention. In addition, educational status of household head is expected to have positive relation since educated people are more open to accept new innovations and technology interventions than illiterate once. The age of the household head is expected to bring negative relationship since aged people are expected to supply less labor. In the case of marital status (take married ones) it is expected to find positive relationship since they usually will have large household size to participate in the labor supply. The direction of the relationship between the sex of the household head and the decision to adopt RWH technology is expected that female headed households will have a negative impact. This is because female headed households have less resource and manpower.

Generally, it can be concluded that the influence of household human capital factors on the investment of RWH technology is mixed.

2. Household Physical Capital

As it was observed in the field work, most of the ponds constructed were very close to the households home regardless of the impacts like health problem, accidents etc that can occur to the household. Hence, any investment decision on farm land is directly related with ownership of the land. Moreover, the adoption of RWH technology requires large resources, thus farm households, who have better physical assets (like cattle, oxen, Sheep and goat, Pack animals, poultry, beehives and different assets owned by the household) are the ones who are more likely to invest on such technology interventions, than households who lack or with few physical assets. Hence, physical capital is expected to have positive relationship with investment decision on RWH technology.

3. Household Social Capital

The membership of household heads in local organizations (like edir, equb, marketing cooperative, saving and credit cooperative and Relatives money saving etc) and associations (like peasant, women, and youth associations) are expected to have a positive influence on the farm household's decision to invest on RWH technology. For instance, rural development programs and/or technology intervention schemes launched by government, non government organizations; research institutions and other interested party use local organizations and associations as ways of reaching the farm households. Therefore, being a member of any local organization and/or association could make the farm household learn and be easily convinced, by another farm household, who is a member in same organization or association and has adopted the technology intervention.

4. Household Financial Capital

It is expected that the amount of saving by household and credit obtained will have positive impact to be involved in the investment activity. However, we should note the difference in obtaining, need and access to credit since those who need and have access to credit may not obtain credit. Those who need may not have access and from those who have access some may not be interested to obtain credit due to different reasons like shortage of money for pre-payment, fear of credit etc or due to insufficient supply of seed, cash or fertilizer credit.

The major village level factor

Access to market, transportation, and roads

The village or household access to market, transportation, and roads is expected to be directly related with a farm household's decision to adopt RWH technology.

Plot Level Factors

If the RWH technology is constructed on the plot, some portion of the plot will be covered by water, and this decreases the area of the cultivable farm land, and there by the amount of yield that could otherwise be harvested from the total area of the plot. Besides, if the distance from the plot to the farm household residence is very long, members of the household may be discouraged, to fully use the available family labor power during watering and to efficiently use the water accumulated. This in turn may decrease the interest of the farm household to invest on RWH technology. Farm households with steep slope plots are expected to show greater interest in adopting this technology since with increase in the slope the level of runoff and erosion increases, and also the level of soil depth and water or moisture holding capacity of the soil decreases.

Rainwater harvesting ponds

A farm household's decision to invest on RWH technology as a supplementary source of water in crop production is expected to have a positive impact on the amount of agricultural yield harvested and/or the household's level of income and there by welfare of the household. This is expected because the adoption is expected to improve the level of income and welfare of a farm household either by increasing the amount of yield harvested, or increasing the number of harvesting times per year, and/or by influencing the farm household to produce agricultural commodities with high market value.

METHODOLOGY

The wider range influence and complexity in the transmission mechanism of technology interventions aimed at improving agricultural productivity, on the well being of the society and the ecology, has posed methodological difficulties on impact assessment researches. According to Shiferaw et.al (2003), the basic methodological problems are related with

> “Interrelationships among natural resources, spatial and temporal dimension of impact, and valuation of environmental benefits and costs.”

Qualitative approaches are increasingly used in conjunction with quantitative approaches and such combinations can enhance the validity and reliability of impact evaluations. While quantitative approaches allow statistical tests for causality and isolation of programme effects from other confounding influences, quantitative methods excel at answering impact assessment questions about ‘what’ and ‘how much’, whereas qualitative methods are preferred for exploring questions of ‘how’ and ‘why’. A mix of quantitative and qualitative approaches is ideal because it provides the quantifiable impacts of the intervention as well as an explanation of the processes and relationships that yielded such outcomes (Shiferaw et.al, 2005).

4.3. Description of the Study Area, Data Source and Sampling

The data for the analysis is obtained from a household and plot level survey in Alaba Woreda. The Woreda is located 310 km south of Addis Ababa and about 85km southwest of the Southern Nations Nationalities and Peoples Regional (SNNPR) state capital of Awasa. The Woreda is geographically located $7^{0}17'$ N latitude and $38^{0}06'$ E longitude. It is located west of Oromiya region, north of Hadiya (Sike), east of Kembata Tembaro, south east of Silte and Hadiya zones. It is a special Woreda and has a special status where the administration directly reports to the regional state. There are 73 peasant and 2 urban associations. Alaba Kulito, the capital of the Woreda, is believed to have been found towards the end of the 20th century. According to the recent Woreda population reports

(2004/2005), the total Woreda population is 210,243, out of which 104,517(49.7%) are male and 105,726(50.3%) are female (IPMS, 2005)

The Woreda ranges from 1554 to 2149m asl, but most of the Woreda is found at about 1800m asl. Except for few hills, the Woreda has an agriculturally suitable flat land. Rainfall is a major limiting factor in agricultural production in the area. Agro ecologically, most of the Woreda is classified as Weina Dega .The annual rainfall varies from 857 to 1085 mm, while the annual mean temperature varies from 17^0C to 20^0C with mean value of 18^0C .The area receives a bimodal rainfall where the small rains are between March and April while the main rains are from July to September (IPMS, 2005)

According to FAO classification system the major soils of the woreda are Anosol (ferralic), Andosol (Orthic), Chromic Luvisols (Orthic), Phaeozem (Orthic), Solonchak (Orthic). The most dominant soil of the woreda is Andosol (Orthic) which is followed by Phaeozems (Orthic) and Chromic Luivisols (Orthic) in the second and third order. The soils of the area are believed to be relatively fertile and during good rains farmers can harvest good yield even without fertilizer application. The total area of Woreda is 64,116.25 ha of which 48,337 ha (75%) are considered suitable for agriculture.

Table 4.1. Land use type with its area coverage.

Land use	***Area coverage (ha)***	***%age***
Arable land	44,020.00	68.6
Grazing land	4,316.95	6.7
Forest	4,592.00	7.2
Potentially cultivable	3,644.50	5.7
Uncultivable land	2,805.00	4.4
Others	4,737.80	7.4
Total	64,116.25	100

Source: Alaba Special Woreda Rural Development cited in (IPMS, 2005)

A total of 152 households which are selected using a stratified sampling technique have been surveyed. Based on farming system practiced, the 73 peasant associations in the Woreda are stratified in to two, namely 43 peasant associations with Teff/ Haricot Bean Livestock and 30 peasant associations with Pepper/ Livestock farming system. From each stratum 2 peasant associations were selected randomly and the households within each of the four peasant associations were further stratified by adoption of RWH technology. In the end, from each of the four randomly selected peasant associations, a total of 38 households were randomly selected, where 19 of the farm households adopting the technology and 19 farm households without the technology stratum. Therefore, the survey is conducted on 152 households in four peasant association. The two peasant associations are Hamata and Andgengna Hansha, from Teff / Haricot Bean /Livestock farming system, and the other two peasant associations are Ulegebba Kukke and Mudda Dinokossa from Pepper/ Livestock farming system.

A semi-structured questionnaire has been employed to interview household heads. Besides, group discussion has been undertaken on Indigenous water harvesting technology in eight peasant associations , namely, Kobbo Getto, Andgegna Teffo, Mejja, Chobare Meno, Uletegna Mekalla, Uletegna Hansha, Dinokosa and Wishamo. In the discussion the participants ranges from 10 up to 14 in number and it was tried to make the number of female and male participants to be equal. In addition, even though gender related issue has been included in the household level questionnaire, to supplement our information, group on gender issues discussion has been done in 1st Teffo and Hamata peasant association. Furthermore, interview with experts working in the agricultural office has been under taken. Finally, it should be noted that secondary data was also used from publication, books, articles etc to supplement the data.

4.4. Descriptive Analysis Approach

This part mainly focuses on analyzing the descriptive statistics of the whole data. Specifically, the data mainly contains information regarding household's socioeconomic characteristics. At the household level human capital information like sex, age, household size, marital status, and religion and education status of the household are observed. And under the village level information it includes access to social services and infrastructure, such as seasonal and all-weather roads, town and village markets, cooperative shop and bus station with the rainfall trend or condition being included. This part also includes the financial capital situation of the household, credit access in addition to the saving condition of the household and also the social capital of local organizations and associations. Physical capital endowment such as land and livestock owned in addition to asset ownership of the household is seen. Besides, household's decisions with regard to the use of inputs (labor, seed, oxen, fertilizer, manure or compost and crop choice) are analyzed.

The data includes various features of plot-level factors, mainly with respect to the slope, soil depth, soil fertility, land use, how the household acquire the plot, the plot size and the distance of the plot from the farm household's residence. Besides, based on the farming system crop patter of farm household's has been assessed.

4.2 Description and Measurement of Variables included in the model

Variable Name	Definition and Measurement	No of observation	Frequency (%age)	Mean (Standard error)	Minimum	Maximum
Village – level Factors Peasant association or kebele	Dummy variable for Peasant association or kebele with, % of hhs					
	1= Hamata 2= Andgengna Hansha 3= Ulegebba Kukke 4= Mudda Dinokossa	152 152 152 152	38(25) 38(25) 38(25) 38(25)			
Household access to services and infrastructure	Walking time from the farm household's residence to the nearest, (in hrs.)					
	Town market Village market Cooperative shops All weather road Seasonal road	152 152 152 152 152		2.5674 (.1) 1.2698 (.084) 1.0160 (.053) 1.1167 (.1) .3215 (.028)	.67 .10 .10 .03 .02	8. 33 6.00 3.00 11.50 2.00
Rain fall condition						
	High Medium Low	152 152 152	36 (23.7) 102 (67.1) 14 (9.2)			
HH – level Factors						
	HH – Human Capital					
	Household size, no	152		7.02 (. 24)	0	19
	Age of HHH, Yr	152		42.5(. 95)	20	75
	Dummy variable for Education level of the farm household head with					
	1= Illiterate 2= read and write 3= up to 4th 4=up to 7th 5=up to 10th	152 152 152 152 152	67 (44) 19 (12.5) 25 (16.4) 25 (16.4) 16 (10.5)			

	HH- Physical Capital endowment				1.00	95.00
	Land owned, ha	152		8.67 (.72)	.00	8230.00
	cattle value(local and cross breed),birr	152		1443.95 (106.58)	.00	4270.00
	oxen value (local and cross breed),birr	152		1183.48 (82.89)	.00	1660.0
	value of sheep and goat owned, birr	152		257.44 (27)	.00	4070.00
	Pack animals value (donkeys, mules, horses , & camels),birr	152		314.99 (45.27)	.00	326.00
	Value of poultry, birr	152		41.01 (4.67)	.00	630.00
	Value of beehives, birr	152		35.68 (7.96)	.00	15405.00
	Value of all assets owned, birr	152		373.22 (105.8)		
	HH – Social Capital endowment					
	Dummy variable for household membership in local organization					
	1= Edir only	152	140 (92.1)			
	2= Edir and other local organizations	152	12 (7.9)			
	Dummy variable for household membership in association					
	1=non member in association	152	21 (13.8)			
	2= membership in association	152	131 (86.2)			
	HH – Financial Capital endowment					
	Dummy variable for HH Credit access with, 1=Yes, % of hhs	152	116 (76.3)			
Plot – level Factors						
	Dummy variable for How the household acquired the plot with					
	1= Allocated by the state	1036	483 (46.6)			
	2= Inherited	1036	430 (41.5)			
	3= rent and share cropping	1036	123 (11.9)			
	Dummy variable for slope of the plot with, *% plots*					
	1= Flat	1036	750 (72.4)			
	2= Moderate	1036	280 (27)			
	3= Very Steep	1036	6 (.6)			
	Dummy variable for Soil depth of the plot with, *% plots*					
	1= Deep	1036	43 (4.2)			
	2= Medium	1036	857 (82)			
	3= Shallow	1036	136 (13)			

	Dummy variable for Soil fertility level of the plot with, % plots					
	1= High fertility 2= Moderate fertility 3= Infertile	1036 1036 1036	99 (9.6) 780 (75) 157 (15)			
	Dummy variable for the purpose for which the land is used with, % plots					
	1= Rain fed Cultivation (Cropland) 2= Homestead 3=grazing land, spices, waste land and woodlots	1036 1036 1036	773 (74.6) 149 (14.4) 14 (11)			
	Plot size, in ha.	1036		.3744 (.011)	.03	5.00
	Walking time from the farm household's residence to the plot, in hrs.	1036		.1951 (.007)	.02	2.00
Rainwater Harvesting Technology	Dummy variable for household adoption of RWH technology in the plot in 2005/06 agricultural production with, % plots (Use of RWH technology, 1=Yes)	1036	72(6.95)			
Use of inputs	Total value of inputs used per each plot in 2005/06 agricultural production (in birr)					
	value of Labor power used, (person-days/ha) value of Oxen power used, (oxen -days/ha) value of Seed used, (Kg/ha) Dummy variable for household use of fertilizer with, 1=Yes, % plots Dummy variable for household use of Manure/Compost with, 1=Yes, % plots	1036 1036 1036 1036 1036	 495 (47.8) 242 (23.4)	500.26 (19.85) 182.43 (4.82) 220.19(88.61) 495 (47.8) 242 (23.4)	16.00 10.00 1.80	8933. 3 1333. 3 74400
Value of Crop Yield	The value of agricultural output produced per plot in 2005/06 agricultural production year, (birr/ha)	1036		1095.02 (35.12)	20.00	14933.3

4.5. Model Specification and Econometric Analysis

Since there is no predetermined model that can be used in the quantitative estimation, following Pender and Gebremedhin (2004), models for the use of inputs on each plot (from equation 2 up to equation 6); adoption of RWH ponds (equation 1); and the value of crop production on each plot in 2005/06 (from equation 7 to equation 9) are adopted in this study.

4.5.1. Dependent Variables

- Though many inputs could be listed, which are used in crop production, the main inputs used in crop production and which are analyzed in this study include labor days/ha which includes hired, family, on share cropping bases and on exchange of labor (**L**), oxen power days/ha (**O**), seeds kg/ha(**S**), use of fertilizer (F), and use of manure or compost (**M/C**). A farm household's decision in the allocation of its resource endowment either on the variable inputs used for agricultural production or other opportunities, or its decision on the amount used for the various inputs in crop production depends on several factors.
- To identify the determinant factors that influence the farm households' decision to adopt or invest on RWH ponds ($\mathbf{RWH_p}$)
- The value of crop production of household h from plot p(**Y**)

4.5.2. Explanatory Variables

1. Household- level factors($\mathbf{X_h}$)
    - Human capital (demographic features) - age, household size, educational status.

- Physical capital - land holding, value of all assets owned, value of livestock which includes oxen, packed animals, poultry, cattle etc.
- Social capital- membership in local organization and associations.
- Financial capital-households saving and credit access.

2. Village-level factors ($\mathbf{X_v}$) includes:
    - Indicators of agricultural potential: rainfall condition(here due to lack of adequate information at PA level, during estimation, location dummies has been used in order to capture the difference in rainfall, altitude, population density and other environmental factors for the four PAs included in the study).
    - Household access to services and infrastructure: walking time from the farm household's residence to the nearest input/ output town market, village market, Cooperative shops and all-weather and seasonal road.
3. Plot-level factors ($\mathbf{X_p}$)- Natural capital
    - Indicators of quality of the plot (size of plot, slope of the plot, soil depth, soil type and soil fertility of the plot), how the household acquired the plot, the purpose for which the plot is used and walking time from farm household's residence to the plot in hours.

4.5.3. Model Specification and Estimation issue

To identify the determinant factors that influence the farm households' decision to adopt RWH pond or to invest on various types of RWH ponds, a probit model is estimated.

Hence, a ***RWHp*** dummy variable (where 1=household with RWH technology and 0=household without RWH technology) is modeled as a function of village-level factors (X_V), plot-level factors (X_p), household-level factors (X_h) and pond type which can be plastic covered or concert basement (**P**).These can be written as follows:

$$\mathbf{RWHp = f (X_V, X_P, X_h , P) \ldots\ldots. (1)}$$

In the crop production regression and input use regressions, a logarithmic Cobb-Douglas specification is used. This leads to a theoretically consistent specification for output and input demands, and reduces problems due to outliers and non-normality of the error term found when using a linear specification (Pender and Gebremedhin, 2004).

Thus, the use of inputs – Labor days/ha (**lnL**), Oxen power days/ha (**lnO**), Seeds kg/ha (**lnS**), use of Fertilizer (**F**), and use of Manure/Compost (**M/C**), are modeled as a function of explanatory variables including village-level factors ($\mathbf{X_V}$), plot-level factors ($\mathbf{X_p}$), household-level factors ($\mathbf{X_h}$) and the predicted value of adoption of rainwater harvesting ponds (**RWHp**).The models for the variable inputs can be written as follows:

$$\mathbf{lnL = f (X_V, X_P, X_h, RWHp) \ldots\ldots. (2)}$$

$$\mathbf{lnX_K = f (X_V, X_P, X_h, RWHp) \ldots\ldots(3)}$$

$$\mathbf{lnS = f (X_V, X_P, X_h, RWHp) \ldots\ldots. (4)}$$

$$\mathbf{F \;\; = f (X_V, X_P, X_h, RWHp) \ldots\ldots. (5)}$$

$$\mathbf{M/C= f (X_V, X_P, X_h, RWHp) \ldots\ldots. (6)}$$

*Where, **ln** stands for logarithm*

The econometric model used depends on the nature of the dependent variable. For use of labor, oxen power and seeds on cultivated plots, the least squares regression is used while the regression equations for the variable inputs, fertilizer and manure/compost, Probit model is used since the dependent variable is dummy variable.

Finally, in assessing the impact of RWH ponds on agricultural output, the value of the agricultural output harvested from a plot is modeled in three different alternatives. First, a full model of the value of crop production from a plot is modeled as a function of village-level factors (X_V), plot-level factors (X_p) and household-level factors (X_h). Besides, the use of variable inputs Labor (**ln*L***), Oxen power (**lnO**), Seeds (**ln*S***), Fertilizer (***F***), Manure or Compost (***M/C***) and the predicted value for adoption of RWH ponds (***RWHp***) are included.A full model of the value of crop production from a plot can be written as follows:

$$LnY= f\,(lnL, lnO, lnS, F, M/C, X_V, X_P, X_h, RWHp) \;\ldots\ldots\; (7)$$

However, in the second regression, household-level characteristics (X_h) and adoption of RWH pond (***RWHp***) are omitted. This is because the effect of these variables on production may be indirectly through the use of inputs. Thus, the second - structural model of the value of crop yield is modeled as a function of all factor inputs by excluding household-level factors (X_h) and adoption of RWH pond (***RWHp***) from the regression. Thus the second model of the value of crop yield from a plot is given as follows:

$$LnY= f\,(lnL, lnO, lnS, F, M/C, X_V, X_P) \;\ldots\ldots\ldots\ldots\; (8)$$

The third model developed in this study for the value of crop production is a reduced-form equation, which includes all village-level, plot-level, household-level characteristics as explanatory variables and the predicted value for adoption of RWH ponds. However, it excludes the use of inputs like Labor (**ln*L***), Oxen power (**lnO**), Seeds (**ln*S***), Fertilizer (***F***) and Manure or Compost (***M/C)*** from the model. This specification can avoid the potential for endogenity bias. And also to examine the total effect of all factors on crop production, and whether it is a direct effect on production or indirectly through its effect on the use of inputs and adoption of RWH ponds.

The models for reduced- form specification of the value of crop production from a plot can be written as follows:

$$LnY = f\,(X_v, X_p, X_h, \mathrm{RWHp}) \ldots\ldots. (9)$$

In all cases, the least square regression was used to estimate the value of crop production.

Generally, one important point that should be noted is that, for equation 2,3,4,7 and 8 robust regression is undertaken to avoid the hetroskedasticity problem that was observed during estimation.

4.6. Qualitative Analysis Approach

These approach analysis the perception of experts and farmers regarding the constraints and opportunities of RWH technologies. The qualitative information was gathered using an open-ended question that was included in the questionnaire in order to augment the results of the econometrics analysis.

CHAPTER FIVE

SOCIO-ECONOMIC CHARACTERISTICS AND CROPPING PATTERN

5.1. Socio-Economic Analysis of Sample Households

The descriptive statistics for human capital of the household-level features are given in Table 5.1.The total sample households include 94.1% male-headed and 5.9% female-headed households. Besides, the households with RWH technology are all male-headed. The average family size for the sample households is about seven. The variation in mean family size among households in the two farming systems is very small, the variation among households "with and without" RWH technology is higher.

The mean age of household head in years for the combined sample is 42 .5, indicating farmers with more experience in farming are in the sample. As can be seen from the table, the mean age of household heads shows no variation among the two categories of farming systems and in those 'with and without' the technology.

As can be seen from the table below, large number of the households considered is shown to be married in both farming systems and all those who adopt the technology. Islam is the dominant religion.

Table5.1. Household characteristics distribution of human capital by farming system and adoption of RWH technology

HUMAN CAPITAL	*Teff /Haricot bean/ livestock*	*Pepper/ livestock*	***Total***	*HHs with RWH technology*	*HHs with out RWH technology*	***Total***
Sex						
Male	69$*_1$ 45.4% (90.8)$*_3$	74 48.7% (97.4)	**143** **(94.1)**	76(100)$*_2$	67 (88.2)	**143 (94.1)**
Female	7 4.6% (9.2)	2 1. 3% (2.6)	**9** **(5. 9)**		9 (11.8)	**9 (5.9)**
Household head age	42.5(1 .36)	42.5(1.36)	**42.5(0.95)**	42.32(1.43)	42.68(1.28)	**42.5(0.95)**
Household size	6.89$*_4$ (. 35)$*_5$	7.14(. 32)	**7.02(.24)**	7.7(.39)	6.34(.26)	**7.02(.24)**
Marital status of the household						
married	69 (90.8)	75 (98.7)	**144 (94.7)**	76 (100)	68 (89.5)	**144 (94.7)**
Single	3 (3.9)		**3 (2.0)**		3 (3.9)	**3 (2)**
widowed	2 (2.6)		**2 (1.3)**		2 (2.6)	**2 (1.3)**
divorced	2 (2.6)	1 (1.3)	**3 (2.0)**		3 (3.9)	**3 (2)**
Religion of the household						
Orthodox	2 (2.6)		**2 (1.3)**	2 (2.6)		**2 (1.3)**
Catholic	1 (1.3)		**1 (.7)**	1 (1.3)		**1 (.7)**
Islam	73 (96)	75 (98)	**148 (97)**	73 (96.1)	75 (98.7)	**148 (97.4)**
Protestant		1 (1.3)	**1 (.7)**		1 (1.3)	**1 (.7)**
HHH Education Status						
Illiterate	41 (53.9)	26 (34.2)	**67 (44)**	21 (27.6)	46 (60.5)	**67 (44.1)**
who read & write	10 (13.2)	9 (11.8)	**19 (12.5)**	14 (18.4)	5 (6.6)	**19 (12.5)**
with education level (from 2nd - 4th)	12 (15.8)	13 (17.1)	**25 (16.4)**	16 (21.1)	9 (11.8)	**25 (16.4)**
with education level (from 5th - 7th)	11 (14.5)	14 (18.4)	**25 (16.4)**	16 (21.1)	9 (11.8)	**25 (16.4)**
with education level (from 8th - 10th)	2 (2.6)	14 (18.4)	**16 (10.5)**	9 (11.8)	7 (9.2)	**16 (10.5)**

Source: Own survey and computation (for all tables included in the study).

$*_1$- The numbers out of the bracket shows number of observations in each category for discrete data (for all tables)

$*_2$- The percentage distribution of the variable from the total number of households with and without RWH technology (for all tables)

$*_3$- The percentage distribution of the variable from the total number of households based on the farming systems (for all tables)

$*_4$- In variables with continuous data the value represent the mean of the observation of the variable under consideration under the different farming systems and adoption of RWH technology (for all tables)

$*_5$- In variables with continuous data the values in brackets represent the standard error of the mean (for all tables)

A large percentage of the household heads are illiterate (*44 %*) while those who read and write account 1*2.5 %*. Those with formal education from grade two up to four and from grade five up to seven each account for *16.4 %* , with those from grade eight up to ten being 10.5%. In terms of education-wise distribution, households whose heads are illiterate show significant variation followed by those from grade eight up to ten within the two farming systems. In the "with and without" RWH technology categories, significant variation can be seen among households whose heads are illiterate followed by those who can read and write.

Table5.2. Household characteristics distribution of financial capital by farming system and adoption of RWH technology

FINANCIAL CAPITAL	*Teff /Haricot bean/ livestock*	*Pepper/ livestock*	***Total***	*HHs with RWH technology*	*HHs with out RWH technology*	***Total***
HH Credit Need						
Yes	64 (84.2)	64 (84.2)	**128 (84.2)**	66 (86.8)	62 (81.6)	**128 (84.2)**
No	12 (15.8)	12 (15.8)	**24 (15.8)**	10 (13.2)	14 (18.4)	**24 (15.8)**
HH Credit access						
Yes	60 (78.9)	56 (73.7)	**116 (76.3)**	59 (77.6)	57 (75)	**116 (76.3)**
No	16 (21.1)	20 (26.3)	**36 (23.7)**	17 (22.4)	19 (25)	**36 (23.7)**
Whether the HH obtained Credit or not						
Yes	41 (53.9)	38 (50)	**79 (52)**	45 (59.2)	34 (44.7)	**79 (52)**
No	35 (46.1)	38 (50)	**73 (48)**	31 (40.8)	42 (55.3)	**73 (48)**
HH with Savings						
Yes	28 (36.8)	31 (40.8)	**59 (38.8)**	34 (44.7)	25 (32.9)	**59 (38.8)**
No	48 (63.2)	45 (59.2)	**93 (61.2)**	42 (55.3)	51 (67.1)	**93 (61.2)**

Table 5.2 shows that the financial capital endowment of the sample households. As can be seen, 84.2% of the households need credit but out of these, only 76.3% have access to credit. Moreover, out of those with access only 52% obtain credit. The lower percentage of households that obtain credit could be due to shortage of money for prepayment, being afraid of credit, insufficient supply of credit, inability to repay back the previous credit and different other reasons. As shown in the table, lower variation in the percentage of households that need, access and obtain credit in farming categories can be observed. Of the 79 households who obtain credit, 45 of them have adopted RWH technology. In contrast 31 households have RWH technology from a total of 73 households that didn't obtain credit. In other words, of the total households with RWH technology, around 59.2% of them obtained credit indicating a possible positive association between credit obtained and adoption of the technology. On the other hand, from the total sample households, less than half of them (59 households) have savings. However, as can be seen from the table, about 58% of these households have adopted RWH technology.

Table5.3. Household characteristics distribution of social capital by farming system and adoption of RWH technology

SOCIAL CAPITAL	*Teff /Haricot bean/ livestock*	*Pepper/ livestock*	***Total***	*HHs with RWH technology*	*HHs with out RWH technology*	***Total***
Type of local organization						
Edir	68 (89.5)	72 (94.7)	**140 (92.1)**	69 (90.8)	71 (93.4)	**140 (92.1)**
Edir and marketing cooperatives		2 (2.6)	**2 (1.3)**	1 (1.3)	1 (1.3)	**2 (1.3)**
Edir and saving and credit cooperatives	2 (2.6)		**2 (1.3)**	2 (2.6)		**2 (1.3)**
Edir and equb in cash and kind	3 (3.9)	2 (2.6)	**5 (3.3)**	2 (2.6)	3 (3.9)	**5 (3.3)**
Edir and relative money saving	3 (3.9)		**3 (2.0)**	2 (2.6)	1 (1.3)	**3 (2)**
Type of Association that the HHH is involved						
No association	11 (14.5)	10 (13.2)	**21 (13.8)**	10 (13.2)	11 (14.5)	**21 (13.8)**
Peasant association (PA)	51 (67.1)	60 (78.9)	**111 (73)**	58 (76.3)	53 (69.7)	**111 (73)**
Peasant and women association	4 (5.3)		**4 (2.6)**		4 (5.3)	**4 (2.6)**
Peasant and youth association	10 (13.2)	5 (6.6)	**15 (9.9)**	8 (10.5)	7 (9.2)	**15 (9.9)**
Peasant, women & youth		1 (1.3)	**1 (.7)**		1 (1.3)	**1 (.7)**

As shown in table 5.3, the social capital includes household head involvement in associations and local organizations. Of the surveyed households, 92.1% of them are involved in Edir only and the remaining 7.9% of the households are involved in edir in addition to other local organizations like Equb, relative money saving, marketing cooperatives and saving and credit cooperatives respectively in order of their percentage level. Of the households involved in Edir, almost 50% of them adopted RWH technology. Among the different types of associations, peasant association is the dominant one accounting for 73% involvement of the total households. Around 53% of the households who are members of the peasant association adopt RWH technology.

Table5.4. Household characteristics distribution of physical capital by farming system and adoption of RWH technology

HH PHYSICAL CAPITAL ENDOWMENT	*Teff /Haricot bean/ livestock*	*Pepper/ livestock*	***Total***	*HHs with RWH technology*	*HHs with out RWH technology*	***Total***
Land owned (state allocated & inherited), ha	4.25 (1.35)	7.09 (.41)	**5.67 (.71)**	8.21(.79)	3.13 (1.2)	**5.67 (.71)**
Cattle (both local & cross bred), EB	1454.2(166.)	1433.6 (133.)	**1443(106)**	1835.197(171.95)	1052.697(109.99)	**1443.95(106.6)**
Oxen (both local & cross bred), EB	1046.2 (111)	1320.8 (121)	**1183 (82)**	1524.61(124.77)	842.36(94.86)	**1183.48(82.9)**
Sheep & Goats, EB	222.5 (35.6)	292.3 (40.5)	**257 (27)**	293.2895(39.13)	221.59(37.24)	**257.441(27.1)**
Pack animals (donkeys, mules, horses ,& camels), EB	365.9 (72.1)	263.9 (54.6)	**314.9 (45)**	405.368(67.63)	224.61(58.8)	**314.99(45.3)**
Poultry, EB	37.6 (6.2)	44.3 (6.9)	**41 (4.67)**	56.7368 (7.93)	25.276 (4.27)	**41.01 (4.67)**
Beehives (improved, modified, traditional), EB	46.6 (13.3)	24.7 (8.6)	**35.6 (7.9)**	50.9605 (13.93)	20.395 (7.4)	**35.68 (7.96)**
Assets Owned (plow ,farm equip ,motor pump, radio ,.), EB	484.8(205.8)	261.6 (49.2)	**373 (105)**	633.54(207.47)	112.91(16.2)	**373.22(105.8)**

Household resource endowments such as, land holding, oxen, cattle, pack animals, sheep and goats, poultry, beehives and assets owned are included in table 5.4. They vary both at farming system and in the “with and without” RWH technology category level. As can be seen from the table, the average land holding of the sample households is 5.67 ha, and shows some variation between farming system and in the “with and without” RWH technology category. Particularly, higher average land holding (8.21 ha) is seen among households with RWH technology relative to those without the technology (3.13 ha), which implies that those with wider land holding will probably be more initiated to adopt the technology.

With respect to farm household’s endowment of cattle (other than oxen), the average value of cattle endowment per household for the whole sample was 1443 birr. In addition, households with and without RWH technology have shown significant variation in terms of the average value of cattle owned per household. That is, the average value of cattle owned per household in the "with and without" RWH technology category was found to be 1835.197 and 1052.697 birr respectively. The endowment of oxen, which is the main agricultural resource for farm households in the area, varies among farming systems and in the "with and without" RWH technology. The average value of oxen owned per household for the combined sample was 1183birr. In relation to household endowment of sheep and goats, pack animals, poultry, beehives and assets owned, the average values of the resources owned by households were 257, 314.9, 41, 35.6 and 373 respectively. Generally, it can be concluded that among the physical capital endowments, the average value of cattle is the highest followed by oxen, asset owned, pack animal.

Table 5.5.Household access to market and other service by farming system and adoption of RWH technology

VILLAGE LEVEL FACTORS	Teff /Haricot bean/ livestock	Pepper/ livestock	**Total**	HHs with RWH technology	HHs with out RWH technology	**Total**
Rainfall trend or condition in the area						
Low	10 (13.2)	26 (34.2)	**36 (23.7)**	18 (23.7)	18 (23.7)	**36 (23.7)**
Medium	61 (80.3)	41 (53.9)	**102 (67.1)**	51 (67.1)	51 (67.1)	**102 (67.1)**
High	5 (6.6)	9 (11.8)	**14 (9.2)**	7 (9.2)	7 (9.2)	**14 (9.2)**
Walking time to the Nearest (round trip in hours)						
town market	2.9 (.15)	2.23 (.014)	**2.56 (.10)**	2.6425 (.14)	2.4923 (.15)	**2.5674 (.10)**
village market	1.5 (.155)	1.04 (.056)	**1.27(.08)**	1.2936 (.12)	1.2461 (.11)	**1.2698 (.08)**
cooperative shop	1.19 (.078)	.832 (.066)	**1.02(.05)**	1.0474 (.08)	.9846 (.074)	**1.0160 (.05)**
Bus station	1.93 (.148)	2.19 (.15)	**2.06(.10)**	2.1272 (.15)	2.0037 (.14)	**2.0655 (.10)**
All weather road	1.02 (.087)	1.21 (.18)	**1.12 (.10)**	1.1009 (.11)	1.1325 (.16)	**1.1167 (.10)**
Seasonal road	.38 (.05)	.26 (.026)	**.32 (.028)**	.3436 (.046)	.2993 (.034)	**.322 (.028)**

Location of farm household's residence relative to the important infrastructure and services can be seen from Table 5.5. The combined sample mean for walking time to the nearest town market for a round-trip in hours is 2.57 which is the longest followed by bus station, village market, all weather road and cooperative shop respectively. However, seasonal road is the nearest of all the infrastructures and services depicted on the table by considering the combined sample mean under the farming system. Variation can be observed among the two farming systems where 2.9 being the highest in the town market of Teff farming system and 2.23 in pepper farming system. The least variation is observed in the seasonal road of 0.38 and 0.26 in Teff and pepper farming system respectively. On the other hand, variation in seasonal road for a round trip in hours is small in rainwater harvesting technology category next to all weather road. However, the highest variation can be observed for town market followed by bus station. Walking time to the nearest town market for RWH technology adopters is the highest which might reduce incentive to sell the product that the household start to produce using the technology. But the village market is found to be relatively closer. As in the above table, the rainfall trend in the areas that the survey was undertaken shows that medium rainfall condition dominates. And most of the households that adopt the technology are those with medium rainfall condition.

Table 5.6 presents the descriptive statistics for plot-level factors. Of the total 1036 plots, 46.6% is state owned (i.e., the plot is allocated by state) while 41.5% of the plot is inherited and 5.9% rented. The rest 6% is found on share cropping bases. As can be seen on the table, no household adopted the technology on land obtained by rent and on share cropping bases. Almost 50% of households with the technology adopt it on plot from state and 51.4% on inherited plots. In terms of the purpose for which the plots are used, 74.6% are plots used for crop production while 14.4% and 10.7% are homestead and spice plots respectively. Grazing, wasteland and woodlot constitute only 0.3% of the total. Moreover, of the plots with RWH technology, 95.8% are homestead plots and 80% of plots with out the technology are used for crop production. As shown in the table, Meher is the major season of harvest in both farming systems.

Table5.6. Plot - level characteristics distribution by farming system and adoption of RWH technology

Variables	*Teff /Haricot bean/ livestock*	*Pepper/ livestock*	***Total***	HHs with RWH technology	HHs with out RWH technology	**Total**
PLOT-LEVEL FACTORS						
How did the household acquire the plot						
the state	262 (51)	221 (42.3)	**483 (46.6)**	35 (48.6)	448 (46.5)	**483 (46.6)**
Inherited	212 (41)	218 (41.8)	**430 (41.5)**	37 (51.4)	393 (40.8)	**430 (41.5)**
Rent	21 (4)	40 (7.7)	**61 (5.9)**		61 (6.3)	**61 (5.9)**
Share cropping	19 (3.7)	43 (8.2)	**62 (6)**		62 (6.4)	**62 (6.0)**
Land use						
Crops(cereal)	381 (74)	392 (75)	**773 (74.6)**	2 (2.8)	771 (80.)	**773 (74.6)**
Homestead	75 (14.6)	74 (14)	**149 (14.4)**	69 (95.8)	80 (8.3)	**149 (14.4)**
Grazing	1 (.2)	1 (.2)	**2 (.2)**	1 (1.4)	1 (.1)	**2 (.2)**
Wasteland and Woodlot		1 (.2)	**1 (.1)**		1 (.1)	**1 (.1)**
Spices	57 (11)	54 (10)	**111 (10.7)**		111 (11.5)	**111 (10.7)**
Slope category of each plot						
Flat	413 (80.4)	337 (64.6)	**750 (72.4)**	55 (76.4)	695 (72.1)	**750 (72.4)**
Moderately steep	101 (19.6)	179 (34.3)	**280 (27)**	17 (23.6)	263 (27.3)	**280 (27.0)**
Very steep		6 (1.1)	**6 (.6)**		6 (.6)	**6 (.6)**
Land quality or soil fertility						
High fertility	50 (9.7)	49 (9.4)	**99 (9.6)**	32 (44.4)	67 (7.0)	**99 (9.6)**
Moderate fertility	441 (85.8)	339 (64.9)	**780 (75)**	38 (52.8)	742 (77.0)	**780 (75.3)**
Low fertility	23 (4.5)	134 (25.7)	**157 (15)**	2 (2.8)	155 (16.1)	**157 (15.2)**
Soil depth of each plot						
Deep	8 (1.6)	35 (6.7)	**43 (4.2)**	2 (2.8)	41 (4.3)	**43 (4.2)**
Medium	430 (83)	427 (81)	**857 (82)**	61 (84.7)	796 (82.6)	**857 (82.7)**
Shallow	76 (14.8)	60 (11)	**136 (13)**	9 (12.5)	127 (13.2)	**136 (13.1)**
Season of harvest						
Not applicable	3 (.6)	11 (2.1)	**14 (1.4)**	5 (6.9)	9 (.9)	**14 (1.4)**
Belg	48 (9.3)	50 (9.6)	**98 (9.5)**	9 (12.5)	89 (9.2)	**98 (9.5)**
Meher	428 (83.3)	421 (80)	**849 (81.9)**	34 (47.2)	815 (84.5)	**849 (81.9)**
Belg and Meher (permanent)	35 (6.8)	40 (7.7)	**75 (7.2)**	24 (33.3)	51 (5.3)	**75 (7.2)**
Plot size in hectar	.387 (.017)	.361 (.013)	**.374(.011)**	.1537 (.012)	.3909 (.011)	**.3744 (.010)**
Walking time from home to plot in hours	.185(.0089)	.204(.0101)	**.195(.0067)**	.052 (.002)	.2058 (.007)	**.1951 (.006)**

Furthermore, the mean size of each plot used is 0.374 ha, with high variation in the ‘with and without’ rainwater harvesting technology category and relatively lower variation among the farming system. With respect to walking time from plots to the farm household’s residence, the average walking time for the total sample is around twenty minutes with some variation between the farming systems (about 2 minutes). But, the variation in average walking time in the "with and without" RWH technology is a little bit larger (around 15 minutes).

With respect to plot slope the surveyed households were asked to classify their plots in three categories of flat, moderately steep and very steep. Hence, of the total 1036 plots, 72.4*%* of them are classified as flat while 27% and 0.6*%* are classified as moderately steep and very steep, respectively. Besides, of the plots with RWH technology, 76.4% are flat plots and 23.6% are moderately steep. In terms of soil depth, the households classified the plots in to deep, medium, and shallow representing *4.2%*, 82.7*%*, and 13.1% of the plots respectively. In addition to this, 84.7% of the RWH technology has been adopted in plots with medium soil depth .In relation to plot fertility level, which is based on the farm household's perception 75.3*%* plots are categorized as moderately fertile, 15.2% as poorly fertile and 9.6*%* as highly fertile. Moreover, most of the RWH technology has been adopted in plots perceived as moderately fertile (around 53%) followed by the highly fertile plots (44.4%).

Table 5.7 presents the descriptive statistics for farm households input use decision and level of yield harvested from each plot. Hence, the average value of seed used per hectare for the surveyed households is around 220birr with the highest variation observed among farming systems. However, the variation in the average value of seed among households "with and without" RWH technology is lower than the variation based on farming systems. Households with RWH technology are 111 birr higher in the value of seeds than those without the technology, possibly indicating an increase in the use of more seed by households with the technology. The mean value of oxen power-days for the combined sample is around 182.43birr with small variation among the farming systems and the “with and without” RWH technology categories.

Table5.7. Household input use and value of crop yield earned by farming system and adoption of RWH technology

Variables	Teff /Haricot bean/ livestock	Pepper/ livestock	**Total**	HHs with RWH technology	HHs with out RWH technology	**Total**
Household input use						
use of Fertilizer						
Yes	204 (39.7)	291 (55.7)	**495 (47.8)**	11 (15.3)	484 (50.2)	**495 (47.8)**
No	310 (60)	231 (44.3)	**541 (52.2)**	61 (84.7)	480 (49.8)	**541(52.2)**
use of Manure or Compost						
Yes	121 (23)	121 (23)	**242 (23.4)**	54 (75)	188 (19.5)	**242 (23.4)**
No	393 (76)	401 (76.8)	**794 (76.6)**	18 (25)	776 (80.5)	**794 (76.6)**
use of Herbicide						
Yes	111 (21.6)	112 (21.5)	**223 (21)**		223 (23.1)	**223 (21.5)**
No	403 (78.4)	410 (78.5)	**813 (78)**	72 (100)	741 (76.9)	**813 (78.5)**
use of Pesticide						
Yes	6 (1.2)	9 (1.7)	**15 (1.4)**	2 (2.8)	13 (1.3)	**15 (1.4)**
No	508 (98.8)	513 (98)	**1021 (98.6)**	70 (97.2)	951 (98.7)	**1021 (98.6)**
Total Value of Labor days used per hectare	509.996(28.5)	490.886(27.7)	**500.26(19.854)**	1263.59(183.32)	445.2179(15.26)	**500.26(19.85)**
Total Value of Oxen power days per hectare	199.77(7.306)	165.722(6.25)	**182.43(4.8237)**	226.1453(30.39)	179.9922 (4.79)	**182.43 (4.82)**
Total Value of the amount of Seed used per hectare	365.1(183.456)	85.696(12.85)	**220.19(88.61)**	114.6137(11.92)	225.9502(93.44)	**220.19(88.61)**
Total Value of Yield per hectare - Birr/ha	997.26(42.896)	1189.02(54.9)	**1095.02(35.12)**	2172.697(246.5)	1030.31(33.01)	**1095.02(35.11)**

The total labor usage includes family, hired, sharecropping and exchange with relatives and neighbors. Labor usage can be seen in five different activities: land preparation and planting, weeding and cultivation, watering, harvesting, and threshing. The average value of labor person-days for the total sample households is around 500 birr, with higher variation among the “with and without” RWH technology categories. For instance, the average value of labor person-days used in households with RWH technology is higher by 818.37 birr relative to households without RWH technology showing that more labor is needed by those households adopting RWH technology since more labor is needed in construction of the pond, watering and lifting up of water from the pond.

In relation to the use of modern fertilizer households have used fertilizer in around half of the plots (*47.8%*) and of these more than 50% are in the pepper/livestock farming system. Furthermore, from the total plots with RWH technology, fertilizer has been used in 15.3% of them. Additional information that can be depicted from table 5.5 is that 23*%* of the surveyed households have used Manure or Compost but when consider those that adopt the technology it accounts for 75% of the plots. As can be seen on the table, herbicide use accounts 21% though very small use of pesticide is observed in the farming system and the technology adoption categories.

In terms of the value of crop yield harvested , the average estimated value of crop yield per hectare for the surveyed plots is found to be 1095.02 birr/ha, with less variation among farming systems. The variation among farming systems range up to 191.76 birr/ha, with the lowest crop yield (around 997.26 Birr/ha) being in the Teff / haricot bean /Livestock farming system and the highest (1189.02 Birr/ha) in the pepper/Livestock farming system. Moreover, on average, the variation in the estimated value of crop yield per hectare on plots with RWH technology is 1142.39 Birr/ha with the lowest (around *1030.307* Birr/ha) in those without RWH technology and the highest (2172.696 Birr/ha) in those with RWH technology. This might imply that adoption of rainwater harvesting technology is expected to have incremental impact on yield.

5.2. Cropping Pattern

As part of the assessment for the impact of RWH technology intervention on the farm household's crop choice decision, the study has employed a descriptive analysis of the crop mix for those with RWH technology in the different farming systems. Here, the crop types are classified into categories such as annual crops, perennial crops, vegetables, spices, others and no new crops. As can be seen from table 5.8 below, of the total number of the crop types sawn by all the sample households (382 plots), 188 observations are in the teff/haricot bean/livestock farming system category and 194 observations are under the pepper/livestock farming system category.

In the teff /haricot bean/livestock farming system, of the total *188* observations, 60.1% grow vegetables where as 4.3%, 6.9%, 4.3% represent annuals crops, perennial crops and spices, respectively. In the vegetable crop category cabbage, onions and carrot account 16.5%, 14.9% and 12.2%, respectively.

On the other hand, in the pepper/ livestock farming system, of the total 194 observations 67% is vegetables category where as 6.2%, 4.1%, 2.1% represent annual crops, perennial crops and spices. In the vegetable category which have great share from the different classifications cabbage, beet root, tomato, carrot and onion, account for 16.5, 12.9, 10.3, 9.8 and 8.8 percent, respectively.

Table 5.8 .Types of crop grown after start to use the technology based on farming system

		Category of crop types grown						Total
Farming system	Type of crops grown	Nothing new	Annuals crops	Perennial crops	Vegetables	Spices	Others	
Teff/Haricot bean /livestock	No new crop grown	40 (21.3)						40
	Chat		1 (.5)					1
	Coffee			12 (6.4)				12
	Banana		1(.5)					1
	Sugarcane			1 (.5)				1
	Avocado		2 (1.1)					2
	Papaya		4 (2.1)					4
	Onions				28 (14.9)			28
	Ginger(Jinjible)				1 (.5)			1
	Pepper					6 (3.2)		6
	Carrot				23 (12.2)			23
	Tomato				7 (3.7)			7
	Cabbage				31 (16.5)			31
	Chilli Pepper					2 (1.1)		2
	Kale				4 (2.1)			4
	Sweet potatoes				1 (.5)			1
	Garlic				3 (1.6)			3
	Beet root				15 (8)			15
	If other specify						6 (3.2)	6
	Total	**40 (21.3)**	**8 (4.3)**	**13 (6.9)**	**113 (60.1)**	**8 (4.3)**	**6 (3.2)**	**188**
Pepper/ livestock	No new crop grown	38 (19.6)						38
	Chat		2 (1)					2
	Coffee			8 (4.1)				8
	Orange		1 (.5)					1
	Banana		2 (1)					2
	Pineapple		1 (.5)					1
	Avocado		2 (1)					2
	Mango		1 (.5)					1
	Papaya		2 (1)					2
	Onions				17 (8.8)			17
	Pepper					4 (2.1)		4
	Carrot				19 (9.8)			19
	Tomato				20 (10.3)			20
	Cabbage				32 (16.5)			32
	Lettuce/'Selata'/				5 (2.6)			5
	Kale				6 (3.1)			6
	'Kosta'				4 (2.1)			4
	Sweet potatoes				1 (.5)			1
	Garlic				1 (.5)			1
	Mandarin		1 (.5)					1
	Beet root				25 (12.9)			25
	If other specify						2 (1)	2
	Total	**38 (19.6)**	**12 (6.2)**	**8 (4.1)**	**130 (67)**	**4 (2.1)**	**2 (1)**	**194**

*The number in the bracket shows percentage value
*The number out of the bracket shows frequency

The result on the impact of RWH technology adoption on a farm household's crop choice decision based on farming system, has shown that farm households have started to grow crops which were not previously grown in the area. This crops include vegetables, perennial crops etc.

The result of the crop mix analysis imply that, the shift in farm household's crop choice decision towards highly priced and marketable agricultural products or increment in the number of harvesting per year(intensification), could have a positive impact on the farm households income as well as level of living. However, the level and magnitude of benefit accrue to the farm household will significantly depend on market and infrastructure accessibility. This is because most of the crop categories sawn in farm households with rainwater harvesting technology are perishable; for example, vegetable represent the highest percentage of (60.1%) in Teff/Haricot bean/ livestock farming system and (67%) in pepper/ livestock farming system.

Hence, unless these products are able to reach to consumers immediately after harvested, either their market value will decrease with time or it might be a loss to the farm household. Besides, an examination of the type of crops grown under the vegetable category witnessed that most farm households have concentrated on specific crops (tomato, cabbage, onions, and carrot) and the production and supply of these crops in large quantities might reduce the price of the commodities and there by affect the economic feasibility of the technology. Thus, effort should be made to supply variety seeds to farmers so as to diversify the type of crops grown.

CHAPTER SIX

COMMUNITY INDIGENOUS WATER HARVESTING TECHNOLOGIES AND PRACTICES

The current government household level water-harvesting scheme is being carried out in Alaba. Prior to this, community managed ponds were common in the area. About twenty years ago, water for domestic purpose and for drinking animals was scarce. The problem was aggravated during drought periods. Owing to these, community managed water ponds are widely used in the Woreda currently.

Group discussion has been undertaken on the issue of indigenous water harvesting technologies and practices with an interest to know if it is still used by the community, if it has advantage or drawback, and if there is a plan to do modification on indigenous water harvesting technologies. The discussion covered eight peasant associations of Kobbo Getto, Andgegna Teffo, Mejja, Chobare Meno, Uletegna Mekalla, Uletegna Hansha, Mudda Dinokosa and Wishamo[6].

By classifying periods into prior to 1974, the Derg era and post 1991 before the introduction of RWH technology, it was tried to assess the solutions taken by the people when they face problem of water scarcity for drinking/domestic use, for livestock and crop production.

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[6] *In Kobbo Getto there were 13 participants of whom 5 were women; the second has 11 members of which 5 were women. In Mejja 9 participants with 3 women, in Chobare Meno 11 member with 5 women and 14 members participate of which 4 were women in Uletegna Mekalla. In the six peasant association, 11 members with 4 women followed by 10 members with 4 women and 5 women in Mudda Dinokosa and Wishamo respectively.*

According to the group discussions in the 8 peasant associations, during the period prior to 1974, most of the people use community pond for drinking/domestic use during the rainy season. During dry season seven of the kebeles use Blate River though the people in Chobare Meno use Dijo River. The average time that takes the households to fetch water from the river ranges from 6 to 12 hours depending on the means of transportation used. Small number of community ponds was observed during this period because landowners didn't allow households to construct more. The number of community ponds ranges from 3 to 7 per peasant association, which could be small, medium or large in size. In addition, it was suggested that Blate and Dijo rivers were used for livestock drinking purpose mostly during the dry season though in the rainy season community ponds can be used. In Dinokosa, it was suggested that use of water in 'Borobore' or 'Chorete' (water collected in an eroded area) was common for animals and people. Besides, the people used to depend on rain fall for crop production but couldn't use water from community pond because the landowners didn't allow them to use especially in dry season. However, sometimes during rainy season, those around the community pond used the water for pepper nursering.

During the Derg period, in Kobo Getto, there was an increase in the number of community ponds. Sometimes they get tap water from Kobo Chobare but it had long queue. In Andgegna Teffo, they have pump water supply in the nearest peasant association but it also had long queue making them to continue using water from community pond. There was no division of community ponds for human and animal use. It was observed that there had been an increase in the size of community ponds because Dozers were used to dig bigger once. And also Lorries used to bring water from Blate

River and distribute it to the people in the form of support. In Mejja and in the other peasant associations where group discussion is undertaken, people used community ponds in the rainy season but Blate River in the dry season for human drinking/domestic purpose. In addition, for livestock drinking purpose, they had to bring or go to river in the dry season but relied on community ponds during the rainy season. Rainfall was used for crop production but sometimes some people living around the community pond or Blate river might get the chance to make plant nursering like for pepper.

Post 1991, prior to RWH technology introduction, most people in Kobbo Getto used community ponds and motor water supplies that were available in the area for drinking/domestic use. In Andgegna Teffo there was an increase in community pond depth with the start of division of community ponds for livestock and human use. Those people in Mejja have 5 community ponds and Blate River which is still in use during dry season. They also got motor water in the nearest peasant association and sometimes they use pipe water that is available Ashoka. In Chobare Meno people start to use pond water for crops and get motor water from Besheno. In Dinokosa, due to people's awareness towards getting clean water, they have started to protect community ponds to use it for drinking purpose. Those households who have donkey bring water from the capital Kulito which shows a shift from polluted water to clean water demand even making them to wait for long queue to get water from Gerema. In Wishamo Blate River is used during the dry season. And there was an increase in the number of community ponds into 9 but there is no pipe water supply in the area. In addition, for livestock purpose most of the peasant associations still use Blate (Dijo in Chobare Meno) during the dry season and the community pond during the rainy season except in Andgegna Teffo where they have started to use pipe water for drinking animals too. For crop production they use rainfall except those closer to community ponds where they sometimes use the water for pepper nursering.

In most of the peasant associations, the practice of water harvesting technology has been started during the Haileselasse regime. For example in Kobbo Getto it was started in 1940's learning it from Sankura or Selte area. In Mejja it was before Haileselasse regime in 1920's which they have only one community pond. In Wishamo it was during Haileselasse regime in 1950's by those people who came from other places.

Most of the group discussions in the kebeles indicated that the development of drought situation was started due to shortage of rainfall in 1984/85. The drought leads to water, crop production and health problem resulting in the death of a lot of lives and animals, and migration from the area. However, in Dinokosa the sources of drought were suggested to be three which include sun (when there is rainfall shortage), wind and snow. The topography is different in a way that it is sloppy making the soil to be exposed to runoff and natural catastrophe in all direction. In 1973/74, there was drought in Tigray, Wollo, Gamo Gofa which resulted in famine to occur in Wishamo caused by water shortage, subsequent reduction in food production leading to health problem and death.
Considering factors that initiated the use of water harvesting, shortage of water is identified to be the primary reason in addition to experience from other places and small-scale trials in their houses. However, in Dinokiosa there was a case when someone in their kebele died and people went to Wishamo to bring water. At that time they were not

allowed to take water and they were even told to use animals blood if they want to wash the dead body. And this specific coincidence considered to be the reason, which initiated some of the people to start digging the pond before the dead body was put in place when some of them went to Blate River to fetch water using donkey. In Wishamo, distance from Blate River was one reason that initiated the use of community pond even with women's participation.

According to the information collected from the different group discussions, the types of indigenous water harvesting technologies include community pond, putting cloth on wet grass and squeeze it to get water, use of water collected in a hole found in the branch of tree ('wood banba'), water from the streets, 'Zanza' or 'Weficho'(spongy like material found on Enset) will be squeezed to get water, by cooling water from Shala lake, eat pumpkin most often, kids were not allowed to eat dry foods and to play for long hours in the sun and other simplified ways.

Many differences can be seen between indigenous and modern rainwater harvesting technology. Community ponds are used in group since it is common to all, it can be used for livestock, human drinking and agricultural purpose, clay soil will be selected to reduce water seepage into the ground, it is wider in size, and it is less pure because animals might go inside the pond. On the other hand, modern pond is used individually which is mostly used in dry time for plants and in time of water shortage, used for vegetable or crop production and might result in water seepage when the cement is cracked, small in size, has cement or plastic basement, it is more clean if it is followed up well and save time that used to be spent to fetch water. In general, positive and negative side effects can be observed from both technologies and we need to select the one with more benefit.

During the discussion, information was collected to assess how knowledge of indigenous water harvesting technology developed during the different regimes. During the imperial regime, it was suggested that most of the water harvesting technologies were small in their size and there were few community ponds though with depth. The people dug the ponds with interest, own manpower and initiation.

In Derg regime, the community ponds were dug by the government using Dozer. In some areas, the people contributed 60 birr to cover the fuel consumption of the Dozer, for education, health service and generally for development related activities. During this time, an increase in the size of the community ponds was observed because of the change in land ownership. There was also an increase in the number of community ponds in most areas which might be due to the food-for-work program that was started.

In recent times, the safety net program initiated people to dig more. Food-for-work program continued to be used and the participation of the development agents in the activity was helpful. In some areas there was an increase in the number and size of community ponds like in the Derg regime. However, in some of the peasant associations community ponds are given less attention due to the shift towards using pipe water supply.

The elderly are those who know more on how and where to construct community water pond. They did not have any exposure outside Alaba where there is accumulated knowledge about water harvesting. Rather, it arises from their own experience mainly due to the water shortage problem they were facing.

The criteria's that they take in to account to decide the location of community ponds include flatness of the area, soil type, sloppiness of the land, area central to all the people in the community, distance from road, land size and area with no tree. In addition, the method that they usually consider to reduce water seepage focuses on identifying the type of soil. Most of them continue to dig until they reach a depth of about 4 meters to get yellow or brown soil type. Then water will be sprayed and walked by animals to protect water from passing down into the ground.

Mostly the clearance of the pond is made in the dry season when the water inside the community pond decreases so that the soil can easily be cleaned. On the other hand, if there is water inside the community pond, the parts with no water or only the corner sides will be cleaned. In addition, they fence the pond and ensure its neatness turn by turn. The size of community ponds is determined by the population in a particular area, on the land size, prefer trapezoidal shaped ponds so that animals entering the pond will not face difficulty to get out of the pond and by the peoples capacity or manpower contribution.
According to the information collected, it is estimated that about 4 up to 6 months will be needed to dig large sized community ponds if the construction carried out intensively. It may take one up to three years if the work is delayed due to different reasons. For

medium sized ponds, it might take two up to six months or one year at the maximum. The digging process for small sized ponds might take one up to six months at the maximum. The number of people that are mostly involved in digging of large sized community ponds might reach up to300 people or the whole people in the peasant association. For medium and small sized once, it might take less than 300 people. On the other hand, the time that the different sized ponds need to be filled with water might take from one up to three days during the rainy season and it might take one week up to two months if the rain is short. However, in the dry season, it will take longer time to fill the pond ranging from one month up to one year. In addition, the water inside large sized ponds might last from seven to ten months and around five months for small sized once.

The change that is observed in shape and size of indigenous water harvesting structure overtime is that of an increase in the size of the community ponds and change in shape from circular type to trapezoidal one. And overtime, the existence of health problems related to indigenous water harvesting technology has been observed. It is mainly related to the neatness of the ponds. The problems that are frequently observed include Jardia, Cold, Malaria, Amoeba, Diahrea, skin disease, Taifoid, Cholera, Abdominal Cramp and other water born diseases.

In the dry season the community ponds will be well protected since the demand for water will increase due to users coming from other areas. During this time, the guards will allow people to take water once in three days and make non-participants during the construction to pay some amount per pot. Conflict might arise when those that don't dig and fence get a benefit, when people wash their body inside it, when divert the direction of the runoff, when guards fail to handle their responsibilities well, in time of disagreement some people pollute the water, when guards sell water and when people don’t respect queue.

The role of women from planning to implementation of indigenous rainwater harvesting technology is insignificant. However, indirectly the women will give support by preparing coffee and food services for those people who construct the ponds.

Their role in the construction stage is larger if they are female-headed households especially when there is nobody to help them. Otherwise, mostly, it is the men who play a major role in this stage. The women don’t participate directly. Their major role in this stage is indirect participation in preparing coffee and food service for those who are doing the job. The role of women in maintenance, clearance and watching stage is high when they don’t have a husband. But if they are married, they participate in clearance and taking out soil or dirt material from the pond, fencing the pond, preparing food and coffee service for those who are making the maintenance. However, they don’t participate in watching the community pond since stronger and powerful guards are needed.

CHAPTER SEVEN: GENDER AND RWH TECHNOLOGIES

At present, there is a growing tendency towards the adoption of low cost and simple alternative water management technologies like rainwater harvesting technologies. RWH technologies have the potential to contribute towards the Millennium Development Goals (MDGs) with a view of eradicating poverty and hunger, provision of safe drinking water and sanitation, ensuring environmental sustainability, promoting gender equity and women empowerment. It is one way of improving the living conditions of millions of people, particularly those living in the dry areas. Water scarcity especially for domestic and agricultural purposes compromises the role of women in food production. Hence, provision of water by promoting rainwater harvesting and management technologies reduces the burden on rural women and thus increasing their productivity.

This chapter tries to see the participation of women in male headed households in planning and decision making stage, construction, maintenance, clearance and watching stages. In addition, it will try to address the question if women are benefited and in what terms, and the reasons if they aren't benefited from adoption of the technology. Besides, female headed households were asked if they are selected as beneficiaries and how they are selected, and if not, why not. The constraints that they face to use RWH technology are also considered.

Table 7.1. Women participation in planning and decision making stage

Suggestion given	*Freq (%)*
The culture don't expect them to participate in this stage though they are voluntary	6 (7. 9)
She will accept anything that is decided by her husband	1(1.3)
During planning, she will suggest the time for the work in order to provide a better food service	13(17.1)
Equal responsibility	65(85. 5)
That time I wasn't married so I can't suggest her participation	1(1. 3)
They don't have self initiation and incentive to participate since they can't get time beyond domestic work	2(2.6)

As can be seen in table 7.1 above, most households put equal responsibility among women and men to participate in planning and decision making to be the dominant suggestion accounting for 85.5% of the total rainwater harvesting technology adopters. This is followed by 17.1% of households who have mentioned that during planning, the women suggest the time for the work to provide a better food service.

Table 7.2. Women participation in construction stage

Suggestion given	Freq (%)
She participates directly (by supplying water) and indirectly (by preparing food and coffee) for workers	44 (57.9)
Help by giving the needed raw material (like stone, sand, cement from home to where they work etc.) and remove the soil from around the pond to a bit far area and sometimes participate in the digging process	25(32.9)
No women participation since there was no construction except digging	8(10.5)
After the end of construction, they will keep bringing water and spray it on the pond to protect cracking.	2(2.6)
No, because I was not married	1(1.32)
They will participation though no construction has been done yet.	17(22.4)
Plastic cover used with her agreement and participated by holding the plastic in the corner when covering	1(1.32)
Protect water entry into the pond until the workers finish the digging process	2(2.6)
Since no construction done ,it is not yet known if she is going to participate or not	1(1.32)

As indicated in table 7.2 above, in 57.9% of the households, women participated directly (by supplying water) and indirectly (by preparing food and coffee) for workers. About 33% of the households suggest that, they assisted by providing the needed raw material (like stone, sand, cement from home to where they work etc) and removing the soil from around the pond to a bit far area. Moreover, 22.4% of the households responded that women will participate though no construction has been done yet.

Table 7.3. Women participation in maintenance, clearance and watching stage

Suggestions given	*Freq (%)*
She participates in all	5(6.6)
During maintenance they bring water, raw materials needed, food service and protect pond from being destroyed.	23(30.3)
Clean the area of pond by removing unnecessary things that grow and exist around it, and wastes that enters into the pond water to get clean water	42(55.3)
Since spent most of their time at home they watch kids and animals from getting into the pond accidentally.	55(72.4)
During the dry season they carry out soil or sand that enters inside the pond in the rainy season and prepare it for the next cropping season	38(50)
She participates in time of strengthening the pond	7(9.2)
They watch people from trying to steal water from pond with out getting permission	3(3.95)
Watch family member not to wash cloth inside the pond	1(1.32)

Table 7.3 indicates that, 72.4% of the households responded that women participate mainly in watching kids and animals from getting into the pond accidentally since they spent most of their time at home. This is followed by women participation in cleaning the area of the pond accounting 55.3%. Women participation during the dry season to carry out soil or sand that enters into the ponds in rainy season has taken 50% of the household's response. About 30% of the households participated in maintenance by bringing water, raw material, food service and protecting the pond from being destroyed.

Table 7.4. If female-headed households selected to be beneficiaries

	Freq (%)
Yes	25(32. 9)
No	51(67.1)
Total	76(100)

As indicated in table 7.4 above, 67.1% of the households who adopt RWH technology responded that female-headed households aren't selected as beneficiaries whereas the remaining balance responded that they are selected to be beneficiaries.

Table 7.5. How female-headed households selected to be beneficiaries

Suggestion given	Freq (%)
When they have their own initiation	9 (36)
If they have manpower to support them during the hard work	6(24)
Wider land ownership could be taken as motivation	2(8)
If she can cover cost involved in pond construction	11(44)
Government or agricultural extension is voluntary to give chance for anybody depending on their working ability in agriculture	13(52)
Those who defended that they should have it after they dig other peoples pond	1(4)
They can work by helping each other in different works	2(8)
Based on their participation in the kebele	1(4)

Out of those households who responded that female-headed households are selected as beneficiaries, 52% said that government or agricultural extension is voluntary to give chance for anybody depending on their working ability in agriculture. About 44% replied that it depends on her capacity to cover cost involved in pond construction. Moreover, 36% of them responded that it is own initiation that matters for them to do equal level with men.

On the other hand, out of those households who responded that female-headed households are not selected as beneficiaries, 68.6% of them mentioned that the main reason is economic and manpower problem. Less interest and initiation due to less participation in agricultural work account for 17.6% of the household’s response. About 16% of the households responded that bias exists towards male headed households on the ground that the ladies can’t go through the hard work, and the same percentage for the reason that they don’t have anyone to teach them about its use and purpose.

Table 7.6. Reason (constraints) for female-headed households not to be selected as beneficiaries

Suggestions given	*Freq (%)*
Economic and manpower problem	35 (68.6)
They don't have interest and initiation due to less participation in agricultural work	9(17.6)
The choice is biased towards male headed households on the ground that the ladies can't make it	8(15.7)
They don't have no one to teach them about its use and purpose that means there is lack of enough knowledge about the impact of the technology on agriculture.	8(15.7)
A farmer in Alaba may have 2 or 3 wives and they can share his pond if situations aren't fulfilled to dig their own pond. That means it is her husband who determines what she should do because she doesn't have right to own and manage land by herself.	1(2)
It is thought that they have a shortage of time since they spent their time working in the house- most of their time taken by domestic work.	6(11.8)
I don't know about them- since I didn't see any trial on female headed households	2(3.9)
Culturally it is believed that women can't do the job of men	4(7.8)
The technology adoption supposed to be done in short period of time. So considering them might lag the work. Male not interested to exchange power with female headed households since they will benefit less.	1(2)

As in table 7.7 below, 61.8% of the households said that shortage of economic and manpower is the major constraint for female headed households to use RWH technology. About 16% of the households mentioned that that they have less energy to lift up and apply the water and 9.2% of them said that it is due to less knowledge about the work.

Table 7.7. Constraint that female-headed households face to use RWH technologies

Suggestions given	*Freq(%)*
Shortage of economic and manpower	47 (61.8)
They have less energy to lift up and apply the water	12(15.8)
The burden in domestic work makes them not to handle the whole work involved in pond	6(7.9)
Need support from government or any body to dig pond	4(5.3)
Nowadays side by side ladies are working in the agricultural work	1(1.32)
Less knowledge about the work	7(9.2)
Nothing as long as can cover the cost	1(1.32)
No right to control and manage land	3(3.95)
No incentive given from kebele administration to make them participate	4(5.3)
No female headed household using pond in the kebele, so unable to know problems they face after start to use it	3(3.95)

Our target in table 7.8 is to see in what terms women are beneficiaries from the adoption of the technology. About 78% of the households responded that they are beneficiaries in terms of reduction in expenditure by using vegetable produced for home consumption and selling the remaining to get money which is spent for the purpose they need. More over, 61.8% of the households consider the time saved that used to be spent in fetching water and 22.4% on ability to eat different and new food varieties.

Table 7.8.How women are beneficiaries from the adoption of the technology

Suggestions given	Freq (%)
Save time that was spent in fetching water	47 (61.8)
Reduce expenditure by using vegetable produced for home consumption and sell the remaining to get money and spend it for whatever purpose she needs it	59(77.6)
Able to produce more than once in a year	2(2.6)
Able to eat different and new food varieties	17(22.4)
The ladies got something to do after they finish other domestic responsibilities	3(3.95)
Though we don't benefit in terms of income earning at least after we use it for ourselves we can help those who are in problem	1(1.32)
We are expecting benefit from permanent plants	3(3.95)
Though get some benefit from planted vegetables, due to water shortage some of them dried without giving benefit.	1(1.32)

Table 7.9 indicates the reasons for women not to be beneficiaries from adoption of the technology. Economic shortage, lack of motivation for work and inability to pass through the hard work all accounts 1.3% each.

Table 7.9 Reason for women not to be beneficiaries from adoption of the technology

Suggestions given	*Freq (%)*
Economic shortage	1(1. 3)
Lack of motivation for work	1(1. 3)
It is mostly believed women cannot pass through the hard work with determination and dedication	1(1. 3)

CHAPTER EIGHT

PERCEPTIONS OF THE CONSTRAINTS ANDOPPORTUNITIES IN ADOPTION AND USE OF RWH TECHNOLOGIES

8.1. Farmers Perception

Farm households ‘with’ and ‘without’ RWH technology were asked to indicate responsible person for fetching drinking water, the sources of water and the time required to bring water. Households with the technology were also asked when they have started to use the technology, the time when they first become aware, and the source from where they get the information. They were also asked about the different kinds of training and their relevance. The use of water in the pond, type of RWH technology, the type of water lifting equipments, reason for choosing particular type of technology were also raised in the questionnaire. In addition, how the location of RWH pond was chosen, if the technology adoption was voluntary, if the pond has a cover and the material used, if the pond has floor and fence with the materials used for the fence, how many times a year the household produce using supplementary and full irrigation were also considered. Farm households using a RWH technology were also asked about the problems encountered in adopting the technology, possible solutions to tackle the problems and the benefits that they get by adopting the technology. Besides, reason for not adopting RWH technology was also studied.

Table 8.1. Household responsible for fetching drinking water in order of importance

Responsible body	*1^{stly}responsible*	*2^{ndly} responsible*	*3^{rdly}responsible*
	Freq (%)	Freq (%)	Freq (%)
Father	1(0.7)	20(13.2)	3(2)
Mother	137(90.1)	9(5. 9)	
Son	3(2)	26(17.1)	52(34. 2)
Daughter	11(7.2)	85(55. 9)	6(3. 9)
House maids		2(1.3)	
With participation of people in the neighborhood			2(1. 3)
Total	152(100)	142(93.4)	63(41.4)

Out of 152 households included in our survey around 90% of the households put mother's as the first to be responsible in fetching water followed by 55.9% daughters in the second group. Sons account 34.2% in the third level.

Information on the source of drinking water for households and animals can be seen on table 8.2. Most households put tap water (33.6%) as a primary source of drinking water due to its cleanness. Then 26.3% of the households opt for pond water followed by river (20.4%). In the second level, pond water takes the lead with 30.9% followed by tap water and community pond. Finally, as a third source , most people use river (31.6%).From the result we can conclude that most households prefer to use tap water supply followed by pond water due to its closeness and river to fulfill their water demand.

Table 8.2 Source of drinking water for household and animals (actual use)

Source of drinking water	The 1st for HHH	The 2nd for HHH	The 3rd for HHH	The 4th for HHH	The 1st for animal	The 2nd for animal	The 3rd for animal
	Freq(%)	Freq(%)	Freq(%)	Freq(%)	Freq(%)	Freq(%)	Freq(%)
River	31(20.4)	41(27)	48(31.6)	1(0.7)	40(26.3)	91(59. 9)	15(9. 9)
Community pond	29(19.1)	20(13.2)			43(28.3)	1(0.7)	
Pond	40(26.3)	47(30. 9)	1(0.7)		46(30.3)	21(13.8)	
Tap water	51(33.6)	36(23.7)	7(4.6)		3(2)	2(1. 3)	
water inside a sand		1(0.7)	1(0.7)				
Hand dug well	1(0.7)	1(0.7)			20(13.2)	5(3. 3)	
Total	152(100)	146(96.1)	57(37.6)	1(0.7)	152(100)	120(79)	15(9.9)

On the other side, as source of animal drinking water, most households use pond (30.3%), community ponds (28.3%) and river (26.3%) in the first level. Then most people use river as the second source represented by 59.9% of households.

From the total 152 households surveyed, half of them have adopted RWH technology and the remaining 76 haven’t adopted the technology. As shown in table 8.3 below, out of the farm households with the technology, 60.5% of them said that they have started to use the technology in the year 2003/04, 36.8% of them in 2004/05 and 2.6% of the households adopted it in 2002/03. From the total adopters of the technology, 21 of them were aware about the technology before they have started to use it, and of these households, 15 of them were aware since 2003/04. On the other hand, 36.2% of them said that they were not aware about the technology before they have started to use it.

Table 8.3. When household start to use RWH technology

When did the household start to use RWH technology?		Were you aware about RWH technology before you start to use it?		If yes, since when		From whom did you learn about RWH pond for the first time?	Freq (%)
	Freq (%)		Freq (%)		Freq (%)		
2002/03	2(2.6)	Yes	21(13.8)	1999/00	1(4.8)	Agricultural and natural resource office	75(98.7)
2003/04	46(60. 5)	No	55(36.2)	2001/02	2 (9.5)	District administration	1(1. 32)
2004/05	28(36.8)			2002/03	3 (14.3)	Neighbors	11(14. 5)
				2003/04	15 (71.4)	Relatives	1(1.32)
Total	76(100)		76(100)		21(100)		

From the total households who have adopted the technology, 98.7% of them put agricultural and natural resource office in the Woreda to be the first source to learn about RWH pond. About 14.5% of the households responded that neighbors are the next source of information about the technology.

Table 8.4. Kinds of training on RWH technologies

Have you got any training on RWH?		Kind of training	Freq (%)	Did the training help you in using the water obtained from the pond effectively?	
	Freq (%)				Freq (%)
Yes	76(50)	How to dig	76(100)	Yes	64(84.2)
No	76(50)	How to cover	66(86.8)	No	12(15.8)
		Water lifting and application	55(72.4)		
		How to keep water clean	57(75)		
		Purpose of pond	47(61.8)		
		In selecting pond location	35(46.1)		
Total	152(100)	On pond type	2(2.6)	Total	76(100)

All the households that adopt the technology got training on RWH technology. From the kinds of training that the households got, 100% of the households put training on how to dig the ground to be primary. About 86.8% and 75% of households reported training on how to cover the roof of the pond and on how to keep water clean, respectively. Training on easier way of lifting and application of water account for 72.4% and 61.8% of the training on purpose of the pond.

Though all households who adopt the technology said that they got training, it is only 64 households who have suggested that the training helped them in using the water obtained from the pond effectively while the rest 12 households said that it didn't help them, which could probably be due to their weakness or the distance of their area from where the experts can visit and give advice to the households easily.

Table 8.5. The purpose of the pond water

	Rank1	Rank 2	Rank 3	Rank 4
	Freq(%)	Freq(%)	Freq(%)	Freq(%)
For HHH drinking water	7(9. 2)	15 (19. 74)	**18(23.7)**	2 (2.6)
Drinking water for livestock	4(5. 3)	13 (17.11)	9(11.8)	**14(18.4)**
Nursering	26(34.2)	**21 (27.6)**	12 (15.8)	1(1. 32)
Vegetable production	**31(40.8)**	14 (18.4)	1 (1. 32)	3(3. 95)
Spices production	2(2.6)	1 (1. 32)		
Fruit production		2 (2.6)		
Washing cloths and food cooking	6(7.9)	10(13.16)	19 (25)	4(5. 3)
Total	76(100)	76(100)	59(77.6)	24(31.6)

Farmers were asked to rank the purpose for which the accumulated water was used based on the amount of water utilized in each activity. As can be seen in table 8.5 above, households use the pond water for different purposes including a source of drinking water for animals and households. In addition to using the water for washing cloths and cooking, households use the water for nursering some plants, for vegetable and fruit production. About 40.8% of households responded that they use the water for vegetable production as a supplementary during dry spell periods to be their first choice. In the second rank, 27.6% of the households use the water for nursering. About 23.7% and 18.4% of the households use it for drinking and for livestock respectively.

Table 8.6. Cross tabulation between type of RWH technology and type of water lifting equipments used

	Type of water lifting equipments used								Total
	Pulley	'Commendary'	Pot	Tridle pump	Jog	'Jerikan'	'Tanika'	Bucket	
Ponds covered with plastic and none covered basement	2(4.3)[b]	7(14.9)	2(4.3)		1(2.13)	14(29.8)	3(6.4)	18(38.3)	47(65.3)
% of Total	2.8	9.7	2.8		1.4	19.4	4.2	25	
Ponds with concrete basement	5(20)	5(20)		1(4)		5(20)	1(4)	8(32)	25(34.7)
% of Total	6.9	6. 9		1. 4		6. 9	1. 4	11.1	
Total	7(9.7)	12(16.7)	2(2.8)	1(1.4)	1(1.4)	19(26.4)	4(5.6)	26(36.1)	72(100)

[b] Values in brackets are percentages.

Table 8.6 depicts cross tabulation of the type of RWH technologies adopted at plot level with their corresponding equipments used for water lifting and application. As shown in the table, 65.3% of the households represent those who adopted plastic-lined RWH pond and those waiting for plastic sheet. Concrete structures made of clay and/or cement accounts 34.7%. Of the total 47 households with plastic cover and none basement, 38.3% use metal Bucket for lifting and watering plants while 29.8% of the households use big plastic container' *Jerikan*'. Besides, households with concrete based ponds mainly use mental bucket followed by big plastic container, pulley and 'commendary' each accounting 20% of the households.

In addition, the last raw of table 8.6 shows the distribution of each type of water lifting and application equipments used in the total 72 plots with RWH technology. Thus, from the total households with RWH technology majority of them (36.1%) use metal Bucket for lifting and watering plants followed by use of big plastic container (26.4%) and 'commendary' (16.7%).The highest percentage in the use of metal Bucket for water lifting and watering plants indicates the difficulty for a farm household in terms of time as well as labor days required to irrigate the entire plantation in the plot. This difficulty is due to lack of capital for buying or renting simpler equipments which is a major detrimental factor affecting the rater of rainwater harvesting technology adoption.

Table 8.7 If type of RWH pond was chosen by the household

Was the type of RWH pond that you have adopted chosen by you?		If yes, then what was your reason for adopting the type?	Reason	If not, then who chose the type?	Type
	Freq (%)		Freq (%)		Freq (%)
Yes	8 (10.5)	Cheap	5 (62.5)	Agricultural and natural resource office or DA's	77(100)
No	68 (89.5)	Easy access to get the raw materials required for construction	4(50)		
Total	76(100)				

Another related point is that farm households were asked if the type of RWH pond that they have adopted was chosen by them. As can be seen in table 8.7, eight households responded that they have chosen the type by themselves while 68 households responded that it was chosen by Agricultural and Natural Resource Office or development agents

(DA's) in the Kebele with. Of the 8 households, 5 of them consider its cheapness while the 4 look at easy accessibility to get the raw materials required for construction.

Table 8.8. Who choose the location of RWH pond adopted.

Who choose the location of RWH pond that you have adopted	Freq (%)	If the choice was made by yourself, what was your criteria	Freq (%)
Myself	68(89. 5)	Plot location	75(98.7)
Discussing with neighbors and relatives	5(6.6)	Distance to drainage (easy to get runoff)	76(100)
Agricultural extension	24(31.6)	Plot size	27(35. 5)
		To get clean water	4(5. 3)
		Soil type	2(2. 6)

*%age adds up more than 100 because households were allowed to give more than one criteria

The selection of specific location for the RWH technology (Table 8.8) was mainly done by the head of the household (89.5%) while 31.6% of the households responded that it was selected by agricultural extension workers based on technical criteria, and only 6.6% of the households reported that the site was selected by discussing with neighbors and relatives.

Furthermore, farmers were asked about the criteria that they used during site selection process if chosen by themselves. In this, 100% of the households identified easy access to get runoff as major criteria while location of the plot from residence accounts 98.7%. In addition, plot size was suggested as criteria by 35.5% of the households.

Table 8.9 If the technology adoption was voluntary

Did you adopt the Rainwater Harvesting technology voluntarily?	Freq (%)
yes	74 (97.4)
no	2 (2.6)
Total	76 (100)

As in table 8.9 above, 97.4% of the households responded that they have adopted the RWH technology voluntarily and the rest 2.6% household responded that it was not voluntarily.

Table 8.10. If the pond has a cover and fence

Does your RWH pond have cover?		If yes, what are the materials used?		Does the pond have fence to avoid risk?		If yes, what are the materials used ?	
	Freq(%)		Freq(%)		Freq(%)		Freq(%)
Yes	15(19.7)	Wood	5(33.3)	Yes	52 (68.4)	Wood(acacia tree)	20 (38.5)
no	61(80.3)	Cob	2 (13. 3)	no	24 (31.6)	Cob	2(3.85)
Total	76(100)	'Satera'	4(26.7)	**Total**	76(100)	'Kenchibe'	12 (23.1)
		Wood and 'kenchibe'	2(13. 3)			Cob and 'kenchibe'	3(5.77)
		Wood and 'Sinkita'	2(13. 3)			Wood and 'kenchibe'	13 (25)
		Total	15(100)			'Kenchibe' and thorn	2 (3.85)
						Total	52(100)

* Sinkita and kenchibe are kinds of bush trees. Satera is a grass material

As can be seen on table 8.10 above, only 19.7% of the households that adopt the technology have a cover for their pond while 80.3% of them respond that they didn't put a cover for their ponds. This might result in lots of problems like accident on animals or kids, bad smell when the volume of water lowers which could be source of malaria, high evaporation rate. Of the households with a cover for their ponds 33.3% and 26.7% of them use wood (trees) and Satera respectively. Besides, 13.3% of them use Cob, wood with kenchibe and wood with Sinkita each. On the other hand, with regard to those who use fence to avoid risks, 68.4% of them use it while the rest 24 households don't use fence for their ponds. Most of the households use wood as a material to do the fence followed by using wood with kenchibe accounting 25% and 23.1% of them kenchibe alone.

Table 8.11. Number of harvest using supplementary and full irrigation

How many times a year did you harvest using supplementary irrigation?	Freq (%)	How many times a year did you harvest using full irrigation?	Freq (%)
once	41(53. 95)	once	10(13. 2)
twice	27 (35.53)	twice	2 (2.6)
three times	1 (1. 32)		
Total	69(90.8)	Total	12(15.8)

Out of the 76 households who have adopted the RWH technology, only 69 of them responded for the question about how many time a year the household harvest using the pond as a supplementary irrigation. As can be seen in table 8.11 above, 53.95% of them harvest once using supplementary irrigation while 35. 53% of them harvest twice and only one household three times. On the other hand, 13.2% of the households harvest once using full irrigation while 2 households harvest twice using full irrigation.

Table 8.12 Purpose of the pond

Serial No.	Purpose of the pond	Freq (%)
1	for full irrigation	2 (2.8)
2	for supplemental irrigation	10 (13.9)
3	for domestic use	3 (4.2)
4	combination of 2&3	53 (73.6)
5	combination of 1&2	1 (1.4)
6	combination of 1&3	3 (4.2)
	Total	72 (100)

Of the 72 plots with RWH technology, 73.6 % of them use pond water both for household domestic use and as a supplemental irrigation while 13.9% of them use it for supplemental irrigation purpose only. Besides, combination of full irrigation and domestic use, full irrigation and combination of full and supplemental irrigation is used by 3, 2, and 1 household respectively.

Households with RWH technology were asked to list problems they encountered during implementation and utilization of the technology, and in general the problems cited by farmers can be classified in to eight major categories. As can be seen from Table 8.13, these include problems related to RWH pond (33.7%), 37.9% of the total frequency of responses represents problems related with lack of equipments, 5.76% of responses mentioned problems related with agricultural inputs and 9.47% cited problems related with health. From the categories listed, problem of equipment for water lifting and application is shown to be the dominant one with 37.9%.

Of the pond related problems mentioned on table 8.13, accident on animals and kids, absence of roof cover followed by quickly drying up of the accumulated water problems take the highest share of 39.4, 36.8 and 14.4 percent respectively. The highest percentage observed in the accident could be due to absence of cover for the pond, absence of fence to the pond, and wrong location of the pond which might increase accident on kids due to closeness to the house. The high proportion of uncovered ponds could be due to lack of finance or may be due to less awareness given by the experts or probably due to weakness of the households. Quick drying up of the pond water could be related to the RWH technology or structural design of the technology which emanates from lack of extension workers with the necessary skill about the technology during construction or even lack of roof cover for the pond.

Se No	**Table 8.13**. List of Problems	*CATEGORY OF THE PROBLEMS REPORTED*								*Total*
		RWH ponds	Lack of equipment	Agricultural Inputs	Rodents	Health problems	Labor requirement	Plastic sheet or cement	Other problems	
1	Cracking and water dried up quickly when it is concrete structure	11(14.4)								11(4.53)
2	Lack of equipment to make canal for runoff		1(1. 3)							1(0.41)
3	No roof cover for the pond	28(36.8)								28(11. 5)
4	Problem of water lifting from the pond and lifting equipment		59(77.6)							59(24.28)
5	Insufficient supply of improved seed and not timely provided			12(15.6)						12(4.94)
6	Use of heavy materials to apply water		32(42.1)							32(13.17)
7	Rodents are reducing moral for work by affecting yield, especially vegetables				3(3. 9)					3(1. 23)
8	Accident on animals and kids	30(39.4)								30(12.35)
9	pond is being damaged due to rain which occurred before the end of the construction	2(2.6)								2(0.82)
10	Use of pond water for drinking due to water shortage, results in water borne diseases					6(7. 9)				6(2.47)
11	In dry season if it doesn't have a cover it will be an area to the spread of malaria and in rainy season high erosion into the pond may create bad smell					17(22. 3)				17(7)
12	When compare labor involved in the work and the output found, it is less rewarding.						1(1. 3)			1(0.41)
13	Lack of enough continuous and organized advise or education on how to use and expand the technology	6(7.8)								6(2.47)
14	Nobody has strength to clean the water in the pond except some few	1(1. 3)								1(0.41)
15	Because the water is used for different purpose, it will be finished before the vegetable is ready and after start nursering.	3(3. 9)								3(1. 23)
16	Until now cement or plastic floor isn't done leading us not to produce during dry season since the water in pond will be lost.							12(15.7)		12(4.94)
17	it demands high household digging and construction cost and power.						12(15.7)			12(4.94)
18	inside the pond a lot of animals that live inside the water will be reproduced.				1(1. 3)					1(0.41)
19	Lead us not to produce different fruits using pond water since the price of fruit seed in the market is expensive.			2(2.6)						2(0.82)
20	When we dig the pond in groups, some of the people left in the middle leading us to do it alone or some of the people don't participate well.								2(2.6)	2(0.82)
21	The plastic cover is being affected when some wild animals get into the pond and try to be out of it							1(1. 3)		1(0.41)
22	In cases when the wall of the pond is done by the mixture of cement and kuyisa soil , the water in the pond don't stay long.	1(1. 3)								1(0.41)
23	Total	82(33.7)	92(37. 9)	14(5.76)	4(1.65)	23(9.47)	13(5.35)	13(5.35)	2(0.82)	243(100)

Furthermore, of the problems cited related to the equipments used during pond utilization, the respondents mainly focused on the problem of water lifting equipment and lifting of water from the pond representing (around 78%) followed by problem of water application by using heavy materials reducing interest to produce vegetables in a wider place accounting around 42%. The other problem cited with smaller frequency is also important though with less percentage to be discussed in detail. In summary, majority of the problems cited by respondent households revolves around two issues: those related to RWH ponds and equipment problems

The possible solutions suggested by households with RWH technology to overcome the aforementioned problems are presented in Table 8.14 above. Here, the households have suggested several possible solutions. As can be seen from the header of Table 14, the solution can be summarized in to eight categories to tackle the eight categorical problems in Table 8.13. That is those related to RWH pond, lack of equipments, agricultural inputs, rodents, health problems, plastic sheet cover of the pond, labor requirement for the technology and for those under other problems category.

Se No	**Table 8.14** .List of possible solutions suggested by households with RWH Technologies	SOULUTIONS TO PROBLEMS RELATED WITH								Total
		RWH ponds	Lack of equipment	Agricultural Inputs	Rodents	Health problems	Labor requirement	Plastic sheet or cement	Other problems	
1	Reserve plastic membranes should be prepared for replacement.	11(14.4)								11(4.3)
2	The need of help to buy spadle or other raw material to open canal		1(1. 3)							1(0.4)
3	It is good if government or any other organization gives us help or credit to make us buy iron roof since other raw material don't stay long	29(38.1)								29(11. 3)
4	It is good if government or any organization prepare more simple modern materials either as a help or we can share 50% of the cost or in the form of long term credit to make us produce more		60(81. 5)							60(23. 35)
5	Enough improved seed distribution be available timely and if possible provide us new once which can minimize labor and give immediate output			19(25)						19(7.4)
6	to avoid waste of labor power and time it is good if government or any organization provide more simple modern materials either in the market at lower cost or in long term credit		31(40.8)							31(12.1)
7	It is good if government or any organization gives us drug or medicine to kill Rodents				4(5. 2)					4(1. 56)
8	It is good if professional help be done or education be given on the need of having cover and fence to minimize risk.	29(38.1)								29(11. 3)
9	It is good if the pond is done in a better way and maintenance be done on concrete basements or finalizes the construction before the rainy season by government.	2(2.6)								2(0.78)
10	we are trying to purify the runoff and for safety it is good to have medicine for water borne diseases from concerned body.					7(9.2)				7(2.7)
11	as much as possible it is good to keep neatness of the area and to have malaria preventive medicines					17(22.4)				17(6.6)
13	Having continuous assessment will have a positive impact on how to use and produce in each season and will help to give solution for problems that households face.	14(18. 3)								14(5.45)
15	it is good if we have clean water supply to reduce the purpose for which pond water is being used	3(3. 9)								3(1.17)
16	cement or plastic be provided timely to make the water stay long in the pond							12(15.7)		12(4.67)
17	the need of using labor in exchange to share the difficulty in digging and construction						13(17)			13(5.06)
19	it is good if an organization exists to provide us with different fruit varieties			1(1. 3)						1(0.4)
20	Need for continues follow up when pond is dug in groups								2(2.6)	2(0.78)
22	The need to have plastic to be beneficiary from the pond made of cement and kuyesa soil mixture	1(1. 3)								1(0.4)
23	Can put soil on the top of ponds with roof made by concrete to produce some product and manage our land.								1(1. 3)	1(0.4)
24	Total	89(34.6)	92(35.8)	20(7.8)	4(1. 56)	24(9.34)	13(5.06)	12(4.67)	3(1.17)	257(100)

As can be seen from the last row, majority of the solutions suggested focuses mainly on the need for government support in terms of finance and arranging training or experience sharing tour to household heads or the need for making continues assessment and to do professional help well. Lack of equipments needed and problems related to RWH pond being the dominant problems observed 81.5% of the households responded that they need government support or any other organization to supply them with more simple modern materials either by sharing 50% of the cost or via long term credit so that they can produce more. 40.8% of the households suggest support from government to avoid waste of labor power and time in the process of water application; we need more simple modern materials either in the market at lower cost or via long term credit since the price of water lifting and watering equipments are unaffordable at household level.

In addition, for problems related to RWH ponds, government or any other organization help or credit to make us buy iron roof since other raw material don’t stay long and professional help be done or education be given for the need of having cover and fence to minimize risk accounts 38.1% each while 18.3% indicates the need to have continuous assessment to have positive impact on how to use and produce in each season and will help to give solution for problems that household face.

Moreover, households with RWH technology were asked to list benefits they get after they start to use the technology, and in general the total frequency of responses (251) reported the benefits sited by farmers are classified in to four major categories. As can be seen from Table 8.15, these includes new things found after they start to utilize pond

(48.21%), 39.4% of the total frequency of responses represents benefits related to water supply or availability, 11.6% of the responses mentioned benefits related with production side and 0.8% are those related to individual opinions.

Table 8.15. List of Benefits

Se. No		CATEGORY OF THE BENEFITS REPORTED				Total
		Water supply for	New things	Production side	Individual opinions	
1	domestic use	33 (43.4)				33 (13.15)
2	new food varieties in our diet		47(61.7)			47(18.73)
3	Reduce consumption expenditure by producing what we used to buy from the market		28(36.8)			28(11.16)
4	For animals especially for those who can't go long distance to drink water.	37(48.7)				37(14.7)
5	It was able to get water for households easily and timely	29(38. 2)				29(11. 55)
6	Produce vegetable beyond home consumption and get money to be used for different purposes by selling the remaining amount.		26(34.1)			26(10. 36)
7	Helps to use water for permanent plants during the dry season e.g. Chat, Coffee, Papaya etc			6(7.8)		6(2. 39)
8	Enable us to produce more than once in a year by using the pond water during dry spell period			9(11.8)		9(3. 59)
9	create new job opportunity by developing the habit of working in dry season and use their time better than before		20(26. 3)			20(7.97)
10	Can avoid dry up of pepper nursering by using water in the pond			14(18.4)		14(5.58)
11	The negative side out weights positive one because the pond construction isn't dome well and it has no plastic cover				1(1. 3)	1(0.4)
12	I'm glad that the pond isn't covered by plastic or cement basement because it will help not to create bad smell when small animals died				1(1. 3)	1(0.4)
	Total	99(39.4)	121(48.21)	29(11.6)	2(0.8)	251(100)

Of the new benefits observed, 61.7% of the households respond the existence of new food varieties in their diet while 36.8, 34.1 and 26.3 percent are reduction in consumption expenditure by producing what we used to buy from the market, produce vegetable beyond home consumption and sell the remaining to use the money for different purposes and creation of new job opportunity by developing the habit of working in dry season and use their time which isn't known before respectively. In addition, the existence of water in their compound was seen as beneficial for animals especially for those who can't travel long distance to drink water and help the household to get water easily and timely instead of holding heavy material for a long distance to fetch water with 48.7% and 38.2% respectively. Finally, from the production side, 18.4% of the households responded that it is used to avoid nursering of pepper from being dried while 11.8% of them responded that it helps to produce more than once in a year using the water during dry season and 7.8% use the water for permanent plants during the dry season.

The response of 76 households that do not adopt RWH technology, on the factors hindering them from adopting the technology is presented in Table 8.16. The reasons listed by the respondents are summarized in to six categories. Of the total frequency of responses (122) reported, reasons mentioned related to lack of financial capital problems represent 41.8% particularly related to poor economic situation to cover cost involved in pond implementation. Besides, 17.2% of them are related with lack of knowledge and follow up on the technology and most people don't think that it will give that much benefit. Where as, problem of raw materials mainly due to unfair distribution of raw materials needed to take out the water inside, plot/farm land due to small size land around the homestead and other reasons which mainly includes foolishness or less work initiation mentioned account for 10.7% each from the total responses reported.

Table 8.16 Reasons affecting household RWH Technology adoption decision

No	Reasons affecting household RWH Technology adoption decision	Category of reasons for not adapting RWH Technology						*Total*
		Personal reasons	Plot reasons	Lack of financial capital	Lack of knowledge and follow up	Raw materia l	Other	
1	closely I can use my sons, my brothers or my husbands pond than dig for myself (Dependence on one of the family member that has pond or sharing the pond due to small land ownership)			4(5. 2)				4(3. 28)
2	I can't dig my land below 1 meter (the land is dry and stony which makes it difficult to dig and the need to correct terraced plots.		1(1. 3)					1(0.82)
3	The place where I live isn't suitable to dig pond because it doesn't get runoff as needed		4(5. 2)					4(3. 28)
4	We were waiting for our turn to come in time when ponds were dug in groups but we couldn't get the chance since people don't want to dig without food for work program of the government. In addition, poor economic situation makes us unable to cover the cost individually.			45(59. 2)				45(36. 9)
5	Firstly I was not ready and think it won't give that much benefit. But once I have understood the benefit I am interested to adopt the technology if I got wider private land.				16(21)			16(13.1)
6	thinking that the land around the homestead will not be enough		5(6.6)					5(4.1)
7	Being female-headed I've got nobody to help me out with the work and cost			2(2.6)				2(1.64)
8	Unable to see people using it for the intended purpose and the advantage that the pond gives				3(3. 9)			3(2. 46)
9	Distribution of the raw materials needed to take out the water is not fair					12(15.8)		12 (9.84)
10	the raw materials needed for pond that comes from the government to the kebele heads are being manipulated and given to peoples that the heads know					1(1. 3)		1(0.82)
11	Products produced by pond owners are being stolen due to weakness of the kebele administration				1(1. 3)			1(0.82)
12	Lack of follow up from agricultural office on the connection between DA's and farmers.				1(1. 3)			1(0.82)
13	Though I dig equally with my neighbor, I couldn't get full right in using it because when the land was measured the land having the pond happens to be in my neighbors region						1(1. 3)	1(0.82)
14	I've finished my asset and animals for health expenditure and have family related problem	11(14. 5)						11(9.02)
15	Until now the place was not suitable since the plot was covered by crop		3(3. 9)					3(2. 46)
16	at that time I was in a far country, so I miss it when I return back						2(2.6)	2(1.64)
17	Foolishness or less initiation for work						10(13.1)	10(8.2)
18	Total	11(9.02)	13(10.7)	51(41.8)	21(17. 2)	13(10.7)	13(10.7)	122(100)

Generally, the key findings of the qualitative information gathered from the household survey reveal that, decisions' regarding the location of RWH ponds was made by household heads, which was mainly based on the plot location and easy access to get runoff. However, the site selection has an impact on efficient utilization of water and on technology adoption rate. In addition, it can be seen that, decision on the type of rainwater harvesting pond adopted mainly comes from the Agricultural Office.

Very interesting information that was found from this analysis relates to the benefits of RWH suggested by the households, which is the existence of new food varieties shown to be the major one; this implies that most of the households started to grow crops which were not grown before the technology adoption. This is consistent with results obtained in the econometric analysis of the probit model for the determinant factors for household decision to adopt RWH technology (i.e. higher probability of farm household decision to adopt RWH technology in homestead plot) and, in the crop mix analysis.

The major problems encountered during construction and utilization of RWH ponds include the use of heavy materials like metal Bucket as a water lifting and watering equipment, and high report of accident on animals and kids due to lack of roof cover and fence for most ponds. From the solutions suggested for problems encountered in adoption of the technology, the need of government support to provide more simple modern material either in the market at lower cost or on long-term credit bases was shown to be the dominant one. Moreover, the need for professional help or education on the need of having a roof cover and fence for ponds to minimize risk of accident was also considered.

At the end, reasons for households not to adopt the technology include lack of understanding about the benefit of the technology, the cost aspect and discontinuity of working in group.

8.2. Experts Perception

According to the experts, promotion of improved RWH ponds in Alaba Woreda has been started in 2002/03 by constructing some model rainwater harvesting ponds. The Agricultural office in Awassa, which is the head office for SNNPR, initiated it. At the beginning, they started to initiate the technology promotion by organizing a meeting for some representatives from the region. The meeting was meant to give them training so that they can train the farmers in their respective areas.

Firstly, 12 ponds were constructed for demonstration purpose, of which the two were Dome and hemispherical shaped but the rest were trapezoidal. During this time, peasant associations to adopt the technology were selected based on the topography and agro-ecology. From the selected peasant associations, households were chosen based on their agricultural activity and ability to bring change. In the second step, instead of covering every cost, the government started to give eleven quintals of cement and a construction worker by selecting ten households per peasant association if they dig pond, prepare stone and sand. In some areas, ponds were being constructed by mixing cement and ‘Kuissa’ soil to minimize the amount of cement use during construction. Thirdly, the government only supplied cement but the household covered other necessary things for pond construction including payment for construction worker. Finally, plastic sheet was supplied for twenty-five farmers per peasant association instead of using cement, which was found to be expensive.

To some extent recent development in water harvesting technology has considered traditional methods, since the main reason for the existence of modern water harvesting technology is shortage of water. Shortage of water in the area helped the community to be well aware about the benefit of harvesting rainwater. However, since the modern rainwater harvesting technology was presented as being new, in the beginning it had less acceptance due to risk-aversion behavior of farmers. To increase its acceptance, the agricultural office tried to teach farmers through the extension program by stressing the advantages of household level ponds. Some farmers still prefer community pond because they want to see large volume of water to be used for different purposes rather than using pond water for specific purpose of growing vegetables.

At the beginning, adoption of the technology was relatively easier in Alaba than in other Woreda's especially in areas where demonstration was constructed and in peasant associations nearer to the town. However, the quota system imposed by the region put intense pressure to achieve quantitative result of constructing 5000-6000 ponds. In this case, quality is likely to suffer leading to inefficient utilization of the technology for the intended purpose. Site selection was done hurriedly with less experience that put the junior experts and Development Agents under pressure to construct ponds. Efficient monitoring didn't exist due to capacity constraints like difficulties faced by Development Agents to get vehicles or even animals for transport.

The number of households that have adopted the technology so far is estimated to be around 5000 or 6000 of which 2100 of them use plastic cover. Specifically, in 2002/03, 12 ponds were constructed for demonstration purpose. Then around 3500 micro ponds were planned to be constructed in each of the 2003/04 and 2004/05 years. However, only 150 ponds were planned and constructed in 2005/06 because, during the year, the target of experts was to make farmers use the pond for the intended purpose and see the output than continue expanding the number of ponds.

There are dropouts though experts can't tell the number. The possible reasons suggested for dropping out include:

- Some farmers have a habit of waiting for others to make them use the technology
- Poor quality construction creating cracks on the cemented floor and making the water diffuse into the ground.
- Ownership of pond that isn't cemented
- Fear of malaria spread
- An area where runoff doesn't come easily which could be due to the topography

There are some complaints coming from farmers. These are:

- Absence of fence and roof cover for the pond. This is causing an accident on animals and kids in addition to evaporation problem, which reduces the volume of water quickly.
- Economic problem to cover cost involved in the construction of pond basement. This makes water to diffuse into the ground.
- Laziness or lack of work habit among some of the farmers

- Concrete basement ponds could be cracked due to lack of follow up after they are constructed or using less amount of cement during construction.
- In areas where there is no advise from experts
- Complain over the purpose i.e. difficulty in using it for agriculture when the household is in short of drinking water

In the year 2005/06, the plan was to construct only 150 ponds. This is meant to get the chance of strengthening the existing ponds by fulfilling the need of improved seed, plastic demand and other things that are necessary for households. In addition, it is with the aim of helping households with the technology to develop new food varieties by producing new or existing types of crops using the water in dry spell period. Therefore, the future plan of experts focuses on quality.

There are different kinds of technical and other assistance that are given to farmers who adopt RWH technology. This include how to dig, how to cover the roof properly, water lifting and application techniques, how to keep the water clean, the purpose for which the pond water is used, advice in selecting location of the pond, how to use and manage water, on the shape of the pond, on what to produce and in what amount, on how to make maintenance, the need of using the cement properly during construction, selecting catchment area, to make them fence around the pond and giving practical training for Development Agents so that they can continue to work according to it. The financial assistance that is given to farmers with the technology isn’t in cash form. Rather they will be provided professional assistance during the construction stage and other materials in kind. Recently, it is only plastic cover costing 1000 birr that is being supplied.

Since it was implemented at individual level no major conflict and social problem has been observed arising from RWH technology adoption. Two of the experts responded that there are no health problems related to adoption of the technology. However, one of the experts mentioned that even though no new health problem occurred, some increment in malaria spread is suspected. The same idea was raised by another expert but it was only if the pond doesn’t have a roof cover. Besides, the use of pond water for drinking purpose caused water born diseases.

There are also additional comments given by the experts on the benefit of the technology to minimize shortage of water and enabling to produce some new products in the Woreda. The experts are also planning to focus on quality rather than making intense pressure to achieve quantitative results, which was imposed by the quota system in the region. This is meant to get the chance of strengthening the existing ponds by fulfilling the demand for improved seed, plastic sheet, to make the people develop new food verities by producing new type of crops. In addition, careful site selection process in suitable topography is planned to be considered and are planning to develop monitoring.

CHAPTER NINE: DETERMINANTS OF ADOPTION OF RWH POND, INPUT USE AND CROP YIELD

9.1. Analysis of the Determinants of Households Decision to Adopt RWH Pond

The estimation results of the Probit model for the determinants of household's decision to adopt RWH technology is presented in Table-9.1. As can be shown in the table, from the locational dummies, Ulegeba Kukke shows stastical significance at 10% level. No association has been found between village level factors and technology adoption decision.

Household human capital

Household size is positively correlated with the adoption decision of rainwater harvesting ponds at 5% level of significance. This means households with large family size are more likely to adopt the technology since they can compensate costs involved in hiring labor for any activity that the technology demands. This implies that research and development interventions need to take account of the labor and cost demand of the technology. Households who can read and write, and those who are educated up to grade seven are more likely to adopt RWH. The positive association with the technology adoption can occur with the expectation that they can understand the benefit more easily and are more open to access information than illiterate households. This implies that expansion of education in the woreda will have a positive impact in increasing the adoption decision rate.

Household physical capital endowment

From the household physical resource endowment indicators included in the model, oxen, cattle and pack animals have depicted positive correlation with adoption decision of the technology. This indicates that adoption of the technology requires large resources, thus households with a better physical resource are more likely to invest on technology interventions than those with few physical resource. The positive correlation with oxen power may be due to households focus on agricultural production. However, it should be noted that the significant explanatory variables have insignificant effect in magnitude implying its less importance to make policy implication.

Plot level factors

Among the plot level factors, household decision to adopt RWH pond is more likely in homestead plot. The result indicates farm household's effort to fully utilize family labor so as to meet the human resource requirement during construction and utilization of water, thereby reduce the finance that could otherwise be needed for hiring labor. It can also show the capital constraint faced by households to buy modern water lifting equipment. The most interesting implication of this result is that, the accumulated water is used to produce crops with high market value rater than used as supplementary source of water during dry spells, as initially intended by government when the technology was introduced as country level. Ponds with concrete basement have shown stastically significant negative correlation with adoption of rainwater harvesting pond at 1% level. This implies that the higher cost involved in pond construction will result in less technology adoption decision.

Table-9.1 Determinants of adoption of RWH pond (Probit)

Explanatory Variables	Probit use of RWH technology		
	Coefficient (dF/dx) ‡	**Z**	P>z
Peasant association dummy,cf., Mudda Dinokosa			
Ulegebba Kukke	-0.0007837*	-1.85	0.065
Andegna Hansha	-0.0004302	-1.01	0.312
Hamata	-0.0003513	-0.72	0.472
Household access to services and infrastructure			
Walking time to the nearest town market (in hrs)	-0.0001269	-0.61	0.545
Walking time to the nearest village market (in hrs)	0.0001965	1	0.316
Walking time to the nearest cooperative shops (in hrs)	0.0001392	0.52	0.603
Walking time to the nearest all weather road (in hrs)	0.0002143	1.02	0.308
Walking time to the nearest seasonal road (in hrs)	-0.0000296	-0.06	0.954
Rain fall condition, cf., low			
Medium	-0.0004712	-0.84	0.401
High	-0.000446	-1.46	0.145
Household size	0.000111**	1.96	0.05
Age of household head (in Ln)	0.0002167	0.29	0.772
Education level of household head, cf., illiterate			
Read and write	0.0079635***	3.25	0.001
Up to 4th grade	0.0018686	1.44	0.149
Up to 7th grade	0.00026301*	1.86	0.063
Up to 10th grade	7.41E-06	0.01	0.991
Household resource endowment			
Land owned (in ha)	-0.000184	-0.85	0.395
Value of cattle (both local & cross bred cows, calves, heifers, yearling, bulls)	3.59E-07**	1.98	0.048
Value of oxen (local and breed)	5.24E-07**	2.2	0.027
Value of sheep and goat	-4.44E-07	-0.72	0.472
Value of pack animals (donkey, horse, mule)	6.69E-07*	1.88	0.06
Value of poultry (both local & improved)	2.19E-07	0.64	0.519
Value of beehives (improved, modified, traditional)	3.85E-08	0.27	0.79
Value of all assets owned (plow set, farm equip, motor pump, radio,..	-3.23E-08	-0.33	0.74
Household membership in local organization, cf., members in Edir and other local organizations			
Membership in Edir only	0.0002847	0.7	0.487
Household membership in associations, cf., association members			
No membership in association	-9.37E-06	-0.02	0.985
Household financial capital , 1= yes			
Household with credit Access,1= yes	-0.0000753	-0.17	0.865
Household savings, yes=1	-0.0002764	-0.71	0.478
How household acquired the plot, cf., rented and share cropping			
Allocated by the state	0.5627719	0.00	0.997
Inherited	0.5999944	0.00	0.998
Slope of the plot, cf., steep slope			
Flat	0.0044407	0.00	0.999
Moderate	0.0686505	0.00	0.999
Soil depth of the plot, cf., deep			
Shallow	-0.0002766	-0.32	0.751
Medium	-0.0001365	-0.11	0.912
Soil fertility level of the plot, cf., low fertility			
High fertility	0.0141321	1.25	0.21
Moderate fertility	0.0010029	1.11	0.267
Purpose for which the land is used, cf., grazing ,woodlots and spice land			
Cropland	-0.0002559	-0.33	0.74
Homestead	0.0695164***	4.8	0.000
Plot size in ha (in Ln)	0.0005554	0.94	0.345
Walking distance from household's residence to the plot (in hrs)	-0.00168	-0.72	0.472
Type of pond, cf., ponds with plastic cover and those without a cover			
Ponds with concrete basement	-0.377571***	-4.54	0.000
Number of observations	1036		
LR chi2 (41)	350.92		
Prob > chi2	0.0000		
Pseudo R2	0.6399		

*** is significant at 1%; ** is significant at 5%; * is significant at 10%

‡Reported coefficients represent effect of a unit change in explanatory variable on probability of adopting RWH technology.

9.2. Analysis of the Determinants of Agricultural Input Use

The estimation result for the agricultural inputs of: labor person days per hectare, oxen power days per hectare, seed - kg/ha, fertilizer and manure or compost is presented in Table-9.2.

Use of Oxen Power (Oxen power– days/Ha)

The locational dummies of Ulegeba Kukke, Andegna Hansha and Hamata are positively associated with value of oxen power used relative to Mudda Dinokosa. From the household access to services and infrastructure indicators, only nearness to village market is significantly correlated with more use of oxen power. Probably the correlation could be because of the possibility to get more seed and fertilizer enabling them to use more oxen power in order to increase their agricultural productivity. Moreover, it is shown that medium rainfall condition is positively correlated with the use of oxen power than low rainfall condition.

In the household level factors, household size, heads who can read and write, and those who are educated up to fourth grade are positively associated with the use of oxen power at 1% level of significance. This implies those households having large family size and educated members are more likely to use oxen power to utilize labor available in the family to produce more output.

From the household physical resource endowment indicators, owned land has shown positive correlation with the use of oxen power at 5% level of significance, which implies that more oxen power will be used by heads who own more land. In addition, ownership of goats and sheep, and beehive are stastically significant at 10% level. The significance might imply household's involvement in sheep, goat or honey trading to get extra income and use more oxen power in order to increase agricultural production especially in cases when the household has large land size.

In relation to household head's membership in various associations, the study showed that relative to households with heads a member in association, households with heads not a member in associations are negatively correlated with oxen power use. This might imply, non-members may depend on activities that don't use oxen power as their source of livelihood. Farm households with saving have depicted significant negative association with oxen power use, more likely households with saving are engaged in livestock production, trading or use the money for health expenditure and for some other purposes.

The amount of oxen power used has shown significant positive association with flat and moderately sloped plots in comparison to steep plots. The result might indicate farmers risk aversion behavior due to crop failure which could be caused by high runoff problem. Plots with medium soil depth are less likely to use oxen power compared to plots with deep soil depth. Homestead plots have stastically significant negative correlation at 1% level. This means, it is less likely that households will use oxen power on homestead plots. However, the likely use of oxen power is shown to be significantly higher in crop land plots. An interesting result is found in the relationship between plot size and oxen power use, where larger plot size is significantly associated with lower oxen power use.

The estimation regression analysis also indicates that, adoption of rainwater harvesting technology has a negative stastically significant association with use of oxen power, more likely due to lower use of oxen power and more human labor on homestead plots where the technology is mostly adopted.

Use of Seed (Kg/ha)

The regression result depicts that no evidence has been found between locational dummies and amount of seed used. From the village level indicators, closeness to town and village market is significantly associated with more use of seed, probably the household heads are less likely to be engaged in non-farm labor employment and hence, more emphasis be given to crop production.

With respect to household size, large family size is significantly associated with more use of seed, probably indicating that the members in the household utilize labor by working in agricultural activity which demands more seed. From the education status, households with heads who can read and write, and those with formal education up to fourth grade have shown positive association with use of seed relative to illiterate headed households. Households endowed with large sized land are significantly associated with more use of seed. No significant correlation has been observed between social and financial factors, and amount of seed used.

The result in the correlation between plot level factors and intensity in use of seed, more likely use of seed is shown on cropland and homestead plots. As expected the estimation of the regression analysis indicates that, adoption of RWH pond has stastically significant association with more likely use of seed. This could probably imply the impact of the RWH technology on crop production is indirectly through its effect on intensity of agricultural inputs.

Use of Labor Power (Person – Days/Ha)

As can be seen from the result of the regression analysis, location dummy of Hamata PA is associated with more likely use of labor input at 5% level of significance. From the correlation between household access to infrastructure and service indicators and use of labor input, closeness to village market, town market and seasonal roads are associated with higher intensity in use of labor input. Probably household heads are engaged in farming activity by utilizing more seed, oxen and fertilizer use. Areas with high rainfall depict statistically negative association with labor input use, suggesting the need for more labor input in areas where there is low rainfall.

The result of the regression analysis shows that, a farm household with large family size has stastically significant association with use of more labor. Probably the positive correlation with labor input could be because of either inability of the economy to absorb the excess labor force in extended families or constrained by transaction cost in the labor market and there by the family members are compelled to engage in crop production at the existing plot. Stastically significant negative correlation exists between the age of the household head and use of labor input. That means older-headed households are less likely to supply labor.

Table – 9.2 Determinant factors of input use during 2005/06 agricultural fiscal year

Explanatory Variables	Ln (Seed/ha)	Ln (Oxen-days/ha)	Ln (Labor-day/ha)	Whether fertilizer were used	Whether manure/compost were used
Peasant association dummy,cf., Mudda Dinokosa					
Ulegebba Kukke	-0.245172	0.15099*	0.058052	0.0655231	-0.0197904
Andegna Hansha	0.214534	0.203828***	0.039733	-0.1935646***	0.079232
Hamata	0.001953	0.168604**	0.172659**	-0.1475076**	-0.0190538
Household access to services and infrastructure					
Walking time to the nearest town market (in hrs)	-0.104291**	-0.016135	0.020109	0.206203	-0.0265866*
Walking time to the nearest village market (in hrs)	-0.125701**	-0.072537***	-0.117138***	-0.0425217*	-0.0363848**
Walking time to the nearest cooperative shops (in hrs)	0.034241	-0.02963	-0.057824*	-0.0280787	-0.0054926
Walking time to the nearest all weather road (in hrs)	0.040986	-0.011034	0.022569	-0.0090631	0.0078478
Walking time to the nearest seasonal road (in hrs)	0.184175	0.097555	-0.110871*	0.0753763	-0.129366***
Rain fall condition, cf., low					
Medium	-0.084553	0.112657**	-0.054333	0.0087776	0.0026803
High	-0.091135	0.008501	-0.212387***	0.0527761	0.2818222***
Household size	0.026266*	0.021049***	0.043193***	-0.0024128	0.0094189*
Age of household head (in Ln)	0.125784	0.108762	-0.181818*	-0.0654953	0.0254648
Education level of household head, cf., illiterate					
Read and write	0.230052*	0.231572***	-0.087174	-0.0931605	0.0654167
Up to 4th grade	0.257753*	0.192213***	-0.078671	0.0288443	-0.0862418**
Up to 7th grade	0.083556	-0.024551	0.002305	-0.0171464	0.0307067
Up to 10th grade	0.071938	0.080617	-0.053017	-0.0293807	-0.0785635
Household resource endowment					
Land owned (in ha)	0.007845*	0.006203**	0.00167	0.0027194	-0.0037889**
Value of cattle (both local & cross bred cows, calves, heifers, yearling, bulls)	-1.73E-05	-5.90E-05	-6.98E-05***	4.99E-06	-0.0000345**
Value of oxen (local and breed)	4.28E-05	2.83E-05	4.82E-05*	0.0000103	0.0000485***
Value of sheep and goat	0.000167	0.000129*	-9.97E-07	-5.99E-06	-5.83E-06
Value of pack animals (donkey, horse, mule)	-0.000118	-0.000051	-8.93E-05**	7.97E-06	-5.84E-06
Value of poultry (both local & improved)	-0.000809	0.000172	0.000323	-0.00039	0.0003529
Value of beehives (improved, modified, traditional)	-0.00041	0.000376*	0.000197	0.0003235*	-0.0004251***
Value of all assets owned (plow set, farm equip, motor pump, radio, ...)	3.62E-06	-1.66E-05	-2.19E-05	7.05E-06	-3.57E-06
Household membership in local organization, cf., members in Edir and other local organizations					
Membership in Edir only	-0.215644	-0.115894	-0.210552***	-0.089469	0.0591204
Household membership in associations, cf., association members					
No membership in association	-0.094869	-0.191782***	0.042779	-0.0621948	-0.0014808
Household financial capital , 1= yes					
Household with credit Access,1= yes	-0.137139	0.070683	-0.06814	0.0624094	0.056192*
Household savings, yes=1	-0.072473	-0.327655***	-0.114424**	0.0126967	0.1128724***

Table – 9.2 continued

Explanatory Variables	**Ln (Seed/ha)**	**Ln (Oxen-day/ha)**	**Ln (Labor-day/ha)**	**Whether fertilizer were used**	**Whether manure/compost were used**
How household acquired the plot, cf., rented and share cropping					
Allocated by the state	-0.506682***	-0.141824*	0.084312	-0.1988535***	0.158752***
Inherited	-0.382232***	-0.169708**	-0.111456*	-0.1364283**	0.1498123**
Slope of the plot, cf., steep slope					
Flat	-0.119189	0.530278*	0.446515*	0.1701381	0.3856669*
Moderate	-0.10287	0.51544*	0.547266**	0.1265144	0.2790531**
Soil depth of the plot, cf., deep					
Shallow	-0.021532	0.129045	-0.117212	-0.0475644	0.2127672
Medium	-0.000324	-0.300583***	-0.315847***	0.0428845	0.1378711*
Soil fertility level of the plot, cf., low fertility					
High fertility	0.048873	0.101733	0.035063	-0.0829447	0.1586607**
Moderate fertility	0.144556	0.089368	0.062933	-0.0517906	0.479061
Purpose for which the land is used, cf., grazing ,woodlots and spice land					
Crop land	0.419156***	0.37224***	0.614584***	0.4647761***	-0.0924947**
Homestead	3.09079***	-0.340097***	-0.472505***	-0.5890224***	0.4247779***
Plot size in ha (in Ln)	-0.180882	-0.912926***	-0.779754***	-0.2589599***	0.539933
Walking distance from household's residence to the plot (in hrs)	3.312421	0.011153	-0.12605	0.2058507**	-0.1616669
Adoption of Rain Water Harvesting technology (predicted value), 1=yes	3.312421***	-0.291091*	0.265723*	0.1043238	0.0748814
Constant	4.448353***	4.83144***	6.78531***		
Number of observations	1036	1036	1036	1036	1036
F (41,994)	8.80	14.08	14.46		
Prob > F	0.0000	0.0000	0.0000		
R squared					
LR chi2 (41)				281.62	353.37
Prob > chi2				0.0000	0.0000
Pseudo R2				0.1964	0.3137

*** is significant at 1%; ** is significant at 5%; * is significant at 10%
Reported coefficients represent effect of a unit change in explanatory variable on probability of use of the mean of the data
Ln represents natural logarithm

Furthermore, in relation to the household physical resource endowment, ownership of more oxen power is likely to utilize more labor input than in cattle and pack animal ownership. This is probably due to complementarity. An important point that should be noted is the insignificant impact of this variables when consider the magnitude. In relation to household head's membership in local organization, the study witnessed that, members in Edir and other related local organization are more likely to use labor input than those who are members in Edir only. In addition, households with saving are less likely to use labor input, probably suggesting household's involvement in activities other than agriculture.

The result also shows a mixed correlation between plot level factors and labor input use. For instance, labor input use is significantly greater on plots with flat and medium slope than plots with steep slope, perhaps indicating farmers risk aversion behavior and their emphasis on short term benefit. Since steep sloped plots are more exposed to soil erosion problem. More over, less of labor input is used on inherited and plots with medium soil depth. Homestead plots have stastically significant negative association at 1% level. However, more use of labor input is observed on cropland plots. An interesting result is found in the relationship between plot size and labor input use, where larger plot size is significantly associated with lower labor input use. Finally, as anticipated the estimation of the regression analysis indicate that, adoption of RWH technology has a positive stastically significant association with use of higher labor, most likely due to the higher level of labor requirement during watering , construction an other activities involved.

Use of Fertilizer

As can be seen on table 9.2, the locational dummies for Andegna Hansha and Hamata are associated with less likely use of fertilizer compared to Mudda Dinokosa. From the village level factors, walking time to the nearest village market has a negative correlation with fertilizer use at 10% level of significance. That means households closer to the village market are more likely to use fertilizer. No evidence has been found on the existence of correlation between the likely use of fertilizer and factors like human, social and financial capital part of the household level indicators. Further more, strong positive correlation has been found between value of beehives and the likely use of fertilizer, which is perhaps due to households focus on beekeeping activity enabling them to buy more fertilizer using the incremental income.

In relation to the association between plot level factors and the likely use of fertilizer, crop land plots are shown to have positive association with the use of fertilizer at 1% level of significance. Less fertilizer use is observed on homestead plots due to more possibility to use manure or compost than buy fertilizer. In small plot size it is more likely to use higher amount of fertilizer which is mainly due to an increase in efficiency when household's own small sized plots. Moreover, plots closer to the residence of the farm household have depicted significant correlation with more likely use of fertilizer. Finally, the adoption of RWH technology is shown to have insignificant impact on use of fertilizer suggesting that its impact on crop production isn't seen indirectly through its effect on fertilizer input.

Use of Manure or Compost

As can be depicted from table 9.2, no evidence has been found on the existence of correlation between the use of manure or compost and the locational dummies. From the locational dummies, household's nearness to village market, town market and seasonal road is more likely to use manure or compost inputs. Probably this is due to the use of more labor seed input when the household is closer to this services. In areas where there is high rainfall, more use of manure or compost is observed.

Further more, from the household level factors, households with large family are more likely to use manure or compost, probably due to the availability of labor to carry manure or compost to the farm land. With respect to educational status, household heads with formal education up to fourth grade are less likely to use manure or compost relative to illiterate heads. Most likely this could be affected either by educated headed households positive correlation with more likely use of fertilizer there by reducing the likely use of manure or compost , or these households are constrained by labor required to carry manure or compost to the farm.

In relation to household's physical resource endowment, ownership of large sized land is correlated with less likely use of manure or compost, probably due to its high demand for labor input to carry manure or compost to wider farm lands. Ownership of large number of oxen is correlated with more likely use of manure or compost. Those engaged in livestock production as shown by ownership of large number of cattle and beehives are less likely to use manure or compost.

With respect to the financial capital part, households who have access to credit are more likely to use manure or compost input. Probably due to the possibility of using the credit to buy seed, oxen etc. which might lead to demand more manure or compost .In addition, those with saving are also more likely to use manure or compost. Probably due to their preference to spent it on other things than on fertilizer by replacing it with manure or compost.

Finally, in relation to the association between plot level factors and the likely use of manure or compost, the result witnessed that, state owned and inherited plots are positively correlated with more use of manure or compost. On the other hand, on flat and moderately steep plots, households are more likely to use manure or compost than on those steep sloped plots, probably to avoid risk of crop failure. Medium soil depth is more likely to use manure or compost. Plots that are highly fertile are more likely to use manure or compost than those infertile once because it will be risky for the household to use the input on infertile plot than fertile once. Households are less likely to use manure or compost on cropland plots but more likely to use it on homestead plots, probably due to its closeness to the residence of the farm household. Adoption of RWH technology is found to have insignificant impact on manure or compost.

9.3. Analysis of the Determinants of Crop Yield

Table - 9.3 presents the full model of the value of crop yield (column-2). Here, variables such as household level factors; household – human, social, physical, and financial capital endowment; and adoption decision of RWH technology that were included in the unrestricted OLS regression have been found to be jointly statistically insignificant. In column – 3 and column– 4 results of the structural and reduced models are shown respectively.

As can be seen from the structural model for the value of crop yield, the locational dummies for Ulegebba Kukke and Hamata have shown negative correlation with value of crop yield. From the village level factors, seasonal road have negative stastical significance at 10%. With respect to the impact of plot fertility on value of crop yield, households are more likely to produce more output in moderately fertile plots than infertile once. As can be observed from the table, cropland and homestead plots are more likely to produce more yield. Besides, the result indicates the positive impact of use of labor, fertilizer and seed on value of crop yield.

In the reduced model of crop yield, depicted in column 4 of table 9.3, village level factors, plot level factors, household level factors and household rainwater harvesting technology adoption decision were included in the regression and assessed with respect to their impact on the value of crop yield.

Location dummies for Ulegebba Kukke and Hamata have negative stastical significance on value of crop yield relative to Mudda Dinokosa PA location dummy. The village level factors don’t explain variation in the value of crop production. Moreover, from the household level factors, household size has shown positive association with value of crop yield at 10% level of significance. This implies that households having large family size are more likely to produce more output. With respect to the impact of household physical capital endowment, greater ownership of cattle has shown association with higher value of crop yield (and stastically significant at 10% level).

From the plot level factors included, state owned plot are more likely to produce more output than rented plots. Possibly indicating household's high future discount rate and become less likely to invest on productivity enhancing activities on rented plot. Plots with shallow and medium soil depth are less likely to produce more output than plots with deep soil depth. It is also shown that, cropland and homestead plots are more likely to produce more output compared with grazing, woodlots and spice plots. In addition, a negative significant association is observed between plot size and value of crop yield.

It is shown that stastically positive significant evidence was found on the relationship between household adoption decision of rainwater harvesting technology and value of crop yield. This suggests that household adoption decision of rainwater harvesting technology has a direct effect on value of crop yield in addition to the indirect effects.

It has been already discussed that several factors affect or determine the level of crop yield, directly or indirectly. Finally, this part includes the implication of the determinant factors of input use and crop yield.

Table – 9.3 Determinants factors of value of crop yield

Explanatory Variables	Ln (Value of yield/ha)		
	Full Model ‡	Structural Model ¶	Reduced Model
Peasant association dummy,cf., Mudda Dinokosa			
Ulegebba Kukke	-0.240465**	-0.16942**	-0.272749***
Andegna Hansha	-0.091321	-0.05626	-0.101886
Hamata	-0.332615***	-0.29741***	-0.387513***
Household access to services and infrastructure			
Walking time to the nearest town market (in hrs)	-0.037325	-0.02798	-0.037513
Walking time to the nearest village market (in hrs)	0.039986	0.041098	0.01502
Walking time to the nearest cooperative shops (in hrs)	-0.017744	-0.03863	-0.016557
Walking time to the nearest all weather road (in hrs)	-0.020955	-0.01405	-0.020943
Walking time to the nearest seasonal road (in hrs)	-0.13985*	-0.16159**	-0.083644
Rain fall condition, cf., low			
Medium	0.016212	0.01092	0.003531
High	0.10563	0.095822	0.08433
Household size	0.008924		0.015446*
Age of household head (in Ln)	-0.1558997		-0.13447
Education level of household head, cf., illiterate			
Read and write	0.007438		-0.059152
Up to 4th grade	0.064804		0.110153
Up to 7th grade	0.058197		0.079857
Up to 10th grade	0.123428		0.107066
Household resource endowment			
Land owned (in ha)	0.00154		0.0031
Value of cattle (both local & cross bred cows, calves, heifers, yearling, bulls)	4.44E-05*		4.55E-05*
Value of oxen (local and breed)	-3.44E-05		-1.22E-05
Value of sheep and goat	9.65E-05		8.20E-05
Value of pack animals (donkey, horse, mule)	8.94E-06		-3.14E-05
Value of poultry (both local & improved)	0.000275		0.00021
Value of beehives (improved, modified, traditional)	4.64E-06		-3.61E-05
Value of all assets owned (plow set, farm equip, motor pump, radio, ..)	-8.60E-06		-7.41E-07
Household membership in local organization, cf., members in Edir and other local organizations			
Membership in Edir only	-0.12421		-0.14033
Household membership in associations, cf., association members			
No membership in association	0.133489*		0.077884
Household financial capital , 1= yes			
Household with credit Access,1= yes	0.084706		0.045664
Household savings, yes=1	0.01175		-0.000479
How household acquired the plot, cf., rented and share cropping			
Allocated by the state	0.285989***	0.220717***	0.175439**
Inherited	0.14397*	0.09171	0.047545

Table – 9.3 continued

Explanatory Variables	Ln (Value of yield/ha)		
	Full Model	**Structural Model**	**Reduced Model**
Slope of the plot, cf., steep slope			
Flat	0.107935	-0.05085	0.157219
Moderate	0.213	0.052619	0.253161
Soil depth of the plot, cf., deep			
Shallow	-0.342699**	-0.2061	-0.276843*
Medium	-0.320594**	-0.2085	-0.269564*
Soil fertility level of the plot, cf.,low fertility			
High fertility	0.083002	0.12039	0.042061
Moderate fertility	0.10888	0.136898*	0.099062
Purpose for which the land is used, cf.,grazing ,woodlots and spice land			
Cropland	0.545698***	0.53749***	0.692927***
Homestead	0.22273*	0.273696***	0.376867***
Plot size in ha (in Ln)	-0.056483	-0.02842	-0.123963*
Walking distance from household's residence to the plot (in hrs)	0.085783	0.101174	0.077678
Labor-day/ha (in Ln)	0.101176***	0.110689***	
Oxen-day/ha (in Ln)	0.018104	0.006066	
Seed/ha (in Ln)	0.086711***	0.086715***	
Use of fertilizer,1= yes	0.164603***	0.171696***	
Use of manure/compost, 1= yes	-0.115259*	-0.11909*	
Adoption of Rain Water Harvesting technology (predicted value),1=yes	0.055424		0.510136***
Constant	6.686813*	6.272492***	7.859654***
Number of observations	1036	1036	1036
F (46,989)	8.11		
F(27,1008)		12.18	
F (41,994)			6.14
Prob > F	0.0000	0.0000	0.0000
R squared	0.125	0.0967	0.0953

*** is significant at 1%; ** is significant at 5%; and * is significant at 10%.

Ln= natural logarithm.

‡ Reported coefficients represent effect of a unit change in explanatory variable on probability of use of the mean of the data.

¶ Variables that were jointly statistically insignificant in the unrestricted OLS regression were excluded from the structural model

As can be depicted from the result of the reduced model, household family size is positively correlated with value of yield at 10% level of significance implying that large family will produce more output. From the determinant factors of input use table, households with large family size have shown significant association with use of higher labor, seed, oxen and more likely use of manure or compost. Intensity in use of labor has a positive impact on yield at 1% level of significance. This suggests that yield averages 11% higher per additional labor a household uses. Moreover, average yield increases by around 9% per additional seed amount used by the household. Even though fertilizer isn't significantly affected by household size, fertilizer is positively correlated with value of yield at 1% level of significance. That means yield is more likely to increase with more use of fertilizer input. Household age and education have insignificant impact on value of yield. However, household age has a significant impact on labor. Old age is negatively associated with labor input use. Educational status has a positive impact on seed and oxen input use.

Variations in resource endowment among households will obviously have an impact on the level of crop yield either directly or indirectly through their effect on the household's demand for agricultural inputs. Of the factors, which are used to measure household physical capital endowment, ownership of cattle has a positive impact on the value of crop yield. However, it has insignificant impact when consider the magnitude to make policy implication.

Households with saving are negatively associated with labor and oxen inputs use. Probably they might prefer to be involved in non-farm activities. Credit access and saving have a positive impact on manure or compost input use. Household access to services and infrastructure facilitates the movement of inputs to and outputs from rural parts to towns, where large market is available. The regression result shows an increase in yield when the household is located closer to seasonal road and is stastically significant. Households closer to village market are able to use higher amount of seed, labor, oxen and more likely to use fertilizer and manure or compost input. In addition, households closer to cooperative shops and seasonal roads are more likely to use labor input and those nearer to town market are able to increase seed amount.

The result of the value of crop yield also shows that, state owned plots witnessed stastically significant association with higher value of crop yield. Probably, suggesting that farmers are more likely to invest on productivity enhancing activities on state owned plots. It is also shown that shallow and medium soil depth has stastically significant association with lower yield than on deep soil depth. Finally, crop land and homestead plots are shown to have positive association with value of yield.

The impact of adoption of RWH technology on crop production can be explained in two ways, directly or indirectly. The direct impact is, if the accumulated water is used to supplement the shortage of water during dry spell periods in rain fed crop production, where as the indirect impact is through its effect on intensity in use of agricultural inputs.

The estimation result of the study indicate that, adoption of RWH technology is shown to be positively correlated with value of yield at 1% level of significance. This might imply that the direct impact of the technology adoption on crop production is significant. An examination of the indirect impact shows that, households with RWH technology are significantly correlated with higher use of labor and seed but lower use of oxen power than those without the technology. Intensity in use of labor and seed input has a positively significant impact on yield while oxen power has insignificant impact on yield.

CHAPTER TEN: CONCLUSTIONS AND RECOMMENDATIONS

10.1 Conclusions

Due to population increase in the highland areas, more and more marginal areas are being used for agriculture which led to the degradation of the natural resources .One of the major challenges to rural development in the country is how to promote food production to meet the ever-increasing demand of the growing population. Rainfall in the arid and semi-arid areas is generally insufficient to meet the basic needs of crop production. In degraded areas with poor vegetation cover and infertile soil, most of the rainfall is lost through direct evaporation or uncontrolled runoff. Thus, overcoming the limitations of these arid and semi-arid areas and making good use of the vast agricultural potential under the Ethiopian context, is a necessity rather than a choice. Hence, to alleviate these development constraints, the Federal government and Regional states, and NGOs working in research and development, have invested huge resource on rainwater harvesting technology.

In this study, methodologies including descriptive, econometrics, cropping pattern and qualitative analysis are used to assess the impact of different factors hypothesized to affect farm household’s decision to adopt RWH technology and agricultural productivity. Besides, group discussion has been undertaken on the issue of indigenous rainwater harvesting technologies. Interview has also been done with experts on rainwater harvesting ponds. In addition, gender related to adoption of pond was considered.

In accordance with government's target, the impact of this intervention on agricultural productivity is shown to be significant in the study. The cropping pattern has shown that farm households have started to grow crops which were not previously grown in the area. The crops are those which are highly priced and marketable ones implying the potential of RWH technologies to enhance a farm household's income. However, the benefit depends on market and infrastructure accessibility, and diversification in the types of the crops.

The estimation result of the probit model indicates that, household size, education status, ownership of livestock (cattle, oxen and pack animals),homestead plots and type of pond are the most important factors that determine household's decision to adopt RWH technology.

The Ordinary Least Square estimation of the reduced form model indicates that, the direct impact of household RWH technology adoption on the value of crop yield is found to be stastically significant. On the other hand, an examination of the indirect impact shows that, households with RWH technology are significantly correlated with higher use of labor and seed but lower use of oxen power than those without the technology. Intensity in use of labor and seed input has a positively significant impact on yield while oxen power has insignificant impact on yield.

The qualitative result from farmer's perception indicates that, most of the households started to grow crops that were not grown previously. This result is consistent with what we have found in the crop mix and econometric analysis. In addition, for problem related to water lifting and watering equipments, households suggest for the need of government support to provide more simple modern material either in the market at lower cost or on long-term credit bases. And the need to have professional help or education to make people use roof covers and fence to minimize accidents reported. From expert's perception, it was found out that, to avoid problems resulted due to the focus on quantity target; the experts are planning to focus on quality than quantity in order to increase efficient utilization of the technology.

It was found out that women are getting benefit from the technology adoption as any member of the family. Their participation in the technology adoption is mainly in the watching stage. They also have contribution in planning and decision making stage, and in giving support during construction, maintenance and clearance of the pond. Female headed households are being constrained to be beneficiaries due to economic and manpower shortage. Finally, from the indigenous rainwater harvesting part, it was shown that, due to an increase in awareness of people to get clean water, less attention is being given to the community ponds and are resulting health problem

10.2. Recommendations

The benefit found from the marketable crop started to be grown, depends on market and infrastructure accessibility, and diversification in the types of the crops. Thus, efforts should be made to assess various agricultural commodities as well as to create a market linkage.

The impact of household RWH technology adoption on the value of crop yield has been found to be stastically significant. Therefore, to mitigate the erratic nature of rain fall in the arid and semi-arid parts of the country, development and implementation of rain water harvesting technologies will be helpful to promote productivity and sustainable intensification of the rain fed agriculture.

However, the success of the technology adoption is mainly constrained by problems related to water lifting and watering equipments, and accidents occurring due to absence of roof cover and fence to the ponds. Thus, government support will be needed to provide more simple modern material either at lower cost in the market or on long-term credit bases, and need to give intensive training to make households who adopt the technology use roof covers and fence to their ponds.

From expert's perception, it was found out that, the experts are planning to focus on quality than quantity to increase efficient utilization of the technology in addition to careful site selection and improvement in monitoring. Thus, incorporating this kind of plan in other Woredas will be beneficiary towards a better achievement.

Due to an increase in awareness of people to get clean water, relatively less attention is being given to the community ponds and are resulting health problem. However, it will be advantages to give a better attention to community ponds since it can minimize the purpose that is being provided by household level pond.

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