FARMERS' PERCEPTIONS AND ADOPTION OF MICRO CATCHMENTS FOR IMPROVED ESTABLISHMENT OF AGROFORESTRY TREES IN EAST SHEWA ZONE, ETHIOPIA

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A Thesis submitted in partial fulfillment of the requirements for the award of degree of Master of Science (Land and Water Management) in the Department of Agricultural Science and Technology, School of Agriculture and Enterprise Development, Kenyatta University

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DECLARATION

I declare that this thesis is my original work and has not been presented for a degree in any other university or any other award

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DEDICATION

I dedicate this work to my family for their prayers, encouragement and support they accorded to me throughout this work.

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ACRONYMS AND ABBREVIATIONS

ACIAR:	Australian Centre for International Agricultural Research
ASALs:	Arid and semi-arid lands
CA:	Catchment Area
GDP:	Gross Domestic Product
IB:	Infiltration Basin
MB:	Micro basin
MC:	Micro catchment
NEPAD:	New Partnership for Africa's Development
RWH:	Rainwater harvesting
SPSS:	Statistical package for social sciences
SWC:	Soil and Water Conservation
UNDP:	United Nations Development Program

ABSTRACT

Tree planting on farms has both environmental and socioeconomic benefits. The practice of establishing trees and tree plantations is common among rural population in the dry regions of Ethiopia, who depend on livestock, trees and tree products for subsistence. Despite the importance of trees, their survival in these dry areas is low and often challenged by drought and water shortage. To address the water scarcity problem, two micro catchments specifically, micro basins and trenches were established in East Shewa zone of Ethiopia. This study sought to assess their suitability in enhancing the survival of three tree species namely *Cordia Africana* Lam, *Grevillea robusta* A.Cunn. ex R.Br, and *Mangifera indica* L. Survival of the trees grown in the micro catchments was compared to trees grown in the ordinary planting pits (control). The specific objectives of the study include 1. To assess farmers' perception of the effectiveness of micro catchments in establishment of agroforestry trees. 2. To determine factors influencing adoption of micro catchments for tree survival. 3. To determine the effectiveness of micro catchments in enhancing survival of agroforestry trees. Data to assess farmers' perceptions and factors influencing adoption of the micro catchments were collected through a household survey involving 142 farmers and key informant interviews. Tree survival data was collected at intervals of 6 months from planting time up to 36 months. Using the statistical package for social sciences (SPSS) and STATA descriptive statistics and regression models were used to analyze the data while the Kaplan Meier method using SPSS was used for tree survival analyses. Results showed that over 50% of the respondents perceived the micro catchments to be effective for survival of trees and conservation of soil moisture with a higher preference for micro basins. Variables such as land size, perception of water scarcity as a problem, labor availability had a significant influence on farmers' perception of micro catchments. Further results showed that access to extension information, fencing of trees for protection, number of land parcels, previous use of soil and water conservation methods significantly influenced adoption of the micro catchments. A low survival rate was observed for all the three tree species (<30%) after 36 months in the three treatments. The highest tree mortality rate occurred between the sixth and twelfth months, this was mainly attributed to soil moisture deficit. Trees that had survived beyond 18 months survived up to 36 months. Farmers, perceptions further revealed that the high rate of tree mortality was not only as a result of water scarcity but also due to damage from free-grazing livestock and insect attack. The study concluded that in spite of the positive perception towards micro catchments, these structures may fail to adequately address the problem of low tree survival rate and this may limit their adoption. Therefore, efforts to enhance tree survival should be responsive to all constraints of tree survival and holistic approaches implemented to address the challenges. The study recommends further research into both biophysical and social-ecological factors that affect tree survival, and apt post-planting tree management practices suitable in the area mainly focused on the early stages of tree establishment.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Agriculture is a key driver of the global economy accounting for one third of the global Gross Domestic Product (GDP) (World Bank, 2020). In Africa, the agricultural sector supports more than half of Africa's population (Blein *et al*., 2013). It contributes to about 33% of the, 40% of exports and 70% of employment (InterAcademy Council, 2004). Rainfed agriculture accounts for about 95% of total agriculture in the continent. However, rainfed agricultural production has been constrained by erratic and variable rainfall resulting in frequent drought periods (Kaluski *et al*., 2002). Land degradation, land tenure problems, and increasing population are other challenges that face agriculture in African countries, exposing populations in these areas to food insecurity and poverty risks. (African Development Bank, 2010).

In Ethiopia not only is agriculture the major economic activity, but also a source of livelihood for most people (Gebre & Weldemariam, 2013). The agricultural sector accounts for approximately 50% of GDP, three-quarter of total earnings from exports and employs 80% of the total population (Angelucci *et al*., 2013). Despite its significance in the country's economy, a decline in agricultural production has been experienced over several years. The disaster prevention and preparedness commission report in 2000 recorded a declining rate in Ethiopia of 2.7% between 1991 to 1992, 3.6% from 1993 to 1994, and 11.4% from 1997 to 1998 (Bekele, 2001). Further, a downward trend of 5.2% was recorded between 2004 and 2011 (Angelucci *et al*., 2013). This decline in agricultural production, coupled with population increase has led to high poverty levels and land degradation due to the over-extraction of natural resource base (Bonkoungou, 2001).

Various methods can be applied to reverse the declining trend in agriculture and boost its productivity. These include the application of organic and inorganic fertilizers, better-quality inputs such as seeds, irrigation, post-harvest losses' reduction and integrated pest management approaches (Demeke *et al*., 1997). However, due to limited access to inputs, technologies and unfavorable climatic conditions, these approaches, aimed at benefiting smallholder farmers, the majority of whom poorly resourced, may fail. These farmers are usually constrained by inaccessibility to credit services, deficient money resources, untimely delivery of agricultural inputs and scarce information on markets (Matsumoto & Yamano, 2010; Spielman *et al*., 2011). To address these setbacks, innovative practices such as agroforestry need to be considered for implementation.

Agroforestry is defined as the system in which trees and shrubs are incorporated within the farming system (Nair, 2013). Integration of trees with crops expands farmers' income sources thereby reducing their dependency on a single staple crop, hence fostering their resilience. Such integrated farming systems contribute to enhanced food insecurity, land restoration and prevent adverse effects of climate change. Further, trees help in maintaining high soil water retention capacity; restoring soil fertility and soil organic matter; improving landscapes and reducing pressure on forested lands (Cacho, 2001). According to Young (1990), agroforestry increases farm productivity due to trees' heightened abilities to control soil erosion and conserve soil moisture.

Agroforestry practices, especially in the rain-fed agricultural areas are mainly limited by water scarcity (Li *et al*., 2009). This is mainly as a result of insufficient rainfall, prolonged dry periods, large air humidity deficit, competition of tree crops with neighboring crops and hydraulic conductivity which reduces water availability (Guarnaschelli *et al*., 2012). These challenges necessitate the need for insights as to ways to improve tree survival and growth in these sites (Cao *et al*., 2008) by optimizing the quantity of water accessible to crops and trees by maximizing water permeation in the soil, decreasing runoff, and reducing evaporation (Leye, 2007).

For tree growth, soil and water conservation (SWC) is most critical at the initial stages of establishment for the development of a healthy tree root system (Melle, 1992). Methods such as in situ and ex situ rainwater harvesting (RWH) and irrigation can be implemented to mitigate the detrimental effects of water scarcity. However, irrigation schemes may be unsuitable for the majority of small scale farmers because they are expensive (Mekdaschi & Liniger, 2013). Oweis & Hachum, (2006) note that rainwater harvesting techniques would be more feasible both for crop and tree production in areas where irrigation methods are contentious.

1.2 Statement of the problem

Whether established in forests or as individual stands, studies globally have shown that trees are adversely affected by water scarcity (Close *et al*., 2005; Guarnaschelli *et al*., 2006). In water-stressed areas, both the physical environment and tree physiology are adversely affected thus hindering tree productivity (Akıncı & Lösel, 2012). In the drylands of Ethiopia, survival of tree seedlings outside forests is continually diminishing. The national average for tree survival has been estimated at 20% (Siyum *et al*., 2019) and moisture stress has been attributed to be the key limitation to tree survival (Abrha *et al*., 2020; Ali *et al*., 2017; Tadele & Moges, 2018).

Investments in soil moisture conservation to promote survival of agroforestry trees are minimal while options available for retaining soil water for tree growth have not been adequately assessed and explored (Adimassu *et al*., 2012). Moreover, studies have focused on tree plantations in more degraded lands as opposed to agroforestry trees on homesteads (Alem & Habrova, 2019; Mekuria *et al*, 2011; Mekonnen *et al*, 2017) yet trees planted on homesteads/croplands directly benefit farmers through increased resilience and managing competing land use pressures.

The low focus on suitable technologies to enhance agroforestry in the dry areas necessitates a thorough assessment of soil moisture conservation methods suitable for survival of trees. This study sought to further this knowledge by assessing the effectiveness of two micro catchments namely micro basins and trenches in enhancing tree survival. Additionally, the study sought to elicit farmers' perceptions on the micro catchments and understand socio-economic factors influencing the decision to adopt. The following research questions were addressed by this study:

1.3 Research questions

1) What are farmers' perceptions on the effectiveness of micro basins and trenches in establishment of agroforestry trees?

2) Which factors influence adoption of micro basins and trenches?

3) Are micro basins and trenches effective in enhancing survival of agroforestry trees?

1.4 Research hypotheses

1) There are negative farmer perceptions on the effectiveness of micro catchments for enhancing establishment of agroforestry trees.
2) There is no relationship between farmers socio economic characteristics and adoption of micro catchments.
3) Micro catchments are not effective in enhancing survival of agroforestry trees.

1.5 Research Objectives

1.5.1 General objective

To assess the effectiveness of micro basins and trenches in establishment of agroforestry trees in East Shewa zone, Ethiopia.

1.5.2 Specific objectives

1) To assess farmers' perception on the effectiveness of micro basins and trenches in establishment of agroforestry trees in East Shewa zone, Ethiopia.

2) To determine factors influencing adoption of micro basins and trenches for tree survival and soil moisture conservation in East Shewa zone, Ethiopia.

3) To determine the effectiveness of micro basins and trenches in survival of agroforestry trees in East Shewa zone, Ethiopia.

1.6 Justification of the study

Small to medium agroforestry projects in some parts of Ethiopia such as Tigray, Amhara, Southern Ethiopia have proved that agroforestry has the potential to rehabilitate degraded areas and boost food security (Hassan *et al*., 2016). Furthermore, government initiatives such as the recent establishment of a National Agroforestry Platform aimed at supporting climate-resilient green growth and transformation; and launch of the National Green Development Program present opportunities for scaling up agroforestry practices. However, these efforts may be limited by the low tree survival especially the arid and semiarid areas. This study, therefore, sought to add to the knowledge on tree survival enhancement by assessing the effectiveness of the micro catchments, as possible methods that can be used to enhance tree survival through soil moisture retention.

The success of micro catchments has been widely documented (Li *et al*., 2005; Schiettecatte *et al*., 2005). According to Zhang *et al*., (2013), water is collected in the areas that it is produced and trees and shrubs use the collected runoff in the succeeding dry planting seasons. Plants established in micro catchments have higher possibilities of survival compared to plants cultivated without micro catchments.

Ojasvi *et al*., (1999) indicated that in areas receiving low-rainfall and where water for irrigation is scarce or lacking, micro catchments are suitable for the establishment of trees and shrubs. Due to the ease and relatively low cost of construction, micro catchments, therefore, present an appropriate and inexpensive soil moisture retention option for the rural farming population.

Further to assessing the effectiveness of the micro catchments, this study assessed farmers' perceptions and factors likely to influence adoption decisions, an important pre-requisite to scale up the use of micro-catchments. Results of this study provide great insight into the ongoing Australian Centre for International Agricultural Research (ACIAR) funded project entitled 'Trees for food security' on scaling up the SWC technologies.

1.7 Significance of the study

This study furthers the understanding of improving agroforestry in arid and semiarid areas in Ethiopia through soil-water conservation methods. Results of this study inform farmers of suitable SWC technologies and also inform agricultural and extension agents on the innovations farmers perceive ideal for the conservation of soil water, therefore, forming a base for enhancement of SWC technologies. The study will provide scientific knowledge on the social-economic characteristics of the population and adoptability of SWC measures as well as the effectiveness of the micro catchments in agroforestry tree survival. Additionally, the findings of the study will inform the 'Trees for food security' project implementers on the suitability of the soil moisture retention structures and their scaling up potential in the study area.

1.8 Conceptual framework

Trees are important in the semiarid areas due to their ability to improve resilience for smallholder farmers through the provision of beneficial products and services. The study by (Iiyama *et al*., 2017) found that the establishment of agroforestry trees for high-value products such as timber, fruits, fodder was not common in the semiarid areas yet such trees would contribute to the improvement of livelihoods for farmers in these sites owing to their limited livelihood sources. The study found that high-value agroforestry trees had been widely adopted in the subhumid sites which are less arid. This implies that prolonged drought, which results in inadequate soil moisture is the major limitation for the establishment of trees in the semiarid areas.

To address this problem, micro basins and trenches were established in the study site. Adoption and continued use of these technologies is envisaged to conserve soil moisture and enhance the survival of trees. This would, in turn, encourage the establishment of the high-value agroforestry trees. Adoption is dependent on socio-cultural, economic, institutional, and technology-specific factors. Moreover, farmers' perception of the effectiveness of the micro basins and trenches is paramount in fostering understanding about the willingness of farmers to adopt the technology (Figure 1.1).

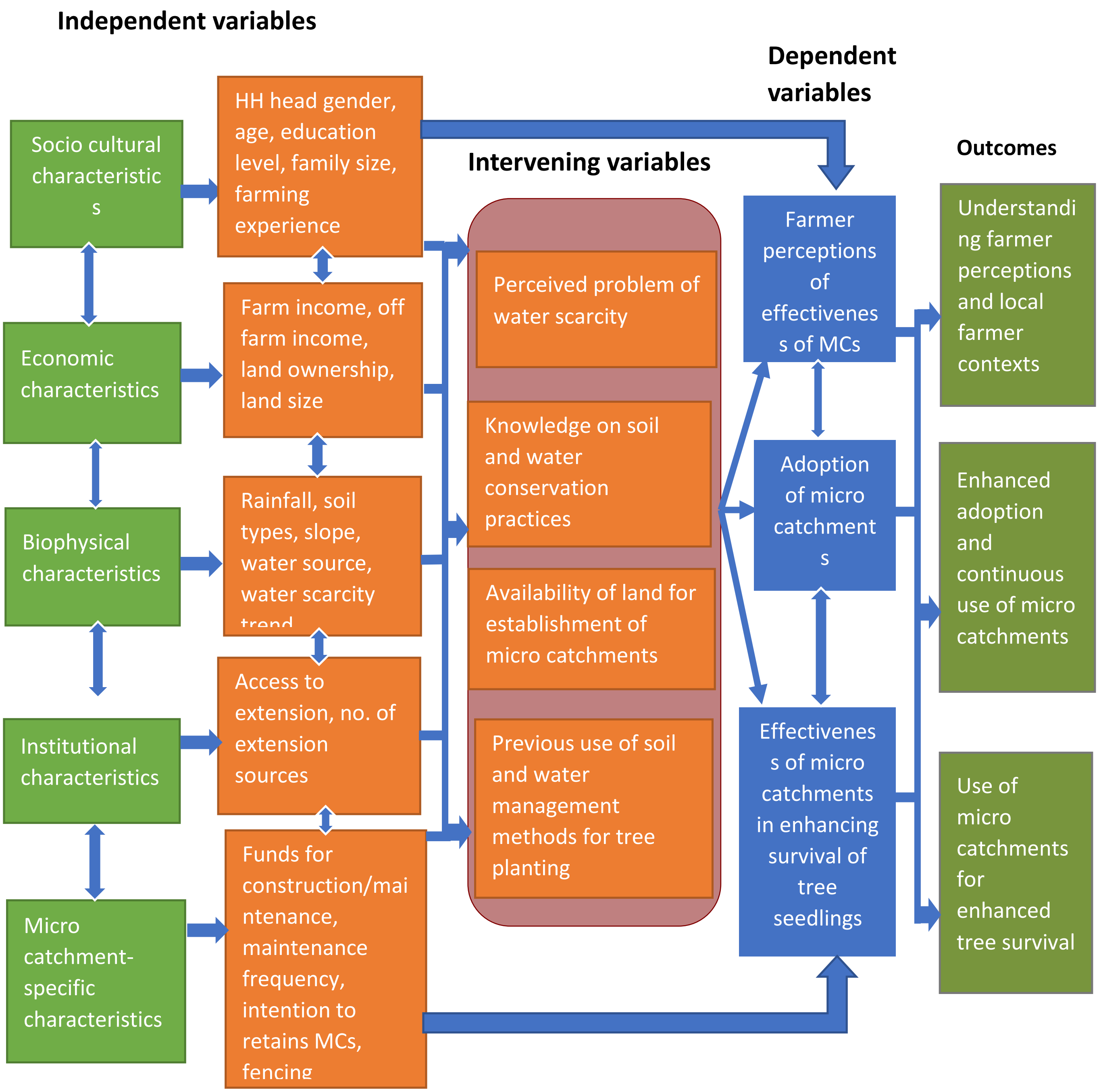

Figure 1.1: Conceptual framework linking the variables of the study

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This chapter presents a review on water harvesting and soil and water conservation practices, micro catchment water harvesting, socio economic factors influencing perception and adoption of soil and water conservation technologies, soil and water conservation practices for tree establishment in Ethiopia and research gaps.

2.2 Water harvesting and soil moisture conservation approaches

Boers & Ben-Asher, (1982) describe water harvesting as a method for interception and concentration of runoff into a storage structure for agricultural utilization in the dry regions. The main reason for rainwater harvesting is to alleviate water scarcity for domestic and agricultural use (Ibraimo & Munguambe, 2007). Therefore, water harvesting is vital in the arid and semiarid areas due to water shortage. Rainwater harvesting system on farmland entails an area that produces runoff, which is referred to as a catchment area and an area that receives the runoff, referred to as a cropping basin. The harvested water may be stored right in soil profile or in small reservoirs (Oweis & Hachum, 2006).

Appropriate rainwater harvesting method is dependent on rainfall distribution, topography, soil type and depth, and farmer characteristics (Oweis & Hachum, 2006). Prinz & Singh, (2000), describe three major types of rainwater harvesting. First, water collected from rooftops, compacted areas or surfaces for domestic and agricultural use. Secondly, the micro catchment system, where runoff is collected in a catchment and water stored in the lower depths of an adjoining percolation pond. Lastly, macro catchment water harvesting approach, where runoff from hill slope catchments is relayed to the cropping area. The micro catchment system also referred to as in situ rainwater harvesting is mainly used in the cropping system. It is a system in which runoff is prevented in a cropped land by holding rainwater and prolonging its infiltration in the ground (Hatibu *et al*., 2000).

Water harvesting in African countries including Ethiopia has received increased attention following the widespread drought experienced in the 1980s (Hatibu *et al*., 2000). Alem, (1999) noted that in-situ, roof and runoff irrigation water harvesting are the main water harvesting methods in Ethiopia. The study also noted that building of terraces, soil bunds, stone bunds, grass strips, and micro basins was extensively applied in soil and water conservation.

2.3 Types and benefits of micro catchment water harvesting

According to Boers & Ben-Asher (1982), micro catchment water harvesting is a method where runoff is collected in a catchment and water stored in the lower depths of an adjoining percolation pond or recharge basin with a less than 100 m flow distance. Micro catchment system aims at runoff water storage in the root zone during the growing season of a tree or crop (Boers *et al*., 1986). The micro catchment system plays a significant role in conserving water especially in the Arid and semi-arid lands (ASALs) that experience erratic rainfall, prolonged dry spells and where installation of irrigation systems is expensive. Therefore, micro catchments are ideal in these dry areas due to their ease of construction and its relatively low cost (Ibraimo & Munguambe, 2007).

The design of micro catchments is influenced by crop water requirements, topography, soil conditions, and the local climate. The size of the runoff producing area should correspond to the runoff receiving area because enough runoff water must be generated and stored (Bruins *et al*., 1986). The average size of micro catchments ranges from 0.5m^2 to 1000m^2 for row crops, trees, and shrubs where the mean rainfall varies from 100mm to 650mm (Sharma, 1986). Runoff area to basin ratios may range from 1:1 to 20:1 (Li *et al*., 2005).

Different patterns that have been used in design of micro catchments include: a square infiltration basin in one corner of the micro catchment, an infiltration basin in the centre of the micro catchment with radial flow direction, a triangular micro catchment with an infiltration basin in one corner, terrace with infiltration basin receiving water from catchment area on one side, ridge and furrow type with infiltration basin receiving runoff from catchment area on two sides (Boers & Ben-Asher, 1982).

Benefits of using micro catchments as a method of soil water conservation have been demonstrated in various studies for example, Sepaskhak *et al*., (1997) found that yields obtained from grapevines cultivated in the micro catchment were higher than yields from vines cultivated with no micro catchments due to the higher soil water content in the micro catchments. In India, more *Ziziphus mauritiana* Lam. seedlings planted in micro catchments survived compared to seedlings planted in conventional planting pits (Ojasvi *et al*., 1999). Tubeileh *et al*., (2009) indicated that construction of micro catchments in the degraded valley of Syrian increased soil moisture hence enhancing the suitability for the establishment and growth of olive plantations in the area. Moreover, Gupta, (1995) established that the construction of moisture conservation structures positively influenced the tree root development, hence accelerating nutrient-uptake by the trees. Rocheleau *et al*., (1988) reckoned that the retained soil moisture aids in improving growth of naturally propagating early tree seedlings whose growth may have been be stunted by moisture stress and continual browsing by animals.

2.4 Farmers’ perception towards adoption of soil and water conservation technologies

According to Segers *et al*., (2008) perception is an assortment of beliefs, judgments, and attitudes towards a phenomenon. Adesina & Baidu-Forson, (1995) explain that the concept of farmers’ perception of agricultural innovations has continued to gain interest among social scientists who investigate the influence of farmers’ subjective assessments on adoption. Farmers may perceive an innovation differently from field extension officers and researchers, thus the importance of evaluating these perceptions prior to introducing, implementing and scaling out of a technology to ensure local buy-in. Sinja *et al*., (2004) proposed that findings from such assessments should be communicated to the innovation creators for their insight into farmers’ views on the technologies.

Information on farmers’ perceptions of a technology guides in the design of demand-driven technologies and ensures farmers participate in technologies deemed to be beneficial to them. This prevents scenarios such as reported in Gebre & Weldemariam, (2013) who observed that farmers participated in mechanical technologies for soil and water conservation in Ethiopia against their will because contrary to their expectations, the structures heightened the severity of erosion problem on their land due to inappropriate design by the Development Agents.

Farmers have local knowledge of the existing problem and possible solutions therefore, any program should be cognizant of this knowledge and a holistic view of the problem (Moges & Holden, 2007). As such, farmers should be motivated to adopt the technologies based on their indigenous knowledge with appropriate scientific advice

(Zegeye *et al*., 2010). Many studies have connected people's adoption behavior to their perceptions, attitudes, beliefs and existing indigenous knowledge (Adams *et al*., 2013).

In addition to determining farmers' preferences, Raghav & Sen, (2014) established that education and awareness creation about a technology plays a vital role in adoption where farmers exposed to the technology tend to have a stronger preference for adoption. Differential access to information may lead to variations in perceptions and farmers' ability to revise their initial perceptions. As such suitable extension approaches should be identified to encourage access to technology information among farmers (Joshi & Pandey, 2005). Extension workers ought to understand farmers' predilections and restrictions in order to effectively implement the technologies (Khan *et al*., 2008).

Studies have shown that farmer perceptions (among other factors) largely influence the decision to adopt rainwater harvesting innovations for household and agricultural purposes. According to Teklehaimanot, (2003), variations observed in the take-up and implementation of rainwater harvesting methods were affected by dissimilarities in farmer perceptions and opinions towards the innovation, yet the living conditions of the farmers were almost similar. In Bangladesh, Karim *et al*., (2005) observed that the positive perception of rainwater quality in the coastal region contributed to the social acceptance of rainwater harvesting approaches in the area.

According to He *et al*., (2007), uptake of RWH and supplemental irrigation technologies in China was significantly influenced by farmers' positive attitudes towards the technologies. The same study further underscored the necessity to create awareness about the benefits derived from a technology through capacity development as well as providing support to institutions promoting rainwater harvesting innovations. Wandji *et* *al*., (2012) emphasized the need to consider farmers' perceptions when considering factors affecting adoption of a technology to avoid biased results and technology failure.

2.5 Factors affecting adoption of soil and water conservation technologies

According to (Sinja *et al*., 2004), adoption and implementation of improved agricultural methods is vital for increasing productivity and hence curbing the problem of food insecurity in Africa. Therefore, attention is increasingly being focused to adoption of innovations that aim at improving agriculture and conservation of the environment so that sustainable technologies can be introduced to improve farmer livelihoods (Ndambiri *et al*., 2013).

According to Ndiema *et al*., (2012) adoption goes through four phases namely, knowledge phase, interest phase, evaluation phase, trial phase and ultimately adoption where a farmer commits to a technology. Users' decisions to accept or reject a technology reflects the relevance of the technology to them (Sinja *et al*., 2004). These decisions are linked to farmers' conservative attitudes which vary among individuals based on age, gender education level and social status (Ndiema *et al*., 2012).

Farmers' perceptions and attitudes towards a technology are highly significant to adoption. Farmers tend to adopt technologies that they perceive are most likely to be rewarding and beneficial as opposed to technologies perceived to be risky and uncertain (Negatu & Parikh, 1999). This may be informed by prior experience of a similar technology or knowledge acquired from different sources. Farmers should, therefore, be encouraged to join organizations, groups or institutions where they can be trained on the benefits of a technology (Sidibé, 2005).

Marenya & Barrett, (2007) observed that adoption of natural resource management technologies is limited by resource constraints. The study showed that households with larger land sizes, more livestock, labor and nonfarm income had a higher likelihood of investing and continuing with the soil conservation technologies. Similarly, Foti *et al*., (2008) found that the availability of labor and draught power positively influenced the adoption of environmental conservation methods. The importance of extension support was underscored in Baidu-Forson, (1999), where it enables awareness creation on the benefits of a technology. Furthermore, community training and sensitization on the importance of a technology greatly contribute to adoption hence livelihoods improvement (Mutekwa *et al*., 2005). Additionally, membership in a farmers' organization significantly affects adoption (Sidibé, 2005).

With regard to rainwater harvesting technologies, Baguma & Loiskandl, (2010) reported that adoption was influenced by the provision of subsidies such as hardware equipment that expands rural water supply. According to Gebregziabher *et al*., (2013) other factors that have an effect on adoption include household size, landholding, ownership of livestock, education level, access to technical information and involvement in community social networks. The same authors further asserted that decisions to adopt of rain water management technologies also depend upon adoption of other similar or complementary technologies hence the need to adopt a holistic approach while promoting them.

Studies have further shown that education status and engagement in social responsibilities positively influenced the adoption of rainwater harvesting technologies (Murgor *et al*., 2013). Similarly, He *et al*., (2007) alluded that education status, interaction with extension agents and positive attitude contributed to the adoption of RWH technologies. Factors such as small sizes of land, lack of access to credit facilities, negative farmer perception, inadequate technical experience and lack of access to construction materials were found to influence adoption negatively (Murgor *et al*., 2013).

According to Deressa *et al*., (2009), socio-economic variables including farmer education level, age, income from farming activities, livestock holding, credit access, alongside biophysical variables including agroecological zones, rainfall and temperature influenced the adoption of rainwater management technologies in the Ethiopian highlands. In Zimbabwe, Mutekwa *et al*., (2005) found that the adoption of rainwater harvesting related innovations was influenced by the land ownership and size, agricultural operation costs, soils, and institutions' efficiency in disseminating information.

2.6 Soil and water conservation for tree establishment in Ethiopia

About 75% of the total landmass in Ethiopia is categorized as arid, semiarid or dry subhumid. These zones are susceptible to drought due to low rainfall (UNDP, 2014). About 83% of the residents in these areas are prone to food insecurity because of their over-reliance on rain-fed cultivation which is vulnerable to variable and erratic rainfall resulting to crop failure (Zappacosta *et al*., 2012; Moges & Gebregiorgis, 2013). As a result, widespread hunger, malnutrition and heightened poverty levels have been experienced in these regions (Mbow *et al*., 2014).

According to Hillbrand *et al*., (2017) agroforestry has the potential to reverse this trend. Agroforestry systems can control land degradation, increase soil water availability as well as provide local communities with varied food and non-food products thereby contributing to food and nutrition security, generating income, improving livelihoods, and combating poverty. Worku *et al*., (2017) adds that agroforestry in Ethiopia contributes to increasing natural forest coverage, ecological succession, reducing natural resource degradation, increase the availability of fuelwood and earning cash income and then reduce pressure of using dung for domestic fuel source.

In spite the well-known benefits of agroforestry, its adoption remains low, and in some areas where there has been adoption, the technologies have been discontinued after some time (Meijer *et al*, 2015). In Ethiopia, efforts are mainly geared towards massive tree planting projects that been initiated to reclaim degraded forest lands, and marginal lands (Meaza & Gebresamuel, 2013). However, these projects have been faced with poor tree survival attributed to inappropriate species selection, lack of aftercare, and moisture and nutrient stress at the planting site (Asmelash *et al*., 2019).

According to Meaza & Demssie (2015) multipurpose tree planting is underutilized at the homesteads in Ethiopia yet the trees play a significant role in poverty alleviation and can improve income opportunities and diets. Proper management and use of the available land in the homesteads can reduce the problem of landlessness and manage competing land use pressures. However, research on enhancing survival of tree seedlings on homesteads is lacking (Mahari, 2014). This study seeks to contribute to the knowledge on enhancing survival of agroforestry trees, an important prerequisite to promoting agroforestry through homestead multipurpose tree planting.

2.7 Summary of research gaps

The semi-arid areas of Ethiopia are menaced by low agricultural productivity. Agroforestry has the potential to increase farm productivity and improve household livelihoods. However, its success has been hindered by the low tree survival rate and this has contributed to subsequent low adoption. Most research in the semiarid areas of Ethiopia is focused on massive tree planting efforts that have been put in place to restore communal degraded lands and deforested areas. Distribution of multipurpose trees for individual planting is common, however there is scant research on enhancing survival of the multipurpose trees as less follow-up is done after tree distribution. This study seeks to fill this gap by assessing the effectiveness of micro catchments in enhancing survival of trees planted on homesteads. In addition, the study seeks to contribute to the understanding of farmer perceptions and factors affecting adoption of micro catchments, to promote scaling up of the soil and water conservation practices for tree survival.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study area

The study was carried out in four study sites namely, Zeway, Meki, Mojo and AlemTena which are located in Adami Tulu Jido Kombolcha, Dugda, Lume and Bora districts (woredas), respectively. The four districts are in the East Shewa zone of Ethiopia, located between 38° 40’ E - 39° 4’ E and 7° 52’ N - 8° 30’ N. They are within the central rift valley in Ethiopia (Figure 3.1).

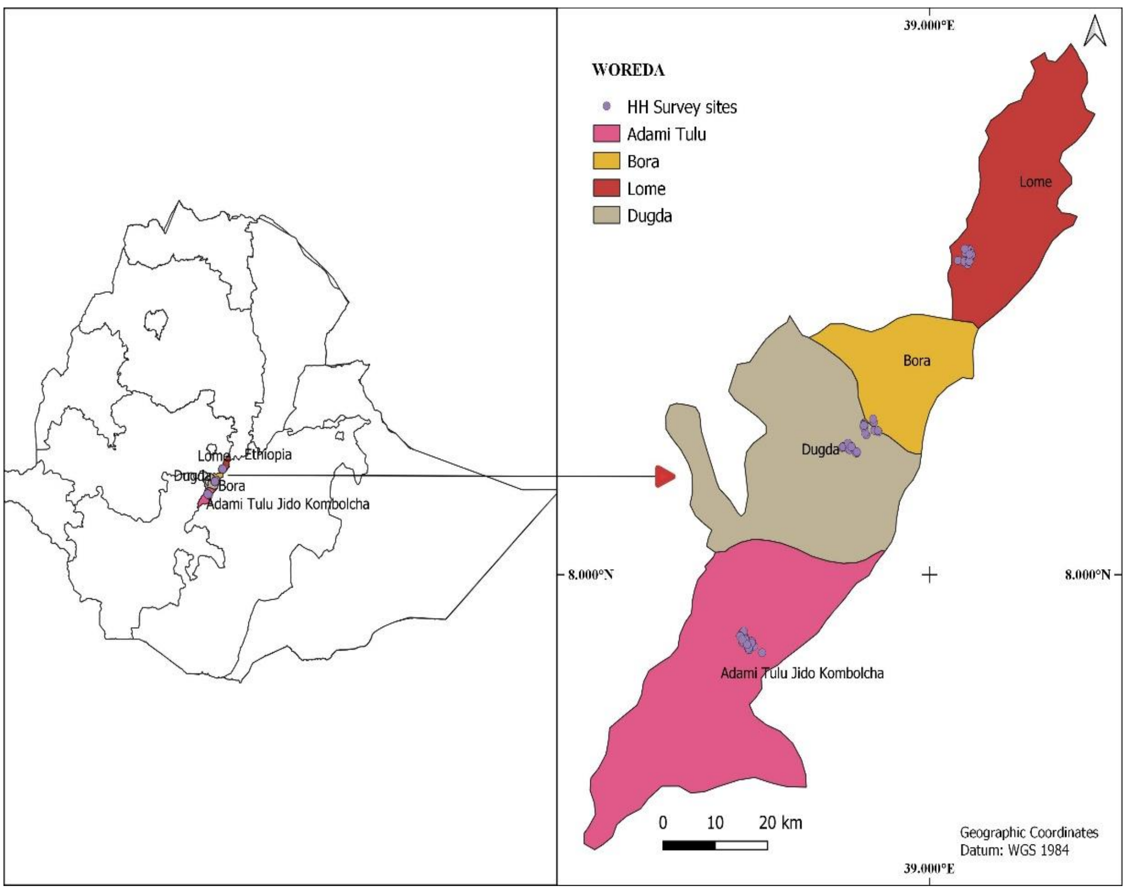

Figure 3.1: Location of the study sites in East Shewa zone

East Shewa covers a geographic area of about 8,370 Km^2 and is characterized by variable and erratic rainfall, during the summers and dry cold and windy winters (Meshesha *et al*.,2012). Rainfall has a unimodal distribution, received between April and September. This is the main cropping season. Most of the areas in the zone experience an average annual rainfall ranging approximately between 600 mm to 1000 mm. Temperatures range from 10˚C in high altitude areas to above 30˚C in lowlands. The mean monthly temperature ranges from 17^0c in December to 22^0c in May.

East Shewa zone is characterized by dissected high plateaus and mountains associated with hills, valleys, and gorges. Elevation in East Shewa extends from around 1600 meters above sea level in Adami Tulu to above 2300 in Lume district. Common soil types in East Shewa zone can include Andosols, Vertisols, Cambisols, Regosols, Luvisols, Phaeozems and Fluvisols (Endale *et al*., 2017). Andosols extend over the four sites while Vertisols and mainly in northern Lume. Phaeozems are found in Dugda and Bora woredas. The origin of these soils is mainly from volcanic ashes. They have limited depth and are poorly drained which limits their agricultural production. Other challenges with these soils include poor physical structure, micronutrient imbalances, low phosphorus levels, and vulnerability to leaching.

The local population is mainly comprised of small-scale subsistence farmers. Agriculture is mainly rainfed and tree-crop-livestock is the main farming system. Main crops grown in the area include maize (*Zea mays* L.), teff (*Eragrostis tef* Zucc), wheat (*Triticum spp L*) sorghum (*Sorghum bicolor* L) and beans (Phaseolus vulgaris L). The main vegetation types are natural Acacia woodlands and savanna vegetation. Trees comprising

Acacia spp, Faidherbia albida (Delile) A. Chev.), *Cordia Africana* Lam, *Croton macrostachyus* Hochst. ex Delile are common on farms. Free grazing of cattle and goats on farmlands is the dominant livestock system (Iiyama *et al*., 2017).

3.2 Research design

3.2.1 Data collection

To achieve objectives one and two, a household survey and key informant interviews were carried out. Data on the demographic information of the respondents, respondent's knowledge of SWC structures, structures adopted and the reasons for adoption, willingness of the respondents to continue with the conversation structures, farm characteristics, institutional variables and their effect on adoption were collected using a semi-structured questionnaire. The questionnaire was administered to 142 respondents who were selected using the sampling procedure outlined in section 3.2.2.

3.2.2 Sampling procedure

Both purposive and random sampling techniques were used to select the study sample. The study used a sampling frame that comprised all farmers who had been issued with trees by the Trees for food security project for a period of at least one year (since 2013), the sampling frame had 225 farmers. These farmers were also exposed to soil and water conservation technologies which were micro basins and trenches. Some farmers chose to construct the micro catchments for tree planting while others did not. The sample size of 142 was determined using the formula by Yamane (1967) below:

$$n=\left[(N/[1+N)(e)^{2}\right]$$

Where;

n represents the sample size

z^2 is the critical standard score at 95% confidence level which is 1.96

e is the is the level of precision given at ±5%

N is the population which is 225

Out of the determined 142 farmers in the sample, 72 were comprised of farmers who had already constructed the micro catchments. These farmers were selected purposively from the sample. All the 72 farmers had constructed at least one micro basin while 56 had constructed a trench in addition to the micro basin. No farmers interviewed had constructed a trench alone. Seventy farmers from the sample did not have any micro catchment and were selected randomly among the farmers with no structures; they formed the control group.

Prior to administering the questionnaire, a pilot study was undertaken to pre-test the questionnaire to ensure that it captured relevant information befitting the study sites. After the pre-test, a final questionnaire was developed (Appendix 1) and this was administered to the sampled population.

Key informant interviews were also used to triangulate results obtained through the household survey to increase validity. Four key informants – one from each district were interviewed. These were selected based on their knowledge of soil and water conservation aspects in the study site. Information on land use, water resources, challenges in accessing water resources, soil and water conservation techniques among others were documented (Appendix 2).

3.2.3 Data collection for objective 3- Experimental design

To fulfill objective three, an experiment was set up in the four sites where Trees for Food security project was implemented to assess the effectiveness of micro catchments in enhancing the survival of tree seedlings. The four study sites were chosen as representatives of dry areas where soil and water conservation methods were being introduced to enhance the survival of trees. The experiment was conducted for 36 months from June 2013 to June 2016 with 29 farmers who were selected from the larger group of 72 farmers. The 72 farmers had been included in the household survey that was conducted to determine farmers' perceptions and socio-economic factors influencing adoption of the micro catchments.

The experiment consisted of three treatments that represented the water conservation methods namely, micro basin with a radius of 60cm and a depth of 28cm (Figure 3.2), a trench with a length of 160cm, width of 40cm and a depth of 49.9cm (Figure 3.3) and the ordinary planting hole, constructed according to individual farmer's requirements, which formed the control. The 29 farmers were involved in the experiment voluntarily and were selected from the four districts and these comprised the replications.

Figure 3.2: Micro basin with a *Grevillea robusta* tree seedling in Adami Tulu district

Farmers were expected to have different planting techniques hence a likely source of variation was expected.

Figure 3.3: Trench with a *Mangifera indica* seedling in Adami Tulu district

Three tree species were studied in the experiment, they include *Cordia africana, Mangifera indica* (mango) and *Grevillea robusta.* Each farmer had at least one tree species with three seedlings planted in the micro catchments and the ordinary planting pit. For each species, a farmer had at least 3 seedlings each planted in each of the treatments. Based on the availability of space, labor, and willingness, a farmer could have more than one tree species as long as all the treatments were represented. The trees planted in different treatments were replicated across the different farmers. Details of the specific trees planted by different farmers in different treatments are presented in Appendix 3.

For each of the three treatments, 10 tree seedlings of *G. robusta*, 11 of *C. africana* and 21 of *M. indica* were assessed totaling to 42 seedlings of the three tree species per treatment. Therefore, 63 seedlings of mango, 33 seedlings *C. africana* and 30 seedlings of

G. robusta totaling to 126 seedlings for all the treatments were assessed. Assessment of tree survival was taken after six months and survival of trees was indicated by the presence of a tree seedling in the treatment.

3.3 Data Analysis

3.3.1 Analysis of farmer perceptions of the micro basins and trenches and key informants data

Farmers' perception was the dependent variable and it was based on respondent's feedback on the effectiveness of the micro catchments in the survival of the trees. These responses were subjected to a five Likert scale, 5 for the most positive and 1 for the most negative. The independent variables used are summarized in Appendix 4. The choice of the independent variables was determined from previous similar studies (Miheretu, 2014; Biratu & Asmamaw, 2016; Gebre & Weldemariam, 2013).

Frequencies were used to determine the percentage of respondents under each category. Further analyses using ordinal logistic regression were conducted to determine whether there was any association with the independent variables such as farmer characteristics, farm characteristics, water source, labor and funds for construction and maintenance, maintenance activities and access to extension services.

The ordinal regression model was used for these analyses due to the ordinal nature of the dependent variable and its application in similar studies (Shiferaw & Holden, 1998; Sudarmadi *et al*., 2001; Shrestha & Alavalapati, 2006; De Groote *et al*., 2010). Moreover, according to Minetos & Polyzos, (2007), the model necessitates fewer assumptions in ascertaining the relationship between the dependent variable and independent variables. The model as defined by McCullagh (1980) is illustrated below.

In evaluation of the structures, parameters were defined as

$$\theta_1\text{=prob(score of 1) / prob(score greater than 1)}$$

$$\theta_2\text{=prob(score of 1 or 2) / prob(score greater than 2)}$$

$$\theta_3\text{=prob(score of 1,2 or 3) / prob(score greater than 3)}$$

$$\theta_4\text{=prob(score of 1,2,3 or 4) / prob(score greater than 4)}$$

The probability of scoring up to and including the last score is 1, hence explaining the lack of odds in the last category

All the odds are of the form

$\theta_j = Prob\ (score \leq j) / prob\ (score > j)$ Or

$\theta_j = Prob\ (score \leq j) / 1\text{-}prob\ (score \leq j)$

Therefore, the ordinal logistic regression model will be:

$ln(\theta_j) = \alpha_j - \beta X$

Where:

- θ is the probability of an event occurring
- j is the scale of the categories which ranges from 1 to the number of categories minus 1
- α_j is the intercept
- β is the regression coefficient

Data from the key informants' interviews was analyzed qualitatively using content analysis (Krippendorff, 2004). Feedback from the interviewees was collated and grouped in six main categories: Sources of water for the community; General soil and water conservation methods in the district; Soil and water conservation methods used for trees; Hinderances to agroforestry; and Recommendations. Common themes and patterns were identified and summarized to give specific scenarios for each context. Data were analyzed using SPSS and STATA soft wares.

3.3.2 Analysis of factors influencing adoption of micro basins and trenches

The dependent variable was binary coded as 1 for households with the micro catchments and 0 for households without the micro catchments. Explanatory variables include, age of household head, gender of household head, education level of household head, number of family members, farm size, land ownership, access to extension, household income, tree planting, tree protection through fencing, use of other soil and water conservation methods (Appendix 5).

Both descriptive statistics and a binary logistic regression model were used to analyze the data. Percentages, means, frequencies and standard deviations were used to present the general household characteristics. Associations of categorical variables between farmers with the SWC structures and those without the structures were computed using Chi square test. T-test was used to compare mean differences between the two groups. To assess the factors that determine the probability of adoption of the micro catchments, a binary logistic regression model was used.

The binary logistic regression model was used due to its appropriateness in determining how the independent variables affect the dependent variable that has only two groups, that is adoption and non-adoption of a technology. The model is helpful in determining how the probability of events occurring is affected by the independent variables and has been widely used in adoption studies (He *et al*., 2007; Zhou *et al*., 2008; Jara-Rojas *et al*., 2012; Gebre & Weldemariam, 2013; Tesfaye *et al*., 2014; Saguye, 2017).

The model was specified as defined by Gujarati & Porter, (2009) is shown below:

$$P_i = \frac{1}{1+e^{-(\beta_1+\beta_2 X_i)}} \qquad (1)$$

Equation (1) is rewritten as $P_i = \frac{1}{1+e^{-z_i}} = \frac{e^z}{1+e^z}$

Where:

- P_i is the probability of adoption of the water conservation technologies
- e is the exponent that is the base of the natural logarithms
- z is the function of explanatory variables expressed as:

$$Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k$$

β_0 is the intercept and $\beta_1, \beta_2 \ldots, \beta_k$ are coefficients representing individual explanatory variables $X_1, X_2 \ldots, X_k$

If the probability of taking up the water conservation technologies is given as P_i, the probability of not taking up the technologies $(1 - P_1)$ will be given as

$$1\text{-}P_1 = \frac{1}{1+e^{z_i}}$$

The above equation can be rewritten as

$$\frac{P_i}{1\text{-}P_i} = \frac{1+e^{z_i}}{1+e^{-z_i}} = e^{z_i}$$

The equation above illustrated the odds ratio. The odds ratio was defined by this study as the probability of a farmer taking up micro catchments to the probability of a farmer not taking up any micro catchment. Taking the natural log of the above equation, we obtain:

$$L_i = ln\left(\frac{P_i}{1-P_i}\right) = Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k$$

L_i is the log of odds ratio.

From the equation above, the estimated coefficients reflect the effect of the explanatory variables to its log of odds {ln [1/(1-*p*)]}

3.3.4 Analysis of effectiveness of micro basins and trenches in enhancing survival of trees

Data on tree survival was analyzed using the non-parametric Kaplan-Meir curve also known as product limit estimator. Differences in survival between the trees, both by species and treatments were assessed using the log-rank test. The Kaplan Meir method is widely used in survival analyses (Calviño-Cancela & Rubido-Bará, 2013; Jimènez *et al*., 2014; Valdés-Rodríguez *et al*., 2017; Roman *et al*., 2014; Fuentes-Ramírez *et al*., 2011; Yamashita *et al*., 2016). The method allows computation of interval-censored data for which death occurred between two periods and the exact period is unknown (Kaplan, & Meir 1958). First, probabilities of occurrence of an event at a certain point of time are computed. Then successive probabilities are multiplied by earlier computed probabilities to get the final estimate (Kishore *et al*., 2010).

The survival function according to Kaplan & Meir (1958) was given as:

$$S(t_j) = (1 - \frac{d_j}{n_j})$$

Where $S(t_j)$ is the probability of survival at time t_j

d_j Number of subjects dead at time t_j

n_j Number of subjects alive before time t_j

$t_0 = 1$ and $S_0 = 1$. The value of S(t) was constant between times of events, and therefore the estimated probability was a step function that changes value only at the time of each event (Clark *et al*., 2003).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents findings on general household characteristics, farmers' perceptions of the micro catchments, factors influencing their adoption and effectiveness of the micro catchments in enhancing survival of trees. The results are presented systematically for each objective. A discussion of the key findings with reference to previous studies is provided.

4.2 Association of household characteristics and adoption of micro catchments

4.2.1 Gender of household head

Households totaling to 142 were interviewed for the study, 72 households (51%) had the micro catchments while 70 households (49%) did not have any micro catchment. Of the household heads interviewed, 122 (86%) were male-headed while only 20 (14%) were female-headed. The total number of males and females interviewed is presented in Table 4.1. Chi square test indicated there was no evidence of association between gender and ownership of water conservation structures (χ^2=2.755, p=0.097). This implies that gender of the household did not influence the decision to adopt the micro catchments. Similarly, Alufah *et al*., (2012) and Dikito-Wachtmeister, (2001) found no significant association between male-headed and female-headed households in the adoption of SWC technologies. In contrast, Legesse *et al*., 2012 found that male-headed households that adopted the SWC technologies were significantly more than female-headed because men are more involved in farm technologies and are aware of their benefits, also because this practice is labor-intensive therefore less suitable for women.

Table 4.1: Gender of the household head and adoption of water conservation

	Gender of household head			
	Male		Female	
	Frequency	%	Frequency	%
Households with no micro catchments	64	52	6	32
Households with micro catchments	59	48	13	68
Total	122	100	20	100

4.2.2 Age of household head

Household heads without micro catchments were relatively younger than household heads with micro catchments. Their mean ages were 38 and 44 years, respectively. T-test results showed households without the structures were significantly younger than households with the structures (P=0.006). These findings are consistent with Abdulai & Huffman, (2005) who found that household heads that were older were more inclined to adopt the micro catchments compared to their younger counterparts due to their accumulated experience, knowledge and resources. Moreover, older household heads are better experienced in farm-related activities and are able to perceive a problem better. After the perception of the problem, they would be more receptive to a technology to address the problem (Alufah *et al*., 2012).

4.2.3 Number of household members in various age groups

The age groups, 6-20 and 20-60 years had the majority of the household members (Table 4.2). Overall, the total number of household members in all age groups was greater for households with micro catchments. Large families are considered as possible sources of labor, which is required for adoption of SWC technologies which tend to be labor intensive (Abebe & Sewnet, 2014).

Table 4.2: Number of household members in various age groups

Age group (years)	Households with no micro catchments (mean)	Households with micro catchments (mean)
Less than 5	59	63
6 to 20	176	211
20 to 60	178	191
Above 60	8	12

4.2.4 Education level

The majority of household heads both with the micro catchments (58%) and those without (47%) had acquired a primary level of education. A relatively high percentage of household heads had not acquired formal education; 40% of them had micro catchments while 32% had not constructed (Table 4.3). Only one respondent had attained a college level of education but did not have any micro catchment.

Table 4.3: Education level of household head and adoption of water conservation

Education level	HHs with no MCs N=70	HHs with MCs N=72
	%	%
Primary education	47	58
No formal education	40	32
Secondary education	11	10
College education	1	0

Fischer's exact test showed that the education level was not significantly associated with structure ownership (Fisher's Exact: $\chi 2 = 2.566$, $p = 0.317$). Further interactions with the farmers showed that the main source of information about water conservation was from the government extension agents, training in farmer training centers and by NGOs/project staff. It was further observed that none of the households that own the micro catchments indicated to have acquired the information by learning it in school. This could explain why education was not associated with the acquisition of knowledge and skills on soil and water conservation structures. Similarly, Baumgart-Getz *et al*., 2012 found that formal education was insignificant in adoption while extension positively influenced adoption of agricultural best practices.

4.2.5 Household income

Crop income was the major income source both for households with the micro catchments (86%) and households without (84%). More than 60% of the households with the structures and more than 50% of the households without the structures mentioned receiving income from livestock and livestock products. Business income was relatively common with more than 30% of the respondents mentioning to derive their livelihood from it. On average, both the households with the structures and those without had three sources of income. There was no significant difference between the two groups in terms of the number of income sources.

It was further observed that households with the micro catchments had sold a wider variety of farm products within 12 months from the time of the survey compared to households without the micro catchments (Figure 4.1). Products from trees such as fruits, fodder, and timber had been sold by some households with the structures but not by households without the structures implying that households with the structures benefit more from trees and would, therefore, be more disposed to planting trees than households without the structures. These findings are consistent with Karidjo *et al.*, 2018 where farmers reported that they would be motivated to adopt a technology if it had the prospects of increasing household income.

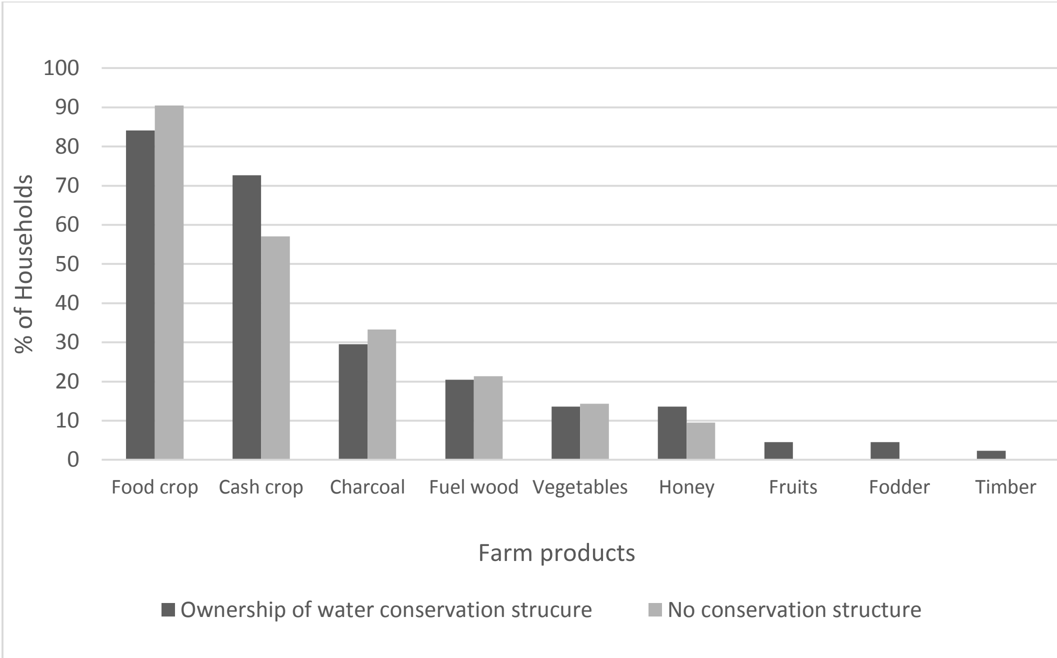

Figure 4.1: Sale of farm products for income

4.2.6 Land ownership

To determine land holding characteristics, farmers were requested to indicate the number of land parcels owned and for each of the land parcels further probing was done to determine the specific characteristics such as ownership status, size and slope. Land sizes differed slightly, the mean average land size for the farmers with the micro catchments was 2.50ha and households without the micro catchments was 2.48ha. No significant difference in land size was found between the two groups.

Of the households that owned land, 86% had constructed the micro catchments while 74% did not have the micro catchments. It was observed that of the more households that had rented land had no micro catchments in place. Households with conservation structures had on average three land parcels and households without conservation structures had on average two parcels of land. For the main parcel of land, majority of the households with the micro catchments owned the land, as opposed to leasing. A significant difference in ownership was observed between the two groups ($\chi2 = 10.686$, $p = 0.030$). This implies that more households with the structures owned land compared to those without the micro catchments. Therefore, this was likely to encourage them to construct the micro catchments and subsequent tree-planting which is a relatively long-term investment on land. Similarly, Miheretu & Yimer, 2017 found that tenure security encouraged farmers to invest in conservation practices as the benefits are long-term in nature. Land was generally flat for most of the respondents in the study. Table 4.4 shows land holding characteristics in the study site.

Table 4.4: Comparison of Landholding between households

	No micro catchments N=70	Have micro catchments N=72
Mean size of land owned (ha)	2.48	2.50
Mean number of parcels owned	2.83	3.12
Status of land ownership (% of respondents)		
Owned	74	86
Gift	30	17
Rented	23	21
Slope of the land (% of respondents)		
Flat	100	99
Gentle slope	9	11
Very steep	0	1

4.3 Tree planting practices

Farmers were asked whether they had planted any tree within two years prior to survey time, the niche planted and whether they had used any soil and water conservation method. Results show that 94% of the farmers had planted at least one tree. Most of the trees had been planted at the home compound and these comprised multipurpose agroforestry tree species such as *Mangifera indica, Grevillea robusta, Cordia africana, Carica papaya* among others. It was further observed SWC measures were used for the high-value trees as shown in Table 4.5.

Table 4.5: Trees planted and use of soil and water conservation method

	MCs used		Total
Trees planted within 2 years	No	Yes	
Mangifera indica	19	48	67
Persea americana	7	9	16
Carica papaya	25	16	41
Moringa spp	19	13	32
Acacia spp	28	7	35
Cordia africana	13	16	29
Eucalyptus spp	16	4	20
Schinus molle	14	10	24
Grevillea robusta	9	20	29
Melia azedarach	13	8	21
Azadirachta indica	22	8	30
Faidherbia albida	8	2	10
Sesbania sesban	16	1	17
Leucaena leucocephala	4	4	8
Albizia gummifera	1	0	1
Psidium guajava	1	2	3
Jacaranda mimisifolia	5	4	9
Delonix regia	6	2	8
Casimiroa edulis	0	1	1
Olea africana	1	0	1
Coffee	2	0	2
Total	229	175	404

This indicates that farmers attach high value to the trees such as *Mangifera indica, Persea americana, Cordia africana, Grevillea robusta,* because of their perceived future benefits, therefore, apply methods to enhance their survival.

4.4 Extension services

Extension information is critical in technology adoption. More households with the micro catchments accessed information from the various sources compared to those without the micro catchments (Figure 4.2).

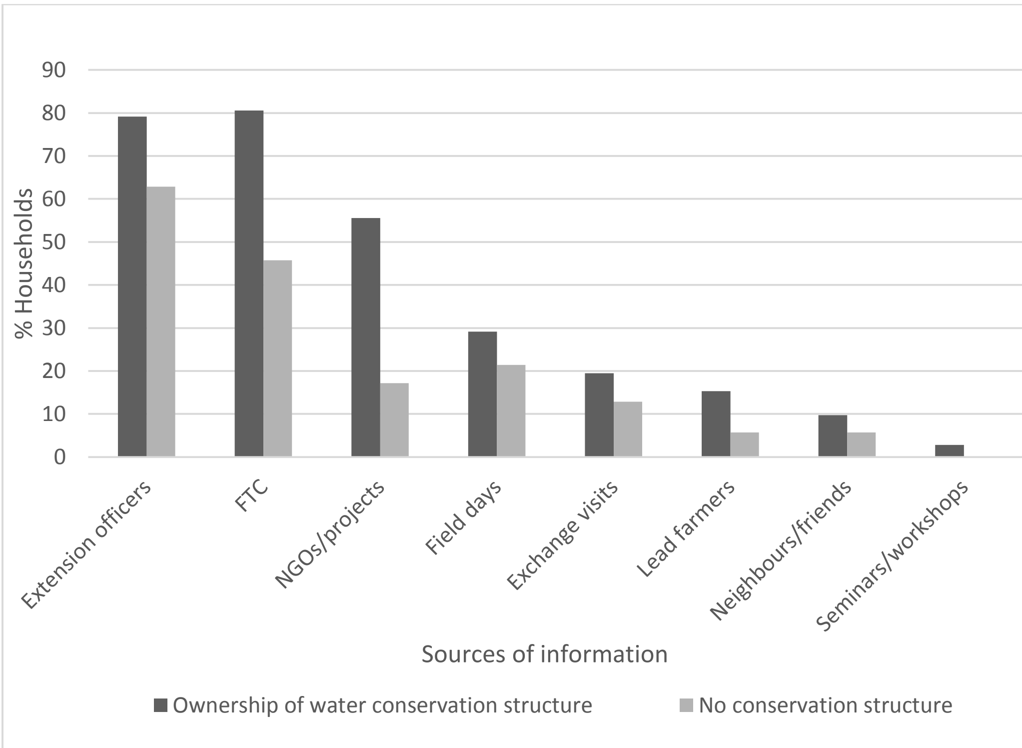

Figure 4.2: Sources of extension information

For both groups, government extension was the most common source of information. Chi square tests showed that of all the households that accessed government extension services and extension from NGOs/projects, those with the micro catchments were significantly more than those without ($P<0.005$). This implies that government extension and extension from NGOs/projects is effective in the dissemination of SWC information. According to Asfaw & Neka, (2017) extension services create awareness and provide technical information and farmers who receive these services are more likely to adopt new SWC technologies and maintain the existing ones.

4.5 Farmer perceptions of the micro catchments

4.5.1 Perception of the effectiveness of micro catchments in enhancing survival of trees and soil moisture conservation

To understand farmer perceptions on the effectiveness of the micro catchments, the respondents were asked how they perceived them in relation to survival of trees. 52% and 50% of the farmers indicated that micro basins and trenches were very good in enhancing survival and growth of tree seedlings respectively. Trenches were perceived to be poor by majority of the households (Figure 4.3). Generally, a larger percentage of the households (those who ranked the micro catchments as very good and good) perceived the micro basins to be better than the trenches.

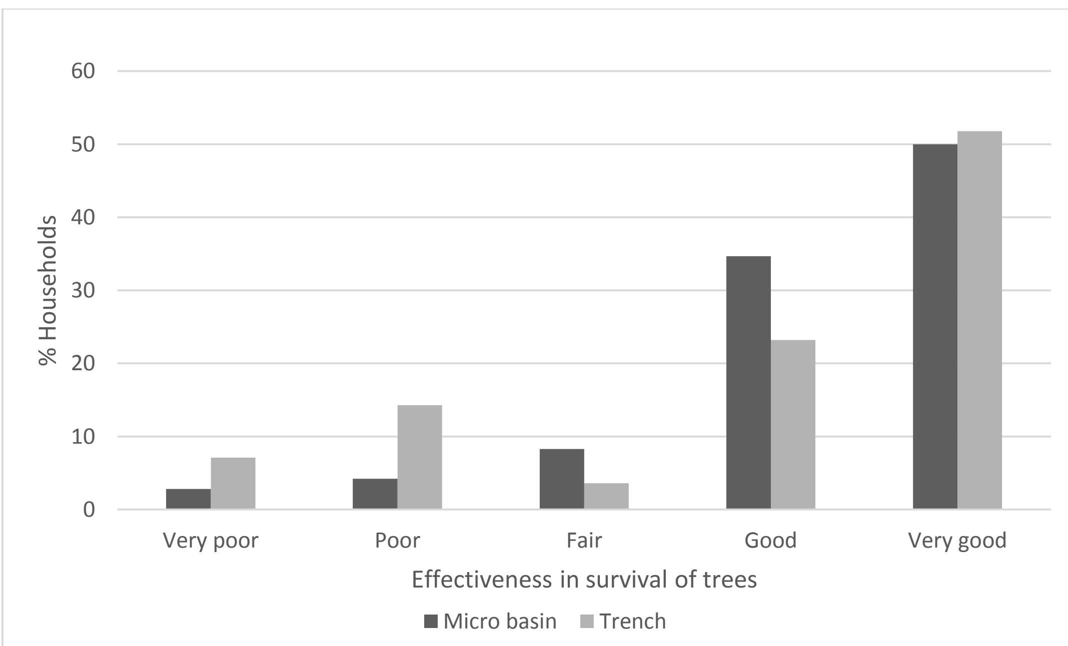

Figure 4.3: Effectiveness of micro catchments in enhancing survival of trees

In conservation of soil moisture, 54% of the respondents with micro basins and 59% with the trenches rated the structures as very good. Nine percent of the farmers rated the trenches as poor compared to only 1% who perceived micro basins to be poor. More households ranked the micro basins to be better than the trenches (very good and good) as shown in Figure 4.4.

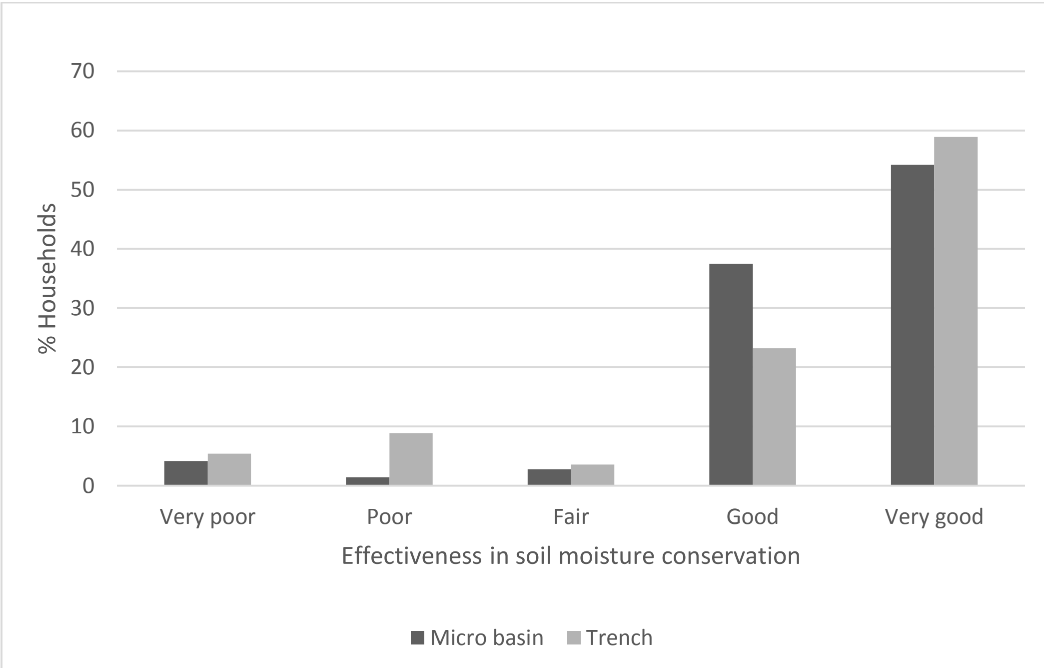

Figure 4.4: Effectiveness of micro catchments in soil moisture conservation

4.5.2 Perceived benefits of the micro basins and trenches

Farmers were further asked to give the reasons for the various responses given. This was aimed at understanding beneficial or detrimental factors associated with the structures. The main benefits of the structures are summarized in Table 4.6.

Table 4.6: Perceived benefits of micro catchments

Benefits	Micro basins N=72 %	Trench N=56 %
Soil moisture retention	88	81
Improve survival of trees	79	84
Improve health of trees	45	33
Fast rate of tree growth	60	61
Improve quality of soil	28	18
Environmental conservation	1	0

Among the various benefits of micro basins given, soil moisture retention had the most respondents (88%) while most respondents (84%) perceived trenches to be most suitable for improving survival of trees. A relatively higher percentage also perceived micro basins to be suitable for improving survival of trees (79%) and trenches to be effective in soil moisture conservation (81%). These findings are in agreement with findings in Derib *et al*., (2009) in Northwest Ethiopia where they found that micro basins and trenches were most effective in retaining soil moisture, enhancing survival and growth rates of trees compared to half-moon and ordinary planting pits. They further observed a low decline in survival rates for the trees in half-moon and ordinary planting pits during the first 15 months. Similarly, Rono *et al*., (2013) observed the highest survival rate of tree species in micro basins compared to semi-circular bunds, V-shaped bunds, and sunken pits. They explained that the micro basins could hold sufficient water and not excess to clog the seedlings.

About 60% of the farmers with the micro basins and 61% with the trenches, were of the opinion that the structures are effective in enhancing tree growth. This is consistent with the findings in Abdelkdair & Schultz, (2005) who observed better performance of *Acacia saligna* planted in the micro basins. More than 30% of the farmers mentioned that the structures were beneficial in improving the health of trees. This implies that trees planted within the micro catchments perform better and are stronger. In agreement with this, Li *et al*., (2005) observed that tree height, crown diameter, and collar girth were higher in trees within the micro catchments than those in the control.

Relatively few farmers, 28% and 18% with the micro basins and trenches respectively perceived them to be useful in soil quality improvement. Farmers mentioned that the manure and mulch applied in the structures were retained for a longer time thereby increasing soil fertility around the trees.

4.5.3 Perceived constraints of the micro basins and trenches

For both the micro basins and trenches, labor for maintenance was mentioned as the major limiting factor (Table 4.7).

Table 4.7: Perceived challenges of micro catchments

Challenges	Micro basins N=72 %	Trench N=56 %
Requires a lot of labor to maintain	50	56
Takes a lot of time to maintain	40	18
Seedlings choke due to water	21	32
Attracts pests	18	24
Causes diseases	13	18
Filled with silt	5	3

This contrasts with the results in Zhang *et al*., (2013) who reported that micro catchments are cheap and easy to construct. The possible explanation for the findings of this study is that tree planting takes place during the onset of rains which is also the time for planting crops. Therefore, farmers would prefer to concentrate more on crop production, which is their major source of livelihood.

About 40% of the respondents with the micro basins mentioned that they require a lot of time to maintain. A smaller percentage (18%) reported the same for the trenches. Further discussions revealed that frequent digging was required to maintain trees in the micro basins as opposed to trenches. Therefore, this was perceived to consume a lot of time for the farmers.

Other challenges highlighted were that the micro catchments increased the susceptibility of tree seedling to attack by insects and diseases. Further interrogations showed that attack by pests and diseases was prevalent in the area and seedlings were generally affected.

4.5.4 Micro catchments preferred by the farmers

To deepen the understanding of the structures preferred, between micro basins and trenches, farmers were asked what structures they preferred. 68% preferred micro basins and 32% trenches (Figure 4.5).

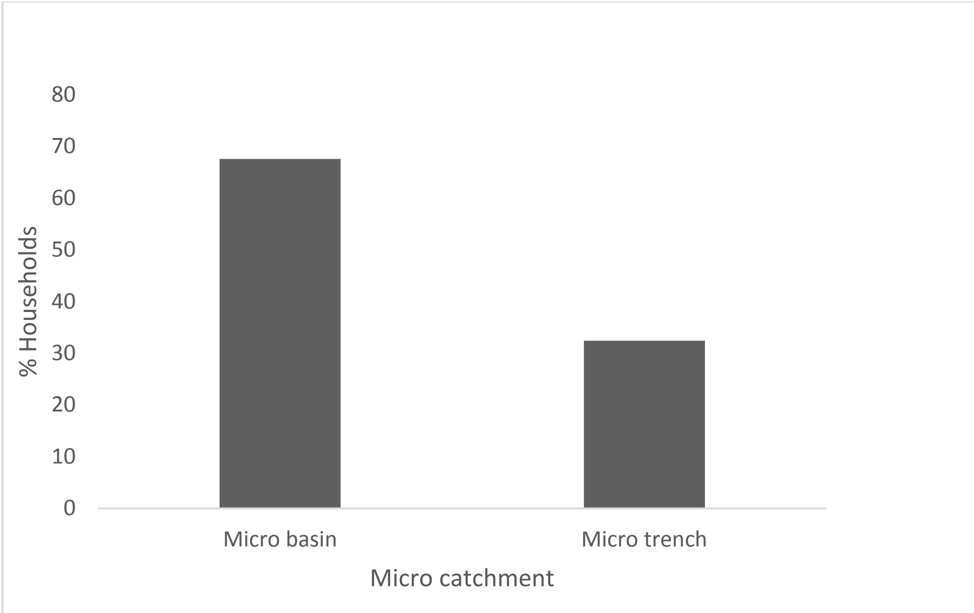

Figure 4.5: Micro catchments preferred by the farmers

Micro basins were preferred because of their ease in construction and maintenance compared to the trenches. Farmers reported that micro basins were similar to the ordinary planting holes that they had been used to hence found them easier to construct. Farmers that preferred the trenches stated that they required lesser maintenance. Both structures were commended for their soil moisture conservation ability and appropriateness of the structures to the soil type and topography in the four districts.

4.5.5 Water scarcity

To gain a deeper understanding of farmer perceptions towards SWC technologies, assessing whether water scarcity is perceived to be a problem is essential. This study sought to determine whether farmers perceived water scarcity to be a problem such that they would be motivated to invest in water conservation technologies to address the challenge. 63% of the respondents perceived water scarcity to be very severe (Table 4.8). This is because majority of the respondents rely on rainwater for their farm and domestic needs. Yet rainfall is highly erratic and unreliable. Similar to these findings, studies in the central Rift Valley (Adimassu *et al*., 2013); Nile basin (Deressa *et al*., 2009) as well as the central highlands; (Amsalu & de Graaff, 2007; Adimassu *et al*., 2013) have reported rainfall unpredictability and prolonged dry spells in Ethiopia.

Table 4.8: Severity of water scarcity

Severity of water scarcity	Frequency	%
Very severe	45	63
Moderately severe	13	18
Severe	13	18
Not severe at all	1	1
Total	72	100

The perceived causes of increasing water scarcity and drought cases include rainfall variability, deforestation, increasing population growth that results in high demand for water, lack of awareness on water conservation techniques, overstocking, lack of afforestation initiatives, lack of optimal utilization of groundwater and lack of appropriate rainwater harvesting and water conservation methods.

4.5.6 Relationship between farmers' perceptions and variables measured at household level

For both micro basins and trenches, an ordinal regression model was run to assess the effect of explanatory variables on farmers' perceptions of the effectiveness of the micro catchments in enhancing survival of trees. Results of the model for perception of the micro basins and trenches in survival of trees are presented in Tables 4.9 and 4.10.

Table 4.9: Farmers perception of the effectiveness of micro basin in enhancing survival of trees analyzed through ordinal logistic regression

Ordered logistic regression					**Number of obs = 72**	
					LR chi2(21) = 40.78	
					Prob > chi2 = 0.0060	
Log likelihood = -62.618587					**Pseudo R2 = 0.2456**	
MB Effectiveness in tree survival	**Coef.**	**Std. Err.**	**z**	**P>|z|**	**95% Conf. Interval**	
Gender of household head	.0395189	.7760298	0.05	0.959	-1.481471	1.560509
Education of household head	-.0820571	.5107921	-0.16	0.872	-1.083191	.919077
Number of household members (20-60yrs)	-.293457	.2549815	-1.15	0.250	-.7932115	.2062975
Water source for domestic use-Groundwater	.2467615	1.82983	0.13	0.893	-3.339639	3.833162
Water source for domestic use -Pond	14.38974	2429.231	0.01	0.995	-4746.815	4775.595
Severity of water scarcity	.9079756	.541888	1.68	0.094	-.1541055	1.970057
Trend of water scarcity	.6815384	.6920845	0.98	0.325	-.6749223	2.037999
Access to extension information	.8075555	0.48	0.48	0.628	-2.458931	4.074042
Total Land size Ha	**.5549557**	**.2282325**	**2.43**	**0.015**	**.1076282**	**1.002283**
Source of Construction labor-NGOs	-14.36532	1570.018	-0.01	0.993	-3091.544	3062.813
Source of Construction labor -Labor exchange	-16.84382	1570.018	-0.01	0.991	-3094.023	3060.335
Source of Construction labor -family labor	1570.017	1570.017	-0.01	0.992	-3092.459	3061.895
Source of Construction funds – farm income	1.091227	.8951095	1.22	0.223	-.6631549	2.84561
Source of Construction funds- off farm income	1.21411	1.996401	0.61	0.543	-2.698764	5.126984
Source of maintenance funds – farm income	-1.90127	1.303632	-1.46	0.145	-4.456343	.6538022
Source of maintenance funds- off farm income	.3923577	1.824226	0.22	0.830	-3.183059	3.967774
MB Intent to retain	.0011458	.0013239	0.87	0.387	-.001449	.0037407
MB Intent to retain time	.0019133	.0011879	1.61	0.107	-.0004148	.0042415
MB maintenance	-.0008219	.0016124	-0.51	0.610	-.0039821	.0023384

Table 4.10: Farmers perception of the effectiveness of trench in enhancing survival of trees analyzed through ordinal logistic regression

Ordered logistic regression — **Number of obs = 72**; **LR chi2(21) = 85.51**; **Prob > chi2 = 0.0060**; **Log likelihood = -66.242106** — **Pseudo R2 = 0.3922**

Trench Effectiveness in tree survival	Coef.	Std. Err.	z	P>|z|	95% Conf. Interval	
Gender of household head	-1.080129	.8474843	-1.27	0.202	-2.741168	.58091
Education of household head	-.2068967	.6288436	-0.33	0.742	-1.439408	1.025614
Number of household members (20-60yrs)	.0460028	.290192	0.16	0.874	-.5227631	.6147687
Water source for domestic use-Groundwater	-.6110341	1.590876	-0.38	0.701	-3.729094	2.507026
Water source for domestic use -Pond	.468647	2.127627	0.22	0.826	-3.701426	4.63872
Severity of water scarcity	**-1.155526**	**.4450497**	**-2.60**	**0.009**	**-2.027807**	**-.2832444**
Trend of water scarcity	1.147062	.606146	1.89	0.058	-.0409625	2.335086
Access to extension information	-4.06705	2.454665	-1.66	0.098	-8.878106	.744006
Total Land size Ha	**.8019007**	**.2670177**	**3.00**	**0.003**	**.2785557**	**1.325246**
Source of Construction labor-NGOs	2.572828	2.778569	0.93	0.354	-2.873068	8.018723
Source of Construction labor -Labor exchange	-25.00555	32724.97	-0.00	0.999	-64164.76	64114.75
Source of Construction labor -family labor	**3.019442**	**1.314538**	**2.30**	**0.022**	**.4429946**	**5.595889**
Source of Construction funds – farm income	1.018178	.8497112	1.20	0.231	-.647225	2.683582
Source of Construction funds- off farm income	2.477125	1.61439	1.53	0.125	-.6870213	5.64127
Source of maintenance funds – farm income	1.285945	1.195177	1.08	0.282	-1.056558	3.628449
Source of maintenance funds- off farm income	2.11346	1.76884	1.19	0.232	-1.353402	5.580323
Trench Intent to retain	-.0017907	.0021129	-0.85	0.397	-.0059318	.0023505
Trench Intent to retain time	.0017565	.0015651	1.12	0.262	-.001311	.004824
Trench maintenance	**.0094957**	**.0021449**	**4.43**	**0.000**	**.0052918**	**.0136996**

For both micro basins and trenches, Total land size had a significant positive effect on perception ($P<0.005$). This indicates that farmers with larger land sizes have a positive perception of the micro catchments compared to those with smaller land sizes. The possible reason for this finding could be due to the availability of space. Positive perception for SWC amongst farmers with large land sizes has been supported in literature where Gebre & Weldemariam, (2013) observed that farmers who owned bigger farm sizes were positive and more interested in retaining SWC structures on their farms especially when they perceive the problem well.

As hypothesized, the variable, severity of water scarcity had a significant effect on the perception of the effectiveness of the trenches. These results indicate that households that perceive water scarcity to be very severe would be positively inclined towards the trenches. This variable also gives more insight into knowledge of the problem of water scarcity that is to be addressed by the micro catchments, an important step in informing on the probability of adoption and sustainability of a technology. These results are consistent with findings in Miheretu, (2014) who found that perception of soil erosion as perilous encouraged farmers to adopt practices aimed at the conservation of soil. Other studies have also reported on the adoption of coping mechanisms to address a perceived problem (Adimassu *et al*., 2013; Deressa *et al*., 2011; Amsalu & de Graaff, 2007).

Family labor for construction had a significant and positive influence on the perception of trenches. This infers that households that used family labor for the construction of the trenches perceived them to be effective compared to those who used other forms of labor such as hiring. The results are consistent with Biratu & Asmamaw, (2016) who found that larger households were more willing to participate in SWC activities due to the availability of labor. Moreover, Walie, (2015) reported that the establishment of SWC measures requires much labor and amongst the various sources of labor, family labor is more readily available and affordable.

As expected, the maintenance of the trench influenced perception positively. This implies that households maintained the trenches because they perceived them to be useful and therefore were willing to invest time and labor in them. According to (Gebre & Weldemariam, 2013), this would also be an indicator that the farmers intend to retain the technology.

For the micro basins, gender of the household head positively influenced perception and had a negative influence on perception for the trenches. For both the structures, gender did not significantly influence farmers' perception. This was against what this study expected because according to Saguye, (2017), males are expected to be more positive about a technology as they are perceived to be better disposed to information on new technologies. These findings agree with Meseret, (2014) who found no association between gender and farmers’ views on environmental conservation practices.

Education of the household head was found to have a negative and insignificant effect on perception. The first possible explanation for this would be that majority of the farmers were either not educated or having attended school up to the primary level. These levels would be too low to enable farmers to understand complex environmental phenomena. The second possible reason would be that majority of the farmers reported to acquire information on soil and water conservation methods from extension agents. This implies that such information is not directly obtained from the formal education system.

These findings are consistent with Tang *et al*., (2013) who found that education had no significant influence on the perception of farmers on water scarcity.

Access to extension information did not influence farmers' views and opinions of the micro basins and trenches, yet this was the major source of information. Extension has been reported to build people's capacity on the importance, application, and management of soil and water conservation (Dachito *et al*., 2017). Taye, (2006) observed that extension is mainly focused on agricultural technologies with less attention on SWC technologies, therefore farmers focus less on these technologies.

The coefficients, funds for construction and maintenance were insignificant for both micro basins and trenches. Farmers reported that farm income was used in the construction and maintenance of the micro catchments. This implies that they may not have spent cash directly because, for majority of them, family labor was used both in construction and maintenance of the structures. Frequency of maintenance positively influenced perception, but the effect was not statistically significant. The variables, intent to retain the micro catchments and retention time were also not statistically significant.

4.6 Factors influencing adoption of micro basins and trenches in establishment of agroforestry trees

The results of the binary logistic regression model are presented in Table 4.11.

Table 4.11: Binary Logistic regression results on factors affecting adoption of micro basins and trenches

Binary logistic regression				**Number of obs = 142**		
				LR chi2(21) = 147.21		
				Prob > chi2 = 0.0000		
Log likelihood = -24.807289				**Pseudo R2 = 0.7479**		
Variable	**Coef.**	**Std. Err.**	**z**	**P>|z|**	**95% Conf. Interval**	
Land ownership	**2.323**	**1.084**	**2.14**	**0.032**	**0.1978**	**4.4473**
Number of land parcels	**0.736**	**0.364**	**2.02**	**0.043**	**0.0228**	**1.4491**
Use of other SWC method	**5.181**	**1.103**	**4.70**	**0.000**	**3.0185**	**7.3427**
Number of sources of extension	**1.192**	**0.566**	**2.11**	**0.035**	**0.0831**	**2.3006**
Fencing	**5.507**	**1.508**	**3.65**	**0.000**	**2.5523**	**8.4620**
Gender of household head	-0.473	1.434	-0.33	0.742	-3.2832	2.3377
Age HH head	0.004	0.036	0.10	0.922	-0.0671	0.0742
Education HH head-No education	-0.612	1.095	-0.56	0.576	-2.7573	1.5331
Education HH head-Secondary	-1.466	1.749	-0.84	0.402	-4.8954	1.9625
Number income sources	-0.043	0.406	-0.11	0.916	-0.8397	0.7535
Total household members	0.062	0.176	0.35	0.726	-0.2834	0.4069
Total Land size Ha	-0.434	0.347	-1.25	0.211	-1.1140	0.2455
Access to extension agents	-1.287	1.246	-1.03	0.302	-3.7301	1.1560
Access to extension- FTC	0.850	1.381	0.62	0.538	-1.8566	3.5575
Access to extension- NGO	0.325	0.910	0.36	0.721	-1.4577	2.1084

As hypothesized, land ownership significantly influenced adoption of micro catchments. Results show that the log odds of adoption increase by a factor of 2.322 for farmers who own land. These results are comparable to those in Kassie *et al*., (2009) who found that ownership of land positively influenced the acceptance of sustainable land management practices. Landowners tend to accept technologies where investments are long term and benefits will accrue to them in the long term compared to tenants who may not hold the land for longer periods (Foti *et al*., 2008).

The number of land parcels had a significant positive impact on adoption whereby the log odds of adoption increase by a factor of 0.735 for every increase in a parcel of land owned *cetaris paribus*. Land parcels can be used as a proxy for wealth indicating that farmers who have more land parcels have the financial and human capital required to manage the plots as well as implement SWC technologies. These results oppose the findings in Alufah *et al*., (2012), who observed that farmers with many plots tend to give less attention to recommended farming practices, especially if they are labor or time-consuming.

Consistent with the expectations of this study, the use of at least one SWC method in tree planting was found to be positively influence adoption of micro catchments and highly significant at P=0.000. The positive coefficient suggests that the log odds of adoption of micro catchments increases by a factor of 5.1806 for households who have used at least one SWC method in planting trees holding all other independent variables constant. This implies that the use of a technology may encourage adoption of other similar technologies because farmers are already aware of their benefits. Similarly, Anley *et al*., (2006) observed that integrating local soil conservation practices with modern ones improves the natural conservation system and gives the farmers a wide variety of different technologies for adoption.

As expected, the variable for the number of sources for extension information was positive and was significant. Other factors held constant, the log odds for adoption increases by a factor of 1.191 for every unit increase in the number of extension sources. This implies that households with micro catchments had more access to information than those without. Extension services, a proxy for access to information is critical for SWC technologies. For SWC technologies to be effective, prior needs assessment and situational analysis are paramount to ensure that the technologies to be established befit the specific contexts. For this study, farmers highlighted that they had acquired extension information mainly from the government extension agents and contact with NGOs/project personnel. Through this contact, they had acquired knowledge on the importance of the micro catchments, technical skills on design and construction and therefore facilitating their adoption (Anley *et al*., 2006). Similarly, He *et al*., (2007) observed that contact with extension agents had a significant positive effect on adoption of rainwater harvesting technologies.

Fencing was highly significant in influencing adoption of micro catchments. The log odds of adoption increased by a factor of 5.507 for farmers who had fenced their trees. Being a pastoral area, free grazing is common thereby impeding survival of trees. Navroodi, (2015), observed that grazing was the major hindrance to tree species regeneration. To enhance survival of trees, protection of these seedlings through fencing is critical. According to Mugwe *et al*., (2001) grazing of livestock is an impediment to survival of young seedlings thereby farmers tend to fence the trees planted to protect them from livestock damage. Similarly, Baudron *et al*., (2015) reported more trees of different species in farms enclosed from livestock. Other studies have also demonstrated the importance of farm enclosures aimed at enhancing survival and regeneration of trees and rehabilitation of degraded areas (Mekuria *et al*., 2007; Mekuria *et al*., 2011; Angassa & Oba, 2010).

Gender was found to influence adoption of micro catchments negatively but not significant. The decision to adopt a technology may differ between households headed by men and women. Some studies have shown that men are highly likely to adopt new technologies (Adesina *et al*., 2000) while others have shown that females are likely to adopt (Kassie *et al*., 2009). However, gender by itself may not influence the decisions to adopt. Control of critical resources may influence adoption decisions as well. In rural African households, there is inequity in access and ownership of productive resources between males and females where men tend to have greater control hence a comparative advantage in adoption (Gebregziabher *et al*., 2013). Consistent with these results, were the findings in Alufah *et al*., (2012) where they found insignificant relationship between household head's gender and implementation of micro catchments.

As expected, age of the household head was found to have a positive effect on adoption, implying that farmers that are older may adopt the micro catchments unlike the younger farmers. However, this effect was not significant. Adesina & Chianu, (2002) attributed the tendency of the older farmers to adopt technologies to a deeper understanding of the problem, therefore, more willing to adopt measures that will counter the problem. Similarly, Abdulai & Huffman, (2005) observed that older farmers would be more inclined to adopt than younger farmers. This may be attributed to their experience, accumulated knowledge, and resources. In contrast, Sidibé, (2005); Chianu & Tsujii, (2004) and He *et al*., (2007) found that younger farmers would be willing to risk in adopting new technologies.

Education of household head was not significantly associated with ownership of micro catchments. The possible explanation for this is that farmers received information on SWC from extension agents and NGOs. None of the farmers reported having received this information from the learning institutions. Moreover, education levels were low amongst the farmers interviewed, the majority of who were illiterate or had attained education up to the primary level (Table 4.3). Results of this study are consistent with the findings in Jara-Rojas *et al*., (2012) and Baguma & Loiskandl, (2010).

Number of income sources was found to be negatively associated with adoption inferring that households with more sources of income were less disposed to adoption of micro catchments. The relationship was however not significant. The possible explanation for the negative coefficient is that farmers with several sources of income are busy with other activities thereby having less time for SWC related activities. Furthermore, the alternative income-generating sources could be providing faster cash benefits than the conservation efforts which are more of capital accumulation than cash income (Amsalu & de Graaff, 2007).

As expected, the coefficient for the number of household members was positive but not significant. Household size was taken as a proxy for labor availability. The lack of significance could be explained by the prioritization of labor for farming and livestock keeping activities which are the main sources of livelihood. de Graaff *et al*., (2008) observed that there is more labor available in larger households hence higher likelihood of adoption of technologies.

4.7 Effectiveness of micro basins and trenches in survival of agroforestry trees

4.7.1 Survival of *Cordia africana* in the micro catchments

Six months after establishment of *Cordia africana*, the highest survival rate (82%) was recorded for trees in the control. A 64% survival rate was observed for trees in the micro basins and trenches (Figure 4.6). By 12 months, a decline in survival was observed in all the treatments with the control having four trees surviving (36%) and three surviving

(27%) in both the micro basin and trench. A further decline was observed at 18 months, where three trees were remaining in the control and two were remaining in each of the micro catchments. This survival rate remained constant from 18 months until 36 months. Over the entire period, trees in the control performed better than those in the micro catchments. Survival in the micro basin and trench was similar over the entire period of the experiment.

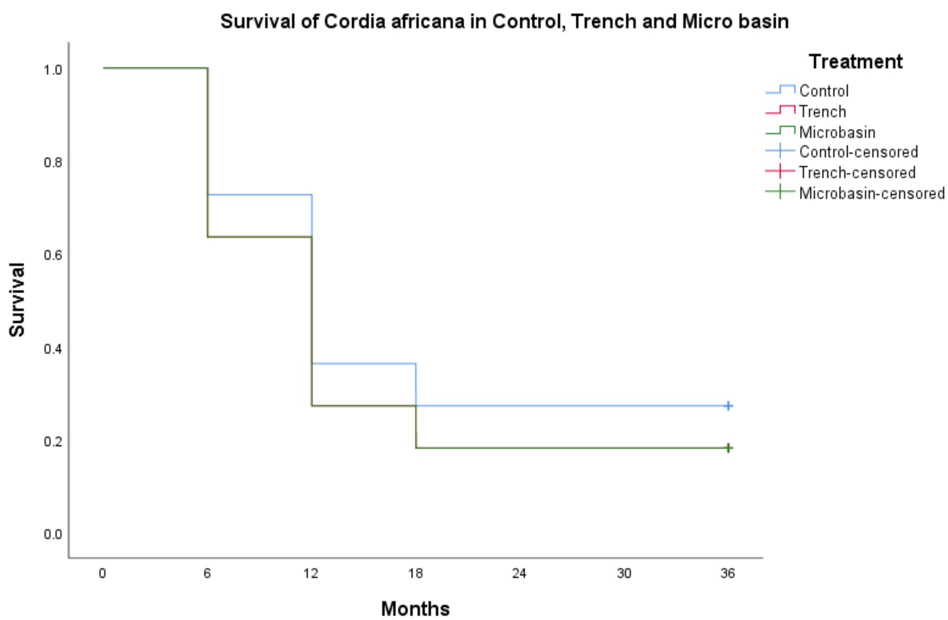

Figure 4.6: 36-month survival of *Cordia africana* in micro basin, trench and control

4.7.2 Survival of *Grevillea robusta* in the micro catchments

Within the first six months, survival rate of *Grevillea robusta* was recorded at 70% (7 seedlings) for trees in the control, 40% (4 seedlings) for trees in the micro basin and 30% (3 seedlings) for trees in the trench. After 12 months, 4 trees were remaining in the control and there having no change in the micro basin and trench, the three trees were still surviving. Within 18 months, three seedlings were remaining in the micro basin, and two in both the trench and control (Figure 4.7). Of the three treatments, most trees that survived had been planted in the micro basins.

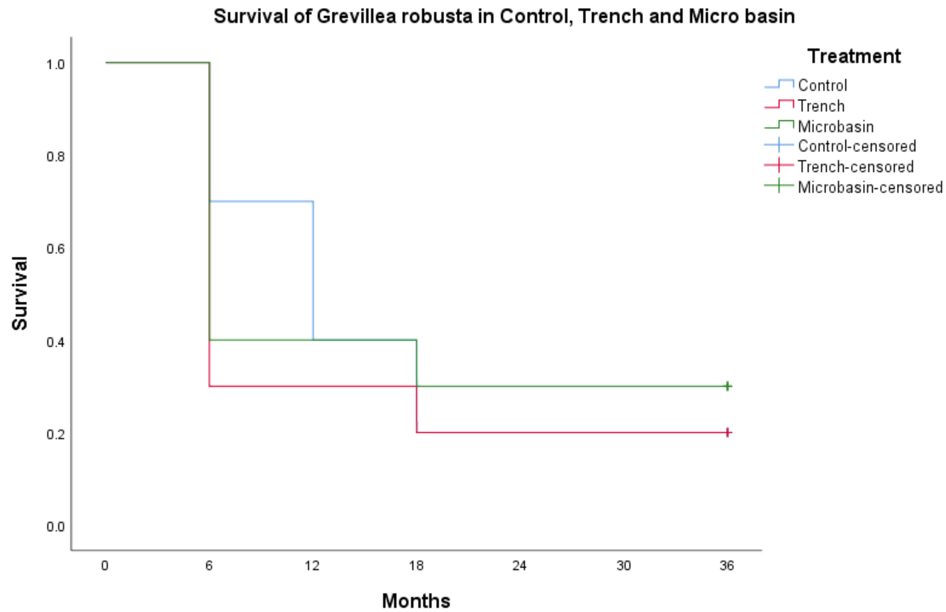

Figure 4.7: 36-month survival of *Grevillea robusta* in the micro basin, trench, and control

4.7.3 Survival of *Mangifera indica* in the micro catchments

A 57% survival rate (12 seedlings) was recorded for mango trees planted in the control while a 38% rate (8 seedlings) was recorded for mango trees planted in both the micro basins and trenches. Within 12 months, survival rate declined to 5 seedlings in the control and 7 trees in both the trench and micro basin. A declining trend was observed up to the end of the experiment where 4 trees were surviving in the micro basin and 3 trees in both the control and the trench (Figure 4.8). Trees in the micro basin performed better than trees in the trench and the control.

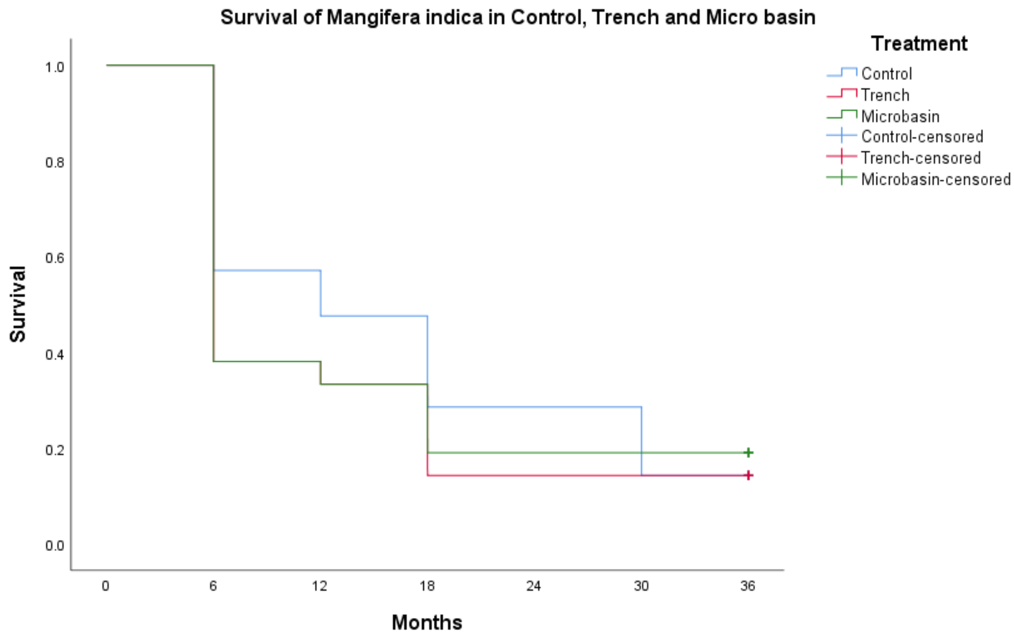

Figure 4.8: Survival of *Mangifera indica* in micro basin, trench and control up to 36 months

4.7.4 Effects of micro catchments on tree survival

Contrary to the expectations of this study, Log rank tests showed no significant differences for survival of the three-tree species in the three treatments (Table 4.12).

Table 4.12: Overall comparisons of tree survival in micro basin trench and control

Tree Species	Overall Comparisons	Chi-Square	df	Sig.
Mangifera indica	**Log Rank (Mantel-Cox)**	**0.368**	**2**	**0.832**
	Breslow (Generalized Wilcoxon)	1.517	2	0.468
	Tarone-Ware	1.001	2	0.606
Grevillea robusta	**Log Rank (Mantel-Cox)**	**0.34**	**2**	**0.844**
	Breslow (Generalized Wilcoxon)	1.337	2	0.512
	Tarone-Ware	0.733	2	0.693
Cordia africana	**Log Rank (Mantel-Cox)**	**0.425**	**2**	**0.809**
	Breslow (Generalized Wilcoxon)	0.405	2	0.817
	Tarone-Ware	0.422	2	0.81
Pooled	**Log Rank (Mantel-Cox)**	**0.216**	**1**	**0.642**
	Breslow (Generalized Wilcoxon)	1.62	1	0.203
	Tarone-Ware	0.958	1	0.328

This suggests that the micro catchments did not significantly influence survival of either of the tree species. The findings contravene a past study conducted by Derib *et al*., (2009) in Northwest Ethiopia where micro basins and trenches were reported to be more effective in retaining soil-water and enhancing survival of trees compared to half-moons and ordinary planting pits. Other studies have also shown better performance for trees planted within the micro catchments compared to those without (Schiettecatte *et al*., 2005; Li *et al*., 2005; Mugwe, *et al*., 2001; Rono *et al*., 2013).

The highest tree mortality rates were observed from six months to one year (12 months) after planting. Farmers reported a similar trend of survival for trees planted in previous years whereby most species that failed to survive died between 6 and 12 months. Similar to our findings are the results reported in Bahamonde *et al*., (2017) who observed a low rate of seedling survival in the first year, followed by less than 10% survival rate in the second year. Moreover, Mahari, (2014) asserted that seedlings less than one year are vulnerable to death due to moisture stress because they do not have an extensive root system to access water from a large soil volume.

The findings of this study can be explained in terms of local weather patterns. This is because, in the study area, trees seedlings are planted during the main rainy season which falls between June and September (Taffesse *et al*., 2012). Sufficient water can be accessed by tree seedlings during the rainy season, therefore trees are less likely to suffer from water scarcity thereby guaranteeing their successful establishment.

Six months after planting falls in the month of January. Trees are still young and require frequent management activities especially watering because this is the onset of the dry season. However, farmers reported that they are not able to sufficiently water the trees because majority of them depend on water from community taps that are located far from their homes. Moreover, the primary use of the water fetched is for domestic and livestock, therefore, trees are given less priority.

To augment the findings in the experiment, farmers were asked to report the duration that the trees survived after planting and the perceived causes of death based on their past experiences. The highest tree mortality rate was reported to be between 6 and 12 months. Water scarcity, insect attack and livestock browsing were highlighted as the main causes of tree mortality. Farmers indicated that the problem of moisture scarcity was so severe that the micro catchments could not sufficiently conserve soil moisture required for the growth of trees.

It is noteworthy that the death of seedlings during the dry period may occur directly due to moisture stress or because of drought-exacerbated factors such as pests, diseases, competitors among others (Engelbrecht *et al*., 2005). Drought reduces soil moisture, alters the soil and root environment, interferes with the leaf and atmosphere interface, decreases water and carbon dioxide fluxes, consequently limiting the growth of trees (Bréda *et al*., 2006).

Insect attack was also mentioned as a challenge hindering tree survival. It was reported that *Grevillea robusta* and *Mangifera indica* were most susceptible to attack. Jaimez *et al*., (2013) reported high significant damages on the trees due to insect attack that led to high mortality rates. In addition, Bucagu *et al*., (2013) reported that termite damage was one of the major constraints for survival of *Grevillea robusta* in Rwanda. Up to 42% of the farmers reported that termites affected survival of trees in the drylands of northern

Ethiopia (Mahari, 2014). Further interactions with the farmers showed that they were not well informed on managing the insect problem.

Another explanation for the high mortality rate was destruction of the trees by livestock as a result of the free grazing system predominant in the area. Despite farmers having planted trees around the homesteads to enhance protection from livestock, it was observed that the livestock grazed freely on the homesteads as well thereby destroying the trees. Similar to findings of this study, other studies have attributed the low seedlings survival rates to livestock browsing as well. These studies have been focused on the outfields (Mekonnen *et al*., 2008; Wassie *et al*., 2009) and forest fragments (Mahari, 2014). Results from this study show that livestock browsing is also a potential problem in the homesteads and therefore tree protective systems should be harnessed.

Feedback from the key informants showed that in addition to water scarcity, other factors influence tree survival. These include free grazing, pests and diseases, termites among others (Table 4.13). Further feedback showed that there were already SWC measures for tree planting, but these were focused on the communal lands as means of restoring these lands. They noted that for agroforestry tree planting, farmers only used ordinary pits so micro catchments would be an improvement to the existing agroforestry initiatives.

Table 4.13: Feedback from key informants interviewed in Adami Tulu, Dugda, Bora and Lume districts

Theme	Adami Tulu	Dugda	Bora	Lume
Sources of water	Rainfall, Lake Zeway, Groundwater, ponds	Rainfall, Ground water, Meki river-drying, Lake Zeway, ponds	Rainfall, Ground water, Awash river	Rainfall, ponds, Mojo river, ground water
SWC methods	Micro basins, eyebrow basins, stone bunds, communal ponds	Soil bunds, gabions, stone bunds, check dams Communal/degraded land, tree planting	Trenches, half-moons, soil bunds, terraces, tree planting	Tree planting, soil/stone bunds, half-moons, gabions, check dams, brushwood, enclosures
SWC for trees	**Ordinary pits**	**Ordinary pits**	**Ordinary pits**	**Ordinary pits**
Hinderances to agroforestry	**Termites, pests/diseases, free grazing, water scarcity**, lack of skills on tree management, SWC labour intensive, economic constraints	**Water shortage**, Lack of awareness on management, **free grazing**, camel migration (near Awash region), flooding-8 kebeles, inadequate extension staff	**Water scarcity, Free grazing**, lack of awareness on management practices, less interest in tree planting (pumice business), **termites**	**Water shortage,** inadequate skills, low farmer willingness, **free grazing**, poor soil quality, labour intensive
Recommendations	Training/ demonstrations on tree planting and management, pest control, by laws on free grazing	Farmer training, demonstrations, women/youth involvement, model farmers, provision of materials	Training, policy enforcement on tree planting/free grazing, construction of ponds	By-laws, awareness creation, technical training, technology demonstration

From 18-36 months, survival rate for all the trees was observed to be relatively steady. This implies that trees surviving up to 18 months have a high possibility of surviving and growing to mature trees. The main cause of tree death reported during this period was attack by moles and flooding (in one part of the village which borders the hills). These findings underscore the need for enhanced care for trees from planting time to 12 months because the probability of trees growing to maturity was higher for trees that survived up to 12 months. Furthermore, Akaji *et al*. (2017) emphasized the importance of tree seedling survival at young stages to ensure trees mature to adult stages.

In this context, results show that by themselves, micro catchments may fail to fully address the high tree mortality rate in East Shewa, because other factors such as insect attack and livestock damage constrain tree survival. Therefore, understanding the local context (Coe *et al*., 2014) and using locally available solutions is important in ensuring that the right approaches are taken to enhance tree survival. Moreover, farmers revealed that the management activities they applied were not optimal for the trees mainly because they lacked adequate skills in the required management activities.

Similarly, Iiyama *et al*. (2013) explained that farmers lack the essential information and guidance required for optimal management of trees. Yet management practices were found to significantly affect the yield potentials of *Jatropha* seedlings under their study. The authors further emphasized on the need for optimal management at the early tree-growth stages to avoid offsetting the positive effects of subsequent management activities. Farmers in the study further reported that they lacked sufficient labor and to manage trees due to the cropping and livestock-related activities that are ongoing during tree planting activities.

To ensure optimal survival of trees at initial phases of establishment, proper post-tree planting management practices such as watering, mulching, manuring, weeding and tree protection are critical at the early stages. Despite the establishment of the micro catchments, a high mortality rate for the trees largely attributable to water scarcity was recorded thus underscoring the importance of adequate soil moisture. Access of water during the dry periods is imperative because it enables the young trees in their survival, height, branch growth, root length and subsequent growth (Cao *et al*., 2008). Findings from Garcia-Forner *et al*., (2016), showed that watering trees enables them to survive longer before, during after drought periods. Higher water availability also improves the health and growth of trees (Chen *et al*., 2017). Hailemariam *et al*., (2018) observed that seedlings grown under adequate soil water availability grew better than those under water stress.

Other management practices such as mulching, manuring, weeding and tree protection from livestock have been shown to enhance survival of trees if applied efficiently at the early stages of tree planting (Mekonnen *et al*., 2017). Mulching enhances the availability of soil moisture for the trees by reducing evaporation, allowing redistribution of moisture within the soil profile thereby improving the performance of the young trees. Application of manure (farmyard or compost) enhances tree survival through the addition of nutrients in the soil while weeding contributes to increased nutrient availability due to less competition by weeds. Fencing enables the protection of trees from destruction by livestock.

CHAPTER FIVE

SUMMARY CONCLUSIONS AND RECOMMENDATIONS

The study highlighted that farmers had a positive perception of both micro basins and trenches mainly due to their ability to enhance the survival of trees through soil moisture conservation. Factors such as labor availability, land size, maintenance of the structures and discernment of water scarcity as a problem influenced perceptions of the farmers on effectiveness of the micro catchments.

Adoption of the micro catchments was influenced by factors such as land ownership, number of parcels owned, use of at least one soil and water conservation method previously, fencing for tree protection and number of extension sources that farmers had access to influenced adoption.

A low tree survival rate was observed for the three-tree species assessed under the study (*Cordia africana, Mangifera indica, and Grevillea robusta)* in both micro basins and trenches. The highest tree mortality was observed within the first 12 months, which was attributed mainly to water scarcity. In addition to water scarcity, farmers and key informants attributed the low tree survival rate to other factors such as insect attack and livestock browsing.

Overall, the study concludes that there is a high potential to promote SWC technologies as demonstrated by the positive perception by farmers towards the technologies. However, micro catchments in isolation may not fully address the problem of low tree survival as evidenced by the low level of survival for trees planted in the micro catchments.

The study recommends enhanced awareness creation on soil and water conservation practices through extension services as this results in positive perception and adoption of SWC measures. To counter the overarching problem of low survival rate, the study recommends the implementation of holistic approaches responsive to all constraints to tree survival. Measures such as additional watering from small scale ex-situ water harvesting structures and post-tree planting management practices focused at the early seedling establishment stages can be implemented to enhance survival. Further research on both biophysical and social-ecological factors that affect tree survival, and appropriate tree management practices suitable in the area is recommended.

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APPENDICES

Appendix 1: Household Questionnaire

Questionnaire no.______________________

GENERAL INFORMATION

Date of interview	
Interviewer's name	
Supervisor's name	
Interview start time	

SECTION A

A1: Household identification

1. Name of household head		
2. Gender of Household Head of (*1=Male 2=Female*)		
3. Age of Household Head		
4. Education level of Household head (*1=No formal education 2=Primary education 3=Secondary education 4=College education 5=University education)*		
5. Respondent's name		
6. Gender of respondent		
7. Relationship with household head *(1=Household head 2=Spouse 3=Son 4=Daughter 5=Other relative)*		
8. District/*Woreda* name		
9. Village/*Kebele* name		
10. Household GPS coordinates	Altitude	
	Latitude	
	Longitude	

A2: Household characteristics

11. Please provide the following information about your household

	Total	Male	Female
Total number of household members			
Members < 5 years			
Members between 6 to 20 years			
Members between 20 to 60 years			
Members above 60 years			

A3: Household income

12. What is the main source of income of Household head ____________*1=Paid employment (monthly salary) 2=Casual wages 3=Farm income 4=Business income (other than farm products) 5=Rental income 6= Crop income 7=Livestock income 8=Other (specify)*

13. Household income in the last 12 months?

Type of income	Was income received from this source in the last 12 months? *1=Yes 0=No*
Crop income	
Livestock income	
Paid employment (Salary)	
Other paid employment (daily wages)	
Business (other than farm products)	
Remittances- Gifts/ donations/ Income from children	
Loan/ Credit from formal institutions e.g. banks, cooperatives, registered groups	
Loan/ credit from informal sources e.g. friends, unregistered groups	
Payment from the government/programs/projects e.g. pension	
Rental income from land/houses	
Renting out farm equipment/animals	
Others (specify)	

14. During the last 12 months, did you obtain income from any of the following farm produce?

Farm produce	Sold in the last 12 months *1=Yes 0=No*
Food crop	
Cash crop	
Fruits	
Vegetables	
Timber	
Fuel wood	
Charcoal	
Livestock	
Livestock products e.g. milk, eggs	
Manure/compost	
Fodder e.g. Napier grass etc.	
Honey	
Other (specify)	

A4: Land holding characteristics

15. How many parcels of land do you own__________

16. Please provide the following information for each of the land parcels

Parcel ID	Parcel name	Size	Unit of measurement *1= Acre 2= Ha 3= Sqm 4= Are (10m X 10m) 5=Timad 6=Kart 96= other (specify)*	Status of land *(1=Owned 2= Rented 3= Gift)*	Slope of land *(1=Flat 2=Gentle slope 3=Very steep)*	Type of land use *(1=Cultivated 2=Grazing 3=Fallow 4=Forest 5=Others)*	Do you have trees on this parcel? *1=Yes 0=No*	If yes, what proportion is covered by trees? *1=Whole plot 2=Half plot 3=Less than half*
1								
2								
3								
4								
5								

A5. Trees

17. In the last 24 months, did you plant any tree seedlings? *1=Yes 0=No*
18. If Yes in *(above)* please give the following information

Species name	Location planted (code c)	Did you use any conservation structure? *1=Yes 0=No*	If yes, give reasons for using conservation structure	If No give reasons for not using conservation structure

SECTION B: WATER CONSERVATION STRUCTURES WITHIN HOUSEHOLDS

19. Do you have any micro catchments on your farm? *1=Yes 0=No*___________

If Yes, please go to Q. 25, If No, please go to Q. 20

20. Why haven't you established any water conservation structure? *1=No problem of water scarcity 2=Expensive to construct 3=Lack of enough time 4=Lack of labor 5=Lack knowledge/skills for construction 6=Lack of space on my land 7=Others (specify)*____________________________

21. Have you approached any farmer /institution inquiring about the structure? __________*1=Yes 0=No*

22. If Yes, please indicate the source of information *1=government extension officers 2=other farmers 3=learnt in school 4=farmer exchange visits 5=agricultural shows 6=Training in FTC 7=media (TV, radio, newspaper, internet) 8=parents/relatives 9=NGOs/project initiatives 10=others (specify)*__________________________

23. Would you be willing to establish any water conservation structure on your farm? 1=*Yes 2=No*______________

24. If yes, what structure would you establish and why?

Soil moisture conservation structure	Reason for its establishment

25. Please give the following information about the water conservation structures

Type of structure	Micro basin	Trench
Type of tree in the structure		
Year of establishment		
Who constructed the structure? 1=*Family labor 2=hired 3= labor exchange 4=NGO/project*		
Please specify the source of funds for constructing these structures: *1=farm income 2=off farm income e.g. employment 3=savings 4=loan/credit, 5=NGO/project support 6=Others(specify)*		
Is the structure maintained? 1=*Yes 0=No*		
If No, why is the structure not maintained? *1=lack of funds 2=lack of labor 3= structure not useful 4=Other (specify)*		
If Yes, who maintains the structure*? 1=Family labor 2=hired 3=labor exchange 4=NGO/project*		
Please specify the maintenance activities applied *(1=digging 2=weeding 3=manure application 4=others (specify))*		
How frequently are the structures maintained? 1=*Monthly 2=Quarterly 3=semi-annually 4=annually 5=never*		
Please indicate the season most appropriate time for maintenance of the *structures (1=dry season 2= wet season)*		
Please give your reasons for your answer above		
Please specify the source of funds for maintaining these structures: *1=farm income 2=off farm income 3=savings 4=loan/credit, 5=NGO/project support 6=Others(specify)*		
How much costs are incurred in maintaining the structures		
Do you intend to maintain these structures future? *1=Yes 0=No*		
How long do you intend to maintain this structure? *1=more than five years 2=1-5 years 3=less than one year*		

26. Do you get any benefits from the structures______________ *1=Yes 0=No*

27. If Yes, please list the benefits in the table below:

Type of structure	Benefits of the structure? *1=soil moisture retention 2=improve survival of trees 3= improve health of trees 4= fast rate of tree growth 5=improve quality of soil 6=Other (specify)*
Micro basin	
Trench	

28. Do you experience any problems with the structure? 1=*Yes 0=No*_____________

29. If yes, please answer the following questions

Type of structure	Type of problem *1=Expensive to maintain 2=seedlings choke due to water stagnation 3=attracts pests 4=causes diseases 5= requires a lot of labor to maintain 6= takes a lot of time to maintain 7=Others (specify)*
Micro basin	
Trench	

SECTION C: PERCEPTION OF MICROCATCHMENTS FOR IMPROVEMENT OF TREE GROWTH

C1: Severity of water scarcity

30. Is water scarcity a major problem on your farm? *1=Yes 0=No*_________

31. If yes, how severe is the problem? *1=Very severe 2=Moderately severe 3=severe 4=less severe 5=Not severe at all*

32. Please give reasons for your answer above
____
____
____
____

33. Do you think this problem overtime is *1=increasing 2=decreasing 3=remaining the same*?

34. Give reasons for your answer above
____
____
____
____
____

35. Does the problem of water scarcity have any negative impact on tree growth? __________*1=Yes 0=No.*

36. If yes, please indicate the level of negative impact on trees *1=Far too large 2=large3=neutral-neither large nor small 4=small 5=Too small*______________

37. Give reasons for your answer above

____
____
____
____
____

38. Do you think the problem of water scarcity can be solved? *1=Yes 0=No*______________

39. If yes what methods can be used?

____
____
____
____
____

C2: Effectiveness of micro basin and trench for tree growth and soil moisture conservation

40. Please indicate your view of the micro catchments in the table below

Type of structure	Effectiveness in survival and growth of tree seedlings *(1= Very poor 2=Poor 3=fair 4=Good 5=Very good)*	Please give reasons for your answer	Effectiveness in soil moisture conservation *(1= Very poor 2=Poor 3=fair 4=Good 5=Very good)*	Please give reasons for your answer
Micro basin				
Trench				

41. Between micro basin and trench which structure do you prefer _____________*1=Micro basin 2=Trench*

42. Please give reasons for your answer above
____
____
____

43. What problems do you think are associated with the water conservation structures?

Type of structure	Challenges (*1=Expensive to maintain 2=seedlings choke due to excess water stagnation 3=attracts pests 4=causes diseases e.g. root rot 5= requires a lot of labor to maintain 6= takes a lot of time to maintain 7=Others (specify)*)
Micro basin	
Trench	

44. Are you aware of any other water conservation structures suitable for growth of trees? *1=Yes 0=No*_____________

45. If Yes, what structures are you aware of?
____
____
____
____
____

46. How did you know about these structures? *1=government extension officers 2=other farmers 3=learnt in school 4=farmer exchange visits 5=agricultural shows 6=Training in FTC 7=media (TV, radio, newspaper, internet) 8=parents/relatives 9=NGOs/project initiatives 10=others (specify)*___________________________

47. What other methods of soil moisture conservation for trees would you prefer?____
____
____
____

C3: INSTITUTIONAL SUPPORT

48. Do you have any access to information on water conservation structures 1=*Yes 0=No*__________*?*

49. If yes, please provide the following details

Source of information	*1=Yes0=No*
Visits by extension officers e.g. DAs, woreda officers	
Farmer Training Centers	
Neighbors/ friends/relatives	
Group members/lead farmers	
NGOs/projects/programs	
Seminars/ workshops	
Farmers exchange visits	
Farmers field days/ Agricultural shows	
Others (specify)	

Thank you for your time!

Interview End Time: _______

Appendix 2: Key Informants interview Checklist

1. Personal characteristics
   - Name
   - Age
   - Designation
   - Woreda
2. What are the main farming systems in this area?
3. Has there been any change in land use and land cover and if yes what are the changes that have been observed?
4. Has there been any change in weather patterns/ climate change and if yes, what changes have been observed?
5. What are the main water resources in this area and how accessible are they to the communities?
6. How does the community balance between different water uses from the various sources?
7. Which soil and water conservation methods are in place in this area?
   - In-situ rain water harvesting
   - Runoff systems
   - Roof catchments
8. How is the adoption of SWC among farmers in this area, what are the hindrances?
9. Which methods are most suitable for crops and trees and why?
10. What are the benefits, opportunities and challenges in promoting soil and water conservation?
11. What recommendations would you give to ensure high adoption of SWC in the area

Appendix 3: Details of farmers involved in tree planting in the different treatments

					Treatment			Tree species		
No.	**Name of farmer**	**No. of tree species**	**Tree Species**	**Total trees planted**	**MB**	**Trench**	**Control**	**Mango**	**Grevillea**	**Cordia**
1	Abee Dire	1	*Mangifera indica*	3	1	1	1	3	0	0
2	Aman Dalu	3	*Cordia africana*	3	1	1	1	0	0	3
			Grevillea robusta	3	1	1	1	0	3	0
			Mangifera indica	3	1	1	1	3	0	0
3	Amara Biftu	2	*Cordia africana*	3	1	1	1	0	0	3
			Grevillea robusta	3	1	1	1	0	3	0
4	Bedaso Kufa	1	*Cordia africana*	3	1	1	1	0	0	3
5	Bula Oda	1	*Mangifera indica*	3	1	1	1	3	0	0
6	Dame Biratu	1	*Mangifera indica*	3	1	1	1	3	0	0
7	Densa Usheta	2	*Cordia africana*	3	1	1	1	0	0	3
			Grevillea robusta	3	1	1	1	0	3	0
8	Dorre Kunbi	1	*Mangifera indica*	3	1	1	1	3	0	0
9	Duga Kare	1	*Grevillea robusta*	3	1	1	1	0	3	0
10	Edaso Gemechu	3	*Cordia africana*	3	1	1	1	0	0	3
			Grevillea robusta	3	1	1	1	0	3	0
			Mangifera indica	3	1	1	1	3	0	0
11	Edushe Guye	2	*Grevillea robusta*	3	1	1	1	0	3	0
			Cordia africana	3	1	1	1	0	0	3
12	Fanose Belayneh	1	*Mangifera indica*	3	1	1	1	3	0	0
13	Fetela Dodota	1	*Mangifera indica*	3	1	1	1	3	0	0
14	Galatu Usena	2	*Grevillea robusta*	3	1	1	1	0	3	0
			Mangifera indica	3	1	1	1	3	0	0
15	Gutema Demble	1	*Mangifera indica*	3	1	1	1	3	0	0
16	Hassana Usmanna	1	*Mangifera indica*	3	1	1	1	3	0	0
17	Hawa Ibrahim	3	*Cordia africana*	3	1	1	1	0	0	3

			Grevillea robusta	3	1	1	1	0	3	0
			Mangifera indica	3	1	1	1	3	0	0
18	Jarso Doba	1	*Mangifera indica*	3	1	1	1	3	0	0
19	Kacha Bula	1	*Cordia africana*	3	1	1	1	0	0	3
20	Mojo Nagashi	1	*Mangifera indica*	3	1	1	1	3	0	0
21	Neguse Adugna	1	*Mangifera indica*	3	1	1	1	3	0	0
22	Otocho Gidirsa	3	*Cordia africana*	3	1	1	1	0	0	3
			Grevillea robusta	3	1	1	1	0	3	0
			Mangifera indica	3	1	1	1	3	0	0
23	Roba Shumi	1	*Mangifera indica*	3	1	1	1	3	0	0
24	Safo Nuri	2	*Grevillea robusta*	3	1	1	1	0	3	0
			Mangifera indica	3	1	1	1	3	0	0
25	Shenga Woji	1	*Cordia africana*	3	1	1	1	0	0	3
26	Tsadik Sabre	1	*Mangifera indica*	3	1	1	1	3	0	0
27	Tufa Huluka	1	*Mangifera indica*	3	1	1	1	3	0	0
28	Washo A/Bulti	1	*Cordia africana*	3	1	1	1	0	0	3
29	Yohanis Abiyo	1	*Mangifera indica*	3	1	1	1	3	0	0

Appendix 4: Dependent variable, independent variables, measurement level and expected outcome on farmers perception

Name of variable	Value labels	Measurement level	Expected outcome
Dependent variable Y= farmers Perception on effectiveness in survival of trees Perception on soil moisture conservation	1= Very poor 2= Poor 3= Fair 4= Good 5=Very Good	Ordinal	
Independent variables			
Gender of household head	1 = male 2 = female	Binary	+
Education of household head	(*1=No formal education* *2=Primary* *3=Secondary* *4=College* *5=University*	Nominal	-
Number of household members (20-60yrs)		Continuous	+
Water source for domestic use	*1=Rain water, 2= river, 3= groundwater, 4= pond, 5= tap water, 6= lake*	Nominal	+/-
Severity of water scarcity	*1=Very severe 2=Moderately severe 3=severe 4=less severe 5=Not severe at all*	Ordinal	-
Trend of water scarcity	*1=increasing 2=decreasing 3=remaining the same*		+
Access to extension information	*1=Yes 0=No*	Binary	+
Total Land size Ha		Continuous	+
Source of Construction labor	1=*Family labor 2=hired 3= labor exchange 4=NGO/project*	Nominal	+/-
Source of Construction funds	*1=farm income 2=off farm income*	Nominal	+/-

	e.g. employment 3=savings 4=loan/credit, 5=NGO/project support 6=Others(specify)		
Micro catchments maintenance	1=*Yes 0=No*	Binary	+
Source of maintenance labor	1=*Family labor 2=hired 3= labor exchange 4=NGO/project*	Nominal	+/-
Frequency of maintenance	1=*Monthly 2=Quarterly 3=semi-annually 4=annually 5=never*	Nominal	+
Source of maintenance funds	*1=farm income 2=off farm income e.g. employment 3=savings 4=loan/credit, 5=NGO/project support 6=Others(specify)*	Nominal	+/-
Intent to retain micro catchments	*1=Yes 0=No*	Binary	+
Micro catchment retention time	*1=more than five years 2=1-5 years 3=less than one year*	Nominal	+

Appendix 5: Dependent variable, independent variables, measurement level and expected outcome on adoption

Name of variable	Value labels	Measurement level	Expected outcome
Dependent variable Y= Adoption of micro basin and trench	*1= Yes* *0= No*	Binary	
Independent variables			
Gender of HH head	*1 = male* *2 = female*	Binary	+
Education level HH head	*(1=No formal education* *2=Primary* *3=Secondary* *4=College* *5=University*	Nominal	+
Age HH head		Continuous	+
Total household members		Continuous	+
Number of income sources		Continuous	+/-
Access to extension information	*1=Yes 0=No*	Binary	+
Number of sources of extension information		Continuous	+
Land ownership	*(1=Owned 2= Rented 3= Gift)*	Nominal	+
Total Land size Ha		Continuous	+
Number of land parcels		Continuous	+/-
Use of other SWC method	*1= Yes* *0= No*	Binary	+
Fencing	*1= Yes* *0= No*	Binary	+