SOIL AND WATER CONSERVATION TECHNOLOGIES FOR CLIMATE SMART AGRICULTURE IN METSEKO WATERSHAD OF KILTE AWLAELO WOREDA OF TIGRAY, ETHIOPIA

M.Sc. THESIS

KIFLOM MESHESHA FIKADU

HAWASSA UNIVERSITY, WONDOGENET, COLLEGE OF FORESTRY AND NATURALRESOURCE, WONDO GENET ETHIOPIA

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APPROVAL SHEET-I

This is to certify that the thesis entitled **"Soil and Water Conservation technologies for climate smart agriculture in Metseko Watershed of Kilte Awlaelo Woreda of Tigray, Ethiopia**" submitted in partial fulfillment of the requirements for the degree of Master's with Climate- smart agricultural land scape assessment, the Graduate Program of the Department of Agro forestry, and has been carried out by Kiflom Meshesha Fikadu Id. No CSAL/Ro13/10 under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

Submitted by:

Beyene Teklu (Ph.D.)	___________________	___________________
Main Advisor	Signature	Date
Fantaw Yimer (Ph.D.)	___________________	___________________
CO- Advisor	Signature	Date

OCTEBER, 2019

APPROVAL SHEET- II

We, the undersigned, members of the Board of Examiners of the final open defense by **Mr. Kiflom Meshesha Fikadu** have read and evaluated his thesis entitled **"Soil and Water Conservation technologies for climate-smart agriculture in Metseko Watershed of Kilte Awlaelo Woreda of Tigray, Ethiopia."** This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree.

Members of the Examination Board

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SGS Aproval	Signature	Date

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Kiflom Meshesha Fikadu

CANDIDET'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled entitled Soil and Water Conservation technologies for climate smart-agriculture Metseko Watershed Kilteawlaelo Woreda Tigray Region in partial fulfilment of the requirements for the award of the degree of Master of Science and submitted to the School of Graduate Studies, Wondo Genet College of Forestry and Natural Resource, Hawassa University is an authentic record of my own work carried out during the period from October, 2018 to May 2019 under the supervision of Beyene Teklu (Ph.D.) and co-Advisor Fantaw Yimer (Ph.D.).

The work contained in this thesis has not been previously submitted for similar or for other purpose at any higher institution or elsewhere to the best of my knowledge.

Kiflom Meshesha Fikadu	___________	____________
Student Name	Signature	Date

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ABBREVIATIONS AND ACRONYMS

AP	Available phosphorous
AU	Africa union
BD	bulk density
BoFED	Bureau of Finance and Economic Development
CE	cation exchange
CEC	Cation exchange capacity
CSA	Climate-smart agriculture
DA	Development agent
EPID	Extension and project implementation Department
FAO	Food and agricultural organization
FGDs	Focus Group Discussion
FHH	Female Household head
GDP	Gorse Domestic Product
Ha	Hectare
HH	Household head
MHH	Male household head
NGO	Non-Governmental Organization
RECs	Regional Economic Community’s
REST	Relief Society of Tigray
SD	standard deviation
SMC	soil moisture content
SOC	Soil Organic Carbon
SOM	Soil Organic Mater
SWC	Soil and Water Conservation
TN	total nitrogen
WFP	world food program
WOARD	Woreda office of Agriculture and Rural Development
WOFED	W0reda Office of Finance and Economic Development

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ABSTRACT

Community-based Soil and Water Conservation (SWC) practices have been adopted in the Tigray region over the last four decades with the aim to rehabilitate the degraded lands. Nevertheless, studies addressing the types of SWC activities and its effects on soil fertility, crop yield improvement, socioeconomic role, soil erosion reduction and in general as climate smart agricultural practices were limited. Thus, this study aimed to identify the major SWC activities and assess their implications on enhancing water availability, access to irrigation, improving soil fertility crop productivity and as climate smart agriculture practices. To achieve this objective household survey and focus group dissociation were employed with a total of 207 smallholder farmers who adopt. Further soil sample were taken for physicochemical analysis from soil and water conservation treated and non-treated fields at a depth of 0-15 and 15-30 cm using soil auger and cylindrical cores, respectively. Results revealed that all respondents were at the active age group 30-60 years, and the majority did not attend school. The result that implementing SWC activates has enhanced water availability, irrigation accessibility besides its positive role in soil fertility and crop productivity. Furthermore, the implementation of SWC activities creates the opportunity of earning more income to buy agricultural inputs and save money. This implies that the significant positive role of SWC activities for enhancing sustainable crop productivity without impairing the resource which are pillars of SWC activities as a means of climate-smart agriculture particularly in arid areas of Ethiopia. Government should be participated together with local peoples in SWC implementation. Climate smart agriculture Technologies practices in the study area are not practiced based on standard techniques. Further training for, DA's on CSA Technologies is suggested.

Keywords: Climate smart agriculture, Crop production, Soil and water conservation, Soil erosion, Water storage structures,

1. INTRODUCTION

1.1. Background

Land degradation remains one of the biggest environmental problems particularly in the developing countries as it directed to agricultural productivity from which more than 80% of the GDP derived from agriculture (Slegers, 2008). Land degradation and soil fertility deterioration coupled with poor agricultural productivity are the major challenges in developing countries, like Ethiopia (Holden and Shiferaw B, 2004). In Ethiopia, where cultivation has a history of several centuries, land degradation is an apparent threat to smallholder farmers who could not afford to buy fertilizer inputs.

The problem is very serious particularly in Ethiopian highlands where agriculture mainly practiced and the largest share of produce obtained (Semu Arayaselassie , 2018). The problem of land degradation is worse in the bottomland watersheds where saturated soils are easily removed by sheet, rill erosion and gullies are formed (Ayele G. *et al*., 2015). Extensive loss of the fertile topsoil through erosion substantially impair crop productivity and water retention capacity of the soil, which leads to loss of soil productivity and yield potential (Berhanu Afro Kebede *et al.*, 2016). To reverse the problem of land degradation, terracing and reforestation have long been implemented in most parts of Ethiopia as a means of soil and water conservation (Berhanu Afro Kebede *et al.*, 2016).

Tigray regional, state has long traditions of soil and water conservation practices as most parts of the region are dominated by mountains and undulating landscapes which exacerbate the loss of soil fertility through erosion (Munro *et al*. 2019).

The study was conducted in Kilte-Awlaelo Woreda which is among the several woreda within the Tigray region where SWC practices have a long tradition. SWC serves as a means of enhancing crop productivity through reducing erosion and protecting the soil loss and enhancing water infiltration (Esser and Mitiku Haile, 2002).

Given the fact that most areas of the Tigray region are characterized by erratic rainfall and prolonged drought, enhancing water infiltration through SWC is a solution for growing crops. The sustainable production of crops through practicing SWC in areas where rainfall is erratic. In this regard, the governments of the Tigray region and donors have been proactive in implementing soil and water conservation practices in different parts of the region to tackle the problem and enhance production and productivity. Thus, SWC strategies were designed to promote food security through minimizing degradation and desertification to enhance water infiltration and water supply for varies such as irrigation (Esser and Mitiku Haile, 2002).

In Tigray, the total area of land terraced between 1988 and 1995 is approximately 418500ha, which accounts for 52% of the total terraced in the region (Getachew, 2014). SWC in Tigray mostly focused on sustainable development of the agricultural sector through maintaining soil fertility and enhancing soil and water retention capacity and biophysical environment (Abera B, 2003).

Different soil and water conservation technologies with a diversity of methods have been implemented in Tigray(Desalew Adugnaw, 2013) . Harvesting surplus water reclaimed marginal lands by applying suitable conservation measures through growing trees, shrubs and grasses were few among many types of SWC techniques (Lakew D *et al*., 2005)

Effective SWC practices, including physical and biological measures, have a substantial benefit for achieving and sustaining food security in smallholder farming, through the successful rehabilitation and management of natural resources (Fantaw y kebede and Awdegenet, 2013). Implementation of soil and water conservation practices reduce erosion to acceptable levels where soil loss can be offset by natural soil development, improve the physical structure of the soil, increase or maintain the level of organic matter, make the best use of available water and maintain the soil fertility level by reducing nutrient loss

(Darghouth *et al*., 2008). The process of restoring depleted land and soil resources is quite slower than erosion and deterioration (Wallenstein, 2017).Many Years are required for restoration and soil reconstruction to a productive state. Residents of a community need to learn how to use and maintain the effects of damage to this vital resource (EA, 2010).

To move towards the goal of sustainability and the efficient use of water and land resources important changes in human attitudes and behavior are needed (FAO, 2006).

Many studies have examined SWC practices and the suitable management of these vital agricultural resources. A variety of practical methods of SWC measures are used and they are broadly grouped into physical (mechanical or technical), biological (vegetative) and agronomic measures (so-called best management practices) (FAO, 2006). Found that Ethiopian (Konso and Tigray) farmers used both traditional and improved practices for soil and water conservation.

According to (Ashoori *et al.*, 2016), compared barley crop and biomass incomes above the bund (soil accumulation area) and below the bund (soil loss area) of Fanya juu terraces in the ‘Andit- Tid’ area of northern Shewa during three cropping seasons from 1986 to 1987. The average barley yield was 1650 kg ha-1 above the bund, which was 43 % higher than below the bund. So, soil and water conservation are a pillar of climate-smart agriculture which to help to obtain the optimal level of production from a given area of land while possession soil loss below a critical value.

The soil loss tolerance value is defined as the rate of erosion at which soil fertility formation can be maintained over 25 years (Z Adimassu *et al.*, 2012). The effect of conservation measure in reducing soil loss generally varies with soil type, topography, climate and intensity of the measure .e.g. the distance beet ween terraces or density of vegetation cover (Z Adimassu *et al.*, 2012) . Gives equations that can be used to calculate the required terrace spacing when the natural conditions are required protection factors known.

1.2. Statement of the Problem

Land degradation increases the vulnerability of people to the adverse effects of climate change, by reducing soil organic carbon , concentration and water holding capacity, which in turn decreases agricultural productivity (Melesse Berhane *et al*, 2013). The Ethiopian government, non-governmental organizations’ and the community made an effort to adopt different coping mechanisms. According to Bekele W, (2003) community-based soil and water conservation practices in Muga watershed in the east Gojam of Ethiopia, indicated improvement in livelihood resources such as income, soil fertility, land productivity, forest, water, and food supply.

The study area is naturally exposed to many problems such as repeated drought, flood, food insecurity, and chronic famine as well as irregular rainfall and environmental degradation; combined problems in economic activities. To overcome the problems of land degradation, several soil and water conservation measures have been initiated by the government and non-governmental organizations’ in several parts of the study area (SAERT, 1994). The efforts aimed at reducing the degradation of natural resources and at the same time enhance adaptation to climate change. However, the advantages of structure as a means of avoiding climate hazards are not appreciative by the local people. Hence, this study has investigated that the contribution of soil and water conservation technologies for climate smart -agriculture.

1.3. Objectives

1.3.1. General Objective

- ✓ To evaluate the contribution of Soil and Water Conservation Technologies for improving crop productivity in Metseko water shade.

1.3.2. Specific objectives

- ✓ To evaluate the major soil and water conservation Technologies practiced in the study area.
- ✓ To assess the role of soil and water conservation technologies for climate smart agriculture for water availability and for the expansion of irrigation farming system.
- ✓ To assess the role of adopting climate-smart agriculture on socio-economic study.
- ✓ To assess the potential of soil and water conservation technologies for SOC sequestration in agro ecosystem.

1.4. Research questions

To address the stated objectives, the study attempted to answer the following questions.

- ✓ What are the major soil and water conservation activities practiced in the area as a means of climate-smart Agriculture in the study area?
- ✓ What is the role of implementing soil and water conservation activities for water availability and irrigation accessibility at Metseko watershed?
- ✓ What is the role of socio-economic in adopting activities?
- ✓ What is the potential of soil and water conservation for soil fertility and crop yield improvement at Metseko watershed?

1.5. Significance of the Research

This research aims to investigate the role of soil and water conservation Technologies for climate smart agriculture. The findings would hopefully enrich the information on physical structures such as terraces, bunds, trenches, check dams, and biological activities such as plantation of different plant species on the physical structures and participation of the local community on all practices. The findings of the study is believed to be an important source of information for policymakers and planners at the regional and national levels in the design and implementation of soil and water conservation more importantly, region and Woreda experts, as well as Kebele Das.

1.6. Scope and limitation of the study

This study is undertaken in Kilte Awlaelo Woreda Metseko water shade mainly related to soil and water conservation practices and its benefits for productivity improvement in line with climate-smart agriculture. Due to the resource (such as time, finance and materials), Transport, Topography of the area may be constraints, The study also focuses on soil and water conservation technologies for climate smart agriculture. This study begins in January 2019 and ends on October 2019.

2. LITERATURE REVIEW

2.1. Soil and Water Conservation Overview

2.1.1. Soil and Water Conservation in Ethiopia

Land degradation remains one of the main environmental problems in Ethiopia, threatening and it has been a major global agenda because of its adverse impact on the environment and food security and the quality of life (Slegers, 2008). The topsoil of Ethiopia is experiencing a faster rate of erosion (Holden and; Shiferaw, 2004). The degree of soil loss for Ethiopia varies greatly from place to place.

The deeply established areas of Northern Ethiopia are among those with the maximum rate of soil loss since the environment is extremely degraded as associated with the Southern part of the country. At current, the forest reserves of the country are projected to be 2.5-3% of the total land, and around 100,000 hectares of forest are misplaced annually (Berhanu AfroKe bede *et al.*, 2016). About 1 billion tons of topsoil also supposed to be eroded annually in line with this, declares that the average soil erosion is 42 tones/hectare/ year in the croplands (Sectors, 2009).

Soil and water conservation is one of the climate-smart agricultural (CSA) practices (FAO, 2016). These widely practice across the country and included a variety of conservation activities such as Fanya juu and different types of terraces (stone bund, Soil bund, deep trench, bench terraces, and different vegetative and agronomic practices) mainly to protect soil erosion. By the action of the government of Ethiopia, huge areas have been covered with terraces and millions of trees are planted. Because, problem considerable efforts have been made; since rehabilitated degraded environment and stop further degradation is the key method against erosion (District *et al.*, 2017).

The positive effects of soil and water conservation occur through time and practicing SWC technologies depends on the ability of the technologies to improve economic and environmental benefits. While there is a bulk of information regarding the adoption of SWC practices, little information is documented on the economic and environmental

It is progressively documented that suitable conservation of soil properties is a pre-condition for sustainable rural development strategies particularly in the highlands of Ethiopia (EA, 2010). However, most of the projects for soil conservation planned at the center and implemented at the local level show little attention to the question of whether the local people could apply to techniques on their farm fields.

Alike with the above knowledge at the end of the project; farmers did not have attention to enlarge new techniques to the rest of the farm fields. This is partly credited to the costly nature and problem of the flexibility of the new technology otherwise not contextualize. Furthermore, planners in the field assume that it is the accountability of the native population for the overall maintenance of the structures made by a project (For and Agents, 2013).

The technical organized knowledge of soil conservation has also conservatively regarded the knowledge of soil conservation of native people as ‘pre-logical’ or irrational and in doing so have either discharged or greatly played down its cogency. However, the age-old indigenous soil conservation process developed from experiential knowledge and experience of the individual principles of soil, of the relations through which these elements are smoothly run and of how these relations change through short and most extensive periods (Nyssen, and Schu, 2015). Therefore, Climate-smart agriculture is not a well-defined set of practices or a wholly new type of agriculture. Rather it is an approach that combines different methods under a climate change umbrella (FAO, 2016). Assesses the risks and needs of a specific farm or farming community through a climate impact lens and then addresses them using practices chosen for that particular situation. It gives farmers tools and a pathway to make their operations and livelihoods more productive and resilient in the face of climate change, while also helping reduce their climate impacts (Morgan *et al.*, 2010).

CSA includes proven practical technics such as mulching, intercropping, conservation agriculture, crop rotation, combined crop-livestock management, agro biodiversity, improved grazing and improved water management practices (FAO, 2016).

Suitable practices will vary according to the region, ecosystem, climate, and crop. Some common examples of climate-smart agriculture practices that can increase productivity and resilience include planting diverse crops, which spreads climate risk and diversifies income streams; composting and soil management techniques, which improve soil fertility; and water saving, harvesting, and retention systems, which improve water availability during times of drought (Mitku Haile, *et al*., 2006) .

Therefor Land degradation increases the vulnerability of people to the adverse effects of climate change, by reducing soil organic carbon concentration and water holding capacity, which in turn reduces agricultural productivity and local resource assets (S Berhane *et al*, 2013). Thus, this study tries to identify and evaluate soil and water conservation as a means towards climate-smart agriculture (CSA) is an approach for transforming and reorienting agricultural systems to support food security under the new realities of climate change.

2.1.2. The Indigenous Knowledge and Experience of SWC in Ethiopia

Indigenous soil and water conservation techniques can be divided into ethnic-engineering agroforestry and agronomic practices. People were previously conscious of the negative consequences of soil erosion on agricultural production and the environment centuries ago (Forch, 2003). As a result, soil and water conservation practices happen as indigenous knowledge in some areas of the country. For example, the Konso people in southern Ethiopia are recognized for traditionally well-developed terraces, where the terrace technologies are registered by the United Nations Educational. Scientific and Cultural O Indigenous soil conservation is more of general and relies almost exclusively on perception and experience whereas scientific once characterized by a greater ability to break data presented to the senses and reassemble it in different ways. Even though there is a clean border between scientific and indigenous knowledge and practice, efforts must be taken to balance them.

Most studies serve to illustrate and reinforce the value of indigenous soil conservation as the basis for improved conservation of soil resources (Yeshambel Mulat, 2013) . For-example the indigenous knowledge on soil conservation at 'Konso' people South West Ethiopia will deliver a more detailed account, report, and analysis of indigenous soil conservation as a model. organization as a world heritage (Yeshambel Mulat, 2013).

The Konso terraces are estimated to be older than 400years (For and Agents, 2013). Some rudimentary and poorly established terraces and lynches depicted on older aerial photographs and physical remnants can also be observed in different parts of the northern highlands.

According to (Mitku Haile, and Stillhardt, 2006). Reported old lynchets in the Tigray region, suggested that indigenous knowledge on SWC technologies and bunds are not only partial to the Konso area but are also found in other parts of the country. Though the SWC in Ethiopia enclosed very few areas and most of them, except those in Konso, have limits in layout and building quality (For and Agents, 2013).

As the government understood the problem of land degradation, it took policy actions. In this regard, a forest and wildlife conservation and development policy were declared in1988.Ec (District *et al.*, 2017). Following this policy, the government initiated various studies and capacity-building programs and massive SWC interventions (Shiene, 2012). The capacity building programs involved training of professionals at the national level and farmer on the local. In this respect, SWC was comprised of the university curriculum, and the order to train farmers was assumed to the Ministry of Agriculture. SWC interventions in the highlands observed both on mechanical and biological methods (For and Agents, 2013). The mechanical measures included the building of bunds, terraces, diversion ditches, check dams, micro-basins, and hillside terraces.

The biological measures comprise enclosure of degraded land from human and animal interference, tree seedling production, agroforestry on farmlands, afforestation, and tree planting at homesteads and in exclosures tree enrichment (Esser and Mitiku Haile, 2002). In the highlands, drought-affected areas such as Harerege, Wollo, Gonder, north Showa and Tigray were targeted (Esser and Mitiku Haile, 2002).

The basis for the implementation of the SWC interventions on a large scale was the 1975 land reform and the establishment of peasant associations. The reform gave farmland(use right) to the farmers that motivated them, and the PAs facilitated the implementation of SWC and played an instrumental role for labor mobilization (Berhanu AfroKe bede *et al.*, 2016). The SWC interventions showed an inconsistent adoption trend over time. Initially, farmers viewed the structures as showing limitations, as they were not getting immediate returns (EA, 2010). Among the limitations, farmers mentioned were that the mechanical structures on farmlands abridged the area of cultivable land, harbored rodents, and the structure was labor-intensive (Boyd *et al.*, 2000).

Despite the problems of soil erosion and poor soil fertility, this awareness of SWC is to be taken extremely because farmers have small and disjointed farmlands As (Boyd *et al.*, 2000) reported that superior farms with less livestock, on steep slopes and with poor fertility accepted the practice better than those with contrasting conditions.

The rural land administration and use policy declared in 2005 is an indication of the government's promise to follow up on the previous initiatives. The policy applies proper land use and gives clear demarcation based on the slope of the land (Lakew Desta, *et. al.,* 2005). The aim of the current interventions is not only in-situ soil conservation but also the protection of giant hydropower dams against sedimentation. The Nile tributaries originating from the Ethiopian plateau annually transmit about 180 million tons of sediments(Melesse Berhane *et al.*, 2013). The sediments threatened reservoirs downstream, where some have been annually losing nearly 1% of their capacity (Desalew Adugnaw, 2013).

The SWC interventions have positive impacts such as reducing runoff and soil erosion finished reducing the detachment and transportation of erosion procedures, improving basin hydrology, maintaining and/or improving farmland soil fertility and thereby improving/maintaining agricultural production, reducing sediment load to natural and human-made reservoirs and reducing degradation; (Berhanu AfroKe bede *et al.*, 2016).

2.1.3. Soil and water conservation in Tigray

According (Esser and Mitiku Haile, 2002), Reported that in the Aksum area, SWC measures have been practical for periods, most likely first applied during the Aksumite Kingdom (400 BC to 800 AD). Terracing was developed under traditional agriculture in the Tigray Highlands around the Churches of the highlands.

Land degradation attraction increasing awareness during the 1980s (Nyssen *et al.*, 2000). A paradigm shift took place from projects dealing mainly with physical and chemical aspects of degradation towards the integration of a broader range of disciplines. The pre-1980 period was largely dominated by a technical-fix approach, where a physical problem was recognized and a physical solution approved (Nyssen *et al.*, 2000). Since then, research has tried to integrate different aspects of land degradation and rehabilitation.

The terms used to identify problems and solutions have varied through conservation, desertification, drought control, agroforestry, sustainable agriculture, on-farm adaptive research and so forth (Binyam A. and Desale, 2014). Emphasis is now on production possibilities, on social, legal, and institutional constraints, and specific technical issues. An important development in research is the improved teamwork between scientists, administrators, and farmers knowing the need for a joint effort to solve the several problems of soil erosion (Esser and Mitiku Haile, 2002).

The harshness of soil erosion in the Tigray region is the result of the mountainous and hilly topography, torrential rainfall, and low degree of vegetation cover (Nyssen *et al.*, 2000). Deforestation started previously 2000 years ago in many parts of Tigray; soil erosion has made cultivation of old farmland impossible. Farmers have been involuntary to constantly cultivate new and more marginal areas (Esser and Mitiku Haile, 2002).

Soil conservation aims to facilitate an optimum level of production from a given area of land while keeping soil loss under a critical value. The result of a conservation measure in reducing soil loss generally varies with soil type, topography, climate and intensity of the measure, e.g. the distance between terraces or density of vegetation cover (Binyam A. and Desale, 2014) . Gives equations that can be used to calculate the required terrace spacing when the natural conditions and the required protection actor are known .The term cross-slope barriers embrace the whole range of terraces, ditches, drains, and banks used to manage run-off or soil loss on sloping lands (Binyam A. and Desale, 2014).

In cases where cultivation is done by hand, the width of the terrace is of less importance. Construction of terraces requires a great deal of labor input, which is a major constraint to their application. In some areas, terraces with outward slopes are built, or the labor input is spread over time by progressively moving towards level terraces over several years.

According to (Binyam *et al.,* 2014), the grass strip should be vigorous, easily propagated, provide a good quantity of palatable fodder and not invasive into the crop area to be effective. In some cases, however, livestock must be kept away from the grass strips for the grass to grow to the proper height. Grass which is unsuitable for fodder can be used, such as vetiver grass Vetiver is quite commonly used for this purpose since it can be grown almost universally (Nyssen, *et.al,* 2015). Several other species can be used for vegetation strips depending on the preferences of farmers(Nyssen *et al.*, 2000).

These technologies included: physical measures such as the use of stone bunds, contour farming and drainage, biological measures such as planting trees; and agronomic measures such as spreading manure, leaving crop residues in the field and allowing land to remain fallow (Esser and Mitku Haile 2002). Water conservation by farmers of the Tigray region consisted of physical measures such as earthen bunds, contour bunds and agronomic measures such as dibbling for transplanting rice seedlings (Amsalu A. and deGraaff J, 2007). The soil conservation practices adopted were developed to minimize soil erosion, to conserve soil and water and to protect the soil long-term productivity. These include agronomic measures such as fallow pastures, cover crops, crop rotation, ridge planting, and stubble retention on the soil (Amsalu A. and deGraaff J, 2007) .

Distinguishing the threat of land degradation and benefits of SWC practices, the government of Ethiopia is promoting SWC technologies for improving agricultural productivity, household food security and rural livelihoods , (Berhanu Afro Ke bede *et al.*, 2016). The continued use of SWC seemed mainly determined by the actual economic profitability and environmental benefits, and determinant factors for effectiveness.

Benefits of the various SWC practices implemented. The evaluation of the effectiveness of these SWC practices that are alleged to enhance productivity is very important to evaluate their performance in reducing land degradation and rehabilitating the land (Berhanu AfroKe bede *et al.*, 2016). Assessing the impact of past efforts and proper understanding of the improvement in the livelihood of smallholder farmers is essential to draw lessons and improve the efficiency of the SWC practices.

2.1.5. Biological Conservation Practice in Tigray

2.1.5.1. Agronomic Conservation Practices

According to the study of Esser and Mitku Haile,(2002). Among 52 farmers in the Hager Salam Woreda uplands of Tigray, 48 of them were practicing crop rotation. Many of the farmers applied crop rotation as a means to conserve soil fertility by planting legumes one year and non-legumes the following cropping season, like bean or lentil, then barley or wheat. Farmers also integrate legumes into their crop rotations every four years. Other old-style soil conservation measures are contour plowing, grass strips, and tree planting.

The old-style way of tilling graded contours is used by nearly all farmers. Due to the population increase, traditional fallow periods have become very short and rare, if existent at all. Manure is used by some farmers, but due to the lack of fuel wood, it is most commonly dried and used for cooking and heating purposes (Nyssen *et al.*, 2015).

Wheat and barley are the major crops grown in the highland areas of Tigray whereas, in the lowlands, sorghum, sesame, and maize are most usually grown (W.Simeneh, 2015). Due to the erratic rainfalls and frequent droughts, maize is grown to a lesser degree than before. The production of sorghum has been also reduced due to the late begin of the rains and the influence of parasitic weed Striga.

Teff is full-grown in all of the altitudinal zones but is most common in the lowlands. And minor crops grown in the area are millet, chickpea, sesame, Niger seed, lentil, and flax Lathyrus. The relative importance of these crops varies in different areas. Mixed cropping is regularly practiced to minimize risk Currently, most farmers do the effective operation of resources and cropping season since their primary aim is to minimalize risk (Berhanu AfroKe bede *et al.*, 2016).

2.1.5.2. Intercropping practice in Tigray

Intercropping is another practice of cultivation used by farmers to improve soil quality and productivity. The aim of intercropping is to enhance the yield of farmland by using resources that cannot be used by a single crop (Kamruzzaman, & Takeya, 2008). Intercropping is practiced by a large proportion of farmers in developing countries (Kamruzzaman & Takeya, 2008)

While Intercropping has been widely practiced in Tigray It involves two or more crop species or genotypes like maize with beans Teff with lentil growing together and coexisting for a time. This latter criterion distinguishes intercropping from mixed mono-cropping and rotation cropping. Intercropping is common, particularly in the whole region and woreda with high amounts of subsistence agriculture and low amounts of agricultural mechanization (Brooker *et al.* 2005).

2.1.5.3. Agroforestry *Practice in Tigray*

Agroforestry is practiced to some degree, although relatively rarely. In keyihtekli a type of irrigated home gardening including citrus trees and banana is practiced. It is not a multi-layer scheme; however, it sets as home gardens normally. In the same area, scattered trees on cropland are also found, but the trees are widely spaced and probably have little consequence in maintaining soil fertility (Nyssen *et al.*, 2015).

Agroforestry is widely researched in Tigray, and possible agroforestry trees are listed in detail in Bekele-Tesemma et al.(1993) or Orwa et al.(2009). Several studies have addressed benefits of agroforestry systems in relation to coffee production in Southern Ethiopia. Other research has been directed towards systems with more scattered trees: Furthermore, their study highlighted that farmers perceive the E. camaldulensis as a species that is harmful to soil. Along the same line Hadgu et al . (2009) have shown that Faidherbia Albida improves barley productivity in Tigray unless it is planted in a system together with E.camaldulensis.

Traditional agroforestry species in some agricultural systems in Tigray (Noulekoun et al, 2016) and that it improves soil quality in the sites (Gelawet al., 2015).

When trees are incorporated extensively scattered in agricultural plots common names are evergreen agriculture (Hadguet al., 2011; Garrityet al., 2010), or parkland agroforestry (Mokgolodi et al., 2011; Sanchez, 1995).

2.1.5.4. Area closure practices

Ethiopia, and particularly the Tigray region, has been facing continuous deforestation and consequent land degradation due to mainly agricultural expansion, overgrazing and unsustainable extraction of wood products (Bishaw 2001).

In an attempt to reverse this trend, many efforts have been made in the region since the 1970s (Pohjonen and Pukkala 1990, Tekle 2001). The rehabilitation of degraded lands through establishing exclosures was among such efforts (Birhane 2002, Mekuria *et al*. 2011, and Mengistu *et al*. 2005). Exclosures are areas protected from human and animal interference by a physical boundary or a social fence (meaning communal restriction to access) to promote natural regeneration of plants and thus reduce further degradation of formerly degraded lands.

The practice of area closure (hereafter referred to as "enclosure) was tried and found successful, with results that became apparent in a relatively short period.

The objective of the practice is to maintain economically productive and biologically diverse vegetation (Zoebisch M, 2002). Rather than less valuable open degraded land, The practice has helped to change marginal lands to potentially productive areas, that can providing important vegetation assets for energy sources based on biomass, of which 78–80% of the total household energy supply of the country (Kitalyi, *et .al.,* 2002).

Enclosures are sources of wood for construction, farm implements, and non-timber forest products. They also play an important role in conserving remaining soil resources and improving soil fertility. Enclosures improve soil fertility by augmenting soil nutrients from decomposed plant remains. Enclosures also limit nutrient loss from a site by controlling runoff (vegetation acting as a physical barrier to soil erosion (Kitalyi *et al.,* 2002).

2.2. Physical Conservation Practices

The majority of the physical SWC practices constructed were soil bunds, stone bund, deep trenches and, bench terrace in area closures, grazing, and fallow land. Likewise, the commonly skillful biological SWC includes maintaining natural vegetation and tree plantation, plantation of valley bottoms, and stabilization of physical structures using natural vegetation, vetiver grass and elephant grass (Berhanu AfroKe bede *et al.,* 2016).

Bench terraces are extensively functional in the tropics in indigenous conservation systems. Terracing might have developed in western Asia and then spread southwards to Africa, westward to the Americas, and eastward to Southeast Asia, mainly by recognized sea routes (Esser and Mitiku Haile, 2002). More probable, it may have changed independently in several areas as farmers were forced to cultivate steep lands. The building of terraces is not new to Ethiopia (Berhanu AfroKe bede *et al.*, 2016). The Konso of southern Ethiopia are well known for their traditional soil and water conservation practices. Their farming is based on an elaborate system of terraces, a variety of other soil and water conservation practices and the integration of livestock and forestry with the rest of their agriculture.

Stone bunds are usually quite shared in the dry zones of the tropics since they are relatively easy to construct during the dry season. Sloping bunds are present in many parts of Ethiopia (Shiene, 2012). That greatest of the terraces seen in Tigray are only half-formed so that the ramparts only rise about one-third of the perpendicular intermission among benches, and thus are mainly ineffective in controlling soil erosion. Other physical conservation measures traditionally constructed by farmers in Tigray include check dams and cut-off drains (Nyssen *et al.*, 2000).

2.3. Carbon Sequestration in Soils

Soil carbon sequestration is the process of transferring carbon dioxide from the atmosphere into the soil through crop residues and other organic solids, and in a form that is not immediately reemitted. This transfer or sequestering of carbon helps off-set emissions from fossil fuel combustion and other carbon-emitting activities while enhancing soil quality and long-term agronomic productivity. Soil carbon sequestration can be accomplished by management systems that add high amounts of biomass to the soil, cause minimal soil disturbance, conserve soil and water, improve soil structure, and enhance soil fauna activity. Continuous no-till crop production is a prime example (Sundermeier *et al.,* 2004).

3. MATERIALS AND METHODS

3.1.Description of the Study Area

3.1.1. Geographic Location

Kilte-awlaelo Woreda is situated in an Eastern administrative zone of Tigray and one of the seventh rural Woreda of the eastern zone found in the south of the eastern administrative zone. It is located at 45 km to the north of Mekelle, which is the capital city of the region and bordered by Enderta district to the South, with Saesie-tsaedaenba district to the North, with Hawzien district to the Northwest and Atsbi-wenberta kebele to the East. It encompasses eighteen rural kebeles with 64 sub kebeles (kushets), according to Woreda office of finance and economic development (WoFED, 2012).

The study area is geographical, located between $13^{0}46'$ - $13^{0}59'$ N latitude and 39^{0} $36'$-39^{0} $42'$ E longitude. According to the Kilte-awlaelo Woreda office of Agriculture and Rural Development, the Woreda has a total area of 101,758 hectares and the arable land accounts for 19,809.5 hectares. The altitude ranges from 1900 – 2460 meters above sea level.

Study Area Location.

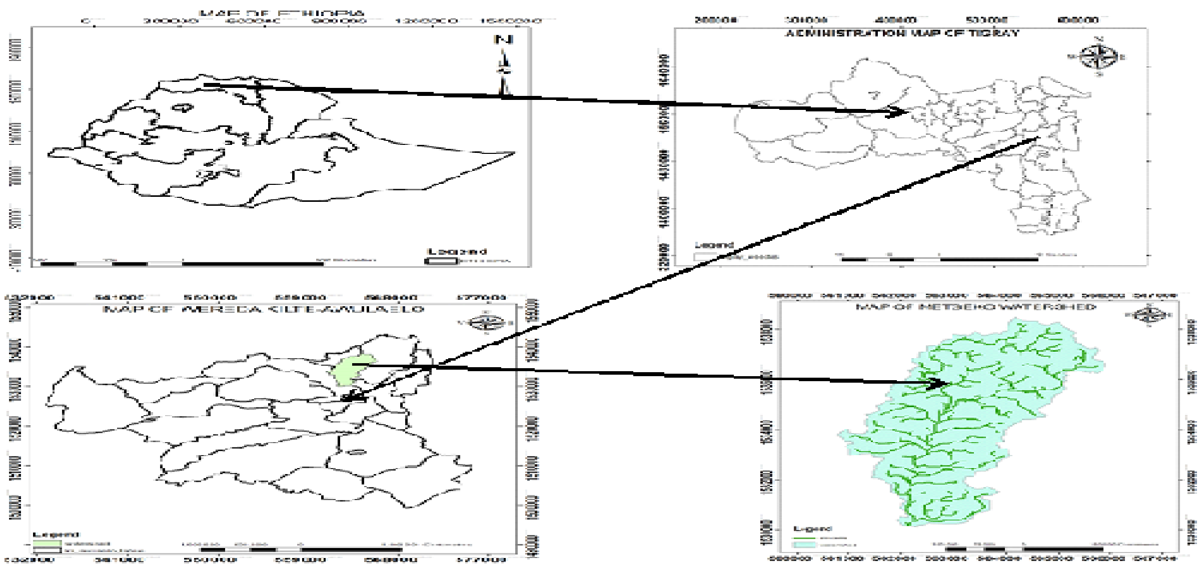

Figure. 1. map of the study area of Metseko water shade

3.1.2. Climate

The Annual average temperature range is from 17^0c - the 23^0c the maximum monthly average temperature is in May/June, while the minimum temperature is in October and December (WoFED, 2012). The study area is characterized by Woina-Dega agro-climatic zone. Drought is common so, that moisture stress is the main problem for agricultural production. The area exhibits a uni-modal type of erratic and unreliability rainfall which occurs between June–August ranges from 350-450mm. (WoFED, 2012).

3.1.3. Population and Demographic Characteristics

According to the Central Statistics Agency (2007) Woreda based census result; the total population of the district is estimated to be 119,772 of which 48.8% (58438) are male while the remaining 51.2% (61334) is female population. The total numbers of household heads are 27049, of which 69.1 % (18692) are male-headed households, while the remaining 30.9 % (8357) are female household heads. The majority of the population in the study area belongs to the Tigrian ethnic group engage in agricultural activities (WoFED, 2012).

3.1.4. Resource endowment and farming systems

Agriculture is the main means of living for all inhabitants of the Woreda. The dominantly practice Mixed crop-livestock farming system which depends on rainfall. However recently farmers adopted irrigation-based crop cultivation in some area of the Woreda the introduction of water harvesting .The major crops grown in the area is Hanfets, Wheat, Teff, and Barley according to the data of the (WoARD) the average size of landholding of farm households in the Woreda is 0.5 hectares.

3.1.5.. Existing Land Use

The land-use profile study of Woreda indicates that Kilte-Awlaelo Woreda has total land coverage of 101,758 hectares. Of this total area; the dominant portion is covered by forest (including area enclosure, individually managed hillsides, and community enclosed) area estimated 45.89%, rugged mountains and gorges (miscellaneous land) which constitute 20.14 %, and arable land, grazing land and settlement area accounts for 19.47 %, 7.79 %, and 6.71 % respectively.

3.1.6 Vegetation Covers

An area closure and privately managed hillsides contributed to the regeneration of vegetation cover of the area. Trees like acacia species and shrubs of Dodonaea Angustifolia and eucalyptus are found in the protected area. The eucalyptus tree is the dominant species found around the homesteads and privately manage hillsides in the Woreda in general and in the study area Metseko water shade in particular.

Community members were more motivated to plant Eucalyptus trees than others due to the characteristics of the plant (fast-growing nature, tall and straight poles, ease of establishment and market demand for construction in the Woreda and all over the region). At the national level, 89% of the energy consumption goes to household energy demand. Within households, traditional fuels such as (fuel wood, dung, and residues) have a share of 99.6% of the total household energy consumption (WBISPP, 2004). This energy behavior is the main threat to enclosed areas of the Woreda.

3.2. Site Selection and Sampling Design

To select the study area first the woreda in the eastern zone has been stratified in to these which are owned developed and not well developed water shade. Based on this procedure the Kilte-Awlaelo Woreda was purposively selected. The Woreda involves six well developed watersheds. Then, out of the six watersheds “Metseko” watershed was selected randomly.

Again to determine a representative sample of household, sample farmers were stratified into adopters and non-adopters from the sampling frame that obtained from the extension office of the kebele who lived with in the watershed. Then, the individual respondents were selected systematically based on the formula of Yamane (1967) with the confidence level of 95% and P= 0.06 *(*Khamung, 2015). Thus, the sample size was obtained from the strata.

$$\mathbf{n} = \frac{\boldsymbol{N}}{\mathbf{1}+\boldsymbol{N}(\boldsymbol{e})^{\mathbf{2}}}$$

Where:

n = the sample size,

N= is the population size, and

e =is the level of precision

By using the above formula with a precision level of (e) 6% the sample size in the watershed was determined using their proportion of the total households.

Table1 Household sample size of the study area

Household Charactertics	adaptors (N=45) (=162)	Non adaptor (N=162)	Total (N=207)
Sex			
Male	86.7 (39)	88.9 (144)	88.4 (183)
Female	13.3 (6)	11.1 (18)	11.6 (24)
Total	100.0 (45)	100.0 (162)	100.0 (207)

Sources: field survey, 2019

3.3. Data Collection

The data used in this study were obtained from both primary and secondary sources. All the necessary quantitative data required for the study were gathered through a farm household survey conducted from January to February 2019. At the beginning stage of the survey, informal meetings were undertaken with a group of farmers to understand the general agricultural and socioeconomic situation of the population of the study area. Also, informal meetings with key informants (farmers, elder people, researchers, women, experts, and development agents) were held to gain in-depth knowledge about the area and to pre-test the farm survey questionnaire.

To collects the primary data structured and semi-structured questionnaire, focused group discussion, key informant interview, and direct observation were employed. Secondary data were also collected from different published sources such as books, journal articles, and official reports and websites mostly related to this research topic. Before the commencement of the household survey, the questionnaire was tested with few households to adjust the questionnaire and avoid any ambiguities.

3.3.1. Household survey

A Household survey was conducted at each respondent's house. For the survey head of households were considered. Respondents were asked about household characteristics (family size, age of households, educational status, etc.).Types of climate-smart agriculture adopted its benefits and their perceptions on the role of climate-smart agriculture for sustainable crop production and food security. Furthermore, the advantage of practicing climate-smart agriculture for soil fertility maintenance and its role of sustainable crop and livestock production were asked.

3.3.2. Key Informant Interviews

For key informant interview farmers who lived for a long period in the area and have deep knowledge were considered. Accordingly community and religious leaders, as well as women, were included. In a key informant interview, a total of 12 people were open-ended questionnaire was used.

3.3.3. Focus Group Discussions

One focus group discussions were conducted in each study kebele. In a focus group, a discussion group of 36 people has participated. The major points discussed were the time of climate-smart technology adoption, its acceptance, and the perception of the technologies.

3.3.4. Secondary Data

Secondary data were collected from different journals, articles, books, and government documents. Higher experts of the Woreda were used to supplement additional information necessary to substantiate the study

3.4. Soil sample collection and sample size

Soil sample was collected from fields of farm households who participated in climate-smart agriculture implemented and those who do not engage in adopting climate-smart agriculture .The soil samples were, taken from 0-15 cm and 15-30 cm depth from both farm household fields within the open space above the bund (soil accumulation area) and below the bund (soil loss area) and the middle of the terrace. Soil samples were taken from four corners of the field and one in the middle from 0-15 cm and 15-30 cm depth (Fig 2).

Two sets of soil samples were taken, one set for the determination of physicochemical properties (carbon content, soil texture, nitrogen, and phosphorus) and the second set for the determination of soil bulk density. Accordingly, a total of 40 soil samples 20 from the area where climate-smart agriculture implemented while the rest 20 from farm fields where no climate-smart agriculture was implemented were taken.

Furthermore, soil samples were taken using core sampler for bulk density determination while the composite sub-samples were taken for physiochemical analysis. The soil samples for physicochemical analysis were air-dried and passed through 2mm sieve.

SOC was analyzed using a titrimetric method (Walkley, and Black, 1934). Then the soil texture classification (USDA) was used to determine soil texture class. The following formula was used to calculate the bulk density using coarser fragments correction (Pearson *et al.*, 2005). Bulk density (g cm^{-3}) = mass of oven-dried weight (gram) /volume of the core (cm^3).

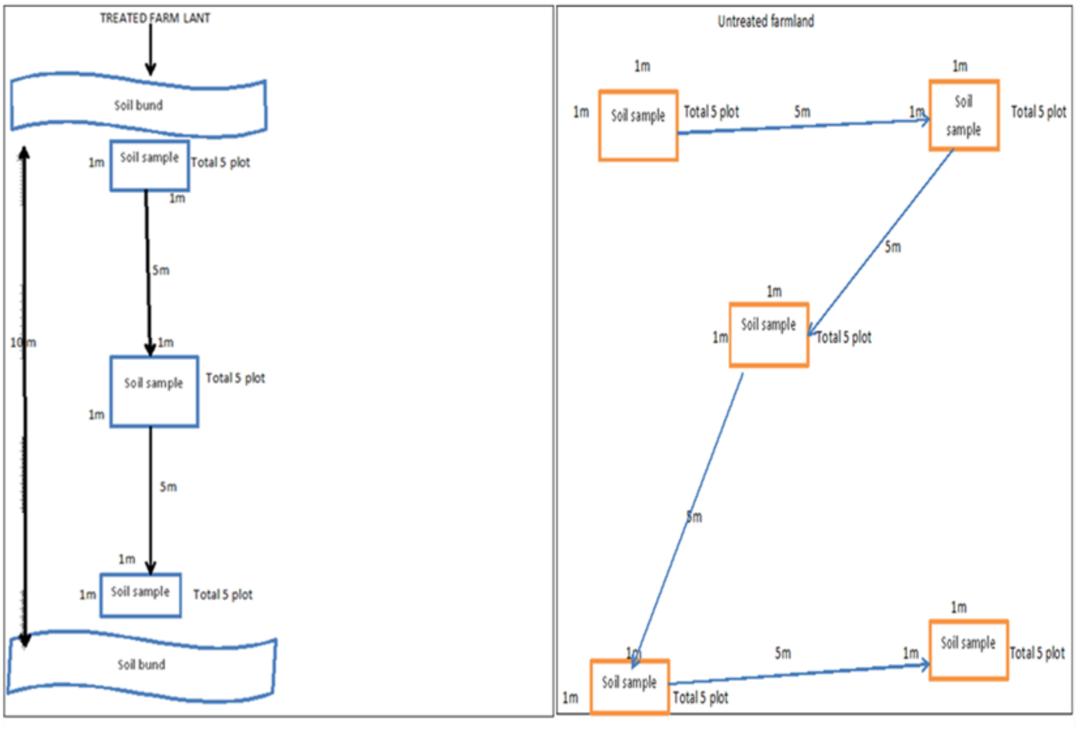

Figure 2 Sample plot design

3.3.4. Data Analysis Method

The data were summarized using Microsoft Office Excel, and Analysis of data was performed using the Statistical Package for Social Science (SPSS) of version 20software. Descriptive statistics were used to compute mean values, percentages, Frequencies, and other important Analysis of variables of concern. The mean value was used for comparison or to test whether there is a significant difference in crop yield and soil properties between treated and untreated agricultural farmlands.

4. RESULTS AND DISCUSSION

4.1. Household Characteristics

Out of the sampled households, 86% of the respondents were males and the remaining 14% were female (Table 2). The majority of respondents were at active age group and this is constant with the study of Bekele and Drake, (2003) .who reported the role of the active age group in adopting new technology. The result indicated that almost all respondents did not attend school.

Table 2 Household characteristics of the respondents

Household characteristics		№ respondents	Percent (%)
Sex	Male	183	86.3
	Female	24	13.7
	Total	207	100.0
Age group	18-30	21	8.0
	31-60	157	73.0
	>60 years	29	19.0
	Total	207	100.0
Educational status	illiterate	165	84
	1-4	28	10.6
	5-8	14	10.6
	Total	207	100.0

Source: survey result, 2019

Similarly, the importance of active age groups in soil and water conservation practices was reported by Daniel and Mulugeta (2017). This is explained as an educated society can easily understand and accomplish the desired task such as new technologies (Aberha, 2008).

4.2.Types of soil and water conservation in the study area

The dominant climate-smart technologies implemented in the study area are indigenous terracing, stone and soil bund and deep trench (Table.3). The physical structure was covered with plants that are used for feed and fuel wood besides its role as soil erosion control. In the study area, indigenous terracing is widely adopted (39.8%) followed by soil bund (31.2%) (Table3). The stone bund is commonly implemented in sloppy areas .which is partly organized through safety net programs. The reason for building a stone bund in sloppy areas was to reduce erosion. Both stone and soil bund are acknowledged for their efficiency in protecting soil from erosion.

Although Mitiku *et al*. (2006) reported the low adoption of these technologies elsewhere it is not true for the study area. The wide adoption of stone and soil bund is to maintain more rainfall given its impermeable nature.

Table 3 the main SWC practices and Technologies practiced in the area

Types of SWC structures	№ of respondents	Percent (%)
Indigenous terracing	106	39.8
soil bund	83	31.2
stone bund	42	15.8
Deep trench	34	13.1
Total	263	100

Source: Survey result, 2019

This implies that these soil and water conservation structures are best suited for sloppy areas of semi-arid and semi-arid areas agro-ecological zones.

Figure 3 physical and biological conservation practices in the study area

4.2.1. Effectiveness of SWC structures in reducing soil erosion

Respondents ranked the effectiveness of physical structure built as a means of climate-smart agriculture (Table .4.). About 40% of the respondents gave the highest rank for deep trench followed by soil bund while very few (<12 %) did not understand the role of both structures as a means of soil erosion.

An earlier study conducted in the Tigray region reported a similar result (Kirubel *et al.* 2011). The wide adoption of the stone bund also related to the easily availability of raw materials in the area (Alemtsehay *et al*. 2017). Indeed about 42% of respondents gave high rank for stone bund (Table 4). This is consistent with the previous study conducted by Nyssen *et al.* (2008) .who were reported that stone bunds are important in sediment deposition.

Table 4 Soil erosion protection effectiveness ranking of different conservation structures in the study area

Conservation structure	Rankings			
	None	Less	High	Very high
Soil bund	55 (20.9%)	38 (14.4%)	88 (33.5%)	82 (31.2%)
Stone bund	31(11.8%)	42(16%)	109(41.4%)	81(30.8%)
Deep trench	29(11%)	40(15.3%)	92(34.9)	102(38.8%)

Source: survey result, 2019

Deep trench structure is another SWC practice in the study area that contributes a significant role in reducing soil erosion and also enhances water infiltration. In contrast, about 15.3% gave less rank for the effectiveness of deep trench as a means of reducing soil erosion. The reason may be due to inappropriate construction and management of the structure.

4.3. Role of climate-smart technologies for water availability and access to irrigation

The implemented soil and water conservation technologies resulted in a dramatic increase in access to spring water development and hand-dug wells (Table.3.).This implies the multiple roles of SWC activities in enhancing water availability besides its role in reducing erosion. According to group discussion, before the implementation of climate-smart technologies .the water sources were for the major issue in the area.

This is similar to the study reported by Berhane *et al*. (2013). *That,* soil and water conservation practices have a big role in improvements of infiltration, decreases in the surface runoff to improve the groundwater flow by shallow aquifer recharge that increases the surface water increment, other studies by Haileslassie *et al*. (2005). It also reported the positive role of soil and water conservation activities for groundwater recharging and increased the rate of infiltration. The better availability of water triggers irrigation use for crop cultivation. According to the woreda office of agriculture and rural development office report, the implementation of SWCactivities increased area under irrigation from 5.25 hectares to (37.75) hectares, which is an 86% increase in irrigated areas.

Table 5 Major sources of water before and after implementation of SWC practices in the study area

Sources of water	Response (%)	
	Before	After
Spring development	24 (9.1%)	95 (40.3%)
Hand-dug well	57 (21.7%)	80 (30.4%)
River diversion	42 (16%)	20 (20.0%)
Borehole	0 (0%)	6 (2.2%)
None	140 (53.2%)	51 (19.3%)
Total	263	99.6%

Table 6 A**ccess to irrigation in the study watershed**

Irrigation status in the watershed	Number of respondents	Percent (%)
Farmers having irrigation accesses	109	41.4
Farmers not having irrigation access	154	58.5
Total	263	100

Source: field survey, 2019

According to focus group discussants, the problem of water scarcity was worse before the implementation of the physical infrastructure which significantly impairs crop production and causes food insecurity. During that time almost none of the farmers had irrigation access which currently increased to 86 % (Table.5). Besides irrigation, the water is also used for drinking purposes and the increased access to water reduces the distance women travel to fetch water.

Figure 4 water sources after implementation of SWC

4.4. The role of adopting climate-smart adoption on socio economic study

Socioeconomic sustainability is commonly explained by the amount of income made sufficient to food security and other expenses. For smallholders of tropical countries being self-sufficient in food reduce uncertainty related to price fluctuation and market dependency for food.

In this regard implementation of climate-smart technologies reduce the market dependency of smallholder farmers in the study area (Table.6.). As a result of the implemented (SWC) activities, the majority of the respondents (82.2%) can cover their expenses for agricultural input which is vital for enhancing crop productivity and food security. Therefore SWC practices have a role in enhancing the income of smallholder farmers as the number of respondents who have saving increased by 14% after the implementation (Table.6.)

Table 7 Household covers their expenditure an annual income before and after SWC

	Expenditure item	Before SWC Intervention		After SWC Intervention % improvement		Improvement in percent (%)
		Yes	No	Yes	No	
1	Purchase of Agricultural inputs & Equipment	90	173	243	20	58.2%
2	Improvement of the House	81	182	183	80	38.7%
3	Purchase of medicine or/drugs	174	89	220	43	17.4%
4	Purchase of household equipment's	221	42	215	48	-2.2%
5	Purchase of Cloth	121	142	229	34	41.%
6	Purchase of crops for consumption	212	51	225	38	4.9%
7	School expense	98	165	189	74	34.6%
8	Saving in banks	0	263	226	37	14.%

Source: Survey result, 2019

4.5.The potential of SWC technologies for SOC sequestration in agro ecosystems

Soil degradation associated with rapid depletion of soil chemical, biological and physical composition is severely affecting agricultural production and productivity (Fleskens and Stringer, 2014; Jasmien *et al*. 2015). The losses of the essential nutrients are a common problem in a semi-arid area of northern highlands of Ethiopia (Hishe *et al*., 2017). This study shows that practicing SWC activities as climate-smart agricultural technology had statistically significant ($p<0.05$), effects on soil physicochemical properties of the soil (Table.8.) Application of SWC activities increased soil organic carbon which is a proxy for soil bulk density. Furthermore practicing SWC activities significantly increased soil total nitrogen (TN %) and water holding capacity of the soil (SMC). This is in line with Selassie *et al* (2015) , who stated that SWC supplemented with rehabilitated vegetation cover had a positive impact on improving the total nitrogen in the soil. The lower concentration of nitrogen in the treated land may be caused by leaching; the downward movements of nitrogen below the root zone (MAFRI, 2011).

Table 8 Effects of SWC practices on soil physic-chemical properties

SWC	Soil Properties						
	Bd(g/cm^3)	SMC (%)	PH.	TN (%)	AP (%)	SOC%	CEC (meq/100g)
Practiced (n=22)	1.31±0.11	10.57±0.6	7.45±0.6	0.21±0.0	23.09±4.6	0.74±0.2	24.58±2.57
Unpracticed (n=16)	1.41±.048	6.86±0.75	7.00±0.0	0.11±0.0	23.41±3.0	0.65±0.1	21.68± 2.7
P-value	0.001	0.02	0.00	0.04	0.813	0.02	0.00

Source: experimental result data, 2019.

Statistically, no significant difference between fields practicing SWC and fields within the available phosphorus   a similar study has been conducted by (Osman, 2013) .who reported that available phosphorus is higher in lands treated with soil and water conservation.

The higher soil organic carbon in fields treated with SWC activates has increased the water holding capacity of the soil. A Similar study was conducted by Taye *et al*. (2013) in the northern Ethiopian highlands.

4.5.1. SWC for crop yield improvement

As indicated in Table 8 in areas where SWC practices are implemented, soil organic carbon and soil moisture contents were improved. The improvement in soil fertility has a direct positive effect on crop productivity. The result in Table 9 indicated a significant higher cereal crop yield harvested from fields treated with SWC than untreated fields, which is related to the higher soil fertility to the previous than the latter. The positive advantage of SWC on crop yield also reported ease where (Hishe *et al*., 2017). Other studies also confirmed the maize yield advantage of SWC activities (Abdul-Hanan *et al*, (2014).

Table 9 Mean ±SD of crops yields harvested from fields treated and untreated with SWC structures (n=15)

SWC	Crop type			
	Wheat Q^{-ha}	Barley Q^{-ha}	Hanfets Q^{-ha}	Teff Q^{-ha}
Practiced	31.4±5.15[a]	31.73±3.4 [a]	33.8±4.4 [a]	16.73±3.9 [a]
Unpracticed	25.6±5.21[b]	20.13±3.6 [b]	25.1±4.15 [b]	11.33±3.5 [b]
P-value	0.02	0.00	0.01	0.03

Source: Survey data, 2019

Values with a different letter within the column are significantly different

5. CONCLUSIONS AND RECOMMENDATION

5.1.Conclusion

The adoption and participation of farmers in soil and water conservation structures age, sex, and educational status were important in adoption new technologies such as, Soil and water conservation, and shows a positive effect on the implementing of SWC and, soil erosion reduction and crop production improvement of the area.

The study considered treated and untreated land areas with soil and water conservation structures for comparison using descriptive statistics. There is a variation of soil properties between treated and untreated land areas with soil and water conservation practices. Except for available phosphorus, there is a significant positive effect of soil and water conservation structures on soil chemical properties.

Crop yields also vary between treated and untreated lands and soil and water conservation shows a positive significant effect on land productivity by increasing moisture availability and nutrients due to its importance in erosion reduction.

5.2.Recommendation

Based on the result, the following recommendations are forwarded by the researcher.

- Government should be participated together with local peoples in SWC implementation.
- Introducing Land leveling technologies to decrease slope percent and Increase the infiltration rate of the soil (reduce erosion) is suggested.
- The area is degraded and moisture stress, so CSA Technologies should be implemented regularly
- All local communities should have to participate in SWC works to increase the productivity and improvement of soil fertility and crop production.
- Such CSA Technologies practices in the study area are not practiced based on standard techniques so they need to follow the standard techniques. For that providing training to Das on CSA technologies is necessary.

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APENDEX -1

Household Survey Questionnaires

I .GENERAL INFORMATION OF THE RESPONDENT

Part1. Household Survey Questionnaire

1.1. Back ground Information

Woreda/District name ----------------------------

Agro ecology zone---------------------------------

PA/Kebele name-----------------------------------

Community water shed name--------------------

Respondent number -------------------------------

Date of interview -------Starting time -----------

Enumerator’s name---------------------------------.

PART-2 - HOUSEHOLD DEMOGRAPHIC CHARACTERISTICS

2.1...Please indicate your sex by **circle**

2.2. Sex: 1. Male, 2...Female

2.3. Please indicate Age by circle:

1. 18-30 years

2.31-60 years

3. > 60 years

2.4. Family Size

Sex	Age in years						Total
	.< 7	8-18	19- 30	31- 45	46- 60	>60	
Male							
Female							
Total							

2.5. Education Status: (√)

Illiterate	1-4	5-8	9-12	Above certificate

3: HOUSEHOLD SOCIO-ECONOMIC CHARACTERISTICS.

3.1. Occupation?

Farmer	Trader	Teacher	DA	Health officer	Others

3.2. What about the area of farm is soil and water conservation practices are implemented?

Hectares	< 0.25 ha	0.25-0.75ha	0.75-1ha	1-2ha	>2ha
Farm size					
Treated farm land by SWC					

3.3. Soil and water conservation practices and interventions

3.3.1. What are the main Soil and water conservation practices and Technologies intervened in the watershed to control soil erosion, moisture harvesting and controlling of land degradations before and after soil and water conservation interventions?

S. N	Types of techniques	Practices in soil and water conservation interventions? 1. Yes 2. No	If yes when		How effective to reduce erosion? 1. None 2. less 3. high 4.very high	
			Before SWC intervention	After SWC intervention		
1	Indigenous Terracing					
2	soil bunds					
3	stone					

	bunds					
4	Deep trench					
	Others					

3.3.1.1. What is the **main** cause of soil erosion in your farm land? Please indicates by circle

1. Improper tillage, 2. Sloppiness 3.Deforestation 4.High rainfall 5. Absence of protection measures 6. Overgrazing 7.Others

3.3.1.2. Have you ever participated in any soil conservation work initiated by Government or NGOs? 1. Yes 2. No

3.3.1.3. Do you have soil and water conservation measures on your farm land, grazing land? 1. Yes 2. No

3.3.1.4. Who did the soil and water conservation practices in your land? 1. Myself and my family 2. Community 3. Others (specify, if any)

3.3.1.5. Do you think that there is an improvement of soil fertility and productivity due to the soil and water conservation practices /interventions on your farm? 1. Yes 2. No

3.3.1.6..If you do not have information about soil and water conservation what are the reasons do you think?

a. Lack of awareness about climate change

B. Lack of institutional supporting about such information

c. Lower educational status

d. Disclosure to mass media

3.3.1.7. Do you see any impact from the soil and water conservation on your agricultural production? Yes/ No

If your answer is yes for question No.3, what kind of impact do you observed?

Failing of crops sometimes	
Failing of crops totally	
Production per ha is decreasing	
Production per ha is increasing	
Crop disease and weeds are increasing	
Increased problem of livestock disease	
Increased problem of seasonal flooding	

4. Water technology sources and practices introduced in the watershed?

4.1. Major Sources of water technologies introduced in the watershed

S.N	Major Source	Number of water sources Before soil and water conservation intervention	Number of water sources After soil and water conservation intervention.
1	Spring development		
2	Hand Dug well		
3	River diversion		
4	Pond		
5	Borehole		
	Others		

5. Depending on the study watersheds,

5.1. Income at House Hold level

5.2. What are your main sources of income before and after soil and water conservation (watershed intervention?

5.3. Do you feel that your household income has improved after Soil and water conservation interventions? 1. Yes 2. No

5.4 If "yes" what factors contributed for enhancing the house hold income?

5.5. How your total annual incomes cover for your household expenditure after soil and water conservation intervention? 1. Decreasing 2. Increasing 3 No change 4. Difficult to tell the change

5.6. In your opinion, how has your living standard changed after the soil and water conservation interventions? 1. Improved a lot 2. Improved a little 3. No change 4. Difficult to tell the change

6. Crop yield stability of the (2014, 2015, 2016, 2017, 2018) years

S.N	Type of major Crops	Do you grow crops Before and After soil and water conservation intervention .1.Yes 2.No		Productivity Qt/ha		Total Production (Qt)	
		Before SWC	After SWC	Before SWC	After SWC	Before SWC	After SWC
1	**Grain Crops**						
1.1	Hanfets						
1.2	Wheat						
1.3	Teff						
	Others						

6. 1. What kind of farming do you practice?

Farming type	in %	
	Before SWC interventions	After SWC interventions
Rain fed		

Question 6.2: measure the role of soil and water conservation practices on household food security and climate smart agriculture.

Line	Product Type	Units Type	No units produced per year	Value per unit (Birr)
1	Cut poles from the tree			
2	Cut branches			
3	Fodder (leaves)			

4	Fuel wood			
5	Charcoal			
6	Grass (cut and carry)			
7	Honey production			
8	Fruit production			

6.3. What type of problems did you observe in the soil and water conservation practices?

Code	Possible Problems for Discussion	✓ Tick on confirmed points
1	Lack of awareness	
2	Technical problem	
3	Free grazing	
4	Lack of maintenance	
5	Lack of technical leaders	
6	Lack of integration with biological conservation	
7	Specify others	

6.4 Household covers their expenditure, annual income before and after swc

s/N	expenditure item	before swc tervention		After swc Intervention % improvement		Improvement in percent (%)
		YES	NO	YES	NO	
1	Purchase of Agricultural inputs &Equipment					

2	Improvement of the House					
3	Purchase medicine Or drugs					
4	Purchase of household equipment’s					
5	Purchase of Cloth					
6	Purchase of crops for consumption					
7	School expense					
8	Saving in banks					

6.5. On your opinion, what are the possible solutions to the problems associated to the soil and water conservation approach? (It *is open-ended question*)

1. -------------------------
2. -------------------------
3. -------------------------
4. -------------------------------------
5. ------------------------------------
6. ------------------------------------

<u>Qualitative Data Collection Tools discussion point for FGD</u>

- **Wealth, Income, Land holding and Land productivity**

1. Are you originally from this kebele?

2. In your opinion what is soil and water conservation?

3... How would you describe soil and water conservation over the last 5 years

4. How do you evaluate your land productivity without soil and water conservation practices? and with soil and water conservation practices?

5. Did the conservation measures on your land accompanied with moisture holding and then better productivity? Do you use improved seeds for better productivity?

6. In your area did the participants own wealth or increases income because of their participation in soil and water conservation practices? If yes how explain by more discussion?

7. What change did the soil and water conservation practice made to your area?

8. Are there more conservation measures done by the government and NGOS on communal and private (farm) land?

9. What proportion of farm land that need treatment has been covered with protection measure since the past five years? If not all, why not? Who is responsible to maintain the constructed conservation measures, especially the one which was constructed in the farm land?

10. Did the communities have undertaken any maintenance work in soil conservation structures so far?

11. How do you manage the farm land or private in your area? What are the mechanisms to share the benefits from the conserved farm land among the communities?

12. What impact do you observed after the construction of soil and water conservation measures?

13. Is there any benefit that is gained from the soil and water conservation practices to the community?

14. In your opinion, do the soil and water conservation activities contribute to the food security in the watershed? I yes, how If no why?

15. Do you or anybody in your localities built assets (at household level) due to the involvement of soil and water conservation practices or the benefit obtained from the conserved areas?

16. Would you please tell us the any improvement in the lives of your community and households (in terms of increase income, increase productivity) due to the soil and water conservation measures compared with the previous years? If there any benefits do you think these benefits will continue in the future? Why? How?

17. Are there any unintended negative impacts of the soil and water conservation interventions?

Appendices -2 Plate of Study Area

Appendix 2.1 Soil sample should be taken

Appendix 2.2 desiccation with focus group (FGD) and key informants

Appendix 2.3 expansion of irrigation land due to the implementation of SWC technologies