



**EFFECTS OF INTEGRATED USE OF GRASS STRIP COMBINED WITH SOIL BUNDS  
ON SELECTED SOIL PROPERTIES: A CASE OF DALTA SUB WATERSHED IN  
ESSERA DISTRICT, SOUTHWESTERN ETHIOPIA**

**MSc THESIS**

**BY:**

**TIZITAW GODARO TOLOLA**

**HAWASSA UNIVERSITY**

**INSTITUTE OF TECHNOLOGY, SCHOOL OF GRADUATE STUDIES**

**MAY, 2024**

**HAWASSA, ETHIOPIA**

THE DEPARTMENT OF AGRICULTURAL ENGINEERING,  
FACULTY OF BIOSYSTEMS AND WATER RESOURCES ENGINEERING  
SCHOOL OF GRADUATE STUDIES  
HAWASSA UNIVERSITY  
HAWASSA, ETHIOPIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS  
FOR THE DEGREE OF MASTERS OF SCIENCE  
IN SOIL AND WATER CONSERVATION ENGINEERING

BY: TIZITAW GODARO TOLOLA

ADVISOR: MARKOS MATHEWOS (Ph.D)

CO-ADVISOR: ABIOT KETEMA (Ph.D)

MAY, 2024

HAWASSA, ETHIOPIA

**ADVISORS' APPROVAL SHEET**  
**SCHOOL OF GRADUATE STUDIES**  
**HAWASSA UNIVERSITY**

This is to certify that the thesis entitled “**EFFECTS OF INTEGRATED USE OF GRASS STRIP COMBINED WITH SOIL BUNDS ON SELECTED SOIL PROPERTIES: A CASE OF DALTA SUB-WATERSHED IN ESSERA WOREDA, SOUTHWESTERN ETHIOPIA**” submitted in partial fulfillment of the requirements for the degree of Masters' with specialization in Soil and Water Conservation Engineering, Department of Agricultural Engineering has been carried out by Tizitaw Godaro Tolola ID NO; GPSWCE R/0008/13, under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

NAME OF STUDENT	SIGNATURE	DATE
TIZITAW GODARO TOLOLA	_____	_____

NAME OF MAJOR ADVISOR	SIGNATURE	DATE
MARKOS MATHEWOS (PH.D.)	_____	_____

NAME OF CO-ADVISOR	SIGNATURE	DATE
ABIOT KETEMA (PH.D.)	_____	_____

NAME OF SCHOOL HEAD	SIGNATURE	DATE
TAREKEGN ELIYAS (Msc)	_____	_____

**EXAMINER’S APPROVAL SHEET  
SCHOOL OF GRADUATE STUDIES  
HAWASSA UNIVERSITY EXAMINERS’ APPROVAL SHEET**

We, the under signed, members of the board of examiners of the final open defense by Tizitaw Godaro Tolola have read and evaluate his/her thesis entitled “EFFECTS OF INTEGRATED USE OF GRASS STRIP COMBINED WITH SOIL BUNDS ON SELECTED SOIL PROPRIETIES: A CASE OF DALTA SUB WATERSHED IN ESSERA WOREDA, SOUTHWESTERN ETHIOPIA” and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree.

_____	_____	_____
Name of Major Advisor	Signature	Date
_____	_____	_____
Name of Internal Examiner	Signature	Date
_____	_____	_____
Name of External examiner	Signature	Date
_____	_____	_____
Name of chairman	Signature	Date

## DECLARATION

The author confirm that I have done this research independently by my own without any other sources than the one indicated in the citation. Ideas that have taken directly or indirectly from an external source have been acknowledged and cited properly. This thesis is submitted in partial fulfilment of the requirement for soil and water conservation engineering at Hawassa University. This thesis is deposited in Hawassa university library and is made available to borrowers under the rule of library. I solemnly declare that this thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

Name: Tizitaw GodaroTolola

Signature: -----

Date: -----

Contact Address:

Email: [tizealem@yahoo.com](mailto:tizealem@yahoo.com)

## **ACKNOWLEDGEMENT**

First, I would like to thank the almighty of God for his guidance and grace upon me during my work and in all my life. I want to sincerely thanks to my advisor Dr. Markos Mathewos Department of Agricultural Engineering, Institute of Technology Hawassa University for his valuable guidance, suggestions and constructive comments in preparing the proposal, research guidance and finalizing the thesis Without his encouragement, suggestion and support the completion of this research work would not have been possible. I am also thankful to my Co-advisor Dr. Abiot Ketema Department of Agricultural Engineering, Hawassa University for his comments, suggestion and guidance from the very beginning of my research work.

I would like to express my sincere appreciation to Essera Woreda Administration office for financial support they rendered to my research work, and Similarly, Hawassa University is acknowledged for educating me the MSc degree. I would like to acknowledge Essera Woreda Woreda Agricultural Office staffs who have given me necessary data and information needed for the research.

I would like to acknowledge the SNNPR Agricultural research center and Hawassa University soil laboratory for Laboratory Soil testing support extended to me in my research work. Particularly, I am thankful to Mr. Haile Michael Debelke and Mr. Alemu Ayele who have supported my research in many ways.

I am grateful to my beloved wife Alemnesh Arefa and my Dad Mr. Godaro Tolola and my Mom Ms. Ayelech Gebre who have given me moral support, strength and encouragement in completing my thesis on time.

## ACRONYMS AND ABBREVIATIONS

Av.P	Available phosphorous
ATP	Adenosine Tri-Phosphate
ANOVA	Analysis of Variance
BD	Bulk Density
CEC	Cation Exchangeable Capacity
CSA	Central Statistical Authority
DA	Developmental Agent
DNA	Deoxyribonucleic Acid
ETB	Ethiopian Birr
FAO	Food and Agricultural Organization
FFW	Food for Work
FGD	Focus Group Discussion
FTC	Farmer Training Centre
HHs	Household Heads
ISWC	Integrated Soil and Water Conservation
LSD	Least Significance Difference
LLPPA	Local Level Participatory Approach
MOA	Ministry of Agriculture
MOARD	Ministry of Agriculture and Rural Development
NGOs	None Government Organazations
PRA	Participatory Rural Appraisal
RCBD	Randomize Complete Block Design
SAS	Statistical Analysis Software
SLM	Sustainable Land Management

SNNP	South Nation Nationalities and Peoples of Ethiopia
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SWC	Soil and Water Conservation
SWCPs	Soil and Water Conservation Programs
SWERS	Southwestern Ethiopia Peoples Regional State

## Table of Contents

<b>CONTENTS</b>	<b>PAGE</b>
<b>ADVISORS' APPROVAL SHEET</b> .....	<b>I</b>
<b>EXAMINER'S APPROVAL SHEET</b> .....	<b>II</b>
<b>ACKNOWLEDGEMENT</b> .....	<b>III</b>
<b>DECLARATION</b> .....	<b>IV</b>
<b>ACRONYMS AND ABBREVIATIONS</b> .....	<b>V</b>
<b>TABLES OF CONTENTS</b> .....	<b>XII</b>
<b>LIST OF TABLES</b> .....	<b>XIII</b>
<b>LIST OF FIGURES</b> .....	<b>XV</b>
<b>LIST APPENDICES</b> .....	<b>XVI</b>
<b>ABSTRACT</b> .....	<b>XVII</b>
<b>CHAPTER ONE</b> .....	<b>1</b>
<b>1. INTRODUCTION</b> .....	<b>1</b>
1.1. Background .....	1
1.2. Statement of the problem .....	4
1.5. Significance of the Study .....	5
1.6. Scope of the study .....	5
<b>CHAPTER TWO</b> .....	<b>6</b>
<b>2. LITERATURE REVIEW</b> .....	<b>6</b>
2.1. Farmers Adoption on Biological Soil and Water Conservation .....	6
2.2. Effects of Conservation Measures on Soil Physical Properties.....	10
2.2.1. Effect of Grass strip for soil and water conservation.....	10
2.2.2. Effect of Desho Grasses for Soil and Water Conservation.....	10

2.3. Effect of Integrated Use of Grass Strip and Soil Bund and slope gradient on selected soil physio-chemical properties .....	11
2.3.1. Effects of Integrated Use of Grass Strip and Soil Bund and slope gradient on selected soil physical properties .....	11
2.3.2. Effect of grass strip and soil bund and slope gradient on selected soil chemical properties .....	13
<b>CHAPER THREE.....</b>	<b>18</b>
<b>3. MATERIALS AND METHODS .....</b>	<b>18</b>
3.1. Description of the Study Watershed.....	18
3.1.1. Land Use and Coverage.....	19
3.1.2. Topography and Climate .....	19
3.1.3. Types of Soil .....	20
3.2. Sources of data .....	21
3.2.1. Soil Sampling and Laboratory Analyses .....	21
3.2.1.1. Soil Sampling .....	21
3.2.1.2. Soil Laboratory Analysis .....	22
3.3. Farmers Adoptions and Management of Physical SWC Practices .....	23
3.3.1. Qualitative Data Sources .....	23
3.3.1.1. Key Informant Interview .....	23
3.3.1.2. Focus Group Discussion .....	23
3.3.1.3. Field Observation.....	24
3.3.2. Quantitative Data Sources .....	24
3.3.2.1. Household Interview.....	24
3.3.2.2. Sample Size Determination .....	25
3.3.3. Selecting Factors Affecting Physical SWC Practices.....	26
3.3.4. Data analysis .....	27

3.3.4.1. Data Collection of Soil Physical and Chemical Properties .....	27
3.3.1. Data Collection and Soil Sampling .....	27
3.4. Soil Laboratory Analysis.....	28
3.5. Farmers Adoption on Construction Physical SWC.....	29
3.5.1. Sampling Techniques .....	29
<b>CHAPER FOUR .....</b>	<b>30</b>
<b>4. RESULTS AND DISCUSSIONS.....</b>	<b>30</b>
4.1. Soil Physico-chemical Properties Affected by Grass strip Combined with Soil bunds.....	30
4.1.1. Effect on Soil texture .....	31
4.1.2. Effect on Bulk Density.....	31
4.1.3. Effect on Soil moisture content.....	32
4.2. Effect of Soil Bund and Soil Bund with Grass Strips under three Slope Gradient on selected Soil Physical Property .....	33
4.2.1. Effect on Soil pH.....	35
4.2.2. Effect on Soil Organic Matter (SOM).....	36
4.2.3. Effect on Total Nitrogen .....	36
4.2.4. Effect on Available Phosphorous (Av. P) .....	37
4.2.5. Effect on Cation exchange capacity (CEC).....	37
4.3. Effect of Soil Bund and Soil Bund with Grass Strip under three Slope Gradient on selected Soil Chemical Property .....	38
4.4. Correlation Analysis between Studied soil variables.....	39
4.5. Farmers Adoption on the Using Grass strip Combined with Soil Bunds as Soil erosion conservation strategy in study area.....	42
4.5.1. Farmers' Adoption towards on Soil Erosion and SWC .....	43
4.5.2. Farmers' Adoption in Physical SWC Practices.....	43
4.5.3. Benefits Obtained From Physical SWC Practices.....	45
4.5.4. Problems of SWC Practices in the Dalta sub watershed .....	45

4.5.5. Reasons of Damaging Physical Soil and Water Conservation on the Farm Land .....	46
<b>5. CONCLUSIONS AND RCOMMENDATIONS.....</b>	<b>30</b>
<b>5.1. CONCLUSIONS.....</b>	<b>30</b>
<b>6. REFERENCES.....</b>	<b>52</b>
<b>7. APPENDICES .....</b>	<b>52</b>
<b>8. BIOGRAPHICAL SKETCH.....</b>	<b>30</b>

## LIST OF TABLES

<b>Tables</b>	<b>Page</b>
<i>1: Sample size distribution selected sampled kebeles .....</i>	<i>26</i>
<i>2: Distribution of sample size of respondents by kebeles .....</i>	<i>30</i>
<i>3: Effects of Integrated Use of Soil bund, Soil bund with grass strips and With Soil bund under three slope gradients on selected Soil physical properties .....</i>	<i>37</i>
<i>4: Soil pH, TN, CEC, OM, exchangeable cations between soil bund, Soil bund with grass strip and Non-conserved at 0 to 20cm soil depth Dalta watershed. ....</i>	<i>40</i>
<i>5: Effect of slope gradient on selected soil pH, OM, TN, Av. P and CEC.....</i>	<i>41</i>
<i>6: Correlation on soil physico-chemical properties .....</i>	<i>44</i>
<i>7: Farmers' adoption of SWC technologies.....</i>	<i>47</i>
<i>8: Household perception on problems of soil and water conservation Structures in the Dalta sub watershed. ....</i>	<i>49</i>
<i>9: Independent t-test on factors influence grass strip to Stabilization soil bund.....</i>	<i>50</i>
<i>10: Basic household characteristics. ....</i>	<i>51</i>
<i>11: Socio-demographic Characteristics of HHs in Dalta sub-watershed .....</i>	<i>51</i>

## LIST OF FIGURES

<b>Figures</b>	<b>Page</b>
<i>1. Location Map of the Dalta.....</i>	<i>18</i>
<i>2. The long-term Mean rainfall and temperature information in the study area (2006-2020) ..</i>	<i>20</i>
<i>3. Soil Types of the Dalta Sub-watershed.....</i>	<i>21</i>

## LIST APPENDICES

<b>Annex</b>	<b>page</b>
<i>1: Effect of Slope gradient on selected physical soil properties (Mean and Std. Error of Mean).....</i>	<i>59</i>
<i>2: Results of one-way ANOVA of effect of conservation structure on selected physical soil properties.....</i>	<i>60</i>
<i>3: Results of one-way ANOVA of Effect of Slope gradient on selected chemical Soil properties .</i>	<i>61</i>
<i>4: Effects of Integrated Use of Soil bund, Soil Bund combined with grass strip &amp; non-conserved under three slope gradients on selected Soil chemical properties .....</i>	<i>62</i>
<i>5: Soil sample taking procedure from reconnaissance survey of site selection on laboratory .....</i>	<i>63</i>
<i>6: Questionnaire .....</i>	<i>64</i>

## **ABSTRACT**

*Soil erosion by water constitutes to the most widespread and damaging process of soil degradation. The aim of this study was to determine the effects of integrated use of grass strip combined with soil bunds on selected soil proprieties, to evaluate the Effects of integrated use of soil bund and grass strip combined with soil bunds under different slope gradient and To assess farmer's adoption on using grass strip combined with soil bunds as soil erosion conservation measures at Dalta sub-watershed. 246-households selected randomly from three kebeles by using systematic random sampling techniques. Three land management practices (Land treated with soil bund alone, soil bund with grass strip and untreated adjacent control plot) were evaluated under three slope of lower slope (3-8%), middle slope (8-15%) and upper slope (15-30%). A total of 27 soil samples were collected from the top 20 cm soil depth with three replication in 'X' design square from 10 m x 10 m plots. The results showed that soil Bulk density (Bd), moisture content (MC), soil pH, soil organic matter (SOM), total nitrogen (TN) available phosphorous (Av.p) and cation exchange capacity (CEC) were significantly ( $p \leq 0.05$ ) different on land treated by soil bund and soil bund with grass strip as compared to the untreated adjacent control plots. The result also showed, the contents of sand, silt and clay were significantly different with the change in the slope gradient. There were no significant ( $p \leq 0.05$ ) differences on soil texture between the conserved and non-conserved lands but significant difference with respect to slope gradient. The contribution of soil bund and soil bund with grass strip were effective and promising for land rehabilitation and improving soil properties through minimizing erosion and farmers' adoption towards the practices at Dalta sub watershed, southwestern Ethiopia.*

*Generally, the difference observed in soil physical and chemical properties between slope positions is not due to grass strip malfunction at slope positions but caused by past erosion events and topographic effects on soil property. Moreover, further research need to be conducted on socio-economic aspects for a better understanding the impact of integrated soil and water conservation interventions.*

**Keywords:** *soil bund, grass strip combined with soil bund, soil properties*

# CHAPTER ONE

## 1. INTRODUCTION

### 1.1. Background

Soil is one of the fundamental components of the earth system, which regulates biogeochemical and hydrological cycles, and provides goods and services to the human being and biological diversity (Keesstra *et al*, 2012). The productive land in Ethiopia generally and Southwestern region especially has been exposed to degradation and menace both economic and survival of the people (Dawit, 2014). Soil erosion is a major part of land degradation that affects the physical, chemical and biological properties of soils and results in on-site nutrient loss and off-site sedimentation of water resources in Ethiopia (Hurni, 1993).

World Resource Institute of the United Nations Environment Program estimated that 100 million hectare of land are degraded and completely disappeared with their original biotic functions and 1.2 billion hectares (10%) of the earth's vegetative surface are moderately degraded of which about one fourth is found in Africa and Asia and the rest three-fourth in North America. Undoubtedly, environmental degradation (soil erosion and climate change) has direct effects on agricultural productivity and food security (Demelash & Stahr, 2010).

Agriculture in Ethiopia is not only an economic activity but also a way of life for which agricultural land is an indispensable resource upon which the welfare of the society is built. The livelihood of the vast majority of the population depends directly or indirectly on this sector. Needless to mention, such dependence obviously leads to increased vulnerability of the economy to problems related to land degradation (AdimassuTeferi, 2012)

Population pressure, mismanagement of agricultural lands, deforestation and overgrazing are among the major causes of soil erosion and environmental degradation. The average annual rate of soil loss in Ethiopia is estimated to be 12 tons/hectare/year, and can be even higher on steep slopes (greater than 300 tons/hectare/year or about 250 mm/year) where vegetation cover is scant (Alemu, 2000).

In Ethiopian highlands, high population pressure, continuous and steep slope cultivation, low vegetation cover, deforestation and inadequate soil conservation practices cause annual soil

about 1.5 billion metric tons (Nile, 2011). To combat land degradation at a national level, environmental conservation and land rehabilitation effort was started in 1970s, with a particular focus on the construction of physical structures (bunds, terraces etc.) in the fast-deteriorating highland areas of Ethiopia (Nile, 2011). The intention of these efforts is to reduce soil erosion, restore soil fertility, rehabilitate lands, improve micro-climate, and boost agricultural production and productivity (Derege et al., 2018).

The presence of heavy grazing practices resulted in soil compaction, removal of vegetation, increased sheet and rill erosion, and selective removal of fine soil materials (clay and silt particles) in the degraded adjacent land (Viera Valencia & Garcia Giraldo, 2019). The major pull factors for adopting the introduced SWC measures on their plots of land were found to be perception of soil erosion as a critical problem, availability of labor, small land holding size, access to extension service, land tenure security, participation and positive attitude of farmers towards the introduced SWC measures (Miheretu, 2014). Recognizing land degradation as a major environmental and socio-economic problem, the governments of Ethiopia and NGOs have intervened to alleviate the problem. As a result, large areas have been terraced using soil bunds or other physical means, protected by area closures and planted degraded lands with tree seedlings. The country still loses a large amount of fertile top soil and the threat of land degradation is broadening alarmingly (Erkossa & Ayele, 2003). Further, Biological practices are quick and cheaper than physical structures, compassionate to rehabilitation lands, protect land from further degradation, and stabilize physical structural for long period (Nile, 2011). Soil and water conservation interventions are first a response to the perceived land degradation problem. It includes all forms of human actions to prevent and treat soil degradation, Physical soil and water conservation practices are categorized into two: traditional (indigenous) and improved practices. Whatever the measures might be, these measures aim to control run off, improve soil fertility and harvest water (Markos et al., 2019). Sustainable land management (SLM) has emerged as an issue of major international concern. This is not only because of the increasing population pressure on limited land resources, demanding for increased food production, but also by the recognition of the fact that the degradation of land and water resources is accelerating rapidly in many countries in general and Ethiopia in particular (Haile et al., 2006).

Since 1970's in collaboration with international partners, Ethiopia has made substantial efforts to introduce soil and water conservation technologies to reduce the risks of soil erosion and associated problems (Pascual-Ferrer et al., 2014). In Ethiopia the main challenges of soil and water conservation include, focus on initial construction of physical structures (e.g., terraces, bund, etc.), implement uniform Soil and water conservation interventions are first a response to the perceived land degradation problem., fail to integrate physical structures with biological practices, top-down extension approach, and provide little attention to indigenous knowledge (Haile et al., 2006). The soil and water conservation efforts are less successful in the area. Lately, the government has realized the cause failures in soil and water conservation efforts and give due attention to integrate physical structures with biological practices, enhance community engagement at various stages, and promote untapped indigenous soil conservation practices. Accordingly, in 2007 Ministry of Agriculture and Rural Development has adopted the framework of WOCAT (World Overview of Conservation Approaches and Technologies) to implement Sustainable Land Management (SLM) Program. As WOCAT framework focus on locally tried and tested techniques, the public and private partners use grass strip across the escarpment in densely populated highland for sustainable land management program (Smith, 2010).

*p. pedicelluatum* belongs to the family of Poaceae and native to tropical countries ( Welle et al., 2006; Smith, 2010). This grass has an extensive root system and produces high biomass per unit area (Ramirez et al., 2010). This grass had been used to protect croplands from soil erosion and degradations in highlands of Ethiopia ( Welle et al., 2006; Abiy et al., 2015), to rehabilitate degraded land (Smith 2010), and to improve grazing land and livestock feeding (Welle et al., 2006; Danano, 2007).

As compared to other grasses (e.g., *elephant P. purpureum*, *vetiver V. zizanioides*) used for land management practices in Ethiopia, grass strip is among the most desirable one to control erosion and rehabilitate degraded land (Abiy et al., 2015). Based on the grass's character (e.g., root system) and diverse roles (erosion control, land rehabilitation, feed for cattle), grass strip is probably widely distributed and used for land management practices in Ethiopian highlands and others countries with similar agro-ecology. However, farmer's use of grass strip to protect cropland from erosion, rehabilitate degraded land and livestock feeding is uneven among

farmers. Farmers' use of land management practices are affected by institutional, technological, and socioeconomic factors (Pascual-Ferrer et al., 2014). In the study area, very limited information is available on farmers' use of grass strip, and the effects of grass strip and soil bund at different slopes category on soil properties.

## **1.2. Statement of the problem**

Soil is the only media, which supports the germination, growth and maturity of crops in association with other life supporting systems for better yield. The well-being of present and future generations depends on the fertility status of soil in agriculture countries like Ethiopia (Kc et al., 2020). Agricultural activity influences soil and water conservation changes. These changes have a significant impact on agriculture is a major contributor for the economic development of Ethiopia. These changes have a significant impact on hydrology, the natural resource (soil fertility, land productivity), socioeconomic and environmental systems. Soil Erosion is one of the most important environmental problems among various forms of land degradation that poses serious challenge to the food security of the population and future development prospects of the country (Www.kemkes.go.id, 2020). SWC play an essential role for erosion control and for sustainable watershed management (Tigest Alemayehu, 2018)

Integrated use of grass strip and soil bund are the most widely practiced intervention in the study area, so that farmers use Integrated use of soil bund and grass strip combined with soil bunds to protect their crop land from erosion. Increasing pressure on agricultural land were the major threats to soil fertility management in the study catchment. Sustainable soil management technologies and practices, which have been supported by research finding, on effects of these interventions (Integrated use of grass strip and soil bund) to keep soil fertility, and improve soil physico-chemical properties were no reported/studied and gap transferred to farming communities in the study area. So knowing the effect of Integrated use of soil bund and grass strip combined with soil bunds to improve land management practices and soil physical and chemical properties, that support agriculturalist of the study area and as well as in similar agro-ecological zone in the country. Therefore, this study aimed to evaluate the effect of integrated use of soil bund and grass strip combined with soil bunds on selected soil physical and chemical properties at Dalta sub-watershed.

### **1.3. Research Objectives**

#### **1.3.1. General Objective**

The general objective of this study was to determine the effects of integrated use of soil bund and grass strip combined with soil bunds on selected soil properties in Dalta sub watershed

#### **1.3.2. Specific Objectives**

- i. To compare the Effects of integrated use of grass strip combined with soil bunds on soil physico-chemical properties
- ii. To compare the Effects of integrated use of grass strip combined with soil bunds under different slope gradient on selected soil physico-chemical properties.
- iii. To assess farmer's adoption on using grass strip combined with soil bunds as soil erosion conservation strategy.

#### **1.4. Research questions**

1. What are the Effects of integrated use of soil bund and grass strip combined with soil bunds affect the physical characteristics of the soil?
2. What are the Effects integrated uses of soil bund and grass strip combined with soil bunds affect the chemical characteristics of the soil?
3. What are farmers' adoptions about using soil bund and grass strip combined with soil bunds as a soil conservation method in the watershed?

#### **1.5. Significance of the Study**

This study examined the effects of soil and water conservation (SWC) on soil properties in the Dalta sub watersheds. Therefore, the output of this research enhances awareness SWC. It also contributes to designing appropriate conservation technologies and intervention policies for sustainable technologies and sustainable soil and water conservation practices. It gives useful information for Ministry of Agriculture working to solve soil erosion and other related environmental problems. It also has a better understanding of the kind of training required for farmers in the study area.

#### **1.6. Scope of the study**

This study was under taken in three Kebeles of Essera woreda, these are Arus Angala, Senget and Shada Tela. It was focused on effects of integrated use of soil bund and grass strip combined with soil bunds on selected soil properties: A case of Dalta sub watershed in Essera woreda, southwestern Ethiopia.

## **CHAPTER TWO**

### **2. LITERATURE REVIEW**

#### **2.1. Farmer's Adoption of SWC**

Adoption is defined as the degree of use of new technology in long run equilibrium when the farmer has full information about the new technology and its potential. In the context of aggregate adoption behavior, diffusion is defined as the spread of new technology within a region. The adoption of improved SWC technologies in developing countries has attracted much attention from scientists and policy makers mainly because land degradation is a key problem for agricultural production (De Graaff et al., 2008). According to De Graaff et al. (2008), there are three phases generally includes the awareness, evaluation and the trail stages and eventually leads to starting investment in certain measures. The actual adoption phase is the stage where by efforts or investments are to implement SWC measures on more than a trial basis. The third phase, final adoption, is the stage in which the existing SWC measures are maintained over many years and new ones are introduced on other fields used the same farmers.

Kessler, (2006) considered SWC measures fully adopted only when their execution is sustained and fully integrated in the household's farming system. Therefore, introduction of SWC technologies may not lead to sustained land rehabilitation unless the farmers proceed to final adoption. Despite the ecological and economic benefits and substantial efforts to promote SWC technologies, the reality is that SWC technologies have not been widely adopted by small holder farmers in Ethiopia. The literature identified several factors that determine the adoption and performance of SWC technologies. These are farm level and farmer (house hold) attributes (Derege et al., 2018). The farmer or household attributes include: the demographic and socioeconomic variables and among the farm level attributes are the biophysical conditions of the farm plots. However, because of the presence of agro-ecological differences, the variables that affect one area may not be true for other areas. Therefore, it is necessarily important to test whether or not the variables have similar results

##### **2.1.1. Farmers adoption on biological soil and water conservation**

Soil and water conservation measures are important adaptation measures for farmers to handle with and resist the potential risk of soil erosion. For example, farmers can handle with and

reduce the production risk caused by soil erosion through the construction of engineering measures such as soil and water conservation projects, biological measures such as grain for green and grass and conservation tillage measures such as less tillage and no-tillage (Susha et al., 2018). To a certain extent, the control of soil erosion depends on farmers' adoption behavior of soil and water conservation measures. Farmers as a "rational economic man," the most important basis for farmers to adopt soil and water conservation measures are their cost-benefit situation. If the adoption of soil and water conservation measures can improve farmers' profits or production efficiency, then the measures will be quickly spread and adopted by many farmers. In a certain period of time, if the adoption of soil and water conservation measures cannot bring economic benefits such as cost-saving and yield-increasing to farmers, it will greatly affect the promotion of the measures (Huang et al., 2020).

(Derege et al., 2018) reported, in principle and practice, the biological measures are the cheapest, most easily adoptable and effective measures, but little attention was given. In cultivable land, the compatibility of species with intended annual crops to be grown in inter-structure, poor survival of some species is an issue as the land is subjected for open grazing during off-seasons, lack of seed or seedling supply, clear research outcomes to select species and scaling up biological measures on such land use. Even though those quantified effects and the role of SWC on runoff and flood regulation/control have been recognized, adoption of the structures is still low ( Admassu et al., 2012) pointed out that our understanding of farmers' knowledge and their perception of factors that influence their land management practice is paramount importance for promoting sustainable land management. (Wolka, 2014) reported that the current SWC measures based watershed management activities which are carried out by various approaches including massive public campaign, NGOs, safety nets, should intensively work on awareness of the land users, so that rate of perception can be improved. Technical support and monitoring should be strength ended to select the appropriate structures, design and specification. Wherever possible, biological measures such as enclosures, tree and shrub planting and management, Agroforestry, strengthening the structures with grass or shrub, should be given priority due to their multiple and sustaining roles. Many case studies indicated that biological measures and soil fertility management could improve effectiveness of the structure and soil fertility (Zougmore et al., 2004; Admassu et al., 2012). The technical approach should also give due attention for livestock management which significantly creates conditions for soil erosion and damage of the built

structures. As anticipated, farmers' perception of soil erosion problem affects the adoption of soil conservation measures positively and significantly (Kassie et al., 2008). The implication is that farmers who feel that their farmlands are prone to soil erosion are more likely to adopt soil conservation measures than those who do not perceive the problem of soil erosion.

### **2.1.2. Factor Affecting Adoption of Soil Conservation Measures**

A sizeable body of literature exists which describe and analyses factor affecting soil conservation. Many factors bear on farmers' decisions about adopting soil conservation measures. Following Ervin and Ervin (1982), it is possible to hypothesize the decision making process to adopt soil conservation measures starts from farmers' perception of erosion problem. These are personal, physical, economic, and or institutional factors, but usually not all simultaneously. The adoption and use of soil conservation practices is conceptualized as the decision-making process. Each category of factors is hypothesized to influence one or more of the decision-making process components. Each component can be visualized as a major step in the decision to control erosion. The process is set in motion by the recognition of an erosion problem. That perception is viewed as a product of the land owner's personal characteristics that might cause a more acute awareness of the seriousness of the erosion (e.g., formal education), coupled with the actual physical characteristics of the land he operates. As shown, government or academic educational programs can be used to heighten the perception of erosion problems. From an economic perspective, perception of the degree of erosion problem and its impact on short term returns and land values should be highly correlated with the farmer's willingness to pay for conservation measures. Shiferaw and Holden (1998) noted the perception of soil erosion problems, household size, and farmer's perceptions of technology, specific attributes and land quality differentials as important in shaping conservation decision.

#### **2.1.2.1. Personal factors**

Personal factors such as education level, farming experience, conservation attitude and family size are factors which influences adoption of soil conservation. Higher education levels are hypothesized to be associated with improved knowledge about conservation measures and the productivity effects of erosion. It can be viewed as influencing a landowner's disposition to use practices because of increased information on erosion control, the productivity consequences of

erosion, and higher management expertise benefits and costs. Thus, positive relationships were expected between education and all dependent variables. Farmers' attitudes toward environmental quality and conservation issues should reflect their public concerns about resource use, and consequently, may affect their perceptions of erosion problems and their farm conservation actions. Those personal characteristics involving acquisition costs can be interpreted as human capital. The degree of physical erosion potential of a farmer's land also may persuade him to choose a particular practice.

#### **2.1.2.2. Physical factors**

Factors such as farm size, slope, farm terrain, type of erosion, soil amendments, location of farm land and land quality differentials are some physical factors which affect farmers' ability to adopt method of soil conservation (Arellanes and David, 2003; John, 2008; Shiferaw and Holden, 1998).

#### **2.1.2.3. Economic Factors**

Research conducted since the 1950s indicates economic constraints affect the decision to conserve soil. Economic factors may either enhance or constrain farmers' dispositions towards erosion control. For example, high debt levels may inhibit investment in capital intensive terraces, while high net farm income will present tax advantages for the same practice. Educational programs, technical assistance, and cost sharing are institutional instruments to persuade farmers to use practices. Economic constraints such as wealth status of the farmers, off-farm income, annual income, cost of fertilizer and debt status are factors which tends to increase or reduce incentives for soil conservation (Eleni, 2008; Enki et.al, 2001; John, 2008; Million and belay, 2004). The final step is the determination of soil conservation effort, a function of the effectiveness and extensiveness of individual practices over the farm's land.

#### **2.1.2.4. Institutional Factor**

Institutional Factors portrays the role of educational and technical assistance programs in affecting perception of erosion problems, decision to use practices, and erosion control effort.

In addition to this, institutional factors like secure land tenure right, access to credit and extension training to farmers affects farmer's decision to conserve soil (Eleni, 2008;

Gebremedhin and Swinton, 2003). All factor categories influence effort, but in different ways than they influence the decision to use one or more practices. Personal factors, such as management ability, affect the proper application and maintenance of practices, especially on widely varying topography and soils. Physical factors, which define erosion potential, determine potential productivity benefits over the entire farm unit. Because practices that reduce erosion to a greater degree usually cost more, conservation effort is hypothesized to depend heavily on economic factors and cost-sharing payments.

## **2.2. Effects of Conservation Measures on Soil Physical properties**

### **2.2.1. Effect of grass strip for soil and water conservation**

The effectiveness of grass strips in reducing runoff sediment load and soil erosion has been attributed to the filtering capacity of strips as well as their ability to slow down surface runoff and enhance deposition. Such attributes are based more on common sense than on the outcome of scientific investigations. However, there has been a renewed interest in recent years in understanding the mechanics of flow through porous barriers and their effectiveness in reducing the transport of sediment and pollutants down slopes, or into receiving waters, from agricultural lands (Dorioz et al., 2011). Because of the increasing interest in management of riparian lands to reduce the amount of nutrients and pollutants in runoff to streams, there is a need to study the effectiveness of grass strips in reducing downstream impact of intensive land use (Dorioz et al., 2011).

### **2.2.2. Effect of Desho (*p. pedicelluatum*) grasses for soil and water conservation**

*p. pedicelluatum* is among the locally available, multipurpose and potential feed resources in Ethiopia (European Plant Protection Organization, 2014; Leta et al., 2013). It is a perennial grass found in the Southwestern Ethiopia Peoples' Region of the country. The *p. pedicelluatum* is also available in other tropical countries and is palatable to cattle, sheep and other herbivores (Food and Agriculture Organization, 2010). *p. pedicelluatum* has the ability to recover after water stress even under severe drought conditions (Noitsakis et al., 1994). Moreover, the grass serves as a business opportunity for farmers in Ethiopia (Dorioz et al., 2011).

## **2.3. Effect of Integrated Use of Soil Bund and Soil Bund Combined with Grass Strip and slope gradient on selected soil physical properties**

### **2.3.1. Soil texture**

Soil texture refers to the relative proportion of soil particles (sand, silt and clay) in a sample of soil. Or it refers to the percentage distribution of sand, silt, and clay separates. Texture is considered as basic property of a soil; because it is not readily subject to change in the field (Brady, 1990). Based on USDA (1987) (United State Department of Agriculture) system, soil particles are divided in to 3 groups based on their size. These are sand, silt, and clay.

Based on USDA soil textural triangle reported by Tamrat et al. (2018), the soils textural classes of lands treated with grass strip and *p. pedicelluatum* were clay while degraded grazing was clay loam. Soil clay fraction was significantly ( $P = 0.05$ ) affected by grass strip and *p. pedicelluatum*. The highest quantity of clay fractions was recorded under lands treated with grass strip and *p. pedicelluatum* whereas the lowest was in the adjacent degraded grazing land. A similar amount of clay fraction was found at lands treated with grass strip and *p. pedicelluatum*. This indicates grass strip and *p. pedicelluatum* have equal potential to minimize rates of erosion, keep clay materials in its original place, and capture eroded clay materials.

Tigest and Getachew., (2018) reported that Soil texture was significant difference between sand and clay content ( $p < 0.05$ ,  $R^2$  of 0.68 for sand and 0.71 for clay). Specifically, among the treatments, soils of non-conserved plot had the highest mean value of clay and the lowest sand ( $p < 0.05$ ) content. There was no significant difference among treatments that were managed through different SWCPs. Bund stabilized with pigeon pea in the gentle slope showed significant ( $p < 0.05$ ) means variation with bund stabilized with grass strip in the gentle slope.

Soil textural fractions of sand and clay with slope gradient and whereas sand showed significant variation along the treatments and none was observed with clay. The mean sand content was upper (30.18), middle (11.89) and lower (25.32) when the slope gradient was 3-8%, 8-15% and 15-30%, respectively soil property and the position on the landscape (slope gradient) which cause the variation in texture rather than the age of structures. With steep landscapes, transportation and translocation of fine particles are expected ( Worku, 2017). In line with above

result (M. Bekele et al., 2016) agree that, the textural fractions of sand, clay and silt showed a significant variation ( $p < 0.05$ ) with the three slope gradients (upper, middle and lower).

They were also shown a significant difference ( $p < 0.01$ ) between the two soil depths (0-20cm) and (20-40cm). While no significant variations were observed between the two land types. This indicates that the soil texture is the inherent soil property and the position on the landscape (slope gradient) and the soil depths are the factors which cause the variation in soil texture than the soil conservation practices.

### **2.3.2. Soil Bulk density**

Soil Bulk density defined as the mass (weight) per unit volume of dry soil (including pore space). The volume in this case is the sum of the volume of the soil solids and the volume of the pore spaces. Bulk density of a soil depends on the porosity and organic matter content of the soil (Murphy B. and Hazelton P., 2016). (The higher the porosity and organic matter, the lower is the bulk density and vice versa. Generally, in normal soils bulk density ranges from 1- 1.65  $\text{g/cm}^3$  (in a very compacted soils, sometimes, it goes up to 2  $\text{g/cm}^3$ ) (Landon J, 1991).

### **2.3.3. Soil moisture content**

Soil moisture indicates the amount of water present in the soil. It is commonly expressed as the amount of water in (mm) present in a depth of 1 m of soil (mm/m). The amount of water stored in the soil is not constant with time. Moisture content Calculation of the results of soil analysis is done on the basis of "oven-dry" soil for comparison purposes. For this reason a sub-sample is oven dried at 105°C shortly before soil analysis; the loss in soil weight is supposed to be hygroscopic water, which is physically adsorbed in the pores and on the surface (Sahlemedhin and Taye, 2000).

Soil moisture showed significant variation at ( $p \leq 0.05$ ) with respect to treatment. Higher soil MC (19.6%) was observed in farm plots with SWC measures as compared with non-conserved farm plots (17.6%). In respect to slope gradients there was a significant variation ( $p \leq 0.05$ ) between upper and middle slope. Other finding agree that effect of grass strip increase soil moisture storage by a range of 1.9% to 50.1% at various soil depths, Maize yield increased by 50%, Soil

loss and runoff water 70% to 130% higher (Ncube, 2007). But slope-treatment interaction effect didn't show any significant variation at ( $p \leq 0.05$ ) as reported by (Challa et al., 2016).

Moisture content of soil varied between with and without grass strip farm land ( $P < 0.001$ ). The moisture content for soil taken from grass strip farm land was 7.25% while that of the non-grass strip farm land was 6.8%. The higher moisture content of soil from grass strip farm land might be due to the fact that the grass strip hedges slowed down the runoff water allowing more time for water to infiltrate; the hedge reducing soil erosion and conserving soil moisture on site (Du et al., 2023).

## **2.4. Effect of Grass Strip and Soil Bund and Slope Gradient on Selected Soil Chemical Properties**

### **2.4.1. Soil pH**

The pH value of a solution is the negative logarithm of hydrogen ion concentration. Soil pH is measured potentiometrically in the supernatant suspension of a 1:1 or 1:2.5 soils: liquid mixture by using a pH meter. Soil pH depends on a variety of factors including all five soil forming factors plus the season of the year, cropping practice, the soil horizon sampled, the water content at the sampling time and the way the pH is determined. The soil pH is easily determined and provides clues about other soil properties.

The soil pH greatly affects the solubility of minerals. For instance, in acidic soils the phosphate ions react with iron, aluminum, manganese ions to form insoluble phosphate, since acidic soils have high amount of exchangeable aluminum, manganese and iron. This report is agree with (Information, 2015) consider to soil reaction (pH) and there is no significant differences were observed in their mean values of grass strip, Vetu-compost and Vetu-mulch.

The presence of better pH under grass strip, elephant grass and Sesbania is attributed to the presence of high OM, clay fraction, better CEC and basic cations (Teklu, Seleshi & Awulachew, 2011). The mean of soil pH significantly varied between treatments ( $P \leq 0.05$ ). (Masresha and Solomon, 2016) reported that reduction in PH could be an indication of high leaching intensity of bases and their probable replacement by acid forming elements that are caused by the high amount of rainfall. The overall pH value of the study area ranged between 6.03 and 6.66. It was

lower in moderate slope control farm land and higher in the bund found at lower slope stabilized with pigeon pea reported by (Tigest & Fisseha, 2018).

Other findings show that there is no significant difference observed in soil pH with treatments as well as along slope gradient and the mean values of soil pH were lower in control farm land and as compared to stone bund and stone faced soil bund, this variation might be due to leaching of cations in controlled farm plot due to absence of SWC structure that trap soil as well as low ground cover in the farm as compared to the conserved farm plot. Soil pH was lower in slope >30% (5.88) and higher in 3-15% (5.97) slope (Worku, 2017)

#### **2.4.2. Soil organic matter**

Organic matter enhances the soil in many ways. It is also important for physical, chemical and biological soil properties. The organic matter builds and improves soil structure, thereby, improving soil drainage, infiltration of water into the soil, aeration and water holding capacity. The improved soil structure results in well-developed plant root system and healthier, more disease resistant crops. Soil organic matter increases the cation exchange capacity of a soil and provides a neutralizing or buffering effect on soil pH (preventing rapid changes in pH).

The concentration of organic carbon is lower in the upper slopes compared to the lower and middle slopes in both treated and untreated fields (Hana, 2017). In other findings conservation effect on Soil Organic Matter (SOM) showed significant variation  $R^2 = 0.87$  ( $p < 0.05$ ) with respect to treatments.

The SOM content under the non-conserved plots was significantly lower than all the other treatments. In line with the above findings organic carbon content under the un-conserved land was significantly lower than the content in the conserved land, this might be because of the decomposition of different plant biomasses on the soil of conserved land. Other findings show that, the use of grass strip and *p. pedicellatum* ensure sustainable land management practices plants and grass strip had an ameliorative effect on soil quality, it not only increased the soil organic matter in the surface soil, but also improved the physical and biological properties which are important for crop production and the environment in general (Materechera, 2010).

The significantly lowest SOM occurred in non-conserved plot (2.4%), while the highest (3.01%) SOM showed in the plot which was conserved with Bund + pigeon pea + gentle slope ( Tigest and Getachew, 2018). Soil organic carbon (SOC) and total nitrogen (TN) were significantly ( $P \leq 0.05$ ) improved through the use of grass strip and *p. pedicelluatum* to rehabilitate degraded land. The highest amount of SOC and TN were recorded at lands treated with grass strip followed by *p. pedicelluatum* while the lowest was at the adjacent degraded grazing land. The presence of high SOC and TN under grass strip is due to high biomass return from grass strip (Teklu Erkossa, Seleshi Bekele Awulachew, 2011). On the other hand, SOC content of the soil showed an increasing trend since establishment of integrated SWC indicating that it is a promising way of carbon sequestration on agricultural land (Mume et al., 2018).

### **2.4.3. Total nitrogen**

Nitrogen (N) is one of the major nutrients required for the nutrition of plants and is often the controlling factor in plant growth. Traditional land management practices have a significant role in adding and maintain the total nitrogen contents of soil. Those fields with biological and physical land management practices showed significant different in the amount of total nitrogen than the untreated fields (Bonanomi et al., 2011). Total nitrogen (%) differed significantly between the treatment, slope positions and also between the treatment slope interaction at ( $p \leq 0.05$ ), matching the soil OM distribution. The overall TN content in soils under non-conserved farm plots was significantly lower (0.17%) than the content under graded stone bund 6 years of age (0.24%) (Challa et al., 2016).

The significant difference in the total nitrogen content among conserved and non-conserved treatments could be SWC structures stabilized with nitrogen fixing plants (Challa et al., 2016). Grass strip has been demonstrated to highly tolerate and accumulate high concentrations of nitrogen (N) and phosphorous (P) (Truong, 2000). Total nitrogen content for both treated and untreated farm fields is rated low that it's not shows a significant difference. This low value of total nitrogen could be due to the fact that the area is moist kola and this may cause leaching of nitrogen in the soil and the other reason might be related to management problems in improving the nitrogen content by growing leguminous plants that fix nitrogen from the air through the nodules of their roots (Kasahun Kitila., 2016).

Next to nitrogen, phosphorus has more widespread influence on both natural and agricultural ecosystems than any other essential elements.

#### **2.4.4. Available phosphorous**

The available soil phosphorus (Av.P) was significantly ( $P > 0.05$ ) improved with the use of soil bund and soil bund with grass strip. The highest amount of Av. P was observed under land treated with soil bund and soil bund with grass strip (3.857) and lowest at grazing land (2.867) (Solomon et al., 2018). Other report shows that slope is factors for the significance of available phosphorous, a relative higher mean value of available phosphorus is observed in non-conserved land in the gentle slope while lower value of available phosphorus showed in bund stabilized with pigeon pea in gentle slope plants (Tigest and Getachew, 2018). The results also showed that available phosphorous and available potassium did not significantly varied ( $P > 0.05$ ) both with the treatments and slope gradients. The mean value of Av-P and Av-K within treatments as well as slope gradients showed a slight difference. The mean Av-P and Av-K in soil under conserved plots was relatively better than in the non-conserved plots (Hailu et al., 2012).

#### **2.4.5. Cation exchange capacity**

The CEC is a measure of the soil particles ability to exchange cations with freely mobile cations added to the soil matrix. The value of CEC slightly increased in all slope classes. However, it was slightly decreased in untreated fields. Similarly, the highest quantity of CEC and exchangeable bases were recorded at land treated with soil bund and soil bund with grass strip while the lowest at non-conserved land. The presence of high soil organic matter and clay fractions are contributed for better CEC and exchangeable bases at lands treated with soil bund and soil bund with grass strip.

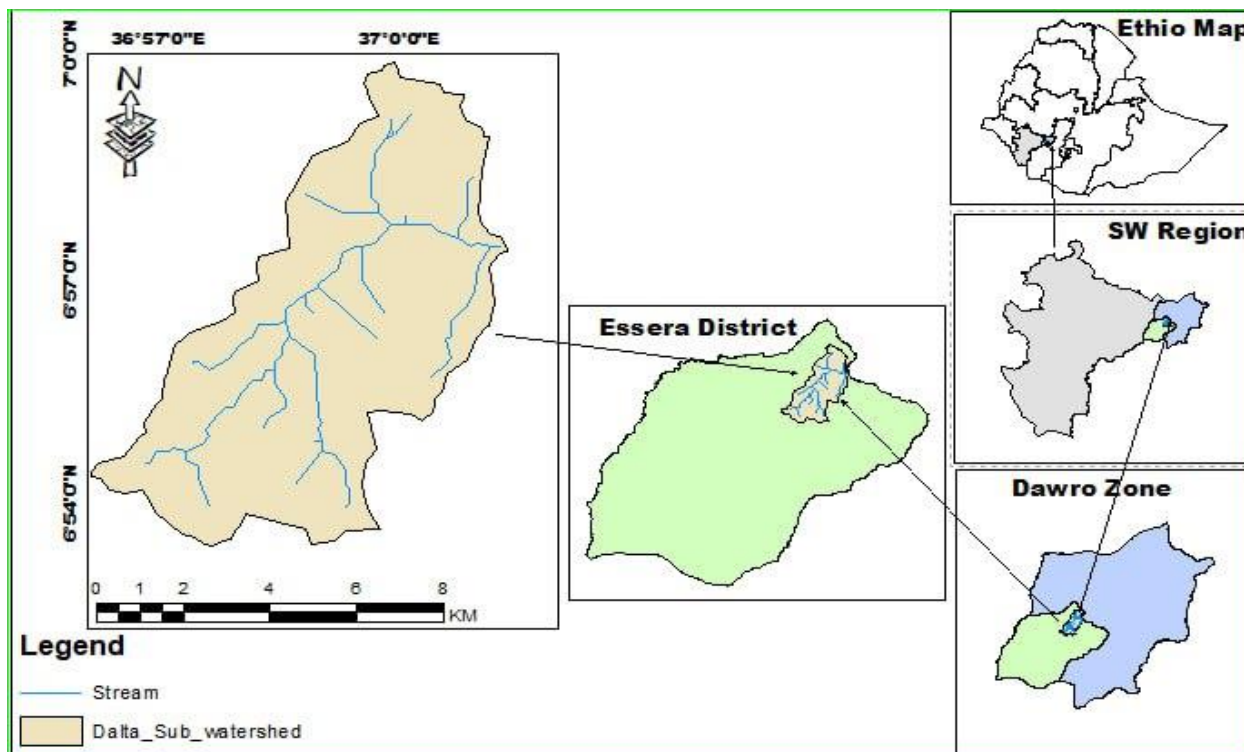
The analysis of variance showed that the overall mean CEC values did not significantly vary ( $p < 0.05$ ) with respect to treatments and slope gradients. The variations between treatments as well as slope gradients were very small. This could be attributed to the soil texture, particularly to clay soil (Challa et al., 2016)

## CHAPER THREE

### 3. MATERIALS AND METHODS

#### 3.1. Description of the study watershed

The Study was conducted in Dalta sub-watershed located in Essera Woreda, Dawuro Zone of the South-western Ethiopia Peoples Regional State (SWERS). Essera woreda is one of 11 Woreda in Dawuro zone. It is bordered on the north by Tocha woreda, on the north-east by Mareka woreda, on the west by the Konta Zone, on the south east by the Loma woreda, and on the south by Gofa zone. The Woreda administrative town is known as Bale: It is about 575 km southwest of Addis Ababa and 323 km from Hawassa, and 79 km far from Tercha town. The altitude ranges from 1501 to 2500 m above sea level. In Essera district there are 26 kebeles and 3 municipalities. Some of these kebeles are newly emerged by splitting larger kebeles due to population growth and for management purpose. Based on the CSA (2007), this district has a total population of 64,950, of whom 32,833 are Male and 32,117 are Females; 4,030 or 6.21% of its population are urban dwellers. Area of Dalta sub-watershed is 5582.75ha. Geographically, it is between latitude  $06^{\circ}59'30''$ -  $7^{\circ}30'00''$ N and longitude of  $36^{\circ}57'00''$ -  $37^{\circ}10'00''$ E (Figure 1).



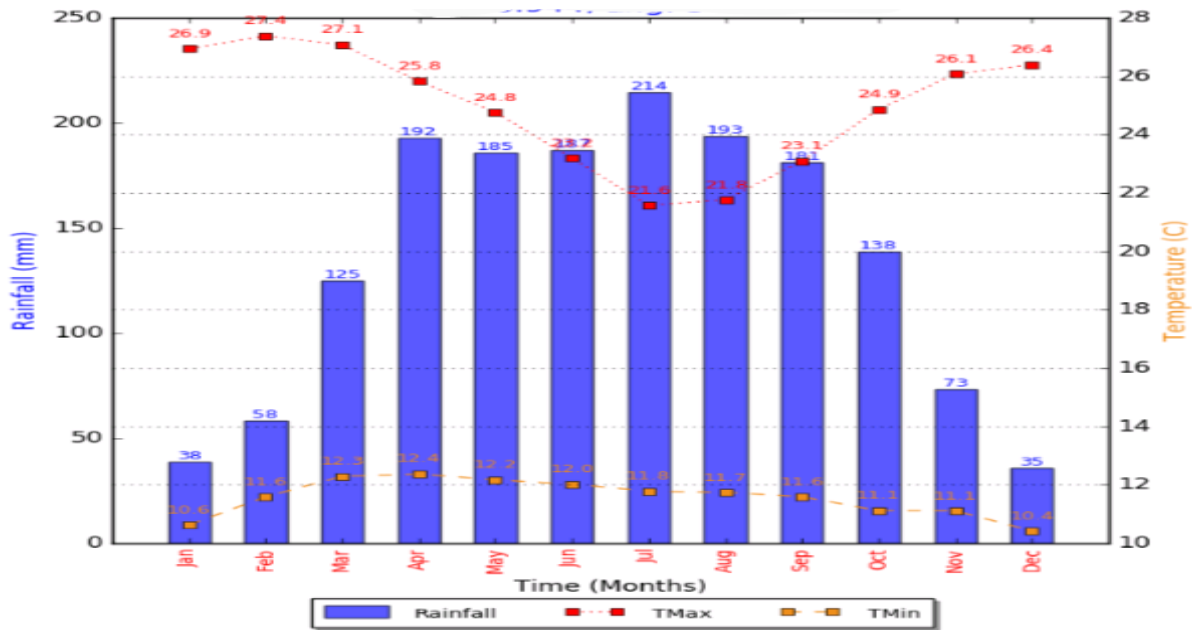
**Figure 1.** Location map of the Dalta Sub- watershed

### **3.1.1. Land Use and Coverage**

The main land use of the Dalta sub watershed is dominated by rain-fed agriculture (93%), which small-holder farmers mainly own. According to their area coverage, the major annual food crops grown in the area, includes cereals (*Zea mays*, *Sorghum bicolor*, *Hordeum vulgare*, *Triticum spp*, and *Eragrostis tef*) pulses (beans, peas). Maize and wheat followed by beans and peas were grown in the highest proportion. The most common agro-forestry tree species, in the grazing and enset farm in the study area includes, *Cordiaafricana*, *Millettiaferruginea*, *Ficus spp.*, *Grevillarobusta*, *Acacia spp*, Coffee (*C.arabica*) and some fruit trees like *Mangiferaindica L.*, and *Persea Americana*. Musa acuminate and root crop (potatoes and taro) are also grown considerably especially in enset farm land. Enset is a plant native to Ethiopia that is often referred to as the false banana because, not surprisingly, of its resemblance to the banana plant. It is grown in the less arid highlands of the south-western region of Ethiopia. Farm land covers a much larger area than other land-use cover types and the area of Dalta sub-watershed is 5582.75 ha.

### **3.1.2. Topography and Climate**

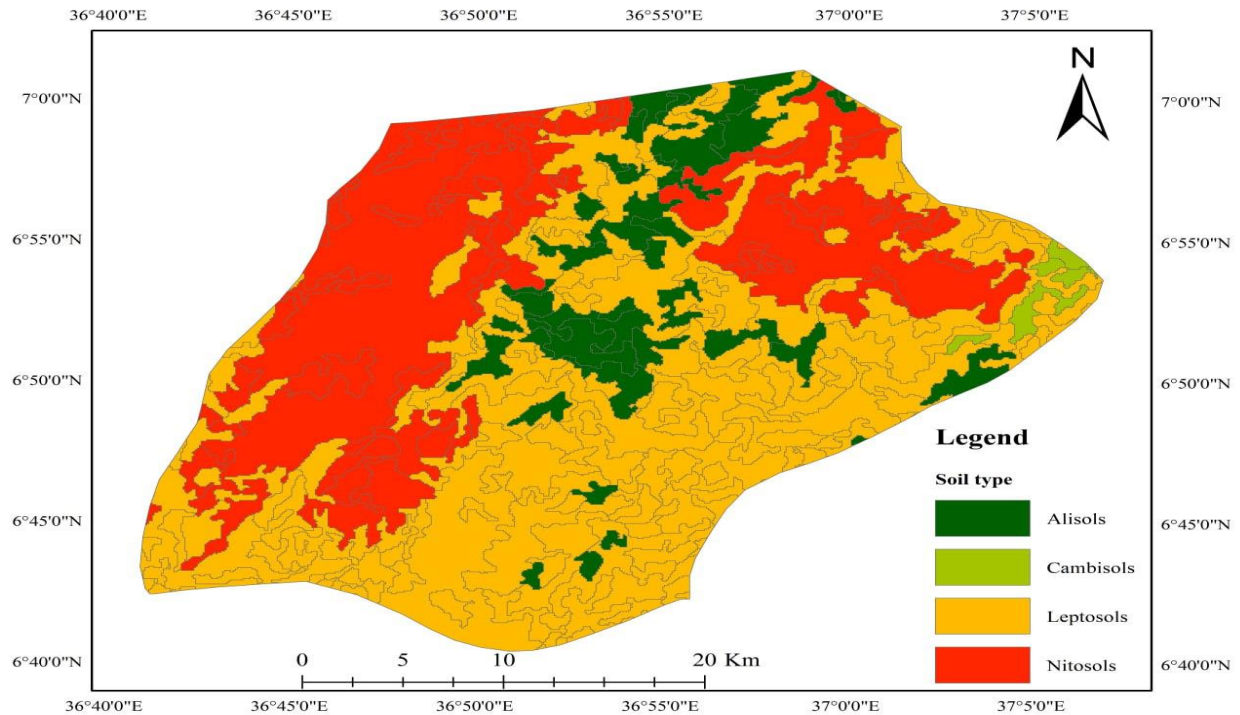
The Ethiopia climate condition is determined by altitude (Getachew., 2014). The same is true, that a large part of Essera woreda is characterized by rugged topography that consists of very high mountains; deeply incised canyons, gorges, valleys, plains and plateaus. This district falls into three agro-ecological regions, of which, kolla within (500-1500 masl), weyna-dega within (1501-2500 masl) and Dega above (> 2500 masl). However, the climate under conditions slightly varies from rural kebele to kebele, due to a difference like relief (Figure 2). The rainfall is bi-modal the main rain season (Meher) starts in July and extends to the August and the (Belge) season starts in March and extends to June. It is distributed unevenly through ought the year. The area receives an average a new rainfall of about 1600.5mm and has an average annual temperature ranging from 17.6 to 27.5<sup>o</sup>c mixed farming system is main economic action practiced and regarding the Agro-Ecology, 47% was tropical, 32% was Subtropical and 21% was temperate as Essera Woredsa Agricultural and Natural Resource Management Development office (Challa et al., 2016).



**Figure 2.** The long-term mean rainfall and temperature information in the study area (2006-2020)

### 3.1.3. Types of Soil

The soil classification, the study area types of soil, namely: Leptosols, Eutric Nitosols, planosols, Haplic Xerosols, pellic vertisols, Calcaric, and flubisols. Eutric Nitosols, planosols and Haplic Xerosols mainly cover the study area (Challa et al., 2016). The study area soil types more of Leptosols. The soil volume then expands as it wets up. This swell action creates serious engineering problems and generally prevents formation of distinct, well-developed horizons in these soils (Figure 3).



**Figure 3.** Soil types of the Dalta sub-watershed

### 3.2. Sources of Data

To find the accurate information about the study area, two types of data sources were used. These are primary and secondary data sources. The primary data was collected from farmers, field survey, interview, focus groups, laboratory analysis, and questionnaire survey, Kebele elders person, cultural leaders and Woreda agricultural development offices and Secondary data sources was collected from published materials and internet/ web pages.

#### 3.2.1. Soil Sampling and Laboratory Analyses

##### 3.2.1.1. Soil sampling

For soil analysis, sites were selected from soil bund, soil bund with grass strip and non-conserved farm plots. In the case of both soil bund and soil bund with grass strip, sampling plots refer to the area between the two successive soil bunds of equal or greater than seven years old was sampled from upper, middle and lower slope positions. In the case of non-conserved plots, the sampling plots refer to the area under cultivation, which is found adjacent to soil bund and soil bund with grass strip plots. Plots with bunds and adjacent plot without bund had similar

history of land management, soil type and slope. In plots with soil bunds and soil bund with grass strip, soil samples were collected from three sub-plots, that is, near bund at down slope side, middle point and upslope side from the next bund. This was replicated three times per plots and the plough layer (0-20cm) was considered. Similar procedure was followed to collect soil samples in other three plots. Adjacent to each soil bund and soil bund with grass strip, the non-conserved field was considered for soil sampling. In no bund fields, soil was sampled from upper, middle and lower slope positions considered. The upper, middle and lower slope positions has slope of 3 – 8%, 8 – 15 and 15-30 slope respectively. Soil samples were collected from the top depth at four corners and canter of a plot of 10m x 10m size using “X” sampling design (R. Margesin, (2005). With sharp edged and closed, circular auger pushed manually down the soil profile. A total of 27 soil samples (3 treatments \* 3 slope gradients \* 3 replications \* 1 depth: 0-20cm) were collected in a Randomize Complete block Design (RCBD) for laboratory analysis. The samples were analyzed for Total Nitrogen (TN), Available Phosphorus (AP), Soil Organic Carbon (SOC), Available Potassium (AK) and soil texture.

#### **3.2.1.2. Soil Laboratory Analysis**

Collected Soil samples were bagged separately with appropriate labels and transported to the laboratories. In the laboratory, soil samples were air dried by in an open air. The air-dried soil samples were crushed to pass through a 0.5 mm sieve in preparation for laboratory analysis. Soil texture, pH, soil organic matter, Total Nitrogen, Available phosphorus and CEC was analyzed in SNNPR Agricultural Research centre soil laboratory section and moisture content and bulk density was analyzed in Hawassa University Main camps soil laboratory section.

Soil texture was determined following the Boycouos hydrometric method (Bouyoucos, 1962) after destroying organic matter using hydrogen peroxide ( $H_2O_2$ ) and dispersing the soils with sodium hexameta phosphate ( $NaPO_3$ ). Soil organic carbon (SOC, %) content was determined following the Walkley and Black method (Challa et al., 2016). Total N content of the soil was determined by wet-digestion, distillation and titration procedures of the Kjeldahl method as described by (Challa et al., 2016). The available phosphorus content of the soil was determined using Bracey method (Challa et al., 2016). The available potassium was determined by flame emission spectrophotometer (Challa et al., 2016).

### **3.3. Farmers Adoptions and Management of Physical SWC Practices**

In addition to soil analysis, the study applied socio-economic issues related to soil erosion and conservation practices. Thus, qualitative and quantitative data on farmers' opinion on soil erosion, adoption and management of conservation structures and factors affecting adoption of physical SWC in Dalta sub-watershed was acquired using household interviews, key informant discussions and focus group discussions as outlined below.

#### **3.3.1. Qualitative Data Sources**

##### **3.3.1.1. Key Informant Interview**

For the sake of in detail understanding on the physical SWC implementation and management practices, effects on soil fertility depend on crop yield in the study area, physical SWC practices are the solution for reducing rural poverty, the adoption methods of new SWC, well adopted technologies and commitments of farmers to sustainable use and the different factors determine the adoption of conservation practices were open ended question was prepared. All these key informants were better understanding on crop production problems and the effects of physical SWC practices on soil macronutrients and management practices problems. They explained from their experience as decline in soil fertility due to soil erosion and land degradation change for crop production. Key informants were selected purposely from the woreda and kebeles agricultural experts of Natural Resource Experts, watersheds development committee, and kebele administrator. Based on data saturation, 5 key informants were employed.

##### **3.3.1.2. Focus Group Discussion**

Focus group discussion (FGD) was held with selected model farmers of the sample kebeles, kebele leaders, elder people, religious leaders, agriculture extension workers and woreda SWC supervisor using a supporting checklist. Each group had 1-12 members who were selected purposefully for the study. The farmers were selected based on their perception experience, plot location, soil and water conservation practices and continues use of on their farmland. One FGD was conducted per kebele in each of the three sampled kebeles. The focus of the discussion was problems of soil erosion; importance of physical SWC, adoption rates specifically; the objectives and importance of physical SWC structures, the approach by which the conservation structures

were introduced, and the effects of physical SWC structures on controlling soil erosion and improving soil fertility. Finally, the different factors determine the adoption of conservation practices; challenges and limitations in building and repairing the structures, and commitment to replicate and repair the introduced structures were evaluated.

### **3.3.1.3. Field Observation**

Direct observation is one of the important methods of primary data collection (*Ep Ective Data Collection*, 2000). It helps to generate ideas helpful to modify questionnaire for survey, group discussion and key informant interview and to acquire information about the physical setting of the area. These observations was take farmers to assess what they did to conserve the soil and water, erosion status, the problems face them on their fields and measure they take to mitigate the problems. The data were also being obtained from primary sources mainly related to adoption behaviour and assessment of farmers' awareness to the SWC practice through observation. In the sampled kebeles, household heads that adopted and non-adopted was identified during field observations. Adopters who have physical SWC structures on their farmland and those who have not physical SWC structures on their farmland can be identified as non-adopters.

## **3.3.2. Quantitative Data Sources**

### **3.3.2.1. Household interview**

Household interview was a typical method to collect primary data from the sample households. A structured interview questionnaire that had involved both closed and open-ended questions were prepared and used to generate data from the respondents. Household survey was conducted through face-to-face interview of the respondent. Household heads were appropriate respondents for the questionnaires designed for the survey. The issues to be addressed in the questionnaire encompass fundamental information that includes socioeconomic characteristics, the cause and consequences of soil erosion, seriousness of soil erosion problems, types of built SWC structures, recognized effects and advantages of built physical SWC structures, and favourable situations at HHs level that support building or rebuilding of the physical SWC structures. In addition, challenges in building and repairing the physical SWC structures, limitations of the

SWC structures and the factors that determine the adoption and repair of SWC structures were considered.

### 3.3.2. Sample Size Determination

Essera woreda has 26 kebeles, and 3 municipalities. The woreda has total population of 64,950 people with 12, 159 household heads (HHs). For the assessments of farmers' adoption of physical SWC and their influencing on adoption based on PSNP report, three kebeles (Arus Angala, Shada Tela and Senget) was purposely selected. They respectively represent best, medium and low performing kebeles with regard to physical SWC (Challa et al., 2016).

The sample size was determined using a probability proportional to sample size precision technique used hand calculation method (Challa et al., 2016), which was given by;

$$N_o = \frac{t^2 p(1 - p)}{d^2} \dots \dots \dots (3.1)$$

$$n_1 = \frac{n_o}{1} + \frac{n_o}{N} \dots \dots \dots (3.2)$$

$n_o$  = the desired sample size when population is greater than 10,000

$n_1$  = No. of samples size when the population < 10,000

$t$  = 95 percent confidence

$p$  = 0.1 proportion of population to be included in sample,

$N$  = total number of population

$d$  = degree of accuracy desired (0.05).

The result from above formula 92, 72 and 82 HHs respectively from Arus Angala, Shada Tela and Senget equal distributed and were selected by quota and random sampling technique from a list of Kebele farmers in the watershed and out of watershed.

**Table 1:** Sample size distribution selected sampled kebeles

No	Kebeles	Total number of Households	Sample size
1	Arus Angala	274	92
2	Shada Tela	240	72
3	Senget	260	82
Total		774	246

### 3.3.3. Selecting Factors Affecting Physical SWC Practices

For selecting factors affecting adoption of physical SWC, literature consultation and personal experience in the watershed were dominantly considered. Its data were generated through semi-structured questionnaires administrated to the sampled respondents through face-to-face interviews. Factors expected to influence the adoption of SWC technology such as demographic characteristics (sex, age and family size), socioeconomic variables (education and livestock size), physical variables (farm size, plot numbers and location of plots) and institutional factors (access to training and agricultural extension) were gathered. These variables were selected based on an exploratory survey, literature review, personal observation, group discussions and key informant's interview in study watershed. Previous studies in different part of globe identified factors that determine the adoption of SWC measures included demographic, socio-economic, institutional and physical factors (Challa et al., 2016). A set of qualitative and quantitative variables were used to model factors driving adoption of SWC and the response variable was a binary variable, which was assigned by coding. Finally, binary regression modelling, which is also discussed below in detail was used to produce an explanatory model of factors driving adoption of SWC in the study area. All the data were computed using SPSS (Statistical Package for Social Sciences) version 16.0.

### **3.3.4. Data analysis**

Based on data obtained from laboratory Soil and water conservation structure (soil bund, soil bund combined with grass strip and adjacent non-conserved farm plots and slope gradient was used as independent variables and the soil parameters as dependent variables. The significance difference of parameters of soil property due to effects of soil bund and soil bund with grass strip compared with adjacent non-conserved plots was tested by using one sample t-test. Because we want to know whether our sample comes from a particular population but we do not have full population information available to us. The slope gradients and location between bunds was tested using analysis of one way ANOVA at  $P \leq 0.05$  level of significance. Soil properties with significant differences among the landscape positions and relative location in the watershed were analyzed for the significance of mean differences in relation to landscape positions and watershed locations separated by the Least Significant Difference.

The data collected in the HH survey was analyzed by one sample t- test to know the relationship between the dependent and independent variables. That was helpful to compare the mean of adopters and non-adopters of soil and water conservation measures with respect to continuous variables such as age, farm size, farm slope, numbers of farm, education and number of livestock farmers owned, access of training and access to extension services.

### **3.4. Soil Laboratory Analysis**

The collected subsoil samples from five corners of the delineated plot were mixed to make a single composite sample for laboratory analysis. It was then air-dried, grinded, and passed through a 0.5 mm sieve before the laboratory analysis. Samples for organic carbon and total nitrogen analysis were further sieved by a 0.5 mm sieve. Selected soil physico-chemical properties such as soil texture (soil particle size proportions), bulk density, soil moisture content, total nitrogen, organic carbon, available phosphorus and cations exchange capacity were analysed using standard laboratory procedures at Southern National Regional State Agricultural Research Centre soil laboratory and Hawassa University Main campus Soil Laboratory.

The core soil samples were used for determinations of soil moisture content and bulk density. Whereas, the disturbed soil samples were used for the analysis of soil texture, Soil texture fractions (sand, silt, and clay contents) is obtained by sieving and decantation procedures

according to (Challa et al., 2016). Soil bulk density is determined by the soil core method which is the ratio of oven-dried mass of soil to core volume (Challa et al., 2016). Soil Moisture contents, wet soil samples was weighed and placed in an oven at 105°C for 24 hours till constant weight attainment and then the weight of dry samples was measured. The following formula (Challa et al., 2016) was used to calculate the soil moisture content for every sampling period using gravimetric method.

$$SMC = \frac{W_w - W_d}{W_d} * 100\% \dots \dots \dots (3.3)$$

Where: *SMC* = Soil moisture content on mass basis (%)

*W<sub>w</sub>* = Weight of the wet soil (g),

*W<sub>d</sub>* = Weight of the dry soil (g)

The volumetric soil moisture content,  $\theta$  (%) was determined by considering the density of the soil water as 1 g/cm<sup>3</sup> ( $\rho_w$ ).

Where: *W* = soil moisture content on mass base (%)

$\rho_b$  = bulk density (g/cm<sup>3</sup>) of the soil.

Soil chemical properties were determined using procedures recommended for each property. Soil organic matter (SOM) was determined by the wet combustion procedure of the Walkley and Black method (Challa et al., 2016). Soil TN was measured after sulphuric digestion following the Kjeldahl distillation process (Challa et al., 2016). Soil pH was determined by a pH meter using a 1: 2.5 soil: water ratio (Challa et al., 2016). Available phosphorus was determined using the Bray II method (Challa et al., 2016). Cation exchange capacity (CEC) was determined by the ammonium acetate (pH 7) method using the percolation tube procedure (Challa et al., 2016). The NH<sub>4</sub>O process determined the exchangeable bases and cation exchange capacity (CEC). The Ca<sub>2</sub><sup>+</sup> and Mg<sub>2</sub><sup>+</sup> were determined by the atomic absorption spectrophotometer, whereas Na<sup>+</sup> and K<sup>+</sup> were determined by the flame photometer procedure.

### 3.5. Farmers Adoption on Construction Physical SWC

#### 3.5.1. Sampling Techniques

The sample size for household survey with large population is calculated by using the following formula to estimate the target group from the population in the study area. To determine the Sample size from the total households, we can use the categorical data by using Yamane formula (1967:886) with the acceptable margin of error 5%.

Then the sample size of households is 
$$n = \frac{N}{1+N(e)^2}$$

Where:  $N$  is the total number of households in the sampled study area.

$e$  is the margin of error = 0.05 or 5%

$n$  is the sample size of households in the study area

Thus the total number of households in the study area is 774 households

$$n = \frac{774}{1+774(.05)^2} = n = \frac{774}{1+2.15} = 246 \text{ households} \dots \dots \dots (3.4)$$

The procedure for taking each sample size from the population, were first the entire population ( $N$ ) were arranged in a classified sequences, the sample size ( $n$ ) was selected, the interval ( $k$ ) between two samples were calculated, sampling interval was added to the chosen random number to add the next member to a sample and repeat this procedure to add remaining member of the sample. Accordingly:

$$K = \frac{N}{n} = \frac{774}{246} = 3.15 = 3 \dots \dots \dots (3.5)$$

Therefor every 3<sup>th</sup> household from the sample were chosen until reach to expected total sample size. Based on the equation, 1, the sample sizes of surveys were 246.

**Table 2:** Distribution of sample size of respondents by kebeles.

No	Names of kebeles	Total household	Sampled household size	Sampling Techniques
1	Arus Angala	292	92	Random sampling
2	Shada tela	221	72	Random sampling
3	Senget	261	82	Random sampling
	Total	774	246	

During household survey, socioeconomic data was collected through a semi-structured questionnaire. Data and information on their perception of farmers on trends of SWC, changes as result of practicing physical soil and water conservation and farmers' adoption on constructed physical soil and water conservation structures was collected.

## CHAPER FOUR

### 4. RESULTS AND DISCUSSIONS

#### 4.1. Soil Physico-chemical Properties Affected by Soil Bund and Grass Strip Combined with Soil Bunds

##### 4.1.1. Soil Particle Size Distribution

Soil particle size fraction of sandy and clay show significant difference ( $P < 0.05$ ) between in with soil bund, grass strip and both soil bund and grass strip. The silt is did not show significant difference between in with soil bund, soil bund with grass strip and un-conserved (Table 3). However, there was a higher mean value of sand content was observed in without soil bund (25.71%) in upper slope, and the lowest was in with soil bund (24.77%) in middle slope and soil bund with grass strip (24.51%) in middle slope. The average silt content of the soil constituted in with soil bund, soil bund with grass strip and without soil bund, although a relatively slightly higher value was observed in the with soil bund and soil bund with grass strip. The clay content of the soil constitutes the high mean value clay content in with soil bund (41.55%) in middle slope and soil bund with grass strip (42.35%) in lower slope than that of without soil bund (32.68%) in middle slope. This is in line with the study of (Challa et al., 2016), who reported the highest mean value of clay contents in the conserved plots than in the non-conserved plots. However, the mean value of sand content was relatively greater in non-conserved (38.71%) farm lands than in the conserved farm lands (with soil bund 24.77% and soil bund with grass strip 24.51%). This finding also agrees with previous report (Challa et al., 2016). This might be due to fewer contents of organic matter that minimize the sandy aggregates to contain moisture (Table 4 & 5). The soil with no management practice is subject to soil erosion and removal of finer soil fraction with runoff water. Accordingly, the texture of soil with conservation practices was better (clay loam) compared to none conservation practice (sandy clay loam). The soil textural class of the site falls under clay loam which is the favourable textural class for agriculture. The soil textural fractions of sand and clay showed significant variation with ( $P = 0.0024$ ) and ( $P = 0.002$ ) respectively while silt fractions did not show significant variations under treatment (Table 3). On the other hand, the silt contents of the recorded results from the areas were non-significant ( $p > 0.05$ ) between conserved and non-conserved with SWC structure (Table 3). This

result was in agreement with (Challa et al., 2016), who found a higher mean silt proportion in woodland and fallow land than on cultivated land without soil bunds.

#### **4.1.2. Effect on Bulk Density**

The mean value of bulk density in soil bund, grass strip and both soil bund and grass strip was  $1.14\text{g}\cdot\text{cm}^{-3}$ ,  $1.16\text{g}\cdot\text{cm}^{-3}$  and  $1.19\text{g}\cdot\text{cm}^{-3}$  respectively). It showed that the bulk density was higher in the without soil bund than in the with soil bund, soil bund with grass strip and the difference was statistically significant (Table 4). This might be due to soil bulk density increase with subsurface compaction and also due to the presence of significantly higher organic matter and moisture availability differences in with both soil bund and soil bund with grass strip farms. The removal of uppermost soil organic materials by runoff might be the reason for the observed high bulk density value in the conserved farm plot than its non-conserved farm plot.

It is obvious that in the non-conserved cultivated plots the remnants of plants, crop residues, animal dung and other accumulations can be easily washed down by rainfall runoff particularly in the study area. As a result, variations in presence of these organic materials in the soil can create differences in the bulk density of the soil. The finding is in agreement with (Challa et al., 2016), who reported that the mean value of bulk density is conserved areas with SWC practice was lower than that of un-conserved areas mainly due to the decomposition of plant biomasses. (Challa et al., 2016) also, found higher bulk density in untreated farmland than the conserved farmland in Ethiopia. (Challa et al., 2016) described soil bulk density has an inversely proportional relationship with soil organic matter.

The former had significantly lower ( $P < 0.05$ ) bulk density, penetrometer resistances and smaller aggregate sizes but had significantly higher ( $P < 0.05$ ) soil water content and retention properties. Within the grass species however, the soil with grass strip had better properties than that under natural grass (Materechera, 2010).

The non-conserved plot was found to exhibit significantly the highest mean value of bulk density than plots treated with SWCPs. The significant effect of SWCPs on bulk density was observed ( $1.14\text{ g/cm}^3$ ) in the soil bund + grass strip + slope gradient where bulk density was higher in the non-conserved plot ( $1.19\text{ g/cm}^3$ ). This could be attributed to the presence of significantly higher organic matter as a result of conservation practices (Tigest and Getachew, 2018). Similar finding reported that, Bulk density (BD) of the soil significantly differed between with and without grass

strip treatments ( $P < 0.001$ ). The bulk density was higher for the without grass strip soil ( $1.19 \text{ gm/cm}^3$ ) than for the with grass strip soil ( $1.17 \text{ gm/cm}^3$ ) (Abdisa et al., 2013).

Statistical analysis revealed soil bulk density was significantly ( $P = 0.05$ ) improved with the implemented rehabilitation practices where the highest value ( $1.25 \text{ gm/cm}^3$ ) was observed at degraded grazing land and lowest at land treated with grass strip and soil bund. Demelash & Stahr, (2010) also indicated that decrease in bulk density on cultivated soils in the lower than in the higher slope gradients.

The soil bulk density (Bd) didn't show a significant variation with treatments although higher mean value was observed in control farm land as compared to the 5 and 10 years aged soil bund based SWC structures. The soil bulk density also showed significant difference ( $P = 0.0451$ ) with the slope gradients. The results indicate that soil Bulk density has a direct relation with slope gradient which might be attributed to the corresponding decline in soil organic carbon content with the increase in slope gradient/steepness (Worku et al., 2012).

#### **4.1.3. Effect on Soil moisture content**

A soil moisture content of the study areas has shown significant, difference ( $P \leq 0.05$ ) between with soil bund, soil bund with grass strip and without soil bund with SWC measures (Table 4). The highest mean value of SMC recorded from soil bund and soil bund with grass strip with SWC was 18.26% and 18.85% whereas, the mean value of SMC for without soil bund was (16.32%) which may be a result of water conservation structures that reduces runoff and increases infiltration and soil moisture content. Finding is in line with that of (Challa et al., 2016) who stated that moisture contents of farms land with SWC practices was higher than that of cultivation farms without any conservation structures. The area having larger organic matter contents has the ability to capture moisture.

**Table 3:** Effects of Integrated Use of Soil bund, Soil bund combined with grass strips and Without Soil bund under three slope gradients on selected Soil physical properties

Treatment SWC	Slope gradient	Sand (%)	Clay (%)	Silt (%)	Textural class	BD (gm/cm <sup>3</sup> )	MC (%)
Soil bund	Upper (3-8%)	25.71	40.46	34.16	C	1.25	18.26
	Middle (8-15%)	24.77	41.27	33.96	C	1.007	14.58
	Lower (15-30%)	26.76	40.57	34.67	C	1.115	15.30
Soil Bund With Grass	Upper (3-8%)	22.51	42.35	41.81	C	1.16	18.85
	Middle (8-15%)	23.87	41.67	39.34	C	1.17	17.88
	Lower (15-30%)	24.71	40.56	39.01	C	1.14	17.51
Un- conserved	Upper (3-8%)	38.71	32.68	31.35	C	1.23	14.82
	Middle (8-15%)	38.71	32.68	30.75		1.12	15.12
	Lower (15-30%)	38.71	32.68	30.43		1.15	16.32
LSD (0.05)		NS	NS	NS		NS	4.69
CV		4.923	2.122	4.592		5.24	5.27
P value		0.024	0.002	0.006		0.0015	0.010

**Note:** - *Bd* = bulk density, *MC* = Moisture content, *C* = Clay, *CV* = Coefficient of variation, *LSD* = least significant difference. Means followed by different letters in a column differ significantly and those followed by same letter are not significantly different at  $p < 0.05$  level with respect to slope gradient.

#### 4.2. Effect of soil bund and soil bund with grass strips under three slope gradient on selected soil physical property

Effect of soil bund and soil bund with grass strips on selected soil physical properties indicated that, there was no significant variation ( $p < 0.05$ ) with respect to conservation treatment in the soil textural fractions of sand, silt and clay this may be due to weathering, soil weathering is a relatively slow process, texture remains fairly constant and is not altered by soil conservation practices (Table 3). The result is in agreement with Yonas et al. (2017) who reported that, the non-significant difference in soil texture may be due to the young age of SWC practices that cannot make significant change on soil weathering. Conservation practice soil bund, soil bund

with grass strips and un-conserved farmland have similar effect on soil textural fraction. The effect of conservation practice on Soil bulk density and soil moisture content varied significantly ( $p=0.0001$ ) in farm land conserved with soil bund and soil bund with grass strips as compared to non-conserved control farm land (Table 3). The soil bulk density (Bd) showed a significant variation with respect to treatments, although the higher mean average value was observed in non-conserved control farm land ( $1.25\text{gcm}^{-3}$ ) as compared to the conserved farm land of soil bund ( $1.13\text{gcm}^{-3}$ ) and soil bund with grass strips ( $1.09\text{gcm}^{-3}$ ) conservation practice. The achieved soil bulk density improvement is due to organic matter addition from Treatment Soil properties

Treatment	% Sand	% Silt	% Clay	Textural Class	BD/ $\text{gcm}^3$	MC
non-conserved	38.71	32.68	31.75	clay	1.19	14.82
soil bund	24.77	41.55	33.96	clay	1.14	16.83
soil bund with grass strip	24.51	42.35	41.81	clay	1.16	17.88

LSD (0.05) of treatment value was without MC the all the treatment was NS and MC was 4.69. The CV of treatment value was 4.923, 2.122, 4.592, 5.24 and 5.27. The plants, reduction of physical soil loss, and exclusion of grazing practices and human interference. The result is confirmed by (Tamrat et al., 2018) and S.Karl., (2010) also reported that soil under non-conserved treatment was found to exhibit higher soil bulk density than treatments by SWC structure. Further, soil bund and soil bund with grass strips had similar effects on soil bulk density. Soil moisture content showed significant variation at ( $p=0.0001$ ) with respect to treatment. The Higher mean average value of soil MC was observed soil bund 18.26% and soil bund with grass strips 18.85% in the farm plots with conserved farmland SWC measures as compared with control farm land plots 16.32% (Table 3). This is because of the conservation practice of soil bund and with grass strips root systems holds soil particles, improves structure, and conserves moisture through trapping conventional eroded sediment, minimizing erosion, evaporation, surface runoff and modifying soil microenvironment. In un-conserved farm land there were open land which exposed to degradation; erosion and evaporation, that factor in non-conserved control farm land reduce soil moisture. So soil moisture content is lower in non-conserved control farm land when compare to conserved farm land of soil bund and soil bund with grass strips conservation practice. This is because of the conservation practice with soil bund and soil bund with grass strips result in reducing run-off velocity and enhanced water infiltration during the rains. The result is agreed with (Solomon et al., 2018) who reported, the root system of soil bund with grass strips holds soil particles, improves structure, and soil water

retention through minimizing erosion and evaporation. Soil bund and soil bund with grass strips conservation practice have similar effect on soil moisture while non-conserved control farm land has low soil moisture content. The result in line with report of (Lemma et al., 2015).

#### **4.2.1. Effect on Soil pH**

The mean values of the pH of the soil at the soil bund (5.45) and soil bund with grass strip (5.89) were higher than that of the without soil bund (5.24; Table 4). The ANOVA result revealed that the mean difference of soil pH between soil bund, soil bund with grass strip and without soil bund was not significant. The result was in agreement with (Challa et al., 2016) who reported non-significant but relatively higher acidity levels in the non-conserved than conserved lands. This may be attributed to the high annual rainfall in the plots without soil bund that result in the leaching of the cations and leaves exchangeable complexes.

The mean value of soil pH was lower in non-conserved farmland as compared to conserved farms due to leaching of cations in controlled farm plots for the absence of SWC practiced. The relatively lower mean value in non-conserved may be related to excessive rainfall coupled with dissected topography, leaching, and discharge of important soil nutrients, whereas the greater pH value in conserved is related to the reduction of the removal of important minerals. However, on the other hand, (Challa et al., 2016). Found significantly lower soil pH value (higher acidity) in the conserved than their non-conserved counter parts in the Dalta sub- watershed.

They further explained that the high magnitude of erosion in non-conserved land leaches soluble bases, minerals and subsequently contributes to soil acidity, whereas the less removal of soil organic matter in the conserved land improves the pH value of the soil. However, according to the acidity rating of (Challa et al., 2016) the soil under both the SWC treatment and untreated plots was medium acidic. A similar finding was reported by (Challa et al., 2016), in which the lowest value of soil pH in cultivated land in un-treated with conservation structures which can be due to the result of high microbial oxidation which produce organic acid, soil erosion processes as well as basic cations depletion.

#### **4.2.2. Effect on Soil Organic Matter (SOM)**

Analysis of variance showed that soil organic matter content was significantly varied between the treatments with soil bund, Soil bund With grass strip and without soil bund ( $p \leq 0.039$ : Table 4). The highest mean value of soil organic matter content in soils under Soil bund With grass strip was recorded which is (1.78%) than the content under with soil bund farm land plots which is (1.66%) and without Soil bund farm land plots which is (1.59%) less than the conserved farm plots. This might be attributed to accumulated and retained OM due to SWC measures undertaken in the watershed, whereas the lowest OC may be attributed to the loss in the form of decaying leaves, stems, roots and due to SWC practice to reduce surface runoff, soil loss, and retain water that enhances crop growth and contributes to SOM input from surface soil due to a lack of physical barriers. Likewise, land with SWC measurement significantly improved soil organic carbon compared to farm land without SWC (Challa et al., 2016).

This might be attributed to accumulated and retained OM due to physical SWC structures undertaken in the plot, whereas the lowest OM may be attributed to the loss due to absence of physical SWC structures. The result was in agreement with the finding of (Challa et al., 2016) who reported that soil organic carbon content of conserved plot was higher when compared to the non-conserved plot.

As organic matter is the main supplier of nutrients in low-input farming systems, a continuous decline in the soil OC content of the soils is likely to affect the soil productivity and sustainability. The availability of soil organic matter can be an important symbol of soil quality because it can positively affect other most soil functions (Challa et al., 2016). However, the mean values of organic carbon for CP and NCP were rated low (Challa et al., 2016). This can be primarily attributed to strong soil erosion, Continuous cultivation, harvesting crop residues, and animal Dung (Challa et al., 2016).

#### **4.2.3. Effect on Total Nitrogen**

The mean of total nitrogen content in soil bund with grass strip plots was significantly higher (0.32%) than the content with soil bund plots (0.26%), and without soil bund farmland plots (0.18%) lower than that of conserved plots, which has also shown the increased nutrient content soil bund with grass strip and with soil bund compared to without soil bund practices on adjacent

farmlands (Table 3). In addition, the increased nutrient availability under soil bund with grass strip and with soil bund could be related to the higher amount of SOM in them. This might be related with low level use of nitrogen containing imputes, plant residues, and manure (Challa et al., 2016). This is due to the area being covered with structures treated with biological measures that are used to conserve soil such as Acacia spices and tree plantation which is used as fodder and has a nodule on their roots that are used in fixation of nitrogen. The result is also in agreement with the report of (Challa et al., 2016) who stated total nitrogen in conserved lands of the Delta sub-watershed was higher than the total nitrogen content in the equivalent sites without conservation measures.

#### **4.2.4. Effect on Available Phosphorous (Av. P)**

The experimental results of ANOVA showed that Av.P (ppm) result shown significant variation of  $P < 0.05$  between the treatments (soil bund, soil bund with grass strip and without soil bund, Table 3). With regard to soil bund, soil bund with grass strip and without soil bund the maximum mean value (13.89 ppm) was recorded for soil bund with grass strip and the minimum (13.08 ppm) was observed in without soil bund plot. Although, the soil in the area is deficient in available phosphorous content, better availability was observed at conserved soils. This might be due to the relative effect of SWC on runoff and soil loss in the conserved soils. Similarly, high phosphorous content was observed in the conserved plots than that of non-conserved plots (Challa et al., 2016). These were perhaps due to the difference in the past land degradation resulting from continuous cultivation and soil erosion, also it might be due to the fact that soil of the study area was within the of moderately acid to slightly acidic 6 to 6.5 that the soil with a  $P^H$  of less than 6.5 commonly has deficiencies of phosphorous. This study is in line with the findings of (Challa et al., 2016) who reported that most of the Ethiopian soils are deficient in available phosphorus concentration due to low pH (acidic), the intensive cropping system, imbalanced use of fertilizer, and nutrient mining.

#### **4.2.5. Effect on Cation Exchange Capacity (CEC)**

The result of ANOVA presented that the soils had statistically significantly varied with treatments ( $P \leq 0.05$ ), with soil bund, soil bund with grass strip and without soil bund ( $P \leq 0.05$ ) (Table 3). The higher mean value of CEC recorded from soil bund with grass strip (19.21meq/100g) than without soil bund farm plots (17.91meq/100g) this might be due to soil

acidity minimized for the leaching of cations ( $H^+$ ) in soil bund with grass strip farm plots (Table 3). This finding agree with (Challa et al., 2016) who reported the mean value of CEC recorded from treated with SWC measures was greater than that of the CEC recorded from non-conserved farm plots measurement detects the amount of ions in the solution; the greater the number of cations, the greater the conductivity reading. This could be due to the effect of management measures that reduced the removal of sediments and limited leaching produced to a certain degree of higher sandy content and CEC in the soil bund with grass strip. Our finding was consistent with the study results of (Challa et al., 2016) who observed higher CEC content in conserved plots than non-conserved lands.

**Table 4:** Soil pH, TN, CEC, OM, exchangeable cations between soil bund, Soil bund with grass strip and Non-conserved at 0 to 20cm soil depth Delta watershed.

variable	pH	TN (%)	CEC Cmol/Kg	SO (%)	K <sup>+</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	Av.P (ppm)
Soil bund	5.45	0.26	18.04	1.66	1.41	23.9	7.21	0.97	13.45
Soil bund with grass strip	5.24	0.32	19.21	1.78	1.51	25.56	7.86	0.99	13.89
Un-conserved	5.89	0.18	17.92	1.59	1.39	10.92	6.26	0.81	13.08
P value	0.94	0.005	0.014	0.039	0.001	0.32	0.13	0.03	0.001

#### 4.3. Effect of Soil Bund and Soil Bund Combined with Grass Strip under three Slope Gradient on Selected Soil Chemical Property

The effect of slope gradient indicated that, variations in soil chemical properties were also statistically significant ( $p \leq 0.05$ ) under different slope positions. The overall mean value of soil pH was found to be low ( $5.22 \text{ ppm} \pm 0.15$ ) in the Lower (15-30%) slope and high ( $5.88 \text{ ppm} \pm 0.13$ ) in the Upper (3-8%) slope gradient (Table 6). This might be due to the influence of the slope gradient through its effect of facilitating soil erosion and the leaching of soluble base cations, which in turn increased the concentration of  $H^+$  ion in the soil solution and reduced soil pH. This result agreed with the findings of Mulat et al. (2020) as the slope gradient increases, soil pH decreases. OM also showed a statistically significant variation ( $p < 0.05$ ) between the different slope gradient (Table 6). Higher OM was recorded at upper (3-8%) slope when

compared to lower (15-30%) slope gradients. OM showed an inverse relationship with slope gradient; i.e., as slope gradient increases, OM declines. This might be associated with the removal of organic matter from the higher slope areas and its subsequent deposition in the lower slope areas via water erosion. The result agrees with Mathewos et al. (2018) who found that, the organic matter removal from the upper slope to the lower slope positions. The highest amounts of soil TN, Av.P, and CEC were observed at lower slope gradients when compared to upper slope gradients (Table 6). This may be due to soil organic matter better at lower slope gradient and positively correlated to total nitrogen, available phosphorus and cation exchange capacity.

**Table 5:** Effect of slope gradient on selected soil pH, OM, TN, Av. P and CEC

Slope gradient	Soil Chemical properties				
	pH(1:25)	% OM	% TN	Av.P(ppm)	CEC(meq /Kg)
<b>Upper (3-8%)</b>	5.22±0.15	2.28±0.24	0.15±0.21	5.61±0.18	26.31±0.17
<b>Middle (8-15%)</b>	5.42±0.19	2.52±0.17	0.19±0.26	6.14±0.21	27.12±0.23
<b>Lower (15-30%)</b>	5.88±0.13	2.89±0.14	0.25±0.23	7.14±0.16	29.81±0.20
<b>LSD (0.05)</b>	0.180	0.164	0.011	0.430	1.108
<b>CV</b>	3.12	6.04	5.58	4.81	3.73

#### 4.4. Correlation Analysis between Studied Soil Variables

Soil organic matter was highly positively correlated with, TN, Av.P, CEC and soil pH ( $r = 0.99^{***}$ ), ( $r = 0.89^{***}$ ), ( $r = 0.92^{***}$ ), ( $r = 0.59^{***}$ ) respectively, while it was highly negatively correlated with soil bulk density ( $r = -0.81^{***}$ ) (Table 8). This could be attributed to the accumulation of bases that were assumed to have been effect of biological SWC practice (Soil band and Soil band with grass strips) that reduce erosion and soil loss and improve the overall soil properties or health. This is confirmed with the finding of Hall R. (2008). Soil organic matter is considered to be a storehouse of numerous plant nutrients, and influences a number of other soil properties. The correlation indicates may be when decomposition is high, the soil organic matter is better as a result total nitrogen become high because of the biological SWC practices are nitrogen fixer.

The presence of better TN under conserved farmland with Soil band and Soil band with grass strips may be due to attributed to the presence of high OM, clay fraction and better CEC. Hence, it is likely that much of the nitrogen content of the soil is largely released into the soil from the organic fractions of the soil. SOM positively correlated to soil pH this, could be due to microorganism found in Soil band and Soil band with grass strips faster the decomposition rate, which improve soil organic matter and reduce soil acidity. Similar finding agree that deposition of basic cations and soil organic matter contributes for the improvement of soil pH (Tekalign, 2011).

SOM content highly negatively correlated with soil bulk density ( $r = -0.81^{***}$ ). The presence of Soil band and Soil band with grass strips trap and minimize soil loss and relatively higher clay fraction and OM content this might be lowers soil bulk density. Finding in agreement show that, Soil organic matter improves soil aggregate, which influence total porosity of the soil that negatively affects soil bulk density Mathewos et al. (2018). Other author also reported that low bulk density indicated a favourable condition for a better root growth, improved aeration, and increased infiltration, which improves the productive capacity of the agricultural land (Gupta 2010). The negatively correlated with soil bulk density could be due to the effect of biological SWC practice and slope gradient on the soil moisture storage capacity and biomass production. This is in agreement with Tamrat et al. (2018) reported that, the enclosure of woody legumes and other plants in land management activities reduces soil bulk density, increase soil organic matter, granulation porosity, and prevents soil loss. Other authors reported the presence of intense grazing practices leads to soil compaction and increase erosion (Abinet, 2011). Soil bulk density is high when the land is non-conserved because of low pore space between soil particles, washing due to erosion, human and animal trampling makes the soil more compaction as a result soil in un-conserved plot have higher bulk density compared to conserved plot. This reason makes SOM and soil bulk density negatively relationships. In line with this; (Achalu et al. (2012) revealed that organic matter decreases bulk density through its positive effect on soil aggregation.

The implemented biological SWC practices conserved farmland with (Soil band and Soil band with grass strips) are significantly contributing to soil fertility improvement because the small increase in soil OM has a role for soil fertility then, un-conserved adjacent control farmland.

**Table 6:** Correlation on Soil Physico-chemical Properties

	Sand	Clay	Silt (%)	Bd (g·cm <sup>-3</sup> )	Mc (%)	pH	OM	TN	Av.p	CEC
Sand	<b>1</b>									
Clay	0.13 <sup>ns</sup>	<b>1</b>								
Silt (%)	-0.70****	-0.78****	<b>1</b>							
Bd (g·cm <sup>-3</sup> )	-0.82****	-0.39 <sup>ns</sup>	0.79****	<b>1</b>						
MC (%)	0.89****	0.27 <sup>ns</sup>	-0.74****	-0.91****	<b>1</b>					
pH	0.72****	0.41 <sup>ns</sup>	-0.72****	-0.69****	0.58*	<b>1</b>				
OM	0.78****	0.27 <sup>ns</sup>	-0.67****	-0.81****	0.95****	0.89****	<b>1</b>			
TN	0.78****	0.20 <sup>ns</sup>	-0.62****	-0.79****	0.94****	0.45 <sup>ns</sup>	0.99****	<b>1</b>		
Av.p	0.77****	0.374 <sup>ns</sup>	-0.73****	-0.75****	0.84****	0.57****	0.89****	0.89****	<b>1</b>	
CEC	0.72****	0.41 <sup>ns</sup>	-0.73****	-0.83****	0.89****	0.58****	0.92****	0.91****	0.93****	<b>1</b>

Note: - \*\* significant at the 0.001 level, \* significant at the 0.05 level; MC=moisture content, BD=bulk density, TN=total nitrogen, OM=organic matter and CEC=cation exchange capacity.

#### **4.5. Farmers Adoption on the using Grass Strip Combined with Soil Bunds as Soil Erosion Conservation Strategy in Study Area**

A large number of indigenous SWC measures are practiced by farmers in the study area. They have been using different indigenous SWC measures before the introduction of new SWC technologies minimize the rate of soil erosion on their plots of land. These measures are traditional ditches (boyi), traditional waterway (Gorf Mekided), mixed cropping, contour ploughing, crop rotation and dib. It was the farmers who reported that the indigenous soil and water conservation practices were flexible, fitting into the farming systems, cheap and simple to construct. However, the majority of farmers indicated that the indigenous SWC measures are less effective than the introduced ones in tackling the soil erosion problem. The SWC technologies have been implemented in the study area since 2003 with the objective of conserving and rehabilitating the degraded lands and improving the livelihood and food security situation of the households. It follows the Local Level Participatory Approach (LLPPA), which is a bottom up participatory approach using various PRA (Participatory Rural Appraisal) techniques and watershed management principles, which encourages land users to develop their own plans for land rehabilitation and assets creation. This approach is also assuming to integrate indigenous SWC practices but it was found out that this was not given much emphasis on indigenous SWC measures. The SWC technologies use food for work incentives. However, almost all farmers (99%) confirmed that they would continue to carryout SWC measures in their plots of land in the event SWC activities were support. This partly indicated that the sustainability of SWC activities in the study area. The SWC technologies newly introduced in the study area are soil bunds; soil bund combined with grass strip, stone bunds, hillside terrace and cut off drain. These are physical soil conservation measures. Farmers had a favourable perception about the introduced SWC measures. They stated that the dominantly perceived benefits gained from using the introduced SWC measures are reduced soil erosion, increase in soil productivity, better growth of crops along the SWC structures and new land reclaimed along gullies. The introduced SWC measures seem to be accepted and widely practiced by farmers. They were implemented and using the introduced SWC measures in the rest of plots without using incentives. In addition, the majority of the sampled farmers did some maintenance work on the newly introduced SWC measures on their plots of land before they started ploughing. This indicates in part at least the sustainable adoption of the introduced SWC measures in the study area. The major pull factors

for adopting the introduced SWC measures on their plots of land were found to be perception of soil erosion as a critical problem, availability of labor, small land holding size, access to extension service, land tenure security, participation and positive attitude of farmers towards the introduced SWC measures.

#### **4.5.1. Farmers' Adoption to wards on Soil Erosion and SWC**

Despite farmer's awareness on soil erosion problems and government efforts, etc, farmer's adoption of the structures remain below expecting.

Reasons are site-specific and the commonly cited factor that positively influences the adoption process includes: formal education, frequency of extension agent visit area of cultivated land, access to information, slope of the land, perception of profitability, trust, ranking of soil erosion as a priority in agricultural production and membership in a farmers' association. Some socio-economic and biological components such as distance of plot from home, family size, high fertility, insure land tenure, shortage of labor and capital; problems of fitness of the SWC technologies, foregone land productivity and lack of short-term benefits are listed negatively influencing factors of the adoption.

The current SWC based watershed management activities which are carried out by various approaches including massive public participation, NGOs, Government organization, safety nets, etc, should intensively work on awareness of the land users so the rate of adoption can be improved. Technical support and monitoring should be strengthened to the appropriate structure, design and specification. Wherever, possible, biological measures such as enclosures, free and shrub planting and management, agroforestry, strengthening the structure with grass or shrub, etc., should be given priority due to their multiple and sustaining roles. Many cases studies indicated that biological measures and soil fertility management could improve effectiveness of the structure and soil fertility (Zougmore et al., 2002; Adimassuet el., 2012). The technical approach should also give due attention for livestock management which significantly creates conditions for soil erosion and damage of the built structures.

#### 4.5.2. Farmers' Adoption in Physical SWC Practices

In the study area, the majority of farmers had constructed and was maintaining physical SWC structures on their cultivated lands. In the low-potential areas of the study area, where the government has emphasized SWC structures, nearly all farmlands in the sample that required physical SWC structures had been terraced and were thus able to minimize the rate of soil erosion and improved ecosystem services. However, in the high-potential areas, where the emphasis was low, the achievements of physical SWC structures were below the anticipated levels. We found that lack of awareness of physical SWC structures' possible long-term benefits, low short-term economic benefits of SWC structures, and political factors significantly determine farmers' use of SWC structures. However, accessibility to the main road did not have significant impacts on the construction and maintenance of SWC structures. Therefore, a change in farmers' attitudes about SWC measures and their role in tentative soil erosion and related impacts are important in order to encourage the construction and maintenance of these structures.

**Table 7:** Farmers' adoption of SWC technologies.

Item description	Frequency	Percent (%)
<b>Did you know the introduced SWC technologies before?</b>		
Yes	54	67.2
No	23	30.2
<b>Who is responsible to construct and maintain the structures?</b>		
Community participation	24	28.4
Family labor	52	65.3
Financial incentives	1	1.4
Labor exchange	2	2.7
<b>What is your adoption judgment of SWC measures?</b>		
Very good	45	58.2
Good	31	43.4
Poor	1	1.4

#### **4.4.3. Benefits Obtained From Physical SWC Practices**

The survey results showed that 73.4% of sampled households were benefited (yield, moisture and soil fertility is increased) from practicing of physical SWC structures on their farmland, whereas 46.6% of respondents said that they were not benefited from practicing of SWC on their farm land. This implies that most of respondents were know the benefit of the SWC. The household benefited from the adaptation of SWC structures as they observed changes in soil fertility, land productivity and water holding capacity of soil also indicated that physical SWC practices were widely acknowledged as being effective measures in arresting soil erosion, moisture and as having the potential to improving land productivity.

#### **4.4.4. Problems of SWC Practices in the Delta Sub watershed**

Although there had been great efforts in SWC practice in Africa, including Ethiopia, land degradation especially soil erosion is still escalating from time to time (Gadisa & Hailu, 2020). This can be attributed to the in appropriateness of conservation practices, the inefficiency of experts, lack of awareness of farmers, land tenure relationships, and the like (Challa et al., 2016). The focus group discussion result revealed that more than 83% of physical SWC was implemented starting from December 15. In another way December is the intensive harvesting season in the study area, Hence, the SWC measures implementation program was overlapped with the intensive harvesting seasons in the area. In this regard, all respondents complained about the timing of SWC measure implementation. During key informant interview, development agents confirmed that during planning, SWC intervention, a top-down approach was pursued where woreda office of agriculture and natural resources tell them what they are going to do and the opportunity for the farmers and DA's in participating at all level of the planning the intervention was rare.

**Table 8:** Household perception on problems of soil and water conservation Structures in the Dalta sub-watershed.

Problems related to SWC	Farmers response to the problem	
	Frequency	Percentage
Reduce the size of farm land	53	19.87
Difficult to turn oxen	79	34.82
Labor intensive	94	34.31
Difficult to implement technically	58	21.23

Farmers in the study area asked to rank from the listed problems of physical SWC structures, including soil bund and soil bund with grass strip and they revealed as 34.31% labor intensive, 34.82% difficult to turn oxen, 21.23% difficult to implement technically and 19.8% said the structure reduces the size of their farm plot (Table 7). This result is supported by (Challa et al., 2016) who reported as, from the interviewed farmers, the majority reported that some conservation measures like bund, cut off drain and waterways were difficult to tillage, need much labor, need incentives to implement, difficult to implement and reduce farm size.

#### **4.4.5. Reasons of Damaging Physical Soil and Water Conservation on the Farm Land**

As respondent said 35.2% physical soil and water conservation structures that done on the farmland was completely or partially damaged because of hindered oxen ploughing, poorly designed construction and 30.2% of respondent said that structures were damaged, because of structures consumes space and put too much cultivable land out of production. Whereas 34.6% of respondents was not practicing of structures on their farmland. The most dominant problem for the farmers completely removing or partially removed the physical soil and water conservation from their farm land were hindered oxen ploughing, poorly designed and constructed, structures consumed space and put too much cultivable land out of production. On

the other hand, large livestock sizes can destroy the grass strip while grazing on the croplands after harvest. Because of this, smaller land and livestock holders use grass strips to stabilize soil bunds, minimize erosion and enhance soil productivity. This argues with the finding of (Challa et al., 2016) who stated that land and livestock holding size has a strong association with farmer's adoption on the uses of biological land management practices such as grass strips to minimize land degradation problems and enhances land productivity. This disagreement is arising due to the use of similar land management practice for lands under different conditions: already degraded land for restoration and stable cropland for maintaining productivity. Accordingly, the current study deal with the use of grass strips (land management) to preserve stabile croplands for sustainable production, while the former study deal with the use of land management practices to restore degraded land.

**Table 9:** Independent t-test on factors influence grass strip to stabilization soil bund

Dependent variables		Mean	S.D	t-test	Sig.
<b>Livestock holding (TLU)</b>	Grass strip user	2.84	1.03	-2.43	0.014
	Non- user	3.62	1.46		
	Soil bund user	3.18	1.36	-2.67	0.018
	Non- user	3.87	1.49		
<b>Land holding size (ha)</b>	Grass strip user	0.71	0.35	-3.21	0.001
	Non- user	1.03	0.52		
	Soil bund user	0.95	0.39	-3.56	0.003
	Non- user	1.21	0.58		
<b>Farming experience (year)</b>	Grass strip	28.63	11.02	1.38	0.155
	Non- user	25.23	10.43		
	Soil bund user	33.21	12.32	1.62	0.187
	Non- user	28.43	11.37		
<b>Family size (number)</b>	Grass strip user	1.34	0.72	0.14	0.832
	Non- user	1.54	0.78		
	Soil bund user	1.45	0.89	0.18	0.891
	Non- user	1.71	0.94		

**Table 10:** Basic household characteristics.

<b>Descriptive Statistics</b>					
<b>Item descriptions</b>	<b>N</b>	<b>Minimum</b>	<b>Maximum</b>	<b>Mean</b>	<b>Std. Deviation</b>
<b>Age of respondent</b>	246	25	75	45.23	10.53
<b>Family size</b>	246	2	13	5.34	2.12
<b>Landholding size (Ha)</b>	246	0.25	18	2.93	3.37
<b>Period of residence (years)</b>	246	8	64	33.15	10.11
<b>Livestock size</b>	246	0	31	6.45	5.72

**Table 11:** Socio-demographic characteristics of HHs in Dalta sub-watershed

<b>Descriptive Statistics</b>					
<b>Item description</b>	<b>Frequency (N = 246)</b>	<b>Percent (%)</b>	<b>Item description</b>	<b>Frequency (N = 246)</b>	<b>Percent (%)</b>
<b>Sex</b>			<b>Marital Status</b>		
<b>Male</b>	68	88.31	<b>Married</b>	8	3.7
<b>Female</b>	9	11.69	<b>Widow</b>	3	1.38
<b>Age (years)</b>			<b>Educational level</b>		
<b>&lt;30</b>	4	5.2	<b>Illiterate</b>	<b>Uneducated</b>	30
<b>30 - 40</b>	22	28.6	<b>Read &amp; Write</b>	10	13.0
<b>41 - 50</b>	18	23.4	<b>1 - 4 grade</b>	16	20.8
<b>51 - 65</b>	30	39.0	<b>5 - 8 grade</b>	16	20.8
<b>&gt;65</b>	3	3.9	<b>9 – 12 grade</b>	5	6.5
<b>Family size</b>			<b>Period of residence (years)</b>		
<b>0 - 2</b>	5	6.5	<b>&lt;10</b>	2	2.6
<b>3 - 5</b>	33	42.9	<b>11 - 20</b>	5	6.5
<b>6 - 8</b>	32	41.6	<b>21 - 30</b>	31	40.3
<b>&gt;8</b>	7	9.1	<b>&gt;30</b>	39	50.6

## **5. CONCLUSIONS AND RCOMMENDATIONS**

### **5.1. CONCLUSIONS**

The study revealed that, the use of Soil bund and Soil bund combined with grass strips as soil and water conservation practices in Dalta sub-watershed had been found beneficial in protecting the cultivated land from erosion and the corresponding soil nutrient depletion. Further, the results of the soil analysis showed that most of the soil physical and chemical properties had significant variations with respect to conservation practices and slope gradients.

Biological SWC practices (Soil bund and Soil bund combined with grass strips) are amazing types of grass species, which plays a vital role in reducing soil erosion, and restoring degradation of land through storing sediment, hold water and enhancing the water holding capacity of a soil. The farmlands treated with Soil bund and Soil bund combined with grass strips in the study area for the last five consecutive years have improved, soil pH, soil organic matter, total nitrogen, available phosphorus, and cation exchange capacity through minimizing erosion and adding organic matter in the soil. The study showed that when the slope gradient increases significantly increases soil Bulk density and sand content while SOM, total N, available phosphorous and cation exchange capacity were decreased.

Generally, the soil physical and chemical properties were better in farmland conserved with Soil bund and Soil bund combined with grass strips plots than the non-conserved adjacent control farmland and biological SWC practices (Soil bund and Soil bund with grass strips) are promising impact to rehabilitate degraded lands, erosion control, and sustainable watershed management and improve soil physical and chemical properties.

Based on results of the research carried out; the soil of an area which was treated by effects of integrated use of grass strip combined with soil bund splot has shown a significant physicochemical property improvement than the soil of the adjacent non-conserved land. It minimizes the bulk density of the soil relative to the non-conserved land thereby creates a conducive condition for the development of plants on the conserved land. The pH of the soil also able to increase which in turn facilitates the availability of major nutrients such as phosphorus in the soil of conserved land. Generally, the major macro-nutrients required for green plants such as the soil organic carbon, nitrogen, potassium and phosphorus concentrations in the rehabilitated lands which were maintained by various soil conservation practices were found to be significantly higher than the concentration in adjacent unmanaged degraded lands. The research

result indicates that the soil conservation practices have positive impacts in improving the fertility status of the degraded lands. And it addresses the problem of improper land use practices and maintains the productive capacity of the lands by minimizing the soil nutrient deterioration rate. Therefore it is mandatory to apply the integrated uses of soil bund and soil bund with grass strip in all agricultural land use types such as farmlands, grazing lands, coffee and private forestlands of the study area. The result of the study also indicated that integrated uses of soil bund and soil bund with grass strip practices can benefit farmers through restoring the productivity potential of the degraded land as well as improving its nutrient content. Consequently it is better if proper attention will be given to the practices by the government to achieve the transformational plan in agricultural sector.

Assess farmers' adoption of SWC technologies in Dalta sub- watershed of Omo gibe River Catchment, Ethiopia. The results indicated that almost all of the respondents perceived soil erosion as a serious land degradation. However, almost all of them confirmed that soil erosion can be controlled. The key causes of soil erosion that realized by them were deforestation due to agricultural expansion followed by farm land steepness. Soil erosion has resulted in the decline in land productivity, creation of rill and gullies on their farm land. Moreover, almost all of them are willing to adopt introduced SWC technologies and it has been perceived as the most efficient in arresting soil erosion. In Dalta sub-watershed, the majorities of the farmers have already known and practiced various types of introduced SWC technologies (Soil bund, Fanyajuu, cut-off drain, waterways, and afforestation) before the implementation of sustainable land management program. Besides frequent technical assistance, almost all of the respondents strongly believed that construction and maintenance of SWC activities is farmers' responsibility. Hence, almost all respondents (94.8%) expressed their willingness to continue maintaining the established structures with their very good adoption judgment of technologies. Therefore, farm-level adoption of technologies is the key element for the success of a watershed management intervention. However, the study finding showed that construction of introduced SWC technologies was time-consuming and high labour-demanding and needs frequent technical support for design construction for their sustainability. In addition to the investigation of farmers' adoption option, the technical specification of SWC technologies should be evaluated in terms of design and their effects on soil-water resources and effectiveness in controlling erosion quantitatively.

## **5.2. Recommendation**

Based on the above finding the following recommendation can be drawn for further consideration and improvement of physical and chemical properties of the soil in the study area in particular and in the country in general.

Parallel to construct Soil bund and planting grass strips on Soil bund for soil and water conservation purpose, supplementary leguminous fodder varieties should be planted along the hedgerow to increase the soil fertility maintenance and feed value of the grass for livestock. Thus, a strong effort requires from the government and other stakeholders to promote the utilization of Soil bund and Soil bund with grass strips for land rehabilitation practices through improving factors significantly affecting the use of Soil bund and Soil bund with grass strips for rehabilitation and soil conservation. Thus, this study recommends, to improve soil physical and chemical property, integrated physical structure and biological soil and water conservation practice could be added for better effect. Moreover, further research need to be conducted on the use of Soil bund and Soil bund with grass strip on socio-economic aspects for a better understanding of the sustainable use of the land resource.

## 6. References

- Abiy, G., Getahun, Y., & Genene, M. (2015). Assessment of farmers perception and adaptation mechanism to soil erosion problem in Shomba Kichib, Gimbo District, Kaffa Zone, South West Ethiopia. *African Journal of Agricultural Research*, 10(27), 2608–2616. <https://doi.org/10.5897/ajar2014.9404>
- AdimassuTeferi, Z. (2012). Exploring the potential of co-investments in land management in the Central Rift Valley of Ethiopia. In *Economics* (Vol. 35).
- Bekele, M., Lemenih, M., Sciences, A. R.-J. of N., & 2016, undefined. (2016). The effects of integrated soil conservation practices on soil physico-chemical properties: the case of Menesibu District, West Ethiopia. *Core.Ac.Uk*, 6(23), 35–45. <https://core.ac.uk/download/pdf/234656781.pdf>
- Bekele, W., & Drake, L. (2003). Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: A case study of the Hunde-Lafto area. *Ecological Economics*, 46(3), 437–451. [https://doi.org/10.1016/S0921-8009\(03\)00166-6](https://doi.org/10.1016/S0921-8009(03)00166-6)
- Bonanomi, G., D'Ascoli, R., Antignani, V., Capodilupo, M., Cozzolino, L., Marzaioli, R., Puopolo, G., Rutigliano, F. A., Scelza, R., Scotti, R., Rao, M. A., & Zoina, A. (2011). Assessing soil quality under intensive cultivation and tree orchards in Southern Italy. *Applied Soil Ecology*, 47(3), 184–194. <https://doi.org/10.1016/j.apsoil.2010.12.007>
- Challa, A., Abdelkadir, A., & Mengistu, T. (2016). To cite this article: Abay Challa, Abdu Abdelkadir, Tefera Mengistu. Effects of Graded Stone Bunds on Selected Soil Properties in the Central Highlands of Ethiopia. *International Journal of Natural Resource Ecology and Management*, 1(2), 42–50. <https://doi.org/10.11648/j.ijnrem.20160102.15>
- Chapman, G., Gray, J. M., Murphy, B., Atkinson, G., Leys, J., Muller, R., Peasley, B., Wilson, B., Bowman, G., McInnes-Clarke, S. K., Tulau, M., Morand, D., & Yang, X. (2011). Assessing the condition of soils in NSW. Monitoring, evaluation and reporting program, Technical report series. January 2015.
- Dawit, B. (2014). the Status of Community Participation in the Rehabilitation of Degraded Land. a Case Study of Shebedino Woreda, Sidama Zone, Southern Ethiopia.
- de Graaff, J., Amsalu, A., Bodnár, F., Kessler, A., Posthumus, H., & Tenge, A. (2008). Factors influencing adoption and continued use of long-term soil and water conservation measures in five developing countries. *Applied Geography*, 28(4), 271–280.

<https://doi.org/10.1016/j.apgeog.2008.05.001>

- Demelash, M., & Stahr, K. (2010). Assessment of integrated soil and water conservation measures on key soil properties in South Gonder, North-Western Highlands of Ethiopia. *Journal of Soil Science and Environmental Management*, 1(7), 164–176.
- Dorioz, J. M., Gascuel-Oudou, C., Merot, P., & Trevisan, D. (2011). Landscape control on diffuse pollution : a critical review on some investigations on phosphorus – retaining landscape features. 14th International Conference, IWA Diffuse Pollution Specialist Group, 141–155. [http://prodinra.inra.fr/ft?id=%7B56FDDCE5-0C54-49B1-A001-F2327ECA3DC6%7D%5Cnhttp://www.dipcon2010.org/DIPCON2010\\_Issues\\_and\\_Solutions\\_to\\_Diffuse\\_Pollution.pdf](http://prodinra.inra.fr/ft?id=%7B56FDDCE5-0C54-49B1-A001-F2327ECA3DC6%7D%5Cnhttp://www.dipcon2010.org/DIPCON2010_Issues_and_Solutions_to_Diffuse_Pollution.pdf)
- Du, B., Gu, M., Hu, Z., Zhan, X., & Wu, G. (2023). Thermodynamic analysis of extracellular electron transfer during ethanol oxidation in anaerobic digestion systems. *Biomass and Bioenergy*, 172(March), 106755. <https://doi.org/10.1016/j.biombioe.2023.106755>
- Erkossa, T., & Ayele, G. (2003). Conference on International Agricultural Research for Development. Indigenous Knowledge and Practices for Soil and Water Management in East Wollega, Ethiopia, 310, 1–15.
- Effective data collection. (2000). 11(3), 341–345.
- Gadisa, S., & Hailu, L. (2020). Effect of Level Soil Bund and Fayna Juu on Soil Physico-chemical Properties, and Farmers Adoption Towards the Practice at Dale Wabera District, Western Ethiopia. *American Journal of Environmental Protection*, 9(5), 107. <https://doi.org/10.11648/j.ajep.20200905.12>
- Haile, M., Herweg, K., & Stillhardt, B. (2006). Sustainable land management: a new approach to soil and water conservation in Ethiopia. Centre for Development and Environment (CDE) and NCCR North-South, University of Bern, Switzerland.
- Hailu, W., Moges, A., & Yimer, F. (2012). The Effects of ‘<i>Fanya juu</i>’ Soil Conservation Structure on Selected Soil Physical & Chemical Properties: the Case of Goromti Watershed, Western Ethiopia. *Resources and Environment*, 2(4), 132–140. <https://doi.org/10.5923/j.re.20120204.02>
- Huang, X., Lu, Q., & Yang, F. (2020). The effects of farmers’ adoption behavior of soil and water conservation measures on agricultural output. *International Journal of Climate Change Strategies and Management*, 12(5), 599–615. <https://doi.org/10.1108/IJCCSM-02->

2020-0014

- Hurni, H. (1993). Land degradation, famine, and land resource scenarios in Ethiopia. In World soil erosion and conservation. <https://doi.org/10.1017/cbo9780511735394.004>
- Information, C. (2015). Integrated Soil Fertility Management in Africa: from Microbes to Markets ( ISFM Africa 2012 ) Conference Information , Program and Abstracts. October 2012, 22–26.
- Kasahun Kitila, A. J. and M. W. (2016). EC AGRICULTURE Research Article Evaluation and Demonstration of Different Organic Matter for Soil Fertility Improvement in Shashemene and Kofele Districts of West Arsi Zone, Ethiopia. 5(January), 728–737. <https://doi.org/10.14662/ARJASR2016.047>
- Kc, B., Pandey, B., Chand, H., Bhusal, P., Pandit, S., & Khanal, S. (2020). Promotion of Organic and Sustainable Agriculture Through the Use of Bio-Fertilizers. *Journal of Wastes and Biomass Management*, 3(1), 1–8. <https://doi.org/10.26480/jwbm.01.2021.01.08>
- Kessler, C. A. (2006). Decisive key-factors influencing farm households' soil and water conservation investments. *Applied Geography*, 26(1), 40–60. <https://doi.org/10.1016/j.apgeog.2005.07.005>
- Mathewos, M., Dananto, M., Erkossa, T., & Mulugeta, G. (2019). Land use land cover dynamics at Bilate Alaba sub-watershed, southern Ethiopia. *Journal of Applied Sciences and Environmental Management*, 23(8), 1521. <https://doi.org/10.4314/jasem.v23i8.16>
- McCauley, A., Jones, C., & Jacobsen, J. (2005). Basic Soil Properties. *Soil and Water*, 1–12. [http://landresources.montana.edu/SWM/PDF/Final\\_proof\\_SW1.pdf](http://landresources.montana.edu/SWM/PDF/Final_proof_SW1.pdf)
- Miheretu, B. A. (2014). Farmers' Perception and Adoption of Soil and Water Conservation Measures: the case of Gidan Wereda, North Wello, Ethiopia. *Issn*, 5(24), 2222–1700.
- Mume, T., Geneti, T., Gemechu, T., & Lule, D. (2018). Research Activities of Pre-Extension Demonstration of Agricultural Technologies supported by Agricultural Growth Program ( AGP-II ) Donor partners ACKNOWLEDGEMENTS The authors would like to thank the World Bank and all other donor partners of research wor. June, 25–27.
- Ncube, B. (2007). Understanding cropping systems in the semi-arid environments of Zimbabwe: options for soil fertility management. *Understanding Cropping Systems in the Semi-Arid Environments of Zimbabwe: Options for Soil Fertility Management*, 155. <http://edepot.wur.nl/36056>

- Nile, B. (2011). Promoting improved rainwater and land management in the Blue Nile ( Abay ) basin of Ethiopia. Fao. <http://nilebdc.wordpress.com>
- Pascual-Ferrer, J., Pérez-Foguet, A., Codony, J., Raventós, E., & Candela, L. (2014). Assessment of water resources management in the Ethiopian Central Rift Valley: environmental conservation and poverty reduction. *International Journal of Water Resources Development*, 30(3), 572–587. <https://doi.org/10.1080/07900627.2013.843410>
- Susha, V. S., Das, T. K., Nath, C. P., Pandey, R., Paul, S., & Ghosh, S. (2018). Impacts of tillage and herbicide mixture on weed interference, agronomic productivity and profitability of a maize – Wheat system in the North-western Indo-Gangetic Plains. *Field Crops Research*, 219(February), 180–191. <https://doi.org/10.1016/j.fcr.2018.02.003>
- Teklu Erkossa, Seleshi Bekele Awulachew, D. A. (2011). Soil fertility effect on water productivity of maize in the upper blue Nile basin, Ethiopia. *International Soil and Water Conservation Research*, 3(2), 123–130. <https://doi.org/10.1016/j.iswcr.2018.01.004>
- Tigest Alemayehu<sup>1</sup>, & Fisseha<sup>2\*</sup>, and G. (2018). Effects of soil and water conservation practices on selected soil physico-chemical properties in Debre-Yakob Micro-Watershed, Northwest Ethiopia. *Ethiopian Journal of Science and Technology*, 10(1), 29.
- Truong, P. N. V., & Truong, P. N. V. (2000). The Global Impact of Vetiver Grass Technology on the Environment. *Proc. Second International Conference on Vetiver*, January 2000. <http://130.203.136.95/viewdoc/summary?doi=10.1.1.557.217>
- Viera Valencia, L. F., & Garcia Giraldo, D. (2019). In *Angewandte Chemie International Edition*, 6(11), 951–952. (Vol. 2).
- Wolka, K. (2014). Effect of soil and water conservation measures and challenges for its adoption: Ethiopia in focus. *Journal of Environmental Science and Technology*, 7(4), 185–199. <https://doi.org/10.3923/jest.2014.185.199>
- Www.kemkes.go.id. (2020). *Satukan Tekad Menuju Indonesia Sehat*, 10 (February).

## 7. APPENDICES

**Annex 1:** Effect of Slope gradient on selected physical soil properties (Mean and Std. Error of Mean)

SWC Structure		Clay	silt	sand	Soil moisture	Bulk Density
Soil bund plots	Mean	41.55	33.96	24.77	18.83	1.14
	Std. Error of Mean	1.91	1.54	.78	1.72	.051
SB with GSr plots	Mean	42.35	41.81	24.55	16.88	1.16
	Std. Error of Mean	1.87	1.94	1.13	1.69	.12
No-conserved land	Mean	32.68	31.75	38.71	14.82	1.19
	Std. Error of Mean	1.52	1.51	1.18	1.63	.077
Total	Mean	38.86	35.84	29.34	16.84	1.16
	Std. Error of Mean	1.76	1.66	1.36	1.68	.082

**Annex 2:** Results of one-way ANOVA of effect of conservation structure on selected physical soil properties

SWC structure		Sum of Squares	df	Mean Square	F	Sig.
Clay	Between Groups	128.000	1	128.000	4.650	.047
	Within Groups	440.444	16	27.528		
	Total	568.444	17			
silt	Between Groups	364.500	1	364.500	14.372	.002
	Within Groups	405.778	16	25.361		
	Total	770.278	17			
sand	Between Groups	144.500	1	144.500	14.633	.001
	Within Groups	158.000	16	9.875		
	Total	302.500	17			
Soil moisture	Between Groups	174.758	1	174.758	5.804	.028
	Within Groups	481.775	16	30.111		
	Total	656.533	17			
Bulk Density	Between Groups	.008	1	.008	.089	.769
	Within Groups	1.423	16	.089		
	Total	1.431	17			

**Annex 3:** Results of one-way ANOVA of Effect of Slope gradient on selected chemical Soil properties

Soil parameters		Sum of Squares	df	Mean Square	F	Sig.
Soil pH	Between Groups	.524	2	.262	1.656	.224
	Within Groups	2.375	15	.158		
	Total	2.899	17			
organic matter	Between Groups	2.589	2	1.294	4.133	.037
	Within Groups	4.698	15	.313		
	Total	7.286	17			
Available phosphorus	Between Groups	.051	2	.025	8.902	.003
	Within Groups	.043	15	.003		
	Total	.094	17			
Total nitrogen	Between Groups	156.243	2	78.122	10.381	.001
	Within Groups	112.877	15	7.525		
	Total	269.120	17			
Cation exchange capacity	Between Groups	121.161	2	60.581	5.316	.018
	Within Groups	170.925	15	11.395		
	Total	292.087	17			

**Annex 4:** Effects of Integrated Use of Soil bund, Soil Bund combined with grass strip & non-conserved under three slope gradients on selected Soil chemical properties

Treatment	Slope class	Sample plots	pH(1:2.5)	%SOM	%TN	AV.P (ppm)	CEC (meq /Kg)
With Soil bund	Upper slope(3-8)	Plot 1	4.00±0.13 <sup>a</sup>	2.66±0.19 <sup>a</sup>	.26±0.03 <sup>a</sup>	7.98±0.52 <sup>a</sup>	33.37±1.72 <sup>a</sup>
		Plot 2	4.12±0.17	2.74±0.23	.23±0.02	7.91±0.52	33.21±1.72
		Plot 3	4.31±0.19	2.78±0.27	.21±0.018	7.94±0.48	33.00±1.58
	Middle slope(8-15)	Plot 1	4.72±0.17	3.29±0.36	.24±0.021	7.87±0.44	32.89±1.41
		Plot 2	4.91±0.19	2.98±0.28	.21±0.018	7.57±0.38	32.98±1.53
		Plot 3	5.00±0.20	3.31±0.37	.22±0.019	7.43±0.32	33.07±1.62
	Lower slope(15-30)	Plot 1	5.45±0.16 <sup>b</sup>	3.00±0.32 <sup>b</sup>	.21±0.02 <sup>b</sup>	6.96±0.35 <sup>b</sup>	29.91±1.46 <sup>b</sup>
		Plot 2	5.23±0.13	3.21±0.34	.18±0.012	6.51±0.26	23.87±1.14
		Plot 3	5.48±0.18	3.36±0.39	.29±0.05	6.31±0.21	27.00±1.34
Soil bund combined With grass strip	Upper slope(3-8)	Plot 1	4.92±0.21 <sup>a</sup>	3.10±0.31 <sup>a</sup>	.23±0.03 <sup>b</sup>	7.81±0.43a	31.12±0.62 <sup>ab</sup>
		Plot 2	4.93±0.18	3.26±0.36	.18±0.027	7.93±0.48	27.37±0.31
		Plot 3	4.81±0.16	2.71±0.28	.15±0.023	7.43±0.32	29.67±0.58
	Middle slope(8-15)	Plot 1	4.72±0.17	2.56±0.24 <sup>a</sup>	.20±0.025	7.65±0.48	33.87±0.76
		Plot 2	4.81±0.13	3.31±0.42	.25±0.037	7.78±0.50	29.23±0.45
		Plot 3	4.51±0.16	2.59±0.25	.23±0.03	7.32±0.28	32.18±0.51
	Lower slope(15-30)	Plot 1	4.32±0.14 <sup>bc</sup>	2.57±0.27 <sup>b</sup>	.19±0.01 <sup>bc</sup>	6.71±0.31 <sup>b</sup>	29.60±0.99 <sup>b</sup>
		Plot 2	4.46±0.12	2.25±0.21	.24±0.05	6.32±0.28	29.23±0.95
		Plot 3	4.49±0.100	2.59±0.28	.22±0.03	6.12±0.24	29.39±0.97
non-conserved	Upper slope(3-8)	Plot 1	4.12±0.29 <sup>c</sup>	1.93±0.21 <sup>c</sup>	.13±0.02	4.52±0.06 <sup>c</sup>	22.79±0.95 <sup>c</sup>
		Plot 2	4.00±0.25	1.98±0.25 <sup>c</sup>	.19±0.028	4.21±0.05	22.53±0.89
		Plot 3	3.92±0.21	1.84±0.19 <sup>c</sup>	.14±0.022	4.86±0.07	22.21±0.84
	Middle slope(8-15)	Plot 1	3.87±0.17	1.73±0.17	.21±0.03	4.14±0.03	22.00±0.79
		Plot 2	3.82±0.19	1.56±0.15	.20±0.029	4.91±0.09	21.56±0.94
		Plot 3	3.75±0.15	1.48±0.13	.15±0.023	4.16±0.04	22.13±0.81
	Lower slope(15-30)	Plot 1	3.70±0.16 <sup>c</sup>	1.84±0.17	.17±0.024	4.33±0.21c	22.43±1.33 <sup>c</sup>
		Plot 2	3.72±0.18	1.91±0.19	.14±0.018	4.01±0.12	21.81±1.17
		Plot 3	3.61±0.13	1.67±0.13	.12±0.016	4.24±0.17	21.45±1.11
<b>LSD (0.05)</b>		NS	0.67	0.05	2.86	NS	
<b>CV</b>		3.12	6.04	5.58	4.81	3.73	

**Annex 5: Soil sample taking procedure from reconnaissance survey of site selection on laboratory**



# HAWASSA UNIVERSITY SCHOOL OF GRADUTE STUDIES

## DEPARTMENT OF BIOSYSTEMS ENGINEERING

### Annex 6: Questionnaire

Semi-structured Household level questionnaire developed on farmers Adoption of soil erosion and effectiveness of soil and water conservation practice on soil fertility and crop productivity in Dalta Sub-watershed in Dawuro zone Eseraworeda, SWEPRS.

#### A. Survey Area

Region \_\_\_\_\_ Zone: \_\_\_\_\_ Woreda: \_\_\_\_\_ PA: \_\_\_\_\_

Date of Interview \_\_\_\_\_

Name (Household head) \_\_\_\_\_ Age \_\_\_\_\_ Sex \_\_\_\_\_

#### B. Household characteristics

1. Ages: (1) 26 – 45 (2) 45– 64 (3) >64

2. Family size: (1) 1 – 2 (2) 3 – 6 (3) >6

3. Educational status the of household (1) Cannot read & write (2) Read & write

(1 - 4)(3) Elementary School (5 - 10) (4) Secondary School >10)

4. What is your land holding size (ha)?

a) Home garden area \_\_\_\_\_ ha

b) Cultivated lands \_\_\_\_\_ ha

c) Grass/wood plots \_\_\_\_\_ ha

d) Total land holding \_\_\_\_\_ ha

5. How do you prepare the land for planting?

a) Hoeing b) Oxen plough c) Others, specify \_\_\_\_\_

## 6. Livestock ownership

Order	Type of livestock	Unit	Quantity
1	Total no of Cattles owned	Number	
2	Total no of goats and sheep owned	“	
3	Total no of equine owned	“	
4	Total livestock owned		

### C. Erosion problems (If answers are more than one circle more than once).

1. Is there soil erosion problem on your farm? A/ Yes B/ No

2. If there is erosion on your farm, which part of your farm is most affected?

a/Home garden fields b/Outer fields? c/Grass lands d/conserved land

3. If yes, how is the severity of erosion on your farm plots at present?

a) Severe b) Very severe c) Moderate

4. Which are the effects of soil erosion?

a) Poverty b) Land become out of cultivation c) Low yield

5. What are the major problems or constraints for crop production in your farm?

a) Land is too small b) land is too infertile

c) Lack of oxen d) others, specify \_\_\_\_\_

6. What do you do with your crop residue?

a) Burn them b) Use them as feed

c) Use them for cooking d) others, specify\_\_\_\_\_

7. If soil fertility is declining, how do you cope with it?(If answers are more than one Circle more than once)

a) Apply manure b) Apply fertilizer c) Apply SWC measures

8. Do you use some kinds of practices to maintain or enrich soil fertility of your cultivated land?

a) Yes b) No

9. If yes, which of the following practices do you use?

a) Use of fertilizer b) Use of manure c) Intercropping d) SWC Measures e) Others (specify) -----

10. Is low soil fertility a constraint in your farm? Yes.....No.....

If yes, what are the main causes of low soil fertility in your farm?

a) Soil erosion b) Drought c) erratic rainfall d) Land shortage e) Lack of input use

11. What is your suggestion to improve soil productivity in your farm?

a) Farmers sensitization until they adopt SWC techniques

b) Technical support in terracing and bunds construction

c) Farmers trainings and experience sharing

d) Provide incentive to the farmers

12. What is your aptitude of adoptions on using grass strips as a soil conservation method?

a) It is difficult tasks b) it's a measure that should be contained c)it's a measure that shouldn't be contained d) it is must be sustainable measure

13.Does the integrated use of a grass strip and a soil bund affect the chemical characteristics of the soil? a) Yes b) No

13. Does the integrated use of a grass strip and a soil bund affect the physical characteristics of the soil? a) Yes b) No

## **8. BIOGRAPHICAL SKETCH**

The author, Mr. Tizitaw Godaro Tolola was born in South-western Ethiopia Peoples Regional state, Dawuro Zone, Essera Woreda, Guza kebele in June 21, 1994 G.C. He attended primary education at wushay Junior Secondary School and he attends 9<sup>th</sup>- 12<sup>th</sup> Essera secondary and Preparatory high school. He completes his preparatory education July 07/ 2012 G.C. He joined Ambo University in September 12/2012 G.C and received a BSc degree in Agricultural and Bioprocesses Engineering on July 24, 2018 G.C. After his graduation, He employed in south western Ethiopia Peoples Regional state in Dawuro Zone Essera Woreda water mines and energy office for 3 years. He joined Hawassa University Institute of technology in Post Graduate Studies in 2021G.C.by soil and water conservation engineering. Currently he has been working at south western Ethiopia Peoples Regional state in Dawuro Zone Essera Woreda water mines and energy office.