ADDIS ABABA UNIVERSITY
GRADUATE PROGRAMS
COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES
CENTER FOR ENVIRONMENTAL SCIENCE

LAND USE MANAGEMENT PRACTICES ON SELECTED SOIL PROPERTIES, ITS IMPACT ON SOIL EROSION AND LAND USE LAND COVER CHANGES IN KABE WATERSHED, BLUE NILE CATCHMENT OF NORTHERN ETHIOPIA

FIKRU ASSEFA MENGSTIE

A DISSERTATION SUBMITTED TO THE CENTER FOR ENVIROMENTAL SCIENCE IN FULFILMENT OF THE DEGREE OF DOCTOR OF PHILOSOPHY (ENVIROMENTAL SCIENCE)

ADDIS ABABA UNIVERSITY

ADDIS ABABA, ETHIOPIA

JUNE, 2024

Addis Ababa University
Graduate Programs
College of Natural and Computational Sciences
Center for Environmental Science

This is to certify that the dissertation prepared by Fikru Assefa Mengstie, entitled; **Land Use Management Practices on Selected Soil Properties, Its Impact on Soil Erosion and Land Use Land Cover Changes in Kabe Watershed, Blue Nile Catchment of Northern Ethiopia** and submitted in fulfillment of the degree of Doctor of Philosophy (Ph.D.) degree in Environmental Science complies with the regulations of the university and meets the accepted standards.

Signed by the Examiners:

	NAME	SIGNATURES	DATE
1.	**- - - - - - - - - - - - - - - - - --- - - - - - -**	**- - - - - - - - - - -**	**- - - - - - - - - - -**
2.	**- -**	**- - - - - - - - - - -**	**- - - - - - - - - - -**

Signed by the Supervisors:

1.	**- - - - - - - - - - - - - - - - - --- - - - - - -**	**- - - - - - - - - - -**	**- - - - - - - - - - -**
2.	**- -**	**- - - - - - - - - - -**	**- - - - - - - - - - -**

Chair of the Center for Environmental Science

ABSTRACT

Alterations in land-use management strategies like the cultivation of steep slopes, overgrazing, or limited fallow periods, and slope position affect the physiochemical properties of soils. Transitioning land from forest cover to cultivated areas could diminish organic residue inputs, potentially resulting in decreased soil fertility, increased rates of soil erosion, loss of soil organic carbon and nutrients, and an accelerated rate of soil degradation. In this study, we assessed the impacts of land-use management on selected soil physiochemical properties under various terrain slopes and with & without soil and water conservation (SWC) measures in a disturbed landscape in the Kabe Watershed of the northern part of Ethiopia by using composite and core soil samples for laboratory analysis. Also, we explore farmers' decision to adopt soil and water conservation (SWC) practices by structured questionnaire survey and focus group discussion methods applied to collect the necessary information from farm plots and households. Hundred households with 282 sampled plots were interviewed and several fields were visited during transect walks. The Tobit regression model in SPSS was used for analysis. In addition, data were analyzed using descriptive statistics. On the other hand, we estimate soil loss in different land-use systems and slope categories using the Revised Universal Soil Loss Equation model with the help of the ArcGIS process applied for this study. It was analyzed in Ethiopian conditions by using data of erosivity (R) based on interpolation of rainfall data, soil erodibility (K), vegetation cover (C) and satellite images, topography slope and steepness (LS), and conservation practices (P). Ultimately, we analyze and forecast the patterns of land use land cover alterations from 1986 to 2019 within the research region through the utilization of qualitative and quantitative data gathered via Geographical Information System (GIS) and remote sensing (RS) methods. Field observations and consultations with local elders were additionally utilized to confirm the findings obtained from remotely collected data.

According to the findings, for all slope positions with and without soil and water conservation (SWC), SM content, TP, silt, and clay proportions of soil were lower in the cultivated land compared with grazing and forest land use types. Relatively, soil BD and sand fraction were higher in the cultivated land than in grazing and forest land use types. The terrain slope position influenced the sand content of forest, grazing, and cultivated land types, with an increase observed from lower to upper slope positions. In contrast, the silt and clay fractions generally decreased from lower to upper slope positions. Available phosphorus (P) and organic carbon (OC) levels were consistently below the standard across all land use types (LUTs). In addition, the mean soil loss was relatively highest (20.01 t $ha^{-1}yr^{-1}$) under cultivated land followed by grassland (0.69t $ha^{-1}yr^{-1}$) and it was lowest (0.17 t $ha^{-1}yr^{-1}$) under forestland given that the average soil erosion across the entire watershed was 6.95t $ha^{-1}yr^{-1}$. In addition to this, 90% of local farmers believed that soil erosion was controlled by different rehabilitation techniques. According to the analysis of geographical information system (GIS) and remote sensing (RS) data, the expansion of cultivated land, forest lands, and grazing lands exhibited a consistent and gradual increase throughout the period between 1986 to2019, primarily at the cost of shrubs and wetlands. In summary, to conserve both soil & water resources and rehabilitate the watershed, policymakers need to implement appropriate land conservation strategies based on land-use structure & slope difference. Lastly, this study recommended an involvement of the concerned body to end the fast deprivation of shrubs and wetlands in the watershed.

Keywords: Ethiopia, Kabe Watershed, Land Use and Cover Types, Soil Erosion Loss, Selected Soil Physicochemical Properties

ACKNOWLEDGMENTS

My deepest gratitude goes to my supervisors Prof. Teshome Soromessa and Prof. Eyasu Elias for their unreserved and tremendous advice from the beginning to the successful completion of my PhD dissertation. They helped me a lot in shaping the framework of the paper to its final appearance as such. Especial thanks to you Prof. Teshome Soromessa, who read the final dissertation work, commented on how to shape it in a better way, and for statistical analysis assistance.

I also extended my gratitude to Dr. Mesfin Sahile on geographical information system and remote sensing and Legesse Assefa on revised universal soil loss equation assistance, Woreillu Wereda and its surrounding weredas administration office in South Wollo Zone, Amhara Region, all other offices in the Wereda of respective study sites and Kebele development agents were so kind in permitting to access to the Kebeles of the Wereda with their blessing and passion, thus there are no words to thank them. All smallholder farmers in all Kebeles gave me special interviews and shared their gathered knowledge with me, I heartedly thank them. My warm appreciation goes to the secretary of the Center for Environmental Science for on-time information exchange during my research activities.

It is more than a word to thank the Center for Environmental Science Head Dr. Amhed Hussen, Graduate program coordinator of the Center Dr. Yedilfana Setarge, Environmental Resources Conservation and Management stream coordinator of the Center Dr. Meron Tekalign, all staff and students at the Center for Environmental Science for their formal and informal advice, positive and unreserved support in activities important for my dissertation job.

I am intensely grateful to my Father Aba Assefa Mengstie, my Mother Emahoy Habesha Tadesse, my wife W/o Melkamwork Damtew, and my children (Yonas, Simon, and Etsehiwot), who were always eager to see my success, have got a special place not only for their unreserved effort in this study but also in all my academic endeavors.

I am indebted to Wollo University, which rendered its unreserved financial support starting from the beginning to the end of the final study.

DEDICATION

This PhD dissertation was dedicated to the memory of my Sister Enat Assefa Mengstie.

TABLE OF CONTENTS

Contents **Pages**

LIST OF FIGURES

Contents **Pages**

LIST OF TABLES

Contents **Pages**

LIST OF APPENDICES

Contents **Pages**

LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
ANRS	Amhara National Regional State
ANSWERS	Areal Non-point Source Watershed Environment Response Simulation
AOI	Area of Interest
ARARI	Amhara Region Agricultural Research Institute
AWHC	Available Water Holding Capacity
BSc	Bachelor of Science
CC	Climate Change
C: N	Carbon to Nitrogen Ratio
CEC	Cation Exchange Capacity
CGS	Council of Graduate Studies
DA	Development Agent
DAP	Diammoium Phosphate
DBH	Diameter at Brest High
DEM	Digital Elevation Model
DGC	Department Graduate Committee
Dr.	Doctor
E	Simpson's Evenness Index
EA	Exchangeable Acidity
EBC	Exchangeable Basic Cation
EC	Electrical Conductivity
ECEC	Exchangeable Cation Exchange Capacity
ERDAS	Earth Resource Development Assessment System
ESLCE	Ethiopian Schools Leaving Certificate Examination
EUROSEM	European Soil Erosion Model
FAO	Food and Agriculture Organization
FC	Field Capacity
FGD	Focus Group Discussion
GIS	Geographical Information System
GLM	General Linear Model

GPS	Global Positioning System
HH	Household
HIV/AIDS	Human Immunodeficiency Virus Acquired Immunodeficiency Syndrome
IDM	Inverse Distance Weight
IDW	Inverse Distance Weighted
LUTs	Land Use Types
LULCC	Land Use Land Cover Change
LSD	Least Significance Difference
MAP	Mean Annual Precipitation
Masl	Meter above sea level
MAXLIKE	Maximum Likelihood Classifier
MC	Moisture Content
MMF	Model of Morgan and Finney
MSc	Master of Science
MS	Mean Square
MUSLE	Modified Universal Soil Loss Equation
NA	No Answer
NS	Not Significant
OLS	Ordinary Least Squares
PBIAS	Average Percentage Bias Error
PCA	Principal Component Analysis
PSNP	Productive Safety Net Programme
PWP	Permanent Wilting Point
R^2	Coefficient of Determination
RCBD	Randomized Complete Block Design
RD	Relative Density
RF	Rainfall
RRMSE	Residual Root Mean Square
RS	Remote Sensing
RSG	Reference Soil Groups
RUSLE	Revised Universal Soil Loss Equation

SAS	Statistical Analysis System
SCRP	Soil Conservation Research Project
SEM	Standard Error of Mean
SOC	Soil Organic Carbon
SOMM	Soil Organic Matter Model
SPSS	Statistical Package for Social Science
SRTM	Shuttle Radar Topography Mission
SWC	Soil and Water Conservation
TEB	Total Exchangeable Base
TLU	Tropical Livestock Unit
UNEP-WCMC	The United Nations Environment Programme - World Conservation Monitoring Centre
USLE	Universal Soil Loss Equation
WEPP	Water Erosion Prediction Project

PUBLICATIONS

1. Effect of Changes in Land-Use Management Practices on Soil Physicochemical Properties in Kabe Watershed, Ethiopia (Article link: https://journals.sagepub.com/doi/10.1177/1178622120939587
2. "Evaluating Soil Loss for Identification of Land Risk Area in the Kabe Watershed of Ethiopia," Applied and Environmental Soil Science, vol. 2022, Article ID 7679104, 13 pages, 2022. https://doi.org/10.1155/2022/7679104.
3. Farmers' Decisions on Adoption of Soil and Water Conservation Practices in Kabe Watershed in Blue Nile Basin, Ethiopia **(Under review in** https://www.editorialmanager.com/heliyon/default2.aspx**)**
4. Land Use and Land Cover Change Analysis Using GIS and Remote Sensing: The Case of Eastern Part of Blue Nile Catchment of Ethiopia **(Status- submitted)**
5. Impacts of climate change on the socioeconomic status of smallholder farmers: The Case of the Eastern part of the Blue Nile catchment of Ethiopia **(Status- submitted)**

CHAPTER ONE

1. INTRODUCTION

1.1 Background

Land-use management practice changes such as the cultivation of steep slopes, overgrazing, and no or limited fallow periods, and lack of effective institutions to enact regulations or laws that enhance sustainable land management practices have remarkable effects on the dynamics of soil properties (Muñoz-Rojas et al., 2015; Pereira et al., 2018). Land-use change was a general term for the variation and conversion of the earth's surface by human factors and natural events such as flooding, fire, and climate fluctuations (Roy, P.S., 2022). On the contrary, land cover, in its narrowest wisdom, often assigns only the plants that are either natural or man-made on the earth's surface. Knowledge of the allocation of land use and land cover was essential for preparation and management activities (Rahaman et al., 2020). Changes in land use practices were strongly linked with direct and indirect human actions that put long-term pressure on the environment thereby aggravating land-use transformation. Changes from farming land to residential use and degradation of land by overgrazing and deforestation were examples of the land-use transformation (Detebo et al., 2021; Mohammed et al., 2015).

Changes in land cover density and intensification of agriculture aggravate the leaching rate of soil organic carbon and nutrients and an accelerated rate of land degradation (Mondal et al., 2020). The line was also true, for example, integrated management of arable soil was the key to dealing with most complex soil properties, thereby maintaining the land cover dynamics (Endalamaw et al., 2021).

Ethiopia is part of the dynamic land use management change where more than 60% of the country's highlands were once forested and currently, the percentage of forest cover is becoming the lowest (Hailu et al., 2020). Research conducted in the near vicinity of the area, northwestern Ethiopia by Damtea et al. (2020) and Zewdie et al. (2015) indicated that land cover change in the area and country at large was an outcome of natural and socioeconomic factors and their utilization by man both in time and space. According to the findings of Bizunhe (2023) Ethiopia, a dominantly mountainous country with highly erodible soils on steeply sloping land, loses an estimated 1 billion tons of topsoil each year mainly as a result of water and wind erosion.

Moreover, erratic and erosion precipitation cycles, inadequate recycling of manure and crop residues into the soil, limited use of external plant nutrient sources, deforestation, and excessive grazing notably contribute to the degradation of land (Assefa et al., 2020). Tsegaye (2019) indicated that only little reliable data were available to quantify the consequence of land use management alter on selected soil properties (Gashaw et al., 2018). Land degradation and recurrent drought were the major threats to rain-fed agriculture in the semi-arid Ethiopian highlands (Thi et al., 2023). That has undergone rapid population growth leading to the intensive change of normal forest and plain into cultivated land units (Abazinab et al., 2022). Impact of degradation threats soil properties indicated that soil degradation is the main cause for the pasting of earth fertility, which decrease the productive capacity of the land (Gregory et al., 2015).

To summarize, the factors contributing to land degradation in Ethiopia included cultivating on steep and fragile soils without sufficient investments in soil and water conservation (SWC) or vegetation cover, erratic rainfall patterns leading to erosion, reduced fallow practices, insufficient recycling of dung and crop residues into the soil, limited use of external plant nutrients, deforestation, and excessive grazing (Hailemichael et al., 2020).

Thus, with appropriate management of the factors controlling erosion and degradation, it was possible to increase agricultural productivity and reduce poverty (Francaviglia et al., 2023). Hence, all endeavors should be focused on preserving the physical, biological and socioeconomic as well as environmental elements to enhance the production of food crops, livestock, timber, and other goods by employing sustainable practices on the planet. Therefore, reducing resource degradation, increasing agricultural productivity, reducing poverty, and achieving food security were major challenges of the countries in tropical Africa, like Ethiopia.

Land use and land cover change was a general term for the variation and conversion of the earth's surface by human factors and natural events such as flooding, fire, and climate fluctuations. In contrast, land cover, in its narrowest sense, often designates only the vegetation that was either natural or man-made on the earth's surface. Knowledge of the distribution of land use and land cover was essential for planning and management activities (Y.P. Lin Verburg et al., 2009 and Nedd et al., 2021).

Observing and mitigating the adverse impacts of land use and land cover alterations while ensuring the continuity of vital resource production has thus emerged as a key focus for researchers globally (Obubu et al., 2022). The transformation of land use and land cover has evolved into a pivotal element within contemporary strategies aimed at resource management and environmental change monitoring. Subtropical highlands of the Kabe Watershed areas in Wereillu District constituting the areas where the present study was conducted were not exceptions to these problems. However, few ineffective SWC practices had been constructed for maintaining the fertility of the soils in the area but locally available data of soil erosion loss, LULC status, and several effects of different SWC practices, slope positions, and land use types on soil fertility status were not studied yet. This local change in LULC and soil loss from the different land use types can be monitored using GIS, remote sensing, and recent satellite data in combination with the ground survey needed.

1.2 Statement of the Problem

In traditional agricultural systems, farmers rely on practices such as bush fallow, crop residues, household waste, animal manure, and various organic nutrient inputs to sustain soil fertility and enhance soil organic matter content. The soils of the Ethiopian highlands are deficient in most macro/micronutrients and organic matter content (Elias, 2016).

In Ethiopia, the national economy and the contribution of agriculture to the national economy were strongly linked to rainfall patterns. This was reflected particularly in the Blue Nile hand basin of Ethiopia where agriculture be practiced in sloping landscape, land degradation was apparent and ineffective SWC practices were mainly applied. Moreover, land degradation will honestly influence the natural resources base thereby affecting livelihoods and productivity of land.

On the other hand, issues of land use and land cover change and soil fertility problems in the African farming systems have involved the concentration of many researchers and have risen to top policymakers in recent years. In least developing countryside like Ethiopia, where a large proportion of the human population depends on natural resources for their livelihoods, there were increasing competing demands for utilization, development, and sustainable administration of land possessions (e.g., natural vegetation), resulting in land use & land cover changes. Many land use type changes (e.g., conversions of grasslands to croplands, fallowing croplands, replacement of infertile croplands to eucalyptus plantations) were being practiced in the highlands of Ethiopia (like Kabe Watershed).

In recent decades, remote sensing (RS) with satellite data has been widely used to obtain land use/cover information such as degradation level of forest and wetlands, rate of urbanization, intensity of agricultural activities, and other human-induced changes. However, these biophysical approaches do not give information about why changes occur. Understanding land use land cover study requires understanding of people and their societal situation; their priorities; livelihood strategies; views on the land; and the wider implication of social, political, cultural, biophysical and institutional factors among others.

Understanding land use and soil erosion dynamics in the highlands of Ethiopia (like Kabe Watershed), especially in regions like Northeastern Amhara, can provide crucial insights for sustainable land management and conservation efforts. Particularly, studies aimed at integrating land use change and socioeconomic data in the central highlands of Ethiopia were few. Hence, this study was the first of its kind to explore farmers' decision to adopt different SWC practices, effects of slope position, different land use types, and those SWC practices on selected soil physiochemical properties, and their insights about LULC change with related to soil-related issues. In addition to the above issues, exploring the impacts of different situations on soil physicochemical properties was a hot topic in agricultural management concerning the amount of soil erosion loss; our review showed that there was no significant research work conducted in the study area. As a result, we implemented this research on the rain-fed agriculture-dominated Kabe Watershed, Northeastern parts of the Blue Nile Basin in the Amhara region, Ethiopia.

1.3 Objectives

The main objective of the study was to explore land use administration perform on selected soil physiochemical properties, their impact on soil erosion, and land use land cover changes in Kabe Watershed.

Specific objectives

- To investigate the effect of changes in land use management practices on selected soil physicochemical properties;
  - ✓ To explore the effect of land use types and slope position on soil physiochemical properties.
  - ✓ To examine the effect of soil and water conservation practices, land use types, and slope position on soil physiochemical properties under interaction effect.
- To know farmers' decisions on adoption of soil and water conservation practices;
  - ✓ Assess soil and water conservation measures across land use types and slope positions in improving soil fertility.
- To explore the quantity of soil loss by erosion in the Kabe Watershed;
  - ✓ To assess the impacts of land use categories and slope positions on soil erosion rates.
  - ✓ To measure the amount of total loss of soil by erosion from the study watershed.
- To demonstrate land use and land cover change analysis through the utilization of Geographical Information Systems (GIS) and Remote Sensing (RS).
  - ✓ To generate land use/land cover maps of the years 1986, 2000, and 2019.

- ✓ To quantify land use & land cover change from 1986 to 2019.

1.4 Research Questions

The study aimed to tackle the following pertinent inquiries for each distinct objective:

- **Specific objectives 1:** To investigate the effect of changes in land use management practices on selected soil physicochemical properties;
  - ✓ What is the consequence of soil and water conservation practices on soil physiochemical properties in the Kabe Watershed?
  - ✓ What are the property of soil and water conservation, land use types, and slope positions on soil physiochemical properties in the Kabe Watershed?
  - ✓ How to assess the terrain effects on the spatial variability of soil physical and chemical properties?

Specific objectives 2: To analyze farmers' decisions on the acceptance performance of soil and water conservation practices;

- ✓ What are the actual soil and water conservation practices implemented in the research area? Is it effective or not by measuring the fertility of soil physiochemical properties?
- ✓ By what percentage of local farmers decide to adopt those soil and water conservation practices?

Specific objectives 3: To explore the quantity of soil loss by erosion in the Kabe Watershed

- ✓ What is the amount of total loss of soil by erosion from the study watershed?
- ✓ How much of the loss amount of soil by erosion from each land use type and slope position in the watershed?

- ✓ What is the perception of the local community on soil erosion?

Specific objectives 4: To show land use and land cover change analysis using GIS and Remote Sensing.

- ✓ Is there any significant land use land cover change in the study area over the past 34 years?
- ✓ How to generate land use/land cover maps of the years 1986, 2000, and 2019?
- ✓ How does land use/land cover change from 1986 to 2019?

1.5 Significance of the study

In Ethiopia, land use and land cover alterations were documented across regional scales, contributing to shifts at a national level. The majority of these changes involved the conversion of natural forest (shrubs) to agricultural land, primarily derived by human activities. In addition, the effects of change in land use/cover practices and how to increase smallholder farmers' perception of those impacts were not examined. Specifically, in Kabe Watershed there were no such studies done in the previous time. Nevertheless, through time based on the satellite image, the status of natural shrubs has degraded. Hence, this thesis aimed to assess the natural and trajectory of land use and land cover modifications within the watershed over the past 34 years, understanding the influence of land use management practices on specific soil physiochemical characteristics, investigating soil erosion rates, and enhancing farmers' awareness of the implications of soil erosion in the research area. By utilizing different studying techniques, land use and land cover change in designated areas can be monitored and mapped for specific research and analysis.

Furthermore, in evaluating the impacts of alterations in land use management strategies on soil erosion, we examined variations in forest, grazing, and cultivation land use categories with and without soil and water conservation methods in the Kabe Watershed. Therefore, this study was highly significant in views of scientific knowledge acquired; as a baseline data for future studies on the effect of changes in land use management practices on selected soil physicochemical properties; amount of soil loss by erosion from the entire watershed as well as from the different land use types and slope positions inside the watershed; land use/cover change and how to create and increases perception of farmers about the impacts.

1.6 Definition of Conceptual Terms

Soil - is the upper layer of earth in which plants grow, a black or dark brown material typically consisting of a mixture of organic remains, clay, and rock particles.

Land management - is the procedure of managing the utilize and development (in both urban and rural settings) of land resources. Land resources are used for a variety of purposes, which may include organic agriculture, reforestation, water resource management, and eco-tourism projects.

Land Use Management System - means the system of regulating and managing land use and conferring land use rights using schemes and land development procedures.

Land use and land management – practices exert a significant influence on natural resources, encompassing water, soil, nutrients, flora, and fauna. Land use information is used to develop solutions for natural resource management issues such as salinity and water quality.

Livelihood - is the sum of ways in which households make ends meet. It also refers to the means of securing the necessities of life such as food, water, shelter, and clothing.

Poverty is a widely used term in development discourse; it encompasses both income and non-income dimensions of deprivation, including lack of income and other material means, lack of access to basic social services such as education, health, and safe water, lack of personal security, and lack of empowerment to participate in the political process and in decisions that influence someone's life (Panagos et al., 2018; Rodrigo Comino, 2022).

Smallholder farmers - are farmers who own small plots of land on which they grow subsistence crops and one or two cash crops relying largely on family labor. Smallholder farming was characterized by small farm size, low technology, low capit alization, and living in different Zonal level of the country.

Conservation Tillage – encompasses various methods and approaches aimed at planting crops in the remains of prior crops, intentionally retained on the soil surfaces. Reducing tillage reduces soil disturbance and helps mitigate the release of soil carbon into the atmosphere. Conservation tillage also improves the carbon sequestration capacity of the soil.

LU/LC Change - refers to the alteration and transformation of the terrestrial surces of the Earth by human activity (Adhikari et al., 2022; Shrestha et al., 2012).

Composite samples - are a mixture of individual samples, or subsamples, generally collected from multiple locations and mixed to form a single composite sample. By combining multiple subsamples into a single composite sample, we can minimize the effects of soil variability by averaging the soil properties over larger areas.

CHAPTER TWO

2. LITERATURE REVIEW

The reviews provide a description, summary, and critical evaluation of pertinent work about the research problem being investigated and are expected to provide an overview of sources explored in a particular topic and demonstrate how the research fits within a selected field of study. Literature reviewed in this study generally addressed argumentative, integrative, historical, methodological, systematic, and theoretical aspects of the research.

2.1 Land use management practices on selected soil physicochemical properties

2.1.1 Land, Land Use, and Land Use Types

Land represents a distinct region of the Earth's terrestrial surfaces encompassing all aspects of the biosphere located directly above or below this surface, comprising the immediate climate, soil and topographical features, plant and animal communities, and the historical and current human settlement patterns (Prabhu, 2021). Land serves as a fundamental elements of production, historically intertwined with economic advancement throughout much of human civilization (Gomiero, 2016).

According to Prabhu (2021), land use entails the organization, actions and resources that individual employ in specific areas to generate, alter, or preserve them. This encompasses rural, urban, and industrial land utilization. Environmental elements like soil attributes, climate, terrain, and flora dictate land use. It underscores the crucial and limited nature of land as a primary resources for various human endeavors such as agriculture, industry, forestry, energy generation, habitation, leisure, and water management and retention (Guo et al., 2020). Land use practices impact the distribution and provision of soil nutrients by directly modifying soil characteristics and by affecting changes within the root zone.

Primary land use categories includes agriculture, grazing, forestry, settlement and industry, with each category containing further subcategories (Bigelow et al., 2017). Grasslands represent a land use category characterized by predominant natural grass communities, scarcity of shrubs, and the absence of trees (Adhikari et al., 2022). Natural forest land refers to areas where forests have self-established, comprising indigenous tree species. In Ethiopia, significant deforestation and environmental degradation have occurred. The primary drivers behind forest clearing for agriculture and grazing, as well as the exploitation of forests for fuel wood and construction materials (R. Kumar et al., 2022). The devastation of forests carries extensive consequences for humanity as a whole and holds global significance.

2.1.2 Overview of Soil Fertility Status in Ethiopia

Ethiopia encounters a broad array of challenges related to soil fertility that necessitate solutions extending beyond the conventional use of chemical fertilizers, which has been the predominant practices thus far. Key obstacles involve topsoil erosion, with certain reports ranking Ethiopia among the most severely affected countries by erosion globally, alongside Lesotho and Haiti W. A. Abebaw (2019) with erosion rates averaging 10-13mm annually, widespread acidity issues affecting more than 40% of the nation’s soil. Substantial organic matter depletion resulting from the extensive use of biomass and dung for fuel, diminished levels of essential macro and micronutrients, and compromised soil physical attributes due to salinity issues, Ethiopia faces a multifaceted soil fertility challenges. Enhancing soil fertility in Ethiopia is paramount for boosting crop yields (Bayu, 2020).

2.1.3 Impacts of Land Use Change on Soil Physical Properties

Soil fertility and productivity are significantly shaped by the physical attributes of soil, including features like structure, textures, bulk density, water retention capacities, and aeration levels. These properties exhibit variability across different locations and even within micro environments due to both natural processes and human interventions. Land use practices and management strategies play a crucial role in altering various physical characterizes of soil. For example, cultivation practices, the extent of cultivation, the tools employed, and the specific land use types can all impact the physical properties of the soil (Chimdi et al., 2012; Moore et al., 2023).

2.1.3.1. Soil texture

Soil texture is determined by the proportions of sand, silt, and clay within a soil, representing the relative distribution of particles of different sizes in the soil. This composition, knwn as soil separates, quantitatively defines the soil’s coarseness or fineness based on the percentages of sand, silt and clay excluding organic and cementing materials (Ahouet et al., 2023).

Research indicates notable variations in sand, silt, and clay fractions across cultivated, grazed and wooded areas, with declining clay content serving as a potential indicators of reduced weathering intensity (Haile et al., 2022; Yihenew et al., 2015).

2.1.3.2. Bulk density and total porosity

Soil bulk density (BD) represents the dry soil mass per unit volume and varies based on texture, structure, pore space, aeration, and water contents. Changes in bulk density impact water and oxygen availability, influenced by factors like land use and management practices. Intensive cultivation typically raises bulk density, reducing overall porpsity. A study found the highest mean bulk density (1.41g/cm^3) on grazing land and the lowest (1.35g/cm^3) in forested areas (Amhakhian et al., 2021; Yeshaneh, 2015).

A study conducted by Haile et al. (2022) and Selassie et al. (2015) showed the elevated soil porosity in woodlots is likely due to increased organic matter and finer soil particles. Surface soil porosity ranged from 54% to 45%. An optimal total pore space for crop cultivation is typically around 50%. Alemu et al. (2015) and Mtyobile et al. (2020) reported a suitable range of total porosity values for crop cultivation.

2.1.3.3. Soil water content and retention capacity

Soil water content is essential in determine soil wetness, water retention, pre-runoff absorption, and vital water supply for optimal plant growth. Quantifying moisture levels is critical for comprehending soil behavior, plant health, and various physical processes, influencing variations in infiltration, drainage, and evapo-transpiration across different land uses (Haile et al., 2022; Selassie et al., 2015). The soil moisture content can vary between high and low levels based on the occurrence or lack of rainfall.

The fluctuation in soil moisture content percentages could stem from variations in their sand, silt, and clay compositions (Chimdi, 2015; Chimdi et al., 2012; Kidane et al., 2019). Instead, research reveals in profiles ranging from surface to lower horizons under grazing and cultivation, the soil-water content at field capacity (FC) and available water-holding capacity (AWHC) diminished with depth. This trend might be attributed to the decline in silt and organic carbon (OC) levels, alongside the rise in bulk density with depth. This suggests a strong correlation between available water and silt content in many soils (Alemu et al., 2015; Donis et al., 2017; Mtyobile et al., 2020).

2.1.4. Impacts of Land Use Type Changes on Soil Chemical Properties

Chemical properties play a pivotal role in soil fertility by influencing nutrient availability to plants and microbes. A chemically rich soil provides essential nutrients in accessible forms, maintains a balanced pH, and is devoid of harmful substances. These properties are subject to alteration based on management practices and land use variations, impacting soil organic matter, nitrogen levels, and vital nutrients (Heluf et al., 2001; Kateřina Zajícová et al., 2019a).

2.1.4.1. Soil reaction and electrical conductivity

Soil pH reflects the hydrogen ion concentration in soil solution, indicating acidity or alkalinity levels and the activity of H+ and OH- ions. It serves as a gauge for chemical soil reactions, offering insights into potential nutrients imbalances or toxic conditions (Hazelton et al., 2016; Stevens et al., 2018). Soil acidity (low pH) is ordinary in all regions where precipitation is elevated sufficient to arrive at substantial quantities of cations (Ca^{2+}, Mg^{2+}, $K^{+,}$ and Na^{+}) from the surface layers of soils (Bhardwaj et al., 2021).

The agricultural fields in Gidd Ayana Districts exhibited a higher soil pH value of 6.01, whereas the soils in Wayu Tuka districts showed a lower pH values of 4.63, as documented by (Chimdi, 2015; Kidane et al., 2019).

The elevated soil pH in the coffee agro-ecosystem likely resulted from the abundant organic matter present, which can bind strongly with aluminum and ion ions, moderating their impacts on soil pH and reducing acidity. Conversely, the increasing soil acidity in cultivated areas may be attributed to the persistent use of ammonium – based fertilizers like diammonium phosphate ($(NH_4)^2HPO_4$), which upon microbial oxidation, generates potent inorganic acids (Nigussie et al., 2012; Wang et al., 2019).

2.1.4.2. Soil organic carbon, total nitrogen, and available phosphorus

Soil organic carbon (OC) encompasses a variety of organic materials from plants and animals. Changes in land use impact soil OC. Research revealed lower organic matter levels in croplands and pastures compared to forests, attributed to seasonal coverage, over-cultivation, grazing pressure, and imbalanced soil nutrients. Erosion, accelerated by plant cover removal, likely contributes to reduced organic matter in croplands and pastures, woodlots maintain rich organic matter due to dense vegetation, high biomass, and litter accumulation (Alemu et al., 2015; Pal et al., 2012; Petit-Aldana et al., 2019).

Total soil nitrogen (TN) comprises both inorganic and organic nitrogen forms. Inorganic nitrogen encompasses soluble forms like NO2- and NO3-, exchangeable NH4+, and non-exchangeable NH4+ bound to clay, calculable by subtracting inorganic nitrogen content from total soil nitrogen. Organic nitrogen consists to various identifiable and unidentifiable forms (Wiesler, 2017). Alterations in land use also lead to notable variations in total nitrogen content. Typically, several studies have shown higher total nitrogen levels in forest soils compared to cultivated land soils (Chimdi et al., 2012; Moghimian et al., 2017; Yitbarek et al., 2013).

Phosphorus (P), crucial macronutrients, is vital for plants growth due to the substantial quantities plants need. In natural ecosystems like forests and grasslands, plant uptake of P is limited by the element's low total presence and its poor solubility. The available P levels in agricultural topsoil's ranged from 7.34 to 11.30ppm when assessed using the Bray-II methods, as reported by (Chimdi et al., 2012; Kidane et al., 2019). The peak available phosphorus (P) content in the surface soils of cultivated land may be attributed to residual effects from ongoing P fertilizer application.

2.1.4.3. Exchangeable bases and total exchangeable bases

Exchangeable basic cations (EBC) comprise Ca, Mg, K and Na. in (Nel et al., 2022; Yitbarek et al., 2013). Exchangeable basic cations, Ca, Mg, Na, and K were significantly ($P \leq 0.05$) different in woodlot (subsurface) due to land use (Alemu et al., 2015). Considering the main effects, the highest mean value of exchangeable K was observed in the soils of the grazing and forest lands and the lowest (0.32 coml (+) kg^{-1}) was recorded in the soils of the cultivated land (Seyoum, 2016). Agricultural soils, the typical order of distribution for exchangeable basic cations is Ca>Mg>K>Na, observed at a pH of 5.5 or higher.

The lower exchangeable Mg levels in cultivated soils my result from ongoing Mg removal during crop harvests. Continuous cultivation can deplete Ca^{2+} and Mg^{2+}, particularly in acidic tropical soils (Hailu et al., 2015; Seyoum, 2016).

2.1.4.4. Cation exchange capacity and percent base saturation

The woodlot land use type exhibited a higher cation exchange capacity, as reported (Alemu et al., 2015). The reduction in cation exchange capacity was primary linked to deforestation and continuous cropping, as reported (Chimdi, 2015). Across all land uses, cation exchange capacity (CEC) declined from grazing land to forest land and then to cultivated land in line with organic carbon content. The highest CEC was found in the top layer with the most organic carbon. Continuous cultivation leading to organic carbon loss may diminish CEC in cultivated soils. Soil CEC is influenced by the levels of humus and clay, two key colloidal substances.

Historically, percent base saturation, previously known as total exchangeable bases (TEB), is calculated as the sum of the major exchangeable cations Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} [ΣExch. (Ca + Mg + Na + K)/CEC] multiplied by 100%. A study by Chimdi (2015) revealed that in Sasiga District, the CEC was lowest at 4.18%, while in Gidda Ayana District, it peaked at 37.86%. In Girar Jarso, land use notably influenced soil base saturation ($P<0.01$). the lower base saturation in cultivated lands's top layer suggests fewer bases present, contrasting with viryin/grazing lands in Ethiopia's central highlands. Additionally, base saturation decreased significantly from 50.42% in the surface soil to 42.60% in the subsurface soil of grazing land, distinct from cultivated and forest lands (Seyoum, 2016).

2.1.4.5. Cation exchange capacity of the clay fraction

Clay minerals can absorb and retain ions in an excgangeable form. Among the most common exchangeable cations in clay minerals, the typical order of relative abundance includes Ca^{2+}, Mg^{2+}, H^{+}, NH^{4+}, and Na^{+}. Donis et al., (2017) reported that in the surface layes, clay CEC was greater at 8.25cmo kg-1in grazing land and lesser at 5.25cmol kg-1 in cultivated land. Conversely, high CEC/clay values were observed in the surface soil. The CEC clay for clay minerals was not notably high at 96.85 cmol kg-1 in virgin land. Instead, the cultivated land units 6 and 11 displayed the highest (108.23 cmol kg-1) and lowest (46.67 cmol kg-1) mean values, respectively by (Akinde et al., 2020).

2.1.4.6. Exchangeable acidity

Exchangeable acidity (EA) represents the combined presence of hydrogen and aluminum ions in soil solutions. Research revealed significant EA variations across different land uses ($P<0.01$). The highest EA value (2.76 cmol kg-1) was found in the topsoil of cultivated land, while the lowest (1.10 cmol kg-1) was in the subsoil of forestland. The elevated EA in cultivated soil surface may be linked to decreased base-forming cations due to continuous inorganic fertilizer use and farming practices. Intensive cultivation and ongoing inorganic fertilizer application could exacerbate soil acidity levels (Seyoum, 2016). Research indicated that deforestation, intensive farming, and the use of inorganic fertilizer result in increased exchangeable acidity levels in the crop fields across the surveyed districts of the East Wollega Zone (Chimdi, 2015).

2.1.4.7. Effective cation exchange capacity

Effective cation exchange capacity is the total of exchangeable bases and exchangeable acidity, influced by land use. In a study, effective cation exchange capacity exhibited a pattern similar to that of the soil's total cation exchange capacity (Seyoum, 2016). In the Girar Jarso study, significant differencein ECEC across land use were found ($P<0.01$). the highest ECEC (26.29 cmol kg-1) was in grazing land, while the lowest (14.07cmol kg-1) was in cultivated land. Across soil depths, the surface layer had a mean ECEC of 19.90 cmol kg-1, higher that the subsurface layer (18.49cmol kg-1). Overall, ECEC in Girar Jarso correlated with CEC and OC (Seyoum, 2016).

2.1.5 Impacts of LULC Changes on Selected Soil Physicochemical Properties

Land use practice impacts soil nutrient distribution and availability by directly changing soil properties and affecting biological processes within the root zone. For instance, clearing of forests diminishes the soil carbon (C) within a few years of early alteration and substantially lowers minerals of nitrogen (N) (Cardinael et al., 2022). Kassa et al. (2017) investigated the property of land use type changes on soil excellence and inhabitant flora degradation and re-establishment in the highlands of Ethiopia. Results showed deforestation and then long-standing farming caused organic matter and total nitrogen to decrease and also changes in soil surface (0-10 cm) indicated phosphorous, potassium, available potassium, Ca^{2+}, Mg^{2+}, saturation point, and cation exchange capacity.

Soil properties answer to changes in LULC was investigated at dissimilar points in time and spatial scale. In tropical regions, for example, Safaei et al. (2019) have studied the effects of land cover change on soil resources and the results showed that conversion of climax vegetation to managed human-managed land use systems triggered to reason low soil arrangement constancy, defeat of organic matter, decrease in nutrient stock, and reduction in soil organic carbon.

LULC change causes soil degradation which refers to the decline in long-term productive potential (Mariye et al., 2022). In other words, to the decline of soil quality, or the reductions of attributes about specific value to humans (Bünemann et al., 2018). It has become a global issue because of its unconstructive impacts on the environment and socio-economic aspects (Filatov et al., 2019). It also enhances the share of primary production for human consumption but decreases the share available for other ecosystem functions. For example, forest transitions impact hydrological cycles, climate change, biodiversity crises, and soil and water conservation (Vacek et al., 2023).

LULCC affects soil organic matter, which is primarily plant residues, in different stages of decomposition. The accumulation of SOC within the soil is a balance between the return or addition of plant residues and their subsequent loss due to the decay of these residues by microorganisms. The presence of organic matter in the form of plant residues on the soil surface shields the soil from the detrimental effects of rain, wind, and sunlight. When these residues are removed or burned, the soil becomes vulnerable to adverse climatic influence, and the soil organisms lose their main energy sources (Alewoye et al., 2020). Soil organic matter (OM) is vital for sustaining agro-ecosystem productivity and the lasting preservation of soil and water resources. Sufficient OM levels are crucial in upholding or enhancing chemical fertility, soil porosity, water infiltration capacity, moisture retention, and resilience against water and wind erosion (Aytenew et al., 2020).

Land use change, inappropriate agricultural practices, and climate change can all lead to a net release of C from soils to the atmosphere, enhancing the problems of greenhouse gas release (Moinet et al., 2023). Soil organic carbon is thought designate the main component of the global carbon cycle, holding more than the atmosphere and vegetation combined (Ramesh et al., 2019).

Land use and land cover can impact soil chemical and physical properties throughvarious human activities like deforestation, tillage, livestock disturbance, harvesting, planting, and fertilizer application etc. In Ethiopia, several studies Fentie et al. (2020); Karltun et al., (2013); Kiflu et al., (2013) Yihenew et al., (2013) have careful the property of land use land cover and their organization on soil properties. For instance, Fentie et al. (2020) found comparable higher OC, and TN under grassland as evaluated to cereal farms, whereas they found higher available P under enset farms than pasture land and cereal farms in the Tejibara watershed, Ethiopia. Another study by Molla et al. (2022) also significant alterations in chosen physical and chemical aspects were observed when comparing cropplants, forestlands, and grazing lands in the southeastern highlands of Ethiopia Yifru et al., (2011) have also studied soil in different land cover and land use types in Bale, southeast Ethiopia. In this study, soil organic carbon and total nitrogen were high in natural forests while these were low in the cultivated fields. Land use practices affect the distribution and supply of soil nutrients by directly altering soil properties and by influencing biological transformations in the rooting zone.

2.1.6 Soil Testing

Advancements in understanding soil nature and properties have improved the assessment of soil potential and limitations for suitable land use and sustainable agricultural productivity. Therefore, soil testing is crucial for gaining a deeper insight into its properties (Tekwa et al., 2011). Soil testing involves evaluating the nutrients supply capacity of soil through physical, chemical, and biological assessments. It entails a quick chemical analysis to determine plant-available nutrients, salinity, acidity, and elemental toxicity, while more broadly, it encompasses a comprehensive program offering interpretations, assessments, and fertilizer recommendations based on soil chemical analysis and additional factors (Datta et al., 2018). Overall, soil testing is a precise and indispensable tool crucial for evaluating soil fertility status.

2.2 Farmers' Decision on acceptance of different SWC practices in Ethiopia

Ethiopian government first recognized the impact of soil erosion after the 1973 - 1974 famine (Berlie, 2015; Haregeweyn et al., 2012), which occurred in the highly degraded parts of the country, particularly in Tigray and Wollo (Alemayehu T., 2023). Immediately, SWC measures were identified as a top-priority intervention to reduce soil loss and improve crop yields and people's livelihoods (Alemayehu T., 2023). Well-known traditional SWC measures have long been practiced in some areas of the country (Mekuriaw et al., 2018). In this initiative, the nation was divided into two zones: the arid zone, known as low-potential areas with soil fertility and rainfall suitable for rain-fed farming, and the non-arid zone, termed high-potential areas where rainfall is insufficient for rain-fed agriculture (Alemayehu T., 2023).

The government subsequently encouraged farmers in the low-potential areas to implement SWC measures whereas in the high-potential places, the government encouraged farmers to adopt improved inputs, for instance chemical fertilizers and seeds, to produce higher yields[1]. Although the government did not encourage farmers of the high potential area to practice SWC measures; some farmers have been practicing SWC measures on their cultivated lands (Mekuriaw et al., 2018). Furthermore, the government of Ethiopia instituted a countrywide physical soil and water conservation construction movement in 2011 that runs for 2 months (mostly January and February) every year in high-potential and low-potential places. The campaign aimed at mobilizing the community to construct the necessary structures following watershed conservation principles. This approach is

[1] Yield means an amount produced of agricultural activities.

intended to change the attitudes of the farmers and ensure that the SWC structures are sustainable and effective.

2.3 Soil Erosion

Two primary forms of erosion exist: geologic and accelerated erosion. Geologic erosion is a gradual natural process integral to soil formation over extended periods, unaffected by human activities. It contributes to rock wear and soil profile development, in contrast, accelerated erosion, caused by human activities like deforestation, intensive farming, and grazing, occurs when erosion rates surpass a critical threshold. Erosion risk varies across watersheds based on factors like topography, soil properties, climate, and land use practices (A. Kumar et al., 2022).

The removal of topsoil is taking place in the following ways: -

1. **Sheet Erosion**

Raindrops hitting the soil disperse and splash particles, moving them from their original places. Splash erosion occurs when raindrops bombard the soil surface, leading to the displacement of soil particles and the formation of craters (Lv et al., 2023).

2. **Rill Erosion**

Rill erosion is the erosion that happens in small channels or rills, formed when water from sheet erosion gathers to create concentrated channels (Dunne et al., 2020; Nearing et al., 2011).

3. **Gully Erosion**

Erosion rates escalate with the rise in flow velocity during rill erosion. The convergence of water in rills to form large channels leads to gully erosion (Dabney et al., 2015; R. P. C. Morgan, 2009).

4. **Stream Channel Erosion**

Stream channel erosion occurs as flowing water cuts into the channel bottom, deepening it (Bisson et al., 2017; Tucker, 2009). Soil erosion might not be readily apparent at the surface levels as raindrops transport particles, but becomes more evident when water flow concentrations, forming rills and gullies (Dabney et al., 2015; R. P. C. Morgan, 2009).

2.3.1 Major Causes of Soil Erosion

The primary factors contributing to accelerated water erosion include rainfall intensity, soil characteristics, land slope, and land use practices. Land use is the most significant factor, followed by slope, soil erodibility, and rainfall erosivity. Livestock concentration in shrinking grasslands leads to overgrazing, reducing vegetative cover and organic content, altering plant species composition, and compacting the soil. Additionally, various socio-economic factors, such as knowledge, resources, motivation, and organizational policies, contribute to degradation through inappropriate land use practices (Amenu, 2019; Panel et al., 2011).

2.3.2 Estimation of Soil Erosion Loss

Soil erosion modeling involves simulating erosion processes in watersheds, considering complex interaction influencing erosion rates. Parametric models like and physical process-based models are used to calculate soil loss, categorized based on simulated physical processes, model algorithms, and data dependencies. Empirical models, the simplest types, are statistical, relying on observation to characterize responses (Harrell Jr, 2015; Little et al., 2019). The universal soil loss equation (USLE) was developed to forecast soil loss from sheet and rill erosion in agricultural fields under specific conditions. The modified universal soil loss equation (MUSLE), an adaptation of the USLE, extends its application to various conditions by incorporating a hydrological runoff factors for estimating sediment yield. EUROSEM is a process-based model used for evaluating and predicting soil erosion risks in fields and small catchments (R. Morgan et al., 1998; Raza et al., 2021). The Morgan and Finney Model (MMF) is an empirical model designed to estimated mean annual soil loss from field-sized areas on hill slopes, grounded in a robust physical foundation (R. Morgan et al., 1994; Raza et al., 2021).

2.3.2.1 USLE Model

The universal soil loss equation (USLE) was established by (McGregor, 1978), it has been a global tool for approximating soil erosion risk for four decades, due to its data and computation demands, efforts have been made to develop more precise and less resource-intensive models. Despite being widely used at regional and national levels for its simplicity and standardization, USLE has limitations it does not account for gully or stream-channel erosion and is not tailored for large-scale operations (Calderón-Celis et al., 2018; Desmet et al., 1996).

2.3.2.2 RUSLE Model

The revised universal soil loss equation (RUSLE) was regarded as an enhanced alternative to the original USLE model (Kratzert et al., 2018; K. G. Renard et al., 1997; K. G. Renard et al., 1991). The RUSLE model predicts average annual soil erosion rates on field slopes based on factors like rainfall, soil types, topography, crops, and management practices (Wischmeier, 1965). When integrated with GIS, it swiftly identifies high erosion areas in watersheds accurately. This empirical model necessitates measurements of variables such as rainfall, soil characters ties, slope, and land management practices. Moreover, long-term regions rainfall data is crucial for accurate estimations (K. Renard et al., 1993; K. G. Renard et al., 1994).

In mathematical terms, the Revised Universal Soil loss Equations (RUSLE) is represented as: A (tons/ha/year) = R * K * LS * C * P …………………………………..equation (1)

A stands for the average annual soil loss, with R representing the rainfall erosion factors, K the soil erodobility factor, L the slope length factors, S the slope steepness factors, C the crop management factors, and P the erosion control or land management factors. The updated Revised Universal Soil Loss Equation includes the following assumptions:

- ✓ The USLE presumed uniform runoff distribution across catchments, with some runoff directed into rills and gullies. Rill erosion is a significant element in the RUSLE model
- ✓ The USLE calculated runoff as excess precipitation minus soil infiltration without accounting for soil saturation during extended rainfall, leading to increased runoff and erosion. It also overlooked sediment accumulation in concave slopes and was used solely in areas experiencing net erosion.
- ✓ The USLE did not account for converging and diverging terrains, a limitation addressed in the RUSLE model.

2.3.3 Major Factors Affecting Soil Erosion Loss

Soil erosion on fields is influenced by various interconnected factors like climate, soil attributes, topography, and land cover practices. Rainfall plays a crucial role in soil loss by dislodging soil particles and contributing to runoff (R. Morgan et al., 1994; Raza et al., 2021). Rainfall erosivity refers to the erosion power of rainfall (Amara et al., 2020).

Slope length (L) and steepness (S) factors illustrate how topography influences erosion. Slope length is described as the distance from where overland flow begins to where deposition starts or flow becomes concentrated in a defined channel (Wischmeier et al., 1978). Studies have shown longer slopes and steeper gradients lead to faster overland flow velocities and increased erosion (Haan et al., 1994; Shen et al., 2016).

Factor “C” in the revised universal soil loss equation (RUSLE) signifies the impact of cropping and management practices in agriculture, as well as the influence of ground, tree, and grass cover in non-agricultural settings on mitigating soil loss. Higher vegetation cover correlates with reduced soil loss. According to Benkobi et al. (1994); K. G. Renard et al., (2017); Qin et al., (2018), among the factors influencing soil loss, vegetation cover, alongside slope steepness and length, is the most sensitive.

The conservation practice factors (P), also knows as the support factor, and reflects the reduction in soil loss achieved by specific conservation practices. It quantifies the impact of soil and water conservation efforts on mitigating erosion (Ebabu et al., 2022; Endalamaw et al., 2021; Omuto, 2008).

2.3.4 Geographic Information Systems

Advancements in computer technology and spatial analysis tools since the latter half of the 20^{th} century have enabled tasks such as storing, retrieving, and visualizing data concerning various aspects of the Earth’s surface (Blanco et al., 2023).

Geographical information System (GIS) serve as a crucial tool for organizing spatial data, facilitating analysis, modeling, and visualizing outcomes (Tao, 2013). Widely adopted in environmental science and land use fields, GIS is integral to diverse applications ranging from watershed monitoring to military exercises, spanning disciplines like natural resources management, agriculture, urban planning, and more (Aboulola, 2017).

2.3.5 GIS and Modeling Soil Erosion Loss

GIS software capabilities are enhanced when integrated with various analytical models, such as those for resources allocation, population forecasting, land-use planning, transportation, and site selection (Aboulola, 2017). Modeling within a GIS framework involved creating a digital database that interfaces with mathematical models. For instance, planner can link land cover and topographic data with environmental parameters like surface runoff and terrain configuration. This integration aids in refining models like the USLE, enabling accurate predictions of agricultural pollutants loads and nonpoint source pollutant transport based on watershed characteristics such as soil types, slope, vegetation, and area (Blanco et al., 2023).

2.3.6 Impacts of LULC Changes on Soil Erosion Rate

Land use and land cover alterations play a pivotal role in global environmental shifts, encompassing soil degradation and highlighting the swift population expansion in tropical regions. The escalating need for resources like firewood, timber, pasture, shelter, and food crops is driving the degradation of conversion of natural land covers, notably tropical rainforests, into croplands at an alarming pace (Blanco et al., 2023).

Ethiopia’s agricultural land predominantly relies on ox-plough systems, leaving the soil vulnerable to erosion, especially at the start of the rainy season. Rain-fed farming on steep slopes without adequate safeguards leads to significant soil erosion issues in the country (Ebabu et al., 2023; Hurni et al., 2010). Soil erosion stands out as Ethiopia’s primary land resource challenges, resulting is substantial losses of soil, nutrents, water, and agrobiodiversity annually (Yigezu Wendimu, 2021). The ecological consequence of land use land cover change (LULCC) in thiopia encompass diminished soil quality impacting plant growth, reduced access to clean water, decrease surface water levels, aquifer depletion, and biodiversity decline (F. Tilahun, 2022).

There are two main types of soil erosion: geological (natural) and accelerated erosion. Geological erosion occurs naturally without human intervention, maintaining a balance between soil formation and erosion. Accelerated erosion, typically caused by agricultural activities disrupting this balance, is more severe than geological erosion (Glenn, 2020). Soil loss, measured as the quantities per unit area, is commonly referenced for small areas. in highly erodible conditions, the soil loss or sediment yield is constrained by the runoff's transport capacity. Modification is topography, vegetation, and soil properties along the watershed frequently diminish this transport capacity (Mutchler et al., 2017; Zhang et al., 2018).

2.4 Land Use Land Cover Change

Land cover and land use are two interconnected ways of assessing the Earth's surface, land cover describes the physical state of the surface and immediate subsurface, while land use signifies how human activities alter the land and for what purpose (Tewabe et al., 2020). Examples of land use include grazing, recreation, agriculture, urbanization, logging, and mining. A shift in land cover involves transitioning from one cover type to another or modifying within the same category. Conversely, land use change occurs when human activities lead to alterations in land use for various purpose like habitation, infrastructure development, agriculture, and leisure activities (Nuissl et al., 2021).

2.4.1 Relationship between Land Use and Land Cover

The link between land use and land cover involves mutual influce: change in one can impact and be influenced by the other, yet they are not always directly causative. A specific land use types can align with a single and cover or encompass multiple covers (Briassoulis, 2011; Ren et al., 2019). For example, a farming system might comprise various covers like cultivated land, woodlots, improved pastures, and settlements. Conversely, a single land cover type can serve multiple purposes. Natural forest areas, for instance, can support activities such as hunting, gathering, fuel wood collection, recreation, and wildlife conservation (Mavhura et al., 2019; Verheye et al., 2011).

2.4.2 Drivers of Land Use Land Cover Change

The immediate drivers of land use land cover change (LULCC) stem from the direct actions of local communities, influenced by various underlying factors like economic, social, and political conditions (Abebaw, 2020; Zelleke et al., 2010). About 54% of Earth's land surface experience disturbance from both human activities and natural elements. (Briassoulis, 2011; Ren et al., 2019). In Ethiopia, vast region once covered by vegetation have been converted to cultivated land. Leading to soil erosion, environmental degradation, and position a significance risk to the land (Ebabu et al., 2023; Hurni et al., 2010).

Technological advancements like the adoption of mechanized large-scale farming, alterations in farming practices involving intensification, and inadequate technological practices in forestry (resulting in inefficient logging methods) are key technological contributors to land use and land cover change (LULCC), notably in tropical deforestation. Cultural influences, comprising motivation, shared memories, personal narratives, attitudes, values, beliefs, and perspectives of individuals, communities, and land stewards, play a significant role in shaping decisions regarding land use and land cover, often exerting a profound impact (Giuliani et al., 2022; E. Lambin et al., 2007).

2.4.3 Applications of GIS and Remote Sensing Techniques for LU/LCC

Giuliani et al. (2022) says traditional data collection methods like demographic data, censuses, and sample maps have proven inadequate for urban land use management. Hence, precise data on land use and land cover changes is crucial for various stakeholders.

Remote sensing plays a vital role in assessing deforestation levels, habitat fragmentation, urban expansion, wetland deterioration, and other landscape-scale changes. This valuable data can be incorporated into carious models spanning regional to global scales, aiding in parameter zing carbon fluxes and hydrological processes. As a result, remote sensing data serves as a fundamental tool fro addressing crucial ecological inquiries with implications at regional and global levels (Rose et al., 2015).

Remote senescing offers a versatile platform for gathering, storing, visualizing, and analyzing digital data critical for detecting land use and land cover changes (LULCC), as well as for land use planning and modeling tools (Bufebo et al., 2021; Rimal, 2011). In the realm of LULCC, remote sensing refers to the capacity to identify surface alteration using satellite sensors (S. Kumar et al., 2020; Oumer, 2009; Rimal, 2011).

2.4.4 State of LULC Changes in Ethiopia

According to the Ministry of Mine and Energy, Ethiopia spans cover 1.12million km^2. Approximately 55% of this expanse lies below 1500masl, classified as lowland, while the remaining 45% stands above 1500masl, categorized as highland (Kibru et al., 2021; Tefera, 2011). These issues are intricately connected to climate change and land use land cover changes (LULCC). LULCC, encompassing alterations in forest covers, stands out as a significant environmental concern in Ethiopia (Alemu et al., 2015).

In Ethiopia's highlands, agriculture has expanded, encroaching on vegetated areas like shrub land, woodland, and forests since the 1860s. However, this agricultural expansion at the expense of vegetation lands has intensified since the 1980s, worsening the situation. (Teweldebrihan et al., 2023). According to M. Abebaw (2020) and B. Turner et al. (1994) across developing nations I Africa, Asia, and Latin America, there is a significance statistical relationship between population growth and land use land cover change (LULCC). Several studies conducted in various regions of Ethiopia have also identified population growth as a primary driver of LULCC.

2.4.5 Impact of LULC Change on Agricultural Production

Land use/land cover change involves altering the Earth's surface due to human activities and natural occurrences like floods, fire, and climate variations. Land cover encompasses the physical surface elements like water, vegetation, and bare soil, while land use involves human practice such as farming. Forestry and grazing. These dynamics offer insights into how human activities interact with the environment (Prakasam, 2010; P. S. Roy et al., 2022). Changes in land use/land cover result from actions, impacting essential resources. A crucial concern is the potential long-term threat to food production and vital resource due to the transformation of production land for other purpose, like converting agricultural areas into residential zones and the degradation caused by overgrazing.

CHAPTER THREE

3. METHODS OF THE STUDY

3.1. Study Area Description

This study was conducted in the Kabe Watershed (Wereillu District), which was part of the Jemma sub-basin of the Blue Nile (Abbay) Basin, South Wollo Zone of Amhara Region, Ethiopia. Kabe Watershed was found 470 km North of Addis Ababa (Capital city of Ethiopia). Where land degradation was strongly linked with climate variability pushed farmers to abandon small rainy seasons. According to the Amhara Regional Bureau of Finance and Economic Development, the population size of Wereillu Wereda was about 162,874 (2009 census) and had a 5.7% share of the zone's total population. Out of the total population, nearly 95 percent live in rural areas while 5 percent was in small towns. The average household size in the Wereda was 4.4. The population density was 106.7 persons per square km. This indicates that it was one of the most highly populated areas in the country. Women-headed households were 10,905 while men-headed households were 25,203. Based on the South Wollo Zone of Amhara region Agricultural office report, Wereillu was one of the food deficits Wereda with 42% of the population under the poverty line (based on country measurement).

Traditional methods of increasing soil fertility were practices such as fallowing and use of farm residues manure and crop rotation were abandoned long ago. Fallowing was little because population pressure had forced them to crop every plot of land available every year. Organic sources such as crop residues were completely removed from farmlands either for animal feed, fuel, or house construction purposes. Cow dung, which was supposed to be used as farm residue manure, was a major source of household bio-fuel.

Some farmers use compost. Crop yields under rain-fed conditions were quite low due to the combined effects of limited use of inputs and poor agronomic practices.

Land use land cover changes

Prior to outlining the watershed, a site survey was conducted through transect walks, followed by delineating the watershed boundary using GIS with online satellite imagery (see Figure 1). While in the field, sample points denoting different land use types and slope positions were marked during the visit. Key land use categories including forests, grazing areas, and cultivated lands were identified. Delineation of dominant land-use types and terrain slope positions defines the required number of composite soil samples per each LUT for selected soil physical and chemical analysis. Agricultural and grazing land types were the dominant LUTs in the Kabe Watershed. Agricultural lands were mainly found in agriculturally accessible areas and downhill. Grazing lands, on the contrary, were mostly situated on moderately steep terrain slopes and around the homestead area of the community. The soil in the area was plowed with traditional agriculture and tillage frequency ranges from 1 to 4 times per cropping season Nyssen et al. (2000); Yohannes et al. (2021), depending on crop types usually owned and managed by individual farmers.

Climate

Kabe Watershed was found in different kebeles of Wereillu District and geographically located (39° 24' 30" to 39° 27' 8.7" E, and 10° 47' 14.1" to 10° 53' 35.8" N) (Figure.1). according to the Ethiopian National Meteorology Authority, data from the Kabe Wollo station shows that the average annual rainfall in the regions was approximately 1215.6mm, with the highest precipitation recorded in July, closely followed by August. Based on 34 years of climate data (1986 - 2019), the mean minimum and maximum annual air temperatures of the area were 8.2^{0}C and 19.9^{0}C, respectively, with mean annual air temperature of 14.8^{0}C with the warmer month occurring in June and colder in November. There was a large elevation gradient in the watershed encompassing plains, midland areas, and mountains. The watershed lies to the south of Yewel Mountain. Water in the Kabe Watershed flows from the upstream mountain, called Yewol (which was the Northern part of the Watershed) to the Selgi River (which also was in the Southern part of the Watershed) downstream and joins to one of the Blue Nile tributaries called Betho River.

Socioeconomic status

Out of the total population of the watershed community, almost all were rural residents but few were created in a small town called "Kabe" inside the watershed. According to our transect fieldwork observation in the study time, severe environmental degradation problems like soil erosion and nutrient depletion which in sum constrained agricultural production in the area were the common phenomena. The main dependence of local farmers on the economy was mainly rain-fed agriculture. As a result, persistent drought and many crop failures were common phenomena, all of which in turn resulted in chronic food shortage and poverty. Farmers carry out a crop-livestock mixed farming system. However, low soil fertility, crop diseases like rust and weeds, and lack of agricultural inputs including improved seeds and moisture stress were the main problems of crop production in the watershed.

Topography

We segregated the study area into three topographic states upstream, middle part, and downstream of the watershed. Kabe Watershed altitude varies from 1749 masl near the Selgi River to 3856 masl at the top of Yewol Mountain. The topography of the area was not uniform and most part was characterized by hilly and steeply dissected topography with moderately steep-to-steep slopes. It was located in the drier parts of the country. Like the study area, earlier research suggests that different fundamental barriers could be responsible for the poor management of soil and water resources in drought-prone dry land regions of Ethiopia (Amede et al., 2014). The study areas were places where access to markets was medium and some NGOs were devoted to working with the local communities in improving water and land use management practices. Therefore, all the information illustrated below would represent the area where the watershed was located.

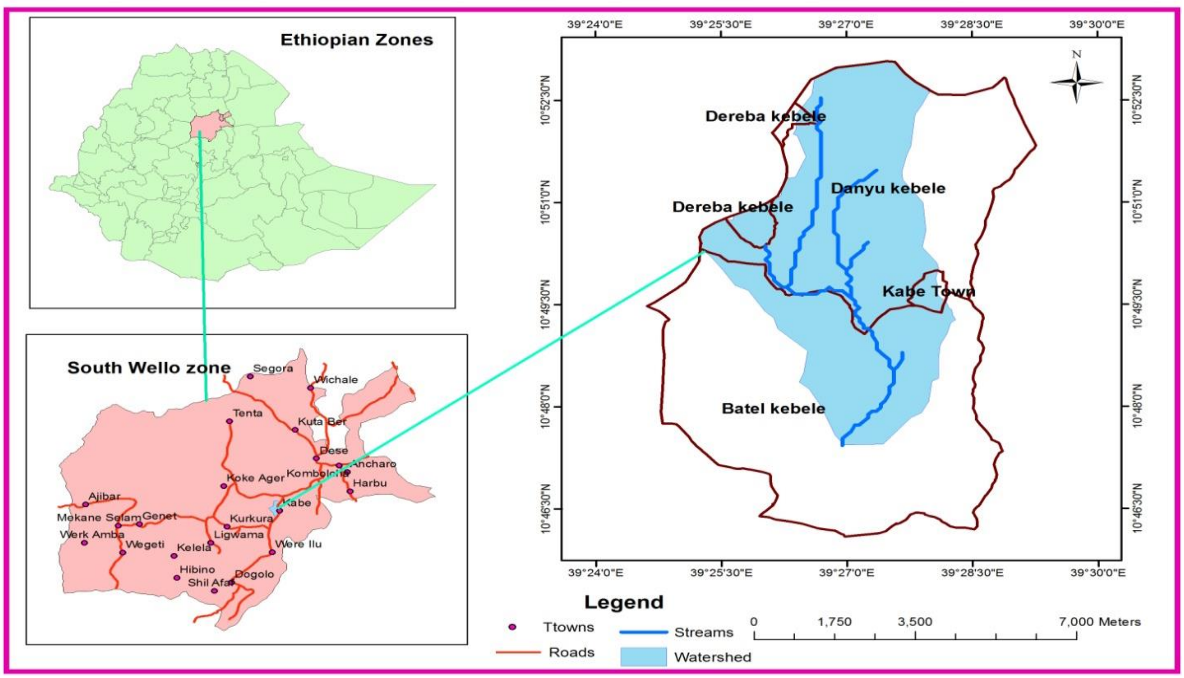
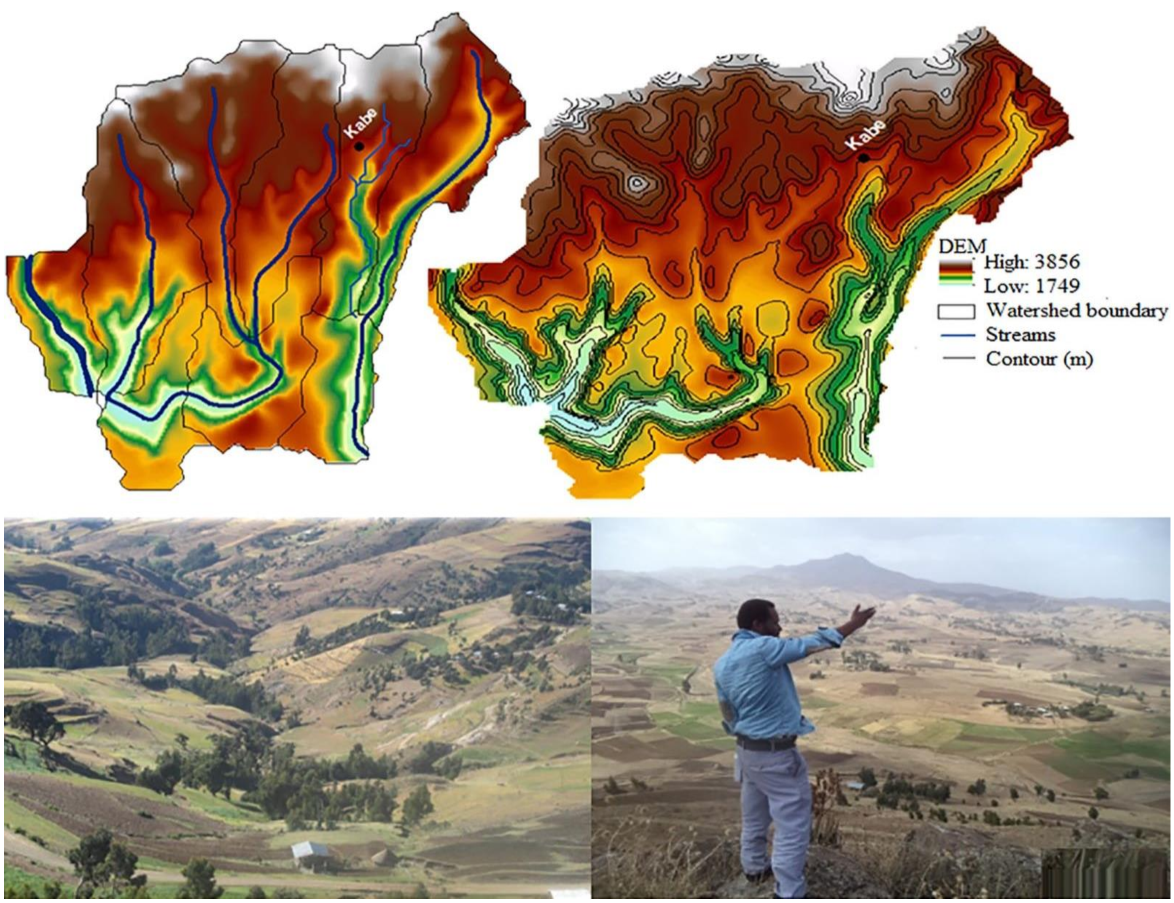


Figure 1: Map of Kabe Watershed

Forest and Vegetation status

In the study area, the cover of perennial components including trees and shrub species was low. Those happened because of a combination of several driving forces such as an increase in population which led to diminishing land size and forced to focus on short-term crop benefits to answer the immediate (its high demand for house construction and good prices on the market) need for food for farmers. Moreover, little attention to perennial crops might be the main reason for the problem of poor integration of perennial components in the landscape. Some trees and shrubs species were identified in the study sites that were planted at the homesteads as live fences and as woodlots in parts of the farms, which were not appropriate for crop production. Natural vegetation (Shrubs) was declining over time and *Eucalyptus* species were becoming dominant in the watershed. Within the Kabe Watershed, Eucalyputus plantations were the predominant tree species. Nonetheless, the primary natural forests have suffered fragmentation and degradation due to human activities like deforestation for agricultural, pasture, firewood and construction.



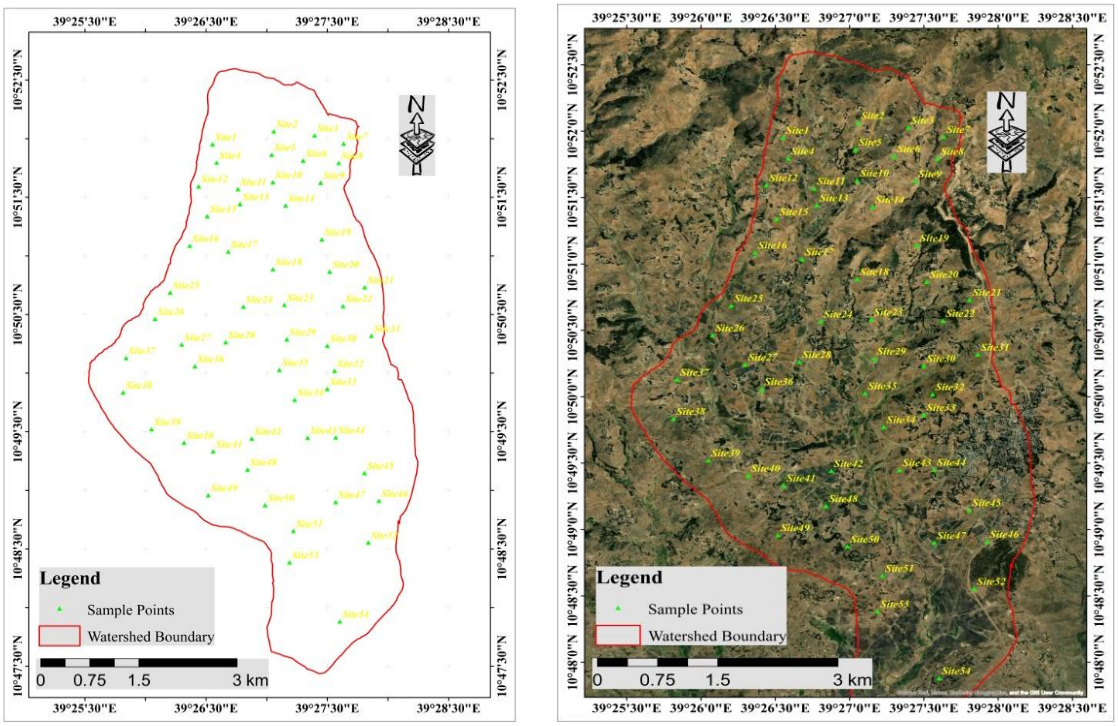


Figure 2: Terrain elevation (Upper) and soil sample correction distribution Map (lower)

Soil types and farming practices

The major part of the study area was characterized by the high status of extractable micronutrients. Following the diversity in the indicated characteristics of the soils, four Reference Soil Groups (RSG) were identified in the Kabe Watershed. These soil groups were Vertisols, Luvisols, Cambisols, and Leptosols (Hailu et al., 2015). The district's agricultural system is primarily characterized by mixed farming, with livestock rearing and subsistence crop cultivation playing vital roles in supporting the community's livelihoods. Almost all households in the Wereda were dependent on subsistence crop farming. In recent years however, except for some kebeles in the mountainous areas of Kabe Watershed, especially those in the plain do not receive much rainfall during the *Belg* season (short rains between March and April exist), as a result only a few farmers do produce during *Belg*. Most farmers in the Wereda produce only once during the *Meher* season when rains were generally received between July and September. Of the total cultivated land area, 91% was rain-fed. In the year 2016/2017, during the Belg season 5,482 ha and Meher season, 34,709 ha was covered by cultivated. The average land holding in the Wereda was 0.86 ha with a fragmented landholding system under rain-fed conditions, whereas it was 0.174 ha under irrigation. In the rain-fed system, the main types of crops grown were bread wheat (*Triticum aestivum*), fenugreek (*Trigonella foenum-graecum*), barley (*Hordeum vulgare*) and Teff (*Eragrostis tef*), Horse bean (*Vicia faba*), lentils (*Lens culinaris*), and field peas (*Pisum sativum*) were also grown in small proportions (Wereillu Wereda Agricultural Office, 2015).

3.1.1 Study Site Selection Criteria

Selection processes were built on the eligibility criteria established before the beginning of identifying, locating, and retrieving the research needed to address the problem of the study. The researchers in summary prioritized study site selection mainly based on population size, the nature of the intervention, cost, time, and cultural range. Kabe Watershed was selected based on the ecological representativeness of the intended study objective, not yet studied, accessibility, and facility for the study arrangement.

3.2 Methods of Land Use Management Practices on Selected Soil Physicochemical Properties

3.2.1 Soil sampling design and land cover distribution

The spatial sampling technique involved the classification of landscape in varying slope positions as lower (1% - 15%), middle (15% - 30%), and upper (30% - 45 % and above) slope positions. These slope classes were selected based on the availability of the same slope classes at different land-use types. Identify slope by sighting through a clinometer, the measuring line was placed on the target, and % slope was read from the scale. Both eyes were open, as one eye read the scale, and the other eye sight on the target. Identifying land use types by field observation. Representative sampling fields were then selected based on vegetation and cultivation history, which was categorized as forest, grazing, and cultivated LUTs. Following the identification of 3 different land-use types across the watershed and classification of the terrain in 3 slope ranges, a total of 54 composite soil samples were collected at the depth 0-30 cm from each of the LUTs (i.e., forest, grazing, and cultivated land) stratified into upper, middle and lower slope positions (See the soil sample correction distribution map in Figure 2 and Appendix 14).

The samples were taken both at conserved/treated and unconserved/untreated areas in considering different land-use types in 2016. Based on tropical soil and soil survey methods (Young, 1976), data were collected at three slope positions for three different LUTs both at treated and untreated areas total of 54 samples (two treatments × 3 LUTs × 3 slope positions × 3 replicates). At each point, soil samples were taken using a 5 cm diameter auger and core sampler for bulk density analysis. Each composite soil sample was collected from a 10m x 10m at least 100 m a part demarcated plot (Bigalke et al., 2020). Eighteen core soil samples were collected in a randomized sampling design for laboratory analysis. To make one composite soil sample, 1kg of each subsample was mixed well, and about 1kg of the mixed composite samples was properly labeled. Finally, 54 total composite soil samples were prepared and gently sieved through a 2 mm mesh to remove stones and roots, and were sealed in plastic bags for laboratory analysis.

3.2.2. Soil sample preparation and laboratory Analysis

Following the field procedure, composite soil samples were air-dried, mixed, and passed via a 2mm sieve for selected soil physicochemical properties (Buraka et al. 2023). Eighteen undisturbed core samples from all land use types and at varying slope positions (lower, middle, and upper) were used to parameterize selected soil physical properties such as soil bulk density, total porosity (TP), and soil gravimetric moisture content.

Soil bulk density (BD) for 18 undisturbed soil samples was assessed utilizing a volumetric cylinder. The calculation involved dividing the mass after over-drying at 105^0c by the volume of the over-fried core, a method commonly known as the core sampler method (Blake et al., 1986). Nonetheless, the average soil particle density ($2.65 g/cm^3$) Brady, N. and Weil, R. (2016) was considered and the total porosity was calculated using the experimental soil bulk density and the average particle density, following equation (2) below. The soil particle size distribution was determined using the Bouyoucos hydrometer method, as detailed (Bouyocous, G.J. 1962; Rowell DL. 1994).

Total Porosity (%) = (1-BD/PD) *100 ……………………………………… Equation (2)

Where: PD is particle density (g/cm^3) and BD is bulk density (g/cm^3)

Following this, the soil texture triangle compares the percentages of soil particle compositions to determine the soil type. This allows for scientists to observe each of the twelve soil types within a single tool (See Appendix 19).

In the soil chemical analysis process, the soil organic carbon (OC) content was extracted using hydrogen peroxide (H_2O_2), and the soil were dispersed with sodium hexametaphosphate ($NaPO_3$). Following this, the soil particle size distribution analysis was conducted using the Boycouos hydrometric technique (Bouyoucos, 1962). Besides, we analyzed soil total N content, pH, cation exchange capacity (CEC), and exchangeable cations (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}) using the method explained in Table 1.

Table 1: Laboratory analysis methods for selected soil physiochemical parameters

Variable	Laboratory analysis procedure	Reference
Soil bulk density	Calculated as the ratio of the mass of oven-dried soil to its volume	(Blake & Hartge, 1986)
Gravimetric soil moisture content	Moisture content is computed as the ratio of the weight of wet soil to the weight of soil after oven drying	(Bilskie & Scientific, 2001)
Total porosity	Calculated from bulk and particle density	(Hao et al., 2008)
Soil texture	Hydrometer analysis	(Gee & Bauder, 1986)
Soil pH and Electrical Conductivity (EC)	Determined from soil suspension solutions prepared with soil-to-water ratios of 1:2.5 (w:v) using a pH meter and an EC meter, respectively.	(Sonmez et al., 2008)
Soil Organic carbon content	Determined following the method described by Walkey and Black (1934)	(Walkey & Black, 1934)
Total nitrogen, TN	Analyzed using the Kjeldahl method	(Kjeldahl, 1883)
Available phosphorous	Extracted using the Brady procedure	(Brady & Weil, 2002)
Cation exchange capacity (CEC) and exchangeable bases (Ca, Mg, K and Na)	Determined after leaching the soil using ammonium acetate (1N NH_4OAc) at pH 7.0.	(Chapman, 1965)
	Ca and Mg were measured using atomic absorption spectrophotometry	(Williams et al., 1962)
	Sodium and potassium were assessed using flame photometer emission spectrophotometry	(David, 1960)
Percent base saturation (PBS)	Computed as the sum of base-forming cations (Ca,Mg,K and Na) divided by the CEC of the soil, then multiplied by 100	(Mehlich, 1978)

3.2.3 Statistical Analysis

Statistical analyses were conducted using statistical methods of Statistical Package for Social Science (SPSS[2]). The soil property data obtained from laboratory analysis were evaluated using the general linear models (GLM) within the statistical analysis system procedures as a statistical tool to break the mean, standard error; F & P values, and test significance of differences between each soil properties based on different

[2]SPSS (Statistical Package for the Social Sciences) is a software package used for the analysis of statistical data.

independent/fixed variables. Bayesian statistics, ANOVA[3], and Pillai's trace test were employed for mean values of the soil physiochemical properties that were found to be statistically significant. The effect of LUTs, SWC practices, and slope position against soil physiochemical properties and their interactions were tested at $\alpha = 0.05$.

One-way ANOVA was used to analyze the mean values of different physiochemical properties of soil as dependent variables. This included soil texture (sand (%), silt (%), clay (%), silt/clay), Bulk density (BD) (g/cm^3), Soil moisture (SM) (%), silt-clay ratio (SCR), Total porosity (TP) (%), soil reaction (pH), Electrical Conductivity (EC) (ds/m), Soil Organic carbon content (OC) (%), Total Nitrogen (TN) (%), Available phosphorous (AP) (ppm), Cation exchange capacity (CEC) (cmol kg^{-1}), Exchangeable bases (Calcium (Ca) (cmol kg^{-1}), Magnesium (Mg) (cmol kg^{-1}), Sodium (Na) (cmol kg^{-1}), Potassium (K) (cmol kg^{-1})) and Percentage base saturation (PBS) (%). The independent variables were LUTs (Forest, Grazing, and Cultivation area), slope position (upper, middle, and lower), and treated/untreated SWC areas. Percentage changes in the soil physiochemical properties of cultivated and grazing land types compared to forest land were explained as,

$$CI = \left(\frac{C_{L,\ orGL} - F_L}{F_L}\right) * 100 \qquad ---------------\text{Equation (3)}$$

Where C_L represents percentage changes in the mean value of soil physiochemical properties of cultivated or grazing land compared with forestland types. C_L, G_L, and F_L were mean soil physiochemical property values for cultivated, grazing, and forest land use types respectively. Sample site LUTs were dominantly cultivated, grazing, and forest, which can be validated with the recent planimetric surveys. Figure 2 shows watershed and

[3] ANOVA (Analysis of Variance), a statistical method in which the variation in a set of observations is divided into distinct components

stream definition (top left), elevation, and 100m interval contour map (top right) and study aerial photo observation showing various LUTs and slope positions (lower panel). The spatiotemporal land cover distribution for three snapshots, namely, 1986, 2000, and 2019, and the aerial view of the terrain topography was also shown.

3.3 Methods of Farmers' Decisions on Acceptance of Soil and Water Conservation Practices

Structured questionnaire surveys and focus group discussion methods were utilized to gather essential information from farm households (Kebede et al., 2014). 100 households were surveyed, and 282 plots along with multiple fields were inspected during transact walks. The Tobit regression model was used for analyzing correlations among area, household, the study focused on plot characteristics and the adoption of three types of soil and water conservation practices. Data analysis involved descriptive statistics and cross-correlation methods.

3.3.1 Methods of Data Analysis

Analyzing factors influencing the adoption of soil and water conservation technologies was challenging due to varying agro-ecological and socio-economic conditions among farmers (Bekele & Drake, 2003). To tackle this challenge, the study assumed that each farmer aims to maximize utility but determines the acceptance of SWC practices based on individual perceptions of utility and the specific attributes of their situation and location. Therefore, the adoption of soil and water conservation practices was believed to be influenced by a set of attributes values unique to the land plot, some of which were region-specific, village-specific, farm-specific, or plot-specific.

To accomplish the analysis at the plot level, the data acquired for each plot were analyzed using descriptive statistical techniques and econometric analysis (Tobit Regression Model) provided by the Statistical Package for Social Sciences (SPSS). For the informal key informant interviews and field observation notes, a qualitative analysis was used.

3.3.2 Specification of the Statistical Model

Farm households in Kabe Watershed vary in their use of different soil and water conservation structures on cultivated land. Despite promotion efforts, some households did not use these measures, resulting in reported proportions of zero for SWC implementation of their land. As noted in Greene (2003), when a dependent variable shows a substantial numbers of zero values, employing a censored regression model like the Tobit model is necessary as standard OLS regression may not be suitable "fails to account for the qualitative difference between limit (zero) and non-limit (continuous) observations". Therefore, understanding the factors influencing the adoption of SWC practices necessitates utilizing a censored regression model. Censored regression is favored as it incorporates data both at and above the limit to estimate the regression. Following Amemiya (1984), the Tobit model can be constructed by introducing a new random variable, y*, which is determined by a set of variables represented by the vector x:

$$\begin{aligned} & y_i^* = \beta' x_i + \varepsilon_i, \\ & y_i = 0 \text{ if } y_i^* \le 0, \\ & y_i = 0 \text{ if } y_i^* > 0, \end{aligned} \qquad \text{……………..…………………………………………………...Equation (4)}$$

In the Tobit model, yi represents the observed dependent variable with limitations, y^*_i, stands for an unobservable latent variable, x_i is a vector of factors influencing y*, B denotes unknown parameters, e_i are residual assumed to be normally distributed with zero mean and constant variance a^2, and I indexes the observed values from 1 to *n*. the model assumes censoring at 0 (though other values are possible) and normally distributed error terms. Parameters are estimated by maximizing the relevant log-likelihood function.

…………Equation (5)

$$\log L = \sum_{y_i > 0} -\frac{1}{2}\left[\log(2\pi) + \log\sigma + \frac{(y_i - \beta' x_i)}{\sigma}\right] + \sum_{y_{i=0}} \log\left[1 - \Phi\left(\frac{\beta' x_i}{\sigma}\right)\right]$$

Where L is the Likelihood Function and Φ is the cumulative normal distribution function. The marginal effect on y (observed variable) of a change in an explanatory variable x differs from the value of the β coefficient in the censored regression model. The marginal effects were a function of the x values, and are given by:

$$\frac{\partial E[y_i \mid x_i]}{\partial x_i} = \beta \cdot \Phi\left(\frac{\beta' x_i}{\sigma}\right)$$,……………………………………………Equation (6)

Where Φ is the cumulative normal distribution function; Often these marginal effects were calculated and reported at the mean values for the vector x, although in principle they could be calculated for individual households. Hawkins (1993) proposed a useful decomposition of these marginal effects because a change in the x's has two different effects. One is that x influence the conditional mean of y^*_i in the positive segments of the distribution. However, x also influences the likelihood of the observation falling within that section of the distribution. Expressed mathematically, this decomposition is as follows:

$$\frac{\partial E[y_i \mid x_i]}{\partial x_i} = P[y_i > 0]\frac{\partial E[y_i \mid x_i, y_i > 0]}{\partial x_i} + E[y_i \mid x_i, y_i > 0]\frac{\partial P[y_i > 0]}{\partial x_i},$$ **…..**Equation (7)

Where *P:* indicates probability. Both the marginal effects and their decomposition will be reported for this study.

3.3.3 Hypothesis of Variables

A farmer's decision about SWC practices can be conceived of having two components: whether to use SWC practices and, if so, how many different practices to use on how much land. Both of these components were assumed influenced by several factors that were related to a farmer's objectives and constraints. The dependent and independent variables employed in this analysis are listed below. The independent variables were hypothesized to influence the use of SWC measures positively (+), negatively (-), or both positively and negatively (+/-). The sign of the parameter coefficient for variables in the last category would depend on the relative strengths of the different effects and would be indeterminate a priori.

The dependent variables (Y_i) represent the SWC practices in each plot and were represented by the length of the soil and stone bund constructed (m/ha), the length of the improved cut-off drain (check dam) constructed (m/ha) or numbers of trees (no/ha).

The independent variables (X_i) represent factors at both the HH and plot level (Table 2). For household-level analysis: age of the household head (years), education level of the household head (years), off-farm income)in birr), livestock count of the household, recent extension service (1 if received, 0 if not), social status of the household head (1 if holds a social leadership role in the Kebele, o if not), perception of the household head regarding soil erosion issues (1 if perceives soil erosion as a problem of the farm, o if not), land tenure security (1 if farmers expects to use the plot for their lifetime, 0 if not). At the plot level, the variables include the area of total cultivated land (ha), the ratio of total land to labor (hectare per person days), walking distance to the farm plot from home (minutes), slope category of a plot (one flat; zero otherwise).

Table 2: Classification of independent variables

No	Variable group	Individual variables
1.	HH Demography	Age, Education, Gender, Family size, Perception of SWC and Social position, …
2.	HH Economics	farm size (area of cultivated, grass, land), ratio of total land to labor, Livestock holding, Off-farm income
3.	Institutional	Visits by DA (extension service), Technical support, Training, Security of land and Market distance, . . .
4.	Biophysical	Slope, Level of soil fertility, Type of soil erosion, Distance of each plot from home

3.4 Methods of Soil Erosion Loss Rate Estimation

Several erosion models were available to predict soil loss and to assess the soil erosion risk (Fekadu et al., 2022; Kinnell, 2010). The Revised Universal Soil Loss Equation (RUSLE) was an empirical model most widely used for soil loss estimation (Hurni, 1985). RUSLE was selected for its emphasis on surface residue effectiveness in erosion reduction and the consideration of residues near the soil surface. Unlike USLE, RUSLE acknowledges non-uniform runoff distribution, accounting for runoff concentration in rills and gullies. The equation was the update of the original Universal Soil Loss Equation (Wischmeier et al., 1978). In RUSLE, the rainfall-runoff factor of the original USLE (Universal Soil Loss Equation) was replaced by the rainfall erosivity factor while K (soil erodibility factor), LS (slope length and steepness factor), C (land cover management factor) and P (support practice factor) were the same parameters as in the original USLE factors (Geleta, 2011). The RUSLE computes the average annual erosion expected on field slopes and is shown in Equation (1) above in section 2.3.2.2. For reminding $A=R\times K\times LS\times C\times P$, Where:

- ⇨ A represents the annual soil loss due to sheet and rill erosion in tons per hectare per year ($t\ ha^{-1}\ yr^{-1}$)
- ⇨ R stands for the rainfall erosivity factor
- ⇨ K denotes the soil erodibility factor
- ⇨ LS signifies the slope length and steepness factor
- ⇨ C represents the cover management factor
- ⇨ P is the support practice factor (Figure 3).

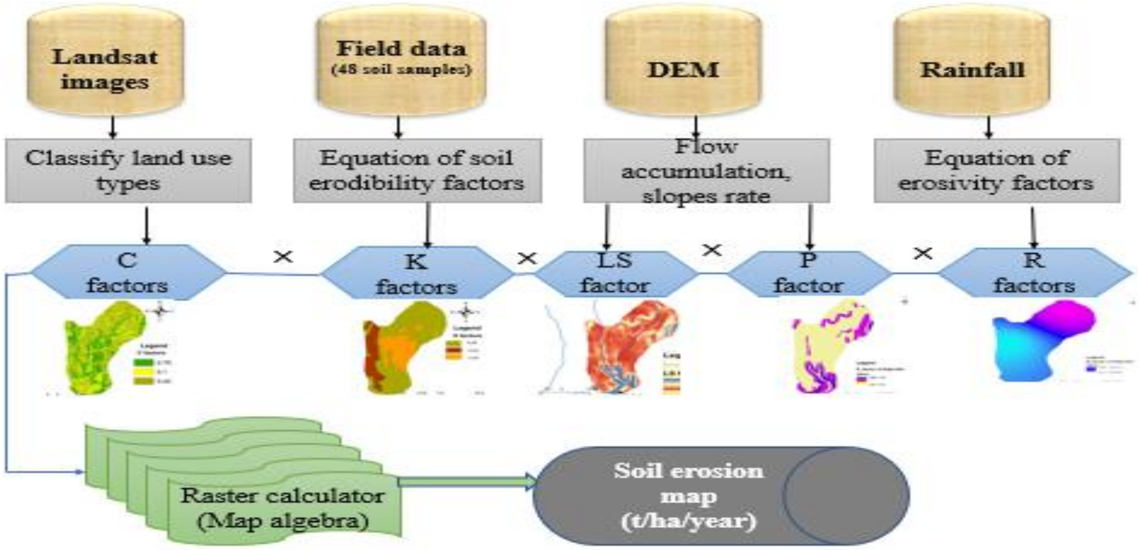


Figure 3: Flow chart of modeling Soil Erosion

3.4.1 Rainfall Erosivity (R)

Rainfall erosivity represents the energy that initiates sheet erosion, subsequently leading to rill erosion and eventually forming gullies. The erosivity estimates in the rainfall data were a straight raindrop influence and were partly due to the runoff that rainfall produces. Even though there were different computational techniques to compute the erosivity factor across the globe depending on the use of various inputs, estimating rainfall erosivity here was based on the calculation of R generated by Hurni (1985), resulting as of a spatial analysis regression Helldén (1987) adapted designed for Ethiopia stand on annual precipitation

R = -8.12*0.56P (Hurni, 1985)---Equation (8)

Where; R is the annual rainfall erosivity factor, and P is the Mean annual precipitation (mm) (see it in Appendix 16) of nearby stations acquired over the last 34 years. To compute the R factor, a formula be used stand on the average yearly rainfall.

Table 3: The average rainfall and erosivity

No	Metrological station	Average rainfall (mm)	Erosivity
1	Dessie	1,145	634.37
2	Wereillu	1200	665.28
3	Kombolcha	1090	603.46
	Average	1,145	634

Interpolation has been performed toward show the spatial surface sharing of soil erosion based on average 34-year (1986 – 2019) mean annual precipitation data. When performing this spatial analysis of IDW (Inverse Distance weighted) the principle that things found to be closer to one another were more alike than those that were farther apart was used by specifying the cell size (grid) into 30m. Based on the data obtained and Hurni (1985) equation (8) the average rainfall and erosivity of the three stations were 1145 mm and 634 respectively (see in Table 3 above and in Figure 4 below).

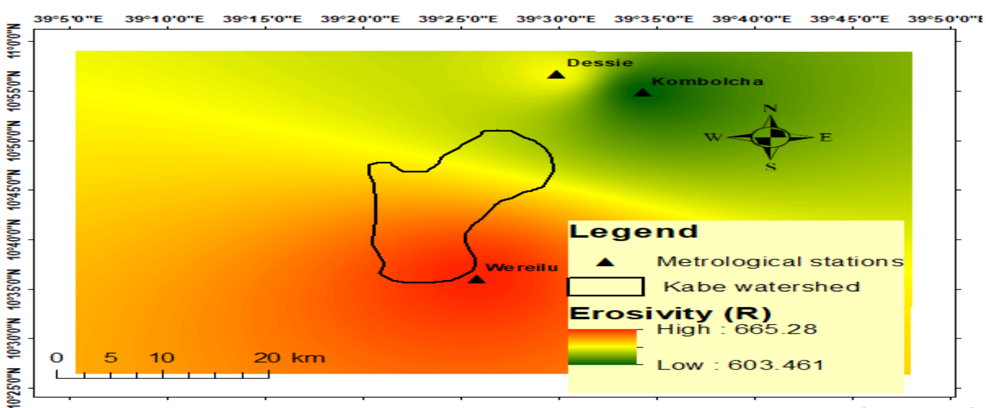


Figure 4: R-Factor Map of Kabe Watershed

3.4.2 Soil Erodibility Factor (K)

The erodibility of soil (K) was determined based on the soil type, which was affected by the structure and texture of the soil, organic carbon (OC) contents, and soil permeability. The inherent properties of the soil had more influence on being liable to erosion than other factors. However, some soils erode more readily than others do even when all other factors were the same. The K factor was distinct as the rate of soil loss per unit of R on a unit plot and indicates the relative ease at which the soil was detached and transported (Endalamaw et al., 2021; K. G. Renard et al., 1997). For these lessons, the FAO soil map was used to derive the data on soil physiochemical properties. Based on the (Norman et al., 1995) equation and FAO soil fraction of sand, silt, clay, and organic carbon content of the soil, the K-factor of the study area was found to be 0.37. After having established the K value because of the FAO soil map, the K value was put into the geo-database (Equation 9) and converted the feature class into grid raster format with a 30 m cell size (Figure 5).

K = fcsand× Fsi-cl×Forgc×Fhisand×0.1317--Equation (9)

$$\mathbf{Fcsand} = \left[0.2 + 0.3exp\left(-0.0256\, SAN\left(1 - \frac{SIL}{100}\right)\right)\right]$$

$$\mathbf{Fsi-cl} = [\frac{SIL}{CLA + SIL}]^{0.3}$$

$$\mathbf{Forgc} = [1.0 - \frac{0.25C}{C + \exp(3.72 - 2.95C}]$$

$$\mathbf{Fhisand} = 1.0 - \frac{0.70SN1}{SN1 + \exp(-5.51 + 22.9SN1}$$

Where SAN, SIL, and CLA represent the percentages of sand, silt, and clay, respectively; C denotes the organic carbon content, and SN1 is calculated by subtracting the sand content from 1 and dividing by 100. Fcsand corresponds to the low soil erodibility factor, Fsicl is the soil erodibility factor for soils with a high clay-to-silt ratio, Forgc is the factor diminishing soil erodibility for soils with high organic content, and Fhisand is the factor reducing soil erodibility for soils with high sand content.

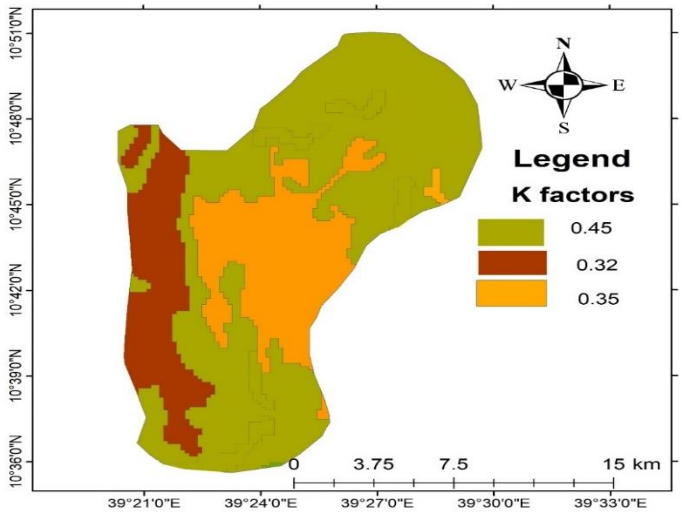


Figure 5: K-Factor Map of Kabe Watershed

3.4.3 Slope Length and Slope Steepness (LS)

The speed and extent of runoff depend on the slope of the land. Generally, the larger the slope, the greater the velocity of excess water and erosion expected. The slope distance end to end and steepness were variable on the different land units of the lessons district. The slope length and gradient had an important bearing on soil erosion (Gindi, 2022). We were classifying the slope of Kabe Watershed into six for general purposes (Figure 6).

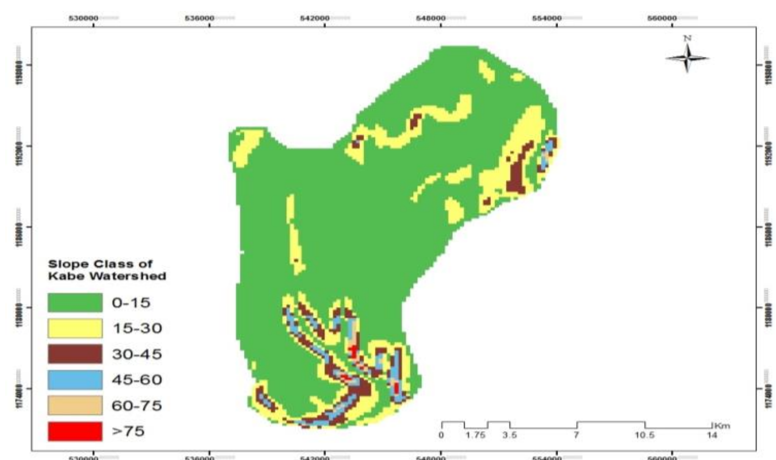


Figure 6: Slope classification map of Kabe Watershed

The Slope classification Map of Kabe Watershed (Figure 6) shows that areas of different slopes categorized as: 0-15% – Level to nearly level; 15%-30% – Gently sloping to undulating; 30%-45% Undulating to rolling; 45%-60% Rolling to moderately steep; 60%-75% – Steep; Over 75% – Very steep. It would be used for the slope length and slope steepness of the study for the study area. But when we can’t classify the slope of Kabe Watershed this like, it can’t simply get the result of slope length and slope steepness (LS).

Having this data, the LS - Factor symbolizes the impact of slope length (L) and its steepness (S) on soil erosion. LS factor in USLE characterizes the ratio of soil loss on a given slope length and steepness to soil loss (Pham et al., 2018). DEM from the USGS was important to compute the slope length factors with the help of the ArcGIS environment. According to Moore & Burch (1986), the LS factor was analyzed using the next equation:

LS = Power (Flow accumulation*(Cell size/22.13), 0.4) * power (sin (slope in degree * (0.01745/0.09, 1.4)) * 1.4) -- Equation (10)

Where LS was the collective slope length and steepness factor. Flow accumulations (see it in Appendix 16) were resulting beginning the Digital Elevation Model (DEM) (see it in Appendix 17) having a cell size of 30 m and sin of slope (degree) was nothing but sin of slope angle in degrees of DEM. In short, DEM was used to develop flow accumulation with a resolution of 30 m and sin of slope (degree). Based on (Equation 10) the LS - factor of the study area was computed and it was 4.94 maximum and 0 minimum values (See LS map in Figure 7).

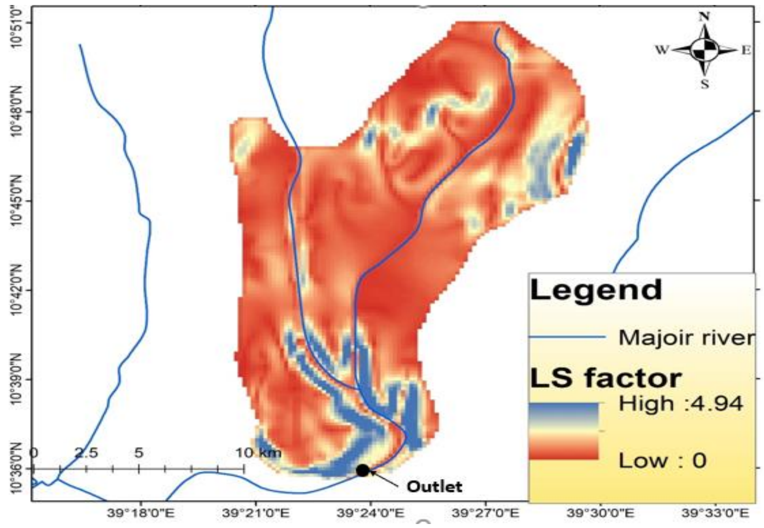


Figure 7: LS - Factor map of Kabe Watershed

3.4.4 Crop Management Factor (C)

Soil erosion could be different depending on rainfall erosivity and the morphology of the plant cover. The falling rainfall protected by vegetation cover could reduce soil erosion on certain lands. The protecting plants could be crops, weeds, or trees. Different stages of crop growth affect the generation of crop management factors and the need for the growth period and year of the plants. It denotes the proportion of soil loss from land with particular vegetation/crop cover compared to the soil loss from continuous bare fallow in the same conditions (Kinnell, 2010; Wischmeier et al. 1978; Yohannes et al. 2018).

Table 4: Estimated Crop Management Factors of Kabe Watershed

Land Cover	C-Factor
Forest land	0.01
Cultivated land	0.25
Grazing land	0.15

When generating crop management factors, it was so important to consider the year's periods corresponding to different stages of crop growth. To account for the role of surface cover and drive C-factor values, land use types data was generated from Landsat images of

30 m resolution (See Table 4 above). To classify the land use types, GIS and remote sensing applications such as the maximum likelihood classification algorithm were carried out on the remote sensing data. Once LULC maps were available, C-factor values adapted for Ethiopian conditions were extracted for each grid cell based on Hurni (1985) and set into the geo-database (see C-factor map in Figure 8).

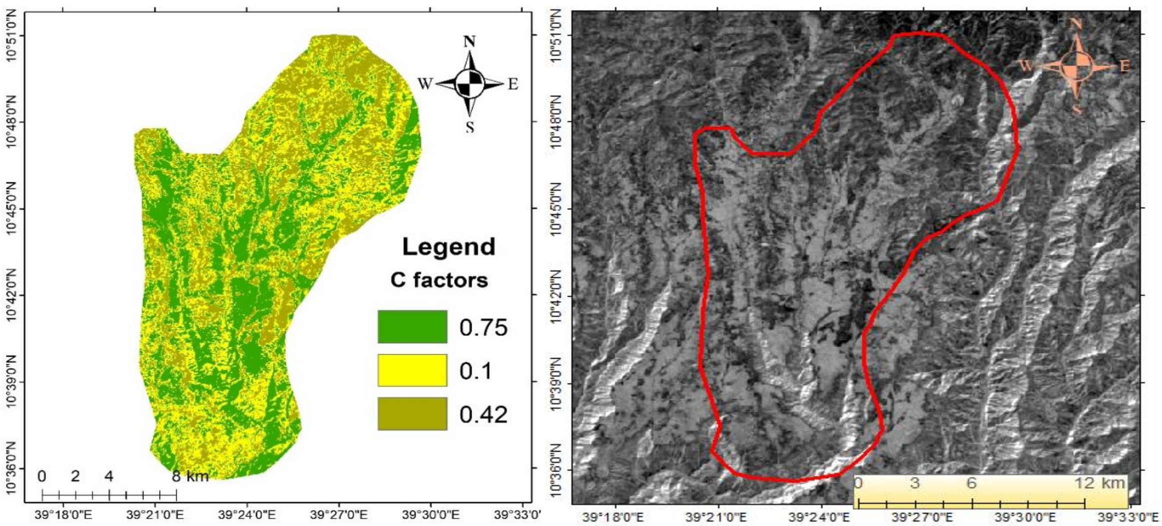


Figure 8: C-Factor map of Kabe Watershed

3.4.5 Support Practice Factor (P)

The soil and water conservation practice factor is the ratio of soil loss under a specific practice to that under up-and-down-the slope farming (Hurni, 1985; Wischmeier et al. 1978). Conservation practices (*P*-value) were considered the application of soil and water conservation practices on the landscape, like terracing, mulching, and gulley control. If no erosion control practice was found in a landscape, then the *P*-value is equal to one, which indicates that the landscape has a high capability of reducing soil erosion. The *P*-value indicates a range between 0 and 1.

Table 5: Estimated support practice generated by (Hurni, 1985)

Management practices	P - value
Ploughing Up and Down the Slope	1
Contour Ploughing	0.9
Applying Mulch	0.6
Intercropping	0.8
Strip cropping	0.8
Grass strips	0.8
Bunds degraded	0.9

Ploughing the farmland on high, sloppy land could increase soil erosion instead of reducing it. Therefore, the farming system in the landscape needs to apply different SWCs with different *P* factors. Studies conducted by Hurni (1985) values for different conservation practices in land use types were provided in Table 5 above.

Table 6: Estimated Management Practice of Kabe Watershed

Land Cover	P - Factor
Forest land supported by terraces and bunds	0.6
Cultivated land supported by contour ploughing	0.9
Grazing land practiced by overgrazing	0.8

Based on Hurni's generated support practices and the status of management practices collected during field data collection, the management practice in the Kabe Watershed area were categorized as follows in Table 6 above and it has been put into the geo-database hence, the P - value was computed using Arc GIS (See its generated map in Figure 9).

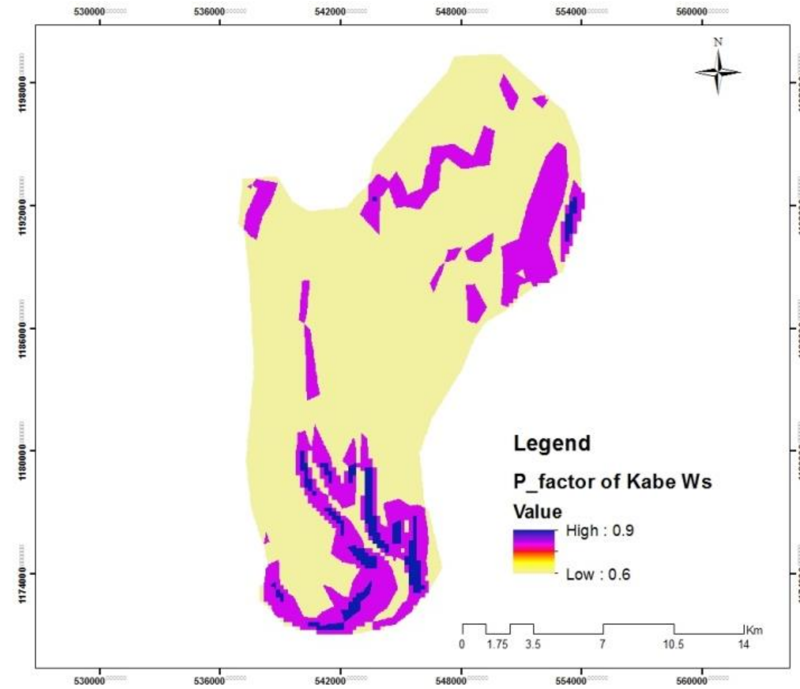


Figure 9: P-Factor Map of Kabe Watershed

3.4.6 Model validation

The RUSLE model was computed to compare the simulated and observed data. The Ministry of Water and Energy in Ethiopia was the data source for the observed data. The RUSLE model output (model simulated) was found in t/ha/year and the stream flow data and suspended sediment concentration considered as observed data were described in m^3/s and g/ml, respectively. Therefore, the unit for the observed and predicted data requires a similar unit for consistent analysis. The observed data were computed using the stream flow and sediment concentration based on Equation (11) for the gauged stations as introduced by Sadeghi et al. (2008).

$$SC = bQ^c$$ -- Equation (11)

Where SC (t/day) refers to sediment loss, Q refers to stream flow rate (m^3/s): b and c were stable, which were strong-minded from the deposit concentration (g/ml) and stream flow.

The Residual Root Mean Square (RRMSE), Coefficient of Determination (R^2), and Average Percentage Bias Error (PBIAS) were used to check the model's performance (Gyamfi et al., 2016; Munoth et al. 2019). When the statistical value shows a high value, then the model has better performance and Vice-versa (Moriasi et al., 2007; Munoth et al. 2019).

3.5 Methods of Land Use Land Cover Change/LULCC/

3.5.1 Sampling Method

Both primary and secondary data sources were utilized for the study. Fieldwork commenced with a reconnaissance visit to the study area, followed by primary data collection. During the reconnaissance survey, ground information was acquired, to define the nature of the ground covers such as cultivated land, wetland, bare land, grazing land, shrub land, and forest lands. Field samples from each land use types were gathered utilizing GPS technology. The history of each land use type was collected from local people by focus group discussion and key informant interviews in the study area. For this purpose, we prepared a closed and open-ended questionnaire was administered to the local inhabitants who were old ages to collect data for causes of land use/land cover change using the purposive sampling method. This method enabled the researcher to select old people from the population and acquire the required data. The total sample size was 60 persons for this purpose.

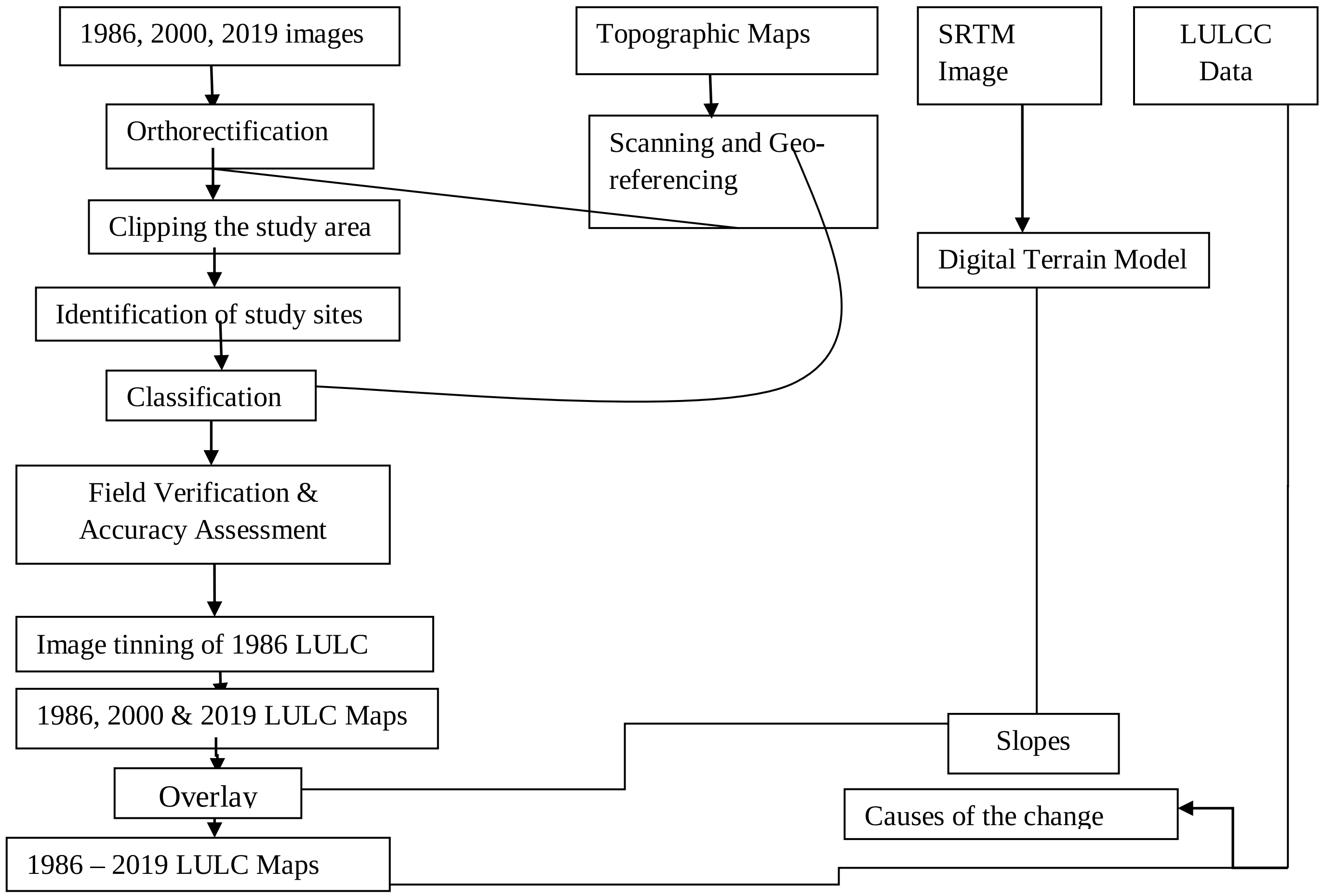


Figure 10: Schematic representation of methodological approach

The primary sources of LULC data include multi-temporal satellite imagery and topographic maps (see Figure 10). Six dates of landsat images obtained during the dry season (refer to Table 7) were gathered from various providers. Satellite images were often used to create or update land cover data layers and they were also used to detect and monitor changes (Bolstad, 2005). For the study, three periods of Landsat satellite images of the region were acquired; in the years 1986, 2000, and 2019. The images were processed and classified in ERDAS IMAGINE and later overlaid in ArcGIS to identify the changes. SRTM (Shuttle Radar Topography Mission**)** image was used to extract the slope in ArcGIS spatial analyst tools and overlaid with land use land cover maps to quantify the amount of land under agricultural activity, which was out of the recommended slope limit for agricultural practices. Topographic maps (local district) with a scale of 1:5000 was also collected to delineate the boundary of interest area and to digitize rivers and roads.

Table 7: Satellite images used

Land sat Types	**Path and Row**	**Date of Acquisition**	**Spatial Resolution (m)**
Landsat-TM	168/052	1986 – 01 - 21	28.5×28.5
Landsat - ETM +	168/052	2000 – 02 - 05	28.5 × 28.5
Landsat - OLI	168/052	2019 – 02 - 01	28.5 × 28.5
Landsat - TM	168/053	1986 – 01 - 21	28.5 × 28.5
Landsat - ETM +	168/053	2000 – 02 - 05	28.5 × 28.5
Landsat - OLI	168/053	2019 – 02 - 01	28.5 × 28.5

A hybrid classification system combining unsupervide and supervised methods was employed to classify all satellite images using ERDAS IMAGINE 10 software. The maximum likelihood classification was utilized for image classification, focusing on selected regions in Landsat TM 1986, ETM+ 2000, and ETM+2019 images. These regions were identified based on field observations, consultations with local elders, topographic maps, image interpretation, and aerial photographs purchased from various sources from Ethiopia Geospatial Institute (its former name was Ethiopian Mapping Agency).

The classification accuracy was censured by selecting 45 random points, tracking them using GPS, and determining their previous land cover class with input from local elders. An error matrix system was then utilized to compare the ground truth with the classified land cover classes across all satellite images (TM 1986, ETM+2000, and ETM+2019). Subsequently, a comprehensive matrix and changes in classes were automatically derived from the classified satellite images.

3.5.2 Data Analysis

3.5.2.1 Image Pre-processing and Classification

Prior to change detection, preprocessing satellite images was a crucial step aimed at establishing a stronger correction between the biophysical occurrences on the ground and the collected data (Coppin et al., 2004). In ERDAS Imagine, data underwent preprocessing for geo-referencing. Mosaic king, and sub setting based on the Area of Interest (AOI). The primary goal of image classification was to assign all pixels in an image to specific LULC classes for extracting valuable thematic information (Boakye et al., 2008).

Field visit aided in identifying primary land use/land cover types. Training samples for each LULC type were chosen by outlining polygons around characteristics locations. Spectral signatures of these LULC types from satellite images were obtained from the pixels within these polygons to minimize confusion during mapping (Gao et al., 2010). The supervised classification employed the Maximum Likelihood Classifier (MAXLIKE) methods with a decision rule for six primary LULC classes. The quantity of training sites varied among classes based on identification simplicity and variability levels. This method, considering spectral details of land cover classes, was widely utilized for per-pixel classification (Qian et al., 2007).

3.5.2.2 Post Classification

Post-classification refinement was conducted to enhance classification accuracy and minimize misclassifications (Harris et al., 1995).ground verification was carried out post-classification to validate the accuracy of the LULC map. Corrections and adjustments were made based on this verification. A comparison between the 1986 and 2019 maps yielded a comprehensive matrix showing categorical changes.

3.5.2.3 Accuracy Assessment

For effective change analysis using classification data, conducting accuracy assessments for each classification is crucial (Owojori et al., 2005). Accurate accuracy assessment is vital for image classification and LULC change detection to precisely understand and estimate changes. It shows how well the classification results align with the ground truth, essential for effective change detection analysis (Owojori et al., 2005). In this study, accuracy assessment was due for the Landsat 7 ETM^+ 2019 the satellite image likely corresponded to ground truth data. Overall accuracy was determined by dividing the total correctly classification sample units by the total number of sample units.

Summary statistics, including land cover areas and conversion matrices, were automatically generated using ERDAS 10 software. The conversion matrix compared images: TM 1986 with ETM+ 2019, TM 1986 with ETM+ 2000, and ETM+ 2000 with ETM+ 2019. Changes in land cover were identified by overlaying classified maps from different dates. Land cover conversions were compared between pairs of years to determine rates of changes using Equation (12).

Rate of land cover changes ($\%yr^{-1}$) = $[(B-A)/A_t] \times 100$ …………………Equation (12)

In the formula, A represents the initial land cover area in hectares, B stands for the final land cover area in hectares, and t denoted the time period in years between A and B.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. Effect of Changes in Land Use Management Practices on Selected Soil Physicochemical Properties

4.1.1 Effect of land use types (Forest, Grazing, and Cultivated) on selected Soil physical properties

Table 8 outline the SPSS and ANOVA analysis of soil physical properties across different land use types. In the Kabe Watershed, forest, grazing, and cultivated lands exhibited clay loam. Loam, and sandy loam textures respectively. The finer texture of grazing lands may be linked to higher clay content and the transition from forest to grazing land use. From the ANOVA analysis, it was also found that here was a significant difference ($p < .05$) for Clay (%), Silt-Clay Ratio (SCR), BD (g/cm^3), and TP% (most soil physical properties were directly affected by land use types in the study area). The mean value of sand fraction (66%) was highest in cultivation areas followed by grazing (48%) and forest (30%); it means cultivated areas were eroded by soil erosion, low water holding capacity, and others. On the other hand, soil structural composition for Forest land use types has the highest both silt and clay accounting for 35% (it may be high water holding capacity). The increased silt fraction in forest land might result from sediment accumulation such as mud flows from landslides, rock erosion caused by tree roots, and the deposition of plant litter undergoing decomposition (Lechisa et al., 2014). Soil moisture (31.33%) was nearly equally abundant both in the grazing and Forest land use types. From the Table 8, it was also shown that TP% was highest in the forestland followed by grazing land use types accounting for 53.96% and 50.19%, respectively. It means that soil porosity in forestland provides more space for microbial growth and improves the aeration of the soil, nutrient availability, and water drainage and retention capacity in the study area.

On the contrary, it was also indicated that except for soil moisture, which was not significant, all other soil physical properties considered in this study (viz., sand%, silt%, clay%, SCR, BD(g/cm^3), and TP%) were highly significant. Soil Moisture (measured by water fraction by volume) in the grazing and forestland use types was relatively higher, which may result from the dominant composition of silt and clay typified by increased water holding capacity. Conversely, soil moisture was low in the cultivated areas characterized by sandy loam texture (66%).

Table 8: Effect of land use types (Forest, Grazing, and Cultivated) on selected soil physical parameters in Kabe Watershed

Parameters	Forest	Grazing	Cultivatec	Mean	SE	F	P	Significance
Sand (%)	30	48	66	48	2.14	172.42	0	***
Silt (%)	35	30	20	28	0.903	239.7	0	***
Clay (%)	35	20	15	23	1.442	58.39	0.021	***
Textural class	Clay Loam	Loam	Sandy Loam					
BD (g/cm^3)	1.22	1.32	1.36	1.3	0.0198	4.79	0	***
SM (%)	31.33	31.33	22.27	28.31	0.905	18.42	0.069	NS
TP (%)	53.96	50.19	48.68	50.94	1.124	1.333	0	***

Abbr.: BD (bulk density); NS, not significant; SCR, silt–clay ratio; SM – Soil Moisture; PD- particle density; TP, total porosity.

4.1.2 Effect of land use types (LUTs) and SWC on selected soil physical properties

Land use changes and soil conservation practices significantly impacted soil physical properties. Table 9 demonstrates significant variations in soil buck density, soil moisture content, porpsity, and soil texture composition across various land use types. The data suggests that land use areas with soil and water conservation measures exhibit lower soil buck density compared to those without such practices. Haile et al. (2022) and Selassie et al. (2015) reported that soil bulk density increases due to continuous farming, leading to lower soil organic carbon and compaction from tillage. Cultivated and grazed areas have higher bulk density from shallow cultivation and livestock impacts. Absence of conservation practices can affect bulk density by reducing organic matter. Forest, grazing, and cultivated lands with conservation show lower bulk density. Grazing intensity in forest areas affects soil water content and organic matter. Soil physical properties show not significance variation with or without conservation. Treated lands exhibit higher total porosity, enhancing soil aeration and drainage. The study area lacks effective soil and water conservation practices.

Table 9: Effect of land use types and soil and water conservation on selected soil physical parameters

Description	Selected Soil Physical Parameters						
LUT/Slope	Sand (%)	Silt (%)	Clay (%)	SCR	BD (g/cm^3)	SM (%)	TP (%)
				Treated			
Forest	31	34	37	0.93	1.1	32	58.49
Grazing	46	31	18	3.1	1.2	32	54.72
Cultivated	65	20	16	1.3	1.3	23	50.94
Mean	48	28	24	1.53	1.3	28	50.94
SE	0.793	0.268	0.802	0.159	0.01	0.717	0.652
F	67.99	110.9	24.6	4.09	35.64	7.3	7.25
P	0	0	0	0.004	0	0	0
Significance	***	***	***	***	***	***	***
				Untreated			
Forest	30	36	35	1.1	1.4	31	47.17
Grazing	49	30	23	1.3	1.4	30	47.17
Cultivated	67	20	15	1.4	1.5	22	43.39
Mean	48	28	24	1.53	1.3	28	50.94
SE	0.793	0.268	0.802	0.159	0.01	0.717	0.528
F	67.99	110.9	24.6	4.09	35.64	7.3	7.25
P	0	0	0	0.004	0	0	0
Significance	***	***	***	***	***	***	***

Abbr.: BD - bulk density; SCR - silt–clay ratio; SM - soil moisture; PD - particle density; TP - total porosity.

For example, a study was carried out to evaluate the impact of soil and water conservation (SWC) practices on soil quality indicators in the Gojam River catchment of Ethiopia Z. Nigussie et al. (2017) indicated that farmlands with SWC measures had relatively improved soil physical properties such as volumetric soil water content, and clay and silt fractions compared with farmlands without SWC measures. They also highlighted that soil chemical properties such as pH, OC, TN, C: N ratio and AP have shown an improvement under SWC practice than without. Other studies have also shown examining the interactions between land use types, soil characteristics, and slope to evaluate the impact of land management practices on soil physical and chemical properties in the other part of Gojeb River, southwest Ethiopia. According to Bezabih et al. (2016), soil propertices varied slightly across land use types with and without soil bunds on different slopes. Cultivated areas, with and without soil bunds, exhibited lower moisture content, porosity, silt, and clay compared to fallow and woody lands, regardless of bund presence. Conversely, the sand fraction and bulk density were higher in cultivated areas than in fallow and woody lands. In addition, a piece of research-based evidence on the effects of SWC practices regarding soil physiochemical properties in the northern highlands of Ethiopia by Guadie et al. (2020) indicated that SWC practices tended to increase soil fertility and most of the soil chemical properties showed relative change with landscape positions.

4.1.3 Effects of slope positions on selected soil physical properties

Table 10 summarizes the ANOVA analysis for selected soil physical properties with slope position. From the table, except (clay%, silt/clay, and BD %), all other physical properties of soil considered in this study were not statistically significant ($p \leq 0.05$) by slope position. As can be seen from Table 10, all variables showed considerably varying records under various slopes. However, from the analysis of variance, it was found that BD (g/cm^3) and SM (measured by water fraction by volume) showed no variation in middle and lower slope positions. It was also indicated that except TP%, sand, and silt contents, all other soil physical properties were highly significant by slope positions. Alternatively, in the upper slope position, sand was higher and soil moisture was low. It means that, in all sandy soil, its water-holding capacity was poor. In the lower slope of our study area, its soil moisture was high due to soil erosion pushing fertile soil from the upper slope position to it and its clay contents were higher. From the Table 10, it was also shown that TP% was relatively highest (50.94%) in both lower and middle slope position than upper (47.17%) slope position. It means that soil porosity relatively in both lower and middle slope position provides more space for microbial growth and improves the aeration of the soil and water drainage in the study area.

Table 10: Effects of slope positions on selected soil physical parameters

Parameters	Upper Slope	Middle Slope	Lower Slope	Mean	SE	F	P	Significance
Sand (%)	54	48	42	48	2.08	2.6	0.083	NS
Silt (%)	27	28	30	28	0.9	1.03	0.366	NS
Clay (%)	18	25	29	24	1.32	5.88	0.005	***
Silt/Clay	2.3	1.2	1.1	1.5	0.17	4.53	0.015	***
BD (g/cm^3)	1.4	1.3	1.3	1.3	0.02	3.36	0.042	**
SM (%)	27	29	29	28	0.91	0.74	0.483	**
TP%	47.17	50.94	50.94	49.13	0.89	17.25	0.086	NS

Abbr.: BD- bulk density; SM- soil moisture; NS, not significant; PD- particle density; TP-total porosity.

For example, Kumar et al. (2019) highlighted the effect of slope positions on selected soil physical properties. Their results of chemical and physical analysis in Mediterranean hill slope vineyards of Montes de Málaga, Spain, showed that, although the average values were similar, materials bigger than 2 mm were predominant along middle and upper slope positions, slope > 55%, and under the vines (56.7%).

4.1.4 Effect of LUT and slope position on selected soil physical properties

For all LUTs and slope positions (Table 11), the means of soil physical properties (viz., sand (%), silt (%), clay (%), SCR, BD (g/cm^3), SM (measured by water fraction by volume), and TP (%)) do not show significant variation with slope position but all are affected significantly. However, it was also indicated that there were changes for individual variables under different LUTs. For example, for soil texture variables; sand, silt, and clay, the overall mean value in all slope positions was 48%, 28%, and 24% respectively. Considering changes in sand, silt, and clay percentage for cultivated land for example, the respective values were 71%, 17%, and 13% for the upper slope and 66%, 21%, and 15% for the middle, and 61%, 23%, and 18% for lower slope positions. This clearly shows the increasing nature of clay content with a decrease in slope (when we go from upper to lower slope positions). On the other hand, silt and sand contents showed a steady decrease with a decrease in terrain slope (when we go from upper to lower slope positions). In addition, in cultivated land types, SCR does not show significant differences in upper and middle slope positions, whereas changes have to be observed for SM, BD and TP. Soil bulk density remains consistent across middle and lower slope positions within the same land use type.

As can be indirect from TP (%) concentration for upper, middle, and lower slope positions (47.17, 50.94 and 50.94 respectively) in grazing intensity and soil erosion vulnerability were higher in the upper slope than middle & lower positions. Bulk density averages higher in cultivated and grazing lands at the upper slope position, while it appears lower in forested areas. the rise in bulk density with higher slope positions in cultivated and grazing areas could be due to ongoing cultivation and livestock impacts.

Table 11: Effect of land use type and slope position on selected soil physical parameters

Description	**Selected Soil Physical Parameters**						
LUT/Slope	**Sand (%)**	**Silt (%)**	**Clay (%)**	**SCR**	**BD (g/cm^3)**	**SM (%)**	**TP (%)**
				Upper slope			
Forest	41	34	28	1.2	1.3	29	50.94
Grazing	50	30	13	4.1	1.4	31	47.17
Cultivated	71	17	13	1.4	1.5	21	43.39
Mean	48	28	24	1.5	1.3	28	49.12
SE	0.252	0.194	0.406	0.138	0.018	0.651	0.25
F	473.45	137.91	78	6	2.3	7	7.22
P	0	0	0	0	0.035	0	0
Significance	***	***	***	***	***	***	***
				Middle slope			
Forest	30	35	36	0.9	1.2	36	54.71
Grazing	49	30	24	1.2	1.3	30	50.94
Cultivated	66	21	15	1.4	1.3	21	50.94
Mean	48	28	24	1.5	1.3	28	52.11
SE	0.252	0.194	0.406	0.138	0.018	0.651	0.62
F	473.45	137.91	78	6	2.3	7	7.21
P	0	0	0	0	0.035	0	0
Significance	***	***	***	***	***	***	***
				Lower or back slope			
Forest	21	37	44	0.9	1.2	29	54.71
Grazing	45	31	25	1.2	1.3	34	50.94
Cultivated	61	23	18	1.3	1.3	26	50.94
Mean	48	28	24	1.5	1.3	28	52.11
SE	0.252	0.194	0.406	0.138	0.018	0.651	0.65
F	473.45	137.91	78	6	2.3	7	7.11
P	0	0	0	0	0.035	0	0
Significance	***	***	***	***	***	***	***

Abbreviations: BD - bulk density; LUT – land - use type; NS - not significant; SCR - silt–clay ratio; SM- soil moisture; PD - Particle density; TP - total porosity.

In addition, they highlighted that soil bunds play a vital role in controlling the variation of soil BD (g/cm^3) by collecting the soil organic matter, thereby weakening the natural stability of soil aggregates and facilitating its susceptibility to erosion. They also indicate that soil condition in the forestland areas was more desirable than in cultivated land use types resulting from the percentage of vegetation. Reduced grazing in forest areas likely led to higher soil moisture, enhancing soil structure and organic matter content.

Alternatively, soil total porosity showed a decreasing trend with an increase in terrain slope for all land use types (Table 11) and TP (%) was also recorded lower in the untreated land use types (Table 9). Soil bulk density and total porosity showed an inverse relationship, where an increase in bulk density corresponded to a decrease in total porosity and vice versa. In Table 9, land use types with soil and water conservation had higher soil moisture content compared to those without such practices, likely due to soil bunds enhancing organic matter and total porosity, thereby improving water holding capacity. Gravimetric soil moisture content varied significantly among different land use types. For forestland cover both with and without any treatment (soil and water conservation) practice, significantly higher soil moisture content was recorded (Table 9). Additionally, in forestland types in the middle slope positions, significantly higher soil moisture content was recorded. In addition, for all slope positions considered, the soil moisture continent was lower in cultivated land than in forest and grazing land in the study areas (Table 11).

Generally, changes in soil moisture content showed varying trends for land use types treated with and without soil and water conservation practices. Considering changes in slope position, soil moisture content showed an unpredictable trend in either of the sloping directions, from upper to lower and vice versa for all land use types and conservation practices (Table 11).

Sand, silt, and clay contents, determining soil texture in land use types with soil and water conservation practices, differed significantly from nearby land use types lacking such conservation practices. Cultivated land was characterized by a significantly higher proportion of sand content than forest and grazing land use types with and without soil and water conservation practices (Table 9). It indicated that cultivated land in Kabe Watershed was characterized as more eroded and its soil fertility was lower because its water holding capacity was lower, and its clay soil contents were lower (i.e. its organic carbon contents were lower). Forestlands exhibited the lowest sand fraction and the highest silt and clay contents. Across all land use types and slope positions, there was only a slight variation in sand, silt, and clay fractions (Table 11).

Cultivation intensity influenced soil texture, impacting particle size distribution at the surface horizon of cultivated lands. Across terrain slope positions, sand content rose from lower to upper slope in forest, grazing, and cultivated lands, while silt and clay fractions typically decreased along the same slope gradient (Table 11).

4.1.5 Effect of land use types (Forest, grazing, and cultivated) on selected soil chemical properties

Table 12 summarizes the SPSS and ANOVA analysis concerning specific soil chemical properties across various land use types. From the table, all chemical properties considered in Kabe Watershed were statistically significant ($p < .001$), except percentage base saturation. The pH-H_2O and EC (measured by decisiemens per meter (ds/m)) were highly affected by alterations in land use types and agricultural management practices. Both tend to increase with an increase in soil land cover and decrease with the intensity of agriculture. As a result, higher pH and EC (ds/m) values were observed in forest and grazing lands and the values were lowered in cultivated land use type areas (Table 12). pH-H_2O (1:2.5) the value in the cultivated land may have decreased due to significant removed of basic cations because washing away of solutes and basic cation tended to lower soil pH value.

Table 12: Effect of land use types (Forest, grazing, and cultivated) on selected soil chemical parameters

Parameters	Forest	Grazing	Cultivated	Mean	SE	F	P	Significance
pH-H_2O (1:2.5)	5.84	5.51	5.19	5.51	0.423	74.56	0.000	***
EC(dS/m)	0.168	0.118	0.100	0.129	0.0048	51.00	0.000	***
OC (%)	3.05	2.48	1.86	2.46	0.074	98.34	0.000	***
TN (%)	0.267	0.216	0.161	0.215	0.0078	35.43	0.000	***
AP (ppm)	4	3	2	3	0.1517	46.31	0.000	***
CEC (cmol(+) kg^{-1})	27	19	13	20	0.895	111.82	0.000	***
Ca (cmol(+) kg^{-1})	29	27	19	25	0.986	14.40	0.000	***
Mg (cmol(+) kg^{-1})	3	3	3	3	0.090	7.55	0.001	***
Na (cmol(+) kg^{-1}))	0.00	0.00	0.00	0.00	0.00	-	-	-
K (cmol(+) kg^{-1})	0.444	0.388	0.00	0.277	0.061	6.17	0.004	***
PBS (%)	77.05	74.72	65.66	72.48	1.769	4.33	0.018	***

Abbreviations: AP- available phosphorous (in ppm-parts per million or mg/kg); CEC- cation exchange capacity; EC-electrical conductivity; OC - organic carbon; TN - total nitrogen; PBS - percent base saturation.

The mean value of pH-H_2O (5.19) the pH was lower in the cultivated land compared to grazing (5.51) and forest (5.84) areas which indicates the forest and grazing land use types were moderately acidic than the cultivated lands (its soil contents were strongly acidic). Soils in the cultivated land were more acidic, with pH-H_2O < 5.4 than those of the forestland and grazing lands, which might increase the toxicity of manganese and aluminum and slower microbial conversion of NH^{+4} to nitrate. Soil acidity could also be decreased by liming the cultivation land, which in turn supplies essential plant nutrients such as Ca^{2+} (cmol (+) kg^{-1}) and Mg^{2+} (cmol (+) kg^{-1}). Except for Mg and Na, the other soil chemical properties considered in this study (i.e., EC (ds/m), OC (%), TN (%), AP (ppm), CEC (cmol (+) kg^{-1}), Ca (cmol (+) kg^{-1}), K (cmol (+) kg^{-1}), and PBS (%)) were lowest in the cultivation areas and highest in the forest cover. On the other hand, soil structural composition for forestland use type was the highest both for silt and clay accounting for 35%. Soil moisture (31.33%) was nearly equally abundant both in the grazing and forestland use types. According to Landon (1991), pH-H_2O values ranged from 5.1 to 5.5, pH-H_2O was strongly acidic, and a value range from 5.5 to 6.0 was classed as moderately acidic (Appendix 1). In this case, the cultivated land use type was strongly acidic compared to the other two land use types. Landon (1991) indicated that a value of soil organic carbon less than 2% was classed as very low in organic carbon content and a value range from 2% to 4% indicates low organic carbon abundance. In this regard, organic carbon was found highest in forestland use compared to cultivated and grazing land.

The causes for acidic soil development were known to be the leaching of bases but this does not hold for the profile investigation; pH-H_2O remained low while base saturation and contents of exchangeable bases were in the high range (Appendix 1 and 11). According to Elias (2002), possible explanations might include acidic parent material, organic carbondepleting management practice, and continuous use of acid-forming fertilizers like DAP (kg) and Urea (kg).

Plants require a correct balance of essential nutrients for healthy growth and performance. Most of the soil types investigated in the Ethiopian highlands were found to be deficient in several of the macro and micro-nutrients, including N (%), P (%), K (cmol (+) kg^{-1}), and others (Elias, 2017; Tefera et al., 2016). On the other hand, in the Kabe Watershed, soils with multiple nutrient deficiencies including phosphorus (P) and potassium (K) in forest and cultivated land use types respectively, were low (Table 12 & Appendix 6 & 10). The reasons for nutrient deficiencies were many and complex. Primary, it was the agronomical unbalanced fertilizer regime that supplies only N and P in the form of DAP (kg). this likely depleted soil nutrients reserves as crops utilize more nutrients beyond N and P. potassium and micronutrients deficiencies (especially Zn, Cu, B) may be notable due to the exclusive use of N (%) and P (ppm) fertilizers. Secondly, low fertilizer application levels lead to the depletion of soil nutrient reserves. The national average rate of application was about 29kg/ha DAP or 17kg/ha N–P nutrients Elias, (2002), which was very low compared to the average nutrient application of 48kg/ha in neighboring Kenya and the world average of 78kg/ha (Makken, 1993). According, to Elias (2017), such low and blanket application was not only inappropriate but also irrelevant in the light of huge diversities in soil types that prevail in the country. However, these practices were slowly changing as the country transformed from the use of DAP and Urea alone to site and soil-specific blend fertilizer recommendations.

4.1.6 Effect of SWC practices on selected soil chemical properties

Table 13 summarizes the ANOVA analysis for specific soil chemical properties concerning soil and water conservation practices. From the table, except for percentage base saturation and calcium, all chemical properties considered in this study were not statistically significant ($p>0.05$). As we know, soil chemical properties were considerably influenced by enforcing soil and water conservation practices. As can be seen from (Table 13), all variables showed considerably varying records under various treatments. However, from the analysis of variance, it was found that AP (ppm), Mg (cmol(+) kg^{-1}), and Na (cmol(+) kg^{-1}) showed no variation between treated and untreated areas. Based on the physical observation of the transect walks, the reason why treated and untreated areas were not significant were the failures of past extensive soil and water conservation efforts largely due to poor planning, poor design of structures, lack of participation by the communities, inappropriate conservation methods, poor linkages with livelihoods of the poor and lack of an integrated approach that goes beyond SWC.

The Table indicated that except Ca and PBS, all other soil variables were non-significant. Selected soil chemical properties like EC (ds/m), OC (%), CEC (cmol(+) kg^{-1}), Ca (cmol(+) kg^{-1}), K (cmol(+) kg^{-1}), and PBS (%) were higher in the treated areas than in the untreated areas in the study area. However, soil pH-(H_2O) was higher in the untreated areas in the Kabe Watershed. On the contrary, soil organic carbon in all land use types and/ or both treated and untreated areas of Kabe Watershed was lower (Tables 12 & 13; Appendix 2). Low organic carbon levels were due to the complete removal of crop residues for livestock feed or burning, while animal dung was converted into “Cake” for household energy.

This deprives the soil of a crucial source of organic carbon and nutrients. Many forms of physical degradation such as topsoil erosion, loss of rooting depth, surface crusting, etc., were secondary features emanating from this basic cause.

Table 13: Effect of soil and water conservation practices on selected soil chemical parameters

Parameters	Treat	Untreated	Me	SE	F	P	Significance
pH-H_2O (1:2.5)	5.46	5.56	5.5	0.042	1.374	0.247	NS
EC (ds/m)	0.133	0.125	0.1	0.0048	0.712	0.403	NS
OC (%)	2.55	2.38	2.4	0.0749	1.260	0.267	NS
TN (%)	0.22	0.20	0.2	0.0078	0.536	0.467	NS
AP (ppm)	3	3	3	0.1517	3.511	0.067	NS
CEC (cmol(+) kg^{-1})	21	19	20	0.895	1.114	0.296	NS
Ca (cmol(+) kg^{-1})	27	23	25	0.9861	5.410	0.024	**
Mg (cmol(+) kg^{-1})	3	3	3	0.0902	1.529	0.222	NS
Na (cmol(+) kg^{-1})	0.00	0.000	0.0	0.000	-	-	-
K (cmol(+) kg^{-1})	0.29	0.25	0.2	0.0615	0.8	0.767	NS
PBS (%)	79.04	65.93	72.	1.538	18.172	0.000	***

Abbreviations: AP, available phosphorous; CEC, cation exchange capacity; EC, electrical conductivity; NS, not significant; OC, organic carbon; PBS, percentage base saturation; SWC, soil, and water conservation; TN, total nitrogen.

4.1.7 Effects of slope positions on selected soil chemical properties

Table 14 summarizes the ANOVA analysis for selected soil chemical properties with different slope positions. From the table, all chemical properties except AP, considered in this study were statistically significant ($p<0.05$). The analysis of variances also found a significant effect at ($p < 0.001$) for Ca (cmol(+) kg^{-1}), K (cmol(+)kg^{-1}), and PBS (%). Soil chemical properties were considerably influenced by terrain slope positions. As can be seen from the table, all variables showed considerably varying records under various slopes.

However, from the analysis of variance, it was found that Na (cmol(+) kg^{-1}) showed no variation with changes in terrain slope. In addition, it was also indicated that except Na (cmol(+) kg^{-1}) and AP (ppm), all other soil chemical properties were highly significant. It means that slope positions affect the chemical properties of soil in the Kabe Watershed. Finally, the mean values of most chemical properties except pH-H_2O, Mg (cmol(+) kg^{-1}), Ca (cmol(+) kg^{-1}), and Na (cmol(+) kg^{-1}), were higher in the lower slope > middle slope > upper slope positions of the study area. We were concluding that, when we go from the upper to lower slope positions of the study area, the soil's acidic contents increase. The reason for this was use of fertilizers, especially those supplying nitrogen, has often been blamed as a cause of soil acidity. Acidity was produced when ammonium-containing materials were transformed to nitrate in the soil. The more ammonium nitrogen fertilizer was applied, the more acidic the soil gets.

Table 14: Effects of slope positions on selected soil chemical parameters

Parameters	Upper Slope	Middle Slope	Lower Slope	Mean	SE	F	P	Significance
pH-H_2O (1:2.5)	5.7	5.5	5.4	5.5	0.04	4.77	0.013	***
EC (ds/m)	0.12	0.13	0.15	0.13	0.005	3.57	0.035	***
OC (%)	2.2	2.5	2.7	2.47	0.071	4.37	0.018	**
TN (%)	0.19	0.22	0.24	0.22	0.008	2.54	0.089	NS
AP (ppm)	2	3	3	3	0.143	4.52	0.016	***
CEC (cmol(+)kg^{-1})	17	20	23	20	0.854	3.68	0.032	***
Ca (cmol(+)kg^{-1})	26	30	19	25	0.77	17.99	0.000	**
Mg (cmol(+)kg^{-1})	4	3	3	3	0.83	5.82	0.005	***
Na (cmol(+)kg^{-1})	0.00	0.00	0.00	0.00	0.000	-	-	-
K (cmol(+)kg^{-1})	0.11	0.06	0.66	0.278	0.049	15.59	0.000	***
PBS (%)	60	74	84	73	1.22	29.92	0.000	***

Abbreviations: AP, available phosphorous; CEC, cation exchange capacity; EC, electrical conductivity; NS, not significant.

4.1.8 Effect of SWC and LUT on selected soil chemical properties

For all land use types considered (Table 15), there was a relatively slightly higher pH-H_2O value for forestland use types without soil and water conservation measures compared to the same land use types with conservation practices. This change in the value of pH-H_2O could be attributed to changes in erosion response. Soil and water conservation practices decrease surface runoff thereby reducing the soil erosion rate, hence improving the availability of soil organic carbon and enhancing crop growth. A relatively higher mean variation of electrical conductivity was observed in forestland use types with and without soil and water conservation practices (Table 15). In contrast, cultivated land with and without soil and water conservation exhibited the lowest electrical conductivity across all slope positions (Tables 15 & 16).

Results showed that for all the land use types considered with and without soil and water conservation, the mean electrical conductivity values in forestland use types increased from the upper to the lower slope position (Table 16). In reality, for hill slope–dominated catchments characterized by significant changes in a soluble anions and cations, along with slope position, move downward with surface runoff, leading to the accumulation of suspended clay towards the lower slope. This in turn might have caused an increase in electrical conductivity values down the slope. In addition, for both land use types, with and without SWC, pH-H_2O and electrical conductivity (ds/m) values showed an increase from Forest > Grazing land > cultivation land (Table 15). The average pH and electrical conductivity (dS/m) values of cultivated lands, with and without soil and water conservation, were markedly lower in all slope categories (Table 16). The decreased soil pH-H_2O in cultivated areas could be due to increased microbial oxidation generating organic acids and a reduction in basic cations. Fertilizer application in cultivation land types might increase the pH-H_2O value or reduce the acidity of soil. From the Table below, it was also indicated that all soil chemical properties were considerably significant.

Table 15: Effects of soil and water conservation and land use types on selected soil chemical parameters

Description LUT/Slope	Selected Soil Chemical Parameters										
	pH(1: 2.5)	EC (ds/m)	OC (%)	TN (%)	AP (ppm)	CEC (cmol(+)kg^{-1})	Ca (cmol(+)kg^{-1})	Mg (cmol(+)kg^{-1})	Na (cmol(+)kg^{-1})	K (cmol(+) kg^{-1})	BS (%)
Treated Area											
Forest	5.8	0.18	3.1	0.27	4	29	31	3	0.00	0.56	81
Grazing	5.5	0.11	2.5	0.22	3	19	30	3	0.00	0.33	80
Cultivated	5.1	0.10	1.9	0.17	2	14	21	3	0.00	0.00	76
Mean	5.5	0.20	2.5	0.22	3	20	25	3	0.00	0.28	72
SE	0.021	0.003	0.033	0.005	0.086	0.375	0.763	0.079	0.000	0.057	1.4
F	34.29	23.17	44.2	13.99	23.49	50.98	8.11	4.4	-	2.7	7.6
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	-	0.031	0.000
Significance	***	***	***	***	***	***	***	***	-	***	***
Untreated Area											
Forest	5.9	0.15	2.9	0.26	4	26	26	3	0.00	0.33	73
Grazing	5.5	0.12	2.5	0.21	2	18	25	4	0.00	0.44	69
Cultivated	5.2	0.09	1.7	0.15	1	12	17	3	0.00	0.00	56
Mean	5.5	0.20	2.5	0.22	3	20	25	3	0.00	0.28	72
SE	0.021	0.003	0.033	0.005	0.086	0.375	0.763	0.079	0.000	0.057	1.4
F	34.29	23.17	44.2	13.99	23.49	50.98	8.11	4.4	-	2.7	7.6
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	-	0.031	0.000
Significance	***	***	***	***	***	***	***	***	-	***	***

Abbreviations: AP-available phosphorous; CEC- cation exchange capacity; EC- electrical conductivity; LUT-land-use type; SWC- soil, and water conservation.

Soil organic carbon (OC%) and total nitrogen (TN) were notably influenced by alterations in soil and water conservation practices (Table 15). For the cultivated land, the mean OC(%) and TN (%) values were less than the value for grazing forest land units, the change being maximum between cultivated and forest land use types. This might result from topsoil erosion, which mainly results from anthropogenic activities that aggravate agricultural activities. Lowering of organic carbon could also result from soil erosion that tended to reduce soil clay content in the cultivated area. Alijani & Sarmadian (2014) explained that soil carbon content could be affected by topographic features, climatic conditions, and the extent of soil and water conservation practices. The value increased from cultivated to grazing land, the highest being forest land use types both with and without soil conservation. The variation in the value of carbon content with changes in forest cover could have resulted from improved nutrient management in the forest and grazing land use types. On the other hand, due to rapid mineralization and poor nutrient management, the value was lowest in the cultivated land cover. This finding was supported by another research (Endalew et al., 2014) on the theme of assessing the impact of land use type change on soil acidity. They found that poor organic carbon and total nitrogen in the cultivated lands have resulted from poor nutrient management. Soil and water conservation practices along with trees in forested areas likely decreased soil erosion, potentially enhancing soil organic carbon and total nitrogen levels.

4.1.9 Effect of LUTs and slope position on selected soil chemical properties

The result showed that Ava. P (ppm) was significantly affected by changes in land use types and slope positions (Table 16). The average means values of Ava. P ranged from two to five (ppm) for cultivated and forest land cover respectively. On the other hand, grazing land has an in-between value. The cultivated land exhibited notably reduced available phosphorus levels, possible due to substantial soil erosion, limited organic and inorganic fertilizer use, and the removal of crop residues, unlike other land use types. Considering the three slope positions, mean Ava. P (ppm) was found to be highest in the forestland. The lowest value was recorded in the cultivated land in all slope positions. For all land use types, high mean values of Ava. P (ppm) was observed in land use types with soil and water conservation practice. Conversely, in both conserved and non-conserved areas, the average available phosphorus (ppm) decreased from the lower to the upper slope positions (Table 16).

Table 16: Effect of land use types and slope position on selected soil chemical parameters

Description LUT/Slope	pH(1:2.5)	EC (ds/m)	OC (%)	TN (%)	AP (ppm)	CEC (cmol(+) kg^{-1})	Ca (cmol(+) kg^{-1})	Mg (cmol(+) kg^{-1})	Na (cmol(+)kg^{-1})	K (cmol(+)kg^{-1})	BS (%)
(Upper)											
Forest	6	0.1	3	0.3	3	23	30	4	0	0.3	67
Grazing	5.5	0.1	2	0.2	2	17	29	4	0	0	62
Cultivated	5.3	0.1	1	0.1	2	11	19	3	0	0	53
Mean	5.5	0.1	2	0.2	3	20	25	3	0	0.3	72
SE	0.012	0.00	0.016	0.005	0.068	0.184	0.427	0.07	0	0.03	1.067
F	82	31	135	12	28	151	30	5.3	-	23	13
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-	0.000	0.000
Significance	***	***	***	***	***	***	***	***	***	***	***
(Middle)											
Forest	5.7	0.16	3	0.3	4	27	37	4	0	0	78
Grazing	5.5	0.11	2.5	0.2	3	19	31	3	0	0.2	75
Cultivated	5.2	0.11	2	0.2	2	14	23	3	0	0	68
Mean	5.5	0.1	2	0.2	3	20	25	3	0	0.3	72
SE	0.012	0.00	0.016	0.005	0.068	0.184	0.427	0.07	0	0.03	1.067
F	82	31	135	12	28	151	30	5.3	-	23	13
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-	0.000	0.000
Significance	***	***	***	***	***	***	***	***	***	***	***
(Lower)											
Forest	5.7	0.2	3	0.3	5	32	20	3	0	1	87
Grazing	5.4	0.11	2.6	0.2	3	21	22	3	0	1	87
Cultivated	5.0	0.11	2	0.2	2	15	16	3	0	0	77
Mean	5.5	0.1	2	0.2	3	20	25	3	0	0.3	72
SE	0.012	0.00	0.016	0.005	0.068	0.184	0.427	0.07	0	0.03	1.067
F	82	31	135	12	28	151	30	5.3	-	23	13
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-	0.000	0.000
Significance	***	***	***	***	***	***	***	***	***	***	***

Abbreviations: AP, available phosphorous; CEC, cation exchange capacity; EC, electrical conductivity; LUT, land-use type.

In this study, land use types change was found to significantly affect cation exchange capacity (CEC (cmol(+)kg^{-1})) and exchangeable cations (K^+, Ca^{2+}, Mg^{2+} and Na^+ (all measured by (cmol(+)kg^{-1})). For all land use types with and without the implementation of soil and water conservation practices, a linear increase in CEC (cmol(+)kg^{-1}) was observed when we went down the slope (Table 16). In all slope positions with and without SWC practice, CEC (cmol(+)kg^{-1}), exchangeable K^+, $Ca^{2+,}$ and Mg^{2+} (all measured by (cmol(+)kg^{-1})) showed a significant increase from cultivated land to grazing and then forest land. However, the two-digit approximation of exchangeable Na^+(cmol(+)kg^{-1}) revealed a relatively varying trend for different slope positions. Exchangeable Na^+ (cmol(+)kg^{-1}) showed a general increase for cultivated and forest land use types down the slope and without implementation of soil and water conservation. On the contrary, a fluctuating value was recorded for grazing land.

4.1.10 Relationship for selected soil physiochemical properties by Correlation matrix

Correlation analysis was performed to evaluate the connections between soil physical and chemical properties. Table 17 shows the statistical correlation between selected soil physical and chemical properties at $p < 0.05$ significance level. As explained in from section 4.1.5, for example, the soils for the specified land use types have a mean pH-(H_2O) value was less than 6.5 (it was acidic soil). Mean values of pH-(H_2O) from forestland soils were statistically different from the cultivated and grazing land ($P < 0.05$). Detailed comparative analysis of soil physical and chemical was provided from sections 4.1.1 to 4.1.9.

Table 17: Correlation matrix for selected soil physiochemical parameters with and without implementation of soil and water conservation measure

	Sand (%)	Silt (%)	Clay (%)	BD (g/cm^3)	TP (%)	SM (%)	
Sand	1						**With SC**
Silt	-1.00	1					
Clay	-0.99	0.97	1				
BD	0.98	-0.99	-0.94	1			
TP	-1.00	1.00	0.97	-1.00	1		
SM	-0.82	0.86	0.72	-0.92	0.87	1	
	Sand (%)	**Silt (%)**	**Clay (%)**	**BD (g/cm^3)**	**TP (%)**	**SM (%)**	
Sand	1						**Without SC**
Silt	-0.97	1					
Clay	-1.00	0.94	1				
BD	1.00	-0.97	-1.00	1			
TP	-0.98	1.00	0.97	-0.98	1		
SM	-0.72	0.87	0.66	-0.73	0.84	1	

	pH	EC	Av. P	OC	TN	CEC	K	Ca	Mg	Na	PBS
pH	1										
EC	0.996	1									
Av.P	0.9	1.00	1								
OC	0.9	0.99	1.00	1							
TN	1.0	1.00	1.00	1.00	1						
CEC	0.993	1.00	0.99	0.99	0.99	1					
K	0.933	0.90	0.93	0.94	0.93	0.88	1				
Ca	0.907	0.86	0.90	0.92	0.90	0.85	1.00	1			
Mg	0.932	0.90	0.93	0.94	0.93	0.88	1.00	1.00	1		
Na	0.839	0.89	0.85	0.83	0.84	0.90	0.59	0.53	0.59	1	
PBS	0.953	0.92	0.95	0.96	0.95	0.91	1.00	0.99	1.00	0.64	1

Hint: All measurement of those selected chemical parameters of soil was listed in above Tables.

4.2. Farmers' Decisions on Acceptance of Soil and Water Conservation Practices

4.2.1 Off-farm Economic Activities

In general, the relationship between off-farm employment and the acceptance performance of soil and water conservation was poorly understood (Reij et al., 2013). Off-farm activities may hurt the acceptance behavior of SWC due to reduced labor availability. Increased engagement of farmers and family members in off-farm activities limited their time on farm land, discouraging their involvement in constructing and maintaining SWC structures. Alternatively, off-farm activities can be a source of income and might encourage investment in farming and SWC.

The survey showed that 56% of the farmers were involved in various forms of off-farm activities. The major off-farm activity was collecting and selling firewood. Other activities were petty trade, pottery, weaving, leather making, labor hired out, and rental of a local “Gary” for transportation. A similar study was reported by Kibret & Geremew (2013) from the Sekela District of West Gojjam Zone, Amhara Regional State, Northwestern Ethiopia.

4.2.2 Perception and Attitude of Farmers on Soil Erosion

The perception of soil erosion as a threat to agricultural productivity and sustainable farming was the key factors influencing the adoption of SWC measures. Farmers who viewed soil erosion as detrimental to productivity and anticipated benefits from conservation were more inclined to adopt these technologies. Conversely, farmers who did not consider soil erosion a significant issue and did not foresee benefits from erosion control were less likely to adopt conservation. Also farmers had varied perceptions regarding the extent of soil erosion on their plots. But, the differences in the percentages of farmers’ judged plot-level soil erosion severity or not.

Out of the sampled farmers, 36% (Figure 11) identified overgrazing as the primary cause of soil erosion, while 20% attributed erosion to deformation. Surprisingly, only 20% regarded cultivation on steep slopes as the leading cause. Meshesha et al. (2012) study in the central Rift Valley, Ethiopia; Desta (2000) in the highland of Amhara region, Ethiopia had similar results.

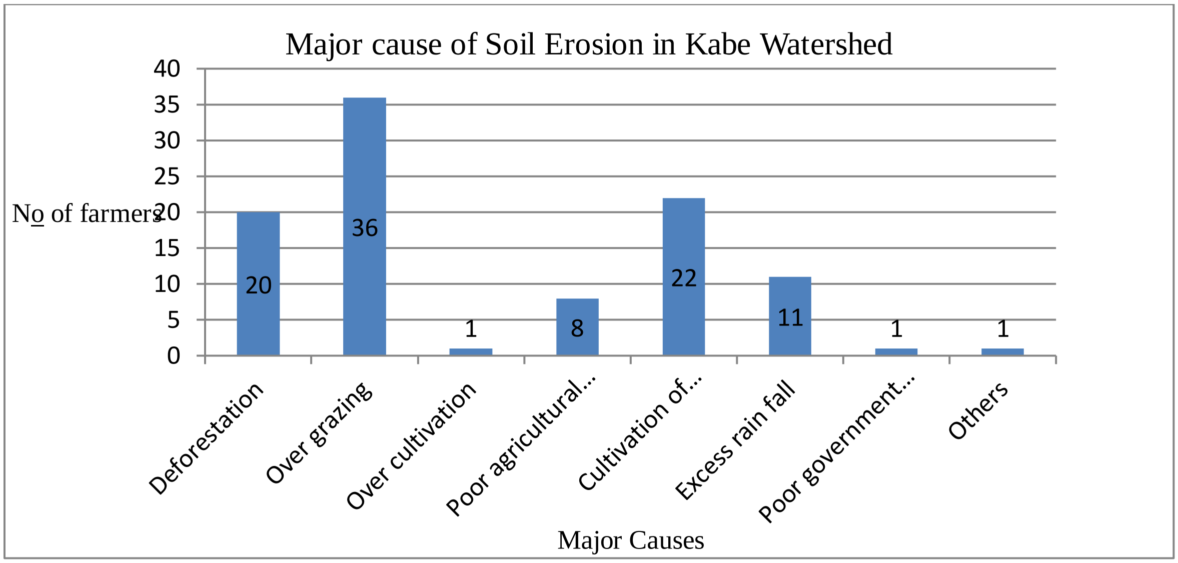


Figure 11: Major causes of erosion

Table 18 the study reflects farmers' awareness and perception of erosion in the Kabe Watershed. All surveyed farmers (100%) acknowledged soil erosion as a concern on their farms. Nearly two-thirds noted an increase in erosion over the past 5 years. Farmers' opinions on erosion's impact on farm production were evenly split between severe and moderate.

The comparison between respondents who perceived soil erosion's impact on farm production as 'smaller' and those rated erosion intensity as 'severe' suggests ambiguity in the link between erosion and land productivity decline among farmers (Table 18). This uncertainty was further supported by farmers' explanations during informal discussions regarding the decreasing fertility levels of their lands, mostly attributed to overuse rather than erosion, overall, farmers demonstrated good awareness of soil erosion issues.

Table 18: Farmers' perceptions of soil erosion hazards in the Kabe Watershed

Perception on erosion	Proportion of total Respondents (%)
Whether soil erosion was perceived as a problem in own farm	
- Yes	100.0%
- No	0.0%
The severity of the problem, if yes to the above question	
- Severe	35.8%
- Medium	62.8%
- Smaller	1.4%
The observed change in soil erosion severity over the past 5 years	
- Has become more severe	65.2%
- Has become less severe	34.1%
- No change	0.7%
The extent of the impact of soil erosion on farm production	
- Severe	45.2%
- Moderate	52.9%
- Has no effect	1.9%
Believing that soil erosion can be controlled	
- Yes	70.0%
- No	30.0%

In addition, the farmers generally believed that erosion could be controlled (70% of respondents). Hence, their lack of interest in adopting the introduced SWC measures cannot be explained by a lack of awareness about the problem and the potential for solving it. In their study in southern Ethiopia, Assefa et al. (2016) also the majority of farmers were knowledgeable about erosion issues but showed reluctance in adopting the introduced technologies. The implication was that a correct recognizing the erosion issues might be essential, yet not adequate for farmers to adopt SWC technologies at the farm level. .

4.2.3 Soil and Water Conservation Practices in Kabe Watershed

Besides the traditional SWC technologies (e.g. traditional stone bund, drainage ditch, agro-forestry, etc.) practiced by local farmers, various improved SWC technologies (e.g. soil bund, fanya juu (a ditch dug along a contour and put the soil uphill to form a ridge), stone faced soil bund, trench, etc.) are implemented. Before the intervention through the Productive Safety Net Program (PSNP), farmers in the region were solely relying on traditional practices until the recent adoption of "improved" soil and water conservation methods.

4.2.3.1 Traditional and Newly Introduced SWC Practices

Until recently, traditional[4] soil and water conservation practices have often been ignored or underestimated by development agents, researchers, soil and water conservationists, and government staff (Mushir et al., 2012). However, surveying both traditional and improved soil and water conservation practices provides an understanding of farmers' way of thinking about the interventions (Bewket, 2007). In the Kabe Watershed, farmers employ traditional and improve soil and water conservation methods to combat land degradation, particularly soil erosion. These techniques range from manure application to traditional and modern cut of drains and tree plantations.

4.2.3.2 Cut-Off Drains

The survey findings indicate that nearly two-thirds of the 282 sampled plots featured traditional to improved cut off drains (or both) (Table 19). Farmers build these drains to safeguarded seeds, fertilizer, manure, and soil from uphill water flow, diverting excess

[4]Traditional soil and water conservation methods refer to practices built upon farmers' indigenous knowledge and experience. They include intensive cultivation, zero grazing, agro-forestry, trash lines, grass strips, minimum tillage, and biological or agronomic methods such as cereal-legume intercropping, rotation and mulching, residues of crop production.

water away from the fields. However, according to farmer's opinions, some of the traditional drain structures enhance soil erosion over time. Transect walks with the key informants confirmed this, revealing several gullies between farm boundaries that were started by the cutoff drains. Farmers in the study area were, therefore, reluctant to install this type of SWC practice. SWC technicians believe that by better surveying, the performance of the cutoff drains can be improved. In studies in most Ethiopian parts, Hurni et al. (2016) and Smit et al. (2017) showed that cut-off-drains constructed by farmers with oxen-drawn ploughs, and reinforced with stones, wood blocks, and grassed soil did not result in serious erosion.

Table 19: Traditional and newly introduced soil and water conservation measures

	Description of SWC practices in the area	Traditional SWC practices	Newly introduced SWC practices	Kabe Watershed	
				Number of plots	Percentage of total land
1.	Application of manure		▲	189	67%
2.	Traditional Cut-off drain	▲		184	65%
3.	Improved cut-off drains	▲	▲	183	65%
4.	Plantation of both Improved and traditional trees	▲	▲	185	66%
5.	Soil/Stone bund terraces	▲	▲	173	61%
6.	Leaving crop residues on the field	▲		212	75%
7.	Contour farming	▲		126	45%
8.	Fallowing	▲		23	8%
9.	Fanyajuu terraces		▲	0	0%

4.2.3.3 Leaving Crop Residues

Another prevalent traditional practices in the region involved leaving crop residues on the field post-harvest, with two distinct types of agricultural crop residues: process residues[5] and field residues[6]. Farmers in the area mainly utilized crop residue to prevent soil ersion rather than to enhance soil fertility. The survey revealed that most farmers adopted this practice for soil protection (Table 19). During transact walks, limited crop residues were observed in farm plots. Key informants mentioned that farmers faced fuel wood and animal feed shortages, leading them to gradually use crop residues for off-plot needs.

Similarly, research conducted by Amede et al. (2001) found that farmers in Ethiopian highlands removed all crop residues from their fields and used them in their livestock pens or home gardens. Some of the residues from cereals (Wheat, Barley, and Teff) and legumes (haricot beans and pea beans) were stored in the home compound and sold as fodder or used to feed livestock during the dry season. Similar studies were found by (Biddle, 2017).

4.2.3.4 Contour Farming

Contour farming involved cultivating along elevation contours to reduce runoff on sloped lands over 6%. It was often combined with practices like cut-off drains and tree planting (both used on two-thirds of surveyed plots). Around45% of plots practiced contour farming (Table 19), recognized for its soil and water conservation benefits. Farmers implemented it during land preparation to create suitable seedbeds before planting. Similar studies happen in Fincha'a Watershed, Western Ethiopia (Tefera & Sterk, 2010).

---

[5] Process residues are those materials left after the processing of the crop into a usable resource. These residues include husks, seeds and roots. Crop residues can be use as animal fodder and soil amendment, and in manufacturing.

[6] Field residues are materials left in an agricultural field or orchard after the crop has been harvest. These residues include stalks and stubble (stems), leaves and seedpods. Good management of field residues can increase efficiency of irrigation and control of erosion.

4.2.3.5 Fallowing

Fallowing, a key method to curb soil fertility loss, was limited to severely degraded land in the study area (Mushir & Kedru, 2012). These lands often ended up converted in stones. Only 8% of surveyed plots were fallow (Table 19). Traditional fallow periods decreased over time due to rising population pressure and declining agricultural productivity, as revealed in discussions with farmers.

4.2.3.6 Application of Manure

Manure application was the most common conservation practice, utilized on 67% of all practices in the study area (Table 19). Farmers concentrated on applying manure near their homesteads rather than to distance lands. Discussions with key informants revealed that farmers increased manure usage due to the expensive nature of inorganic fertilizers like DAP and Urea, which were unaffordable for them.

4.2.3.7 Tree Plantations

On 66% of surveyed plots, trees and non –crop plants were planted, sometimes alongside other conservation methods (Table 19). During transact walks, plants like sisal were noticed planted along contour to prevent runoff and preserve soil and water (Figure 12). These drought-resistant plants, non-edible and animal-resistant, served as borders between fields, offering multiple benefits to farmers. Similarly in Chencha and Arbaminch, southern Ethiopia study by (Assefa et al., 2014).

Figure 12: Nursery site in Kabe Watershed for plantation trees

4.2.3.8 Soil/stone bund Terraces

Approximately 61% of the surveyed plots featured soil and stone bunds (Figure 13, Table 19). In communal lands, particularly in mountainous regions, farmers were motivated to construct binds to benefit from a safety net program. Through focus group discussions with key informants, it became apparent that farmers were well informed about erosion issues in the area and recognized the effectiveness of bund terraces in soil protection. The introduction of new SWC methods like stone and soil bunds received widespread recognition for their efficacy in combating soil erosion and enhancing land productivity. However, due to a top-down approach lacking the involvement of Development Agent with local farmers, the farmer' acceptance of these new soil and water conservation practices appears uncertain (Bewket, 2007; Hishe et al., 2017).

Figure 13: Sample soil/stone bund Terraces in Kabe Watershed

In discussions with key informants, farmers attributed gullies to poorly designed soil/stone bunds by development agents, which can cause erosion if overtopped without spillways. These structures are more suitable for arid regions than high-rainfall areas. farmers seek appropriate technologies to conserve soil and water effectively, as poorly designed practices can lead to erosion in SWC treated areas.

None of the surveyed plot featured Fanyajuu terraces (Table 19), as farmers were unfamiliar with this SWC method. Farmers using Fanya juu terraces highlighted their gradual transitional into bench terraces, low maintenance requirements, and effective runoff control. However, past studies in southern Ethiopia Mengstie (2009) and Tegene (1992) found that farmers deemed soil and Fanya juu bunds unsuitable due to space occupation and pest issues.

4.2.4 Factors Affecting Acceptance of SWC Practices

Based on Table 20, among many hypothesized explanatory variables, only seven variables were found to significantly affect improved soil and stone bund terraces. Five variables significantly affected improved cut-off drains and two variables affected the acceptance of tree plantations. The probability ratios for all cases were significant at $p<5$ percentage probability level. This indicates that there exists useful information in the estimated Tobit regression model result in SPSS.

The findings reveal that the variables with significance ($p>5\%$) influencing the adoption of at least one of the three enhanced SWC practices (soil/stone bund terraces, cut-off drains, and tree plantations) in the research area consist of total farmland area, land-to-labor ratio, household head's age, household heads education level, distance between the farm plot and home, and the slope of the farm plots total family size, total livestock holding capacity, access to training and distance of the market from home. Variables of sex of HH head, perception of erosion problem, social position of HH head, and off-farm income did not significantly differ from zero in any of the three equations.

Table 20: Tobit Model Results of Acceptance of improved soil and water conservation practices

Parameters/ dependent variables	Independent Variables											
	Y_1 (soil/stone bund terrace)				Y2 (Cut-off drain)				Y3 (Tree plantation)			
				Change				Change				Change
	Bi	SE	T-val.	Prob.	Bi	SE	T-val.	Prob.	Bi	SE	T-val.	Prob.
Age of HH head	0.425	0.26	1.62	0.105	0.352	0.14	2.44	0.016	0.470	0.97	0.48	0.629
Education of HH head	3.823	1.96	1.95	0.003	0.114	1.09	0.1	0.917	5.932	7.13	0.83	0.406
Sex of HH head	-3.883	6.73	-0.58	0.565	-4.389	3.71	-1.18	0.238	-22.431	24.6	-0.91	0.363
Total family size	-3.383	1.15	-2.93	0.003	-1.687	0.63	-2.66	0.008	-11.342	4.26	-2.66	0.008
Perception of erosion problem	51.362	28.9	1.78	0.076	18.212	16	1.14	0.256	31.803	106	-0.3	0.765
Social position of HH head	-0.840	1.91	-0.44	0.660	-1.702	1.05	-1.62	0.105	-3.346	6.94	-0.48	0.630
Area of total farmland	20.077	9.31	2.16	0.002	10.373	5.15	2.01	0.045	39.324	34.4	-1.14	0.253
Land-to-labor ratio	-56.63	513	-1.1	0.273	-51.98	287	-1.79	0.005	92.600	875	0.05	0.961
Total livestock holding capacity	1.542	0.32	4.8	0.000	0.561	0.17	3.16	0.002	3.083	1.16	2.65	0.001
Off-farm income	0.016	0.01	1.71	0.089	0.004	0	0.84	0.402	-0.040	0.03	-1.12	0.263
Access to training	-6.173	6.24	-0.99	0.323	-8.474	3.39	-2.5	0.013	22.776	22.5	-1.01	0.312
Distance of market from home	0.113	0.05	2.36	0.019	0.030	0.02	1.15	0.253	0.235	0.17	1.35	Error
Slope of farm plots	16.061	6.83	2.35	0.009	5.188	3.69	1.4	0.161	-0.300	0.23	-1.3	Error
Distance of farm plot from home	-0.311	0.07	-4.65	0.000	-0.209	0.04	-5.67	0.000	195.00	134	1.46	Error

Where, Bi represents the regression coefficient associated with the variable
SE means standard error of the regression coefficient
T-val. is Bi/SE
Change prob. is the probability that Bi is not significantly different from zero

Table 21 presents the actual and expected coefficient signs based on Table 20, also indicating which coefficients were not significantly different from zero. The signs (+ or direct/- or inverse relationship between dependent and independent variables) of the estimated coefficients with significances at 5% or better were consistent with prior sign expectations except for access to training (negative instead of positive, for cut-off drains) and walking distance to market (positive instead of negative, for bunds).

Table 21: Expected sign of the different variable

Description	**Expected sign**	**Sign for bunds (Y1)**	**Sign for cut-off drains (Y2)**	**Sign for tree plantation (Y3)**
Age of the household head	+	(+)	+	(+)
Education of head of household	+	+	(+)	(+)
Sex of household	+	(-)	(-)	(-)
Family size of the household	-	-	-	-
Perception of the household head about the soil erosion problem	+	(+)	(+)	(-)
Social position of the household head	+	(-)	(-)	(-)
Area of total farmland	+	+	+	(-)
The ratio of total land to labor	-	(-)	-	(+)
Livestock holding of the household	+	+	+	+
Off-farm income	+	(+)	(+)	(-)
Access to training about SWC practices	+	(-)	-	(-)
Walking distance to the market	-	+	(+)	(+)
The slope category of a plot	+	+	(+)	(-)
Walking distance to the farm plot from home	-	-	-	(-)

Sign in parentheses () indicates that coefficient was not significantly different from 0 at the p≥5 level.

4.2.4.1 Personal Factors in Relation to Acceptance of SWC

The personal factors that were considered in relation to the adoption behavior of SWC included age, education, family size, and sex of the household head.

Age of farmers

The impact of farmers' age on the adoption of soil and water conservation practices showed a positive and statistically significant association, particularly with cut-off drain types of SWC. Each increment in the age of the household head resulted in a 0.35% increase in the acceptance of improved cut-off drains (Table 20). This positive correlation suggest that as farmers grow older, their inclination towards adopting enhanced cut-off drains improves.

Education of household head

There was a significant correlation between the education[7] level of household heads and the acceptance of soil/stone bund terraces (Table 20). Education increased the acceptance behavior of improved soil/stone bund terraces by 3.8% per additional year of education. This provides support for the hypothesis that better education levels were associated with greater information on conservation measures and in turn results in a greater adoption of soil and water conservation practices. Prasannakumar et al. (2012) found that the education of the HH head was positively related to the acceptance of improved SWC technology. Therefore, if the amount of educated people increases, the country's sustainable development will be improved.

Family size

[7] Education: Refers to the number of years of formal education completed by the head of the household. Educated farmers can understand, analyze, and interpret the advantage of different technologies more easily than uneducated farmers interpret. Therefore, farmers who have greater year of schooling are expected more likely to use soil and water-conserving technologies.

The family size of households had an impact on the investment in all three types of soil and water conservation practices. As mentioned above, population growth has brought about land scarcity and land degradation in the Kabe Watershed. Table 20 was consistent with this because survey results show that a one-person increase in family size decreases the acceptance of soil/stone bund terraces by 3.4%, cut-off drains by 1.7%, and tree plantation by 11.3%. It is plausible that large families do not spend their money on soil and water conservation practices; rather they spend it on food and other necessities.

Sex of household head

It was surprising that the sex of the household variable did not have a significant relationship to any of the three SWC practice proxies, because of the existing strengthened capacity of women farmers for work in the study area.

4.2.4.2 Socio-Economic Factors in Relation to Acceptance of SWC

The main and significant economic factors considered in this study were; the area of farmed, land-to-labor ration, and livestock holding of the household. Economic factors can play an important role in determining the acceptance of SWC practices. Among the economic factors, farm size was an important variable concerning the acceptance of soil and water conservation (Table 20)

Area size of farmland

Increased farmland areas significantly influenced the adoption of improve soil/stone bund terraces and cut-off drains, but not tree plantation. Survey findings indicated that for evey additional hectare of farmland, the likelihood of accepting bunds increased by 20% (Table 20). Large farms typically had available land for soil/stone bunds, whereas smaller farms utilized all available land for crop cultivation. Studies by Deressa et al., (2009) in the Nile basin, Ethiopia, Biratu et al., (2016) in Gusha Temela watershed, Arsi, Ethiopia, and

Tesfaye et al. (2014) in the Gedeb Watershed, Ethiopia similarly observed that farmers with large farms were more inclined to adopt these practices.

Land-to-labor ratio

Land to land-to-labor ratio negatively affected the acceptance of cut-off drain SWC. A unit increase in land-to-labor ratio decreased the acceptance of cut-off drains by 51% (Table 20). Implementation of the SWC structure was labor intensive and therefore implementation was related more to labor availability than to land size. This finding lends support to the hypothesis that as the population grows relative to land resources, land will be more intensively cultivated. Meshesha et al. (2012) in Central Rift Valley, Ethiopia had a similar study.

Livestock holding of the household

Livestock rearing was a significant aspect of the farming system in the study region. Many farmers noted a feed shortage for their livestock, particularly in the dry season. On average, each household's livestock holding, measured in tropical livestock units (TLU), was 3.2 (Appendix 13). Increased livestock holdings were positively related to the acceptance of improved soil/stone bund terraces, cut-off drains, and tree plantation of SWC structures (at a 5% significant level, Table 20). The survey result showed that a unit increase in livestock increased the acceptance of improved soil/stone bund terraces by 1.5%, cut-off drains by 0.6%, and tree plantations by 3.1%. This may imply that money earned from the livestock makes possible the purchase of materials for the construction of SWC structures. Tefera et al., (2010) in the Fincha'a watershed, western Ethiopia had a similar study.

4.2.4.3 Institutional Factors in Relation to the Acceptance of SWC

In this study, institutional factors like visits by development agents, technical support, training, land tenure, and proximity to markets had minimal impacts on the adoption of soil and water conservation practice, except for distance to the market. Surprisingly, increase distance to the market correlated with higher acceptance of soil/stone bund terraces and cut-off drains. For each additional minute of travel to the market, the adoption of soil/stone bund terraces increased by 0.11% and cut-off drains by 0.03%.

Incomplete information provided to farmers, particularly focusing solely on technical aspects and neglecting key farmers-centric criteria, hindered technology adoption. Training had a notably adverse effect on cut-off drain usage due to incomplete information compared t other practices. Consequently, farmers tended to adopt alternative methods instead of cut-off drains when trained, lacking a clear understanding of potential benefits post-adoption.

Testing the impacts of land rental of SWC practices adoption was unfeasible due to the limited number of farmers renting land in the sample. According to Ali et al. (2007), farmers are unlikely to invest in rented land they doubt the possibility of recouping their investments. .

4.2.4.4 Biophysical Factors in Relation to Acceptance of SWC

Biophysical factors, such as proximity to the household and plot slope, influence the adoption of soil and water conservation (SWC) structures. Greater distance between the plot and home correlated with lower acceptance of terraces and cut-off drains. Each additional minutes of walking reduced terrace length by 0.31% and cut-off drain length by

0.25%. In the Kabe Watershed, Ethiopia, it was observed that plots farther from homes discouraged SWC investment. Sloping terrain showed higher use of terraces compared to flat land, with a 16.1% increase in terrace adoption for every unit increase in slope steepness.

Plantations of trees were implemented mostly in flat lands in the study area (Figure 14) because flat lands were degraded mostly by overgrazing, over-cultivation, deforestation, and poor agricultural practices. Farmers were confident to adopt the plantation of trees due to the effectiveness of the measure to rehabilitate degraded land and control erosion on flat land.

Figure 14: Sample plantation trees in the flat area of Kabe Watershed

4.3 Annual Soil Loss by Erosion in Kabe Watershed

Ethiopia faces several soil degradation issues, particularly pronounced in the highlands. Using the RUSLE model, Figure 15 illustrates estimated soil loss in the Kabe Watershed. Continuous cultivation on steep slopes, reduced forest cover, organic matter loss. And inadequate conservation measures contribute to an estimated maximum annual soil loss of 125.241 ton ha-1yr-1. The southern and northern regions of the study areas high risk of erosion due to the absence of modern soil and water conservation structures.

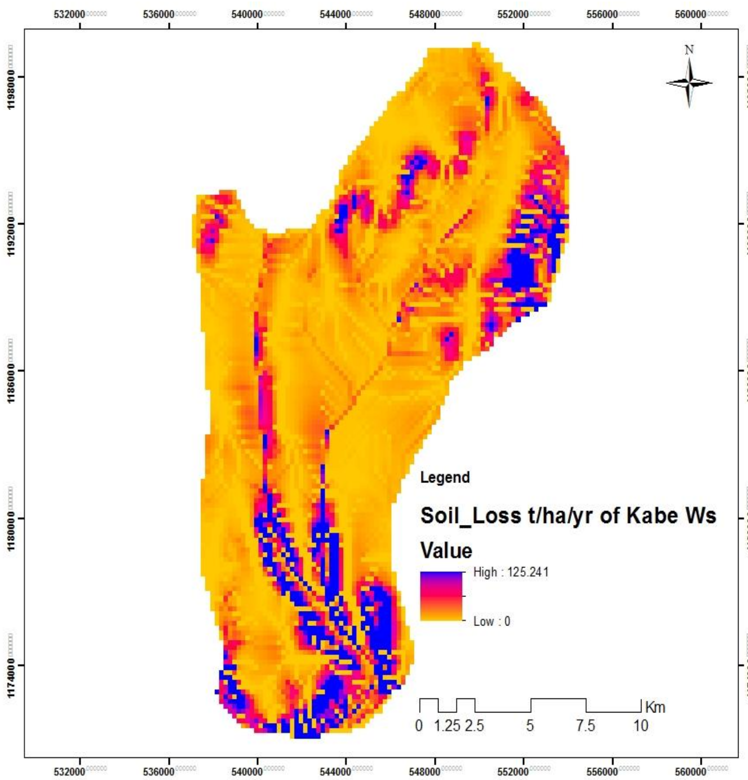


Figure 15: Annual soil loss of Kabe Watershed

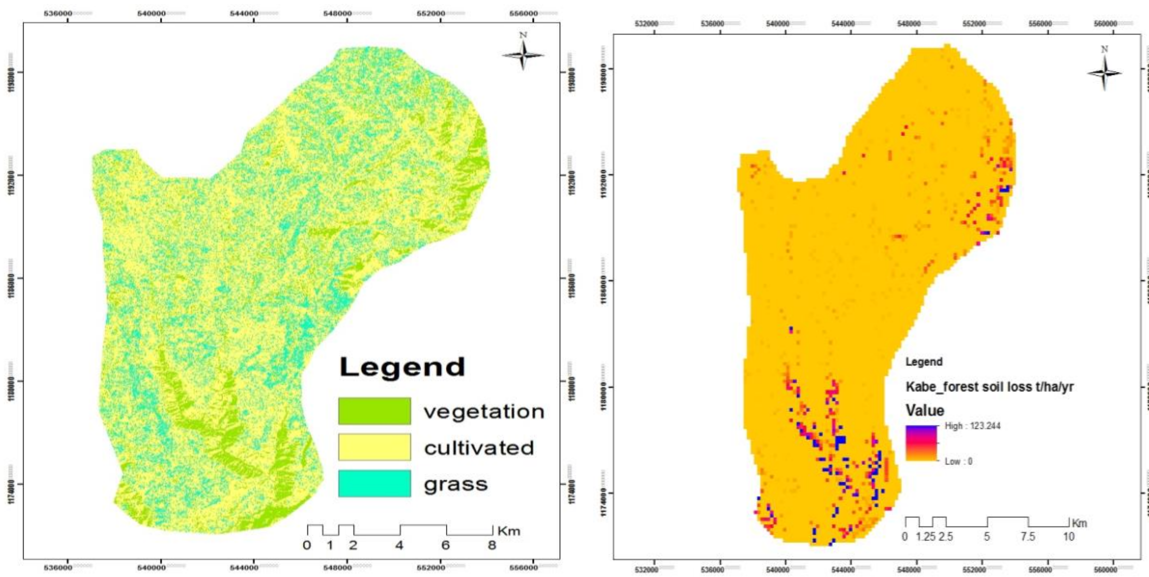
4.3.1 Effects of Land Use Types on Annual Soil Loss by Erosion in Kabe Watershed

Based on the RUSLE model, the result was revealed that the mean soil loss by water erosion was relatively highest (20.01ton $ha^{-1}yr^{-1}$) under cultivated land followed by grassland (0.69 ton ha^{-1}yr^{-1}) while it was lowest (0.17 ton ha^{-1}yr^{-1}) under forest land and overall mean soil loss of 6.95 ton ha^{-1}yr^{-1} for the entire watershed (Table 22).

Table 22: Mean soil erosion rate in Kabe Watershed for different Land use types

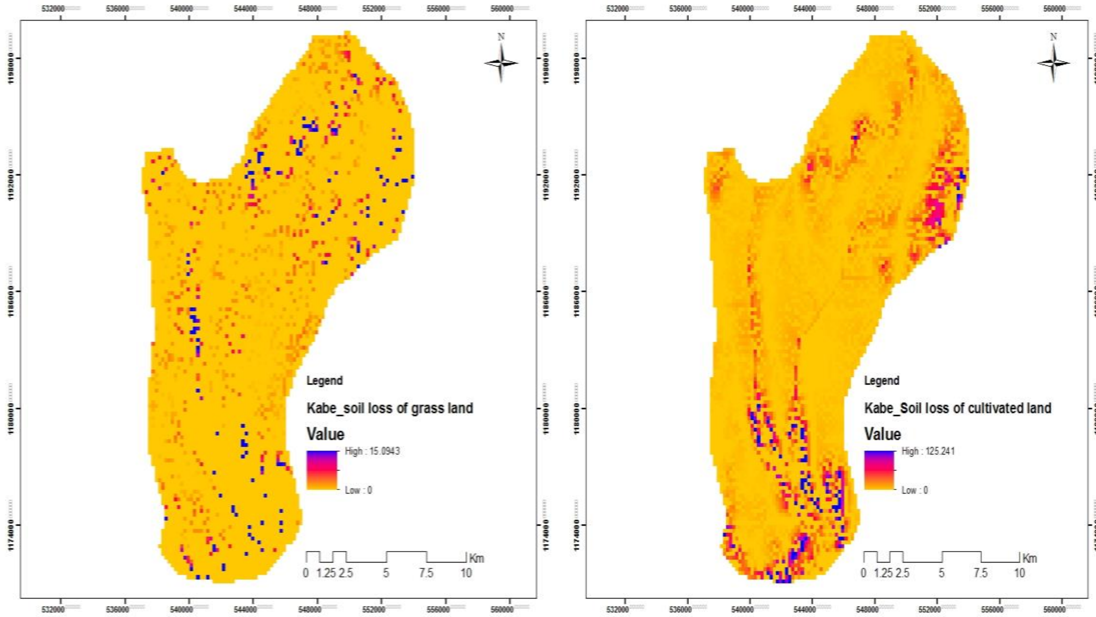
Land use land cover	Max	Min	Mean (t ha-1yr-1)	Standard deviation of mean
Forest land	12.24	0.02	0.17	1.74
Cultivated	125.24	0.05	20.01	7.13
Grassland	15.09	0.006	0.69	0.45
Overall	50.24	0.0	6.95	2.74

Max is maximum soil loss, Min is minimum soil loss, and the total loss is soil loss per ton per year of each LUT



(A)

Figure 16: Land use land cover change by the 3 Land use types in Kabe Watershed



(B) (C)

Figure 17: Soil erosion loss from Forest, Grazing, and Cultivation lands in Kabe Watershed

The analysis indicates that there had been a lower annual mean soil loss rate of 6.95 ton ha^{-1} yr^{-1} (Table 5) as compared to the country (Ethiopia) soil loss tolerable rate of (10 ton ha^{-1} yr^{-1}) Hurni, (1985) and it also showed lower compared with the tropical Africa tolerable soil loss rate of (11 ton ha^{-1} yr^{-1}) (R. P. C. Morgan, 2009). Based on (Figure 17 A, B & C), it was observed that maximum soil loss (125.24 ton $ha^{-1}yr^{-1}$) in the watershed, because of high length and steepness factor value as well as slope value greater than 75%. The forestland soil loss was lower due to the protective capacity of the vegetation and the organic carbon added to the soil that makes the soil stick together. However, in cultivated land soil loss was highest as compared to the rest of the land use types because continuous cultivation of land could be triggered by the loss of organic matter, top fertile soil, and easily eroded by wind and water. Therefore, this study indicated that there was not that much amount of soil coverage in the area.

4.3.2 Effects of Slope Position on Annual Soil Loss by Erosion in Kabe Watershed

For the general slope classification purpose, the study area was classified into six slope classes (Figure 18). From this Figure, we show that small area of the watershed there was a very high (>75%) slope in the study area, and most areas were found under (0-15%) slope positions. Nevertheless, the conditions that affect the mean annual soil loss by erosion were insignificantly (see Table 22 above).

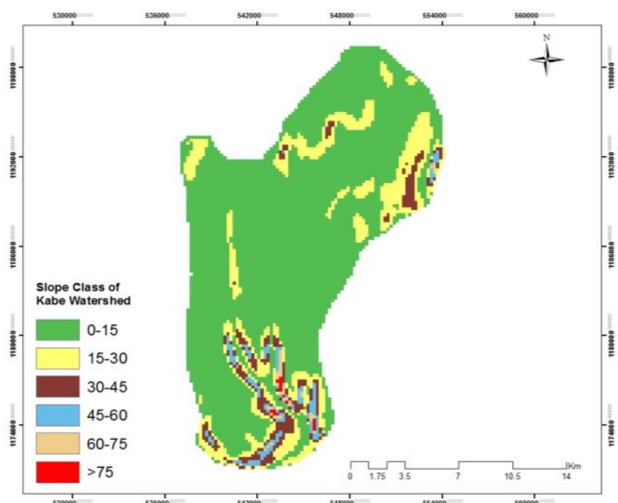


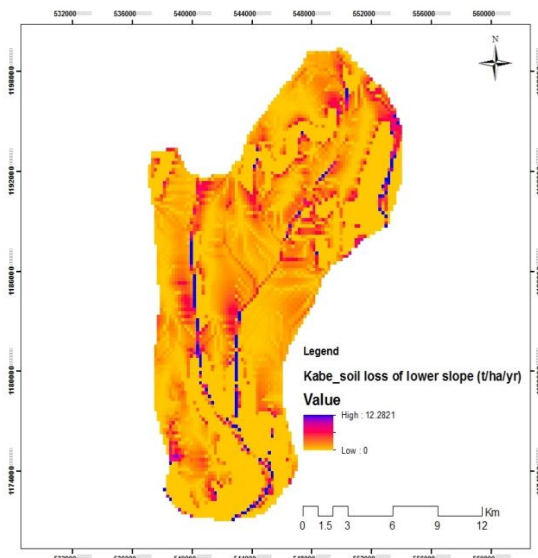
Figure 18: Slope classification in general in Kabe Watershed

The RUSLE model also indicates that the mean soil loss under different (especially in lower, middle, and upper) slope positions was significantly different. Figures 19 and Table 23 below show that the highest mean (13.71ton ha^{-1}yr^{-1}) soil loss by erosion was observed under upper slope position while the lowest mean (1.69ton ha^{-1}yr^{-1}) was under lower slope position of the watershed, on the other hand in the same time the maximum (125.24 ton ha^{-1}yr^{-1}) soil loss by erosion was under upper slope position of the watershed and the minimum (12.28ton ha^{-1}yr^{-1}) soil loss by erosion was under lower slope position of the watershed. Similar researches were reported by Mekuria et al. (2007) in the Tigray region of Ethiopia and Damene et al. (2012) in the Maybar watershed in Wollo, northern highlands of Ethiopia.

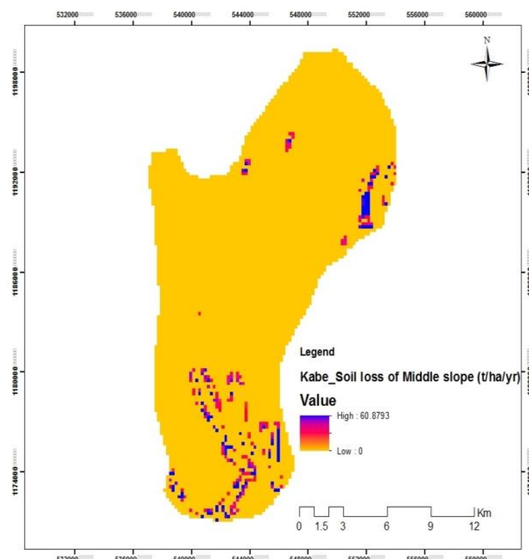
Table 23: Mean soil loss rate of Kabe Watershed for different slope positions

Slope Class	Max	Min	Mean (t/ha/yr)	standard deviation of mean
Lower (15%)	12.28	0.012	1.69	0.43
Middle (30%)	60.88	0.045	3.14	1.17
Upper (>45%)	125.24	0.06	13.71	5.34

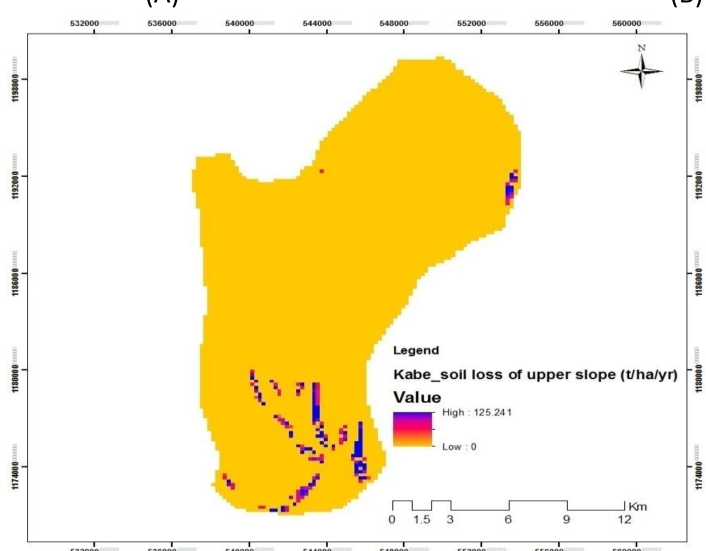
Max loss is maximum soil loss, Min is minimum soil loss, total loss is soil loss ton per year of each slope class



(A)



(B)



(C)

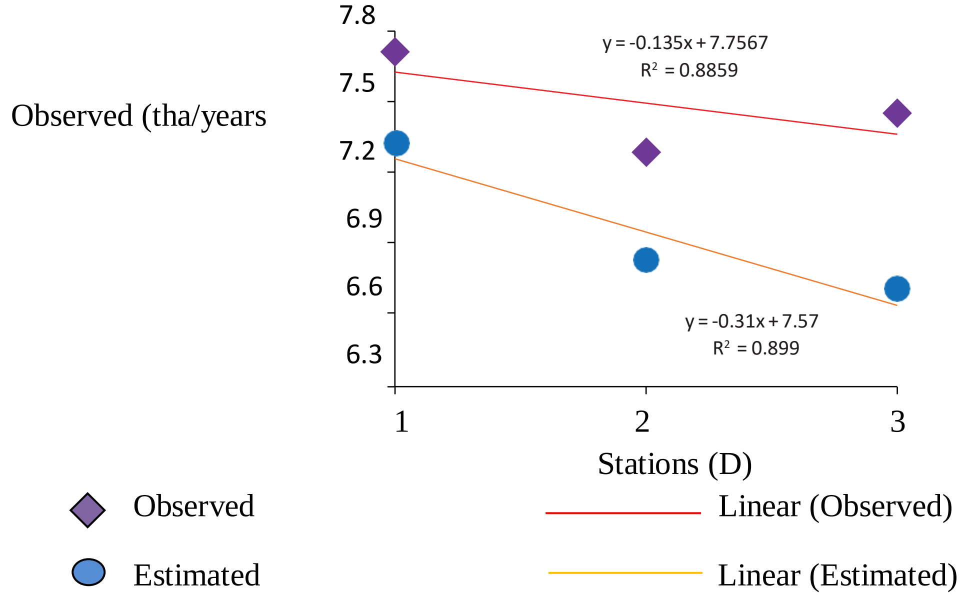


Figure 19: Soil erosion loss under lower, middle, and upper slope positions in Kabe Watershed and observed & estimated soil erosion in the watershed

4.3.3 Model Validation in the Kabe Watershed

The observed and estimated data had shown an insignificant variation in soil loss in the Kabe Watershed ($P < 0.05$, Figure 19). Therefore, the model used in this watershed was suitable for estimating soil erosion in the watershed. The observed mean soil erosion values of the three gauged stations were 7.72 ton $ha^{-1}yr^{-1}$, 7.29 ton $ha^{-1}yr^{-1}$, and 7.45 ton $ha^{-1}yr^{-1}$, respectively, which was reliable with results derived from the existing model.

The experimental and predicted erosion of soil were 7.49 and 6.95 t $ha^{-1}yr^{-1}$, respectively, with a variation of 0.54 ton $ha^{-1}yr^{-1}$. The very few inconsistencies (error = −3.4%) of soil erosion recommend that land use/cover and other climatic factors have been adequately recognized by the RUSLE. Thus, the performance of the RUSLE model indicates a very good performance based on the statistical analysis (PBIAS = −3.22%, R^2 = 0.86, and RRMSE = 0.84). Therefore, it indicates that the experimental data from the study Kabe Watershed was a good fit with the RUSLE models' predictions.

4.4. Land use and land cover change analysis using GIS and remote sensing

4.4.1 State and Characteristics of Land Cover Types

Major LULC types were identified by utilizing field data and satellite imagery. These were cultivated land, wetland, bare land, grazing land, shrubland, and forest land (Table 24). Land cover indicates the physical land type such as grass, forest, or open water whereas land use documents how people were using the land.

Table 24: Description of major land cover types and interpretation keys from the used satellite images

Land Cover types	Description	Key
		Texture
Cultivated land	This category comprises cultivated areas and land being prepared for cultivation. Boundaries are typically delineated broadly to encompass primary agriculture zones, rather than precise field edges, unless the mapping scale permits. It may encompass minor feature within fields (e.g hedges, grass strips, small windbreaks) and farm structures.	Smooth
Wetland	Areas with water logging and mixing with grass, wet grasses, or are around the river and down streams.	Smooth
Bare land	Open lands consist of rocky terrain, rural roads, and inused bare lands.	Coarse
Grassland	Grasslands are regions primary characterized by grass coverage. Areas with grass interspersed with scattered trees and used as pastures are considered part of the grassland category.	Medium coarse
Shrub land	Shrub lands encompass regions with small trees, bushes, and shrubs, varying from dense canopy to more open areas.	Medium coarse
Forest land	These types of land is entirely covered with trees, whether manmade or naturally planted, in a regular arrangement.	Smooth

Hence, within Kabe Watershed, six primary land covers categories were distinguished in each satellite image. The types and extents of land cover for each image date (1986, 2000 and 2019) are detailed below (Figure 20).

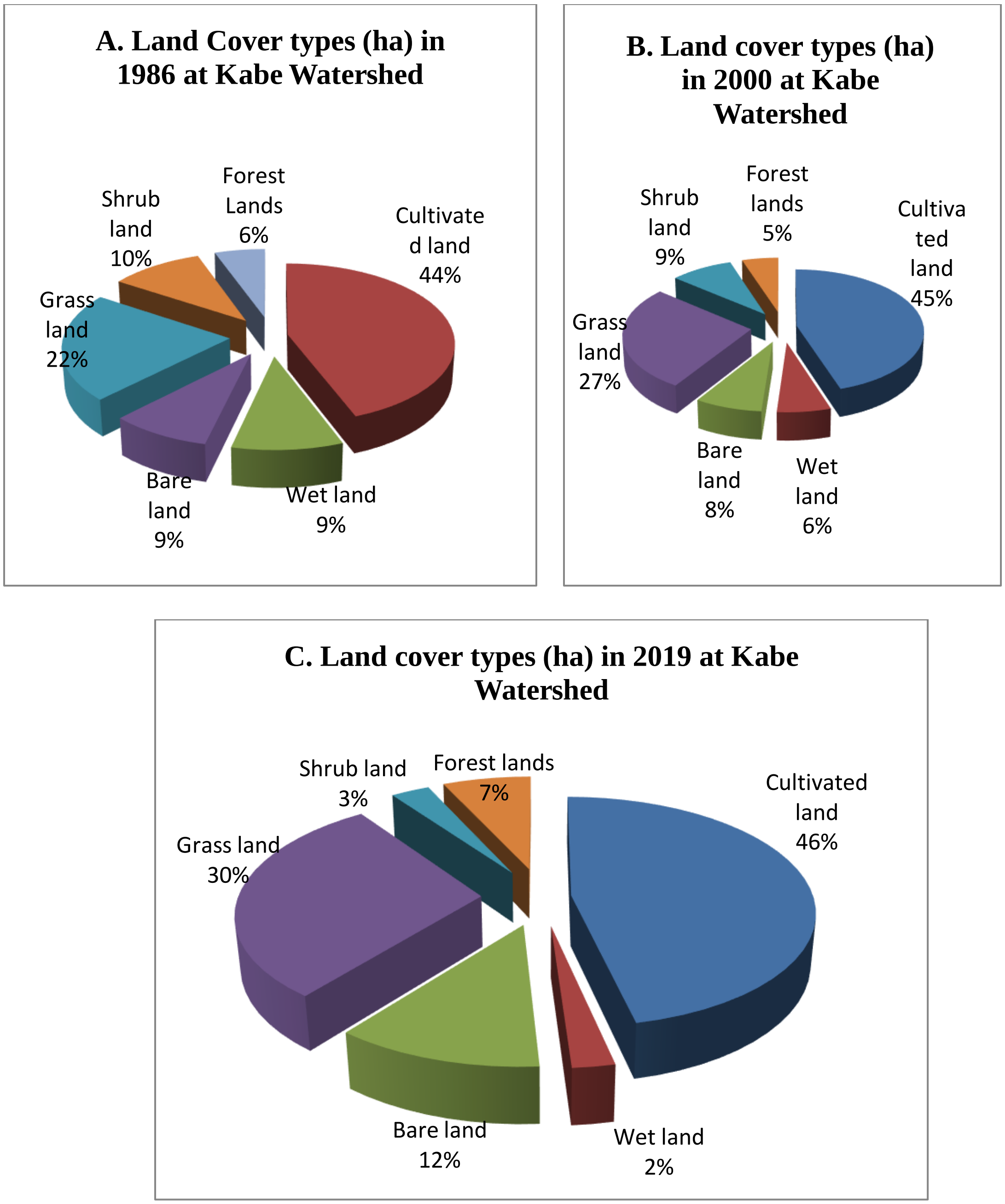


Figure 20: Coverage of each land covers classes in each date of the image

Figure 20 illustrate temporal and spatial changes in land cover types in the Kabe Watershed. In 1986 cultivated land was the dominant cover at 44%, followed by grassland at 22%. Overtime, cultivated and grassland areas increased while wet and shrub lands decreased. By 2019, cultivated and grass lands had increased by 2% and 8% respectively, while wet and shrub lands decreased by 7% each. Conversion patterns over the 34 years period indicate shifts between different land categories: 7% of shrub land and wetland converted to various other covers, while cultivation gained from shrubs/wetlands. Forest areas saw changes, with 1% converting to cultivation in the initial period and 2% gaining from shrubs/wetlands later on. Grazing lands also transformed, gaining from shrubs/wetlands. Bare lands initially converted to other covers, but later gained from shrubs/wetlands.

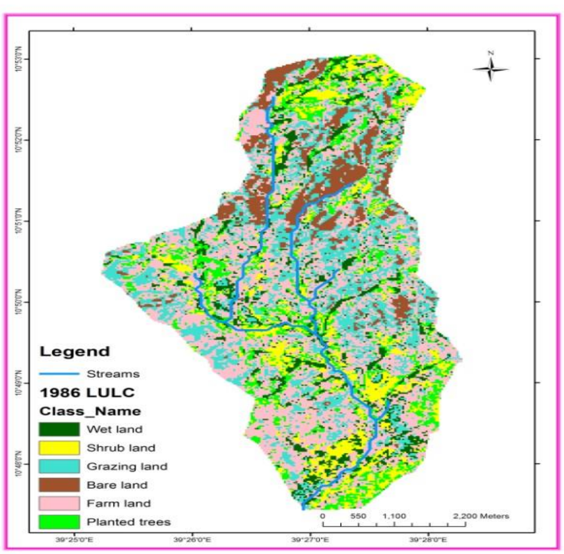
The findings indicate a significant decrease in the coverage of shrub and wetland areas in the Kabe Watershed, while the areas of grazing, cultivated, and bare lands have expanded.

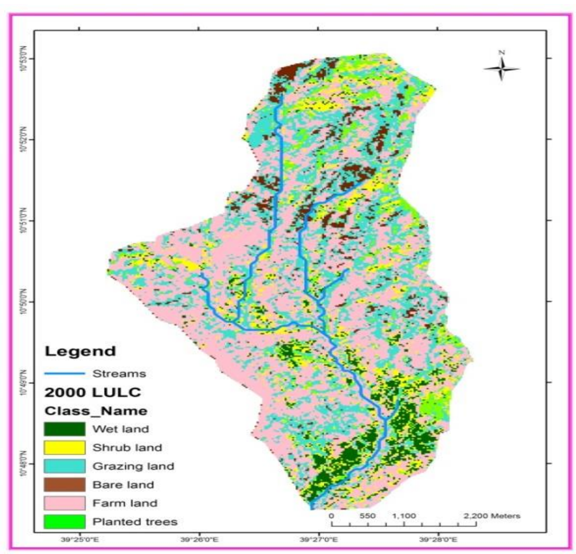
4.4.2 Change Detection Analysis from1986 - 2019

In 1986, the land cover map (Figure 21) showed cultivated land primarily on the gentle slopes near the watershed boundary in the western part, with the rest covered by shrubs and grasslands. By 2000, cultivated land had expanded to dominate the entire watershed, and post 2000; most of the area was under cultivation and grazing, except for a small portion in the steep top and middle areas.

The comparison between 1986 and 2019 revealed significant land use and land cover change over the 34 years study period. Cultivated and grazing areas in the watershed increased by 2% and 8% respectively during 1986-2019, indicating economic influences driving anthropogenic land changes. The shift towards cultivation and grazing in the watershed's main areas and streams was primary due to economic factors. Initially, agriculture expansion focused on marginal lands with steep slopes, but biological constraints like thin topsoil limited further expansion, pushing cultivation and grazing into former shrub and wooded areas. Cultivated and grazing lands were often surrounding by shrub and wetlands areas, especially near catchment zones and main streams,. Conversely, bare land area expanded by 3% over the study period, largely due to rapid deforestation stripping shrub cover, rendering the land unproductive. This led to farmers abandoning these less fertile lands due to economic inefficiency, resulting in a significant increase in barren land. The classification results confirmed a 7% decrease in shrub areas from 1986 to 2019.

Human activities such as deforestation, fuel wood cutting, and extensive cattle grazing have transformed plants into small bush and left barren lands in some areas. illegal forest wood cutting driven by market demands and the intensive use of forest resources for household needs and local construction were identified as significant drives of forest decline in the watershed area.





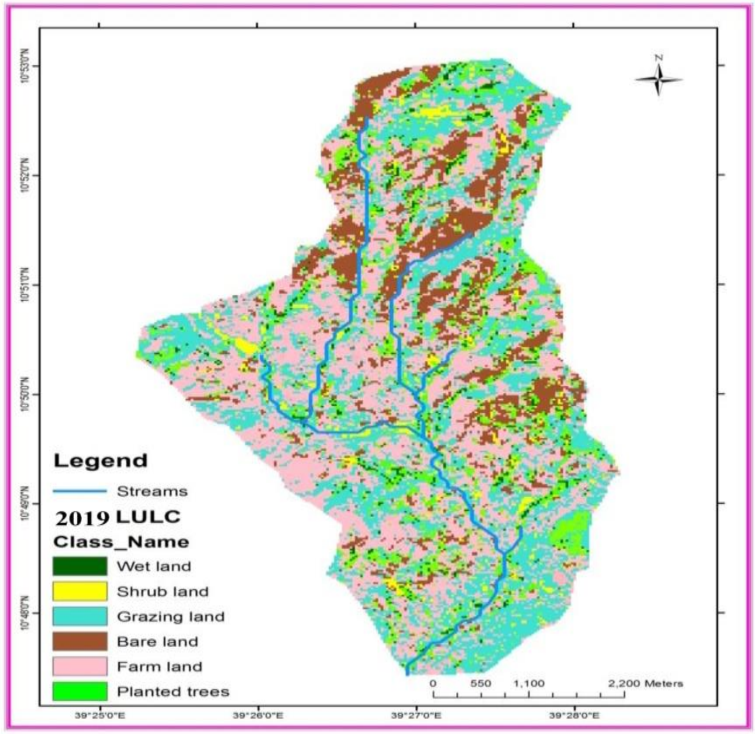


Figure 21: Land covers the dynamic process of 1986, 2000, and 2019

Based on the map and the result, the major LULC classes identified in the study were poorly dispersed forests (planted trees), cultivation, bare/eroded surfaces, shrubland, wetlands, and river bodies. These were identified and delineated on TM 1986, ETM^+ 2000, and ETM^+ 2019. There are varying degrees of spectral signatures on generated imageries and variations in the area.

In the Kabe Watershed, there was a notable shift from grass, shrubs, and planted forests to cultivated lands and grasslands over the years. This transition was predominantly one-way from 1986 onwards. The conversions to cultivated land look two forms: direct conversions, such as from shrubs and grasslands, and systematic conversions, like from continuous forest to fragmented forest, woodlands, shrub lands, and finally to cultivate lands. This systematic shift may be linked to the extraction of forestry resources like fuel wood and construction materials. Farmers did not initially intend to convert these areas to cultivation; rather , it happened gradually overtime.

The map and findings revealed a conversion from fallow cultivated land to grass and shrub lands. On the gentle slope at the watershed boundary, their was minimal forest plantation and large-scale cultivation. In the lower watershed area, agricultural practices intensified, including traditional small-scale irrigation and grasslands.

4.4.3 Rate of Land Cover Change

The rate was transformed into a categorical variable due to its continuous nature. The rate of land cover change depicted a continual trend where some land cover classes expanded over time while others experienced periodic shrinkage. This information is illustrated in Figure 22.

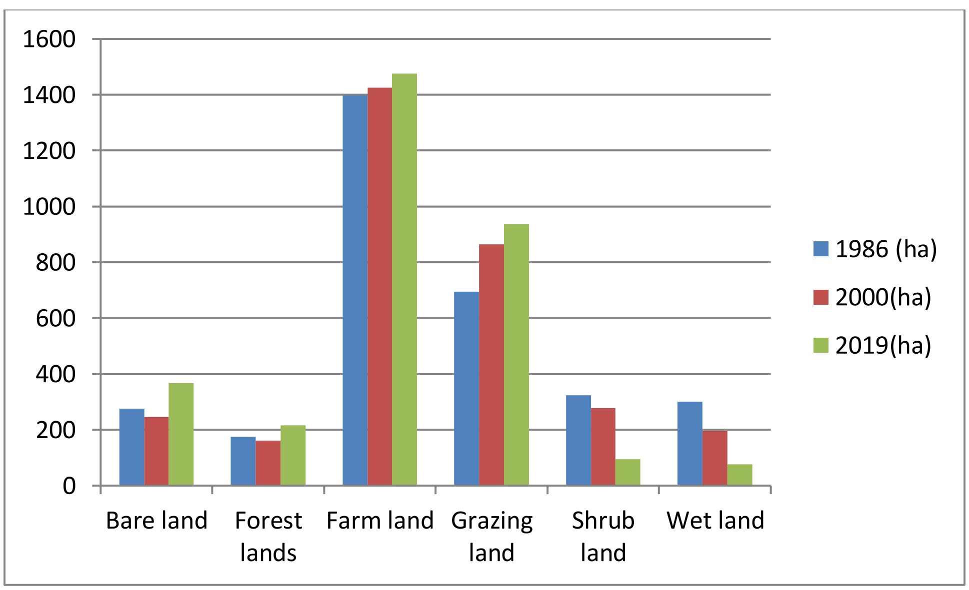


Figure 22: Rate of each land cover change in each period in Kabe Watershed

Based on the Figure 22 bar graph showing both the expansion rate and the rate of shrinkage represented a relative comparison of each land cover type to its original extent in the base year of each period.

The land use and land cover change findings from 1986 and 2019 showed significant shifts in cultivation and grazing areas compared to other classes (Figure 22). Cultivated land expansion steadily increased from 1% in 1986-2000 to 2% in the period from 2000 to 2019. Grazing land also exhibited continuous expansion, while shrubs and wetlands experienced consistent reduction over the past 34 years. Changes in Bare and Planted lands carried in the upper watershed around Yewel Mountain. The rapid growth of grazing and cultivated lands, at the expense of wetlands and shrub lands, indicates a shift towards crop production rather than forest plantation expansion. In 1986, the area had lower population density, limited agricultural activities, and relatively undisturbed environmental conditions. Over time, the landscape transformed, with cultivated and grazing lands expanding significantly.

Another factor driving the rapid conversion of non-cultivated lands to cultivated areas was declining land productivity. According to focus group discussions and informal observations, land productivity can decrease over time due to climate change and ongoing soil erosion. To counter reduced yields, farmers believed that expanding cultivated areas for annual crop production by clearing natural shrubs and wetlands was a viable solution. This expansion could play a role in mitigating climate change and reducing soil erosion. Insights from focus group participants and key informants in the socioeconomic aspects of the study confirmed that the continuous expansion of cultivated land from 1986 to 2019 in the study region was influenced by factors such as rapid population growth, evolving economic activities like mixed farming, community engagement in cas crops, soil nutrients loss, and food insecurity.

4.4.4 Relation of Land Use Land Cover

The relation of land use/cover was reflected by an increment in the total area of cultivation and grazing lands with 2% and 8% increases in the overall area during the study period (34 years) respectively (Figure 20). This increase in the cultivation and grazing land the expansion of the area resulted from swift deforestation, which eliminated shrub cover, and the shifting of wetlands due to climate effects. Soil losses from these practices led to less productive lands, prompting farmers to abandon them for crop production due to economic inefficiency, leading to a significant expansion of barren land. Classification results supported the above-mentioned facts that shrub and wetland areas decreased over the past 34 years by 10% from 1986 to 2019. The major land use types in Kabe Watershed were directly or indirectly related to mixed agricultural practice (since cultivated and grazing land covers 46% and 30% in 2019 respectively). Agriculture-related land use types were the activities include cultivating annual crops, proving fuel sources, and supporting livestock production. Subsequently, Table 25 oulines the relationship between land use types and land covers.

Table 25: Relation of land use types and land cover types

Land Cover type	**Land use types**					
	a	**b**	**c**	**ab**	**ac**	**bc**
Cultivated land	***	**	*	–	–	–
Wetland	**	***	–	–	–	–
Bare land	–	**	–	***	–	–
Grassland	–	***	–	**	–	*
Shrub land	–	***	**	*	*	*
Forest land	*	*	***	*	***	–

Where a = Crop production, b = Livestock production, c = Source of fuel, ab = Homestead, ac = Construction wood production, bc = Settlement.

NB. The more the number of stars indicates the more intensity of that land use type.

In the study area of Kabe Watershed, cultivated lands were primary used for growing annual crops like wheat, barly, teff, and fenugreek, while grass and shrub lands were utilized for livestock grazing. Plantation forests provided fuel and construction wood. Despite thse main purposes, each land cover types had additional users. For instance, cultivated lands were used for grazing livestock after harvesting crops, and grasslands with scattered trees served as a source of fuel wood. Shrub lands also offered alternative uses, such as using scattered trees for fuel wood and potentially using mature trees for construction wood. Although plantation forests were primarily used for forestry purpose, they sometimes conflicted with local farmers' livestock activities.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

In conclusion, soil physiochemical properties significantly differed with variations, in land use types and slope positions. Across all slope positions, soil moisture content, porosity, silt and clay contents were lower in cultivated lands compared to grazing and forestlands, while soil bulk density and sand content were relatively higher in cultivated lands than in grazing and forest areas.

Soils in the cultivated land were strongly acidic; with a mean value of pH < 5.4 than those of the forested and grazing areas in the Kabe Watershed. As low pH affects the availability of nutrients particularly that of phosphorus, correction of the low pH through liming and application of organic materials was critical for sustainable management of these soils. The decrease in soil organic carbon in cultivated land in the study area might be caused by changes in the frequency and pattern of cropping, removal of crop residues, and faster decomposition and oxidation processes as well as soil erosion on cultivated lands. The research unveiled that employing various soil and water conservation practices, in the Kabe Watershed was advantageous in safeguarding cultivated lands against erosion and nutrients depletion.

On the other hand, crop production was constrained by several factors; productivity loss, crop pests, weeds and diseases, and lesser adoption of improved varieties. Agricultural production can be enhanced by the use of technology and other improved farm inputs. So, improved farming methods and new income sources should be promoted with the full package and its production system needs to be market-oriented.

The RUSLE model in Kabe Watershed predicted a lower annual mean soil loss rate (6.95ton ha^{-1} yr^{-1}) compared to the acceptable soil loss rate of 10 tons per hectare per years estimated for Ethiopia, compared to the annual average soil loss rate of 11 tons per hectare per year in tropical Africa.

Over the past 34 years, the Kabe Watershed experienced significant land use and land cover changes characterized by a predominant shift from shrub, wetland, and forest areas to cultivated land. This transition led to rapid shrub degradation, causing an increase in rills and gullies, consequently affecting agricultural production. Respondents also acknowledged that soil displacement from the watershed had negative effects on soil nutrient levels. We should urge an intervention from the concerned bodies like the government and NGOs looking into:

- Implement natural (locally based) rehabilitation mechanics by closed fences on upper slope lands for controlling the topsoil fertility and rehabilitating the area.
- Implement sustainable land use practices to counter the prevailing trend of land use and land cover change observed in the study area.
- Practices integrated soil nutrient management approach for the complex nature of soil physicochemical properties;
- Nutrient-adding practices such as the application of well-balanced blend fertilizers, organic matter (compost, crop residue return), and liming.
- Nutrient-saving techniques (effective and scientific SWC, crop residues return, minimum tillage, Agro-forestry practices (improved fallows, strip cropping, intercropping).

REFERENCES

Abazinab, H., Duguma, B., & Muleta, E. (2022). Livestock farmers' perception of climate change and adaptation strategies in the Gera district, Jimma zone, Oromia Regional state, southwest Ethiopia. *Heliyon, 8*(12).

Abd El-Hamid, H. T., Toubar, M. M., Zarzoura, F., & El-Alfy, M. A. (2023). Ecosystem services based on land use/cover and socio-economic factors in Lake Burullus, a Ramsar Site, Egypt. *Remote Sensing Applications: Society and Environment, 30*, 100979.

Abdullah, A. A., & Wan, H. L. (2013). Relationships of non-monetary incentives, job satisfaction and employee job performance. *International Review of Management and Business Research, 2*(4), 1085.

Abebaw, M. (2020). *Effect of Land Use Land Cover Changes on Farmers Income in Farta Woreda, North Westethiopa.*

Abebaw, W. A. (2019). Review on the role of integrated watershed management for rehabilitating degraded land in Ethiopia. *environment, 9*(11).

Aboulola, O. I. (2017). *A Literature Review of Spatial Location Analysis for Retail Site Selection.* Paper presented at the AMCIS.

Abrha, H., Abraha, B., & Yaebio, G. (2018). Effect of land uses and physical soil and water conservation practices on runoff and soil loss in Western Tigray, Ethiopia. *Asian Journal of Research in Agriculture and Forestry, 2*(1), 1-5.

Adhikari, B. R., Gautam, S., & Paudel, B. (2022). Landslide, land cover, and land use changes and its impacts in Nepal. *Impact of Climate Change, Land use and Land Cover, and Socio-economic Dynamics on landslides*, 149-164.

Aftab, U., & Siddiqui, G. F. (2018). *Big data augmentation with data warehouse: A survey.* Paper presented at the 2018 IEEE International Conference on Big Data (Big Data).

Ahouet, L., Okina, S. N., & Ekockaut, J. A. B. (2023). Effect of lime addition on the particle size fractions and microstructure of a clayey silt. *Arabian Journal of Geosciences, 16*(10), 548.

Akinde, B. P., Olakayode, A. O., Oyedele, D. J., & Tijani, F. O. (2020). Selected physical and chemical properties of soil under different agricultural land-use types in Ile-Ife, Nigeria. *Heliyon, 6*(9).

Alemayehu, B. (2015). *GIS and remote sensing based land use/land cover change detection and prediction in Fagita Lekoma Woreda, Awi Zone, North Western Ethiopia.* MSc. thesis. Addis Ababa University, Addis Ababa.

Alemayehu Tegegn, D. (2023). The trigger of Ethiopian famine and its impacts from 1950 to 1991. *Cogent Arts & Humanities, 10*(1), 2264017.

Alemu, B., Garedew, E., Eshetu, Z., & Kassa, H. (2015). Land use and land cover changes and associated driving forces in north western lowlands of Ethiopia. *International research journal of agricultural science and soil science, 5*(1), 28-44.

Alewoye Getie, M., Legesse, S. A., Mekonnen, M., & Aschalew, A. (2020). Soil properties and crop productivity strategies as a potential climate variability adaptation options in Adefwuha Watershed, Ethiopia. *Earth Systems and Environment, 4*(2), 359-368.

Ali, D. A., Dercon, S., & Gautam, M. (2007). *Property rights in a very poor country: tenure insecurity and investment in Ethiopia*: The World Bank.

Ali, T., Shahbaz, B., & Suleri, A. (2006). Analysis of myths and realities of deforestation in Northwest Pakistan: implications for forestry extension. *International Journal of Agriculture and Biology, 8*(1), 107-110.

Alijani, Z., & Sarmadian, F. (2014). The role of topography in changing of soil carbonate content. *Indian Journal Science Research, 6*(1), 263-271.

Amara, D. M. K., Ullah, K., & Yushu, Z. (2020). Rainfall erosivity estimation for Sierra Leone using non-parametric indices. *Theoretical and Applied Climatology, 139*, 221-236.

Amare, M. T., Demissie, S. T., Beza, S. A., & Erena, S. H. (2023). Land cover change detection and prediction in the Fafan catchment of Ethiopia. *Journal of Geovisualization and Spatial Analysis, 7*(2), 19.

Amdihun, A., Gebremariam, E., Rebelo, L.-M., & Zeleke, G. (2014). Suitability and scenario modeling to support soil and water conservation interventions in the Blue Nile Basin, Ethiopia. *Environmental Systems Research, 3*(1), 23.

Amede, T., Awulachew, S. B., Matti, B., & Yitayew, M. (2014). Managing rainwater for resilient dryland systems in Sub-Saharan Africa: Review of evidences *Nile river basin* (pp. 517-540): Springer.

Amede, T., Belachew, T., & Geta, E. (2001). Reversing the degradation of arable land in the Ethiopian Highlands. *Managing Africa's Soils; no. 23*.

Amemiya, T. (1984). Tobit models: A survey. *Journal of econometrics, 24*(1-2), 3-61.

Amenu, G. (2019). Review on Contribution of Community-Based Participatory Watershed Management Practice for Sustainable Land Management in Ethiopia.

Amhakhian, S., Otene, I., Adava, I., Muhammed, B., Are, E., & Ozovehe, N. (2021). Bulk density of soils from oil palm agroforestry systems in Kogi East, Nigeria. *International Journal of Environment and Climate Change, 11*(12), 396-402.

Angessa, A. T., Lemma, B., & Yeshitela, K. (2021). Land-use and land-cover dynamics and their drivers in the central highlands of Ethiopia with special reference to the Lake Wanchi watershed. *GeoJournal, 86*(3), 1225-1243.

Anley, Y., Bogale, A., & Haile-Gabriel, A. (2007). Adoption decision and use intensity of soil and water conservation measures by smallholder subsistence farmers in Dedo district, Western Ethiopia. *Land Degradation & Development, 18*(3), 289-302.

Asrat, S., Yesuf, M., Carlsson, F., & Wale, E. (2010). Farmers' preferences for crop variety traits: Lessons for on-farm conservation and technology adoption. *Ecological economics, 69*(12), 2394-2401.

Assefa, E., & Bork, H.-R. (2014). Deforestation and forest management in Southern Ethiopia: investigations in the Chencha and Arbaminch areas. *Environmental management, 53*(2), 284-299.

Assefa, E., & Hans-Rudolf, B. (2016). Farmers' perception of land degradation and traditional knowledge in Southern Ethiopia—Resilience and stability. *Land Degradation & Development, 27*(6), 1552-1561.

Assefa, F., Elias, E., Soromessa, T., & Ayele, G. T. (2020). Effect of changes in land-use management practices on soil physicochemical properties in Kabe Watershed, Ethiopia. *Air, soil and water research, 13*, 1178622120939587.

Ayele, G. T., Demessie, S. S., Mengistu, K. T., Tilahun, S. A., & Melesse, A. M. (2016). Multitemporal land use/land cover change detection for the Batena Watershed, Rift Valley Lakes Basin, Ethiopia *Landscape Dynamics, Soils and Hydrological Processes in Varied Climates* (pp. 51-72): Springer.

Ayele, G. T., Tebeje, A. K., Demissie, S. S., Belete, M. A., Jemberrie, M. A., Teshome, W. M., . . . Teshale, E. Z. (2018). Time Series Land Cover Mapping and Change Detection Analysis Using Geographic Information System and Remote Sensing, Northern Ethiopia. *Air, Soil and Water Research, 11*, 1178622117751603.

Aytenew, M., & Bore, G. (2020). Effects of organic amendments on soil fertility and environmental quality: A review. *Plant Sci, 8*, 112-119.

Ayyam, V., Palanivel, S., Chandrakasan, S., Ayyam, V., Palanivel, S., & Chandrakasan, S. (2019). Approaches in land degradation management for productivity enhancement. *Coastal Ecosystems of the Tropics-Adaptive Management*, 463-491.

Ballesteros-Possú, W., Valencia, J. C., & Navia-Estrada, J. F. (2022). Assessment of a cocoa-based agroforestry system in the Southwest of Colombia. *Sustainability, 14*(15), 9447.

Bashagaluke, J. B., Logah, V., Opoku, A., Sarkodie-Addo, J., & Quansah, C. (2018). Soil nutrient loss through erosion: Impact of different cropping systems and soil amendments in Ghana. *PloS one, 13*(12), e0208250.

Bayu, T. (2020). Review on contribution of integrated soil fertility management for climate change mitigation and agricultural sustainability. *Cogent Environmental Science*, *6*(1), 1823631.

Beasly, D., & Huggins, L. (1982). *Areal nonpoint source watershed environment response simulation ANSWERS user's manual*. Retrieved from

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.

Belayneh, M., Yirgu, T., & Tsegaye, D. (2019). Effects of soil and water conservation practices on soil physicochemical properties in Gumara watershed, Upper Blue Nile Basin, Ethiopia. *Ecological processes, 8*(1), 1-14.

Benkobi, L., Trlica, M., & Smith, J. L. (1994). Evaluation of a refined surface cover subfactor for use in RUSLE. *Rangeland Ecology & Management/Journal of Range Management Archives, 47*(1), 74-78.

Bera, A. (2017). Assessment of soil loss by universal soil loss equation (USLE) model using GIS techniques: a case study of Gumti River Basin, Tripura, India. *Modeling Earth Systems and Environment, 3*, 1-9.

Berlie, A. B. (2015). Coping strategies and household food security in drought-prone areas in Ethiopia: the case of lay Gayint District. *Ghana Journal of Development Studies, 12*(1-2), 1-18.

Bewket, W. (2002). Land cover dynamics since the 1950s in Chemoga watershed, Blue Nile basin, Ethiopia. *Mountain Research and Development*, *22*(3), 263-270.

Bewket, W. (2007). Soil and water conservation intervention with conventional technologies in northwestern highlands of Ethiopia: Acceptance and adoption by farmers. *Land use policy, 24*(2), 404-416.

Bewket, W., & Teferi, E. (2009). Assessment of soil erosion hazard and prioritization for treatment at the watershed level: case study in the Chemoga watershed, Blue Nile basin, Ethiopia. *Land Degradation & Development*, *20*(6), 609-622.

Bezabih, B., Aticho, A., Mossisa, T., & Dume, B. (2016). The effect of land management practices on soil physical and chemical properties in Gojeb Sub-river Basin of Dedo District, Southwest Ethiopia. *Journal of Soil Science and Environmental Management, 7*(10), 154-165.

Bhardwaj, A. K., Rajwar, D., & Nagaraja, M. S. (2021). Soil fertility problems and management. *Managing saltaffected soils for sustainable agriculture. Indian Council of Agricultural Research, New Delhi*, 386-407.

Biddle, A. J. (2017). *Peas and Beans* (Vol. 27): CABI.

Bigalke M, Imseng M,Schneider S, Schwab L,Wiggenhauser M, Keller A, Müller M,Frossard E and Wilcke W (2020). Uranium Budget and Leachingin Swiss Agricultural Systems.Front. Environ. Sci. 8:54.

Bigelow, D., & Borchers, A. (2017). Major uses of land in the United States, 2012.

Biggelaar, C. d., Lal, R., Wiebe, K., Eswaran, H., Breneman, V., & Reich, P. (2004). The global impact of soil erosion on productivity. II. Effects on crop yields and production over time.

Bilskie, J., & Scientific, C. (2001). Soil water status: content and potential. *Campbell Scientific, Inc. App. Note: 2S-1 http://s. campbellsci. com/documents/ca/technical-papers/soilh20c. pdf (2 de Abril de 2014)*.

Biratu, A. A., & Asmamaw, D. K. (2016). Farmers' perception of soil erosion and participation in soil and water conservation activities in the Gusha Temela watershed, Arsi, Ethiopia. *International journal of river basin management*, *14*(3), 329-336.

Bisson, P. A., Montgomery, D. R., & Buffington, J. M. (2017). Valley segments, stream reaches, and channel units *Methods in Stream Ecology, Volume 1* (pp. 21-47): Elsevier.

Bizunhe, G. B. (2023). Soil erosion risk analysis in Sidama Region, southern Ethiopia.

Blaikie, P. (2016). *The political economy of soil erosion in developing countries*: Routledge.

Blake, G. R., & Hartge, K. (1986). Bulk density 1. *Methods of soil analysis: part 1—physical and mineralogical methods*(methodsofsoilan1), 363-375.

Blanco, H., & Lal, R. (2023). Water erosion *Soil Conservation and Management* (pp. 23-51): Springer.

Boakye, E., Odai, S., Adjei, K., & Annor, F. (2008). Lansat Images for Assessment of the Impact of Land Use and Land Cover Changes on the Barekese Catchment in Ghana. *European Journal of Scientific Research, 21*(4), 617-626.

Bogunovic, I., Pereira, P., Kisic, I., Sajko, K., & Sraka, M. (2018). Tillage management impacts on soil compaction, erosion and crop yield in Stagnosols (Croatia). *Catena, 160*, 376-384.

Bolstad, P. (2005). *GIS Fundamentals: a first text on Geographic Information Systems*: Eider Press.

Bouyoucos, G. J. (1962). Hydrometer method improved for making particle size analyses of soils 1. *Agronomy journal, 54*(5), 464-465.

Brady, N. and Weil, R. 2016. The nature and properties of soils, Pearson Education, Columbus, EUA.

Briassoulis, H. (2011). Opposition to golf-related tourism development: An interpretivist analysis of an online petition. *Journal of sustainable tourism, 19*(6), 673-693.

Brown, L. R., & Wolf, E. C. (1984). Soil Erosion: Quiet Crisis in the World Economy. Worldwatch Paper 60.

Bufebo, B., & Elias, E. (2021). Land use/land cover change and its driving forces in Shenkolla watershed, south Central Ethiopia. *The Scientific World Journal, 2021*.

Bünemann, E. K., Bongiorno, G., Bai, Z., Creamer, R. E., De Deyn, G., De Goede, R., . . . Mäder, P. (2018). Soil quality–A critical review. *Soil biology and biochemistry, 120*, 105-125.

Buraka, T., Elias, E., & Lelago, A. (2023). Effects of land-use-cover-changes on selected soil physicochemical properties along slope position, Coka watershed, Southern Ethiopia. *Heliyon, 9*(5).

Calderón-Celis, F., Encinar, J. R., & Sanz-Medel, A. (2018). Standardization approaches in absolute quantitative proteomics with mass spectrometry. *Mass spectrometry reviews, 37*(6), 715-737.

Cardinael, R., Guibert, H., Brédoumy, S. T. K., Gigou, J., N'Goran, K. E., & Corbeels, M. (2022). Sustaining maize yields and soil carbon following land clearing in the forest–savannah transition zone of West Africa: Results from a 20-year experiment. *Field Crops Research, 275*, 108335.

Chapman, H. (1965). Cation‐exchange capacity 1. *Methods of soil analysis. Part 2. Chemical and microbiological properties*(methodsofsoilanb), 891-901.

Chimdi, A. (2015). Assessment of the severity of acid saturations on soils collected from cultivated lands of east Wollega Zone, Ethiopia. *Science, Technology and Arts Research Journal, 3*(4), 42-48.

Chimdi, A., Gebrekidan, H., Kibret, K., & Tadesse, A. (2012). Status of selected physicochemical properties of soils under different land use systems of Western Oromia, Ethiopia. *Journal of Biodiversity and Environmental Sciences, 2*(3), 57-71.

Comino, J. R., Senciales, J., Ramos, M. a., Martínez-Casasnovas, J. A., Lasanta, T., Brevik, E. C., . . . Sinoga, J. R. (2017). Understanding soil erosion processes in Mediterranean sloping vineyards (Montes de Málaga, Spain). *Geoderma, 296*, 47-59.

Dabney, S., Vieira, D., Yoder, D., Langendoen, E., Wells, R., & Ursic, M. (2015). Spatially distributed sheet, rill, and ephemeral gully erosion. *Journal of Hydrologic Engineering, 20*(6), C4014009.

Damene, S., Tamene, L., & Vlek, P. L. (2012). Performance of farmland terraces in maintaining soil fertility: a case of Lake Maybar watershed in Wello, Northern Highlands of Ethiopia. *Journal of Life Sciences, 6*(11), 1251.

Damtea, W., Kim, D., & Im, S. (2020). Spatiotemporal analysis of land cover changes in the chemoga basin, Ethiopia, using Landsat and google earth images. *Sustainability, 12*(9), 3607.

Datta, S., Meena, M. C., Barman, M., Golui, D., Mishra, R., & Shukla, A. (2018). Soil tests for micronutrients: Current status and future thrust. *Indian Journal of Fertilisers, 14*(5), 32-51.

David, D. (1960). The determination of exchangeable sodium, potassium, calcium and magnesium in soils by atomic-absorption spectrophotometry. *Analyst, 85*(1012), 495-503.

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global environmental change, 19*(2), 248-255.

Desmet, P., & Govers, G. (1996). A GIS procedure for automatically calculating the USLE LS factor on topographically complex landscape units. *journal of soil and water conservation, 51*(5), 427-433.

Desta, L. (2000). *Land degradation and strategies for sustainable development in the Ethiopian highlands: Amhara Region* (Vol. 32): ILRI (aka ILCA and ILRAD).

Detebo Ashore, A. (2021). *EFFECTS OF LAND USE TYPES AND SOIL DEPTH ON SELECTED SOIL PHYSICOCHEMICAL PROPERTIES AT SENGEYE KEBELE IN DUNA DISTRICT, SOUTHERN ETHIOPIA.* Haramaya university.

Donis, A., & Assefa, K. (2017). Assessement of physicochemical properties of soils as influenced by different land uses in Bedele area in Ilubabor zone, southwestern Ethiopia. *International Journal of Agriculture Innovations and Research, 5*(4), 2319-1473.

Donovan, M., & Monaghan, R. (2021). Impacts of grazing on ground cover, soil physical properties and soil loss via surface erosion: A novel geospatial modelling approach. *Journal of Environmental Management, 287*, 112206.

Dregne, H. (1990). Erosion and soil productivity in Africa. *journal of soil and water conservation, 45*(4), 431-436.

Dunne, T., & Aubry, B. F. (2020). Evaluation of Horton's theory of sheetwash and rill erosion on the basis of field experiments *Hillslope processes* (pp. 31-53): Routledge.

Dwivedi, Y. K., Hughes, L., Ismagilova, E., Aarts, G., Coombs, C., Crick, T., . . . Eirug, A. (2021). Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management, 57*, 101994.

Ebabu, K., Taye, G., Tsunekawa, A., Haregeweyn, N., Adgo, E., Tsubo, M., . . . Aklog, D. (2023). Land use, management and climate effects on runoff and soil loss responses in the highlands of Ethiopia. *Journal of Environmental Management, 326*, 116707.

Ebabu, K., Tsunekawa, A., Haregeweyn, N., Tsubo, M., Adgo, E., Fenta, A. A., . . . Vanmaercke, M. (2022). Global analysis of cover management and support practice factors that control soil erosion and conservation. *International Soil and Water Conservation Research, 10*(2), 161-176.

Ebro, A., Shenkute, B., Haile, G., Sauerborn, J., & Treydte, A. (2011). Land use land cover dynamics in the rift valley of Ethiopia: Implications on food security. *FSC brief, 12*.

Effa, K., Fana, D. M., Nigussie, M., Geleti, D., Abebe, N., Dechassa, N., . . . Girma, D. (2023). The irrigated wheat initiative of Ethiopia: a new paradigm emulating Asia's green revolution in Africa. *Environment, Development and Sustainability*, 1-26.

Elias, E. (2002). Farmers' Perceptions of soil fertility change and management. SOS Sahel and Institute for Sustainable Development. *Addis Ababa, Ethiopia*.

Elias, E. (2016). Soils of the Ethiopian highlands: Geomorphology and Properties CASCAPE Project, ALTERA, Wageningen University and Research Centre (Wageningen UR), The Netherlands (2016), p. 385

Elias, E. (2017). Characteristics of Nitisol profiles as affected by land use type and slope class in some Ethiopian highlands. *Environmental Systems Research, 6*, 1-15.

Emiru, N., & Gebrekidan, H. (2013). Effect of land use changes and soil depth on soil organic matter, total nitrogen and available phosphorus contents of soils in Senbat Watershed, Western Ethiopia. *ARPN Journal of Agricultural and Biological Science, 8*(3), 206-2012.

Endalamaw, N. T., Moges, M. A., Kebede, Y. S., Alehegn, B. M., & Sinshaw, B. G. (2021). Potential soil loss estimation for conservation planning, upper Blue Nile Basin, Ethiopia. *Environmental Challenges, 5*, 100224.

Endalew, B., Adigo, E., & Argaw, M. (2014). Impact of land use types on soil acidity in the highlands of Ethiopia: The case of Fageta Lekoma district. *Academia Journal of Environmental Sciences, 2*(8), 124-132.

Erkossa, T., Geleti, D., Williams, T. O., Laekemariam, F., & Haileslassie, A. (2022). Restoration of grazing land to increase biomass production and improve soil properties in the Blue Nile basin: effects of infiltration trenches and Chloris Gayana reseeding. *Renewable Agriculture and Food Systems, 37*(S1), S64-S72.

Erkossa, T., Wudneh, A., Desalegn, B., & Taye, G. (2015). Linking soil erosion to on-site financial cost: lessons from watersheds in the Blue Nile basin. *Solid Earth, 6*(2), 765-774.

Eyayu, M., Heluf, G., Tekalign, M., & Mohammed, A. (2009). Effects of land-use change on selected soil properties in the Tera Gedam Catchment and adjacent agroecosystems, north-west Ethiopia. *Ethiopian Journal of Natural Resources, 11*(1), 35-62.

FAO, F. (1993). Agriculture Organization of the United Nations, 1996. *Agricultural Food and Nutrition in Africa. Food and Agricultural Organization of United Nations, Rome*, 85-90.

Fekadu, A., Soromessa, T., & Dullo, B. W. (2022). Assessment of the erosion protection service and its economic value of the southwestern Ethiopia forest coffee. *Environmental Challenges, 8*, 100580.

Fenta, A. A., Tsunekawa, A., Haregeweyn, N., Tsubo, M., Yasuda, H., Kawai, T., . . . Sultan, D. (2021). Agroecology-based soil erosion assessment for better conservation planning in Ethiopian river basins. *Environmental research, 195*, 110786.

Fentie, S. F., Jembere, K., Fekadu, E., & Wasie, D. (2020). Land use and land cover dynamics and properties of soils under different land uses in the tejibara watershed, Ethiopia. *The Scientific World Journal, 2020*, 1-12.

Filatov, V. V., Zaitseva, N. A., Larionova, A. A., Maykova, S. E., Kozlovskikh, L. A., Avtonova, V. Y., & Vikhrova, N. O. (2019). Assessment of the Socio-Economic Impact of the Implementation of Regional Environmental Programs for Waste Management. *Ekoloji Dergisi*(107).

Fomin, D. S., Yudina, A. V., Romanenko, K. A., Abrosimov, K. N., Karsanina, M. V., & Gerke, K. M. (2023). Soil pore structure dynamics under steady-state wetting-drying cycle. *Geoderma, 432*, 116401.

Francaviglia, R., Almagro, M., & Vicente-Vicente, J. L. (2023). Conservation agriculture and soil organic carbon: Principles, processes, practices and policy options. *Soil Systems, 7*(1), 17.

Gao, J., & Liu, Y. (2010). Determination of land degradation causes in Tongyu County, Northeast China via land cover change detection. *International Journal of Applied Earth Observation and Geoinformation, 12*(1), 9-16.

Garedew, E. (2010). *Land-use and land-cover dynamics and rural livelihood perspectives, in the semi-arid areas of Central Rift Valley of Ethiopia* (Vol. 2010).

Gashaw, T., Bantider, A., & Mahari, A. (2014). Population dynamics and land use/land cover changes in Dera District, Ethiopia. *Global Journal of Biology Agriculture & Health Sciences, 3*, 137-140.

Gashaw, T., & Dinkayoh, T. (2015). Land use/land cover dynamics in Hulet Wogedamea Kebele, northern Ethiopia. *Current Research in Agricultural Sciences, 2*(1), 36-41.

Gashaw, T., Tulu, T., & Argaw, M. (2018). Erosion risk assessment for prioritization of conservation measures in Geleda watershed, Blue Nile basin, Ethiopia. *Environmental Systems Research, 6*(1), 1-14.

Gashaw, T., Tulu, T., Argaw, M., & Worqlul, A. W. (2017). Evaluation and prediction of land use/land cover changes in the Andassa watershed, Blue Nile Basin, Ethiopia. *Environmental Systems Research, 6*(1), 17.

Gebrehiwot, S. G., Bewket, W., Gärdenäs, A. I., & Bishop, K. (2014). Forest cover change over four decades in the Blue Nile Basin, Ethiopia: comparison of three watersheds. *Regional Environmental Change, 14*(1), 253-266.

Gebrehiwot, S. G., Taye, A., & Bishop, K. (2010). Forest cover and stream flow in a headwater of the Blue Nile: complementing observational data analysis with community perception. *Ambio, 39*(4), 284-294.

Gebremicael, T., Mohamed, Y., Betrie, G., van der Zaag, P., & Teferi, E. (2013). Trend analysis of runoff and sediment fluxes in the Upper Blue Nile basin: A combined analysis of statistical tests, physically-based models and landuse maps. *Journal of Hydrology, 482*, 57-68.

Gee, G. W., & Bauder, J. W. (1986). Particle-size analysis 1. *Methods of soil analysis: part 1—physical and mineralogical methods*(methodsofsoilan1), 383-411.

Geleta, H. I. (2011). *Watershed sediment yield modeling for data scarce areas*.

Geyik, O. (2021). *Sustainable and nutrition-sensitive food systems: nutrient production, trade, and climate change.* Deakin University.

Gindi, B. W. (2022). *Impact Of Land Use/Land Cover And Climate Change On Soil Erosion In Sile Watershed, Lake Abaya-Chamo Sub-Basin, Southern Ethiopia.*

Giuliani, G., Rodila, D., Külling, N., Maggini, R., & Lehmann, A. (2022). Downscaling Switzerland land use/land cover data using nearest neighbors and an expert system. *Land, 11*(5), 615.

Glenn, L. C. (2020). Denudation and erosion in the southern Appalachian region and the Monongahela Basin *Environmental geomorphology and landscape conservation* (pp. 36-56): Routledge.

Gomiero, T. (2016). Soil degradation, land scarcity and food security: Reviewing a complex challenge. *Sustainability, 8*(3), 281.

Greene, W. H. (2003). *Econometric analysis*: Pearson Education India.

Gregory, A., Ritz, K., McGrath, S., Quinton, J., Goulding, K., Jones, R., . . . Pilgrim, E. (2015). A review of the impacts of degradation threats on soil properties in the UK. *Soil use and management, 31*, 1-15.

Guadie, M., Molla, E., Mekonnen, M., & Cerdà, A. (2020). Effects of soil bund and stone-faced soil bund on soil physicochemical properties and crop yield under rain-fed conditions of Northwest Ethiopia. *Land, 9*(1), 13.

Guo, X., Fu, Q., Hang, Y., Lu, H., Gao, F., & Si, J. (2020). Spatial variability of soil moisture in relation to land use types and topographic features on hillslopes in the black soil (mollisols) area of northeast China. *Sustainability, 12*(9), 3552.

Gyamfi, C., Ndambuki, J. M., & Salim, R. W. (2016). Application of SWAT model to the Olifants Basin: calibration, validation and uncertainty analysis. *Journal of Water Resource and Protection, 8*(03), 397.

Haan, C. T., Barfield, B. J., & Hayes, J. C. (1994). *Design hydrology and sedimentology for small catchments*: Elsevier.

Habtamu, A., Heluf, G., Bobe, B., & Enyew, A. (2014). Fertility status of soils under different land uses at Wujiraba Watershed, North-Western Highlands of Ethiopia. *Agriculture, Forestry and Fisheries, 3*(5), 410-419.

Habte, A., Mamo, G., Worku, W., Ayalew, D., & Gayler, S. (2021). Spatial variability and temporal trends of climate change in Southwest Ethiopia: association with farmers' perception and their adaptation strategies. *Advances in Meteorology, 2021*, 1-13.

Haile, G., Itanna, F., Teklu, B., & Agegnehu, G. (2022). Variation in soil properties under different land use types managed by smallholder farmers in central Ethiopia. *Sustainable Environment, 8*(1), 2093058.

Hailemeskel, E., Kassa, M., Taddesse, G., Mohammed, H., Woyessa, A., Tasew, G., . . . Petros, B. (2013). Prevalence of sulfadoxine–pyrimethamine resistance-associated mutations in dhfr and dhps genes of Plasmodium falciparum three years after SP withdrawal in Bahir Dar, Northwest Ethiopia. *Acta tropica, 128*(3), 636-641.

Hailemichael, S., & Haug, R. (2020). The use and abuse of the 'model farmer'approach in agricultural extension in Ethiopia. *The Journal of Agricultural Education and Extension, 26*(5), 465-484.

Hailu, A., Mammo, S., & Kidane, M. (2020). Dynamics of land use, land cover change trend and its drivers in Jimma Geneti District, Western Ethiopia. *Land use policy, 99*, 105011.

Hailu, A. Kibret, K. Gebrekidan, H. (2015). Land nd suitability evaluation for rainfed production of barley and wheat at Kabe Subwatershed, Northeastern Ethiopia. African Journal of Soil Science, 147-156

Hailu, B. K., Abrha, B. K., & Weldegiorgis, K. A. (2014a). Adoption and impact of agricultural technologies on farm income: Evidence from Southern Tigray, Northern Ethiopia. *International Journal of Food and Agricultural Economics (IJFAEC), 2*(4), 91-106.

Hailu, B. K., Abrha, B. K., & Weldegiorgis, K. A. (2014b). Adoption and impact of agricultural technologies on farm income: Evidence from Southern Tigray, Northern Ethiopia. *International Journal of Food and Agricultural Economics (IJFAEC), 2*(1128-2016-92058), 91-106.

Hailu, H., Mamo, T., Keskinen, R., Karltun, E., Gebrekidan, H., & Bekele, T. (2015). Soil fertility status and wheat nutrient content in Vertisol cropping systems of central highlands of Ethiopia. *Agriculture & Food Security, 4*, 1-10.

Haindongo, P., Kalumba, A., & Orimoloye, I. (2022). Local people's perceptions about Land Use Cover Change (LULCC) for sustainable human wellbeing in Namibia. *GeoJournal, 87*(3), 1727-1741.

Hao, X., Ball, B., Culley, J., Carter, M., & Parkin, G. (2008). Soil density and porosity. *Soil sampling and methods of analysis. CRC Press, Boca Raton, FL*, 743-760.

Haregeweyn, N., Berhe, A., Tsunekawa, A., Tsubo, M., & Meshesha, D. T. (2012). Integrated watershed management as an effective approach to curb land degradation: a case study of the enabered watershed in Northern Ethiopia. *Environmental management, 50*(6), 1219-1233.

Harrell Jr, F. E. (2015). *Regression modeling strategies: with applications to linear models, logistic and ordinal regression, and survival analysis*: Springer.

Harris, P. M., & Ventura, S. J. (1995). The integration of geographic data with remotely sensed imagery to improve classification in an urban area. *Photogrammetric engineering and remote sensing, 61*(8), 993-998.

Hartemink, A. E., Veldkamp, T., & Bai, Z. (2008). Land cover change and soil fertility decline in tropical regions. *Turkish Journal of Agriculture and Forestry, 32*(3), 195-213.

Hawkins, D. M. (1993). Regression adjustment for variables in multivariate quality control. *Journal of Quality Technology, 25*(3), 170-182.

Hazelton, P., & Murphy, B. (2016). *Interpreting soil test results: What do all the numbers mean?* : CSIRO publishing.

Helldén, U. (1987). *An assessment of woody biomass, community forests, land use and soil erosion in Ethiopia. A feasibility study on the use of remote sensing and GIS [geographical information system]-analysis for planning purposes in developing countries*: Lund University Press.

Herold, M., Couclelis, H., & Clarke, K. C. (2005). The role of spatial metrics in the analysis and modeling of urban land use change. *Computers, environment and urban systems, 29*(4), 369-399.

Heyder, S. M., Beza, S. A., & Demissie, S. T. (2023). Optimization of land management measures for soil erosion risk using GIS in agricultural landscape of western Hararghe highlands, Ethiopia. *Scientific African, 21*, e01853.

Heyi, D. D., & Mberengwa, I. (2012). Determinants of farmers' land management practices: The case of Tole District, south west Shewa zone, Oromia national regional state, Ethiopia. *Journal of Sustainable development in Africa, 14*(1), 76-96.

Hishe, S., Lyimo, J., & Bewket, W. (2017). Soil and water conservation effects on soil properties in the Middle Silluh Valley, northern Ethiopia. *International Soil and Water Conservation Research, 5*(3), 231-240.

Hurni, H. (1985). Erosion-productivity-conservation systems in Ethiopia.

Hurni, H. (1993). Land degradation, famine, and land resource scenarios in Ethiopia. *World soil erosion and conservation.*, 27-61.

Hurni, H., Abate, S., Bantider, A., Debele, B., Ludi, E., Portner, B., . . . Zeleke, G. (2010). Land degradation and sustainable land management in the highlands of Ethiopia.

Hurni, H., Berhe, W., Chadhokar, P., Daniel, D., Gete, Z., Grunder, M., & Kassaye, G. (2016). Soil and water conservation in Ethiopia: guidelines for development agents: Centre for Development and Environment (CDE); Bern Open Publishing (BOP).

Hussein, A. (2023). Impacts of Land Use and Land Cover Change on Vegetation Diversity of Tropical Highland in Ethiopia. *Applied and Environmental Soil Science, 2023*.

Johns, B., Asfaw, E., Wong, W., Bekele, A., Minior, T., Kebede, A., & Palen, J. (2014). Assessing the costs and effects of antiretroviral therapy task shifting from physicians to other health professionals in Ethiopia. *JAIDS Journal of Acquired Immune Deficiency Syndromes, 65*(4), e140-e147.

Karamesouti, M., Detsis, V., Kounalaki, A., Vasiliou, P., Salvati, L., & Kosmas, C. (2015). Land-use and land degradation processes affecting soil resources: Evidence from a traditional Mediterranean cropland (Greece). *Catena, 132*, 45-55.

Karayel, D., & Šarauskis, E. (2024). Influence of tillage methods and soil crust breakers on cotton seedling emergence in silty-loam soil. *Soil and Tillage Research, 239*, 106054.

Karltun, E., Lemenih, M., & Tolera, M. (2013). COMPARING FARMERS'PERCEPTION OF SOIL FERTILITY CHANGE WITH SOIL PROPERTIES AND CROP PERFORMANCE IN BESEKU, ETHIOPIA. *Land Degradation & Development, 24*(3), 228-235.

Kassa, H., Dondeyne, S., Poesen, J., Frankl, A., & Nyssen, J. (2017). Transition from forest-based to cereal-based agricultural systems: A review of the drivers of land use change and degradation in Southwest Ethiopia. *Land Degradation & Development, 28*(2), 431-449.

Kebebew, S., Bedadi, B., Erkossa, T., Yimer, F., & Wogi, L. (2022). Effect of different land-use types on soil properties in Cheha District, South-Central Ethiopia. *Sustainability, 14*(3), 1323.

Kebede, A. G., Bekele, M., & Woldeamanuel, T. (2014). Natural resource use conflict in Bale Mountains National Park, Southeast Ethiopia. *International Journal of Biodiversity and Conservation, 6*(12), 814-822.

Kibret, K., & Geremew, S. (2013). *Assessment of Factors Influencing Use of Soil Conservation Measures in Sekela District of West Gojjam Zone, Amhara Regional State, Northwestern Ethiopia.* Haramaya University.

Kibru, T., Husseini, R., Birhane, E., Haggar, J., & Solomon, N. (2021). Farmers' perception and reasons for practicing farmer managed natural regeneration in Tigray, Ethiopia. *Agroforestry Systems, 95*, 1327-1342.

Kidane, M., Bezie, A., Kesete, N., & Tolessa, T. (2019). The impact of land use and land cover (LULC) dynamics on soil erosion and sediment yield in Ethiopia. *Heliyon, 5*(12).

Kiflu, A., & Beyene, S. (2013). Effects of different land use systems on selected soil properties in South Ethiopia. *Journal of Soil Science and Environmental Management, 4*(5), 100-107.

Kindu, M., Schneider, T., Teketay, D., & Knoke, T. (2013). Land use/land cover change analysis using object-based classification approach in Munessa-Shashemene landscape of the Ethiopian highlands. *Remote Sensing, 5*(5), 2411-2435.

Kinnell, P. (2010). Event soil loss, runoff and the Universal Soil Loss Equation family of models: A review. *Journal of hydrology, 385*(1-4), 384-397.

Kjeldahl, C. (1883). A new method for the determination of nitrogen in organic matter. *Z Anal Chem, 22*, 366.

Kratzert, F., Klotz, D., Brenner, C., Schulz, K., & Herrnegger, M. (2018). Rainfall–runoff modelling using long short-term memory (LSTM) networks. *Hydrology and Earth System Sciences, 22*(11), 6005-6022.

Kumar, A., Singh, S., Pramanik, M., Chaudhary, S., Maurya, A. K., & Kumar, M. (2022). Watershed prioritization for soil erosion mapping in the Lesser Himalayan Indian basin using PCA and WSA methods in conjunction with morphometric parameters and GIS-based approach. *Environment, Development and Sustainability*, 1-39.

Kumar, R., Kumar, A., & Saikia, P. (2022). Deforestation and forests degradation impacts on the environment *Environmental Degradation: Challenges and Strategies for Mitigation* (pp. 19-46): Springer.

Kumar, S., & Jain, K. (2020). A multi-temporal Landsat data analysis for land-use/land-cover change in Haridwar Region using remote sensing techniques. *Procedia Computer Science, 171*, 1184-1193.

Kumar, V., Parihar, R. D., Sharma, A., Bakshi, P., Sidhu, G. P. S., Bali, A. S., . . . Gyasi-Agyei, Y. (2019). Global evaluation of heavy metal content in surface water bodies: A meta-analysis using heavy metal pollution indices and multivariate statistical analyses. *Chemosphere, 236*, 124364.

Kumaragamage, D., Warren, J., & Spiers, G. (2021). Soil Chemistry. *Digging into Canadian Soils*.

Lal, D., & Namboodhiri, T. (1990). A model for the effect of mean stress on the threshold condition for fatigue crack propagation. *Materials Science and Engineering: A, 130*(1), 37-49.

Lal, R. (2001). Soil degradation by erosion. *Land Degradation & Development, 12*(6), 519-539.

Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. *science, 304*(5677), 1623-1627.

Lambin, E., Geist, H. J., & Ellis, E. (2007). Causes of land-use and land-cover change. *encyclopedia of earth*.

Lambin, E. F., Geist, H. J., & Lepers, E. (2003). Dynamics of land-use and land-cover change in tropical regions. *Annual review of environment and resources, 28*(1), 205-241.

Landon, J. (1991). Booker tropical soil mannual. *A Handbook for soil survey and agriculture land evaluation in the tropics and subtropics. Landon, JR (ed). Booker Tate, Thame, Oxon, UK*, 58-125.

Lechisa Takele, Achalu Chimdi, Alemayehu Abebaw. 2014. Dynamics of soil fertility as in uenced by different land use systems and soil depth in West Showa Zone, Gindeberet District, Ethiopia. Agriculture, Forestry and Fisheries. 3(6), 2014, pp. 489-494.DOI: 10.11648/j.aff.20140306.18

Lemma, T., Anulo, T., & Gezahegn, M. (2018). *Determinants of Farmers' Use of Soil and Water Conservation Practices in Soro Woreda, Hadiya Zone, Southern Ethiopia.* Haramaya University.

Li, H., Zhu, H., Liang, C., Wei, X., & Yao, Y. (2022). Soil erosion significantly decreases aggregate-associated OC and N in agricultural soils of Northeast China. *Agriculture, Ecosystems & Environment, 323*, 107677.

Lin, L., Van der Bolt, F., & Cornelis, W. (2022). Visual assessment of soil structural quality across soil textures and compaction levels–Part II: Examination of profile walls vs Intact soil cores. *Geoderma*, *426*, 116098.

Lin, Y.-P., Verburg, P. H., Chang, C.-R., Chen, H.-Y., & Chen, M.-H. (2009). Developing and comparing optimal and empirical land-use models for the development of an urbanized watershed forest in Taiwan. *Landscape and Urban Planning, 92*(3-4), 242-254.

Little, R. J., & Rubin, D. B. (2019). *Statistical analysis with missing data* (Vol. 793): John Wiley & Sons.

Lv, L., Li, Y., & Zhou, C. (2023). Mechanistic analysis of splash erosion on loess by single raindrop impact: Interaction of soil compaction, water content, and raindrop energy. *Biosystems Engineering*, *236*, 238-247.

Makken, E. (1993). Overview of the agricultural sector in sub-Saharan Africa. *Van Reuler, H. and: The role of plant nutrients for sustainable food crop production in sub-Saharan Africa Prins, WH (eds) pp*, 25-36.

Mariye, M., Jianhua, L., & Maryo, M. (2022). Land use land cover change analysis and detection of its drivers using geospatial techniques: a case of south-central Ethiopia. *All Earth*, *34*(1), 309-332.

Mati, B. M., Morgan, R. P., Gichuki, F. N., Quinton, J. N., Brewer, T. R., & Liniger, H. P. (2000). Assessment of erosion hazard with the USLE and GIS: A case study of the Upper Ewaso Ng'iro North basin of Kenya. *International Journal of Applied Earth Observation and Geoinformation*, *2*(2), 78-86.

Mavhura, E., & Mushure, S. (2019). Forest and wildlife resource-conservation efforts based on indigenous knowledge: The case of Nharira community in Chikomba district, Zimbabwe. *Forest Policy and Economics*, *105*, 83-90.

McGregor, K. C. (1978). C factors for no-till and conventional-till soybeans from plot data. *Transactions of the ASAE*, *21*(6), 1119-1122.

MEBRATE, M. (2020). SELECTED SOIL PHYSIOCHEMICAL PROPERTIES AS INFLUENCED BY SOIL DEPTH AND FARM MANAGEMENT UNDER COFFEE PLANTATIONS IN TELLO DISTRICT, KAFFA SOUTH WESTERN ETHIOPIA.

Mehlich, A. (1978). New extractant for soil test evaluation of phosphorus, potassium, magnesium, calcium, sodium, manganese and zinc. *Communications in Soil Science and Plant Analysis*, *9*(6), 477-492.

Meinen, B. U., & Robinson, D. T. (2021). Agricultural erosion modelling: Evaluating USLE and WEPP field-scale erosion estimates using UAV time-series data. *Environmental Modelling & Software*, *137*, 104962.

Mekonnen, D., Bryan, E., Alemu, T., & Ringler, C. (2017). Food versus fuel: examining tradeoffs in the allocation of biomass energy sources to domestic and productive uses in Ethiopia. *Agricultural economics*, *48*(4), 425-435.

Mekonnen, K., Duncan, A. J., Kefyalew, D., Bekele, T., Wubet, A., & Amede, T. (2013). Enhancing communities' adaptive capacity to climate change in drought-prone hotspots of the Blue Nile Basin in Ethiopia.

Mekuria, W., Veldkamp, E., Haile, M., Nyssen, J., Muys, B., & Gebrehiwot, K. (2007). Effectiveness of exclosures to restore degraded soils as a result of overgrazing in Tigray, Ethiopia. *Journal of arid environments, 69*(2), 270-284.

Mekuriaw, A. (2017). Assessing the effectiveness of land resource management practices on erosion and vegetative cover using GIS and remote sensing techniques in Melaka watershed, Ethiopia. *Environmental Systems Research, 6*(1), 16.

Mekuriaw, A., Heinimann, A., Zeleke, G., & Hurni, H. (2018). Factors influencing the adoption of physical soil and water conservation practices in the Ethiopian highlands. *International Soil and Water Conservation Research, 6*(1), 23-30.

Mengstie, F. A. (2009). *Assessment of adoption behavior of soil and water conservation practices in the Koga watershed, highlands of Ethiopia.* Cornell University.

Meshesha, D. T., Tsunekawa, A., & Tsubo, M. (2012). Continuing land degradation: cause–effect in Ethiopia's Central Rift Valley. *Land Degradation & Development, 23*(2), 130-143.

Millward, A. A., & Mersey, J. E. (1999). Adapting the RUSLE to model soil erosion potential in a mountainous tropical watershed. *Catena, 38*(2), 109-129.

Minale, A. S., & Rao, K. K. (2012). Impacts of land cover/use dynamics of Gilgel Abbay catchment of Lake Tana on climate variability, Northwestern Ethiopia. *Applied Geomatics, 4*(3), 155-162.

Moghimian, N., Hosseini, S. M., Kooch, Y., & Darki, B. Z. (2017). Impacts of changes in land use/cover on soil microbial and enzyme activities. *Catena, 157*, 407-414.

Mohammed, M., & Tarekegn, W. M. (2015). *Evaluation of The Effect of Land use Types on Selected Soil Physico-Chemical Properties in Itang-Ker Area of Gambella Regional State of Ethiopia.* Haramaya University.

MohanRajan, S. N., Loganathan, A., & Manoharan, P. (2020). Survey on Land Use/Land Cover (LU/LC) change analysis in remote sensing and GIS environment: Techniques and Challenges. *Environmental Science and Pollution Research, 27*(24), 29900-29926.

Moinet, G. Y., Amundson, R., Galdos, M. V., Grace, P. R., Haefele, S. M., Hijbeek, R., . . . Powlson, D. S. (2023). Climate change mitigation through soil carbon sequestration in working lands: A reality check. *Global Change Biology, 30*(1), e17010.

Molla, E., Gebrekidan, H., Mamo, T., & Assen, M. (2010). Patterns of land use/cover dynamics in the mountain landscape of Tara Gedam and adjacent agro-ecosystem, Northwest Ethiopia. *SINET: Ethiopian Journal of Science, 33*(2), 74-88.

Molla, E., Getnet, K., & Mekonnen, M. (2022). Land use change and its effect on selected soil properties in the northwest highlands of Ethiopia. *Heliyon, 8*(8).

Molla, M. B. (2015). Land use/land cover dynamics in the central rift valley region of Ethiopia: Case of Arsi Negele district. *African Journal of Agricultural Research, 10*(5), 434-449.

Mondal, S., Poonia, S. P., Mishra, J. S., Bhatt, B. P., Karnena, K. R., Saurabh, K., . . . Chakraborty, D. (2020). Short-term (5 years) impact of conservation agriculture on soil physical properties and organic carbon in a rice–wheat rotation in the Indo-Gangetic plains of Bihar. *European Journal of Soil Science, 71*(6), 1076-1089.

Montgomery, D. R. (2012). *Dirt: The erosion of civilizations*: Univ of California Press.

Moore, I., & Burch, G. (1986). Modelling erosion and deposition: topographic effects. *Transactions of the ASAE, 29*(6), 1624-1630.

Moore, I. D., & Burch, G. J. (1986). Physical basis of the length-slope factor in the universal soil loss equation 1. *Soil Science Society of America Journal, 50*(5), 1294-1298.

Moore, V. M., Peters, T., Schlautman, B., & Brummer, E. C. (2023). Toward plant breeding for multicrop systems. *Proceedings of the National Academy of Sciences, 120*(14), e2205792119.

Morgan, R., Quinton, J., Smith, R., Govers, G., Poesen, J., Auerswald, K., . . . Styczen, M. (1998). The European Soil Erosion Model (EUROSEM): a dynamic approach for predicting sediment transport from fields and small catchments. *Earth Surface Processes and Landforms: The Journal of the British Geomorphological Group, 23*(6), 527-544.

Morgan, R., Quinton, J., Smith, R., Govers, G., Poesen, J., Chisci, G., & Torri, D. (1998). The EUROSEM model *Modelling Soil Erosion by Water* (pp. 389-398): Springer.

Morgan, R., Quinton, J. N., & Rickson, R. (1994). Modelling methodology for soil erosion assessment and soil conservation design: the EUROSEM approach. *Outlook on Agriculture, 23*(1), 5-9.

Morgan, R. P., & Quinton, J. N. (2001). Erosion modeling *Landscape erosion and evolution modeling* (pp. 117-143): Springer.

Morgan, R. P. C. (2009). *Soil erosion and conservation*: John Wiley & Sons.

Moriasi, D. N., Arnold, J. G., Van Liew, M. W., Bingner, R. L., Harmel, R. D., & Veith, T. L. (2007). Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. *Transactions of the ASABE, 50*(3), 885-900.

Mtyobile, M., Muzangwa, L., & Mnkeni, P. N. S. (2020). Tillage and crop rotation effects on soil carbon and selected soil physical properties in a Haplic Cambisol in Eastern Cape, South Africa. *Soil & Water Research, 15*(1).

Muche, M., Kokeb, A., & Molla, E. (2015). Assessing the physicochemical properties of soil under different land use types. *J Environ Anal Toxicol, 5*(309), 2161-0525.1000309.

Muluneh, A., & Arnalds, O. (2010). Synthesis of research on land use and land cover dynamics in the Ethiopian highlands. *Unpublished thesis. Reykjavik, Iceland: Hawassa University*.

Munoth, P., & Goyal, R. (2019). Impacts of land use land cover change on runoff and sediment yield of Upper Tapi River Sub-Basin, India. *International Journal of River Basin Management*, 1-13.

Muñoz-Rojas, M., Jordán, A., Zavala, L., De la Rosa, D., Abd-Elmabod, S., & Anaya-Romero, M. (2015). Impact of land use and land cover changes on organic carbon stocks in Mediterranean soils (1956–2007). *Land Degradation & Development, 26*(2), 168-179.

Mushir, A., & Kedru, S. (2012). Soil and water conservation management through indigenous and traditional practices in Ethiopia: A case study. *Ethiopian Journal of Environmental Studies and Management, 5*(4), 343-355.

Mutchler, C., Murphree, C., & McGregor, K. (2017). Laboratory and field plots for erosion research *Soil erosion research methods* (pp. 11-38): Routledge.

Nanganoa, L. T., Okolle, J. N., Missi, V., Tueche, J. R., Levai, L. D., & Njukeng, J. N. (2019). Impact of different land-use systems on soil physicochemical properties and macrofauna abundance in the humid tropics of Cameroon. *Applied and Environmental Soil Science, 2019*.

Nearing, M., Foster, G., Lane, L., & Finkner, S. (1989). A process-based soil erosion model for USDA-Water Erosion Prediction Project technology. *Transactions of the ASAE, 32*(5), 1587-1593.

Nearing, M., Wei, H., Stone, J., Pierson, F., Spaeth, K., Weltz, M., . . . Hernandez, M. (2011). A rangeland hydrology and erosion model. *Transactions of the ASABE, 54*(3), 901-908.

Nedd, R., Light, K., Owens, M., James, N., Johnson, E., & Anandhi, A. (2021). A synthesis of land use/land cover studies: Definitions, classification systems, meta-studies, challenges and knowledge gaps on a global landscape. *Land, 10*(9), 994.

Nel, T., Clarke, C., & Hardie, A. (2022). Evaluation of simple and multivariate linear regression models for exchangeable base cation conversion between seven measurement techniques on South African soils. *Geoderma Regional, 30*, e00571.

Nigussie, A., & Kissi, E. (2012). The contribution of coffee agroecosystem to soil fertility in Southwestern Ethiopia. *African Journal of Agricultural Research, 7*(1), 74-81.

Nigussie, A., Kuyper, T. W., & de Neergaard, A. (2015). Agricultural waste utilisation strategies and demand for urban waste compost: evidence from smallholder farmers in Ethiopia. *Waste management, 44*, 82-93.

Nigussie, Z., Tsunekawa, A., Haregeweyn, N., Adgo, E., Nohmi, M., Tsubo, M., . . . Abele, S. (2017). Farmers' perception about soil erosion in Ethiopia. *Land Degradation & Development, 28*(2), 401-411.

Norman, J. M., Kustas, W. P., & Humes, K. S. (1995). Source approach for estimating soil and vegetation energy fluxes in observations of directional radiometric surface temperature. *Agricultural and Forest Meteorology, 77*(3-4), 263-293.

Nuissl, H., & Siedentop, S. (2021). Urbanisation and land use change. *Sustainable land management in a European context: a co-design approach*, 75-99.

Nyssen, J., Poesen, J., Haile, M., Moeyersons, J., & Deckers, J. (2000). Tillage erosion on slopes with soil conservation structures in the Ethiopian highlands. *Soil and Tillage Research, 57*(3), 115-127.

Obalum, S. E., Buri, M. M., Nwite, J. C., Watanabe, Y., Igwe, C. A., & Wakatsuki, T. (2012). Soil degradation-induced decline in productivity of Sub-Saharan African soils: The prospects of looking downwards the lowlands with the sawah ecotechnology. *Applied and Environmental Soil Science, 2012*.

Obubu, J. P., Odong, R., Alamerew, T., Fetahi, T., & Mengistou, S. (2022). Application of DPSIR model to identify the drivers and impacts of land use and land cover changes and climate change on land, water, and livelihoods in the L. Kyoga basin: implications for sustainable management. *Environmental Systems Research, 11*(1), 11.

Omuto, C. (2008). Assessment of soil physical degradation in Eastern Kenya by use of a sequential soil testing protocol. *Agriculture, Ecosystems & Environment, 128*(4), 199-211.

Onduru, D., & Muchena, F. (2011). *Cost-benefit analysis of land management options in the Upper Tana, Kenya*. Retrieved from

Owojori, A., & Xie, H. (2005). *Landsat image-based LULC changes of San Antonio, Texas using advanced atmospheric correction and object-oriented image analysis approaches.* Paper presented at the 5th international symposium on remote sensing of urban areas, Tempe, AZ.

Pacheco, F., Varandas, S., Fernandes, L. S., & Junior, R. V. (2014). Soil losses in rural watersheds with environmental land use conflicts. *Science of the Total Environment, 485*, 110-120.

Pakistan, I. (2005). *Rapid environmental appraisal of developments in and around murree hills*. Retrieved from

Pal, S., Panwar, P., & Bhardwaj, D. (2012). Soil quality under forest compared to other landuses in acid soil of North Western Himalaya, India. *Annals of Forest Research, 56*(1), 187-198.

Panagos, P., Standardi, G., Borrelli, P., Lugato, E., Montanarella, L., & Bosello, F. (2018). Cost of agricultural productivity loss due to soil erosion in the European Union: From direct cost evaluation approaches to the use of macroeconomic models. *Land Degradation & Development, 29*(3), 471-484.

Panel, I. R., Consumption, U. N. E. P. S., & Branch, P. (2011). *Decoupling natural resource use and environmental impacts from economic growth*: UNEP/Earthprint.

Pereira, P., Bogunovic, I., Muñoz-Rojas, M., & Brevik, E. C. (2018). Soil ecosystem services, sustainability, valuation and management. *Current Opinion in Environmental Science & Health, 5*, 7-13.

Petit-Aldana, J., Rahman, M. M., Parraguirre-Lezama, C., Infante-Cruz, A., & Romero-Arenas, O. (2019). Litter decomposition process in coffee agroforestry systems. *Journal of forest and environmental science, 35*(2), 121-139.

Pham, T. G., Degener, J., & Kappas, M. (2018). Integrated universal soil loss equation (USLE) and Geographical Information System (GIS) for soil erosion estimation in A Sap basin: Central Vietnam. *International Soil and Water Conservation Research, 6*(2), 99-110.

Prabhu, T. (2021). *Environmental Ecology: Fundamental Concepts of Environmental Ecology* (Vol. 1): NestFame Creations Pvt Ltd.

Prakasam, C. (2010). Land use and land cover change detection through remote sensing approach: A case study of Kodaikanal taluk, Tamil nadu. *International journal of Geomatics and Geosciences, 1*(2), 150.

Prasannakumar, V., Vijith, H., Abinod, S., & Geetha, N. (2012). Estimation of soil erosion risk within a small mountainous sub-watershed in Kerala, India, using Revised Universal Soil Loss Equation (RUSLE) and geo-information technology. *Geoscience Frontiers, 3*(2), 209-215.

Qasim, M., Hubacek, K., Termansen, M., & Khan, A. (2011). Spatial and temporal dynamics of land use pattern in District Swat, Hindu Kush Himalayan region of Pakistan. *Applied Geography, 31*(2), 820-828.

Qian, J., Zhou, Q., & Hou, Q. (2007). *Comparison of pixel-based and object-oriented classification methods for extracting built-up areas in arid zone.* Paper presented at the ISPRS workshop on updating Geo-spatial databases with imagery & the 5th ISPRS workshop on DMGISs.

Qin, W., Guo, Q., Cao, W., Yin, Z., Yan, Q., Shan, Z., & Zheng, F. (2018). A new RUSLE slope length factor and its application to soil erosion assessment in a Loess Plateau watershed. *Soil and Tillage Research, 182*, 10-24.

Rahaman, S., Kumar, P., Chen, R., Meadows, M. E., & Singh, R. (2020). Remote sensing assessment of the impact of land use and land cover change on the environment of Barddhaman district, West Bengal, India. *Frontiers in Environmental Science, 8*, 127.

Ramesh, T., Bolan, N. S., Kirkham, M. B., Wijesekara, H., Kanchikerimath, M., Rao, C. S., . . . Choudhury, B. U. (2019). Soil organic carbon dynamics: Impact of land use changes and management practices: A review. *Advances in agronomy, 156*, 1-107.

Raza, A., Ahrends, H., Habib-Ur-Rahman, M., & Gaiser, T. (2021). Modeling approaches to assess soil erosion by water at the field scale with special emphasis on heterogeneity of soils and crops. *Land, 10*(4), 422.

Reij, C., Scoones, I., & Toulmin, C. (2013). *Sustaining the soil: indigenous soil and water conservation in Africa*: Routledge.

Ren, Y., Lü, Y., Comber, A., Fu, B., Harris, P., & Wu, L. (2019). Spatially explicit simulation of land use/land cover changes: Current coverage and future prospects. *Earth-Science Reviews, 190*, 398-415.

Renard, K., & Ferreira, V. (1993). RUSLE model description and database sensitivity. *Journal of environmental quality, 22*(3), 458-466.

Renard, K. G., Foster, G. R., Weesies, G., McCool, D., & Yoder, D. (1997). *Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE)* (Vol. 703): United States Department of Agriculture Washington, DC.

Renard, K. G., Foster, G. R., Weesies, G. A., & Porter, J. P. (1991). RUSLE: Revised universal soil loss equation. *journal of soil and water conservation, 46*(1), 30-33.

Renard, K. G., & Freimund, J. R. (1994). Using monthly precipitation data to estimate the R-factor in the revised USLE. *Journal of hydrology, 157*(1-4), 287-306.

Renard, K. G., Laflen, J., Foster, G., & McCool, D. (2017). The revised universal soil loss equation *Soil erosion research methods* (pp. 105-126): Routledge.

Richards, J. A., & Richards, J. A. (2022). *Remote sensing digital image analysis* (Vol. 5): Springer.

Rimal, B. (2011). APPLICATION OF REMOTE SENSING AND GIS, LAND USE/LAND COVER CHANGE IN KATHMANDU METROPOLITAN CITY, NEPAL. *Journal of Theoretical & Applied Information Technology, 23*(2).

Rodrigo Comino, J. (2022). Desertification and degradation risks vs poverty: A Key Topic in Mediterranean Europe.

Rose, R. A., Byler, D., Eastman, J. R., Fleishman, E., Geller, G., Goetz, S., . . . Headley, R. (2015). Ten ways remote sensing can contribute to conservation. *Conservation Biology, 29*(2), 350-359.

Rowell DL. 1994. Soil science: Methods and application, Addison Wesley Longman, Limited, England.

Roy, P., Pal, S. C., Chakrabortty, R., Saha, A., & Chowdhuri, I. (2023). A systematic review on climate change and geo-environmental factors induced land degradation: Processes, policy-practice gap and its management strategies. *Geological Journal, 58*(9), 3487-3514.

Roy, P. S., Ramachandran, R. M., Paul, O., Thakur, P. K., Ravan, S., Behera, M. D., . . . Kanawade, V. P. (2022). Anthropogenic land use and land cover changes—A review on its environmental consequences and climate change. *Journal of the Indian Society of Remote Sensing, 50*(8), 1615-1640.

Roy, P.S., Ramachandran, R.M., Paul, O. *et al.* Anthropogenic Land Use and Land Cover Changes—A Review on Its Environmental Consequences and Climate Change. *J Indian Soc Remote Sens* **50**, 1615–1640 (2022). https://doi.org/10.1007/s12524-022-01569-w

Sadeghi, S., Mizuyama, T., Miyata, S., Gomi, T., Kosugi, K., Fukushima, T., . . . Onda, Y. (2008). Determinant factors of sediment graphs and rating loops in a reforested watershed. *Journal of Hydrology, 356*(3-4), 271-282.

Safaei, M., Bashari, H., Mosaddeghi, M. R., & Jafari, R. (2019). Assessing the impacts of land use and land cover changes on soil functions using landscape function analysis and soil quality indicators in semi-arid natural ecosystems. *Catena, 177*, 260-271.

Saguye, T. S. (2017). Analysis of farmers perception on the impact of land degradation hazard on agricultural land productivity in Jeldu district in West Shewa Zone, Oromia, Ethiopia. *Journal of Agricultural Extension and Rural Development, 9*(6), 111-123.

Salahin, N., Alam, M. K., Shil, N. C., Mondol, A. T. M. A. I., Alam, M. J., Kobeasy, M. I., . . . Ahmed, S. (2022). Interactive effects of tillage systems and nitrogen fertilizer rates on the performance of mustard-Boro-aman rice cropping systems under conservation agriculture practices. *Agronomy, 12*(7), 1671.

Selassie, Y. G., Anemut, F., & Addisu, S. (2015). The effects of land use types, management practices and slope classes on selected soil physico-chemical properties in Zikre watershed, North-Western Ethiopia. *Environmental Systems Research, 4*(1), 3.

Selassie, Y. G., & Getachew, A. (2013). Effects of different land use systems on selected physico-chemical properties of soils in northwestern Ethiopia. *Journal of Agricultural Science (Toronto), 5*(4), 112-120.

Seyoum, B. (2016). Assessment of soil fertility status of vertisols under selected three land uses in Girar Jarso District of North Shoa Zone, Oromia National Regional State, Ethiopia. *Environmental Systems Research, 5*(1), 18.

Shaheb, M. R., Venkatesh, R., & Shearer, S. A. (2021). A review on the effect of soil compaction and its management for sustainable crop production. *Journal of Biosystems Engineering*, 1-23.

Shen, H., Zheng, F., Wen, L., Han, Y., & Hu, W. (2016). Impacts of rainfall intensity and slope gradient on rill erosion processes at loessial hillslope. *Soil and Tillage Research, 155*, 429-436.

Shiferaw, A., & Singh, K. (2011). Evaluating The Land Use And Land Cover Dynamics In Borena Woreda South Wollo Highlands, Ethiopia. *Ethiopian Journal of Business and Economics (The), 2*(1).

Shrestha, U. B., Gautam, S., & Bawa, K. S. (2012). Widespread climate change in the Himalayas and associated changes in local ecosystems. *PloS one, 7*(5), e36741.

Shwetha, G., & Reddy, G. S. (2021). Developing soil erosion controlling data layers for MUSLE using RS and GIS: A case study in Raichur district, Karnataka.

Sikora, F., Crouse, K., Heckendorn, S., Huluka, G., Mitchell, C., Moore, K., & Oldham, J. (2014). Cation exchange capacity. *Soil test methods from the Southeastern United States. Southern Cooperative Series Bulletin, 419*, 170-179.

Smit, H., Muche, R., Ahlers, R., & van der Zaag, P. (2017). The political morphology of drainage—how gully formation links to state formation in the choke mountains of Ethiopia. *World Development, 98*, 231-244.

Sonmez, S., Buyuktas, D., Okturen, F., & Citak, S. (2008). Assessment of different soil to water ratios (1: 1, 1: 2.5, 1: 5) in soil salinity studies. *Geoderma, 144*(1-2), 361-369.

Srinivasan, R., & Engel, B. (1991). Effect of slope prediction methods on slope and erosion estimates. *Applied Engineering in Agriculture, 7*(6), 779-783.

Stevens, G., Motavalli, P., Scharf, P., Nathan, M., & Dunn, D. (2018). Crop nutrient deficiencies & toxicities.

Stocking, M. (2014). Soil erosion and land degradation *Environmental science for environmental management* (pp. 287-321): Routledge.

Storck, H., Emana, B., Adnew, B., Borowiccki, A., & Woldehawariat, S. (1991). Farming systems and resource economics in the tropics: farming system and farm management practices of smallholders in the Hararghe Highland. *Vol. II, Wissenschaftsverlag Vauk, Kiel, Germany*.

Tao, W. (2013). Interdisciplinary urban GIS for smart cities: advancements and opportunities. *Geo-spatial Information Science, 16*(1), 25-34.

Tefera, B., & Sterk, G. (2010). Land management, erosion problems and soil and water conservation in Fincha'a watershed, western Ethiopia. *Land use policy, 27*(4), 1027-1037.

Tefera, M. M. (2011). Land-use/land-cover dynamics in Nonno district, central Ethiopia. *Journal of Sustainable development in Africa, 13*(1), 123-141.

Tefera, T., Tesfay, G., Elias, E., Diro, M., & Koomen, I. (2016). Drivers for adoption of agricultural technologies and practices in Ethiopia. *A study report from, 30*.

Tegene, B. (1992). Farmers' Perceptions of Erosion Hazards and Attitudes towards Soil Conservation in Gununo, Wolaita, Southern Ethiopia. *Ethiopian Journal of Development Research, 14*(2), 31-58.

Tekwa, I., Shehu, H., & Maunde, S. (2011). Soil nutrient status and productivity potentials of lithosols in Mubi Area, Northeastern Nigeria. *Agriculture and Biology Journal of North America, 2*(6), 887-896.

Tesfaye, A., Negatu, W., Brouwer, R., & Van der Zaag, P. (2014). Understanding soil conservation decision of farmers in the Gedeb watershed, Ethiopia. *Land Degradation & Development, 25*(1), 71-79.

Teshome, A., de Graaff, J., & Kassie, M. (2016). Household-level determinants of soil and water conservation adoption phases: Evidence from North-Western Ethiopian highlands. *Environmental management, 57*(3), 620-636.

Tewabe, D., & Fentahun, T. (2020). Assessing land use and land cover change detection using remote sensing in the Lake Tana Basin, Northwest Ethiopia. *Cogent Environmental Science, 6*(1), 1778998.

Teweldebrihan, M. D., Gebehiwot, T., Teklewold, H., Dinka, M. O., Abera, W., & Tamene, L. (2023). Understanding the role of push and pull factors on agricultural land expansion: A case study of Adaba and Adiyo district, Ethiopia. *Environmental Challenges, 11*, 100714.

Thi, N. Q., Govind, A., Le, M.-H., Linh, N. T., Anh, T. T. M., Hai, N. K., & Ha, T. V. (2023). Spatiotemporal characterization of droughts and vegetation response in Northwest Africa from 1981 to 2020. *The Egyptian Journal of Remote Sensing and Space Science, 26*(3), 393-401.

Tilahun, A., Asmare, T., Nega, W., & Gashaw, T. (2023). The nexus between land use, land cover dynamics, and soil erosion: a case study of the Temecha watershed, upper Blue Nile basin, Ethiopia. *Environmental Science and Pollution Research, 30*(1), 1023-1038.

Tilahun, F. (2022). *Impact of land use land cover change on soil erosion, watershed prioritization and farmer perciption: The case of Mitka Watershed in Ethiopia.*

Tilahun, G. (2007). Soil fertility status as influenced by different land uses in Maybar areas of South Wello Zone, North Ethiopia. *MS. c Thesis, Haramaya University, Haramaya, Ethiopia. 40p*.

Tripathi, M., Panda, R., & Raghuwanshi, N. (2003). Identification and prioritisation of critical sub-watersheds for soil conservation management using the SWAT model. *Biosystems Engineering, 85*(3), 365-379.

Tsegaye, B. (2019). Effect of land use and land cover changes on soil erosion in Ethiopia. *International Journal of Agricultural Science and Food Technology, 5*(1), 26-34.

Tsegaye, D., Moe, S. R., Vedeld, P., & Aynekulu, E. (2010). Land-use/cover dynamics in Northern Afar rangelands, Ethiopia. *Agriculture, Ecosystems & Environment, 139*(1-2), 174-180.

Tucker, M. E. (2009). *Sedimentary petrology: an introduction to the origin of sedimentary rocks*: John Wiley & Sons.

Turner, B., Meyer, W. B., & Skole, D. L. (1994). Global land-use/land-cover change: towards an integrated study. *Ambio. Stockholm, 23*(1), 91-95.

Turner, B. L., Moss, R. H., & Skole, D. (1993). Relating land use and global land-cover change. *[No source information available]*.

UTUYE, K. U. (2023). *ASSESSMENT OF LAND USE/LAND COVER CHANGE AND ITS DRIVING FORCES IN ADOLA REDE DISTRICT, OROMIA REGION, ETHIOPIA.* HU.

Vacek, Z., Vacek, S., & Cukor, J. (2023). European forests under global climate change: Review of tree growth processes, crises and management strategies. *Journal of Environmental Management, 332*, 117353.

Verheye, S., Ramcharitar, S., Grube, E., Schofer, J. J., Witzenbichler, B., Kovac, J., . . . Lefèvre, T. (2011). Six-month clinical and angiographic results of the STENTYS (R) self-apposing stent in bifurcation lesions. *EuroIntervention, 7*(5), 580-587.

Walkey, A., & Black, I. (1934). Determination of organic matter in soil. *Soil science, 37*, 549-556.

Wang, H., Xu, J., Liu, X., Zhang, D., Li, L., Li, W., & Sheng, L. (2019). Effects of long-term application of organic fertilizer on improving organic matter content and retarding acidity in red soil from China. *Soil and Tillage Research, 195*, 104382.

Wang, S., Wang, Y., Wang, Y., & Wang, Z. (2022). Assessment of influencing factors on non-point source pollution critical source areas in an agricultural watershed. *Ecological Indicators, 141*, 109084.

Wang, X. (2022). Managing land carrying capacity: Key to achieving sustainable production systems for food security. *Land, 11*(4), 484.

Wang, X., Zheng, D., & Shen, Y. (2008). Land use change and its driving forces on the Tibetan Plateau during 1990–2000. *Catena, 72*(1), 56-66.

Wassie, S. B. (2020). Natural resource degradation tendencies in Ethiopia: a review. *Environmental Systems Research, 9*(1), 1-29.

Wiesler, F. (2017). Comparative assessment of the efficacy of various nitrogen fertilizers. *Nutrient use in crop production*, 81-114.

Williams, C., David, D. J., & Iismaa, O. (1962). The determination of chromic oxide in faeces samples by atomic absorption spectrophotometry. *The Journal of Agricultural Science, 59*(3), 381-385.

Wischmeier, W. H. (1965). Predicting rainfall erosion losses from cropland east of the Rocky Mountain. *Agriculture handbook, 282*, 47.

Wischmeier, W. H., & Smith, D. D. (1978). Predicting rainfall erosion losses-a guide to conservation planning. *Predicting rainfall erosion losses-a guide to conservation planning.*

Wola, A. W. (2023). Land Use/Land Cover Change and Its Driving Forces in Mago National Park, Southern Ethiopia.

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.

Worku, G., Bantider, A., & Temesgen, H. (2014). Effects of land use/land cover change on some soil physical and chemical properties in ameleke micro-watershed, Gedeo and Borena zones, south Ethiopia. *Journal of Environment and Earth Science, 4*(11), 13-24.

Yeshaneh, G. T. (2015). Assessment of soil fertility variation in different land uses and management practices in maybar watershed, South Wollo Zone, North Ethiopia. *International Journal of Environmental Bioremediation and Biodegradation, 3*(1), 15-22.

Yifru, A., & Taye, B. (2011). Land use effects on soil organic carbon and nitrogen in some soils of Bale, Southeastern Ethiopia. *Tropical and Subtropical Agroecosystems, 14*(1), 229-235.

Yigezu Wendimu, G. (2021). The challenges and prospects of Ethiopian agriculture. *Cogent Food & Agriculture, 7*(1), 1923619.

Yimer, F., & Abdelkadir, A. (2011). The effect of cropland fallowing on soil nutrient restoration in the Bale Mountains, Ethiopia. *Journal of Science and Development, 1*(1), 43-51.

Yitbarek, T., Gebrekidan, H., Kibret, K., & Beyene, S. (2013). Impacts of land use on selected physicochemical properties of soils of Abobo area, western Ethiopia. *Agriculture, Forestry and Fisheries, 2*(5), 177-183.

Yohannes, H., & Soromessa, T. (2018). Land suitability assessment for major crops by using GIS-based multi-criteria approach in Andit Tid watershed, Ethiopia. *Cogent Food & Agriculture, 4*(1), 1470481.

Yohannes, H., Soromessa, T., Argaw, M., & Dewan, A. (2021). Impact of landscape pattern changes on hydrological ecosystem services in the Beressa watershed of the Blue Nile Basin in Ethiopia. *Science of the Total Environment, 793*, 148559.

Young A (1976). Tropical soils and soil survey. Cambridge University Press.

Zajícová, K., & Chuman, T. (2019). Application of ground penetrating radar methods in soil studies: A review. *Geoderma, 343*, 116-129.

Zajícová, K., & Chuman, T. (2019a). Effect of land use on soil chemical properties after 190 years of forest to agricultural land conversion. *Soil & Water Research, 14*(3).

Zajícová, K., & Chuman, T. (2019b). Effect of land use on soil chemical properties after 190 years of forest to agricultural land conversion. *Soil and Water Research*.

Zeleke, G., & Hurni, H. (2001). Implications of land use and land cover dynamics for mountain resource degradation in the Northwestern Ethiopian highlands. *Mountain Research and Development, 21*(2), 184-192.

Zeleke, G., & Welemariam, M. (2020). Farmers Perception on SWC practices, and its Implication on Land Degradation in Guduru District, Western Ethiopia. *Authorea Preprints*.

Zelleke, G., Agegnehu, G., Abera, D., & Rashid, S. (2010). Fertilizer and soil fertility potential in Ethiopia. *Constraints and opportunities for enhancing the system. International Food Policy Research Institute, sustainable solution for ending hunger*.

Zewdie, W., & Csaplovies, E. (2015). Remote sensing based multi-temporal land cover classification and change detection in northwestern Ethiopia. *European Journal of Remote Sensing, 48*(1), 121-139.

Zewide, I. (2021). Review paper on effect of natural condition on soil infiltration. *Chemistry, 7*(1), 34-41p.

Zhang, X., Hu, M., Guo, X., Yang, H., Zhang, Z., & Zhang, K. (2018). Effects of topographic factors on runoff and soil loss in Southwest China. *Catena, 160,* 394-402.

Zhu, C. (2011). Land Use/Land Cover Change and Its Hydrological Impacts from 1984 to 2010 in the Little River Watershed, Tennessee.

Ziggers, G. W., & Henseler, J. (2016). The reinforcing effect of a firm's customer orientation and supply-base orientation on performance. *Industrial marketing management, 52*, 18-26.

Appendices

Appendix 1: Ratings Criteria adapted to Evaluate Soil pH Value based on London (1991)

1.	Extremely acid	< 4.5
2.	Very strong acid	4.5-5.0
3.	Strongly acid	5.1-5.5
4.	Moderately acid	5.5-6.0
5.	Slightly acid	6.0-6.5
6.	Neutral	6.5-7.5
7.	Slightly alkaline	7.5-8.0
8.	Moderately alkaline	8.0 8.5
9.	Strongly alkaline	8.5-9.5
10.	Very strongly alkaline	9.5-10.0

Appendix 2: Rating Criteria Adapted to Evaluate Soil OC based on London (1991)

1.	Very high	>20%
2.	High	10-20%
3.	Medium	4-10%
4.	Low	2-4%
5.	Very low	<2.0%

Appendix 3: FAO 1984 Erosion Risk Cases

1.	Low	0-7t/ha/yr
2.	Moderate	7-15t/ha/yr
3.	High	15-25t/ha/yr
4.	Very high	25-45t/ha/yr
5.	Severe	45-60t/ha/yr
6.	Very severe	> 60t/ha/yr

Appendix 4: Rating Criteria Adapted to Evaluate Soil Total N (TN) based on London (1991)

1.	Very high	> 1.0 %
2.	High	0.5 - 1.0%
3.	Medium (sufficient)	0.2 - 0.5%
4.	Low (deficient)	0.1 – 0.2%
5.	Very low	< 1.0%

Appendix 5: Ratings Criteria Adapted to Evaluate Soil Av. P based on London (1991)

1. Very high -
2. High >15 mg/kg
3. Medium (Optimum) 5-15 mg/kg
4. Low (deficient) < 5 mg/kg
5. Very low (Acutely deficient) -

Appendix 6: Ratings Criteria Adapted to Evaluate Soil Exchangeable Ca based on London (1991)

1. Very high -
2. High >10 $Cmol_c$ (+)/kg
3. Medium 2-10 $Cmol_c$ (+)/kg
4. Low < 2 $Cmol_c$ (+)/kg
5. Very low -

Appendix 7: Ratings Criteria Adapted to Evaluate Soil Exchangeable Mg based on London (1991)

1. Very high -
2. High >0.5 $Cmol_c$ (+)/kg
3. Medium 0.2-0.5 $Cmol_c$ (+)/kg
4. Low < 0.2 $Cmol_c$ (+)/kg
5. Very low -

Appendix 8: Ratings Criteria adapted to Evaluate Soil Exchangeable Na based on FAO (2006)

1. Very high (Sodic) > 2.0 $Cmol_c$ (+)/kg
2. High (Slightly Sodic) 0.7 - 2.0 $Cmol_c$ (+)/kg
3. Medium 0.3 - 0.7 $Cmol_c$ (+)/kg
4. Low 0.1 – 0.3 $Cmol_c$ (+)/kg
5. Very low < 0.1 $Cmol_c$ (+)/kg

Appendix 9: Ratings Criteria adapted to Evaluate Soil Exchangeable K based on London (1991)

1. Very high -
2. High 0.4 – 0.8 $Cmol_c$ (+)/kg
3. Medium 0.2-0.4 $Cmol_c$ (+)/kg
4. Low 0.03 - 0.2 $Cmol_c$ (+)/kg
5. Very low < 0.03 $Cmol_c$ (+)/kg

Appendix 10: Ratings Criteria adapted to Evaluate Soil CEC based on London (1991)

1. Very high > 40
2. High 25 – 40 $Cmol_c$ (+)/kg
3. Medium 12 - 25 $Cmol_c$ (+)/kg
4. Low 6 – 12 $Cmol_c$ (+)/kg
5. Very low < 6 $Cmol_c$ (+)/kg

Appendix 11: Ratings Criteria adapted to Evaluate Soil Base Saturation based on London (1991)

1. Very high > 80 %
2. High 60 – 80 %
3. Medium 40 - 60 %
4. Low 20 – 40 %
5. Very low 0 - 20 %

Soil organic carbon (OC) is not a nutrient and so its interpretation refers to soil health rather than to soil fertility percentage like (Elias E, 2016).

Appendix 12: Survey on Farmers Decisions on Adoption of Soil and Water Conservation Practices in Kabe Watershed

1. General information

Farmers survey identification: ________________________________

1.1) Respondent name____

1.2) Sex: 1) Male 2) Female

1.3) Age________years

1.4) Marital status: 1) Single 2) Married 3) Divorced (separated)
4) Widow 99) No applicable

1.5) Kebele 1.012 2.013 3. 014 4. 015 5. 016

1.6) Strata 1. Upper 2. Middle 3. Lower

1.7) Distance to Wereda market__________ (in minutes)

1.8) Social position in the kebele

1) Member of kebele council 2) Religious leader

3) Others, specify_____________________ 4) none

1.9) Education level_______________grade

2. Household Characteristics

2.1) Household family members' information

Sex

Male__________ (No),

Female____________ (No)

Age

0-15yr_________ (No),

16-64yr__________ (No),

Greater than 64 ________ (No)

Education

0 grade______ (No),

1-4______ (No),

5-8_________ (No),

9-12_____ (No),

Diploma graduate____ (No),

B.Sc degree________ (No),

Above________ (No)

3. Landholding and farm characteristics

No	Types of land use	Area in hectare (ha)
1.	Cultivated land	
2.	Fallow land	
3.	Grazing land	
4.	Home stead area	
5.	Forest (bush)	
6.	Others	

4. Description of farm plots

Code: 1. Cultivated 2. Grazing 3.Forest 4.Home-stead 5. Cultivated – Home stead 6. Grass – Home stead 7. Grass – forest 8. Forest – Home stead 9. Cultivated - Forest

No	**Description**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**
1.	Area of the Plot (ha)					
2.	Types of major crops grown 1=Teff 2=Barley 3=Wheat 4=Rough pea 5=Chick pea 6=Maize 7=Sorghum 8=Horse bean 9=Field peas 10= others, Dagusa 11=Triticale 12=Noug 13=Onion14=Tomato 15=Potato 16=Millet, 17. NA 18. 1& 6 19. 6 & 17 20. 1, 3 &6 21. 6, 7&17 22. 1, 6 & 17 23. 1 & 17 24. Others					
3.	Fertilizer use (in Kg)					
4.	Traction (oxen)					
5.	Yield (in Kg)					
6.	Seed type 1= local seed, 2=improved 3.NA					
7.	Seed quantity (in Kg)					
8.	Manure (in kg)					
9.	Other chemicals (in liters)					
10.	Distance from home (walking minutes)					
11.	Slope: 1) Flat (0-6%) 2) Gentle slope (6-15%) 3) Steep slope & Mountainous (> 15%)					
12.	Plot fertility: 1) High 2) Medium 3) Low					
13	Source of the plot 1) Inherited 2) Received from kebele 3) Rented in 4) Other ____ (specify)					
14.	Color of the soil 1) Red 2) Black 3) Brown 4) Sandy 5) 2 & 4					

15.	Degree of erosion problem on the plot 1) High 2) Medium 3) Low					
16.	Number of years since the plot is used					
17.	Irrigated 1) Yes 2) No					
18.	Presence of at least one type of improved SWC structures 1) Yes 2) No					
19.	Physical Improved soil and water conservation structures built in meter or No					
	Soil terrace					
	Cut off drain					
	Fanyajuu					
	Planting of d/t trees in No					
	Others, specify					
20.	Who constructed the structures? 1) Community participation 2) Family (hired) labor 3) Financial incentives by government 4) labor exchange 5)NA					
21.	Do improved soil and water conservation structures maintained or not 1) Yes 2) No 3) NA					
22.	Who did the maintenance work? 1) Community participation 2) Family 3) Hired labor 4) Labor exchange 5. NA					
23.	Status (degree) of use of improved soil and water conservation structures (practices) 1) Removed totally; 2) Partially removed 3) Not removed; 4) Modified (adapted) 5) NA					

24.	Traditional soil and water conservation structures built (in meter) 1.Traditional stone bund 2.Traditional ditches 3.Trash (garbage) lines 4. Cut off-drain 5. Plantation 6. Others, specify					
25.	How do you perceive the soil depth of your plot since you owned it? 1) Increased 2) Decreased 3) No change 4) I do not know					
26.	How do you compare the problem of soil erosion in your farm plots after SWC structures are builds? 1) Aggravated 2) Reduced 3) No change 4) I do not know 5) NA					

5) Perception of Soil Erosion Problems

5.1) Do you think that soil erosion is a problem for your farm plots? 1) Yes 2) no

5.2) Give rank to the following major causes of soil erosion in your area?

1) Deforestation ___________
2) Over grazing ___________
3) Over cultivation ________
4) Poor agricultural practices _______
5) Cultivation of steep slopes ______
6) Excess rainfall ________________
7) Poor government polices ________
8) Others (specify) ___________________

5.3) what do you think is the consequences of soil erosion?

1) Land productivity (yield) decline 2) Change in type of crops grown
3) Reduces farm plot size 4) All 5) 1&3 6) others (specify) _______

5.4 Farmers' perceptions of soil erosion hazards

Perception on erosion	Proportion of total respondents (%)
Whether soil erosion was perceived as a problem in own farm	
Yes	
No	___________
Severity of the problem, if yes to the above question	
Severe	
Medium	
Moderate	
Observed change in soil erosion severity over the past 5 years	
Has become more severe	

Has become less severe

No change

Extent of impact of soil erosion on farm production

Severe

Moderate

Has no effect

Believing that soil erosion can be controlled

Yes

No

6) Soil and water Conservation technologies and farmers' attitude

6.1) Do you know the existence of improved soil and water conservation structures?

1) Yes 2) No

6.2) If yes, which type do you know?

1) Stone bunds 2) Soil bund 3) Cutoff drain 4) Water way 5) Fanyajuu 6) Planting of d/t tree 7) NA **8)** 1,2,3 & 4 **9)** 1,2,3,4 & 6 **10)** 1,2,4 & 6 **11)** 3,4 & 6 **12)** 1,2 & 6 **13)** 1,3 & 6 **14)** 1,2,3 & 6

6.3) If yes, what is your source of information?

1) Neighboring farmers 2) Extension agents (DAs)
3) NGOs 4) From field days and Trainings
5) Others, specify____________ **6)** NA **7)** 1, 2 & 3 **8)** 1 & 4

6.4) Which of the following types of soil and water conservation measures are efficient to reduce the problem of soil erosion?

1) Stone bund 2) Soil bund
3) Cut off drain 4) Water way
5) Fanyajuu 6) Planting of d/t trees 7) NA 8) 1,2,3,4
9) 1, 2, 3, 4, 6 10) 1,3,4,6 11) 3,4,6 12) 1,2,6 13) 1,3,6 14) 1,2,3,6

6.5) Have you participated in community SWC activities this year?

1) Yes, 2) No

6.6) Did you undertake the maintenance work by your own?

1) Yes 2) No

6.7) If no, what were the reasons for not doing?

1) I have shortage of labor 2) Lack of skill and knowledge
3) SWC structures are built without my knowledge and willingness
4) I expect the land will be transfer to other farmers
5) There was no need for maintenance 6) 1, 2 & 4 7) all 8) NA

6.8) Do you believe that investment in soil and water conservation practices is profitable in the long run? 1) Yes, 2) No

6.9) If the farmer did not use any improved SWC structures in all his plots, why you did not use it?

1) No problem of soil erosion
2) Shortage of labor
3) Expecting that the structures will be done by financial incentives
4) I feel that the land belongs to the government and it is the duty of the government to maintain the land

5) It reduces farmland

6) Due to problems of rodents and others pests

7) I did not get extension service

8) Others, specify 9) NA

6.10) what are the problems related to each soil and water conservation structures?

Hint, choose from 1-5

Problems	Soil bund	Cut off drain	Water way	Plantation
1. Source of rodents 2. Reduce farm land 3. Difficult to turn oxen 4. Labor intensive 5. Difficult to implement (technically) 6. Costly				

Code:1) 1, 4, 5 **3)** 1, 4, 6 **7)** 2, 4 **8)** 3, 4

9) 2, 4, 6 **10)** 2, 3 **11)** 2, 3, 4 **12)** 1, 3, 6 **13)** 1, 2, 6

14) 1,2,3,6 **15)** 4, 5, 6 1**6)** 2, 6 17**)** 1, 2, 3 18**)** 2,3,4,6

7) Institutional Support

7.1) Do you get extension service? 1) Yes 2) No

7.2) If yes, who provides the extension service?

1) Development agents (DAs) 2) NGOs 3) All 4) Others, specify ___

7.3) How often you have been visited by DAs last year?

1) Once per month, 2) Twice per month,

3) Three times per month 4) Others, specify-___________________

7.4) How often you have obtained extension advice on soil and water conservation practices

1) Once per month 2) twice per month

3) Three times per month 4) Once per three months

5) Twice per three months 6) others, specify_____________________

7.5) Have you participated in training of soil and water conservation for the last five years?

1) Yes 2) No

7.6) If yes, for how many days? ___________days 99) Many 2) NA

7.7 Was the training useful? 1) Yes 2) No 3. NA

7.8 Do you participate from access of Credit? 1) Yes 2) No

Thank you very much for your cooperation!!!

Appendix 13: Conversion factors used to estimate tropical livestock unit (TLU)

Livestock Type	TLU (Tropical Livestock Unit)
Calf	0.20
Weaned Calf	0.34
Heifer	0.75
Cows/Oxen	1.0
Horse/Mule	1.10
Donkey	0.70
Donkey (Young)	0.35
Sheep/Goat	0.13
Sheep/Goat (Young)	0.06
Camel	1.25
Chicken	0.013

Source:(Storck, Emana, Adnew, Borowiccki, & Woldehawariat, 1991)

Appendix 14: Soil Sample location points in Kabe Watershed

Northing	Easting	Sample Site
1201065	548368	Site1
1201121	549303	Site2
1201205	549902	Site3
1200716	548360	Site4
1200901	549258	Site5
1200810	549730	Site6
1201077	550338	Site7
1200774	550266	Site8
1200461	549994	Site9
1200469	549277	Site10
1200358	548750	Site11
1200404	548160	Site12
1200037	548687	Site13
1200102	549468	Site14
1199880	548343	Site15

1199550	548116	Site16
1199376	548607	Site17
1199101	549279	Site18
1199571	550013	Site19
1199066	550132	Site20
1198819	550659	Site21
1198525	550333	Site22
1198542	549452	Site23
1198513	548835	Site24
1198732	547736	Site25
1198319	547509	Site26
1197915	547910	Site27
1197953	548572	Site28
1198000	549489	Site29
1197900	550097	Site30
1198057	550760	Site31
1197505	550207	Site32
1197221	550098	Site33
1197073	549727	Site34
1197421	549290	Site35
1197576	548110	Site36
1197703	547075	Site37
1197161	547031	Site38
1196583	547458	Site39
1196373	547948	Site40
1196236	548384	Site41
1196439	548965	Site42
1196468	550000	Site43
1196459	550227	Site44
1195899	550660	Site45
1195462	550877	Site46
1195443	550228	Site47
1195952	548902	Site48
1195547	548313	Site49
1195392	549166	Site50
1194988	549594	Site51
1194807	550719	Site52
1194493	549536	Site53
1193566	550292	Site54

Appendix 15: Soil Laboratory Analyzed Result

Amhara Regional Agricultural Research Institute (ARARI)

በአማራ ክልል ግብርና ምርምር ኢንስቲትዩት

Sirinka Agricultural Research Center (SARC)

የሰሪንቃ ግብርና ምርምር ማዕከል

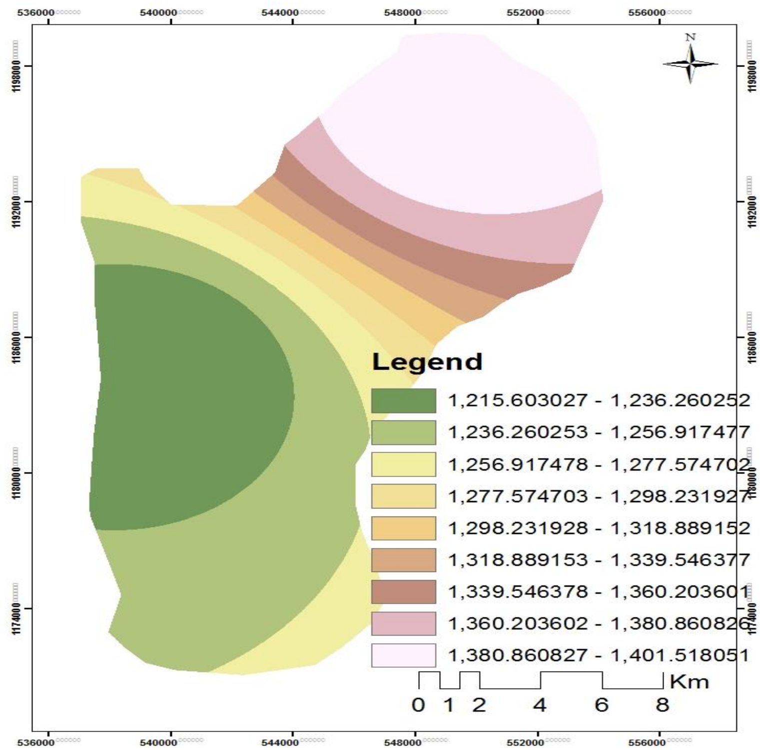
Soil and Water Research Directorate

አፈርና ውሃ ቴክኖሎጅ አቅርቦት ዳይሬክቶሬት

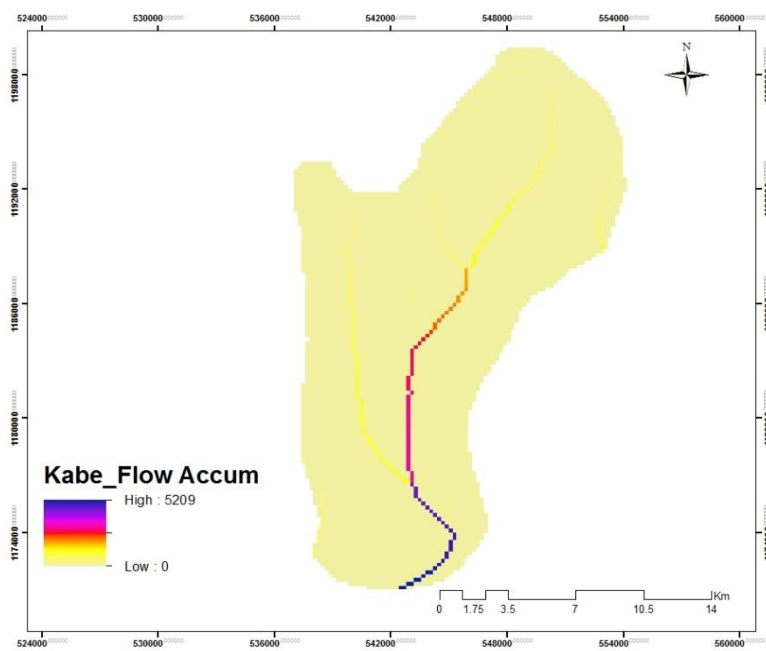
Laboratory result delivery sheet

L No	BD	Porosity (POR)	Ph	EC(Ds/m)	%CLAY	%SILT	%SAND	%OC	%OM	%TN	CEC (Meq/kg)	Av. P	K	Ca	Mg	Na	PBS
1	1.51	41.03	5.33	0.09	14.70	16.35	69.20	1.72	2.141738	0.15	11.56	0.64	0.26	16.57	3.02	0.05	39.67
2	1.24	52.81	5.17	0.11	14.04	20.72	67.33	2.03	2.22779	0.17	13.74	1.88	0.23	25.06	1.59	0.07	75.91
3	1.18	60.14	4.95	0.11	17.71	22.36	60.30	2.20	5.937586	0.19	15.01	2.02	0.28	16.23	2.55	0.09	85.86
4	1.31	48.15	5.55	0.11	4.71	32.35	46.02	2.38	2.211678	0.21	17.04	2.27	0.44	35.00	3.75	0.05	70.40
5	1.19	60.10	5.50	0.12	24.37	30.05	48.57	2.52	2.744102	0.22	19.52	3.69	0.33	32.24	2.05	0.06	79.23
6	1.11	61.14	5.45	0.12	25.04	30.36	42.57	2.67	4.264353	0.23	21.24	2.98	0.51	21.78	2.64	0.07	91.36
7	1.12	50.02	5.88	0.15	29.04	33.35	40.66	2.87	2.798283	0.25	23.79	3.41	0.50	34.19	3.69	0.09	70.55
8	1.13	60.62	5.73	0.17	36.37	34.05	29.66	3.09	1.793788	0.27	28.28	4.40	0.42	39.15	2.77	0.12	82.10
9	1.05	64.79	5.64	0.22	45.69	34.36	22.20	3.49	3.400646	0.30	35.31	5.05	0.56	20.63	2.92	0.28	91.37
10	1.50	42.54	5.39	0.087	10.71	18.05	73.32	1.23	1.163295	0.112	10.30	2.19	0.36	23.43	3.81	0.06	54.48
11	1.45	41.44	5.23	0.096	15.77	20.38	65.00	1.91	0.93701	0.17	12.99	1.40	0.27	19.61	2.80	0.05	59.13
12	1.42	51.15	5.07	0.102	17.37	22.63	62.04	2.10	1.960825	0.18	14.38	1.96	0.37	14.72	1.59	0.08	68.33
13	1.39	45.95	5.61	0.11	20.37	28.36	54.31	2.29	1.525873	0.20	16.02	3.08	0.34	25.09	3.11	0.08	61.61
14	1.42	40.52	5.52	0.114	24.03	30.04	48.00	2.43	1.709044	0.21	18.06	2.47	0.45	30.21	4.17	0.05	70.88
15	1.40	52.54	5.47	0.12	25.37	31.27	45.53	2.62	2.360143	0.23	20.61	2.87	0.58	21.30	2.62	0.07	83.09
16	1.39	48.10	6.28	0.14	26.70	33.68	39.57	2.74	1.944002	0.24	22.35	1.70	0.35	20.96	3.20	0.05	65.45
17	1.32	51.32	5.85	0.15	35.37	35.36	29.34	2.93	1.978819	0.25	26.23	3.68	0.43	35.45	4.10	0.21	74.33
18	1.35	57.60	5.67	0.18	41.71	40.05	20.35	3.21	3.155239	0.28	29.35	3.79	0.60	18.93	3.15	0.12	82.06

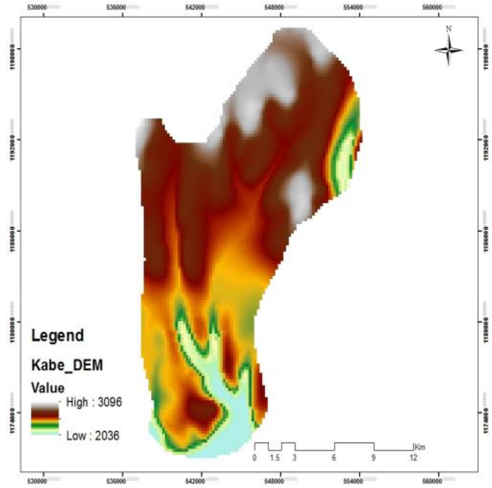
Appendix 16: Mean Annual Precipitation (MAP) in Kabe watershed Result



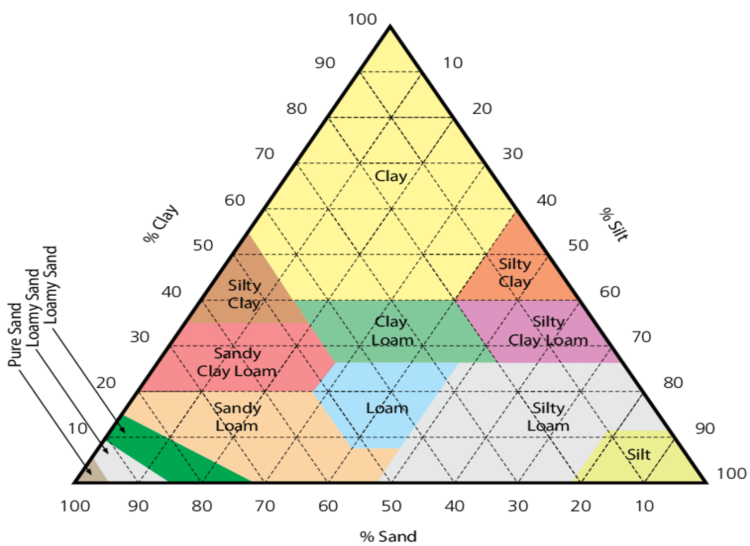
Appendix 17: Flow accumulation of RF in Kabe Watershed Result



Appendix 18: Digital Elevation Model (DEM) in Kabe watershed Result



Appendix 19: Soil textural classification triangle



Soil textures are based on their composition. The 12 types are:

- Sand
- Silt
- Clay
- Loam
- Sandy loam
- Clay loam
- Silty loam
- Sandy clay
- Sandy clay loam
- Loamy sand
- Silty clay loam
- Silty clay