DILLA UNIVERSITY

COLLEGE OF AGRICULTURE AND NATURAL RESOURCE

DEPARTMENT OF NATURAL RESOURCES MANAGEMENT POST GRADUATE PROGRAMME

ANALYSIS OF THE SOIL AND WATER CONSERVATION STRUCTURAL DESIGN AND ITS EFFECT IN RESPONSE TO LAND USE AND LAND COVER CHANGES: THE CASE OF GIDABO RIVER SUB-BASIN

BY:

GETAHUN HASSEN ABBADICO

FEBRUARY, 2022

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A DISSERTATION SUBMITTED TO DEPARTMENT OF NATURAL RESOURCES MANAGEMENT OF DILLA UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (PHD) IN NATURAL RESOURCES MANAGEMENT FOR SUSTAINABLE AGRICULTURE

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CHAPTER THREE

CHAPTER FIVE

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Dedication

I dedicate this work to my father, Hassen Abadico, and my mother, Mulunesh Dolango, who passed away during my study period. This dedication is a symbol of appreciation for their investment to grow me up, love, and care during my all academic journey. I will never forget you. I can imagine your happiness, had you been alive. Rest your soul in Peace!

Declaration

I declare that "Analysis of the Design of Soil and Water Conservation structures and its effect in Response to Land Use and Land Cover Changes: The Case of Gidabo River Sub-basin" is my own work and that all the sources that I used are acknowledged. Also, the work or any part of it has not been previously submitted to any other institution.

GetahunHassen __________ Date 18/2/2022

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List of Acronyms and Abbreviations

AM: Adaptive Management

CBPIWM: Community Based Participatory Integrated Watershed Management

CMM: Community Mass Mobilized

DAP: Diammonium Phosphate

DN: Digital Number

ENVI: Environment for Visualizing Images

EPA: Environmental Protection Authority

ERDAS: Earth Resource Data Analysis System

ET: Evapo-Transpiration

FDRE: Federal Democratic Republic of Ethiopian Government

FFW: Food for Work

GEI: Google Earth Imagery

HH: Household

IAEA: International Atomic Energy Agency

IPCC: Intergovernmental Panel on Climate Change

ISDR: United Nations International Strategy for Disaster Reduction

IUCN: International Union for Conservation of Nature

IWM: Integrated Watershed Management

Land Sat 5 (™): Land Sat Thematic Mapper

Land Sat 8 (OLI): Operational Land Imager

LDNR: Land Degradation Neutrality Report

LLPPA: Local Level Participatory Planning Approach

MEA: Millennium Ecosystem Assessment

MERET: Managing Environmental Resources to Enable Transition

MoARD: Ministry of Agriculture and Rural Development

NIR: Near-Infrared Radiation

OECD: Organization for Economic Cooperation and Development

PSNP: Productive Safety Net Programs

REDD: Reducing Emissions from Deforestation and Forest Degradation

SBD: Soil Bulk Density

SLMP: Sustainable Land Management Programme

SSA: Sub-Saharan Africa

SSW: South-Southwest

SWIR: Short-Wave Infrared

TIRS: Thermal Infrared Sensor

UNCCD: United Nations Convention to Combat Desertification

UNDP: United Nations Development Programme

UN-ESCAP: United Nations Economic and Social Commission for Asia and the Pacific

UNESCO: United Nations Educational, Scientific and Cultural Organization

UNFCCC: United Nations Framework Convention on Climate Change

WMO: World Meteorological Organization

Abstract

Gidabo River sub basin is an area characterized by rugged topography, dense population and indigenous agroforestry system in the Ethiopian Rift valley region. Though different soil and water conservation (SWC) efforts and investments are underway, land degradation and food insecurity problems are increasing that threaten the sustainable development of the area. Moreover, evidence of the causes of soil erosion and success or failures of conservation efforts across different agroecology (altitudinal belt), and soil conservation practices were not sufficiently studied. The objectives of this study were; therefore, to investigate the status, dynamics, drivers, and implications of land use and land cover change (LULCC) of the past thirty-three years (1986-2019) and identify the implemented physical SWC technologies, and design in respect to the standard as well as constraints of conservation practices. In addition, the investigation was carried out on the effect of the physical SWC work on the soil properties along with different agroecology. The study employed an interdisciplinary approach. Data were collected from primary and secondary sources such as Land sat 5 (™), and Land sat 8 (OLI), household surveys, key informants, focus groups, field measurements, lab work, and field observations. For the household survey, 280 participants were selected using a multistage sampling approach. Quantitative data were analyzed by using mean, ANOVA, and chi-square, whereas the qualitative data were analyzed using content analysis. The study revealed that in the past 33 years, about 34% of the area was changed to other land use and land cover (LULC) classes. This implies agroforestry, settlement, forest, and bare land cover were expanded at the expense of shrub/woodland, grassland and cropland classes. For the study period, the highest increment by (14%) and the highest reduction by (10.3%) was observed in agroforestry and shrub/woodland classes respectively. The finding indicated that the LULCC of the area was ultimately driven by the interplay of biophysical, socio-economic, and political factors. Though newly introduced SWC practices have been implemented in 2005 under Safety net and active community participation programme the conservation work is not fully successful in supporting the agroforestry system and improving soil property compared to the existing socio-economic and environmental conditions of the area. The factors that contributed to the problems are small land size, high population pressure, poor adoption of the standard design and principles of SWC, lack of technical skill on the introduced SWC work, lack of labor force, food insecurity, poor access to agricultural inputs, and lack of interest in agricultural work among the youth. Though all these problems commonly found in the study area the levels of constraints were significantly varied along different agroecology. Therefore, the study recommended that a joint effort is needed among all stakeholders (policymakers, political leaders, experts, and farmers) in a way to solve the local constraints and support the agroforestry system. Also rigorous efforts are required to apply the standard design and principles of SWC practices based on agroecological variations that suit for the sustainable development of the area.

Keywords: Design of Conservation Structures, Land Use and Land Cover Change, SWC guideline, Soil Erosion, Soil property

CHAPTER ONE

1. Introduction

1.1 Background of the study

Human impact on land use and land cover change (LULCC) has been recognized since the Neolithic period (first agricultural revolution) (Smith & Zeder, 2013; Lambin et al., 2006). Though LULCC happens due to natural or human factors, human activities are the primary forces of the change (Kabba & Li, 2011). According to Zahara et al. (2016), the extent, intensity, and rate of LULCC are more significant and complicated than they were in the past. LULCC has been occurring rapidly, involving the conversion of forestland to agricultural land, rangeland, grassland, and woodland to bare land and vice versa (Lambin et al., 2003). The change is faster and more noticeable in developing countries (Ellis, 2013; Lambin & Meyfroidt, 2011).

In Africa, the conversion of forest to agriculture and pastureland accounted for about 75 million hectares between 1990 and 2010 (FAO, 2010).Ethiopia is one of the African countries that have experienced rapid and progressively noticeable LULCC since the second half of the 20th century (Mintaet al., 2018). LULCC has both positive and negative impacts on socio-economic and environmental conditions (Lambin& Meyfroidt, 2011). Many research reports indicated that the LULCC that was not supported by the physical and biological conservation work has a higher probability for the adverse impact of LULCC. According to Kindu et al. (2018), LULCC is one of the significant factors in natural resource degradation, threatening biodiversity (Yirsaw et al., 2017), deforestation (Rands et al., 2010), environmental disasters such as intensive soil erosion and landslide (Meshesha et al., 2014) and climate change (Bringezu et al., 2014).

The Ethiopian environmental protection authority (EPA) report (2012) showed that the Ethiopian ecosystem is beyond carrying capacity primarily due to the high population growth, LULCC, cultivation on steep slopes, deforestation, soil degradation, and climate change. Particularly, LULCC is the major factor for socio-economic and environmental problems of the country (Bekele et al., 2018). According to Yesuf et al. (2008), 1 billion m^3fertile top soils were lost per annum in the country which is mainly caused by a land cover change (deforestation), poor agricultural system, poor land management, and high population growth. LULCC and related factors caused environmental disasters such as intensive soil loss of cropland that is about 20,000–30,000 tons/ha/yr, and about 2 million hectares of land that had been extremely degraded and was unsuitable for crop production (FAO, 1986).Therefore, it is important to understand the past through research on historical LULCC, which in turn helps to manage the present and predict future land use (Nigatu (2014).

According to Alemayehu (2009) data of the past on land use and cover patterns are means to evaluate the complex causes and responses to the future trends of human activities and LULCC. In this regard application of tangible and continuous conservation actions on the protection of soil, water, and other natural resources and measuring the effect of conservation work has got higher recognition to guarantee food security to many people (Obalum et al., 2012; Pender et al., 2006). According to Mango et al. (2017), after World War II (WWII), the introduced soil, and water conservation (SWC) measure has been a widespread development program in many developing countries to tackle land degradation through soil erosion.

The government of Ethiopia has given high attention to the SWC measure to be used as a leading natural resource conservation strategy. In Ethiopia, the traditional natural resource conservation activities hold very old age (Hurni et al. 2016). However, institutional-based and large-scale SWCs such as soil or stone bunds, trenches, and ex-closures began in the 1970s and 1980s under the practices of integrated and participatory watershed management (Assefa & Hans-Rudolf, 2016; Haregeweyn et al., 2015; Mekonnen et al., 2014). Though modern conservation had been introduced before the 1970s, still now, the conservation work could not be fully achieved in many areas as long as its age (Elias, 2002). Therefore, intensive and systematic research on the effectiveness of SWC practices in response to LULCC and soil fertility at specific watersheds is a timely and relevant issue.

1.2 Statement of the Problem

The Gidabo River sub-basin is found in the rift valley region of Ethiopia where farming activities have a long history and residents would continue farming (Kippe, 2002). Moreover, the area has an exemplary indigenous agroforestry system and source of water for the multi-billion birr invested Gidabo dam. The area has been affecting by problems such as reduction of productive capacity of agroforestry, and expansion of commercial farming (Bishew 2013); slow transformation of indigenous knowledge and partly migration to the urban area (Legesse,2013), reduction of indigenous knowledge (Maru et al., 2019; Gashaw et al.,2014); expansion of land degradation (Gashaw et al., 2014; Alemayehu, 2003); less productivity of the cropland (Ademe et al., 2017); increment of the annual mean base flow and reduction of percolation (Aregaw et al,.2021); and high population pressure (Ketema, et al.,2020; Temesgen et al.,2018).

As a result, the majorities of inhabitants' in the region cultivates marginal lands, suffers from food insecurity, and are forced to migrate partly from their residence (Alemayehu, 2003). Different studies indicated that SWC practices undoubtedly have a significant role in increasing agricultural production in the areas where agriculture is hindered by erosion, drought, low soil fertility, and moisture stress (Ademe et al., 2017; Mekonen & Tesfahunegn, 2011). In the Gidabo River sub basin traditional SWC practices have been implemented for several years (Beshah, 2003; Kippe, 2002). But the data from the local community and development agents showed that watershed based SWC work has been introduced in the area following the community-based SWC approach and the Safety Net program of 2005 in a way to support agroforestry systems.

In recent years, there has been an increasing recognition for the need for assessment of watershed-based SWC practices of the area, because the area is very dynamic, fragile, and densely populated (Assefa et al., 2018). Despite various researches being carried out on the LULCC, SWC practices, and related factors at the national level, to the best of my knowledge along with the agroecological variation of the Gidabo river sub-basin such studies are very limited. Moreover, evidence of the causes of soil erosion and the success or failures of SWC conservation efforts was not sufficiently studied. According to

Harden, (2014), the local-level study about the complex and immediate causes and indirect driving forces of LULCC is important before any policy intervention.

In this regard, the author used interdisciplinary approaches and analysis of remote sensing along with the perception of local communities to examine the LULC dynamics and its drivers, appropriateness of the design/layout of the SWC technologies, acceptance of SWC work as well as success and failure of SWC structures on soil property improvement. Such a study is vital to understand human-environmental interaction, the responses to the environmental change, and the future sustainability issue of the area.

1.3 Objectives of the study

The overall objective of this study was to assess the design/compatibility, acceptability, and constraints of physical SWC work to curb the adverse impact of LULCC in the Gidabo River Sub-basin of the Ethiopian rift valley region.

Specifically, the study intended to:

- Assess the status, rate, drivers, and implications of LULCC
- Assess the design of SWC in respect to the national guideline
- Identify the constraints to adopt/ adapt the of SWC practices
- Investigate the effects of physical SWC practices on soil property in respect to different agroecology

1.4 Research questions

The research questions were:

1. How LULCC trend is occurring in the study area?
   1.1 What are the major drivers of LULCC in the watershed?
   1.2 What is the adverse effect of LULCC?
2. What are the major introduced SWC technologies used to control the adverse effect of LULCC in the area?
   2.1. How does the applied SWC practice are preventing/reducing the adverse effect of LULCC in the study area?

2.2 To what extent do the implemented SWC measures meet the technical guideline of MoARD (2005)?

2.3 What are the constraining factors for the adoption/adaptation of SWC in the study area?

3. What are the effects of physical SWC practices on the soil's physical and chemical properties?

1.5 Significance of the study

This study includes Spatio-temporal dynamics of LULCC and population-environment interactions in the study of design/compatibility, acceptability, and constraints of physical SWC work to curb the adverse effect of LULCC in the Gidabo River sub-basins. Thus, the result of this study has a significant contribution to the land users, policymakers, practitioners, and scientific community in:-

1. Providing options to understand the trend, implication, and driving forces of LULCC.
2. To keep the standard design and layout of the introduced SWC structures in respect to the standard.
3. Providing a better opportunity to identify the positive and negative effect of LULCC in the area
4. To give an option to readjust the future LULCC and conservation planning in a way to avoid or narrow the adverse effect of LULCC and the constraints of SWC practices for sustainable development in the river basin.
5. Creating a chance to explore the success & failure of the prevailing SWC measures.
6. Predicting the trend, magnitude, and effect of the future LULCC of the study area.
7. Providing significant recommendations for well-organized, farmers' friendly and effective technologies on the future SWC work in the region.
8. Overall, the study is very significant in providing empirical information available on the nature of SWC in response to LULCC in Gidabo River sub-basins, related factors to it, and ways that are helpful to improve land management practices, improve the productive capacity of indigenous agroforestry system, ensure food security and advance livelihood.

1.6 Scope of the study

This research was conducted in the South Eastern rift valley region of the Gidabo river sub-basin. It focused only on examining the dynamics and implications of LULCC from 1986 to 2019 and its driving forces, evaluating the appropriateness, compatibility, and acceptability of the implemented SWC, identifying farmers' constraints to adopt/adapt the SWC activities, and assessing the effect of SWC practices on the physical and chemical fertility of the soil in the river basin.

1.7 Limitation of the study

In the course of data collection, problems were encountered.The major challenges encountered during the study period were political uncertainty (tribal conflict) and the COVID 19 pandemic affected the data collection process through interview and focus group discussion because it was difficult to secure the required number of participants. Also, the respondents were showing insecure feelings due to the nature of the disease. Moreover, during the pandemic the lockdown enforced the researcher to stay at home. The other challenge of the study was poor access of transportation to the peripheral study that made it difficult to transport the sampled soil to the urban area. However, the problems encountered were managed in a way it has no significant impacts on the quality of the research.

1.8 Thesis organization

This thesis is organized into five chapters. Chapter one presents background information, problem statement, objectives, research questions, significance, scope, and limitation of the study. Chapter two presents a literature review that focuses on the interaction between humans and the environment; land use and land cover change over time, drivers of the change, land degradation, and conservation approach over time. Chapter three presents the methodology of the study. It includes physical, societal, and economic settings of the study area, research approach and method of fieldwork, laboratory activities, data type, tools, and methods analysis used. Chapter four refers to that result and discussion part of the research. That was focused on data related to the first, second, and third objective that deals with the spatial and temporal dynamics of LULCC and the driving forces of the study area; type, design, and constraints of physical SWC structures in respect to the standard; the effect of physical SWC structures on the chemical and physical soil fertility at different topography. Chapter five refers to the summary, conclusion, recommendation part of the study, and scope for further research.

CHAPTER TWO

2. Review of Related Literature

2.1 Theoretical perspectives of land use and land cover change (LULCC)

The theoretical perspectives of LULCC refer to the time when human and environmental interaction has changed. History depicts that the first LULCC started during the Neolithic age that was carried out in Mesopotamia about 11,500 years ago, which refers to the beginning of the first agricultural revolution (Bowles & Choi, 2019; Smith & Zeder, 2013, Lal, 2008; Lambin et al., 2006). This refers to LULCC occurring since humans have controlled fire and domesticated plants and animals to satisfy the demand for high production with modification/conversion of the land cover (Lambin et al., 2003). The factors such as populations' pressure and the adverse climatic conditions forced the foragers to start farming in a way to improve their living standards (Bowles & Choi, 2019). Since that time the relations between human society and its environment have changed that addresses how the human community has adapted to or changed its surrounding environment to satisfy its needs and how much the environment affects people driving new innovations and techniques (Mortazavi & Negari, 2010).

2.2. The concept and thought of LULCC

Though the concept of land use has high variability in time and space in biophysical environments, socioeconomic activities, and cultural contexts, it is defined by the purposes for which humans exploit the land cover (Lambin, et al, 2003). In the last few decades, the land use concept has been defined as the activities undertaken on a surface that induce land cover transformation and the purpose (function) underlying that transformation (Ellis, 2010; Lambin, et al., 2006). Land cover is the physical material on the Earth's surface, such as water and vegetation (Lambin et al., 2006). Therefore, LULCC is commonly divided into two broad categories: conversion; that is, from forest to grassland, and modification; from natural forest area to planted forest area (Veldkamp & Lambin, 2001). Earlier land use and cover change have normally been considered as a local environmental issue but it is becoming a force of global importance (Foley, et al, 2005).

Thinking about the patterns of LULCC has increased significantly over the last decade (Turner, 2002). The major thinking about human impact on LULCC is 1/Classic 2/Populist 3/Neo-liberal approaches. The first theory refers to the Classic/Malthusian theory, which was familiar between 1950 and 1975. It argues that population increases threats to natural resources and it claims if the demands of a growing human population surpass the capacity of an environmental system to support it, an ecological crisis will erupt (Blanco & Lal, 2010). According to this school of thought, the LULCC and the related problems are associated with population growth and poverty. It refers to a high population number that creates stress on land resources and the cultivation of marginal lands (Blanco & Lal, 2010).The scholars under this theory believed that since local knowledge is unreliable, unreasonable, and nonscientific for natural resources management, it should be replaced by the technocratic solutions that are expert-led knowledge and innovations (top-bottom approach) (Blaikie, 2000). They also recommended the need for population control to reduce the adverse effect of LULCC and manage natural resources (Stephenson et al., 2010).

The second paradigm is referred to as the populist/Ester Boserup theory. This theory was more familiar in the late 1965s. Scholars argued that the land-use change such as increased productive agricultural land was driven by the population growth and scarcity of land (Darity, 1980; Boserup & Chambers 2014). This school of thought further advocates decentralized and community-based approaches as a key strategy to manage the adverse effect of LULCC. This view stresses the positive role of local technologies, experience and emphasizes bottom-up stakeholder participatory interventions in land management practices (Mazzucato & Nineijer, 2000).

The third paradigm is the neo-liberal approach. This theory integrates both classic and populist views. The scholars under this theory advocate adopting or adapting both approaches to reduce the undesirable impact of LULCC through understanding the existing approaches, policies, institutional setups, and regulations of the constraints of the local people to adopt/adapt conservation technologies (Adger et al., 2001). According to Murniawaty (2019), the human land use process needs to be based on environmental ethics, in a spirit of mutual respect between humans and the natural world. Therefore, this study followed the neo-liberal approach as it favors various technologies available for SWC practices. Because wise use of the environment is necessary in order to keep the ecosystem and sustain the biodiversity in the Gidabo river sub-basin.

2.3 Causes of LULCC

According to Hassan et al. (2016), the cause, extent, intensity, and rate of LULCC are more complicated than they were in the past. It is a dynamic and complex process, which can be the product of human activities and/or natural processes (Leh et al., 2013). Land use decision is driven by the physical, social and economic preferences which have an influence at global, national, regional, and local scales (Brown, et al., 2014; Lambin, et al., 2003). In the same way, LULCC drivers are obviously different at different times, landscapes, and regions (Hassen & Assen, 2018). Though LULCC happens due to natural or human factors, human activities are the primary forces of the change (Kabba & Li, 2011).

A number of research reports depicted that the major human-induced LULCC is related to population growth (Meshesha et al., 2014), agricultural expansion (Mustard et al., 2012), global market forces (Lambin & Meyfroidt, 2011), urbanization (Wang et al., 2016) and pasturing (Wassenaar et al., 2007). According to Harden (2014), the natural drivers of LULCC are volcanic eruption, earthquake, landslide, and climate factors. LULCC were further classified as proximate and underlying drivers (Table 2.1). The proximate or direct human-induced drivers of land-use change originate from intended land use at individual farms, households, or communities level and directly affect the physical land cover (Turner et al., 1994). Underlying or indirect drivers support the proximate (direct) causes of land cover change which is the result of the socio-economic and physical condition of human environments (Geist & Lambin, 2002). The underlying drivers of LULCC may operate at the regional or global levels but it operates more at the local level (Lambin & Geist, 2007). In general, the main categories of LULCC causes are biophysical, socio-economic, political, and cultural forces (Lambin et al., 2003; Luck & Wu, 2002).

Table 2.1 Proximate and underlying drivers of LULCC (land use and land cover change)

Drivers/sources of LULCC	Drivers
Proximate and natural drivers	Topography / Steep slopes (Wischmeier, 1976). Climate factors Barrow 1991), Soil (Bonilla and Johnson, 2012), Pest and disease /Pests (Sternberg, 2008).
Proximate and anthropogenic drivers	Unsustainable land management / land clearing, overgrazing, cultivation on steep slopes, bush burning, (Nkonya, *et al.*, 2011; Pender and Kerr, 1998), agricultural expansion and Infrastructural development (Geist and Lambin, (2004).
Underlying drivers	Population density and urbanization (Grepperud, 1996), Market access (Scherr and Hazell, 1994), Land tenure/ Insecure land tenure (Brasselle, *et al*., 2002), Poverty and food insecurity (Nkonya, *et al.*, 2008; Scherr, 2000), access to agricultural extension services (technology) (Paudel and Thapa, 2004), strong local institutions or policies and non-farm employment or alternative livelihoods.

Source: Mirzabaev et al., (2016)

2.4 Effect of LULCC

LULCC has been occurring rapidly, involving the conversion of forestland to agricultural land, rangeland, grassland, and woodland to bare land and vice versa (Lambin et al., 2003). The change is faster and more noticeable in developing countries (Ellis, 2013; Lambin & Meyfroidt, 2011). Ethiopia is one of the African countries that have experienced rapid and progressively noticeable LULCC since the second half of the 20th century (Minta et al., 2018).

Many research reports indicated that LULCC has direct or indirect interactions with land (soil), climate, hydrology, and other variables of the specific environment. According to Lambin & Meyfroidt, (2011) LULCC has both positive and negative impacts on socio-economic and environmental conditions. If LULCC is not carried out scientifically, the negative impacts on the environment and the socio-economic settings of the present and future generations will not easily be measured (Gete, 2000).Moreover, the LULCC that was not supported by conservation work has a higher probability of the adverse impact of the change. For instance, LULCC is one of the major factors in natural resource degradation (Kindu et al. (2018), threatening biodiversity (Yirsaw et al., 2017), deforestation (Rands et al., 2010), environmental disasters such as intensive soil erosion and landslide (Meshesha et al., 2014) and climate change (Bringezu et al., 2014). In general, LULCC interrupts the ability of natural systems to support human needs and increases the exposure of people and resources to climate change, socio-economic crises, and political uncertainties (Lambin et al., 2001).

2.4.1 LULCC vs land degradation

LUCC is the leading issue and hot topic of global change research (Chang et al., 2018). Because it is more complex terms that describe how people use the land, they include several activities that will cause land degradation (Fisher, et al., 2005). Detecting the change is necessary for the assessment of potential environmental impacts (Nigatu, 2014). Most of the earth's surface is already modified except those areas that are inaccessible (Turner et al., 1994). Land cover changes do not always occur continually and gradually but they may show periods of rapid and sudden change that will harm land resources (Lambin et al., 2003).

According to (Sharma 2010) LULCC has significant impacts on regional or local land degradation, including soil erosion, soil acidification, nutrient leaching, and organic matter depletion. In general, LULCC is considered to be the primary force in determining human impacts on land degradation and the climate system (Martínez & Mollicone, 2012). According to Lambin et al. (2003), concerns about LULCC emerged in the research at the global level several decades ago with the realization that land surface processes influence soil, climate, ecosystem, and hydrology. In connection with the point previously mentioned in recent years, environmental changes including LULCC and their impacts on climate, natural resources (hydrology and soil) have gained increased attention (Nigatu, 2014).

2.4.2 LULCC vs the hydrological cycle

The impacts of LULCC on water resources are the result of complex interactions between diverse factors (Kassa & Gerd, 2007). Land cover has various properties that help to regulate water flows both above and below ground (Kassa & Gerd, 2007). LULCC affects the degree of infiltration, interception, surface runoff, evaporation, ground flow and stream flows, annual and seasonal water yield of the watershed (Mengistu et al., 2009).In this regard changes in vegetation cover have significant impacts on the surface water budget through evapotranspiration from the land surface and the transpiration from plants into the atmosphere (Aghsaei et al., 2020). High evapotranspiration may intensify or weaken the water cycle that may affect the runoff or hydrological cycle. According to Odongo et al. (2019), forestry plantations determine the catchment hydrology and related water resource management of the specific area.

A study by Lin and Wei (2008) indicated that forest harvesting increased the annual mean and peak flows in the spring periods. Changes in vegetation cover have significant impacts on the surface water budget, especially for evapotranspiration (ET), which is an important component of the terrestrial hydrological cycle (Gaertner, 2019). According to Oki et al. (1999), excess water from land is released into the oceans that use to change the water salinity, temperature, and thermohaline circulation. According to Degife et al. (2019), the canopy structure and diversity of plants of the agroforestry system helps to maintain the hydrology of an area by reducing runoff and erosion.

Change in watershed hydrology is one of the major impacts of LULCC, and it determines the socio-economic and environmental condition of the area (flows of rivers and soil erosion) (Zhou, 2014). For instance, better land use land cover is useful to regulate the flow of waters to the dame. It also reduces the amount of deposition. So, land use and land cover of the Gidabo river sub-basin have a significant impact on the sustainability and productivity of the Gidabo dam in the lower basin. Studies reported by Teklay et al. (2019) and Gashaw et al. (2018) showed that the expansion of agricultural land at the expense of vegetation cover increases the runoff potential in a given watershed that will contribute to soil erosion. The above pieces of the literature indicated that the correlation of land cover and water resources for natural resource conservation.

2.5 Historical perspectives of soil and water conservation work (SWC)

According to Chang et al. (2018), studies on LULCC play important role in the effort of soil and water conservation. Therefore, soil and water resources conservation is an essential aspect for sustainable socio-economic and environmental development (Kumar et al., 2019). Among land degradation types, soil erosion is the most severe problem at the global level, which has different types and forms depending on the erosive agents and processes of erosion (Bantider et al., 2021).Various scientific literature showed that the negative impacts of soil erosion problem on agronomic productivity that was globally understood since human beings started agricultural practices (Lal, 2008). For instance, the recorded archaeological evidence was showed many of the ancient civilizations in Greece, Mesopotamia, Rome and Axum were adversely affected by soils erosion (Montgomery, 2012). According to Dotterweich (2013), agricultural terracing used for irrigation began around 6000 BC that was spread to different parts of the globe.

Among the major historic indicators of SWC work were the ancient terraces constructed for soil erosion control and other purposes in China, Nepal, Africa, Peru, Italy, Spain, Greece, and others (Bantider et al., 2021). For instance in China, terracing for agricultural practices date back to 7000 BC, the Caracol “Garden City” of Belize, which is a terrace in Yemen constructed in the 4th Millennia BC (Wilkinson, 2003; Vogel, 1987), and the ancient Mayan landscapes were constructed between AD 562 and AD 680 (Zhao et al., 2013).

Before several millennia, soil and water conservation practice have begun in Africa, by the indigenous people. Some of the soil and water conservation structure in Africa are the Aksumite Kingdom from 400 BC to 800 AD of the Konso bench terraces (Amborn, 1989), the Chencha-Dorze terraces in Southern Ethiopia (Engdawork & Bork, 2014), Gojam ditches systems, soil bund in Tigray and Hararge highland, North Shewa and to some extent, in Wondo Genet area (Hurni, 2016). The 17thc and 18thc terrace in the

Mandara Mountains of North Cameroon (Riddell & Campbell, 1986), Jebel Marra in Darfur Sudan and the Nyanga hills in South Africa, Nyanga hills of the Central and Northern Nigeria, eastern Zimbabwe, and Engaruka in northern Tanzania (Critchley et al., 1994).

The modern soil and water conservation work have started based on systematic research on soil erosion in Russia in the late 19th century (Golosov & Belyaev, 2013) and in Germany in the 18th Century (Dotterweich, 2013). According to the soil and water conservation society report (1941), Hugh Hammond Bennett, the father of soil conservation began a discussion about the need for support for those working in conservation. In this regard, the first meeting of the soil conservation society of America was held in Chicago in 1946 (Helms, 1985). The scientific knowledge about soil erosion and conservation work attracted the attention of the European countries.

In the early 20th century, much advancement have been made on soil and water conservation technologies that focused on innovations, planning, decision making, institutions, and policies. For instance, the 1994 international soil and water conservation congress was a milestone to advance the soil and water conservation approach and philosophy such as interdisciplinary approach, adaptive, innovative and sustainable land management approaches integrative and participatory approach, and bottom-up approaches (Bantider et al., 2021). In the year 1930–1962, the colonial countries introduced the modern soil conservation work at the district level for their raw materials in their colonized countries (Gichuki, 1991). In Ethiopia, in the 1970s and 1980s, among the introduced structural conservation methods Fanya juu and normal bunds are the most common, which aimed to control soil erosion by shortening the length and minimizing the gradient of the slope (Tegegn, 1992).

2.5.1 Historical perspectives of watershed-based SWC

The concept of the watershed has various meanings based on physical, social, economic, and political perspectives which offer life support services to the people (Wani et al., 2008). A watershed can be defined as an area in which all water down a slope to the lowest point/outlet (Darghouth et al., 2008). It also includes the people, their land use, planning and management, environmental management, and productivity (UN-ESCAP, 1997). From the hydrological point of view, the different phases of the hydrological cycle in a watershed are dependent on the various natural features and human activities (Wani & Garg, 2009; Wani et al., 2008).

Watershed-based conservation is the implementation of natural resource management systems for improving livelihoods and promoting beneficial conservation, sustainable use of natural resources (Chisholm & Woldehanna, 2012). SWC practices are the primary step of a watershed management program (Wani & Garg, 2009). The practice of watershed-based conservation dates back to 5000 years when humans were manipulating water and slopes to benefit cultivation and control floods and drought (Darghouth et al., 2008; FAO, 2006). In Europe, the potential of watershed technology started to be fully used at the beginning of the modern era between the 16th and 17th centuries and after WW II, which became an important element of development policies (FAO, 2006). Between 1950 and 1970, big irrigation schemes and hydropower dams were constructed in Asia, Africa, and Latin America to support agricultural development and economic growth (FAO, 2006).

The issue of watershed-based conservation has been gaining increasing significance following a warning from the scientific community in the UN Conference of 1972, 1992, 2002, and 2003, which promote integrated watershed development and alternative livelihood opportunities (Wachs & Thibault, 2009). The watershed-based conservation approach became prominent in developing countries in the 1970s and 1980s typically targeting livelihood improvements, poverty reduction, and resource conservation (FAO, 2006; Darghouth et al., 2008; Tyler & Fajber, 2009). Researchers argue that a watershed development program is considered an effective tool for addressing the global problem of poor infrastructures, scarce resources, high population growth, land degradation, climate change, poverty, malnutrition, and food insecurity (Wachs & Thibault, 2009).

Therefore, watershed-based SWC has evolved and passed through several developmental stages, initially it was the subject of forestry and related hydrology and at this stage, the focus was on “participatory and integrated” watershed conservation. The new generation of watershed-based SWC work is still in its infancy, or at best its adolescence stage in relation to constraints different at the local levels (FAO, 2006).In this regard, soil and water conservation practices are the principal steps of the watershed management program.

Soil and water conservation work refers to the in-situ management such as the construction of contour bunds, graded bunds, field bunds, terraces, broad bed, furrow practice, and other soil-moisture conservation within agricultural fields. The ex-situ management includes the construction of check dam, gully control structures, pits excavation across the stream channel, and farm ponds that protect land degradation, improve soil health, and increase soil-moisture availability and groundwater recharge (Wani, & Garg, 2009).

2.5.2 Principles of watershed-based SWC practices

Watersheds are dynamic systems that are characterized by diverse interactions and spatial relations between humans and the environment that manifest as mixtures of different land-use systems, socioeconomic, cultural, and environmental relationships, flows, and conflicts between the upper and lower parts of a watershed (FAO, 2017). Watershed management is a practice that involves management of land, water, biota, and other resources in a defined area for ecological, social, and economic purposes that institutional, social, economical, and biophysical interaction among soil, water, and land use and the connection between upland and downstream areas (Wang et al., 2016; Folliott et al., 2002). The principle of watershed-based SWC is an important part that integrates the component of watershed-based conservation.

According to Heathcoat (2009) and FAO (2017), the principle of watershed-based SWC work refers to:

1. Treat underlying causes (not just symptoms)
2. Create scientific evidence (don’t rely on common myths)
3. Adopt an integrated approach (continues multi-sectoral, multi-stakeholder, and multi-scale)
4. Confirm holistic planning and implementation for watershed management
5. Search for innovative low-cost solutions and co-financing
6. Ensure institutional arrangements are in place
7. Combine bottom-up and top-down processes
8. Combine traditional knowledge and technical advice through action research
9. Imitate upstream and downstream linkages and compensate for off-site effects
10. Try for gender balance in decision-making
11. Comprise capacity development at all levels
12. Announce a flexible, adaptive, and long-term approach to planning and financing.

2.5.3 Goals and approach of watershed-based SWC practices

The modern natural resource management issues are the underlying uncertainty regarding both cause and effect of resource degradation (Olsson et al., 2019). These uncertainties are the cause for the growing different long-term conservation approaches such as multi-scale, integrative, and participatory resource management (Stankey et al., 2005). One of the approaches for SWC practices is watershed-level conservation. In this regard, any soil and water conservation plans should take into account different principles and adoption approaches that are based on socio-economic and socio-cultural forces before introducing soil and water conservation technologies to create awareness, integrate new technologies with indigenous measures and involve farmers in any decision making processes (Morgan, 2009). The primary goal of soil conservation is erosion control, safe runoff disposal, water retention, fertility improvements, restores the degraded land, and obtaining the maximum and sustained production from a given area of land (van der Esch, 2017).

Erosion is a consequence of how the land is used and is not itself the cause of soil degradation. Therefore, soil erosion should be prevented before it occurs rather than attempting to develop a cure afterward (Danano, 2002). Maintaining the natural rate of soil erosion to the rate of soil formation is the ultimate goal of controlling soil erosion by water including reducing raindrop impacts on the soil, reducing runoff volume and velocity, and increasing the soil's resistance to erosion (Troeh et al., 1980; Morgan, 2009). Adoptions of the SWC process have different phases such as the acceptance phase, the actual adoption phase, and the adoption phase. The actual adoption phase has technical principles and approaches such as a barrier approach to check runoff and soil removal using contour-aligned barriers. This approach is commonly introduced to many new areas of Ethiopia and has been practiced traditionally for a considerably long period (Young, 1997).

2.5.4 Integrated approach of watershed-based SWC

The concept of integrated watershed-based conservation is a holistic approach for environmental planning, management, and wise use of natural resources, which has been introduced in the 1980s and is now widely accepted with the active participation of stakeholders within the respective watershed (UNDP, 2013). According to Wani and Garg (2009), watershed-based conservation is the combination of technologies within the natural boundaries of a drainage area for optimum development of land, water, and plant resources to meet the basic needs of people and animals in a sustainable manner or it is the process of advancing the living standard of the community by offering all facilities required for optimum production (Singh, 2000).

For watershed-based conservation, one size does not fit all: different regions of the country can have watersheds that function in very different ways. Even, neighboring watersheds can have major differences in geology, land use, or vegetation that may need very different management strategies (FAO, 2017). Different communities vary in the benefits they want from their watersheds. Therefore, watershed-based conservation principles advocate adopting SWC practices, minimizing or controlling soil loss, harvesting water, and recharging groundwater, applying an improved variety of seeds, integrating nutrient management, and integrating pest management practices. In this regard, integrated watershed management could benefit different watershed management efforts through the provision of contextual integration, better understanding, and opportunity for management of the specific watershed (Heathcote, 2009).

2.5.5 Multi-stakeholder approach of watershed-based SWC

Stakeholders represent all those who have been involved in the utilization and management of resources at different levels, ranging from local to international delegations such as farmers, administrators, researchers, and development agents (Hurni, 2000 & Grimble, 1995). Multi-stakeholder brings together individuals with different views, interests, and positions have the potential to slow the implementation conflict (Vogler et al., 2017). Watershed-based SWC management requires multidisciplinary skills and competencies, which lead to enhanced awareness of the farmers and their ability to consult with the right people when problems arise (Wani & Garg, 2009).

According to Lange et al. (2015), many efforts at SWC fail because they pay insufficient attention to the different stakeholders involved and their particular interests. Multi-level stakeholder approaches are the leading approach to address effective SWC (Lange et al., 2015). A trade-off arises when stakeholders have several objectives towards conservation work that cannot altogether be achieved, which is balancing conflicting objectives or sacrificing cost in terms of benefits inevitable (Grimble et al., 1995). In this approach, since degradation of soil and water resources is a multifaceted problem, ‘multi-stakeholders are vital to finding ecologically sound, socially acceptable, and economically viable solutions at the local level, which is difficult to achieve at the individual level (Zeleke et al., 2006; Hurni, 1993).

2.5.6 Participatory watershed-based SWC

There is no universal model for participatory planning and implementation of watershed-based SWC activities (Achouri, 2002). Participatory watershed-based SWC work may be defined as a process whereby users define problems and priorities criteria for sustainable management, evaluate possible solutions, implement programs, and monitor and estimate impacts (Singh, 2017). In general, participatory integrated watershed-based SWC is a process of conservation, development, and optimal utilization of natural resources in a watershed on a sustained basis, with a multidisciplinary approach (Winnegge, 2005).In recent years, interest in watershed-based SWC approaches is gaining popularity in the continent of Asia, Latin American, and Africa in response to the problem of soil and water resources (German et al., 2013).

In Sub-Saharan Africa, high population pressure, reliance on agriculture that is vulnerable to environmental change, fragile natural resources and ecosystems, high rates of erosion and land degradation, and low yields have increased vulnerability to the degradation of soil and water resource as well as poverty (Liniger et al., 2011). Watershed-based SWC is serving as a framework for enhancing livelihoods through more efficient and sustainable use of water and soil resources in rain-fed areas and upper catchments (Turton & Farrington, 1998). Despite this increase in interest in watershed-based SWC work, the large range of projects and approaches falling under this umbrella has led to confusion in goals, lack of consistency in approaches, and limited success in putting the concept into practice (Rhoades, 2000).

Approaches for operationalizing watershed-based SWC in ways responsive to local natural resource management concerns and focused on multiple interests are greatly needed (German et al., 2013). Moreover, the time-space interactions between plots and common-pool resources, lateral flows of materials, and interdependence between users in terms of resource access and management require decision-making and intervention strategies beyond the farm level (Johnson et al., 2002).

Latter, the issue of watersheds based SWC on “participation” and “integration” become an important element of conservation works (German et al., 2013). Participatory integrated management of soil and water resources at watershed scale provides various benefits in terms of increasing food production, improving livelihoods, protecting the environment, and addressing gender and equity issues along with biodiversity concerns

(Rockstorm et al., 2007). Though the value of soil differs, traditionally, soil conservation has been targeted in controlling land degradation and keeping the soil in place for crop production. Nowadays, soil conservation is evaluated in terms of increasing crop yields, reducing water pollution, and mitigating greenhouse gases (Blanco-Canqui, 2010).

2.5.7 Effect of watershed-based SWC practices

The overall aim of watershed-based SWC practices is to avoid soil degradation, restore soil productivity, improve the standard of living of the population, and ensure sustainable natural resource use within the watersheds (Alemayehu et al., 2009). So, watershed-based soil and water conservation practices are the primary steps of watershed management programs (Wani & Garg, 2009). Similar studies made by Liu et al. (2008) and Nyssen et al. (2008) have shown that SWC practices have controlled soil erosion, improved hydrology and land productivity of the watershed. Thus, the effects of SWC are various and more subjective. Some conservation practices may have an immediate effect, some may delay and some may produce no monetary impact or value but may have aesthetic effects (Troeb & Donahue, 1991 cited in Dmda, 2001). Soil conservation has become an integral part of land use and receives support within environmental, social, and economic impacts, which is conducive to the maintenance and improvement of soil capital (Dudal, 1981).

The physical effect of SWC measures can be classified into short- and long-term, in-situ and offsite areas, based on the time needed to become effective against soil erosion (Nyssen et al.2007). According to Nyssen et al. (2007), short-term effect of stone bunds is the reduction in slope length and the creation of small retention basins for run-off and sediment. These reduce the quantity and erode the capacity of overland flow. Such effects appear immediately after the construction of the stone bunds and reduce soil loss. The medium- and long-term effects include the reduction in slope angle by formed bench terraces, development of vegetation cover on the bunds and gullies, and change in land management (Seid, 2010).

The social effect of SWC are the foundations for any successful and sustainable land management that often depend on the adaption and social acceptance of that system by the communities (Benstone et al., 1998 cited in Motavalli et al., 2013). The factors such as knowledge, education, geographic variation, social relationship, and time determine the social acceptance/effects of soil and water conservation technology (Gusti, 2016). Social effects of soil and water conservation practices are also reflected through improving crop yield, increasing total cultivable area, ensuring food security, and improving livelihood.

Productivity and conservation objectives are highly complementary because conservation of soil, water, and natural vegetation leads to higher productivity of crops and livestock and thus improvement of livelihoods and social stability (Wolka, 2014). According to Ellis-Jones and Tengberg (2000), assumption without any soil and water conservation crop yields will decline approximately by 1.5% year-1, being equivalent to a 30% decline over 20 years, which is thereat for the farmers' livelihood.

The economic effectt of SWC is occasionally overlooked because economic uses of the conservation are not readily identifiable. After all, soi1 conserving practices often provide long-term benefits in exchange for the immediate cost. It needs wise thinking to balance the obscure costs of operation against the obvious costs of acting to conserve soil (Troeh & Donahue, 1991 cited in Dmda, 2001). Therefore, the use of conservation practices in agricultural production is determined by the different income-earning strategies themselves, and in combination with some of the biophysical and socio-economic conditions (Jansen et al., 2006).This shows the value of soil conservation for preserving productive potential may vary for different parts of a single field; hence the value of soil loss due to erosion may also vary because the value of the soil itself varies over space (Dmda, 2001).

However, the present problem of land degradation indicated that SWC is the issue of ensuring ecosystem services and survival (Morgan, 2009). A conservation technique may be regarded as successful if it reduces the rate of soil loss (Young, 1997; Morgan, 2009).

According to Rosevelt (1937), a nation that destroys its soil destroys itself; therefore, investment in soil conservation is not just for farmers (land users), policymakers, experts, or other individuals but for all life on earth.

2.6 Empirical review of LULCC and SWC

2.6.1 Global characteristics of LULCC

Though there is a lack of standardized global assessment and monitoring systems various studies are indicating the impacts of past, present, and potential future of LULCC (Brovkin et al., (2013).The report by Ellis et al. (2011) and Shevliakova et al. (2009) showed that about one-third of the global land surface has already been altered by land use and land cover changes (LULCC) primarily through deforestation and replacement of natural vegetation with cropland and pastures). According to Lambin et al., (2003), the magnitude of LULCC is large. Estimation shows since the 1850s 6 million km2 of forests/woodlands and 4.7 million km2 of savannas/grasslands/ steppes have converted to croplands. According to, FAO (2010) estimation in the 1990s the world's natural forests decreased by 16.1 million hectares per year.

After the second half of the 20th LULCC and the related problem are significantly affecting the global people that have been a serious concern of the world (Nkonya et al., 2011). On a global basis, land degradation through soil erosion is caused primarily by the land surface activities that lead to LULCC, such as overgrazing (35%), agricultural activities (24 %), deforestation (30 %), fuel wood (7%), and industrialization (4%) (UNCCD,1994). For instance, land degradation mainly caused by LULCC is affecting about 16% of the world's agricultural land (UNDP, 2002). According to UNDP (1992), the adverse impact of LULCC affects the productive, physiological, cultural, and ecological functions of land resources such as soil, water, plants, and animals of the global community. Moreover, the problem is stronger in developing countries (Gedion, 2000).

2.6.2 LULCC in Africa

Understanding how land cover and land use conditions vary in space and time is challenging because it requires more local information that can be estimated using remote sensing techniques and socio-economic data (Sleeter et al, 2018). In Africa, the conversion of forest to agriculture and pasture land accounted for about 75 million hectares between 1990 and 2010 (FAO, 2010). Research confirms that Africa is the most vulnerable continent to the land cover change caused land degradation in the world (Reed & Stringer, 2016; Stringer & Dougill, 2013). The most frequently mentioned causes for land degradation in Africa include high deforestation, overgrazing, cultivation of marginal land, high population growth, and poor land management, which are among the majors (Liniger et al., 2011; Kiage, 2013). According to (FAO, 2005) in the past few decades, the conversion of grassland, woodland, and forest into cropland and pasture has risen dramatically, especially in developing countries where a large proportion of the human population depends on land (soil) for their livelihoods.

The problem of land degradation becomes a critical socio-economic and environmental challenge in Africa that was related to the conversion of forest or grassland to cropland (UNDP, 2013).Though Eastern African (Sub-Saharan) region contains 60% of the global uncultivated arable land the LULCC of the area comprises the conversion of woody natural habitats to less-woody cultivated land (Bughin et al, .2016). The report by FAO, (2010) showed that in East Africa, nearly 13 million hectares of original forest were lost between 1990 and 2010 and the remaining forest is fragmented and continued to be under threat. This region is believed to be the leading in the problems of land degradation (Kirui & Mirzabaev, 2014). The report by Kirui & Mirzabaev (2014) and Anteneh (2011) showed that the land cover change caused a problem of land degradation contributed to the severe poverty and further marginalization of rural people in sub-Saharan Africa. In this regard, in Sub-Sahara Africa, all inhabited land is prone to soil and environmental degradation (van der Esch et al., 2017; FAO 2004).

2.6.3 LULCC and its implications in Ethiopia

The report by Harden, (2014) showed that regional level study about the complex and immediate causes and indirect driving forces of LULCC is important before any policy intervention. But still, there has been no comprehensive assessment of regional LULCC, long-term trends and implications have not yet been quantified (Bullock et al. 2021).Ethiopia is one of the countries in the Sub-Saharan (East African) regions that have suffered severe deforestation and degradation from increased demand for fuel wood, construction wood, and cropping and grazing land (Wogayehu, 2003).In Ethiopia, LULCC is related to two interlocking human and the natural system (Fitsum et al., 1999). According to Alemayehu et al. (2019), the increasing demand for land and related resources often results in changes in land use and cover of the country. In this regard, the smallholder agriculture and soil degradation problem of the country can be seen as a direct result of the past and present LULCC practices (Nigatu, 2014).

Currently, almost all the natural resources of Ethiopia are under pressure due to, increasing population numbers, severe deforestation, and loss of biodiversity and ecosystem services (Wassie 2020). Accordingly, these would cause the loss of forest cover and greater hydrological variability (Kim & Kaluarachchi, 2009). According to the Ethiopian Highland Reclamation Study, LULCC factored soil erosion, before 22 years ago, and revealed that 20,000–30,000 hectares of cropland were being uninhibited annually by soil erosion (FAO, 1986). The report by EPA, (2017) showed that the average annual soil erosion rate was estimated at 12 tons per ha. Because once forest land is converted to agriculture, erosion rates increase following the removal of vegetation, overgrazing, and continuous cultivation (EPA, 2012). The report by Tekle, (1999) showed that LULCC and the related land degradation by soil erosion are causing serious consequences of persistent food insecurity, environmental hazards, such as frequent drought, famine, and social crisis in the country. According to Bojo & Cassels, (1995) LULCC related soil erosion caused Ethiopia to lose about US$ 106 million/year. The economic impact of soil erosion is more significant in Ethiopia due to the lack of capability to protect the existing nutrients and replace lost nutrients.

2.6.4 Global response to the adverse impact of LULCC

One of the implications of the adverse impact of LULCC is land degradation /soil erosion (Cebecauer & Hofierka, 2008). The choices about land use and land management have a significant effect to reduce the negative impacts of the change on the environment and human life (Brown et al., 2014). Particularly natural resource management practices such as soil and water conservation have opportunities to increase the net uptake of carbon from the atmosphere by increasing the amount of area in ecosystems with high carbon content (Brown et al, 2014). According to Vu.Q et al. (2014), since the United Nations Conference on Environment and Development of 1992, continuous efforts have been carried by the global community to hold land degradation challenge but the effort is not fully achieved to the extent of the problem. According to Friedrich et al. (2007), the degradation of natural resources was discussed at the global level concerning the achievement of the millennium development goals.

Also, in 2012 and 2015, the UN has made the necessary decision to manage land degradation summit in New York, aiming at more concerted management of land resources than ever before in a way to achieve the UN sustainable development goal (UNCCD, 2015). Based on the Rio (2015) conference that focused on the adoption of land degradation neutrality, the sustainable development goal implies the environmental importance and the conservation dimension. Application of the global goal into national ones will help to solve the challenges of land degradation, desertification, and drought at the center of the conservation sector and will provide energy towards more integrated responses to climate change and the other major environmental crises of our time (IUCN, 2015).

Research report indicated that the global efforts to reduce/prevent land degradation with proper conservation practices are promising in the future. For instance, in the past three to four decades, about 2.7% of the world’s land areas have been rehabilitated (Le et al., 2016). The IUCN (2015) report showed that nature conservation actors should play a leading role in ensuring the use of integrated ecosystem management approaches to achieving land degradation to ensure sustainability at all levels, optimize synergies, and avoid unwanted trade-offs. Since sustainable development has become the motto in international discussions, several approaches to sustainability assessment have been developed (Becker, 1997).

2.6.5 Watershed based SWC in response to the adverse impact of LULCC in Ethiopia

According to De Barry (2004), studies on watershed management should give a detailed evaluation of the specific processes, influences, and problems in the watershed. This process includes steps for assessing various resources, investigating the history of the watershed, detecting issues, and describing its features within the watershed (Watershed Professional Network, 1999). The Ethiopian government strongly believes in the importance of environmental protection and water and soil conservation campaigns equivalent to building a green economy because it is a means for sustainable development, restoring degraded lands, creating job opportunities, social well-being, and food security. The adoption of watershed-based SWC in Ethiopia has attracted much attention from policymakers because soil erosion becomes a key problem for agricultural production and national development (De Graaff et al., 2008).

In Ethiopia, land conservation has received policy attention particularly following the 1970s famine, and targeted to the improvement and conservation of the biophysical environment and ensuring sustainable development in the agricultural sector and its economy at large (Demeke, 2003). Planning the development of watersheds for Ethiopia has started in the 1980s that aimed to the rural land rehabilitation, natural resource conservation, and development programs but large-scale efforts remained mostly unsatisfactory due to several factors, such as the government-led, top-down, poorly planned watershed, and incentive-based (food-for-work) approach, that focused on engineering measures (reducing soil erosion) (Gebregziabher et al, 2016).

The approach also lacks active community participation, the reluctance of stakeholders, and a lack of manageable planning (Habtamu, 2011). As a result, the minimum planning and sub- or micro- watershed approaches were familiarized and tested at the pilot stage through FAO technical assistance under MoARD from 1988–1991. This was the first step in the advancement of the participatory planning approach to watershed development in Ethiopia. The local Level Participatory Planning Approach (LLPPA) has been approved by the government, NGOs, and bilateral organizations to cope with land degradation and food insecurity in several regions (MoARD, 2005). In the early 2000s, community-based integrated watershed development was announced to realize broader integrated natural resource management and livelihood improvement objectives (Gebregziabher et al., 2016).

The overall objective of community-based participatory watershed development is to improve the livelihood of communities or households in rural Ethiopia through comprehensive and integrated natural resource development (Lakew et al., 2005). The management also aimed at productivity enhancement measures for improved income generation opportunities, enhanced livelihood support systems, and high resilience to shocks; optimize the use of existing natural resources and untapped potentials in both already degraded areas and the remaining potential areas in the country (Lakew et al., 2005).

2.6.6 Implications of watershed-based SWC practices in Ethiopia

In the present day, in Ethiopia, SWC occupies a very important place because, in some parts of the country, the problem of land degradation has gone beyond all limits of setback and the problem is growing very fast (Hurni et al., 2016). Studies have indicated that biological and mechanical soil and water conservation measures can help to reduce soil loss, regenerate vegetation and increase agricultural production particularly in the arid and semi-arid areas where agriculture is hindered by drought, erosion, low soil fertility, and moisture stress (Gebrekidan, 2003). In 1987, the Ethiopian government has prepared the first SWC guideline in Amharic for the development agents, and the second guideline has established in 2016, which organized region-wide campaigns of SWC (Habtamu, 2011). The conservation activities have been carried out by the Ministry of Agriculture, in the past five decades, on cultivated land with contour (level) bunds, afforestation, and terraces on degraded hills (Habtamu, 2011).

The government of Ethiopia is promoting various conservation technologies and approaches to achieve the national development goal such as agricultural productivity, household food security, and rural livelihoods (Demeke, 2003). Institution-based SWC projects and programs have been implemented in the past 50 years in the country, these are Food-for-Work (FFW) (1973–2002), Managing Environmental Resources to Enable Transition to more sustainable livelihoods (MERET, 2003–2015), Productive Safety Net Programs (PSNP, 2005), Community Mobilization through free labor days since 1998, and the National Sustainable Land Management Project (SLMP, 2008–2018) community mass mobilized campaigned of the 30 days since 2010/11 but none were properly repaired and adopted by farmers (Haregeweyn et al., 2015; Amsalu & de Graaff, 2007; Demeke, 2003).

The choice of the most appropriate conservation measures in a particular situation will be determined by local stakeholders based on the local topographic, soil, and vegetation conditions and socioeconomic context (Namirembe et al., 2015). Effective soil and water conservation practices have considerable benefits for attaining and sustaining food security in smallholder farming through the successful rehabilitation and management of natural resources (Wolka et al., 2013). At the same time, continued use of soil and water conservation is mainly determined by the actual socio-environmental benefits and economic profitability to the land users (Gebrekidan, 2003).

A major requirement in watershed management is establishing soil and water conservation technologies but a selection of the appropriate technology for ecological and socio-economic conditions has not been readily available to farmers and field officers (Namirembe et al, 2015). Ethiopia has great climatic variety; therefore, selecting the right conservation technology for the right place is a key problem for farmers in soil erosion-prone areas (Namirembe et al, 2015).

2.6.7 SWC technologies used in Ethiopia

According to Bantider et al. (2021), the choices of soil and water conservation technologies are determined by the driving forces and intensity of soil degradation of the specific area; such as physical, social, cultural, institutional, and economic factors. Traditional conservation measures are well-known in some parts of Ethiopia. For instance, the Konso people's terracing is a very old practice (Hurni, 2016). In the past half-millennium, large-scale modern conservation work has been implemented such as soil bunds, stone bunds, grass strips, cut-off drain, trees planted at the edge of farm fields, contours, and irrigation. Both soil and stone bunds are structures built to control runoff, thus increasing soil moisture and reducing soil erosion (Bantider et al., 2021; Hurni, 2016). Grass strips reduce runoff velocity, allowing for water to infiltrate and trap sediments. Waterways help to direct precipitation flows along specified pathways in farm fields. Water-harvesting structures include dams, ponds, and diversions used to ensure water availability during the dry season (Haregeweyn et al., 2015).

2.6.8 The farmers' willingness to adopt/adapt SWC activities in Ethiopia

Farmers' willingness to adopt /adapt SWC practices is mainly determined by socio-economic, institutional, environmental, and personal factors (Amare & Simane 2017; Atnafe et al., 2015). For instance, the factors that determine the farmers' willingness to adopt/adapt SWC are awareness of soil erosion problem (Pulido et al. 2014); acess to the markets, and better prices for their products (Jones 2002); educational level, the distance of the plot from residence, labor requirement, plot ownership type, the slope of farm plot, contact with extension workers, participation on conservation work, conservation technology, an incentive for conservation, financial source, knowledge to conservation technique and institutional organization (Moges et al. 2017 and Teffera and Sterk 2010).

In this regard, a better understanding of the factors that influence the adoption of SWC practices has become an important concern of the soil erosion problem (Alemu et al., 2019). Because, natural resource conservation planning failures could threaten the sustainability of conservation work and lead to complete rejection of the measures by the local community (Alemu et al., 2019). Hence, critically considering the short and long-term benefits, success, failure, and constraints of SWC work are very important (Mango et al., 2017).

In recent years, more holistic and integrated landscape approaches that go beyond resource conservation towards improved land husbandry and SWC have been promoted using national guidelines known as Community-Based Participatory Watershed Development/CBPWD (MoRAD, 2005). However, the commonly observed problems among the farming communities for SWC programs are lack of genuine participation, reluctance to maintain conservation measures, and unwilling to take responsibility for maintaining development activities on their own (Danano, 2002). The Ethiopian government is currently encouraging landless youths to organize and own a degraded area to rehabilitate and utilize it in a sustainable manner, which enables to ensure the participation of communities in sustainable management of natural resources (MoRAD, 2005). But still in many areas lack of repair and poor adoption of SWC by farmers is a serious challenge for the newly implementing conservation practices (Abebe & Bekele, 2014).

2.6.9 Opportunities and success of SWC practices in Ethiopia

The problem of land degradation through human-induced factors of LULCC in the world is as old as the history of agriculture. Though conservation of natural resources is not fully effective when compared to the extent of resource degradation, now there is a promising condition to prevent the failure of resource conservation work, particularly in the present scenario. According to Birhanu (2014), one of the promising conditions for successful SWC practices in Ethiopia are the existence of environmental policies (green economic policy), experiences in community-based watershed management of SWC, better institutional setup, and research systems, availability of indigenous knowledge, and scientific technologies, the existence of donor support as well as development partners of soil and water conservation.

Regarding indigenous knowledge, Ethiopian farmers have been aware of soil erosion problems and managing techniques to control soil erosion and conserve land resources as parts of agricultural systems (Metiku et al., 2006). Also, some empirical studies confirmed that the SWC intervention in Ethiopia is increasing crop productivity and considerable improvement of water discharge levels in streams and springs, improving water table levels and reducing sedimentation problems in the water harvesting ponds and reservoirs, and enhancing income to reduce food insecurity of smallholder farmers (Haregeweyn et al., 2008 cited in Wolka et al., 2015; Kassa et al., 2013).

The Ethiopian government understands the essence of watershed management for soil and water conservation approaches as evidenced by successfully implemented pilot projects that appear promising (Wolka et al., 2015). Significant effort is occurring to repeat 'community-based participatory integrated watershed management' activities in various regions (Wolka et al., 2015). A very recent good example for the positive result of implementing SWC activities in Ethiopia is the Tigray region experiences, which has won Gold and received the certificate of the 2017 Future Policy Award for the world's best effort for tackling land degradation and improving the fertility of dry lands (Daniel, 2017).Tigray region's achievement in restoring land on a massive scale is an interpretation of Ethiopia's development strategy focused on food self-sufficiency and economic growth by conserving land and promoting sustainable agriculture (Fig 2.1). Also, the "Tigray region conservation success shows that restoration of degraded land can be a reality; the model provides hope for other parts of Ethiopia and African countries to follow suit," (Daniel, 2017).

Fig 2.1 Tigray region conservation view
Source: Daniel (2017)

2.6.10 Conceptual framework of the study

Based on the objectives of the research, this conceptual framework has been used to illustrate the modified concept of DPSIR (Driving force–Pressure–State–Impact–Response), developed by the European Environmental Agency of 1999. DPSIR is aimed at analyzing the cause-effect relationships between interacting components of complex social, economic, and environmental systems, and reacting to the problems (Pillman, 2002).

Many nations have adopted Drivers-Pressures-State-Impact-Response to identify the various causal chains of links between human activities and environmental degradation. The model distinguishes several categories of indicators to explain how the state of the environment is changed due to human activities and how human activities increase or mitigate pressure on the environment (Niemeijer & de Groot, 2008). According to the Organization for Economic Cooperation and Development (OECD) report (1994), the DPSIR framework is composed of five basic issues and combines environmental processes and states with human actions in general.

1. Drivers (D) driving forces are the factors that cause changes in the system. Drivers of land degradation are numerous, complex, interrelated, and predominantly local (von Braun, et al., 2013).
2. Pressures (P) are the effects of driving forces that represent processes affecting the resources (land, soil, vegetation, water) by producing substances or emissions through physical and biological agents, which consequently cause changes to the state or the resources.
3. State (S) is the resource itself such as land, soil, vegetation, water resources, and socioeconomic system. Depending on the changes of state, positive or negative consequences for society may occur.
4. Impacts (I) are the consequences that are identified and evaluated to describe using assessment indices and conservation itself.

5. Response (R) is the measures that are important to adopt or mitigate the stimuli, such as the application of watershed management for soil and water conservation activities (Smeets, & Weterings, 1999).

The DPSIR model shows how a driver or driving force exerts pressure on the land resources and as a result, changes the state of the environment or land. The state of the environment or land can have impacts on people's health, ecosystems, and natural resources. These impacts can result in responses in the form of management approaches, policies, or actions that alter the driving forces, pressures, and ultimately, the state of the environment (Bottero & Ferretti, 2010). The model has rapidly become popular among interdisciplinary researchers, policymakers, and stakeholders for structuring, communicating, and assessment of relevant environmental policy, research works, and different kinds of management issues.

Conceptually, the causal-chain framework makes a lot of sense because it helps to categorize and structure environmental indicators and to highlight the causal relationships between humans and the environment (Niemeijer & de Groot, 2008). In other words, the model has a contribution to highlighting the dynamic characteristics of ecosystems and socio-economic changes. Therefore, application of the idea of DPSIR is very important in the research methodology focusing on the evaluation of watershed management practices for soil and water conservation in response to land use land cover change or to evaluate the land use and land cover change, pressures, and potential management responses of the Gidabo River sub-basin.

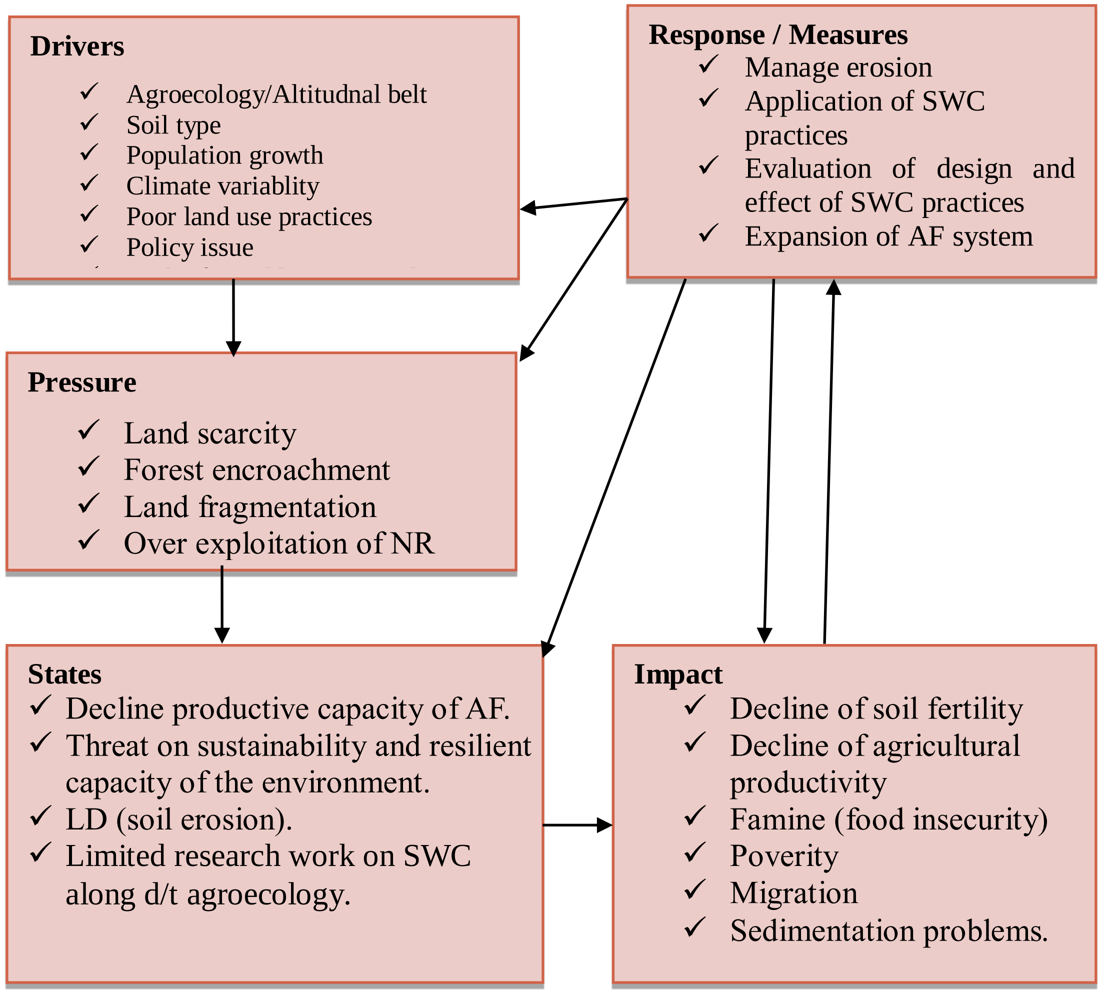

Fig 2.2 Conceptual frameworks on the adverse impact of LULCC and the response to the impact Modified from European Environment Agency DPSIR framework (1998)

CHAPTER THREE

3. Methods and Materials/Methodology of the Study

3.1 Research method and design

The data gathered during the qualitative phase of the study inform the findings of the quantitative review. Similarly, the quantitative results demonstrate the outcomes related to perceptions and experiences shared by participants in the findings of the qualitative data. Therefore reason the researcher used mixed research method and concurrent triangulation design. This method in many situations provides multiple stakeholders and the type of information that they have the most confidence in for use in decision-making (Chelimsky & Shadish, 1997).The concurrent triangulation design was used to give equal priority to the concurrently collected qualitative (QUAL) and quantitative (QUAN) data (Fig 3.7).

The mixed method is important to increase reliability and credibility through the triangulation of different but complementary data on the same topic to better understand the research problem (Morse, 1991). Or it helps to bring together the differing strengths and non-overlapping weaknesses of quantitative methods or it allows cross-validate or substantiates the findings within a study (Creswell & Clark, 2017).

3.2 Description of the study area

3.2.1 Location of the study area

Gidabo river sub-basin is situated in the southeastern Rift valley region of Ethiopia. The area is specified in the limits of 6°11' to 6°34' latitude and 38°12' to 38°32' Longitude. The southeastern rift valley region of Ethiopia is part of the Great East African Rift Valley. The administrative boundary of the Gidabo river sub-basin is in the Southern Nations Nationalities and Peoples and the Oromia Regional States of Ethiopia. The Gidabo river sub-basin covers about an area of 102,738 ha (1027.4 km^2) (Fig 3.1).

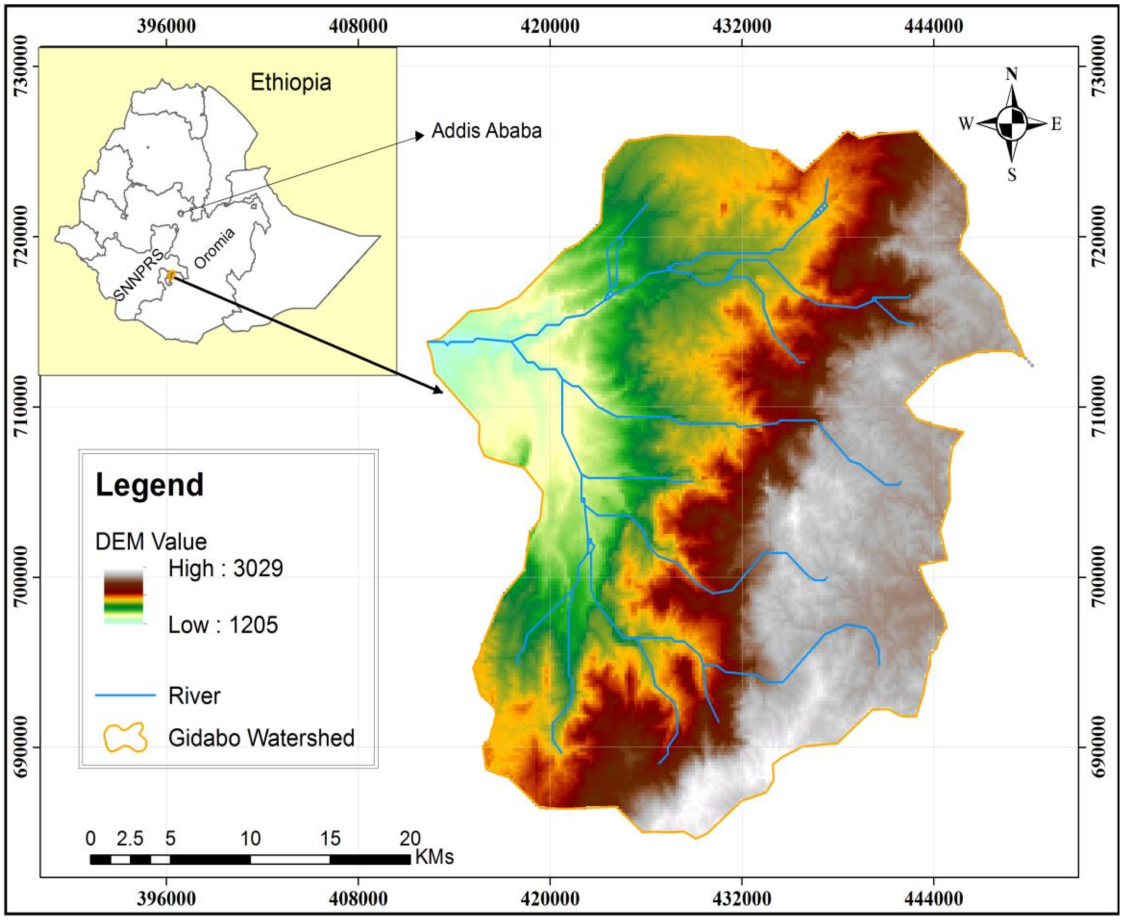

Fig3.1: Location map of the study area

3.2.2 Topography and drainage of the study area

Topographically, the Gidabo river sub-basin landscape can be characterized as one of the rugged topography in the country. The highest altitude of the river sub-basin is about 3029 m a.s.l in the south and the lowest point is 1205 m a.s.l in the west part of the sub-basin. The highland occupies a narrow strip in the eastern part of the catchment forming a flat to the undulating landscape that is slightly dissected with some depressions characterized by seasonal drainage. The escarpment is very steep and marked by major border normal faults. The mountainous escarpment is highly dissected terrain with a dense drainage system. The rift floor is strongly deformed by faults and characterized by rough morphology with narrow uplifted blocks, valleys, and swampy depressions (Mechal et al., 2015).

The geological feature of the Gidabo sub-basin is part of the geological construction of the Ethiopian rift valley, which was formed during the Miocene-Quaternary period. It is mainly the product of different episodes of volcanic eruptions accompanied by tectonic events and sedimentation processes (Mechal et al., 2015). According to Bekele et al. (2018), the area has been highly affected by the late tertiary rifting activity and erosion processes. The report by Ayenew and Becht (2008) showed that the geological and geomorphologic features of the region are related to the volcanic rock (rhyolites, ignimbrites, trachytes basalt, and pyroclast) and lacustrine sediments.

The lithologies of the area can be divided into three major groups: one pre-rift volcanic rock situated mainly in the escarpment, highland and to a lesser extent, in the rift floor which represents the oldest rocks in the area, two the rift volcanic rocks, which are mainly exposed in the rift floor and dominated by silicic volcanic rocks. The volcanic sequences and sediments in the area are densely dissected by extensional fault systems resulting from the rifting process. The major fault types are normal faults having generally similar strikes but some dip to the east and others to the west. Chronologically, they can be grouped into two distinct fault systems. The older, Oligocene-Miocene, NE-SW trending fault system, which characterizes mainly the rift margin and the younger, Quaternary-present, NNE-SSW trending set of faults affecting the rift floor. The drainage system of the basin is strongly influenced by the morphology, which in turn is dependent on the geological phenomena. The stream networks commonly show dendritic drainage patterns that flow from east to west. However, in the southern and northern rift floor, the flow deflects to the northwest and southwest direction, respectively, finally flowing towards Lake Abaya and displays a sub-parallel pattern in the down course sections. There seems to be a strong relationship between the mainstream course and geologic structures in the area.

3.2.3 Hydro climatology of the river sub-basin

According to Mechal et al. (2016), the average annual recharge for 1998–2010 revealed a remarkable decrease from the highland (410 mm/year) towards the rift floor (25 mm/year). The research report by Behailu et al. (2020) showed that in the period from

1985-2018 the surface runoff and evapotranspiration were increased in the study area. Both the spatial and temporal recharge variability is mainly controlled by the climate and land cover. In the rift floor, recharge is found to occur only when annual precipitation exceeds a threshold of approximately 800 mm. A sensitivity analysis reveals that annual recharge is very sensitive to variations in precipitation and moderately sensitive to temperature changes. The relative sensitivity increases from the highland to the rift floor across the watershed. Increases in both precipitation and temperature, as suggested by climate change projections for Ethiopia, appear to have an overall positive impact on recharge in the majority of the catchment (Mechal et al., 2016).

The climate of the Gidabo river sub-basin ranges from humid to sub-humid in the highlands of the escarpment to semi-arid in the low land, which is characterized by warm and wet summer and dry, cold, and windy winter (Mechal, 2015). In Fig 3.2, rainfall data for the last seventy years were collected from three stations named Bule, Wonago, and Dara. The rainy seasons of the study area are characterized by a bimodal pattern. The main rainy (Kiremt in the Amharic language) season occurs from June to September and the small rainy season (Belg in the Amharic language) occurs between Februarys and May (Bekele et al., 2018). According to the information from the meteorological station, the average rainfall of the study area ranges from 900 to 1400 mm in the dry and rainy periods respectively, whereas the average monthly temperature of the area varies from 210C to 250C in the lowland and from 120C to 180C in the highland.

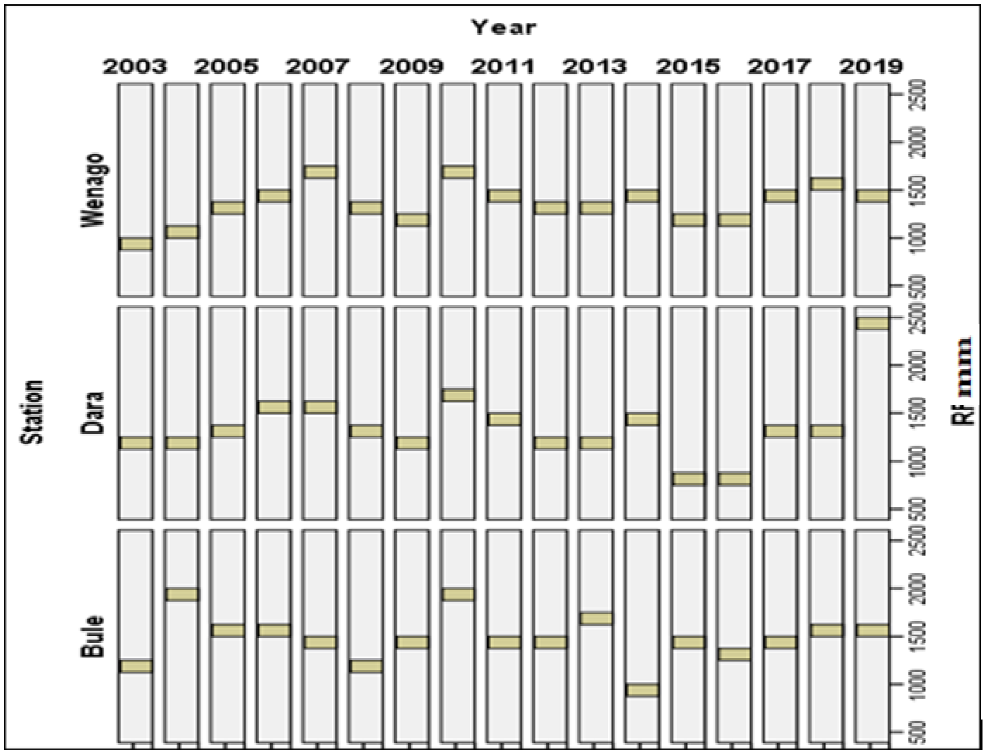

Fig 3.2 Rainfall graphs for different stations

Source: Ethiopian meteorological station (2020)

3.2.4 The socio-economic characteristics

The topographic variation of the area caused economic variation of the people along different agroecology. Though the main economic activity of the river basin is forest-based agriculture (agroforestry), mixed farming (livestock production and cultivation of crops) is the principal occupation of the people in the highland and lowland area of the river basin (Shanka, 2017). Nowadays, agroforestry-based economic activity is highly dominating the river basin that is caused by population growth and variability of climate. The increment of the human population, livestock growth, limited resource, and unsustainable farming techniques in the area forcing farmers to expand their land by clearing bushes and scrubs for crop cultivation, agroforestry, construction purposes, and for fuel as energy resulted in topographic variation (Wolde et al.,2021).

Specifically, in the highland agroecology, farmers are mainly dependent on the production of enset, livestock husbandry (sheep, cattle, and horses), and production of cereal crops and vegetables (potato, ginger, taro, chives). In the midland area, the major livelihood of the community is agroforestry-based agriculture such as enset, banana, coffee, avocado, mango as well as homestead livestock production. Also, fuel wood collection and daily labor in the urban areas are additional livelihood options for the community. The farmers in the lowland are more dependent on annual crop productions such as maize, teff, haricot bean, root crops, collecting fuel wood, charcoal production, and daily labor in the urban area.

In the past few decades, the decline in agricultural production and productive capacity of the agroforestry system increased the food insecure people. Due to this, the Safety Net program, production of fuel wood, charcoaling, and daily labor in the nearby urban area is an increasing livelihood option for survival. A recent report by (Debelo et al. 2017; Degefa 2016; and Legesse 2014) showed that the dominant source of livelihood of the community that depends on agroforestry-based agriculture is losing its productivity due to climate change, high population growth (above carrying capacity for the area), soil erosion, and poor SWC practices. The major sources of income for the households are coffee, enset, fruits, tree products, animals, and animal products (woreda agricultural office, 2020).

3.2.5 Food security conditions of the study area

According to the data collected from the household survey, group discussion, interview, and statistical offices, the area is comparatively better in food self-sufficiency from the surrounding areas because the economy of the inhabitants in the watershed is mainly based on traditional agroforestry systems. The inhabitants obtain most of their feed from the farmland. Research finding indicates that the productivity of the agroforestry system of the area is decreasing due to socio-economic and environmental factors, such as high population density, small land size per household, declining soil fertility (soil erosion), climate variation, heavily (reliance on rain-fed agriculture), and expansion cash crops (Bishaw, 2013). According to the Woreda agricultural and rural development office

(2020) report, besides the above factors, political unrest and insecurity exacerbated the problem of food insecurity and people in certain Kebeles of the midland and lowland area depend on food aid to fill the food deficits. Because the farmers couldn't properly cultivate their land, rather they stay at home.

3.2.6 Social infrastructural development (roads, health centers, and education)

Regarding the infrastructural development of the area, significant changes have been noticed in the study area. The report by Legesse (2013) showed that social infrastructures such as roads constructed, the number of schools established, and health centers built have been increasing. The construction of a road that connects the rural parts to the nearby town is believed to be started in the 1940s following an increase in the demand for coffee in the world market. In this regard, the majority of the people in the rural parts of the study area have access to at least dry weather roads. The commercialization of coffee, fruits, and vegetables appears to be the major motive behind the construction of roads in the area. In the past decade, people are using motorbikes to transport every item from their house to the market center.

In addition to increasing access to primary schools, there has been improvement in access to health facilities. Though two hospitals are found close to the community, Dilla and Yirgalem hospital, access to health stations is increasing in the rural area, which influenced a significant number of people to rely on modern medication. Besides, improvement in road and health care there has been a remarkable development in the number of schools established. For instance, the development of access to primary schools in most parts of the zone helped the majority of children to attend primary education. Yet, most of the secondary schools are found at a far distance from the rural area, the young people attending the school in two ways either travels to schools on daily basis or to stay nearby the schools by renting houses.

3.3 Study Materials

Addressing the complex trends of LULC dynamics and describing the underlying drivers is compulsory to combine biophysical and socio-economic information with remotely sensed data (Lambin et al., 2003). For this research, the study materials such as satellite image, GPs, soil sample collecting materials (hammer probes, plastic bucket, augers, soil sample information sheet, and core rings), note books, pens, topographic map, parkers and camera was used. The satellite image or geographic information system (GIS) and remote sensing data tools (RS) are important materials to obtain data used to compare the historical and current status of LULCC. Also, it is fairly accurate in representing the trends of land cover dynamics than other indicators (Lambin et al., 2006).

To attain the research objectives, satellite images were obtained from Landsat 5 (™) and Land sat 8 (OLI) (Table 3.1). Land sat images (1986, 2000, 2011, and 2019) were downloaded from (https://glovis.usgs.gov/). The criteria to select the year for Land sat images were based on historical events which significantly influenced the LULCC. For instance, the 1986 image has purposefully been selected as a baseline, because of the quality Landsat image and to represent the effect of the formal watershed-based natural resource conservation and development program of Ethiopia in the 1970s and 1980s (Lakew et al.,2005).

Though the Federal government came to power in 1991, the new regime has spent time settling the country after a long time of civil war, formulation of offices, and changing administrative boundaries which slowed down the work of environmental conservation projects. Therefore, the year 2000 image was used to reflect the effect of extensive watershed-based conservation development efforts made by the government and non-government bodies of the military regime from 1974 to 1991 (Lakew et al., 2005).The 2011 image was used to represent the effect of the federal environmental policy that was formally approved in 1997 and the community-based participatory watershed development program of 2005.

The fourth image for 2019 was used to assess the effect of the second community-based watershed managed practices of 2010/2011. This period was known for the 30 days of free labor and massive social movements on watershed management. Also, the 2019 image presented a cut point for the overall effect of the federal government conservation movement from 1991 to 2019. The satellite data selection has been fixed to the dry season, which has a clear sky for the specific years with no cloud cover. Selections of the lowest cloud cover period minimize the cloud effect and associated reflectance (Jensen, 2009). The downloaded images were stacked with all band combinations in the dataset. These data are essential in order to identify the different land use and land cover change dynamics.

Table 3.1 Source of Land sat 5 (™) and Land sat 8 (OLI)

Sensor Type	Path/row	No of Bands	Band combination	Spatial resolution	Acquisition date
Land sat 5 (™)	168/056	7	RGB 432	30 m	5/Jan/1986
Land sat 5 (™)	168/056	7	RGB 432	30 m	28/Jan/2000
Land sat 5 (™)	168/056	7	RGB 432	30 m	10/Jan/2011
Land sat 8 (OLI)	168/056	11	RGB 543	30 m	31/Jan/2019

Source; Downloaded from http://glovis.usgs.gov 2019

3.4 Sources of Data

To address the formulated objectives, the researcher used both primary and secondary data sources. The primary data sources were field observation, field measurement, photographs, soil analysis, household survey, focused group discussion, and key informant interview whereas secondary data sources were published scientific articles, journals, and unpublished literature and reports such as climate, satellite image, demographic and other related data.

3.5 Population of the study area

The study area is one of the densely populated areas in the southern region that holds a large number of populations. According to the reports from agricultural offices and Meshesha et al. (2012) the total population of the study area is about 150,000 and more than70% of the household have 6 to 8 members. The population density in the urban area ranges from 774 to 900 persons per km^2 whereas, in the rural area, it ranges from 300 to 450 persons per km^2. For instance, the 2007 population and housing census result of the CSA showed that the total population of the Gedeo zone increased from 0.4 million to 0.8 million people between 1984 and 2007. Equally, the crude population density increased from 329 persons per km2 in 1984 to 648 persons per km^2 in 2007, indicating the presence of rapid population growth in the area (Kura, 2013).

The household survey result also showed that household size in the highland mainly ranges from 3-8 people, in the midland 2-12 and the lowland it is from 2-7 persons. Among the household members whose ages are between 15 and 65 on average is close to half, who are economically active populations per household. The people under the age of 15 are about 46.4% of the total population. The dependency ratio of the households was found to be 93%, which was almost every member of the household except the very young (below 6 to 7 years) and the old above the 70s has to participate in some household tasks, who are economically active and useful for that specific household member. According to field observation and household survey, children the age above 7 support their families in housekeeping and rearing livestock.

3.6 Sampling techniques and sample size determination

3.6.1 Household sampling techniques

The household sampling was carried out with multi-stage sampling techniques. This technique is important to represent sampling in which larger clusters are further subdivided into smaller, more targeted groupings for surveying. Also, it is easier to implement and can create a more representative sample of the population, reduce costs of large-scale survey research and limit the aspects of a population which need to be included within the frame for sampling. In this regard, three stages were used to select HH respondents (Fig 3.3). In the first stage, stratification based on altitude three agroecological categories were selected (low land, midland, and highland), which are different terms of slope steepness and farming system. The agroecological difference can be defined as a spatial classification of the landscape into area units with similar agricultural and ecological characteristics (Altieri, 1995).

In mountainous countries like Ethiopia, the topography, particularly altitude, steepness, and slope characteristics play an important role in agroecological zonation (Gorfu & Ahmed, 2012; Hurni, 2016). In the second stage, different woredas ((in Ethiopia local administrative group that forms a district/zone) were selected from the identified agroecology. In the third stage, different watersheds were selected from the identified woredas that were used to select sample households. A total of 280 sample households were selected proportionally using a random number table from the identified watersheds. As to the sampling techniques, both probability and non probability sampling were used. Probability sampling was used for household surveys and non probability was used for focused group discussion (FGD) and key informant interview (KII).

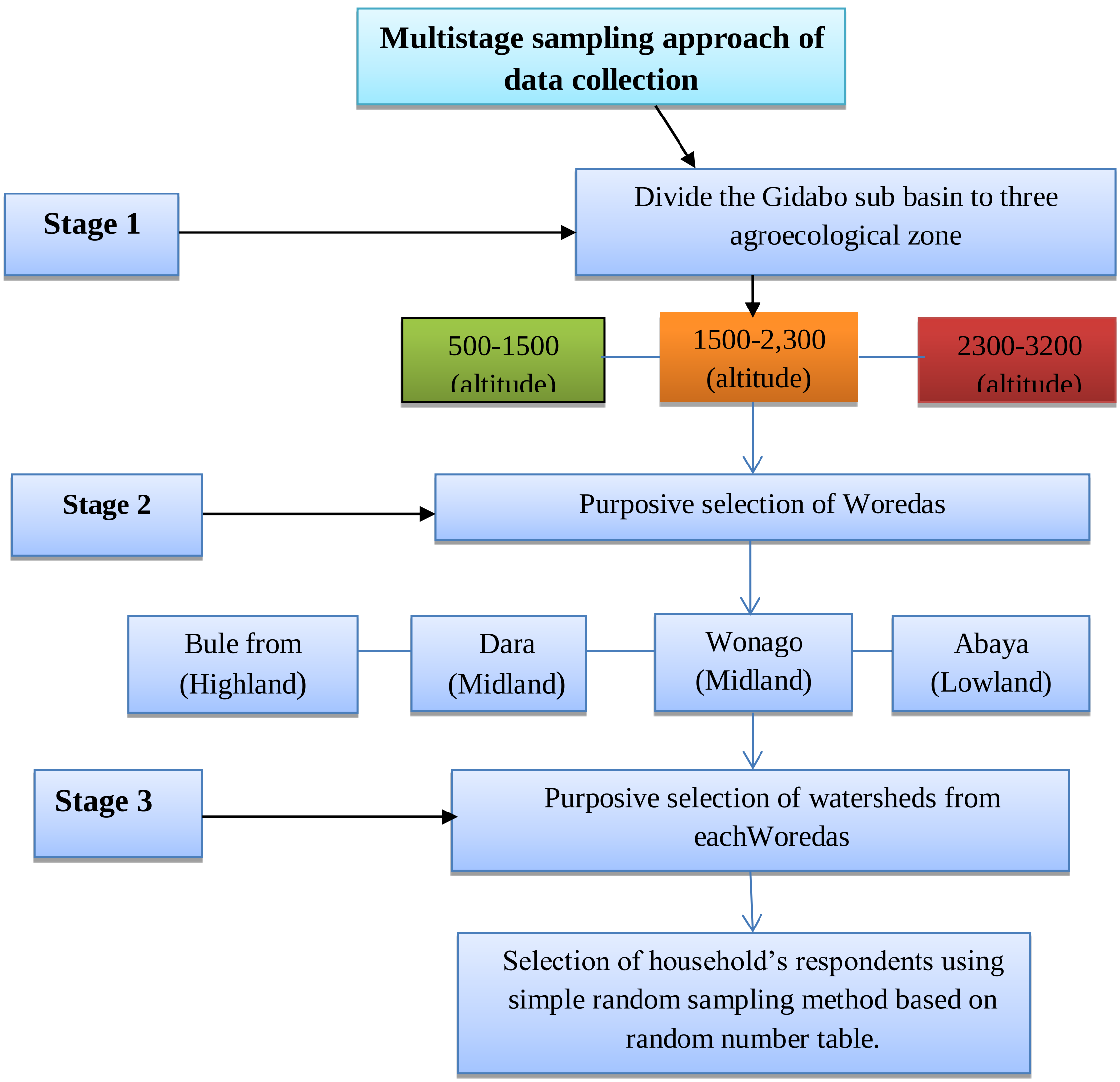

Fig 3.3 Multistage approach of household sampling

3.6.2 Household sample size determination

The larger geographic coverage of the study makes it difficult to cover the whole population. Hence, the researcher decided to select the specific sample households to work with. Then, the sample size determination is carried out based on the representativeness and reliability of the data from the selected watersheds that help to understand the study population and sampling methodologies. The household sample selection was carried out by the Krejcie and Morgan (1970) formula listed in the box

$$\mathrm{S} = \frac{x^2 NP\,(1-P)}{d^2(N-1) + x^2 p\,(1-p)}$$

Where,

S= Required sample size

X = Z value (e.g.1.96 for 95% confidence level)

N=the size total household heads (20,000)

n= the sample size for the population

P= the population proportion (expressed as a decimal) (assumed to be 0.234 or 23.4% of the total population)

d = Margin of Error or Degree of Accuracy at 5% (0.05)

According to the above formula, the household sample size is = 280

3.6.3 Soil sampling technique

For this research, the selection of a plot was carried out using the judgment/targeted sampling method which mainly focused on historical information, visual inspection, and professional judgment (IAEA, 2004; QA, E. 2002). According to Landon and Manual (1991), judgment/targeted sampling is the best option to select representative plots/sites or locations for sampling that are a larger area, critical areas, or high impact sites specifically targeted. In this method, the researcher judged the plot site based on the similarity of the conservation structures, age of SWC structures that has six years along different agroecology/altitudinal belts that were considered as slope variation. SWC within the six years was purposely considered as the commonly distributed SWC technologies are found at different agroecology/altitudinal belts, such as fanya juu, and soil bund and stone bund.

Certain conservation structures that are above six years have lost their design/layout because of cultivation and lack of maintenance. Using the zigzag method a total of 36 composite soil samples were collected from 3 agroecological (altitudinal belt), 3 conservation structures, 3 replicates, and 1 soil depth (0-20 cm) = 27 for treated. The same procedure was carried out for non-treated land of 3 altitudinal belts x 3 replications x 1 soil depth = 9, which is 27+9 =36.The treatments used for comparison were cultivated land treated by SWC structures, and adjacent non-conserved cultivated land, along different agroecological belts. The sampled soil was mixed thoroughly. Then, it was divided into four parts. From the four parts, one part with an average weight of 1 kg was collected in a plastic bucket to form a composite sample. Though there are 17 to 20 essential elements required for plant growth, from a management perspective the primary macronutrients are most often limiting crop production. They serve to increase the yield, growth, and quality of various crops (Morgan & Connolly, 2013).

According to Bhaduri et al. (2014), Morgan and Connolly (2013), and Rowley et al. (2012), the primary macronutrients (N, P, and K) are required in relatively large quantities by plants. The secondary macronutrients are needed relatively in smaller quantities than the primary categories; and therefore, are not often limiting for crop growth (Parikh & James, 2012; Korb et al., 2005). According to Yadav and Meena (2009), micronutrients are needed in far smaller quantities than any macronutrient to plants. Therefore, for this study, the soil fertility indicators such as primary macronutrients (nitrogen, phosphorus, potassium) and other important physical soil properties(clay, silt, sand and soil bulk density), organic carbon, soil pH, cation exchange capacity, and electro-conductivity were analyzed using ANOVA to test the distribution of physicochemical properties of soil along with different agroecology and soil conservation.

Soil bulk density (SBD) is the mass of dry soil (105^0C) per unit of bulk volume, including the air space (FAO, 2006). It can vary substantially among different soil types and be affected by management practices that determine soil fertility through soil compaction and soil resistance to root growth (Grossman & Reinsch, 2002). For this research, the SBD sample was collected from different agroecology/altitudinal belts, conservation structures, and non-treated land. Soil bulk density was measured with the core rings of 5 cm height and 5 cm diameter using the core method described by (De Vita et al., 2013). The fresh weights of soil samples were recorded and oven-dried at 105°C for 24 h after which the dry weights were also recorded. The volume of the core was determined using the following formula $V=\pi\, r^2h$ (cm^3).

Where V = volume of core (cm^3).

π = 3.14

r = radius (r^2) in cm

h = height (cm)

Bulk density (BD) was then determined with the following formula

$$\text{BD } (\text{Mg/ cm}^3) = \frac{Mass\ of\ dry\ soil\ (g)}{Volume\ of\ core\ (\text{ cm3})}$$

3.7 Types of Data and Data Collection Methods

3.7.1 Focus group discussions/FGD

Focus group discussants of the study area were purposefully selected from the sampled watersheds, with a maximum of five to six participants, making it easy to manage the discussion. Based on the variation of population size the number of watersheds was selected proportionally from different agroecology. For instance, Folde, Semanya, and Beluga watershed were selected from the highland agroecology. In the midland Elemo, Mariyam, Legedara, and Lenano watersheds were selected, whereas from the low land Rega, Shepe, and Ulaula watershed were selected.

In the sampled watershed about 14 group discussions were carried out, which is eight FGD in the midland and three for each in the highland and lowland.FGD participants included model farmers, experts, administrators, and development agents from the highland, midland, and lowland agroecology. FGD participation aimed to obtain important qualitative information concerning the perception and knowledge of the participants about the dynamics and driver of LULCC, technologies, and design of SWC, acceptance, impacts, and constraints of the SWC work.

3.7.2 Key informant interview (KII)

Participants for key informant interviews were purposefully selected from the sampled watersheds at different agroecology/altitudinal belts. For the interview, 9 to 11 key respondents were selected considering gender proportionality, age (above 45 years) who perceived better information about historical data on LULCC, resource conservation experience, and social recognition. Based on this arrangement 70 interviewees were carried out in the whole agroecology. The interview mainly focused on the perception, knowledge, and experience of the community on driving forces and characteristics of LULCC of the study area for the past 33 years, SWC technologies, acceptance of the community for the introduced SWC work, constraint to adopt/ adapt the SWC and perception of the farmers on the effect of conservation work.

Priority was given to the elderly informants and development agents because the elders were thought to have sufficient information about the LULCC of the study area as they had lived long enough to witness the changes exhibited. Development agents were thought to have sufficient information about the environment concerning their work and closer interaction with the local community. They also contributed in addressing the appropriate informants who are considered to be knowledgeable and can explain briefly about the issues. In this data collection method, the theoretical framework is given by Turner et al. (1994) and Geist and Lambin (2002) used to categorize the participants' responses about the forces as underlying and proximate drivers of LULCC in the three agroecological zones (Table 4.7).

3.7.3 Field observation

According to Morgan & Harmon (2001), observation is one of the most common forms of data collection approach. In the research, initially, a reconnaissance survey was conducted in different agro-ecologies that were used to characterize and understand the biophysical and terrain features of the study area, such as topography, economic activities, land degradation, soil type, soil and water conservation practices, and land use and land cover. Based on the survey result, LULCC such as agroforestry, degraded land, shrub/woodland, forest land, farmland, grassland, settlement land cover, and different SWC work were identified to be studied.

3.7.4 Household survey

To make a household survey, primarily ten randomly selected households were selected from each watershed to test the validity and clarity questionnaire before launching the real survey. Based on the feedback obtained during the pretesting, an adjustment was made on the flow, consistency, and clarity of the questions. A household survey was carried with close follow-up from the researcher. The survey questionnaires covered a range of information which included farmers' socio-economic and demographic condition, perception on drivers of LULCC, design/dimension of conservation structures, participation in SWC, acceptability of SWC work, and constraints of conservation practices.

3.7.5 Method for SWC structural measurement

For this part, both qualitative and quantitative methods were used to describe/investigate the dimension of SWC structures, acceptability, and constraints of SWC practices in comparison to the national soil and water conservation guideline. The standard guideline tells the measures and approaches that are considered best for the different watersheds at local conditions in Ethiopia (Hurni et al., 2016; Lakew et al., 2005; MoARD 2005). Based on the multistage sampling method, the field measurement was carried on the slope gradient, distance, structural embankments (berm), depth, width, and the vertical interval between SWC structures (Fig 3.4).

The slope gradient was measured with the water level method. A thin plastic rope with 10 m long and 4 m long wooden Poles were used for marking on the ground. Then, the slope was identified with the value variation of the vertical interval and horizontal distance multiplied by 100. Finally, the result on conservation structures from field measurement was compared with the standard prepared for development agents and experts at the Woreda level for different soil characteristics, topography, agroecology, and rainfall conditions (MoARD, 2005).

Fig 3.4 Slope measurements along with the structures

3.8 Procedures of Data Collection

3.8.1 Accuracy assessment of the images

The accuracy assessment of the images was carried out using ArcGIS 10.4 software, which identifies the truth on the ground and is represented on the corresponding classified image. A simple random sampling method was used to collect a total of 280 reference data to ensure that all seven LULC classes were adequately represented depending on the proportional area of each class. The confusion matrix of LULCC was estimated from Land sat 8 of 2019 and Land sat 5 of 2011; corresponding to the reference data from Google earth imagery (GEI) and GPS collected ground-truthing data. However, the accuracy assessment for the years 1986 and 2000 was not conducted because of the limitation of obtaining ground-truthing data, from aerial photos and historical Google Earth imagery. The accuracy assessment was determined using the Kappa coefficient, overall accuracy, producers, and user's accuracies derived from the confusion (error) matrix adopting the methodology described in Congalton and Green (2009) and Jensen and Cowen (1999).

According to the information in Table 3.2, the diagonal matrix indicates sample point classes that are correctly classified whereas off-diagonal elements represent commission or omission errors (Foody, 2002). The error matrix was computed for the overall accuracy of seven (7) land use classes individually and collectively. The overall accuracy was calculated by summing the number of correctly classified values and dividing by the total number of values. The total number of values is the number of values in either the truth or predicted-value arrays. Therefore, the overall accuracy result is 87%, which suggests a strong agreement between classification and truth value. The kappa coefficient measures the agreement between classification and truth values. A kappa value of 1 represents perfect agreement whereas a value of 0 represents no agreement. The kappa coefficient value of the study is 0.85; this value is closer to 1, which represents perfect agreement between classification and truth (Table 3.2).

$$\hat{K} = \frac{N * \sum_{i=1}^{k} x_{ii} - \sum_{i=1}^{k} (x_{i+} * x_{+i})}{N^2 - \sum_{i=1}^{k} (x_{i+} * x_{+i})}$$

i= the class number

N = the total number of classified values compared to truth values = 280

X_{ii} = the number of values belonging to the truth class i that have also been classified as class i (values found along the diagonal of the confusion matrix) = 244

X_{i} = the total number of predicted values belonging to class i (Row totals)

X_{+i} = the total number of truth values belonging to class i(Column totals) correctly classified values 44+ 45+ 35 + 36 + 33+26+25 = 244

K= number of rows in error matrix

Total number of values =280

Overall accuracy: 244/280*100 = 87%

Table 3.2 Accuracy assessments of land use and land cover classes

Land sat 8, 2015	Crop land	Agro-forestry	Forest	Grass land	Shrub/ Wood Land	Settlement	Bare land	Row total	Users accuracy
Cropland	44	1	1	3		0	1	50	**88**
Agroforestry	1	45	2		2	0	0	50	**90**
Forest	0	3	35		2	0	0	40	**88**
Grassland	2	0		36	0	0	2	40	**90**
Shrub / WL	1	2	2	1	33	1	0	40	**83**
Settlement	2	0	0	1	0	26	1	30	**87**
Bare land	3	0	0	2	0	0	25	30	**83**
Column total	**53**	**51**	**40**	**43**	**37**	**27**	**29**	**280**	
Producer accuracy/%	**83**	**88**	**88**	**84**	**89**	**96**	**86**		

Source; Landsat 8 of 2015 and Google earth imagery (GEI)

3.8.2 Radiometric correction and image classification

Using ENVI software, the radiometric correction was carried out using the dark-object subtraction method. This method combines the sun and view angle effects and the sensor calibration with the atmospheric correction. Then, image classification was carried out using both supervised and unsupervised classification. The unsupervised classification was done only to get the spectral characteristics of features on the image whereas the supervised classification method was carried out using the decision rule of maximum likelihood classification algorithm on the ERDAS images 2014 software.

The maximum likelihood algorithm provided a consistent approach to parameter estimation and was developed for many estimation situations with training samples. Then, all satellite data were studied by assigning per-pixel signatures and distinguishing the land area into seven classes based on the specific Digital Number (DN) value of diverse landscape elements (Im & Jensen, 2005). The major delineating classes of the study were cropland, forest land, settlement, grazing land; agroforestry, bush/shrubland, and bare land (Table 3.3). For each of the predetermined classes of the study site, the researcher used a minimum of 10 training samples for settlement and 15 training samples for bare land. Then, 30–75 training samples were randomly selected for cropland, forest land, grass land, agroforestry, and bush/shrub land.

A satisfactory spectral signature ensures that there is minimal confusion among the land covers to be mapped (Gao & Liu, 2010). For this research, pixels enclosed by these polygons were used to record the spectral signatures for the respective land cover types derived from the satellite imagery. As stated by Foody (2002), there are better results with large samples representing each land cover class. However, the required number of training samples to train classifiers depends on the classifier going to be used, the number of features considered and the landscape structure of the classes considered. Since the landscape structure of the present study area consists of a little area for settlement and bare land considered to other classes, few points were randomly selected during an assessment of class labeling which might be equal to the weighted proportion of the landscape.

Accordingly, using ground-truthing sample polygons and online Google earth imagery data visualization and interpretation, the spectral signatures for the respective land cover types were collected. Then, each class was given a unique identity and assigned a particular class testing the spectral distinctness of the training area. Moreover, to enhance signature reparability between forest and agroforestry classes and minimize uncertainties of classification, more GPS-based ground-truthing data of natural forest were geo-referenced coupled with analysis of these feature classes using the human brain (texture, tone, size, shadows, and shape) from the image.

3.9 Data analysis and presentation

The data collected from both primary and secondary sources were analyzed and presented using quantitative and qualitative methods. The structured household survey data such as demographic, socio-economic characteristics, and farmers' opinions were analyzed and interpreted with appropriate statistical tools (Fig 3.5). Secondary data sources such as climate, official reports, and published materials were used to triangulate with the data from key informant interviews and group discussions. Among the statistical tools chi-square, ANOVA, and descriptive statistics (frequency and percentage) were employed. The chi-square was used to test the association between constraints of SWC and different agroecology. Analysis of variance (ANOVA) was used to test the difference of mean among different SWC practices, and agroecology. Content analysis was used for qualitative data to compare the design of the implemented SWC structures with the standards as well as other descriptions.

The physical data analysis was carried out using remote sensing, geographic information system data processing. The magnitude of change for each land use and the land cover class was calculated by subtracting the area coverage of the second year from that of the initial year. The percentage share of gain or loss for each land-use class in the studied periods was then calculated by the formula shown in equation [1] (Shiferaw and Singh, 2011and Puyravaud, 2003).

$$\Delta C\ (\%) = \frac{At2 - At1}{At1} \times 100 \qquad [1]$$

ΔC = Percent change

$At2$ = The final year area

$At1$ = Initial year area

$$R\Delta = \frac{\text{Recent land cover} - \text{Previous land cover}}{\text{Time interval between the two period land covers}} \qquad [2]$$

Table 3.3 Classification scheme for the classification and change detection of LULCC

RN	LULC Classes	General Description
1	Forests	Land with tree cover (or equivalent stocking level) of more than 10 % and area of more than 0.5 hectares (ha). The trees should reach a minimum height of 5 meters (m) at maturity *in situ* (FAO 2010).The UNFCCC for REDD+ purposes forest cover in Ethiopia is referred to as 0.5 ha of size, 20% canopy cover, and 2m height.
2	Grazing Lands	Grass and herb cover with permanent grass cover and some scattered trees or shrubs for livestock grazing including communal, private (protected), and free area. Relatively flat and open areas with good visibility and hill slopes are homogeneous (Eggleston et al., 2006).
3	Cropland	This unit includes perennial and annual crops land area and fallow lands (FAO,2017)
4	Agroforestry land	Agroforestry is the collective term for land-use systems and technologies in which woody perennials (trees, shrubs, and fruits) are used deliberately on the same land-management units as crops and/animals in some form of spatial arrangement or temporal sequence (FAO, 2017).
5	Shrubs/woodlands	Shrubs/woods refer to bushes and young tree species co-dominant with herbaceous plants in terms of coverage (Jensen, 2005)
6	Bare land lands	Land which is unproductive or not used for cultivation or grazing (Ludi & Hurni, 2000)
7	Settlement	It is simply a community where people build houses and live together (Ludi & Hurni, 2000)

Sources: Generated from a different source

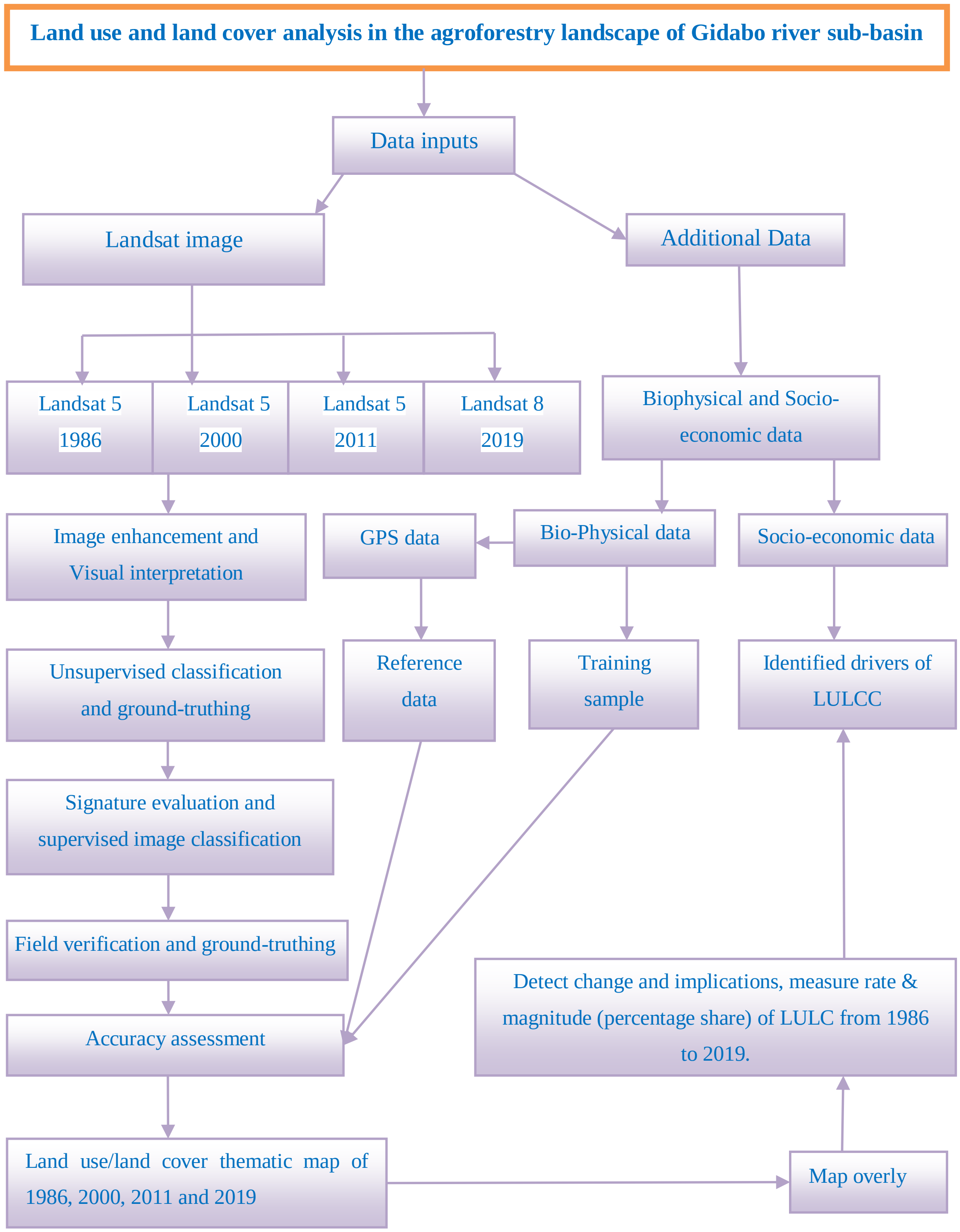

Fig 3.5 Flow chart showing the data sources and methods of analysis of LULCC

Source: Authors formulation

3.10 Procedures for Laboratory Analysis

Analyses of soil samples were carried out to evaluate the relation of soil fertility indicators along with soil conservation practices and agroecology/altitudinal belts. The collected composite soil samples were air-dried, mixed well, and passed through a 2 mm sieve for soil physical and chemical analysis. The soil analysis was carried out following the procedure of Sahlemedhin and Taye (2000) at Wondo Genet College of Forestry and Natural Resources Soil Laboratory Section, Hawassa University Ethiopia. Based on the laboratory procedure, important physical soil properties as well as the chemical property such as total nitrogen (TN), cation exchange capacity (CEC), soil reaction (pH), soil organic carbon (SOC), available potassium (AK) and available phosphorus (AP) were analyzed. Bulk density (BD) of the soil was determined on the soil sample from all treated and non-treated plots of undisturbed land using a core sampler for each sample site.

The chemical soil fertility was analyzed accordingly. The SOC was oxidized under standard conditions with potassium dichromate in sulfuric acid solution. A measured amount of K2Cr2O7 is used in excess to destroy the organic matter and the excess was determined by titration with ferrous ammonium sulfate or ferrous sulfate solution, using diphenylamine indicator to detect the first appearance of oxidized ferrous iron. According to McKenzie, (1994), the procedure of nitrogen determination was carried out by oxidized organic matter by treating the soil with concentrated sulfuric acid, nitrogen in the organic nitrogenous compounds being converted into ammonium sulfate during the oxidation (Cole & Parks. 1946). The acid traps NH4+ ions in the soil, which are liberated by distilling with NaOH.

The liberated NHO3 is absorbed in boric acid and standard H2SO4. Potassium sulfate is added to raise the boiling point of the mixture during digestion and copper sulfate and selenium powder mixture is added as a catalyst. The procedures used to identify all soil nitrogen (including adsorbed NH4) except that in nitrate form. The soil pH is measured potentiometric in the supernatant suspension of a 1:1 soil liquidation mixture by using a pH meter. The liquidation is either water (pH-H2O), a 1 M KCL solution (pH-KCl) or a 0.01 M CaCl2 solution (pH- CaCl2).

The soil EC (soluble salts) was determined in an extract of a known quantity of solids or liquids. The methods commonly used are the EC on the saturated paste 1:10 soil: water ratios. For 1.1 extract part of the water was added for one part of the soil and so on. For the saturated paste extract, water was added to a soil sample until a given mechanical property of the soil is attained: the liquid limit. The electrical conductivity of an aqueous salt solution increased with an increased in temperature (about 2% per uC). Hence, EC should be referenced to a standard temperature of 25°C by adjusting with temperature correction factors. The CEC determined by measuring the total amount of a given cation was needed to replace all the cation from a soil exchange site and it was expressed in centimoles per 100 g of soil (cmo1/100g soil). The ammonium acetate method was suitable for slightly acidic to neutral soils.

The sodium acetate method was used for calcareous soils and the barium chloride triethanolamine method was used for estimating CEC in acid soils as well as for the estimation of exchangeable hydrogen. Available phosphorus was determined using Bray methods. The Bray method was suitable for acid soils and the Olsen method was used for both acid and non-acid soils. Analysis for AK was primarily used for the determination of potassium in acid soils with cation exchange capacities of less than 20 meq/100g. Under this procedure, the sample was extracted with Morgan’s solution and K in the extract was measured by a flame photometer. The data analysis was made to test the significant difference of soil biophysical and chemical indicators along different agroecology, and conservation technologies.

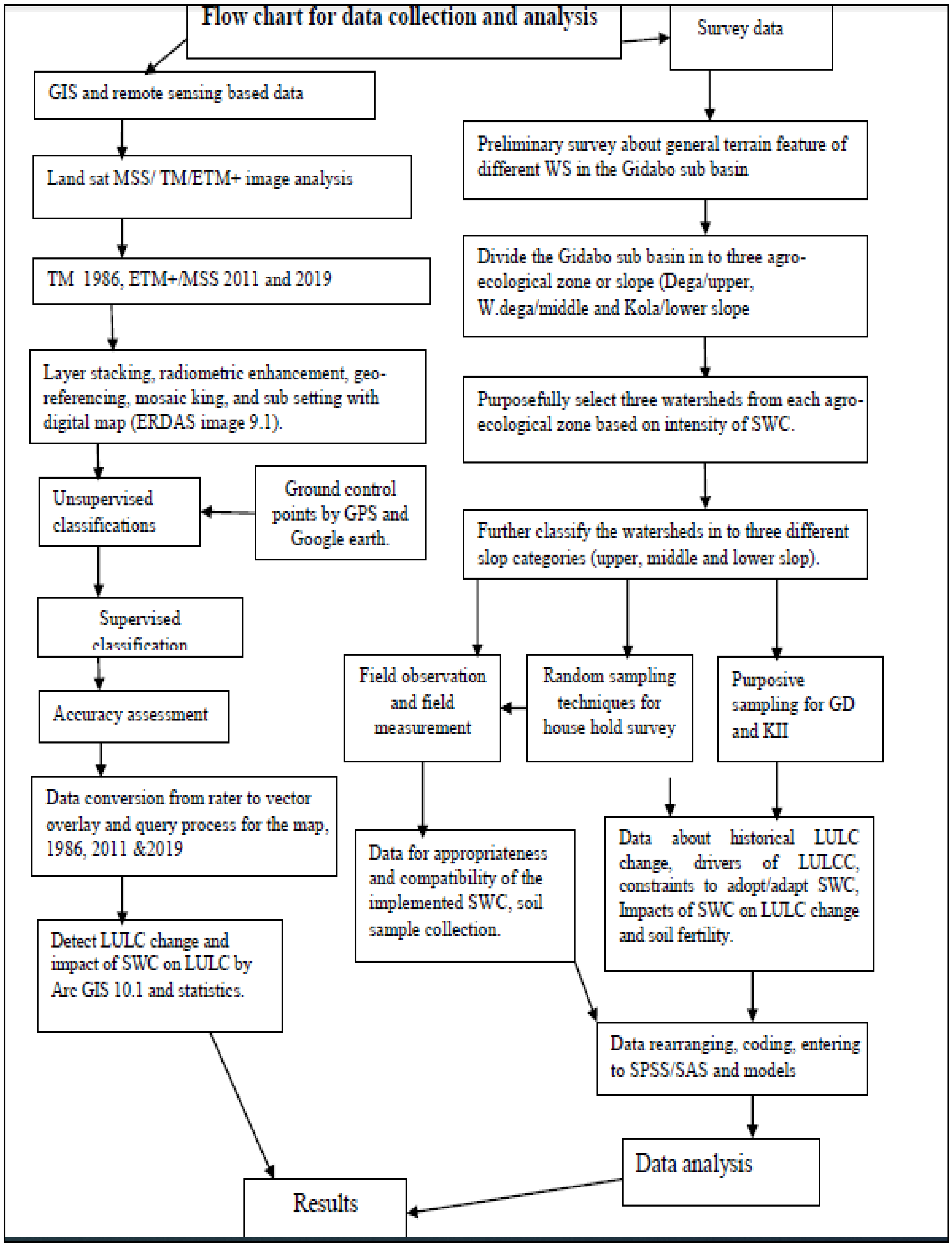

Fig 3.6 General flow chart of the research work
Source: Own formulation

3.11 Ethical consideration of the research

Ethics refers to moral principles that govern the conduct of an individual or group. The protection of human subjects through the application of appropriate ethical principles is important in all research studies. Based on this, different ethical issues were considered in the course of the study. Before the actual beginning of research activities, a support letter was received from the postgraduate office of Dilla University. Then, the letter was given to the regional and local (district or zonal) offices to get site permission. After permission had been obtained from the regional and local kebeles (lower administrative level) officials, groups were contacted to support the study. The zonal and kebeles officials assigned concerned experts and development agents to facilitate the data collection process. Then, a transect walk was made with the expertise to collect physical data of the study area. Also, informal discussions were carried with concerned district officials, agricultural experts, DA's, and key informants to get information about the culture, norm, and way of life of the community. Before the interview and discussion, an introduction was made to participants (respondents) about the objective of the research to develop confidence among interviewees and group discussants. Then, oral consent was obtained from all participants because most respondents may not understand written consent forms. In addition, clarification was made about their rights and privacy to abstain from answering the questionnaire which they were not happy with. After necessary permission was secured data was collected from the local elders, model farmers, development agents, and other concerned bodies to share their experience, perception, and attitude on land use land cover change, land degradation (soil erosion), SWC work, SWC technologies, adoption of SWC, constraints of SWC and related issues. During fieldwork, no one was photographed and recorded without his/her consent.

CHAPTER FOUR

4. Results and Discussion

4.1 LULCC Dynamics, Implications, and Driving Forces

4.1.1 Magnitude and rate of LULCC

Even though all LULC classes have undergone changes in the study area, the magnitude and rate of changes were inherently different. According to the information in Tables 4.1.1 and 4.1.2, in the initial year (1986), agroforestry and cropland alone accounted for about 71.2%. After 33 years, the size of agroforestry and cropland is about 84.4% of the total LULC of the study area. The dynamics of LULC indicate that for the last 33 years, the study area lost annually about 321.2 ha, 197.1 ha, and 31.6 ha of shrub/woodland, grassland, and cropland respectively.

On the contrary, the land with agroforestry, settlement, forest, and bare land showed an annual increment of about 443.7 ha, 65 ha, 33.6 ha, and 4.5 ha respectively. For instance, in the past 33 years, the highest rate of the land cover increment (14%) was recorded on agroforestry and the highest rate of loss (10%) occurred on shrub/woodland (Tables 4.1.1, 4.1.2, and Fig 4.1.1). The image analysis also showed that consistent increment was observed on agroforestry and settlement land classes whereas grassland covers were consistently reduced in the study period. On the other hand, inconsistent change was recorded on the land use class such as cropland, forest land, and bare land cover that mainly related with the driving forces mentioned in section 4.2.7.

Table 4.1.1 LULCC from 1986 to 2019

R.N	**LULC Class**	**1986 (ha)**	**(%)**	**2000 (ha)**	**(%)**	**2011 (ha)**	**(%)**	**2019 (ha)**	**(%)**	
1	Agroforestry	40,964	39.9	45,715	44.5	49,658	48.3	55,606	54.1	
2	Cropland	32,143	31.3	3,5923	35	34,024	33.1	31,100	30.3	
3	Shrub/Wood land	13,359	13.0	4,713	4.6	4,806	4.7	2,760	2.7	
4	Grassland	11,281	11	9,790	9.5	7,794	5.2	4,876	4.7	2019
5	Forest land	4,729	4.6	5,985	5.8	5,378	5.2	5,837	5.7	
6	Settlement	257	0.25	401	0.4	980	0.9	2,406	2.3	
7	Bare land	5	0.01	211	0.2	97	0.1	152	0.15	
	Total area (1986)	102,738	100.00	102,738	100.00	102,738	100.00	102,738	100.00	

Table 4.1.2 Magnitude, percentage share, and rate of LULC change from 1986-2019

LULCC	**Magnitude of LULCC %**	**Gain or loss in (%)**	**Rate of change ha/year**
Agroforestry	14	+35.7	+443.7
Cropland	1	-3.2	-31.6
Shrub/Wood land	10	-79.3	-321.2
Grassland	6	-56.8	-194.1
Forest	1	+23.4	+33.6
Settlement	2.	+836.2	+65
Bare land	0.14	+2940	+4.5

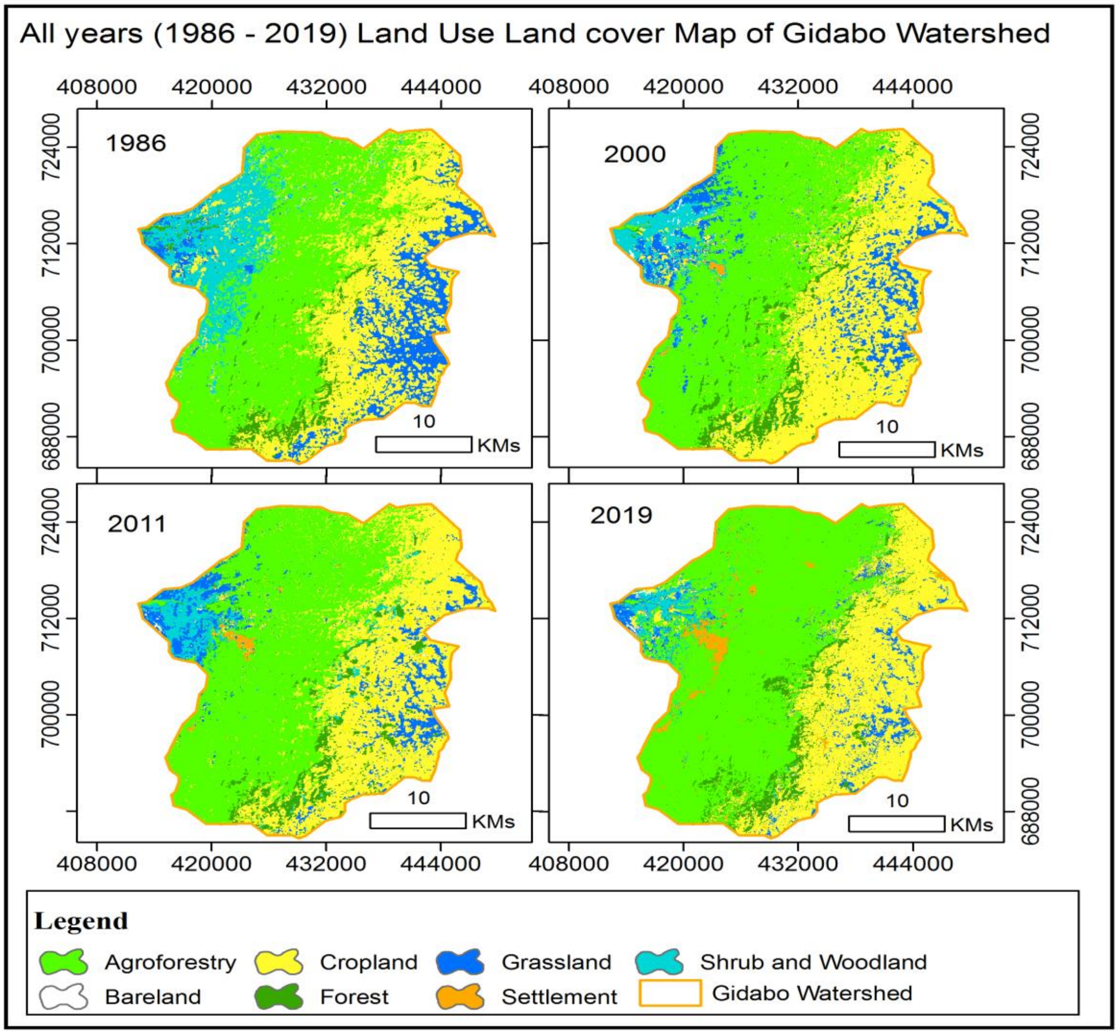

Fig 4.1.1 Classified Land Map of Gidabo river sub-basins from 1986 to 2019
Source: Land sat 5 (™) and Land sat 8 (OLI)

4.1.2 LULCC trajectory result from 1986 to 2019

LULCC trajectory refers to the possibility of land use and land cover change from one land-use class to another taking place in a specific period. LULCC trajectory of the study area was classified into four categories that showed the net loss or gain. The first category was the period from 1986 to 2000. In those 14 years, the net loss occurring in the classes was the following: on shrub/woodland, about 8.6%; grassland, about 1.3%, and forest land, about 1.3%. The net gain of LULCC observed was the following: agroforestry, about 4.73%; cropland, about 3.8%, and on bare land, about 0.19%.According to the LULCC trajectories, 6.2% of the shrub/woodland was converted to agroforestry, 6.3% of the grassland was converted to cropland, and 1.2% of the forest land was converted to cropland cover. In this period, the highest loss (8.6%) and gain (4.73%) were observed on shrub/wood and agroforestry land respectively (Table 4.1.3).

During the interview and FGD participants were requested to explain the trend of LUCC they responded that after Derg came to power in the early 1970s grasslands, shrub/woodland, and forest are changing into cultivated land (cropland) and agroforestry land. The 1974 proclamation of land to the tiller caused every plot of land, which was under communal ownership, to come under the hands of individual farmers are starting to plow, which contributed to the expansion of agroforestry, cropland, and bare land. Similar result report by Worku et al. (2014) showed that in Ameleke micro-watershed, Gedeo and Borena zones, south Ethiopia cropland area increased from 23.33% coverage in 1986 to 31.0% in 2006. Also in the early 1990s, the fall of the Derg regime and in consequence of instability during the transitional period caused the expansion of agricultural land through forest clearance has accelerated, in different parts of Ethiopia may have a contribution to this study area (Mariyea et al, 2019).

The second category of LULC trajectory refers to the period from 2000 to 2011. In this period, about 1.8% of cropland, 2% grassland, and 0.5% of shrub/woodland cover showed a reduction. The interview and FGD participant explained that the population number for each household was highly increased; land fragmentation was accompanied with an agroforestry system that reduced the cropland. In the study area, the people have a culture to apply multiple products (agroforestry), such as planting crops such as banana, fruit trees, livestock, and woody biomass together in a small plot of land. The report by Ketema et al. (2020) showed that population growth and landholding size (land fragmentation) were considered to be the main drivers of LULC changes in humid agro-ecological zones of the East African Rift. Therefore the change in the cropland of the study area implies that the high population growth causes farmers to shift from extensive mono-cropping to multiple cropping or agroforestry system. For instance, about 2.9% of cropland, 2% of grassland, and 1.7% of forest land were converted to agroforestry. The highest gain, about 3.8%, was detected in agroforestry and the highest loss, about 1.9 %, was recorded on grassland land cover (Table 4.1.4).

The third category of LULCC trajectory refers to the period from 2011 to 2019. In this period, about 5% agroforestry, 2.2% forest land, and 1.4% settlement land have shown expansion. On the other hand, about 4.3% grassland, 3% cropland, and 2.1% shrub/woodland showed a reduction. In this category, land use and land cover change trajectory showed that about 4.9% of cropland and 1.37% of shrub/woodland was converted to agroforestry. About 1.4 % of grassland was converted to forest and agroforestry land (Table 4.1.5). According to Mulugeta, (2010), eucalyptus plantation is showing a remarkable expansion due to smallholder farmers' preference for its fast-growth, coppicing ability, easy silvicultural management, poorly palatable to animals, the demand for its wood products with reasonable prices, and their adaptations to a wide range of ecological conditions. The report by Bowman et al. (2001) that forest coverage increased from 5.03% to 9.91% in the study area and coverage of grassland decreased from 6.70% to 2.47%. In the same way in the highland area of Blue woreda, a large area of the grassland cover was converted to plantation forest (Eucalyptus Trees), which has higher economic value than the cost for acidic soil treatment of the area.

The fourth category of LULCC trajectory refers to the period from 1986 to 2019. In these years, about 10% of shrub/woodland, 6% of grassland, and 1% of cropland showed a remarkable reduction. Conversely, about 14% of agroforestry, 2% of settlement land, 1% of forest land, and 0.14% of bare land showed expansion. The reduction of cropland was related to high population growth and the expansion of agroforestry. For instance, the LULC transition of the fourth category depicted that about 8.8% of shrub/woodland and about 6.35% of cropland was added to agroforestry. Also, about 1.4% of shrub/woodland and 1.3% of cropland were converted to settlement and forest land respectively (Table 4.1.6). The change in agroforestry, grassland, shrub/woodland, and bare land classes is similar to the report by (Ketema et al 2020; Worku et al 2014). The result depicts that the LULCC of the area was driven by the interplay of biophysical, socioeconomic, and institutional factors.

Table 4.1.3 LULCC (%) trajectory in the Gidabo sub-basin between 1986 and 2000

LULC 1986	**Agroforestry land**	**Bare land**	**Cropland**	**Forest land**	**Grass land**	**Settlement land**	**Shrub/wood land**	
Agroforestry	**35**	0.0032	2.6	1.49	0.12	0.02	0.15	
Bare land	0.00	**0.0019**	0.001	0.00	0.0022	0.00	0.00034	
Cropland	3.08	0.06	**24.22**	0.54	2.6	0.012	0.43	2000
Forest	0.3	0.5014	1.165	**2.21**	0.053	0.50	0.535	
Grassland	0.024	0.086	6.3	0.10	**4.08**	0.00156	0.5	
Settlement	0.0036	0.009	0.0094	0.0012	0.013	**0.235**	0.011	
Shrub/Wood land	6.2	0.04	0.98	0.1134	2.68	0.118	**3.98**	

Note: The bolded numbers indicate the persistent LULCC

Table 4.1.4 LULCC (%) trajectory in the Gidabo sub-basin between 2000 and 2011

LULC (2000)	**Agroforestry land**	**Bare land**	**Cropland**	**Forest land**	**Grass land**	**Settlement land**	**Shrub/wood land**	
Agroforestry	**41.2**	0	2.3	0.36	0.11	0.10	0.23	
Bare land	0.003	**0.036**	0.027	0	0.12	0.005	0.015	
Cropland	2.9	0.015	**27.05**	1.5	2.080	0.33	1.11	
Forest	1.7	-	0.77	**2.9**	0.012	0.013	0.35	2011
Grassland	1.6	0.014	2.7	0.16	**3.86**	0.11	1.01	
Settlement	0.02	0	0.012	0.001	0.005	**0.35**	0.006	
Shrub/Wood land	0.64	0.035	0.20	0.81	1.44	0.17	**1.9**	

Table 4.1.5 LULCC (%) trajectory in the Gidabo sub-basin between 2011 and 2019

LULCC 2011	**Agroforestry land**	**Bare land**	**Cropland**	**Forest land**	**Grass land**	**Settlement land**	**Shrub/wood land**	
Agroforestry	**45.6**		0.4	1.01	0.14	0.88	0.31	
Bare land	0.002	**0.035**	0.03	0.04	0.02	0.006	0.002	
Cropland	4.9	0.0079	**24.6**	1.37	1.4	0.54	0.24	

Forest	0.9		1.22	**2.8**	0.10	0.039	0.13	2019
Grassland	1.2	0.10	3.09	1.6	**2.58**	0.16	0.4	
Settlement	0.016		0.30	0.01	0.049	**0.56**	0.01	
Shrub/ Woodland	1.37	0.009	0.65	0.45	0.45	0.15	**1.58**	

Table 4.1.6 LULCC (%) trajectory in the Gidabo sub-basin between 1986 and 2019

LULCC	**Agroforestry**	**Bare land**	**Crop land**	**Forest land**	**Grass land**	**Settlement**	**Shrub/ wood land**	**Total**	**Loss (2019)**
Agroforest y	**37.64**		0.48	1.22	0.06	0.42	0.06	39.9	2.23
Bare land	0.0010	**0.001**	0.002	-	0.0010	-	-	0.005	0.004
Cropland	6.35	0.005	**21.06**	1.75	1.3	0.53	0.29	31.3	10.24
Forest land	1.05	0.002	0.63	**4.5**	0.121	0.051	0.3	5.6	2.1
Grass land	0.26	0.081	7.7	0.28	**2.44**	0.1	0.14	11	8.56
Settlement	0.04	0.067	0.045	-	0.042	**0.11**	0.011	0.25	0.14
Shrub/woo d	8.8	0.052	0.355	0.15	0.65	1.14	**1.9**	13	11.14
Total	54.14	0.15	30.3	5.82	4.6	2.34	2.7	100	
Gain (1986)	16.5	0.15	9.24	3.3	2.2	2.23	0.8		
Net change	14.27	0.146	-1	1.2	-6.36	2.09	-10.34		

Table: 4.1.7 Drivers of LULCC and the chi-square value along different agroecology

		Agroecology				Chi-square		
R.N	**Lists of drivers**		Midland	Lowland	Highland	X^2	P-Value	
1	Demographic factors	Yes	144	59	50	11.04	< 0.05	Significant
		No	7	10	10			
2	Economic factors	Yes	143	57	41	27.67	< 0.05	Significant
		No	8	12	19			
3	Cultural factors	Yes	138	54	43	15.81	<0.05	Significant
		No	13	15	17			

4	Natural factors	Yes	137	57	48	6.13	<0.05	Significant
		No	14	12	12			
5	Policy factors	Yes	116	44	35	74.8	<0.05	Significant
		No	35	25	25			
6	Agricultural intensification technology	Yes	107	58	50	6.01	<0.05	Significant
		No	44	11	10			

4.1.3 Drivers of LULCC

4.1.3.1 Demographic factors as drivers of LULCC

Demography of the study area is among the top-ranked factors that significantly affected the LULCC in midland agroecology (table 4.7). About 90% of participants in the household survey and group discussion indicated that population growth increased the demand for more land for cultivation, livestock production, tree plantation, and settlement. The high population growth of the study area also increased land fragmentation in holding size. Thus, farmers started to shift the mono-cropping system to mixed cropping or agroforestry system. This result is in line with the report by Ketema et al. (2020) and Temesgen et al. (2018). As confirmed by satellite image analysis, interviews, and group discussion, the conversion of grassland, shrub/woodland, and cropland to agroforestry systems is largely increased for the study period (Fig 4.1.1).

According to the report by Temesgen et al. (2018), zonal agricultural office (2020), and the central statistical report of Ethiopia (2013), the population density of the highland and lowland area ranges from 300 to 450 persons per sq. km whereas, in the midland, it ranges between 774 to 900 persons per sq. km. This record is the highest population density in the country. According to Bilsborrow and Ogendo (1992), land scarcity exacerbates the conversion of forest to agriculture and other land uses. Therefore, the expansion of the agroforestry system at the expense of grassland and shrub/woodland from 1986 to 2019, forest land from 1986 to 2011, and cropland from 2000 to 2019 were mainly related to the population growth, which supported the rising demand of large human populations. In this regard agroforestry can provides year-round income to support large family sizes (Fig 4.1.2).

Fig 4.1.2 Land fragmentations as a means of expanding agroforestry systems

Source: Field observation in the midland agroecology

4.1.3.2 Natural factors as drivers of LULCC

According to Table 4.7, more than 80% of the participant's interviews and household surveys told that natural factors such as climate variability and steep slope are among the top-ranked factors that significantly affected the LULCC in the highland and lowland area. Participants said that the climate was not as regular as it used to be: it has frequently been erratic and variable that is significantly contributing to the change equally in the highland and lowland agroecology. A similar result reported by Zondag & Borsboom, (2009) natural factors such as frequent drought, high-intensity rainfall, steep slope, and soil erosion highly determine the LULCC in many places.

Many farmers in the lowland and highland agroecology said that the climate variability increased farmers' insecurity about cultivating a similar type of crop (monocropping), fruits, or vegetables. Consequently, they favored using multiple types of cultivation; that is, the agroforestry system. Farmers' sense of insecurity for climate change created the chance to consider the agroforestry system as the best option to adapt to climate change. This perception was confirmed by the satellite image analysis that showed the expansion of agroforestry land cover in all agroecology from the period 1986 to 2019. This result is in line with the findings of Temesgen et al. (2018), in which drought/RF variability was perceived as a driver of LULCC in the study area.

4.1.3.3 Economy as drivers of LULCC

The Ethiopian economy is highly dependent on agriculture. Due to its reliance on rain, it has faced less productivity and fewer unsustainable products. In the midland area, similar to the demographic factors an economic driver has a significant impact on the LULCC of the past more than three decades. According to Table 4.7, about 90% of the participants in the midlands reported that small farm size caused frequent cultivation in the cropland and reduced productivity due to soil loss. The high population growth, diminishing land-holdings, landlessness, and lack of on-farm technological innovation has a significant contribution to the decline in productivity per household (MOFED, 2012). According to the report by Legess (2013), increasing pressure of rapid population growth of the study area diminishing the land is shared among successive family members eventually leading to poverty.

In the midland agroecology that is closer to the zonal town and who had formal education favored engaging in different off-farm activities such as daily laboring, riding a motorbike, shoe shining, charcoaling and commercial farming (Fig 4.1.3). According to the local development agents, off-farm works adversely affected the farmers' land management activity, which undesirably affected the LULCC of the area. Consequently, farmers were unable to feed their families. In this regard, many farmers were trying to get fertile soil from grassland, shrub/woodland, and other marginal lands which, in return, contributed to soil erosion. This finding is in line with the report by Ketema et al. (2020)

that showed the economy dependent on agricultural land expansions was the proximate driver of rapid LULC dynamics in many areas.

Fig 4.1.3 Charcoal marketing in the town of Dilla

4.1.3.4 Agricultural intensification inputsas a driver of LULCC

More than 79% of focus group and interview participants mentioned that agricultural inputs significantly determine the LULCC of the highland agroecology. Also the agricultural intensification technology such as access to chemical fertilizers, seeds, and pesticides has significant effect on the LULCC of the highland and lowland agroecology, because the fertilizer, pesticide, and seeds are necessary to increase productivity, food security and decide land use of the rural community.

This study agrees with the reports by Zondag and Borsboom (2009) and Lambin (2006) that showed a widespread application of biocide (pesticide, fungicide, and insecticide) triggers LULCC intensification. According to the farmers in the study area, the price of agricultural inputs had risen greatly in the last decade. Many farmers could not afford the high price of chemical fertilizer. This challenge forced many farmers to search for fertile soil by encroaching grassland, forest land, and shrub/woodland, which has significantly contributed to the reduction of grassland, and wood/shrub land (Fig 4.1.4).

Fig 4.1.4Shrub/woodland encroachments for fertile land

Source: Field observation

4.1.3.5 Cultural factors as drivers of LULCC

More than 80% of the participants told that the culture of tree planting, inside the Enset and Coffee plantations and rotating one's own house in the Gedeo and Sidama communities has a significant impact on the LULCC of the area. The statistical result showed that the cultural role of the community is among the top-ranked drivers that significantly affected the LULCC in midland agroecology. According to the report by Shiferaw and Singh (2011), culture is a determinant factor in the issue of LULCC for instance, the indigenous knowledge of tree conservation (Songo and Baabbo), and soil treatment (Mona) in the Gidabo river sub-basin. In the study area, there are cultural institutions named 'Songo', Baabbo', and 'Mona' system that were significantly contributed to the expansion of agroforestry and forest land cover.

Songo is a sacred place where trees are reserved for ritual and cultural purposes and Baabbo is a traditional way of tree conservation for various socio-economic purposes (Alambo et al., 2019; Maru et al., 2019). Mona is a traditional acid soil treatment approach with animal dung using a circular fence constructed from bamboo plants to herd domestic animals (particularly for cattle and horses (Maru et al., 2019). Farmers were using several agricultural practices in the treated soil such as the production of enset, cereal crops and vegetables (potato, ginger, taro, chives), and livestock husbandry (sheep, cattle, and horses) side to side of eucalyptus trees, which contributed for the expansion of agroforestry system (Fig 4.1.5). This result is in line with the report by Legesse (2013) and Kippie (2002) about the cultural role for the expansion of the agroforestry system of the study area.

Fig 4.1.5 traditionally sacred place

4.1.3.6 Policy factors as drivers of LULCC

Government policy influence land-use decision-making. In the last 33 years, the government of Ethiopia formulated different policies on natural resource conservation. The government policies are among the top-ranked factors that significantly affected the LULCC of the lowland and highland agroecology. According to Briassoulis, (2009) the government policies are part that play an important role in LULCC. In the study area, the 1980s policy of SWC, resettlement, and land privatization; the 2005 community-based SWC program; and the 2011 green economy initiatives considerably determined the LULCC of the study area.

The report by Yeshaneh et al. (2013) showed that the 1975 land proclamation of Ethiopia took away all lands from the landlords and distributed them to the landless, which in turn caused large deforestation for agricultural expansion. The government policy that is related to urbanization and infrastructure development causes LULCC through conversion of land use classes such as farmland and forests to built-up areas and infrastructures (Anteneh, et al., 2018).In this regard the government policy has significantly contributed to the LULCC of the study area (Fig 4.1.6).

Fig 4.1.6 Plantation carried through the SWC program

4.1.4 Implications of LULCC in the study area

LULCC has several implications at the local, regional and global scales of socio-economic and environmental conditions. In the past, more than three decades about 34% of the area was changed to different land use and land cover classes. In the year 2019 more than 70% of the LUCC accounts for agroforestry and cropland covers, this is the dominant land cover in the study area. Out of this, about 46.7% of the land was covered by the agroforestry system, which was the largest land size, besides this consistent increment was recorded on agroforestry and settlement land. The result is in line with the reports by Degife et al. (2019) and Kippie (2002) on the expansion of agroforestry and settlement land in south-eastern Ethiopia. The other important LULCC observed is the expansion of forest land. A similar result was reported by Meshesha et al. (2014) that showed the expansion of forest land in the Northern Central Highlands of Ethiopia.

The change observed on agroforestry and forest land is desirable from the perspectives of environmental management. The report by Brown (2018) suggests that LULCC that encourages agroforestry can improve the agricultural systems and mitigate the impact of climate change. Conversely, the area is manifesting several socio-economic and environmental problems, such as expansion of bare land,settlement loans, food insecurity, farmers partly migrating to urban areas or shift to non-agricultural activities (daily laboring), and less productivity of the cropland.

Moreover, previous research indicates that the indigenous agroforestry system of the area is gradually declining because of the prevailing dynamics such as loss and modifications of some element of the agroforestry system, abuse of the socio-cultural system, and nonfunctional indigenous institution (Maru et al., 2019; Legesse, 2013), decline productive capacity of agroforestry and prevalence of food insecurity (Bishew 2013), and the increment of annual mean surface runoff and soil erosion problem (Aregaw et al, .2021).

Though the theory of resilient environment and sustainable development are independent, several links between the two concepts can be found in the literature (Lew et al., 2016; Derissen et al., 2011). According to Redman (2014), a resilient environment and sustainable development can be considered complementary approaches. This is maybe the fact that a resilient environment is important to the long-term sustainability of livelihood outcomes that interact with multiple factors (Harris et al., 2020; Espiner et al., 2017). According to Bekele et al., (2019), there are different interacting biophysical, socio-economic, and institutional factors responsible for the LULCC of the specific area.

Hence, the driving factors of LULCC in the study area such as demography, economy, culture, high rainfall or drought, policy, and agricultural intensification significantly determine the LULCC and sustainability issue of the study area along different agroecology. According to Table 4.7 the chi-square result showed that demography, economic and cultural factors have a significant impact on the LULCC of the midland area. For instance, the high population density in the midland area increased the demand for more settlement land and diverse agricultural production in response to its socio-economic and environmental benefits, whereas availability of agricultural inputs (agricultural technology) has a significant impact on the LULCC of the highland area. For instance, the availability of lime is very important to treat the acidic soil in the highland area that is used for the expansion of the agroforestry system.

On the other hand, factors such as high rainfall or drought, weak law enforcement, access to infrastructure, and skilled manpower have equally significant impacts on the LULCC of the highland and lowland agroecology. The result is in line with the report by Bekele et al. (2019) and Temesgen et al., (2018) that showed recurrent drought and weak law enforcement are the factors perceived by the respondent farmers as immediate causes of LULCC. In this regard, the LULCC result of the study area implied that various interacting factors affected the land use and land management process of the study area. Though the existing SWC effort is essential and timely in the study area it should be more scientific and well organized in a way to support the productivity of the agroforestry system and sustainability of the area.

4.2 Design and Constraints of Physical Soil and Water Conservation Structures in the Gidabo River Sub-Basin of the Ethiopian Rift Valley Region

4.2.1 Design of SWC structures Vs the standard along with different agroecology

Measurement of the physical design of SWC in the study area was carried out on the introduced SWC technologies. Among the introduced SWC structures the most widely adopted conservation structures in the selected watersheds are soil bund, fanya juu, and bench terraces in the highland agroecology; micro basins, soil bund, and fanya juu in the midland and low-land area (Fig 4.2.1, 4.2.2, and 4.2.3). For this research work about 601 SWC structures were evaluated for the bottom and upper width, height, vertical interval, spacing between bunds, and length of bunds that were used to be evaluated against the minimum technical standards.

In the selected plot site about 10% of the physical SWC design/layout of the conservation structure that was implemented in agricultural land was measured and compared with the standard recommended for different agroecology, soil depth, and slope gradient as reported by (Hurni et al.,2016; MoARD, 2005) (Table 4.2.1 and 4.2.2). The efficiency and effectiveness of SWC measures are a matter of both the dominant agroecology, the type of conservation measures, and its compatibility (Haregeweyn et al., 2015). During SWC practices several technical mistakes will be committed by experts and these problems become worse when it comes to drainage control structures (Tesfaye et al., 2019). Therefore, the design and dimensions of SWC structures are very much dependent on the runoff rate to be generated from a particular area/watershed (Belayneh and Getachew 2002).

In this regard, the proper design of SWC structures is important for their effectiveness in protecting the soil from raindrop impact and hydraulic forces of runoff (Tesfaye, et al., 2019). Guidelines were prepared to help development agents and various experts at the Woreda (District) level with minimum practical information on work norms and technical standards that support the effect of conservation work (Table 4.2.1 and 4.2.2).

Table.4.2.1 Value for VI for bench terrace at different soil depth and slope gradient

Slope (%)	Soil depth					
	25 cm	50 cm	75 cm	100 cm	1.25 m	1.50 m
<15	<1 m	1 m	1 m	1 m	1 m	1 m
20	2.80 m	5.60 m	8.40 m	11.30 m	14.10m	16.90 m
30	1.80 m	3.50 m	5.30 m	7.10 m	8.90 m	10.60 m
40	1.30 m	2.50 m	3.30 m	5.00 m	6.30 m	7.50 m
50	0.90 m	1.90 m	2.80 m	3.80 m	4.70 m	6.60 m

Source: Local agricultural office conservation manual (2012)

Table 4.2.2 Recommended vertical interval and horizontal distance for soil bund at different soil depth and slope

Slope (%)	Depth of soil(cm)	Vertical interval (m)	Horizontal distance (m)
3–10%	50	1	20
11–25%	60	1.50	8
26–35%	50	2	5
35–44%	50	1.25	5
>45%	25	0.62	5

Source: MoARD (2005)

Fig 4.2.1 Soil bund structure in the midland

Fig 4.2.2, Sample soil bund and micro-basin in the lowland area

Fig 4.2.3, Table bund structure in the highland

Source: Researcher (March 2020)

4.2.2 Evaluation of SWC structures against the design specifications in the highland area

In this agroecology, the sampled structures were selected from the sampled watersheds such as Bulelega watershed which has a total area of 522 ha, from this 52.2 ha was degraded and 25.3ha was treated with SWC structures. The Folde watershed has a total of 311 ha, from this about 37.3ha is degraded and 11.1ha was treated. The third is the Semaniya watershed that has a total area of 364 ha, from the total land the degraded area accounts for about 64 ha, while 35.2 ha was treated with SWC structures.

From the total treated land, 10% of the structures were measured for this study. Accordingly, the total sampled structures in the highland agroecology are 114, which are 40 for Bulelega, 18 for Folde, and 56 is for the Semaniya watershed. The sample indicated that the average number of structures is 16 per hectare because the average distance between consecutive structures is 12m and the horizontal distance is50m. The sampled SWC structures layout/design were evaluated from the bottom and upper width, height, vertical interval, and distance of the ditch to the berm that focused on the minimum technical standards. The measured numerical value of different SWC structures compared with the recommended standard.

I. The length and vertical interval of SWC structures

The total lengths of the SWC structures in the highland area are 5.7km. The length of the structures showed that 37 out of 42 soil bunds are not constructed according to the standard, whereas 39 out of 44 fanya juu structures were not constructed according to the standard. The minimum and maximum length of the structures is 40m and 60m, which has greater horizontal distance than the recommended. According to (Table 4.2.3), more than 70% of soil bund and fanya juu structures are constructed on a slope greater than 16%. Though the availability of natural waterways or suitable boundaries between farms are major factors to determine the length of the structures most farmers did not want to construct a waterway on their plot since it takes out a large area of land. The longer distance of the structures than the recommended has a risk of overflow or overtopping and breakage during high run-off in fragile soils. A similar result was reported by (Engdayehu et al., 2016).

The space between the consecutive soil bund and fanya juu ranges from 10 to 14 m with an average of 12m. In both structures (soil bund and fanya juu) the space between consecutive structures is larger than recommended. The result is in agreement with the report by Tesfaye et al. (2019); Ademe et al. (2017); and Simeneh (2016) in that most of the SWC practices did not follow the site-specific design criteria. The major challenge to the farmers to keep the standard space on the structures is the small land size caused by high population density. When mechanical SWC structures are implemented with a less spacing large area of land can be lost and farmers are not interested in implementing the structure (Engdayehu et al., 2016). The SWC structures with large spacing can lose the ability to hold peak discharge then more runoff can be generated causing overtopping**.** This may initiate rill or gully erosion, which requires more labor and budget to overcome the problem (Tesfaye et al., 2019).

II. Depth, width, and height of the structures

In the highland area the maximum and minimum bottom width ranges from 60 to 40 cm for both soil bund and fanya juu structures. The maximum and minimum height ranges between 80 to 40cm for soil bund and 65 to 45cm for fanya juu. About 95% of the selected SWC technology, soil depth, and slope gradient of this agroecology are similar to the standard, while the size of embankment height, bottom width, and distance of the ditch to the berm is below standard in the range of 2 to 10 cm. In addition, the embankment width of the structures is below the standard on average of 58 cm from the recommended 1m. The result in this agroecology implied that about 43% of the embankment width of the structures failed to meet the standard. This result is in agreement with the report by Tesfaye et al. (2019) and Engdayehu et al. (2016).

The failures of the structures to follow the standard dimension (depth, width, and height) minimize the capacity of the structures to hold the peak discharge generated and to remove the excess runoff at a non-erosive velocity, which may hurt the effect of SWC work. Though the major challenge to follow the standard depth, width, and height of the structures are small land size, during the interview and group discussion the researcher also understood that farmers have lack of skill and knowledge about the standard size of conservation structures. A similar result was reported by Engdayehu et al. (2016).

The overall result of the design/layout of the structures in the highland depicted that the local farmers should get knowledge and skill on the standard SWC guideline, farm material support, agricultural extension services such as training, accessing the supply of inputs timely, frequency of contact with Das, frequency of participation in extension planning, farm demonstration and giving various marketing information are fundamental for the success of natural resource conservation effort of the area.

Table 4.2.3 Technical evaluation of SWC structures in the highland agroecology

The total measured graded soil bund 40	**Implemented**	**Recommended**	**Deviation**
Specifications			
Type of structures	Soil bund	Soil bund	Standard
Workable soil depth (cm)	>45 cm	30–60 cm	Standard
Average slope	17	17	Standard
VI b/n structures (m)	12 m	1.5 m	10.5m
Depth of the ditch	65 cm	60 cm	−5cm
Width of the ditch	50 cm	60 cm	−10cm
Embankment height	57 cm	60 cm	-3cm
Embankment width	75 cm	1 m	−.25cm
Distance of the ditch to berm	20 cm	25 cm	− 5cm
Horizontal distance	50 m	8m	+42m
The total measured graded Fanya juu 60	**Implemented**	**Recommended**	**Deviation**
Specifications			
Type of structures	Fanya juu	Fanya juu	Standard

Workable soil depth	60 cm	60 cm	Standard
Slope	18	18	Standard
VI b/n consecutive structures	12 m	1.5 m	10.5m
Depth of the ditch	60 cm	60 cm	Standard
Width of the ditch	47cm	50 cm	-3cm
Embankment height	55 cm	60 cm	−5cm
Embankment width	60 cm	1.5 m	−90cm
Distance of the ditch to berm	18 cm	20 cm	-2cm
Horizontal distance	50 m	8 m	+42m
Total measured graded bench terrace 14	**Implemented**	**Recommended**	**Deviation**
Specifications			
Type of structures	Bench terrace	Bench terrace	Standard
Average slope	20	20	Standard
Workable Soil depth (cm)	50 cm	50 cm	Standard
VI b/n structures (m)	12 m	1–1.75 m	10.25 m
Depth of the cut	1.5 m	1.5 m	Standard
Width of the bench (flat strip) Horizontal distance	5m 50m	2.15 m 8 m	2.85 m +42 m

4.2.3 Evaluation of SWC structures against the design specifications in the midland area

For this agroecology the sampled conservation structures were selected from the Elemeo watershed, which has a total area of 317 ha, out of this 79 ha is degraded and 23.7 ha was treated. The Mariyam watershed has a total area of 268 ha, out of this 92 ha was degraded and 68.6 ha were treated. Legedara watershed has a total area of 500 ha, out of this 150 ha are degraded and 73 ha is treated. The last is Lenano watershed that has a total area of 500 ha 125 ha is degraded and 50 ha is treated. From the total treated land 10% of the structures were measured for this study. Accordingly, the total sampled structures in this agroecology are 323 which are 109 for Legedara, 75 for Lanano, 36 for Elemo, and 103 for the Mariyam watersheds. The sampled conservation work indicated that the average number of structures is 15 per hectare because the average spaces between consecutive soil bund and fanya juu structures are 20m and the horizontal distance is 30m.

I. Length and vertical interval of the structures

According to (Table 4.2.4), the total horizontal length of the measured soil bund and fanya juu structures is 9.7 km. The length of all structures is on average 25 m longer than the standard. In table 4.2.4 more than 80% of the structures are found in the slope range of 10 to 17%. The maximum and minimum lengths of the fanya juu and soil bund structures are 40 m and 20 m respectively. The vertical distance or vertical interval between the consecutive structures ranges between 15 to 25 m for both soil bund and fanaya juu, as well as 8 to 12 m for the micro basin. In this agroecology the longer horizontal distance and wider vertical interval of the structures are mainly related to the shortage of land (high population density), limited participation in SWC planning, and lack of skill or knowledge about the importance of the standard size among the land users. This study agrees with the report by Tesfaye et al. (2019); Ademe et al. (2017); and Simeneh (2016) in that most of the SWC practices did not follow the site-specific design criteria.

The SWC structures with large spacing can lose the ability to hold peak discharge then more runoff can be generated causing overtopping, which initiates rill or gully erosion. A similar result was reported by Engdayehu et al. (2016). In this regard the SWC dimension (length and vertical interval) that failed to meet the standard in this agroecology should be corrected in consultation with the land user that will give win-win benefits, otherwise, it will not be easy to maintain once gully is formed. Prevention is better than cure, which is more economical than the expensive cost for structural protective measures (Assessment, 2010).

II. Depth, width, and height of the structures

The depth of the ditch has a deviation of 8 cm below the standard in more than 90% of the structures, whereas 75% of embankment height for soil bund and fanya juu structures has a deviation of 7.5 cm below the standard. Regarding embankment width, about 70% of the soil bund and fanya juu structure is below the standard with an average value of 50cm compared with 1 to 1.5 m of the standard (Hurni et al., 2016; MoARD, 2005).

The overall result on evaluation of design and compatibility SWC in the midland indicated that comparatively standard value was observed on the selection of SWC technologies, slope gradient, a distance of the ditch to the barn and bottom width, whereas in more than 95% of the conservation structures the vertical interval, horizontal distance and soil depth are failed to meet the standard.This finding is in agreement with the report by Ademe et al. (2017); Tesfaye et al. (2019 and Engdayehu et al. (2016) in that most of the physical SWC structures were not constructed according the guideline. Failures of the structures to keep the standard dimension will reduce the capacity of the structures to hold the peak discharge generated and to remove the excess runoff at a non-erosive velocity.

In the midland agroecology, the most favorable SWC structure by the farmers was the micro basin, because they assume it did not consume more land than soil bund and fanya juu. About 97% of the participants on a household survey, FGD and KII of the midland argued that the shortage of land, hard clay nature of the soil in certain field, the long-lasting monetary impact of the conservation work, poor agricultural product, and food insecurity were the major constraints to adopt/adapt the standard design. Mainly small parcels of land size (0.2 ha–0.02 ha) for each farming family were challenging to apply the narrower vertical interval between structures.

According to the central statistical data of 2013, the density of the population in most watersheds of the midland area is > 850 persons/km^2. This value is the highest population density at the national level. Therefore, land users were resistant to applying the standard design of conservation structures that consumes more land. In this regard, the standard design will be possible by controlling the high population growth, awareness about the advantages of the standard design of SWC, support to participate in SWC planning, frequent contact with Das, access agricultural inputs timely and expanding the SWC structure that is favored by the farmers.

Table 4.2.4.Technical evaluation of SWC structures in the midland agroecology

The total measured soil bund 110	**Implemented**	**Recommended**	**Deviation**
Specifications			
Type of structures	Soil bund	Soil bund	Soil bund
Slope (in degree)	16	16	Standard
Soil depth (cm)	20 cm	45 cm	−25 cm
VI b/n structures (m)	20 m	1.50 m	+18.5m
Depth of the ditch	40 cm	>50 cm	−10 cm
Width of the ditch	50 cm	60 cm	−10 cm
Embankment height	40 cm	60 cm	−20 cm
Embankment width	50 cm	1.50 m	−1 m
Distance of the ditch to berm	23 cm	25 cm	−0.5 cm
Horizontal distance	30m	8m	+28m
Total measured level fanya juu 91	**Implemented**	**Recommended**	**Deviation**
Specifications			
Type of structures	Fanya juu	Fanya juu	Fanya juu
Slope (in degree)	17	17	Standard
Soil depth (cm)	25 cm	60 cm	−35 cm
VI b/n structures (m)	20 m	1.5 m	18.5 m
Depth of the ditch	50 cm	60 cm	−10 cm
Width of the ditch	60 cm	60 cm	Standard
Embankment height	50 cm	60 cm	−10 cm
Embankment width	50 cm	1.5 m	−1 m
Distance of the ditch to berm	20 cm	20 cm	Standard
Horizontal distance	30 m	8m	+22m

The total measured micro basin 122	Implemented	Recommended	Deviation
Specifications			
Type of structures	Micro basin	Micro basin	Micro basin
Soil depth (cm)	25 cm	45 cm	−20 cm
Average slope	13	13	Standard
VI b/n structures (m)	10 m	2.5 m	7.5 cm
Depth of the ditch	50 cm	55 cm	−05 cm
Width of the ditch	75 cm	75 cm	Standard
Bottom embankment width	1 m	1 m	Standard
Embankment height	30 cm	30 cm	Standard
Distance of the ditch to berm	20 cm	20 cm	Standard

4.2.4 Evaluation of SWC structures against design specifications in the low land area

In this agroecology, the commonly implemented conservation structures are soil bund, and micro-basin, but in a few sloped areas fanya juu structures are implemented. The sampled structures were selected from the Rego watershed which has a total area of 154 ha, out of this 62 ha was degraded and 30 ha were treated. The Shepe watershed has a total area of 8 ha, out of this 5 ha is degraded and 2.6 ha were treated. The third and biggest watershed in this agroecology is the Ulaula watershed that has a total area of 422 ha, from this about 130 ha was degraded and 58.5 ha was treated with SWC structures. From the total treated land, 10% of the structures were measured for this study. Accordingly, the total measured structures in the lowland agroecology are 164 which are 105 for Ulaula, 54 for Rega, and 5 is for Shepe watershed. The sample indicated that the average number of structures is 18 per hectare because the average distance between consecutive structures are 11m and the horizontal distance is 50 m.

I. Length and vertical interval of the structures

The technical result of the structures in the lowland showed that the total length of soil bund and fanya juu structures is 8.2km. The average length of the soil bund and fanya juu structures is 50 m (Table 4.2.5). More than 70% of the structures have an average of 30 m longer than the standard. The maximum and minimum length refers to 60 m and 40 m for soil bund and fanya juu. The maximum and minimum vertical interval of the soil bund and fanya juu structures is 13 m and 9 m, which has an average of 11m higher than the standard. Regarding the micro-basin structures, the mean vertical interval is 5 m. In all structures the higher mean value of vertical interval was recorded compared to the standard.

II. Depth, width, and height of the structures

In the lowland, the maximum and minimum depth of the ditch is 60 cm and 20 cm, whereas the bottom width ranges from 60 to 30 cm respectively. From the measured conservation structures about 75% of the depth of the ditch is an average of 10 cm lower than the recommended, whereas, more than 80% of the structure has standard bottom width that may be related to the need to collect more water. In the case of embankment width, the maximum and minimum value ranges from 60 cm to 30 cm. That refers to about 70% of the embankment width being below the standard that should be 1m to 1.5 m.

The overall result of the structures in the lowland showed that selection of SWC technologies, and bottom width of the ditch was carried out according to the standard. But about 80 % of the vertical interval between structures, horizontal distance, and embankment height failed to meet the standard (Fig 4.2.4). The result is in line with the report by Ademe et al. (2017) and Simeneh (2016) in that most of the SWC practices did not follow the site-specific design criteria based on the soil depth, slope, and rainfall.

According to the data from field observation, focus group discussion, and interview the farmers in the lowland has constraints to adopt the standard design of SWC, such as shortage of land, lack of skill and knowledge about the standard size of SWC structures, poor interaction with the stakeholders, less productivity of the soil, poor infrastructural development, and poor access of agricultural inputs. This result is in agreement with the report by Tesfaye et al. (2019); Simeneh (2016) and Engidayehu et al. (2016).

According to Bashir et al.(2018) and Abraha, (2008) the design and dimensions of conservation structures are very much dependent on the risk of erosion, climate, soil type, runoff control, construction materials, labor force, and improved soil productivity of the specific area. In other words, constructing the standardized dimensions of conservation structures are important to make them capable of holding the generated peak discharge and increasing soil fertility (Hurni et al., 2016). According to Tesfaye et al. (2019), the physical limitations of conservation structures have adverse impacts when it comes to drainage control of structures. Therefore, the implemented conservation structures in the sampled watershed that failed to meet the standards cannot be capable of holding the runoff and that will adversely affect the soil fertility and livelihood of the community.

Table 4.2.5 Technical evaluation of SWC structures in the low land agroecology

Total measured level soil bund is 70	**Implemented**	**Recommended**	**Deviation**
Specifications	Soil bund	Soil bund	Soil bund
Average slope	13	13	Standard
Workable soil depth (cm)	45 cm	45 cm	Standard
VI b/n structures(m)	11 m	1.50m	9.5m
Depth of the ditch	30 cm	50 cm	−15cm
Width of the ditch	32 cm	60 cm	−28cm
Embankment height	55 cm	60 cm	−0.5cm
Embankment width	50 cm	1.50 cm	1m
Distance of the ditch to berm	20 cm	25 cm	-0.5cm
Horizontal distance	50 m	8 m	+42m
The total measured micro basin 79	**Implemented**	**Recommended**	**Deviation**
Specifications			
Type of structures	Micro basin	Micro basin	Micro-basin
Average slope	13	13	Standard
Soil depth (cm)	30 cm	35 cm	-5cm
VI b/n structures (m)	5 m	3.5 m	+1.5
Depth of the ditch	50 cm	55 cm	-5cm
Width of the ditch	50 cm	60 cm	-10cm

Embankment height	20 cm	20 cm	Standard
Embankment width	40 cm	1 m	−60 cm
Distance of the ditch to berm	25 cm	30 cm	−10 cm
The total measured fanya juu15	**Implemented**	**Recommended**	**Deviation**
Specifications			
Type of structures	Fanya juu	Fanya juu	Fanya juu
Average slope	15	15	Standard
Soil depth (cm)	45 cm	45 cm	Standard
VI b/n structures (m)	11m	1.50 m	9.5 cm
Depth of the ditch	50 cm	>50 cm	Standard
Width of the ditch	60 cm	60 cm	Standard
Embankment height	50 cm	60 cm	−10 cm
Embankment width	50 cm	1.50 m	1 m
Distance of the ditch to berm	25 cm	25 cm	Standard
Horizontal distance	50m	8m	+42m

Fig 4.2.4 Conservation work in the lowland

4.2.5 Supportive measures of SWC structures vs the guideline

According to the field observation, more than 70% of the physical conservation structures were not supported by biological treatment. The MoRAD 2005 guideline recommends that physical SWC work should be supported with properly designed structures, planting vegetative materials, and frequent maintenance. A similar report by Engdayehu et al. (2016) showed that the lack of biological treatment of the physical conservation structures limited the impact of conservation work.

In the study area, almost all physical conservation structures had wider vertical intervals distance between consecutive structures. The fact that the higher spacing between structures reduced the ability to hold the peak discharge that could be generated between two structures should have been supported by biological conservation work. Besides the biological limitations, the structures lack regular maintenance and follow-up from the land users and other stakeholders. According to Mekonnen et al. (2014), regular maintenance and structural support determine the effectiveness of any SWC measures. Therefore, the observed limitations in the SWC practices of the sampled study area might cause serious damage to the field through high runoff collection.

4.2.6 Level of community participation in the SWC vs the guideline

In the study area the local community is participating in the SWC practice in two ways the first is the Safety Net program (Fig 4.2.5), and the second is the thirty (30) days of community mass-mobilization (Fig4.2.6).The data from the household survey showed that about 82.7% of the midland, 61.8% of the lowland, and 55.1% of the highland community participated only in the phase/stage of introduction, decide the date and days of conservation work and provide construction materials and implementation stage of conservation work (Table 4.2.6). The result showed that the level of community participation in the SWC work of the area is below the standared. Because the recommended phase of the community participation on SWC starts from problem identification to implementation or the maintenance level (MoARD, 2005). According to Hurni et al. (2016); MoARD (2005), and Förch and Schütt (2004) besides the technical design the success of SWC governs by the principles of active community participation of different actors at different phases of SWC practices from planning and monitoring to the implementation phase.

In this regard the community participation in SWC work can be determined by the approach of SWC, farmers' perception of soil erosion problems, and acceptance of the conservation technologies (Nigussie et al., 2018). If land users failed to perceive land management or SWC enhance agricultural productivity; they would feel reluctant to take action against soil erosion (Tegene.1992).According to the data from the FGD, interview, and household survey the farmers have better knowledge about soil erosion problems and have a positive interest in the introduced SWC technologies. Their knowledge about soil erosion and positive views for the introduced SWC technologies enhanced their interest to participatin diffrent SWC program such as food for work and community campaign. But the level of participation in the SWC practices of the area are limited that may be related with the top-down approach. Therefore, the result on the community participation in SWC work of the study area that failed to meet the lower standard of the SWC guideline may harm the conservation work. In this regard, the effective implementations of the conservation work need to be guided through the application of basic principles/guidelines of SWC (Engdayehu et al, 2016).

Fig 4.2.5 Soil and Water Conservation for food (Safety Net program)

Fig 4.2.6 thirty (30)-day community mass-mobilization for SWC
Source: Researcher (March 2020)

Table 4.2.6 Evaluation of community participation in the SWC practices at d/t agroecology

R.N	Level of community participation in the SWC	Highland agro ecology (%)		Midland agro ecology (%)		Lowland agro ecology (%)	
		Yes	**No**	**Yes**	**No**	**Yes**	**No**
1	Participated only for introduction about SWC practices.	51	49	69	31	53	47
2	Participated in identifying areas of conservation.	17	73	40	60	28	72
3	Participated only for advice	33	67	45	55	37	63
4	Participated in identifying/ prioritizing the SWC technologies.		97	88	12	5	95
5	Participated to decide the date of SWC for Safety Net.	43	57	55	45	39	61
	Participated to decide the date of SWC for free service.	65	35	93	7	74	36
6	Participated to decide on the number of days for SWC under Safety Net.	37	63	40	60	38	62
	Participated to decide the number of days for SWC under free service.	52	48	60	40	56	54
7	Participated to give labor.	60	40	90	10	81	19
8	Participated by contributing materials for construction.	70	30	85	15	77	23
9	The communities have an interest to participate in the conservation work.	65	35	80	20	69	29

4.2.7 Constraints of SWC against the standard

According to the data from the household survey, FGD and KII, farmers perceived that the newly introduced SWC technologies were effective to control soil erosion and improve land productivity (Fig 4.2.7).However, the implemented SWC technologies in many sample sites of the study area failed to fully meet the standards to the extent of controlling soil erosion, increasing land productivity, and food security. The local community said that the failure of the structures to meet the standard was related to the constraining factors listed in (Table 4.2.7).

Table, 4.2.7 Farmers perception on the constraints of SWC and chi-square value

			Agroecology			**Chi-square**		
R,N	Lists of constraints		Midland	Lowland	Highland	X^2	P-Value	
1	Small farmland area	Yes	145	37	32	72.35	< 0.01	Significant
		No	5	33	28			
2	Poor access to fertilizer, seed, and pesticides.	Yes	105	59	56	16.45	< 0.01	Significant
		No	45	11	4			
3	Food insecurity	Yes	132	63	47	5.19	>0.05	Not Significant
		No	18	7	13			
4	Inaccessibility of construction material	Yes	75	45	40	85.89	<0.01	Significant
		No	75	25	20			
5	Lack of technical skill in SWC practices	Yes	76	57	51	33.84	<0.01	Significant
		No	74	13	9			
6	Lack of interest for the young generation to work agricultural activities.	Yes	110	46	40	1.93	>0.25	Not Significant
		No	40	24	20			
7	Lack of frequent and continued maintenance	Yes	112	62	55	0.005	>0.05	Not Significant
		No	38	8	5			
8	Lack of field guidelines for SWC practices	Yes	132	61	53	0.127	>0.05	Not Significant
		No	18	9	7			
9	Weak interaction among stakeholders	Yes	128	59	51	0.006	>0.05	Not Significant
		No	22	11	9			
	Total		150	70	60			

Though the listed constraints are found in all agroecology there is a variation on the degree of constraints of SWC along different agroecology. According to the chi-square result at alpha level 0.05, there was a significant association between land size, access to fertilizers, seeds, pesticides, construction materials, technical skill, and maintenance of the conservation structures versus different agroecology.On the other hand, no significant association between food security, interest of the young generation in farm work, lack of frequent maintenance, field guidelines, interaction among stakeholders versus different agroecology. For instance, the constraints such as small land size or landlessness are more constraining factors to follow the standard SWC guideline in the midland, because the population density in the midland was higher than the lowland or highland agroecology. Whereas, in the highland, the constraints such as access to fertilizers, pesticides, seeds, and skilled manpower were serious challenges to adopt the standard SWC structures that may be related to the remoteness of the areas from the woreda or zonal towns.

The result implies in the lowland areas, the constraints related to poor access to infrastructures, construction materials, and lack of frequent maintenance of SWC structures were serious constraints of SWC work. Reports by Biratu and Asmamaw (2016) and Dawit (2014) indicated that the level of community participation on SWC was determined by the social facilities (transportation and communication). The local farmers also listed other constraints of SWC that challenged the implementation of standard SWC work (4.2.7).These were the complex design of SWC technology and the intensive labor force demanded during the implementation of SWC structures. In the study area, almost all schooled young farming families were migrating to the urban area for nonfarm work, which adversely affect the standard conservation work. The same result was reported by Legesse (2014) in that young people who could attend school was no longer interested in becoming farmers in the study area. This condition harms access of the labor force for SWC and constraints to apply the standard design of SWC work.

4.3 Investigation of the Effect of Physical Soil and Water Conservation Structures on the Soil Physical and Chemical Properties along different agroecology of Gidabo River Sub-basin, Ethiopian Rift Valley

4.3.1 The Effect of SWC Practices on Soil Physical Properties

I. Soil Particle Distribution

For this study, soil particle distribution (clay, silt, and sand) was considered for different soil conservation practices and agroecology/altitudinal belts. ANOVA result at $p \leq 0.05$ showed that sand soil has no significant difference along different agroecology, and SWC treatment, whereas silt and clay had significant differences across various SWC treatments but no difference along with agroecological variation. For instance, the greater mean value of silt soil was recorded in conserved land and clay in non-conserved land of the study area (Table 4.3.1; 4.3.2).

The high concentration of silt soil in the conserved land was attributed to the comparative effect of SWC, which increased the deposition of fine soil particles. Similar results were reported by Belayneh et al. (2019) in the Gumara watershed. Upper Blue Nile Basin, Ethiopia. High clay content in the non-conserved land might be due to the resistance of heavy clay soil that is small particles and not much organic material to hold water. The report by Yirgu et al. (2020) showed the clay soil can resist soil erosion and is less susceptible to erosion hazards. As stated by Mengie et al. (2019) and Asfaw &Neka (2017): soils of the non-conserved land had the highest percent of clay compared to the soils of the conserved one. Thus from the findings, it is possible to conclude that the variation of soil particles such as silt and clay have related to a variation of SWC treatment and resistance to erosion.

Table 4.3.1: Mean standard deviation of soil particles along with different agroecology and soil conservation practices

Agroecoloy/ altitudinal belt	Soil mgt	Number of sample	Sand	Clay	Silt	BD
Highland 2,300-3000m	SB	3	45.33 ± 1.15	24.0 ± 2	34.66 ± 1.15	.66 ± .068
	FN	3	38 ± 2	32.0 ± 2	30 ± 4	1.08 ± .56
	CD	3	49.66 ± 4.72	21.33 ± 8.32	26. ± 2	.65 ± .13
	CN	3	53 ± 6.08	21.0 ± 2.64	26.66 ± 5.5	1.24 ± .51
	F		7.787	3.735	3.647	1.775
	Sig		*.009 ***	*.060 ns*	*.064ns*	*.230 ns*
Mid land (1500 2300m)	SB	3	33.33 ± 6.42	4 3.33 ± 4.16	23.33 ± 3.05	1.28 ± .03
	FN	3	39.33 ± 11.01	40.66 ± 11.7	20 ± 3.46	1.12 ± .020
	CD	3	34.66 ± 8.08	40.66 ± 14.04	24.66 ± 6.42	1.38 ± .44
	CN	3	50. ± 7.21	29 ± 6.55	18.66 ± 2.08	1.45 ± .07
	F		2.451	1.245	1.406	1.212
	Sig		*.138 ns*	*.356 ns*	*.310 ns*	*.366ns*
Low land (500-1500 m)	SB	3	34.66 ± 13.01	52.± 15.09	13.33 ± 2.30	1.22 ± .05
	FN	3	45.33 ± 9.01	42.66 ± 11.54	12 ± 5.29	1.22 ± .04
	CD	3	45.33 ± 3.05	32.66 ± 1.15	22 ± 4	1.12 ± .12
	CN	3	53.66 ± 3.21	30.00 ± 1.73	11 ± 4.35	1.30 ± .09
	F		2.691	3.316	4.454	2.332
	Sig		*.117 ns*	*.078 ns*	*.040 **	*.151 ns*

Table 4.3.2 Posthoc ANOVA comparison of soil physical property along with different agroecology and soil management

Soil variable	Source	SS	DF	MS	F	Sig
Sand soil	Agroecology	.222	2	.111	.001	.999
	Soil management	196.528	3	65.509	.691	.565
Silt soil	Ago ecology	12.056	2	6.028	.156	.857
	Soil management	980.528	3	326.843	8.445	.000*
Clay soil	Ago ecology	22.222	2	11.111	.112	.895
	Soil management	1827.778	3	609.259	6.115	.002*
BD	Agoecology	.319	2	.160	.876	.428
	Soil management	.608	3	.203	1.111	.361

SS (sum of squares), DF (degree of freedom), Ms (Mean squares), F (F ratio).

II. Soil bulk density/SBD

The soil bulk density value of the study area showed that relatively higher SBD was observed in non-conserved plots than in conserved plots. The SBD refers the mass of dry soil (105^{0}C) per unit of bulk volume, including the air space (FAO, 2006). However, the ANOVA result at $p \leq 0.05$ showed that the differences in the mean bulk density of the soil along with different soil treatment, and agroecology were not statistically significant (Tables 4.3.1; 4.3.2). Statistical results of the study area showed that variation of soil treatment and agroecology had no significant impact on the soil bulk density of the study area. This might be due to similarities in the density of the soil minerals and the packing arrangement of the soil. This study agreed with the report by Belayneh et al. (2019 and Negasa, et al. (2017) in that the soil bulk density was not statistically significant variation across different soil conservation practices.

4.3.2 The effect of SWC on soil chemical properties

The chemical property of the soil in the Gidabo river sub-basin at the different altitudinal belt, and SWC treatment practices were assessed from the soil organic carbon, total nitrogen, soil pH, soil electrical conductivity, cation exchange capacity, available phosphorus, and available potassium. Soil chemical properties are the most essential factors that govern the nutrient supplying power of the soil to the microbes and plants.

4.3.3 Soil organic carbon/SOC

The two ways ANOVA at $p< 0.05$ showed that significant variation of SOC across a variation of agroecology (midland, lowland, and highland) and SWC treatment. The study result indicated that the distribution of SOC was significantly affected by agroecology with different climatic characteristics and soil management (Table 4.3.3). For instance, the soil management variation showed that in the midland, the mean SOC had greater value in the land treated with SWC structures than in the non-treated land. In contrast, in the highland and lowland agrology, the mean value of SOC had no significant difference between treated and non-treated land. Furthermore, irregular distribution of

SOC was observed between treated and non-treated land of the highland and lowland altitudinal belt (Table 4.3.3).

The result depicted that, certain conservation structures were not successful in improving the SOC which might be related to constraints limiting the effectiveness of the conservation structures in section 4.2.7.The report by Elias (2002) and Gashaw et al. (2017) showed that the effectiveness of SWC could be determined by the type of land management, slope characteristics, climate, cropping system, soil types, and access to resources. For example, soil organic carbon is highly determined by the level of land management practices (Pathak et al. 2009 and Motsara and Roy, 2008).

Regarding to the agroecological variation the value of SOC was higher in the highland agroecology than midland or lowland. A similar result was reported by Sevgi (2003) the SOC increases as altitude increases. This might be due to the change in the climatic condition at a higher elevation. The other contributing factor may be better land cover with grass, less tillage, and land rotation in the highland area, whereas in the midland and lowland frequent cultivation and less land cover expose the SOC to erosion and contribute to the reduction of SOC. According to Vos et al. (2019) permanent grassland cover topsoil's, which are less disturbed get larger C-inputs than non-grass-covered areas. Also the report by Chan (2008) showed that the SOC is higher in the land with less tillage and better land cover. Therefore, land tillage, grassland cover, and application of manure/ household waste could contribute to the variation of soil organic carbon along different agroecology of the study area.

4.3.4 Total nitrogen

The value of TN in Table 4.3.3 indicated that a significant difference was observed across various agroecology and soil management. In this regard, agroecological differences showed that higher TN is found in the highland and the least is in the lowland. High nitrogen content at high altitudes may be due to wet conditions, which enhanced the activity of nitrogen-fixing bacteria. The low agroecology soil was drier than at high agroecology that limit the nitrogen fixation process. A similar result was reported by (Ram et al., 2015).

Regarding variation of soil conservation, a relatively greater value of TN was recorded in the soil treated with SWC structures of the highland and lowland area (Table 4.3.3). However, in the midland, irregular distribution of TN was observed among different soil conservation practices. For instance, the mean value of TN in the FN and STB structures was lower than in the land not treated with SWC. Nevertheless, the mean value of TN in soil treated with SB structures was greater than in non-treated land. The result on a higher mean value of TN in conserved land of SB structure than non-conserved is in line with the report by Belayneh (2019), Ademe et al. (2017), Hailu, (2017), Asfaw and Neka (2017), and Million (2003) that showed the mean total nitrogen of the soil was greater in conserved land than non-conserved.

The high mean value of TN in the soil treated with SB structure than FN and STB structures in the highland and lowland area indicated that the conservation structures such as FN and STB have failed or did not succeed in improving the total nitrogen content of the soil. It might be due to failure to select the right conservation technology and/or poor design/layout of the structures to keep soil erosion. According to the report by Namirembe et al. (2015), appropriate conservation structures for ecological and socio-economic conditions are necessary for effective conservation work.

4.3.5 Soil pH

According to the data in (Table 4.3.3), the two-way analysis of variance at $p \leq 0.05$ showed a significant difference in soil pH across different agroecology and soil management practices. The result illustrated that variation of agroecology and SWC treatment has a significant impact on the distribution of soil pH of the study area. For instance, agroecological variation showed a lower pH value in the highland than midland or lowland. The result is in agreement with the report by Ram (2015) that showed lower elevation had the highest pH value, which decreased with altitude. According to Ashton (2011), there is higher relation between temperature and soil pH. The increment of temperature causes high molecular vibrations, which results in the ability of water to ionize and form more hydrogen ions. As a result, the soil pH will decrease. In line with this, studies conducted by Zhang et al. (2019) reported that soil pH is highly sensitive to changing natural environments and the presence of heavy rainfall, which results in the leaching of basic cations (remove nitrate contents). As a result, soils of the uplands have lower pH and relatively acidic behavior. Also the higher organic decomposition that release carbon has higher probability to increase hydrogen ion that will reduce the soil pH.

Regarding different soil management, the highest mean value of soil pH was observed in the treated land than in the non-treated land of all agroecology. The result on the distribution of soil pH along different soil management indicated a significant impact of conservation work. The high content of soil pH in the conserved land might be associated with the reduction of the loss of soil organic matter and exchangeable bases through soil erosion and runoff. A report by Gadana et al. (2020), Wolka et al. (2011), and Tugizimana (2015) showed that soil pH was significantly higher in the soil with management practice than in soils with no management practices.

Table 4.3.3 The Posthoc ANOVA comparison of soil chemical properties along different agroecolog and land management practices

Soil variable	Source	SS	DF	MS	F	Sig
OC	Agoecology	116.341	2	58.170	107.747	.000*
	Land mgt	5.727	3	1.909	3.536	.027*
pH	Agoecology	8.006	2	4.003	34.758	.000*
	Land mgt	6.295	3	2.098	18.218	.000*
TN	Agoecology	1.527	2	.764	65.731	.000*
	Land mgt	.081	3	.027	2.324	.080*
CEC (meq/100gm)	Agroecology	2385.032	2	1192.516	274.462	.000*
	Land mgt	39.725	3	13.242	3.048	.005*
EC (µs/cm)	Agoecology	21394.071	2	10697.035	8.481	.001*
	Land mgt	26659.140	3	8886.380	7.046	.001*

Av.K (mg/l)	Agoecology	318819.757	2	159409.879	7.479	.002*
	Land mgt	171542.857	3	57180.952	2.683	.009
Av.P (mg/l)	Agoecology	49.567	2	24.783	49.986	.000*
	Land mgt	11.809	3	3.936	7.939	.001*

4.3.6 Soil electrical conductivity (EC)

The ANOVA results revealed significant differences in soil EC across various agroecology and soil management. For instancein the highland and midland agroecology's conserved soil had a higher mean value of soil EC than non-conserved land (Table 4.3.3). The higher mean value of soil EC in the conserved land might be related to household wastes, livestock manure, dung ash, and other decomposable materials used on the conservation structures, which collectively enhance soil EC over a long time. A similar result was reported by Negassa et al. (2017) where the local farmers mostly throw wastes, residue, dung, wood, and other decomposable materials in the farmland that gradually increase soil EC. Though the higher value of the soil EC in the lowland was found in the treated land, statistically, the difference was not significant among various soil conservation practices.

The study also showed the overall mean value of soil EC in the highland was lower than the midland or lowland. This might be due to temperature variation. According to Butros et al. (2010), when temperature decreases, soil EC decreases slightly because when the temperature is below freezing, soil pores become increasingly insulated from each other and overall soil EC declines rapidly. The report by Bai (2013) showed that the soil's electrical conductivity increases with the increase of temperature. This might be the cause in the study area for the value of soil EC was relatively lower in the highland compared to the amount in midland/lowland.

4.3.7 Cation exchange capacity (CEC)

The total number of exchangeable cations a soil can hold is called its cation exchange capacity (CEC). Statistical results of soil CEC showed significant differences of soil exchangeable cations along with the variation of agroecology/altitudinal belt and soil management practices (Table 4.3.3). For instance, in all agroecology, the mean value of CEC was greater in conserved land than non-conserved land. The result indicated that the SWC practices significantly affected the soil CEC in the study area. The high CEC observed in the conserved land might be caused by conservation work that generates high biomass and control of erosion, consequently increasing CEC in the soil. A study reported by Gadana et al. (2020), Muktar et al. (2020), and Emiru & Gebrekidan (2009) showed that the mean value of CEC content in soils under un-conserved farm plots was lower than the value recorded in conserved farm plots.

The agroecological difference of soil CEC showed a high mean value in the highland and the least in the lowland. The high CEC value in the highland might be due to the high contents of clay soil in the highland that holds or stores cation. But in the midland and lowland agroecology, the sand content of the soil is higher than the highland that has a low holding capacity of the soil CEC. According to Efretuei (2016) and Agronomic Fact Sheet Series (2007) when the soil particle is negatively charged (high clay contents) they attract and hold to cation and reduce leaching down the soil, while the soils with low CEC have low ability to hold water (e.g. sandy soils). Also, the cation exchange capacity of the soil can be lower in heavily weathered kaolinite clay (Brady and Weil 1999). Climate variability may be the other factor that has contributed to the lower CEC in the lowland agroecologyof the study area. For instance, an increase in soil temperature decreases organic matter through combustion, which leads reduction in clay size fraction and the cation exchange capacity of the soil (Úbeda et al., 2009 and Rengasamy, & Churchman 1999).

4.3.8 Available phosphorus (AP)

The result in (Table 4.3.3) revealed that the available phosphorus was significantly different in the study area at $p \leq 0.05$ along different agroecology and soil management practices. For instance, the mean value of available phosphorus (AP) of the soil was greater in conserved land than in non-conserved. The statistical result showed that the SWC structures significantly contributed to the improvement of phosphorus in the conserved soil than in non-conserved soil. These results agree with the finding by

Dagnachew et al. (2019), Tanto and Leakemariam (2019), Hailu et al. (2012), and Tolera (2011) in that the physical SWC measures caused the higher amount of available phosphorus on conserved land.

In the study area, the application of both organic and inorganic sources of AP was important for amending the agricultural land for better land productivity. The high concentration of AP in the treated land could be attributed to the application of compost, manure, and household wastes and chemical fertilizers (urea, CO, NH2), and diammonium phosphate (DAP). Similar findings in the study area were obtained by Ademe et al. (2017). They argued that high AP in the conserved land may be due to the application of organic sources of AP for better land productivity.

The data in (Table 4.3.3) show that, the lower mean value of AP in the midland area than lowland might have resulted from the variation of temperature. The report by Gahoonia et al. (2003) showed that soils with low temperatures have low availability of phosphorus because the release of phosphorus from organic material is hindered by low temperature. The results of this study were comparable to the report by Shara et al. (2021) that showed available phosphorus in the soil increased with decreasing altitude for ($p<0.05$). But the contrary result was observed in the highland agroecology because there is high AP with low temperature than the midland or lowland area.

This result implies the controlling factors for AP in the highland are not related to temperature. As noted by Solomon and Lehmann (2000) the presence of a sufficient amount of AP in the soil is due to management factors. Therefore, the factors that contributed to high AP in the highland agroecology of the study area may be related to soil conservation and less tillage that reduced the removal of AP. Or the high rainfall drop per unit time in the soil surface made the soil crushed to increase the surface area of soil particles, which adsorbs more adsorbed phosphorus.

4.3.9 Available potassium (AK)

The statistical result showed a significant difference in available potassium (AK) was found among different soil soil management practices in the highland and lowland agroecology but not in the midland (Table 4.3.3). The result also depicted that the soil AK was significantly different along with different agroecology/altitudinal belts. For instance, the mean value of soil AK is high in the lowland and least in the midland. The exact mechanism by which factors influence the reaction of potassium in soil is not clearly understood. The lower value of AK in the midland might be related to the variation of land management, soil particles, or soil temperature in the area.

According to Butros et al. (2010), the potassium nutrient of the soil has shown variable distribution along different agroecology due to its greater mobility. The least value of AK in the midland may be related to frequent (over) cultivation of farmers in small plots of land that lead to both soil degradation and erosion of available potassium of the soil. According to Nisha, (2018) continued cultivation of the crops on the same soil without additional input reduces the marginal productivity of the soil due to exhaustion of nutrients, thus the land depreciates.

Exceptional to other chemical properties, AK did not show significant differences in various soil management practices. Though the irregular distribution of AK was recorded within different soil conservation practices of the midland and lowland agroecology, in the highland area, the greater value of AK was recorded in conserved land. The value of (AK) in the highland area was in line with the report by Asnake and Elias (2019) and Wadera (2013), in which higher soil potassium was observed on the treated land than in the non-treated one. The high concentration of AK in the treated land of highland agroecology might be related to the application of plant cover in the treated land. However, in the midland and lowland area, plant material was frequently removed for household energy consumption and it might have facilitated leaching problems. This might contribute to the lower value of AK in the midland and lowland compared to in the highland agroecology of the study area.

CHAPTER FIVE

5. Summary, conclusions, and recommendations

5.1 Summary

This research aims at analyzing the soil and water conservation structural design and its effect in response to land use and land cover changes (LULCC). The issue of LULCC in the area was considered with the assumption of the changes in the socio-economic and environmental variables that are an essential indicator to determine the future relationship between the environment and the community in a way of sustainable development.

The overall finding of this study revealed that dynamic LULCC has occurred in the past 33 years. For instance, in the period from 1986 to 2019, about 10% of shrub/woodland, 6 % of grassland, and 1% of cropland showed a remarkable reduction. On the other hand, about 14% of agroforestry, 2% of settlement land, 1% of forest land, and 0.14% of bare land showed expansion. In the area from 1986 to 2019, about 34% of the area was transferred to different LULC classes. Among the observed LULCC the expansion of agroforestry and forest land cover is essential from the concept of environmental management and sustainable development.

Conversely, the change observed on settlement land, bare land, shrubs/woods land, and grassland pose difficulties in achieving full food security goals and threatens the sustainability of the ongoing agroforestry system. The findings indicated that the LULCC of the area was ultimately driven by the interplay of demographic, technological, economic, natural, cultural, and policy factors that are significantly different along with agroecological/altitudinal variation. Also, the frequently reported problems, such as reduction of the productive capacity of agroforestry, slow transfer of indigenous conservation knowledge, and food insecurity have increased the need for watershed-based SWC that are important to support the agroforestry system of the area. Since 2005 the area has been accompanied by many natural resource management programs such as Safety Net and active Community Participation on SWC that focused on the national guidelines (MoARD, 2005). However, the application of the national guidelines for SWC remains challenging on the ground.

In pursuant of the second objective, an attempt was made to assess the type of SWC technologies, design, acceptability, challenge, and the level of community participation based on the national standard. The study also considered farmers' interests and constraints to adopting/adapting the SWC practices. From the study, it was concluded that the farmers are implementing the SWC technologies, such as soil bund, fanya juu, bench terrace, and micro basin. However, the data from field measurement, FGD, interview, and a household survey showed that many of the physical SWC structures in the sampled watersheds failed to meet the standard design/dimensions (depth, distance, width, height, length, and vertical interval).

This means that in the highland area the SWC structural designs such as embankment width, embankment height, bottom width, a distance of the ditch to the berm, and the vertical interval between structures are below the standard. In the midland, in all measured SWC structures the vertical interval, horizontal distance, and soil depth failed to meet the standard. Also in the lowland area the vertical interval, horizontal distance, and embankment height of the structure failed to meet the standard. The study showed that besides the technical problem, the sampled conservation structures did not fulfill the sound principle of SWC such as the application of supportive (biological) measures, hilltop to downhill conservation approach, and active participation of stakeholders in all phases.

The major constraints to adopt/adapt the standard SWC structures and principles are related to the socio-economic and environmental conditions of the area that were significantly varied along different agroecology. For instance, small land size is a more constraining factor in the midland, than the lowland or highland agroecology. While, in the highland access to fertilizers, pesticides, seeds, and skilled manpower was a serious challenge. Whereas poor access to infrastructures, construction materials, and lack of frequent maintenance of SWC structures were significant constraints in the lowland area.

The physical conservation structures that failed to meet the standard SWC work harm the soil property. Therefore assessment of the soil quality was carried out from the perspective of SWC practices along different agroecology. The study result showed that no significant difference was observed in soil particle distribution along different agroecology. However, a significant difference in silt and clay soil content was observed along with various soil management practices. For instance, a high concentration of silt content was observed in the conserved land that was attributed to the comparative effect of SWC, which increased the deposition of fine soil particles. While high clay content was found in non-conserved land that might be related to the resistant clay soil in the eroded land. Concerning soil bulk density (SBD) no significant difference was observed at all, along with different altitudinal belts, and soil management.

On the topic of soil chemical properties, the statistical result showed that soil properties such as OC, pH, TN, CEC, EC, and AP showed significant differences across various agroecology/altitudinal and soil conservation practices; while AK showed irregular distribution along with different SWC work. Though the effect of SWC on soil property was not satisfactory and unevenly distributed, relatively better soil property was found in conserved land that may be attributed to the reduction of runoff, increment of soil deposition, and retaining the moisture of the soil. Also, the agroecological variation that has different rainfall and temperature significantly affected the soil properties of the study area.

5.2 Conclusion

Based on the study result and the above summary it was concluded that however agroforestry-based agriculture and forest land is increasing for the study period contrary there is an expansion of settlement land, bare land, soil erosion, reduction of grassland, shrub/woodland, and high population pressure on the limited resources. This is evidenced by the irregular distribution of physical and chemical soil properties, increment of food insecurity, high demand for agricultural inputs, increasing dependence on external aids, marginal land cultivation, forest encroachment, youth migration to the urban area, and the limited success of SWC efforts among others. Though the newly introduced SWC practices are implemented in a sense of supporting the agroforestry system the conservation work is not fully successful compared to the existing socio-economic and environmental problems of the area.

According to the study result, the constraints such as small land size, lack of labor force, lack of interest for agricultural work among the youth, food insecurity, lack of technical skill, poor maintenance of conservation work, limited community participation on SWC, and lack of agricultural inputs threaten the sustainability and productivity of the agroforestry system. Because these problems caused the implemented SWC works wholly or partially failed to follow the national SWC guidelines and principles in a way to support the agroforestry practices of the area. Hence, the issue of soil erosion and its consequences continued to adversely affect the socio-economic and environmental conditions of the area.

In this regard, it is impossible to ensure the sustainability of the agroforestry system given that the current dynamic change on bare land, settlement land, shrub/woodland, grassland, and population pressure continues. The stakeholders, particularly land users, government leaders, experts (development agents), and researchers should work together to enhance the productivity of the agroforestry, and forest land cover by managing the principal driving forces behind the LULCC and soil erosion that adversely affect the agroforestry system in the area. Moreover, the national SWC guideline and principle should consider the local condition of the specific area, particularly the culture, environmental, economic, and social aspects of the community. That is important to increase the effectiveness of the conservation work, and reduce the pressure on the limited natural resources in the study area.

5.3 Recommendations

The findings of this research reveal that the observed change on agroforestry and forest land cover have promising conditions that could significantly contribute to future natural resources conservation work. But the sustainability and productivity of the changes were challenged by the multifaceted and complex socioeconomic and environmental factors.

Such complex problems cannot be mitigated if concerted efforts are not in place. What is important in this regard is supporting the agroforestry system with well-organized and integrated SWC work, as well as supporting the agricultural production by technology and improved seeds. It is hoped that the following recommendations will be a means to the problems prevailing in the study area.

I. Apply the national SWC guideline and principles in a way to support the traditional conservation practices and the existing agroforestry system of the area

The ministry of agriculture in Ethiopia prepared the national SWC guidelines and policies for sustainable land management with a sound scientific base. Though traditional SWC work has been implemented for a long time in the study area, the problem of soil erosion and its impact were increasing over time. Among the major factors the traditional SWC practices alone were not successful to conserve the limited natural resources, and also the introduced SWC work failed to follow the standard design and principles of conservation. Therefore, the application of the national SWC guideline in a way to support the agroforestry system of the area is a timely issue. Also the introduced SWC practices should consider the local condition of the study area, particularly the culture, environmental, economic, and social aspect of the community that is useful for food security and sustainable development.

II. Livelihood diversification options must be given to the farmers

Diversifying the livelihood options of the community in the study area is a very important step because it will reduce the pressure on agroforestry, marginal land, scarce resources, and control the expansion of undesirable LULCC (bare land, and settlement land). For instance, parallel to cropland agriculture production of poultry, animal fattening, and producing raw material for the newly planted agro-industry is advantageous to reduce the pressure created on the natural resources by the high population growth and climate variability. In this regard, the regional agricultural office, universities, and other stakeholders can play an important role. This means that a strong linkage should be created between industries and farmers' products. Also improving farmers' climate adaptation capacity is necessary to improve agricultural production through the application of improved seed, pesticide, fertilizers, irrigation, and modern farming tools/technologies.

II. Focus on the local constraints of the SWC work and continuous follow up of the conservation work

Among many challenges of conservation work, lack of focus on local constraints and lack of frequent follow-up/maintenance of the conservation work has adversely affected SWC practices. During interviews with land users and development agents, most government leaders focused on lip service or political consumption rather than practical work to support the community. Because of this, sometimes they give wrong data to the next higher officials or they may call the community for a few days' campaign for the conservation work only for media consumption. After that day, no one sees what has been done on the conservation work. To this end, the researcher recommends that the SWC approach of the study area needs to be critically shaped to address the problems in the ground and frequent follow-up/maintenance of the conservation work.

In addition, access to services such as roads, health centers, and education is important for effective SWC work. For instance, provision of road transport for the farmers creates opportunities to access agricultural inputs, increases farmers' markets for their products, and increases the number of non-governmental organizations, which contribute to natural resource conservation via finance, instrument, or skill transfer. Access to schooling is also helpful to transfer knowledge to the farmers and their families. Health center keeps farmers healthy to be active participants in conservation work. To this end, the researcher recommends that all stakeholders (policy designers, policymakers, political leaders, experts, researchers, and farmers), should work closely to minimize or avoid the local constraints in a way to enhance the performance of the SWC work in the area.

5.4 Suggestions for further research

1. Detailed investigation is necessary about the productive potential of the expanding agroforestry system in a way to sustain socio-economic and environmental development of the study area.
2. The cause and consequences of the high population growth of thearea should be investigated from the perspectives of limited natural resources.
3. Further investigation should be carried out on how to apply the standard SWC practices in densely populated and small plots of land.
4. The advantage and disadvantages of incentive-based (Safety-net) community participation on SWC should be further investigated from the perspectives of hardworking habits.
5. Research should be carried out on how to integrate the indigenous knowledge and positive motive of the community for resource conservation with the introduced SWC practices in a way to avoid the existing challenge of the agroforestry system and SWC practices.

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APPENDICES

Annex 1: List of published articles

1. Land Use and Land Cover Change for Resilient Environment and Sustainable Development in the Ethiopian Rift Valley Region. (Part of the PhD work). Published in the Journal of Environmental Protection and Natural Resources (Ochrona Srodowiska i Zasobow Naturalnych) 2021, (Vol. 32 No 2(88):1-1). Indexed in Scopus, Web of Science and other data bases. (https://sciendo.com/article/10.2478/oszn-2021-0007).

2. Assessment of Design and Constraints of Physical Soil and Water Conservation Structures in respect to the standard in the case of Gidabo sub-basin, Ethiopia (Part of PhD work).Published in the Journal of Cogent Food & Agriculture 2021, (Vol, 7), Taylor & Francis publishing. Indexed in Web of sciences and other data bases.(https:// doi.org/10. 1080/233 11932 .2020.1855818)

3. The Effect of Soil and Water Conservation Structures on the Soil Physical and Chemical Properties in the Gidabo Sub-Basin, Ethiopian Rift Valley. Part of the PhD article, published in the International Journal of Environmental Science and Development 2021, (Vol, 12). Indexed in Scopus and other data bases.(doi: 10.18178/ijesd.2021.12.12.1362)

Annex 2: Rainfall and temperature data

Station Name	Wereda	Altitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dilla	Wenago	1515	56.7	6.6	77.1	146.9	109.6	75.2	74.4	70.8	67.3	128.0	95.4	22.2
Dilla	Wenago	1515	87.3	32.1	63.3	275.5	113.0	40.9	73.7	63.4	126.0	70.0	112.2	45.4
Dilla	Wenago	1515	44.3	9.3	77.0	265.2	246.2	63.7	76.9	95.9	144.8	183.4	58.6	4.0
Dilla	Wenago	1515	15.5	51.4	151.1	206.5	158.4	151.4	53.7	159.5	130.3	292.1	90.1	33.4
Dilla	Wenago	1515	81.3	10.5	94.9	149.8	340.2	201.3	83.2	274.8	212.5	193.3	57.1	0.0
Dilla	Wenago	1515	2.2	4.5	59.2	198.5	213.9	85.1	143.8	89.4	161.7	337.5	74.6	0.6
Dilla	Wenago	1515	52.6	40.8	39.5	207.2	139.6	72.0	25.9	46.0	177.3	156.5	15.9	158.5
Dilla	Wenago	1515	45.4	141.1	203.9	217.0	314.2	139.8	80.5	147.5	132.5	238.7	7.3	8.2
Dilla	Wenago	1515	11.0	23.3	39.5	135.6	276.4	110.5	95.6	180.3	190.0	223.6	198.7	11.5
Dilla	Wenago	1515	14.8	12.6	29.2	136.4	198.9	198.6	162.8	127.1	175.9	181.2	101.4	21.6
Dilla	Wenago	1515	16.9	12.4	98.4	175.5	134.6	93.8	151.5	116.0	158.2	199.8	108.4	17.1
Dilla	Wenago	1515	8.8	23.6	122.6	134.5	368.5	74.9	96.7	104.9	140.4	218.3	109.6	12.6
Dilla	Wenago	1515	6.3	0.3	72.1	145.3	162.9	159.0	81.2	60.7	140.0	151.7	95.5	52.0
Dilla	Wenago	1515	31.5	31.9	56.0	201.2	233.3	126.6	69.8	155.6	66.9	175.6	75.1	22.8
Dilla	Wenago	1515	1.5	36.4	45.7	140.3	237.3	89.4	77.3	206.0	269.2	255.0	65.6	0.0
Dilla	Wenago	1515	1.6	97.7	132.3	225.8	179.8	210.0	8.6	149.4	169.8	230.4	179.8	39.2
Dilla	Wenago	1515	6.1	19.4	59.0	132.8	324.9	172.7	270.4	155.7	115.4	120.6	59.9	19.9
Bule	Bule	2804	93.3	36.7	42.6	163.9	112.0	189.3	145.3	143.5	140.6	72.1	71.5	39.1
Bule	Bule	2804	180.5	53.9	26.2	375.1	132.6	214.1	220.1	260.9	206.1	117.4	95.1	86.2
Bule	Bule	2804	26.6	15.5	58.8	156.2	342.4	152.2	49.2	134.3	276.6	293.6	76.2	0.0
Bule	Bule	2804	13.0	133.1	91.4	275.9	185.5	135.4	82.7	153.5	75.1	202.4	57.2	115.2
Bule	Bule	2804	51.0	31.3	49.7	186.9	167.7	238.1	100.5	159.9	171.3	149.5	124.9	19.3
Bule	Bule	2804	4.8	10.9	58.2	104.6	183.6	176.4	102.8	186.3	111.0	131.3	107.9	52.3
Bule	Bule	2804	76.1	66.3	90.4	223.8	154.0	102.0	42.1	133.2	178.3	146.5	82.5	87.7
Bule	Bule	2804	40.8	162.0	213.1	205.1	336.8	106.2	155.0	179.8	240.6	256.7	12.0	14.6
Bule	Bule	2804	33.0	38.0	33.6	118.0	292.6	74.3	195.0	181.4	207.2	114.9	145.5	37.8
Bule	Bule	2804	5.5	3.0	97.3	161.4	180.5	231.1	129.3	103.8	154.8	201.8	125.6	48.2
Bule	Bule	2804	0.0	46.1	161.0	223.7	264.6	81.9	168.7	197.1	232.5	200.8	91.1	0.0
Bule	Bule	2804	53.7	82.4	94.3	97.4	163.2	152.0	67.6	134.6	119.6	0.0	0.0	0.0
Bule	Bule	2804	8.2	55.6	133.2	213.9	112.7	164.0	45.7	96.6	158.9	186.3	148.6	94.7
Bule	Bule	2804	18.6	63.1	55.9	167.1	152.0	108.1	54.8	108.3	218.1	260.0	87.2	24.8
Bule	Bule	2804	26.5	27.9	95.4	122.3	168.1	106.6	63.9	201.1	277.3	285.0	78.8	0.0
Bule	Bule	2804	6.3	93.6	134.9	268.5	183.2	153.5	22.9	170.0	194.2	170.6	70.5	44.4
Bule	Bule	2804	2.1	21.0	25.6	153.6	248.2	189.5	209.2	175.4	168.3	173.5	148.5	36.5
Kebado	Dara	1807	43.9	3.8	54.8	226.8	163.8	144.8	56.1	134.7	120.2	122.0	59.3	32.8
Kebado	Dara	1807	111.1	63.1	58.9	171.4	153.0	34.0	58.1	106.6	147.1	73.3	89.8	85.4
Kebado	Dara	1807	17.7	7.2	120.1	287.1	209.5	145.9	76.6	59.2	177.5	156.3	17.9	0.0
Kebado	Dara	1807	21.0	55.6	127.5	195.5	207.5	114.9	121.8	160.1	150.2	358.7	77.1	13.6
Kebado	Dara	1807	62.8	76.2	90.3	158.5	270.7	96.9	73.2	252.7	303.0	184.1	36.7	0.0

Kebado	Dara	*1807*	*2.6*	*10.4*	*42.1*	*168.0*	*285.1*	*83.3*	*85.1*	*62.0*	*282.5*	*197.6*	*66.7*	*7.9*
Kebado	Dara	*1807*	*84.8*	*27.0*	*102.0*	*176.1*	*197.7*	*45.0*	*26.4*	*54.4*	*211.6*	*168.1*	*6.0*	*96.9*
Kebado	Dara	*1807*	*47.3*	*130.7*	*162.9*	*289.6*	*282.0*	*165.6*	*147.5*	*181.7*	*95.4*	*119.1*	*26.7*	*5.6*
Kebado	Dara	*1807*	*12.2*	*15.4*	*27.9*	*116.5*	*272.0*	*71.2*	*39.8*	*252.8*	*262.1*	*135.3*	*199.4*	*9.7*
Kebado	Dara	*1807*	*4.6*	*0.0*	*48.1*	*166.0*	*118.3*	*128.1*	*184.6*	*92.9*	*275.1*	*121.0*	*41.9*	*31.9*
Kebado	Dara	*1807*	*28.7*	*7.3*	*107.3*	*209.7*	*119.7*	*101.2*	*54.0*	*139.7*	*150.4*	*135.5*	*88.7*	*60.3*
Kebado	Dara	*1807*	*7.2*	*27.5*	*159.6*	*168.8*	*313.7*	*88.0*	*157.4*	*182.0*	*123.0*	*140.5*	*78.4*	*30.5*
Kebado	Dara	*1807*	*0.0*	*0.0*	*89.6*	*156.7*	*123.5*	*74.8*	*47.6*	*51.1*	*102.2*	*145.8*	*68.2*	*0.0*
Kebado	Dara	*1807*	*0.0*	*27.6*	*34.4*	*66.1*	*80.4*	*64.1*	*62.4*	*131.5*	*113.9*	*135.0*	*64.3*	*0.0*
Kebado	Dara	*1807*	*11.0*	*55.3*	*34.4*	*122.8*	*105.9*	*53.3*	*77.2*	*151.2*	*235.6*	*315.1*	*105.1*	*0.0*
Kebado	Dara	*1807*	*0.0*	*88.6*	*103.2*	*173.2*	*131.4*	*245.2*	*29.2*	*98.4*	*108.8*	*183.9*	*187.1*	*0.0*
Kebado	Dara	*1807*	*22.5*	*45.0*	*150.0*	*210.9*	*599.3*	*276.6*	*131.5*	*291.6*	*287.4*	*209.4*	*153.4*	*22.6*

Rain fall and temprature data from 2003 to 2019

Annex 3 Socio-economic data

Household survey questionnaire for data collection

Part 1 Geographic information

Date of interview/(D/M/Y)--

Region--------------------------------Zone-----------------------------Woreda---------------------

Kebele--------------------------------GPS latitude--

Longitude-----------------------------Elevation--

Agroecology/Altitudina belt 1/ Dega (above 2200 m) 2/ Woina Dega (1500 to 2200 m)

3/ Kola below1500 m

Part 2 Household (HH) demographic information

2.1 Respondent's name: ---

2.2 Gender:(A) Male---

(B) Female---

2.3 Age in years:---

2.4 Marital status (A) Married (B) Not married (C) Divorced/separated

(D) Widow/widower (E) Other, specify------------------------

2.4 Literacy: (A) Did not join any formal schooling (B) Adult education

(C) Writing and reading skill (D) Elementary school (grade 1-8) (E) Grade 9-10

(F) Grade 11-12 (G) TVET (H) Diploma complete (I) University Degree

(J) Other specify--

2.5 Household size including yourself: A/ Male ---------------- B/ Female ------------------

2.6 For how long have you lived in this village? -------------------------------------Year E.C

2.7 What are your major livelihood activities? List according your priority

R.N	Lists of livelihood activities	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th
1	Cultivation of perennial crops											
2	Livestock production											
3	Cultivation of annual crops											
4	Mixed farming (rearing of animals and cultivation of crops).											
5	Agroforestry											
6	Trade											
7	Student											
8	Government employee											

9	Private employee											
10	Daily works											
11	Other mention											

2.8 How did you observe the trend of crop products and productivity in your life experience?

A/ Increasing B/ Decreasing C/ Constant D/ Difficult to estimate

2.9 How you observed the trend of livestock product and productivity

A/ Increasing B/ Decreasing C/ Constant D/ Difficult to estimate

Part 3 Land ownership and land use/land cover change characteristics

Land ownership refers ones owned land by the respondent

3.1/ How much is your total plot size/area in ha ------------------- or timad -------------------

3.2/What are the sources of land ownership rights to each plot /land?

A/ Owned (inherited)

B/ Allocated by the government

C/ Inherited/ Rented

D/ Purchased

E/ Other specify

3.3 / Do you have more than one plot? A/Yes B/ No

3.3.1 If 'Yes' what are your major land use types in your plot?

R.N	Land use type	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	Homestead land										
2	Cultivated land										
3	Forestry land										
4	Pastoral (grazing) land										
5	Agroforestry land										
6	Unused land										
7	Other mention										

3.4/Do you perceive land use and land cover change in the study area?

A/ Yes B/ No C/ No idea

3.4.1 If yes how was the trend of the land use land cover change in their respective order?

R.N	Land use type	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	Forest to grassland										
2	Grazing land to cultivating land										

3	Forest to cultivating land										
4	Cultivating land/forest or grassland to bare land										
5	Forest or grass land to agroforestry land										
6	Grass land to agroforestry land										
7	Forest or agroforestry to settlement										
8	Forest or agroforestry to Shrub/wood land										
9	Shrub/wood land to cultivation land										
10	Other mention										

3.5 What are the causes of land use and land cover change in their respective order?

R.N	Drivers of LULCC	Yes	No
1	Demographic factors (population density, settlement).		
2	Economic factors (agriculture, charcoaling, fuel wood, daily laboring etc.)		
3	Cultural factors (Songo, and Baabbo)		
4	Natural factors (recurrent high intensity rain fall &)drought		
5	Policy or institutional factors (soil and water conservation)		
6	Technological factors (high yield crops, pesticide and fertilizer		
7	Other mention		

Part 4 Communities perceptions and attitude on the soil erosion problem

4.1 Do you think there is a soil erosion problem in your locality/Kebele?

A/ Yes B/ No C/ No idea

4.1.1 If ‘Yes’, what are the indicators of soil erosion over time in your locality? You can choose more than one.

A/ Color of the water

B/ Big gully

C/ Loss of soil fertility

D/ Soil color change

E/Expansion of bare land

F/ Loss of biodiversity

G/ If other---

4.2 What do you think are the causes of soil erosion in your farm land?

Use the following classifications for your answer.

A/ Agree (A) B/Disagree (DA) C/ Partially agree (PA) D/Neutral or undecided (N)

R.N	Causes of soil erosion	A	DA	PA	N
1	Slope of the land				
2	Deforestation				
3	High population growth and related factors				
4	Expansion of agricultural land				
5	Overgrazing				
6	Poor land cover				
7	Nature of the soil				
8	Climate (drought and or torrential rain				
9	Other mention				

4.3 How do you rate the soil fertility status of your farmland?

A/ High B/ Medium C/ Low/poor D/ Not known

4.4 What do you perceive as the trend of soil fertility?

A/ Increasing B/ Decreasing

C/ No change D/ No idea

4.5 How are the trends of soil erosion over time on your farmlands?

A/ Increasing B/ Decreasing C/ Stable D/ Difficult to estimate

4.5.1 If increasing, what are the dominant conservation measures in your Kebeles in their respective orders?

R.N	Conservation measures	1st	2nd	3rd	4th	5th
1	Agronomic measures (mulching, crop rotation, row cropping, strip cropping, multiple cropping, and conservation agriculture).					
2	Vegetative measures (grass strip, orchard strip, natural vegetation strip, and agroforestry).					
3	Physical SWC measures (terraces, check dams, and water harvesting structures).					
4	Management practices (fallowing of land, composting and manuring, and grazing management).					
5	Other mention					

4.6 Is there physical SWC work in your Kebele? A/Yes   B/ No C/ No idea

4.6.1 If 'Yes', among the listed in the table below, which SWC technologies are very common in your Kebele?

R.N	Lists of SWC	Make tick
1	Soil bund	
2	Fanya juu	
3	Stone bund	
4	Trench	
5	Check dam	
6	Bench terraces	
7	Trash line	
8	Micro basin (half-moon)	
9	Water pond	
10	Cut off drain	
11	Other mention	

4.7 Did you support the implementing SWC practices?

A/ Strongly support   B/Partially support   C/ Not at all   D/ Not decided

4.7.1 If you support, why? ---

4.7.2 If you do not support, why? --

4.8 Did you get technical skill and knowledge how to apply the introduced SWC technologies?   A/Yes   B/ No

4.8.1 If 'Yes', what do you think are the criteria to apply physical SWC?

A/Physical land feature B/Social feature C/ Economic factors

D/All are pre-conditions to apply SWC practices   E/ Not known

4.9 Are you satisfied with the SWC design and technology the introduced SWC work?

A/Yes   B/ No   C/ No idea

4.10 How you got the approach of SWC practices?

A/ Democratic   B/ Not democratic   C/Not known

4.11 Is there Kebele level SWC team?   A/Yes   B/No   C/ Not known

4.11.1 Who are the members of the group/ team? --

4.11.2 What are the roles or functions of the team? ---

4.11.3 Do you think that you can influence the decision made by the group/team?

A/Yes   B/ No   C/ Not known

5. Perception and attitude of the people to the community based participatory soil and water conservation practices

5.1 Is there community based participatory soil and water conservation (CBPSWC) in your Kebele? A/Yes B/ No C/ Not known

5.2 If 'Yes', when CBPSWC practices have begun in your locality? --------------------year

5.3 What is/are the objective of CBPSWC? You can choose more than one questions

A/ Conserve soil, rainwater and vegetation to enhance productivity

B/ Create surplus water sources in addition to ground water recharge

C/ Improve income generation and livelihood support systems,

D/ Promoting sustainable farming and stabilize crop yields

E/ Rehabilitating and reclaim marginal lands

F/ Enhance high resilience to shocks

G/ Optimize the use of existing natural resources

H/ If other--

5.4What are the characteristics of CBPSWC practices in your locality?

Use the following classifications for your answer.

1/Agree (A) 2/ Disagree (DA) 3/ Partially agree (PA) 4/ Neutral or undecided (N)

R.N	Characteristics of CBPSWC practices	A	PA	DA	N
1	The community actively participate during problem identification				
2	The community actively participate during prioritization of technologies				
3	The community actively involve during the decision making on the date of conservation work.				
4	The community actively participate to decide the number of days that everyone should participate in watershed management				
5	The community actively participates in managing the SWC practices.				
6	The community only participate for advise				
7	The community participate only to introduce about SWC practices				
8	The community involves only in the stage of decision				
9	If other mention				

5.5 What is your attitude about the implemented CBPSWC practices in terms of characteristics listed in the table below? Use the following classifications for your answer.

1/Agree (A) 2/ Disagree (DA) 3/Partially agree (PA) 4/ Neutral or undecided (N)

R.N	Lists of characteristics of the CBPSWC	A	DA	PA	N
1	Community based SWC practices is continuous process				
2	Several professionals/ experts participated				
3	Women highly involved on CBPSWC practices				
4	Women, young people and elders participate equally at different stages of watershed development.				
5	Flexible approach				
6	Commonly shared benefits and responsibility of stakeholders.				
7	Well planned				
	Size of watershed is highly considered during CBPSWC practices				
8	Adoption of ridge to valley approach (treat from the highest point to the lowest point of the area)				
9	Selection of technologies is in accordance with their suitability to local conditions (experience, materials and resources)				
10	Other specify				

5.6 How do you` perceive the impacts of CBPSWC practices since its implementations?

R.N	Impact of CBPSWC	Increased	Stable/ constant	Decreased	Not known
1	Lands productivity				
2	Nutritional diversity of the household				
3	Availability of livestock feeds				
4	Availability of surface waters				
5	Vegetation cover of the area				
6	Labour cost				

7	Reduction of water and soil losses				
8	Crop production and productivity				
9	Household (HH) saving				
10	Livelihood options of the land users				
13	Improved food security				
14	Soil fertility				
15	Livestock production and productivity				
16	Fuel wood availability				
17	Availability of forest fruits				
18	Risk of pest				
19	Wild life diversity and productivity				
20	Infiltration increased				
21	Social interaction				
22	Other specify				

5.7 How is the motivation of the community to adopt and adapt the watershed based SWC practices? A/ High B/ Low C/ Medium D/ Do not known

5.8 How is the coverage of SWC practices in your Kebele?

A/ Higher B/ Medium C/Lower D/Doesn't known

5.9 Is there a constraint to adapt SWC in your locality?

A/Yes B/ No C/ Not known

5.9.1 If 'Yes', give your argument to the listed constraints to adapt the SWC practices.

R.N	Lists of constraints	Agree	Disagree	Partially agree	No idea
1	Small farm land area				
2	Poor access to fertilizer, seed and pesticides				
3	Food insecurity				
4	Inaccessibility of construction material				
5	Lack of technical skill on SWC practices.				
6	Lack of interest for young generation to work agricultural activities.				
7	Lack of frequent and continues maintenance				
8	Lack of field guideline for SWC practices				

9	Weak interaction among stakeholders				
10	Others				

6/ Access of the community to goods and services

6.1 Does community access to goods and services have an impact on SWC practices?

A/ Yes B/ No C/ Not known

6.1.1 If 'Yes', give your reflection on the impacts of the listed goods and services

R.N	Lists of goods and services	Positive impacts on SWC	Negative impacts on SWC	No impacts	Difficult to decide
1	Access to main road				
3	Access to health center				
5	Access to school				
6	Access to market				
7	Access to research institutions				
9	Access to energy sources				
10	Access to water sources				
11	Access to farmers training center (FTC)				
12	Access to seed and fertilizer				
13	Access to NGOs				
14	Others				

6. 2What is the source of water for your household? A/ Rain B/ Pond C/ Small dame D/ River and stream E/ Well F/ Pipe G/ Roof water harvesting H/If others mention……………………………………………………………………………

6.3 How you perceived the access of water to the community

1/ Increasing 2/ Decreasing

3/ No change 4/ Difficult to know

6.4 If the source of water is increasing what are the causes? ----------------------------------

6.5 What are the main sources of energy for cooking and heating?

R.N	Energy source	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}	7^{th}	8^{th}
1	Charcoal								
2	Cow dung								
3	Crop residual								
4	Kerosene								
5	Biogas								
6	Firewood/fuel wood								
7	Electricity								
8	Other specify								

6.6 From where do you collect firewood?

A/ Community forest B/ Private plantation (farm land)

C/ Market D/ Government forest and shrub lands

E/ Home garden F/If other specify---

6.7 How is the trend of access to fire wood?

A/ Increasing B/ Decreasing

C/ Stable D/ Doesn't know

6.7.1 If access to fuel wood is increasing, what are the factors-------------------------------?

6.7.1 If decreasing, what option you are taking for fuel wood energy problems? You can choose more than one answer.

A/ Expand forest and wood products via conservation, plantation and other related activities

B/ Wise use of fuel wood

C/ Use other energy sources: that, Solar energy, biogas and electricity

D/ Buying forest products from the market

E/ Using all the above listed options

F/ Other---

Part .7 The role of the community to the local development

7.1 What do you think about the community participation in the socio-economic development of the area? 1/ High 2/ Low 3/ Moderate 4/ Doesn't known

7.1.1 If low, what do you think are the factors? ---

7.2.2 If high, what socio-economic change you have observed because of the community involvement in the area--

Part 8 Perception of the households to the priority issues in their locality

8.1 What should be the priority issues that need higher intervention of the government in the Kebele?

R.N	Community priority area	1st	2nd	3rd	4th	5th	6th	7th
1	Expansion of agriculture							
2	Access for credit							
3	Access for seeds and fertilizers							
4	Urbanization							
5	Peace and security							
6	Training and skill exchange on SWC							
7	Expansion of infrastructures such as health, education, road, electric, telephone etc							
8	Other specify							

8.2 What do you want to say about the overall situation of SWC practices of your locality? ---

Guiding question for interview and group discussion with key informants (local elders, community leaders and key informants)

1/ Personal Information

Name (Confined):---

Date of interview: ---

Educational level: ---

Kebele: ---

Agroecology (altitudinal belt): ---

Age: ---

Responsibility among the community: ---

For how long do you know this area: --

1/ Community perception on land use land covers change and land managements

- Place and date of discussion---
- Number of people participating in the group discussion: -------------------------------

2/ What environmental change does you observed in the last three decades? Such as

2.1. Land use and land cover --

2.2. Wild life diversity--

2.3. Plant diversity --

2.4. Local temperature and rainfall variability--

2.5. Land/soil productivity--

2.6. Water quality and quantity--

2.7. If other ---

3. What is your reflection on the research results for LULC change in the Gidabo river sub basin from 1986 to 2019?

3.1 Remote sensing data indicated that in the last three decades shrubs and wood land cover has highly declined from 1986 to 2019, what are the factors for the reduction?-

3.2 Forest cover is increasing slowly from 1986 to 2019; what is the factor for the reduction? ---

3.3 Again crop land cover has been increasing from 1986 to 2011, but it declined by 3% from 2011 to 2019; what are the factors for the reduction after the stated years? -------

3.4. Bare land cover shows increasing from 1986 to 2019, what do you think are the factors for the increment? ---

3.5 In the Gidabo river sub basin from 1986 to 2019 land used and land covered with agro-forestry and settlement have consistently increased, while grass land has consistently reducing. What are the reasons for the consistent change of these LULC of the study area?

3.6 What are the major causes (drivers) of land use and cover change in the area? ----------

3.7 What negative impact does LUCC brought in the Kebele? Such as

3.7.1 Social---

3.7.2 Economic--

3.7.3 Environmental condition of the area? --

4. Characteristic of natural resource conservation work of the study area

4.1 If there is soil erosion problem in your area what is the cause of soil erosion? --------

4.2 What are the consequences of soil erosion problem of the area? --------------------------

4.3 Describe the natural resource conservation measures in the area?

4.3.1 What indigenous conservation measures are there? --------------------------------------

4.3.2 What modern/introduced conservation measures are there? -----------------------------

4.4 Is there SWC guideline? A/Yes B/No C/ Not known

4.5 How is the applicability of the SWC guideline? --

4.6 Do you get technical knowledge about the modern WSC practices? ----------------------

4.7 How do you get the appropriate and compatibility of the modern soil and water conservation practices with the local

4.7.1 Agro ecology--

4.7.2 Slope gradient--

4.7.3 Climate---

4.7.4 Soil type ---

4.7.5 Resources--

4.7.6 With Indigenous knowledge---

4.8 How is the community participation in the the SWC practices? ------------------------

4.9 How you evaluate the community adoption and adaptation characterstics for SWC practices? --

4.10 How do you evaluate the impact of soil and water conservation in terms of LULC? -

- In terms of soil fertility /land productivity? ---

- In terms of food security? --

- If other positive impacts--

4.11 What constraints are there to adopt and adapt SWC measures in the area? -------------

4.12. Do you have additional issues to forward pertaining points for discussion? -----------

Annex 4: Data on the soil properties

Agro ecology	Conservation	% Sand	% Clay	% Silt	Bulk density (g/cm^3/*98.125*	Textural class
Highland	SB	46	22	34	0.72	Loam
	FN	40	30	26	1.73	Clay loam
	CD	55	12	24	0.77	Sandy clay
	CN	49	22	33	1.81	Loam
	SB	46	24	34	0.69	Loam
	FN	38	32	30	0.78	Clay loam
	CD	48	24	26	0.68	Loam
	CN	50	23	24	0.80	Loam
	SB	44	26	36	0.59	Loam
	FN	36	34	34	0.74	Clay loam
	CD	46	28	28	0.50	Loam
	CN	60	18	23	1.12	Loam
Midland	SB	38	40	20	1. 32	Clay
	FN	50	32	18	1.14	Clay
	CD	42	26	20	1.13	Loam
	CN	56	23	18	1.50	Clay
	SB	36	42	24	1.28	Clay
	FN	40	36	18	1.12	Clay loam
	CD	36	42	22	1.12	Clay
	CN	42	28	21	1.49	Clay
	SB	26	48	26	1. 25	Clay
	FN	28	54	24	1.10	Sandy clay
	CD	26	54	32	1.9	Clay
	CN	52	36	17	1.37	Clay loam
Lowland	SB	48	36	12	1.18	Clay
	FN	54	36	8	1.18	Clay
	CD	48	32	18	1.01	Sandy Clay
	CN	56	31	8	1.21	Clay
	SB	34	54	12	1.20	Sandy clay
	FN	46	36	10	1.25	Sandy clay
	CD	46	32	22	1.11	Clay
	CN	55	31	9	1.30	Cay
	SB	22	66	16	1.28	Clay
	FN	36	56	18	1.25	Sandy Clay
	CD	42	34	26	1.25	Clay loam
	CN	50	28	16	1.40	Clay

Agro ecology	Conservation	OC/%	CEC (meq/100 gm	TN %	PH	EC(µs/ cm)	Av.K (mg/l)	Av.P (mg/l)
Highland	SB	5.72	25.48	0.7942	5.87	21.7	155.	6.95
	FN	3.588	18. 95	0.6493	5.40	26.9	151	6.28
	CD	5.538	18.74	0.7374	4.73	44.5	56.2	7.01
	CN	5.68	22.31	0.7924	4.37	20.8	48.0	6.53
	SB	5.70	22.54	0.8342	4.90	29.7	57.4	6.95
	FN	5.148	20.94	0.7374	5.44	29.5	287	6.39
	CD	5.769	18.95	0.7876	4.84	49.3	89.8	7.21
	CN	3.51	18.54	0.3640	4.62	23.4	126.4	6.01
	SB	5.73	25.68	0.8442	5.04	32.2	79.2	8.28
	FN	5. 07	22.24	0.7438	5.62	29.6	260.4	6.88
	CD	5.812	21.65	0.7910	5.09	35.1	102.4	7.35
	CN	5.321	18.31	0.6210	4.24	20.4	44.1	6.00
Midland	SB	3.193	6.67	0. 4281	5.14	20.5	169.6	4.01
	FN	1.248	5.56	0.2876	5.69	102.4	148	5.61
	CD	1.248	5.10	0.3076	5.9	64.5	60.8	3.51
	CN	1.833	6.21	0. 4180	5.11	20.2	56.4	3.68
	SB	3.388	8.48	0. 4757	5.64	21.7	67.2	4.08
	FN	2.028	6.41	0.4148	6.25	216	77.6	6.08
	CD	1.638	5.23	0.3412	6.2	74.9	66.2	4. 01
	CN	1.123	4.20	0.5610	4.30	57.5	50.2	3.01
	CD	3.95	10.7	0. 5325	5.89	22.3	118.8	4.88
	FN	3.003	7.19	0.4389	6.38	227	116.4	4.28
	CD	2.028	5.89	0.3948	6.2	107	123.2	4. 55
	CN	1.213	2.99	0.2452	5.42	80.9	37.8	5.27
Lowland	SB	0.078	0.13	0. 1267	6.16	16.3	290.2	3.95
	FN	0.663	0.91	0.1506	6.41	32.3	171.4	4.61
	CD	1.248	3.63	0.3276	5.69	21.1	59	3.61
	CN	0.068	0.10	0. 1103	6.03	14.3	390.4	3.11
	SB	0.468	0.76	0. 1603	6. 19	25.5	608.6	3.41
	FN	0.819	0.91	0.1572	6.65	59.0	241.4	4.81
	CD	2.106	5.04	0.3615	5.78	21.4	81.2	4.35
	CN	0.39	0.23	0.1136	5.40	22.3	170.6	3.08
	SB	0.858	1.83	0. 2340	6. 36	37.7	344.4	4.41
	FN	1.326	3.17	0.2943	7.30	129.2	338.2	6.34
	CD	2.262	7.73	0.4550	5.81	32.1	88.6	4.41
	CN	1.024	3.25	0.2338	5.02	20.0	47.1	3.06

Annex 5 Data on LULCC matrixes

LULC Change between 1986 - 2000	**Change_Area (ha)**
Agroforestry _ Agroforestry	35982.36393
Agroforestry _ Bare land	0.325505
Agroforestry _ Cropland	2655.667769
Agroforestry _ Forest	2053.612063
Agroforestry _ Grassland	127.943988
Agroforestry _ Settlement	18.51888
Agroforestry _ Shrub and Woodland	154.299083
Bareland _ Bare land	1.371706
Bareland _ Cropland	0.787183
Bareland _ Grassland	2.196782
Bareland _ Shrub and Woodland	0.353269
Cropland _ Agroforestry	3179.095606
Cropland _ Bare land	62.21828
Cropland _ Cropland	24889.97802
Cropland _ Forest	865.625816
Cropland _ Grassland	2695.903911
Cropland _ Settlement	12.46223
Cropland _ Shrub and Woodland	438.592543
Forest _ Agroforestry	297.509299
Forest _ Bare land	1.490351
Forest _ Cropland	1014.203876
Forest _ Forest	2789.546169
Forest _ Grassland	54.643262
Forest _ Settlement	8.474665
Forest _ Shrub and Woodland	362.58277
Grassland _ Agroforestry	25.112928
Grassland _ Bare land	88.413841

Grassland _ Cropland	6460.221559
Grassland _ Forest	124.985194
Grassland _ Grassland	4193.200208
Grassland _ Settlement	1.600718
Grassland _ Shrub and Woodland	516.749826
Settlement _ Agroforestry	3.695053
Settlement _ Bare land	9.085296
Settlement _ Cropland	9.626028
Settlement _ Forest	0.114519
Settlement _ Grassland	13.155088
Settlement _ Settlement	210.108709
Settlement _ Shrub and Woodland	11.684513
Shrub and Woodland _ Agroforestry	6367.031866
Shrub and Woodland _ Bare land	39.378376
Shrub and Woodland _ Cropland	1007.987792
Shrub and Woodland _ Forest	116.485879
Shrub and Woodland _ Grassland	2678.978147
Shrub and Woodland _ Settlement	121.476054
Shrub and Woodland _ Shrub and Woodland	3069.184709
Grand Total	102,738

LULC Change 2000 - 2011	**Area_Change_ha**
Agroforestry _ Agroforestry	46850.60822
Agroforestry _ Cropland	1030
Agroforestry _ Forest	144.495028
Agroforestry _ Grassland	409.645963
Agroforestry _ Settlement	315.470815
Agroforestry _ Shrub and Woodland	901.884858
Bareland _ Agroforestry	975.391986

Bareland _ Bareland	2862
Bareland _ Cropland	104.228443
Bareland _ Forest	1255
Bareland _ Grassland	140.061751
Bareland _ Settlement	40.901823
Bareland _ Shrub and Woodland	1263.388437
Cropland _ Agroforestry	16.714748
Cropland _ Bareland	2656
Cropland _ Cropland	3163.153
Cropland _ Forest	428.945738
Cropland _ Grassland	165.029063
Cropland _ Settlement	101.281045
Cropland _ Shrub and Woodland	1418
Forest _ Agroforestry	461.074797
Forest _ Cropland	466.723996
Forest _ Forest	665
Forest _ Grassland	1631
Forest _ Settlement	155.114513
Forest _ Shrub and Woodland	9.43994
Grassland _ Agroforestry	5068.350372
Grassland _ Bareland	1410.949982
Grassland _ Cropland	1441.789002
Grassland _ Forest	25284
Grassland _ Grassland	250.14655
Grassland _ Settlement	560.910308
Grassland _ Shrub and Woodland	8.125027
Settlement _ Agroforestry	1.819972
Settlement _ Cropland	0.042187
Settlement _ Forest	23
Settlement _ Grassland	30.909562

Settlement _ Settlement	2.05996
Settlement _ Shrub and Woodland	6.412588
Shrub and Woodland _ Agroforestry	32.61459
Shrub and Woodland _ Bareland	16.880926
Shrub and Woodland _ Cropland	14.676704
Shrub and Woodland _ Forest	50.393013
Shrub and Woodland _ Grassland	312.066825
Shrub and Woodland _ Settlement	11.168844
Shrub and Woodland _ Shrub and Woodland	575
Grand Total	102,738.

Change 2000_2011	**Change Area_ha**
Agroforestry _ Agroforestry	42525
Agroforestry _ Bareland	0
Agroforestry _ Cropland	2360
Agroforestry _ Forest	370
Agroforestry _ Grassland	114
Agroforestry _ Settlement	107
Agroforestry _ Shrub and Woodland	239
Bareland _ Agroforestry	3
Bareland _ Bareland	36
Bareland _ Cropland	28
Bareland _ Forest	0
Bareland _ Grassland	124
Bareland _ Settlement	5
Bareland _ Shrub and Woodland	15
Cropland _ Agroforestry	3014
Cropland _ Bareland	15
Cropland _ Cropland	27803

Cropland _ Forest	1541
Cropland _ Grassland	2080
Cropland _ Settlement	337
Cropland _ Shrub and Woodland	1133
Forest _ Agroforestry	1763
Forest _ Cropland	799
Forest _ Forest	3035
Forest _ Grassland	12
Forest _ Settlement	13
Forest _ Shrub and Woodland	363
Grassland _ Agroforestry	1652
Grassland _ Bareland	14
Grassland _ Cropland	2824
Grassland _ Forest	167
Grassland _ Grassland	3975
Grassland _ Settlement	118
Grassland _ Shrub and Woodland	1040
Settlement _ Agroforestry	18
Settlement _ Bareland	0
Settlement _ Cropland	12
Settlement _ Forest	1
Settlement _ Grassland	5
Settlement _ Settlement	359
Settlement _ Shrub and Woodland	6
Shrub and Woodland _ Agroforestry	655
Shrub and Woodland _ Bareland	36
Shrub and Woodland _ Cropland	208
Shrub and Woodland _ Forest	153
Shrub and Woodland _ Grassland	1485
Shrub and Woodland _ Settlement	180

Shrub and Woodland _ Shrub and Woodland	1996
Grand Total	102,738

LULC Change 1986-2019	**Change_Area ha**
Agroforestry _ Agroforestry	38672
Agroforestry _ Cropland	491
Agroforestry _ Forest	1240
Agroforestry _ Grassland	62
Agroforestry _ Settlement	436
Agroforestry _ Shrub and Woodland	63
Bareland _ Agroforestry	1
Bareland _ Bareland	1
Bareland _ Cropland	2
Bareland _ Grassland	1
Cropland _ Agroforestry	6523
Cropland _ Bareland	5
Cropland _ Cropland	21637
Cropland _ Forest	1802
Cropland _ Grassland	1328
Cropland _ Settlement	545
Cropland _ Shrub and Woodland	303
Forest _ Agroforestry	1087
Forest _ Bareland	2
Forest _ Cropland	646
Forest _ Forest	2543
Forest _ Grassland	124
Forest _ Settlement	52
Forest _ Shrub and Woodland	275
Grassland _ Agroforestry	264

Grassland _ Bareland	83
Grassland _ Cropland	7912
Grassland _ Forest	286
Grassland _ Grassland	2511
Grassland _ Settlement	83
Grassland _ Shrub and Woodland	142
Settlement _ Agroforestry	39
Settlement _ Bareland	7
Settlement _ Cropland	46
Settlement _ Forest	0
Settlement _ Grassland	43
Settlement _ Settlement	111
Settlement _ Shrub and Woodland	11
Shrub and Woodland _ Agroforestry	9043
Shrub and Woodland _ Bareland	54
Shrub and Woodland _ Cropland	365
Shrub and Woodland _ Forest	108
Shrub and Woodland _ Grassland	668
Shrub and Woodland _ Settlement	1175
Shrub and Woodland _ Shrub and Woodland	1946
Grand Total	102,738