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Assessment of Physical Soil and Water Conservation (PSWCP) Practices and Estimation of Soil Loss Using the RUSLE Model: Constraints and Challenges in The Debir Wonz Watershed, Yilmana Densa District, West Gojjam Zone, Amhara

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BAHIR DAR UNIVERSITY

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

POSTGRADUATE PROGRAM

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M.Sc. Thesis

By;

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June, 2025

Bahir Dar, Ethiopia

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M.Sc. Thesis

By;

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As member of the Board of Examiners of the Master of Sciences (M.Sc.) thesis open defence examination, we have read and evaluated this thesis prepared by Ayenew Wudu entitled "Assessment of Physical Soil and Water Conservation (SWC) Practices and Estimation of Soil Loss Using the RUSLE Model: Constraints and Challenges in the Debir Wonz Watershed, Yilmana Densa District, West Gojjam Zone, Amhara". We hereby certify that, the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (MSc.) in Soil Conservation and Watershed Management.

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Assessment of Physical Soil and Water Conservation (SWC) Practices and Estimation of Soil Loss Using the RUSLE Model: Constraints and Challenges in the Debir Wonz Watershed, Yilmana Densa District, West Gojjam Zone, Amhara

By: Ayenew Wudu

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ABSTRACT

Due to several factors, most PSWC works have not fully achieved the intended objectives. The disparity between dimensions of the implemented PSWC work and the standard is the main factor. Water-induced soil erosion is the most prevailing form of land resource deterioration in the highlands of Ethiopia, where huge amounts of fertile soil are being lost annually. Most of the Debirwonz watershed was characterized by very severe to severe soil erosion rates, which are associated with the gentle slope. Data were generated through field observation, field measurements, and questionnaires. Measurements were taken from these soil bunds, trenches, waterways, cut-off drains, and check dams from three separate slope classes (lower, middle, and upper slope). The recommended value was analyzed using t-test statistics ($p<0.05$). The household survey data was analyzed by descriptive statistics using the basic Statistical Package for Social Science (SPSS-23), and the RUSLE model was used to estimate annual soil loss. Results showed that the measured mean dimensions of graded soil bunds, such as bund spacing, bund width, bottom embankment width, berm width, and height of embankment, were significantly different at 0.05 from the recommended dimensions at a 95% confidence interval ($t<1.740$) in the watershed. According to the result, 77.7% of the physical design of the implemented PSWC structures of spacing or horizontal distance constructed in the study area were meaningfully wider than the recommended standard and unfit to the standard, and 88.9% of the vertical intervals between soil bunds in the Debir-Wonz watershed were greater than the minimum technical standards. In addition, about 49.8% and 64% of the embankment bottom width of the soil bund and the length of the bund were without the standard. The mean annual soil loss rate in the watershed was estimated to be 0 to 815.99 $t\ ha^{-1}\ yr^{-1}$ with the average annual soil loss of 52.25 t/ha/yr. Major constraints such as 37.5% lack of labor and 22% technically difficult to implement 18% physical factor, 22.3% lack of technical skills, 19.6% lack of awareness, and 1.8% institutional factor are the major constraints in the study area. Through farmers come into view to face such problems. So, the study suggests that well-organized training should be given for experts at different levels to fill the technical gap in their skills, and extension services like demonstrations should be held for all stakeholders before implementing the PSWC practice, and most PSWC practices lack the standard and supportive activities, such as the cut of drain, check dam, biological work, frequent maintenance, and other dimensions. Hence, a well-appropriate design of physical soil and water conservation (PSWC) measures should be prioritized based on soil erosion severity levels.

Keywords: Standard, Geographic Information System, Revised Universal Soil Loss Equation, Remote sensing

ACRONYMS AND ABBREVIATION

BOA	Bureau of Agriculture
DA	Development Agent
DEM	Digital Elevation Model
FAO	Food and Agriculture Organization
FFW	Food for Work
FGD	Focus Group Discussion
GDP	growth domestic product
GIS	Geographic information system
HD	horizontal distance
HHs	households
MoA	Ministry of Agriculture
MoARD	Ministry of Agriculture and Rural Development
NGO	Nongovernmental organization
PSWCP	physical soil and water conservation Practice
RUSLE	Revised universal soil loss Equation
SPSS	Statistical Package for Social Science
SWC	Soil and Water Conservation
PSWC	physical soil and water conservation
SWCM	Soil water conservation management
VI	Vertical interval
YDWAO	Yilmana Densa woreda agriculture Office

CHAPTER 1. INTRODUCTION

1.1. Background of the study

Land degradation in the form of soil erosion is a serious global problem (Engdayehu Getachew et al., 2015). Soil erosion is a serious environmental problem in the world and is responsible for 80% of the current degradation of agricultural land (Megersa Terefe, 2021). However, wide spatial disparity exists in the extent and depth of the problem (Masresha Baile, 2014). Human activity triggers the problem. It is associated with rapid population growth, inadequate attention to the basic natural resources, intense land cultivation, uncontrolled grazing, and deforestation (Mekonnen Mulatie and Melese Asmare, 2011). Soil and water degradation are increasing due to a lack of appropriate identification and evaluation of the degradation process and the relations between cause and effect of soil degradation for each specific situation and the generalized use of empirical approaches for physical soil and water conservation, causing soil erosion and deteriorating agricultural productivity in many parts of the world, including Ethiopia (Wasie Dessale et al., 2020). Soil erosion by water is the most serious environmental problem in Ethiopia, particularly in the highlands, where the topography is highly rugged, vegetation cover is sparse, and shallow soils with low organic matter content are subjected to intensive rainfall (Kidane Dessale & Alemu Biniam, 2015).

The severity of soil erosion in the Ethiopian highlands is the result of the past and present agricultural activities, hilly topography, torrential rainfall, a low degree of vegetation cover, and unsustainable land management (Awulachew Sileshi, 2010). The soil loss rate in Ethiopia is very high compared to the world and the African standard (Haregeweyn Nigussie et al., 2015). The average crop yield from cropland in the Ethiopian highlands is estimated to be very low, mainly due to soil fertility decline associated with removal of topsoil by erosion processes and widespread soil nutrient mining (Sertsu, 2000). Sometimes, wrong selection and implementation of soil and water conservation practices and structures may increase the land degradation process and derived environmental effects (Mulu Abirham et al., 2016). Technical mistakes in soil and water conservation measures like graded bunds, cut-off drains, and waterways are prevalent due to their design on runoff rate to be generated from a particular area/watershed (Hassen Gatahun et al., 2021). Besides, in many places, there exists a mismatch between the area-specific technical criteria (spacing, vertical interval, grading or leveling, and others of the soil conservation measures) and its physical and climatic conditions (Tsegaye Bekele and Awudengist Moges, 2018).The design of PSWC structures is crucial for protecting soil from raindrop impact and hydraulic forces, considering erosion factors and suitability, resulting in achieving both short-term and long-term benefits (Tesfaye Gizaw et al., 2019). Several soil and water conservation practices have since been initiated. However, the effect of the campaign has been failing because the techniques that have been introduced in soil and water conservation were with little attention to whether the local community could easily apply the techniques to their own existing practices (Bekele Amanual et al., 2018). In addition, over the past several decades, Ethiopian government agencies have been trying to support better land use and promote SWC technologies to stop soil degradation and improve people's lives (Bekele Shiferaw and Holden Stein 1999). Reports, however, have indicated a relatively low level of success in this respect across the wider countryside (Zerihun Nigussie et al., 2017).The various methods that farmers participated in the SWC program hindered the suitability of SWC measures, such as physical soil and water conservation structures, reduced the amount of cultivated land, harbored rodents, lacked technical evaluation expertise, were labor intensive, etc. But compared to farmers in the opposite situation, those on steep slopes, with low fertility, and with less cattle were better equipped to apply the methods (Amsalu Aklilu and De Graaff Jan, 2007). Poor construction and lack of regular maintenance of SWC measures are also important issues. To maximize the effectiveness of any SWC measure, regular maintenance is required to avoid structural failure (Engdayehu Getachew et al., 2015). In Debir Wonz, micro watersheds located in the highlands region of Ethiopia are broadly representative of many of these soil erosion challenges. The landscape is dominated by low-input subsistence agriculture with cultivation. The livelihoods of farming communities face severe constraints related to intensive cultivation, overgrazing and deforestation, soil erosion and soil fertility decline, water scarcity, livestock feed, and fuelwood demand (Belay Simane et al., 2013). In coping with these problems, physical soil and water conservation (PSWC) measures have been implemented to alleviate both the problems of erosion and low crop productivity. In mass mobilization approaches, the implementation of soil and water conservation structures with inappropriate design led to soil conservation activities having a lesser impact than expected and resulted in gully formation in many parts of the country. Such a problem may be due to a technical gap and absence of skilled, trained labor (Tesfaye Gizachew et al., 2019). The technical gap, limited awareness, physical factors, labor shortage, and institutional factors cause ’failure of implemented PSWC technologies, which in turn cause serious land degradation. In the study area also, the failure of implemented structures was observed and reported repeatedly in most parts of the country; that could be due to wrong PSWC structural design specifications.

1.2. Statement of the problem.

Soil erosion is the main form of land degradation and is one of the most serious environmental problems in Ethiopia, which causes soil fertility decline in the country. Mainly the developing countries like Ethiopia are more victims of soil erosion. Rapid population growth in recent years has brought about a number of changes despite the awareness of the erosion problem. According to Shiferaw Bekele (1999) and Wogayehu Worku (2006), the effect of intensive farming and farming on steep slopes is decreasing fertility and increasing the incidence of soil loss due to erosion. Specifically, in the study area agricultural lands are under heavy stress due to land degradation. The RUSLE model, a widely used tool for estimating soil loss, needs to be evaluated for its applicability and accuracy in this specific watershed, considering its unique topographic, climatic, and land management characteristics. To solve the problem, different physical conservation works have been underway (Hassen Getahun et al., 2021). Even if the technology of soil and water conservation practices seems like a relatively recent phenomenon, it has been three to four decades since it was introduced. But the conservation work could not achieve the intended objectives. As far as the researcher's knowledge, Assessment of physical soil and water conservation (SWC) practices and estimation of soil loss using the RUSLE model: constraints and challenges had not yet been studied (researched), despite the fact that the Debirwonz watershed implements these measures annually. According to Tsegaye Bekele and Awudengist Moges (2018), there was a discrepancy between the physical and the technical requirements of the soil and water conservation measures. Selecting the right soil and water conservation technology for the right place is a key problem for farmers in the soil erosion areas (Fikirie Kalkidan et al., 2020). In the DebirWonz watershed, while PSWC practices are in place, the extent of their effectiveness is not fully understood, and the challenges hindering their success need to be identified. Hence, the proposed study focused on assessing physical soil and water conservation (SWC) practices and estimating soil loss using the RUSLE model. Evaluating the status of the constructed PSWCP against the national standards can be realistic and a warrant for farmers and policymakers if expressed in understandable ways.

1.3. Objectives of the study

1.3.1. General objective

- ❖ The general objective of the study was to evaluate physical soil and water conservation (pswc) practices and estimate soil loss using the Rusle model in the Debir wonz watershed.

1.3.2. Specific objectives

- ➢ To evaluate the existing physical soil and water conservation practices implemented in the study area against the recommended technical standard.
- ➢ To assess constraints to implement technically appropriate physical soil and water conservation measures in the study area.
- ➢ To estimate average annual soil loss by using the RUSLE model in the study area.

1.4. Research Questions

- ❖ In relation to the research objectives, the study tries to answer the following research questions**.**
- ✓ Are the existing physical SWC practices constructed in the area appropriately designed and layouted based on Ministry of Agriculture SWC technology standards?
- ✓ What are the major constraints to implementing physical soil and water conservation measures in the study area?
- ✓ How much soil was lost in the study area in ton per hactare per year?

1.5. Significance of the Study

This study attempted to assess the physical soil and water conservation (pswc) practices and estimation of soil loss using the Rusle model: constraints and challenges in the Debir wonz watershed. This study provides insight for researchers, readers, and governmental and non-governmental organization on physical soil and water conservation in agricultural development. It aids in implementing intervention measures for soil erosion control and improves practices a mong the community. The findings also contribute to the policymakers, development planners, local land managers, researchers and concerned bodies.

1.6. Scope of the Study

Geographically, the study was conducted in Amhara National Regional State, West Gojjam zone in Yilmana Densa Woreda in Enegadie kebele Debir wonz micro watershed. It was delimited to assess the impact of physical soil and water conservation practices on soil erosion and its constraints. This study has also evaluated soil erosion rate and its severity in the watershed using RUSLE model integrated with the GIS and RS techniques. Factors of RUSLE are generated using the application of GIS and RS and combined with extensive field survey and data collection. It was not easy to study the whole aspects of watershed practical activities or practice such as within the available budget, resource and material. Therefore, it was important to restrict the study size and scope of the problem in to a manageable way.

1.7. Limitation of the study

This study had certain constraints when it was being conducted. Other integrated SWC practices could not be fully addressed by this study, even though it evaluates physical soil and water conservation strategies. In summary, although the RUSLE model is a useful instrument for evaluating soil loss, the accuracy of the model would be enhanced by studies collecting more thorough data on soil that was not being experimented with. The RUSLE model primarily ignores other types of erosion, such as gully erosion, in favor of sheet and rill erosion. The researcher also had to deal with financial limitations and health issues while conducting the study.

1.8. Organization of the study

This paper is organized into five chapters. In the first chapter the introduction of the research is presented. This covers the background of the study, statement of the problem, justification for the study, objectives of the study, research questions, and significance of the study, Scope of the Study, limitations of the study and organization of the thesis. Chapter two presents the literature review which encompasses theoretical and empirical literature review related to previous works on the impact of physical soil and water conservation practices on soil erosion and its constraints in case of Debir wonz watershed .Chapter three deals with materials and methods (description of the study area, Sampling Procedure, Data Collection, Data Analysis).The fourth chapter is deal with results and discussions, and the fifth (the final) chapter is about the conclusion and recomm endations.

CHAPTER 2. LITERATURE REVIEW

2.1. Land Degradation

Land degradation is a serious problem in eastern Africa. Easily 14% of its total area suffers from severe to very severe degradation (FAO, 2004). Almost all lands in Sub-Saharan Africa (SSA) are prone to soil degradation, and Ethiopia is among the most affected countries (Wasie Dessale et al., 2020). Every year, about 10 million hectares (ha) of croplands are abandoned globally and 6.5 million ha in Africa (Melese Asmare and Mebrate Tesfaye, 2018). Due to erosion, a minimum of 12 tons /hectares/year of soils is lost every year in Ethiopia, and the economic impact of this loss is estimated to be about $139 million, which is 3–4% of the agricultural gross domestic product (GDP) of the country (Yaregal Biadgilign; 2022,Mulugeta Demelash and Staher,2010).

2.2. Soil Erosion and Types of Erosion

Soil erosion is a complex and dynamic phenomenon affecting many areas all over the world, involving detachment, transport, and deposition. Detachment of soil particles is due to raindrop i mpact, due to kinetic energy (Atoma Habitamu, 2018).Soil erosion in Ethiopia is a severe issue affecting agricultural agricultural development and insecurity, particularly in highland of areas, causing selective removal of fertile top soil and altering soil carbon stocks (Dagnew Dessalegn et al., 2015). The various studies conducted in the country point out that the loss of soil due to soil erosion is at a large rate.

Erosion affects soil physical conditions (e.g., reducing soil depth, water-holding capacity) and chemical properties (e.g., nutrient depletion) that affect agricultural production (Hurni et al. 2010). In addition, soil erosion causes negative effects on the environment, agronomic productivity, food security, and the overall quality of life (Atnafe Addisu et al., 2015). Loss of arable land due to soil erosion is a widespread phenomenon in the highlands, which account for about 45% of Ethiopia's total land area and about 66% of the total land area of the Amhara Region (Yaregal Biadigilign, 2022).

The potential for soil erosion varies from watershed to watershed depending on the configuration of the watershed (topography, shape), soil characteristics, local climatic conditions, land use, and management practices implemented on the watershed (Atoma Habitamu, 2018).Various human activities cause soil erosion, with running water being the most severe hazard, reducing soil productivity and removing fertile top soil (Melese Asmare and Mebrate Tesfaye, 2018). There are different forms of top soil removal or soil erosion, which are given to the following.

2.2.1. Rain splash erosion

Rain splash erosion is the result of water falling directly onto the ground during rainstorms or when it is intercepted by the canopy and finds its way to the ground (Liramo Mengistu, 2020). Splash erosion is occurs when raindrops bombard the soil surface,weaking natural soil aggregate s and causing water infiltration into the soil by the bombardment of the soil surface by impacting raindrops (Abebe Tesfaye, 2024).

2.2.2 Sheet erosion

Sheet erosion is the movement of soil by raindrop splash and runoff water. It typically occurs evenly over a uniform slope and goes unnoticed until most of the productive topsoil has been lost (Liramo Mengistu, 2020). It occurs uniformly over the slopes,leading to the detachments of top soil and sediment transportation via runoff, can cause remove shallow layers of soil (Atoma Habitamu,2018).

2.2.3 Rill erosion

Initiated at a critical distance downslope where surface runoff concentrates and becomes channeled. Rill erosion results when surface water runoff concentrates, forming small yet well-defined channels (Liramo Mengistu, 2020). It refers to the soil erosion that occurs in small channels, can be reduced by reducing surface water volume and speed of surface water with grassed waterways, filter strips, ripped mulch lines, and contour drains (Assefa Belay et al., 2014). Rill erosion is often described as the intermediate stage between sheet erosion and gully erosion.

2.2.4. Gully erosion

Gully erosion is defined as the erosion process where runoff water accumulates and in narrow channels, causing soil to be removed to considerable depths, with permanent gullies being deep enough to be ameliorated typically ranging from 0.5 to as much as 25–30 m in depth (Haregeweyn Nigussie et al., 2015). Gully systems in Ethiopia can often be considered as gully erosion has also been identified as a major source of sediment for man-made reservoirs and natural lakes, which affects the water holding- capacity of such water reservoirs and hence agricultural productivity by reducing irrigation water availability (Yazie Tsegaye et al., 2020)

2.3. Factors affecting soil erosion by water

Soil erosion on a field scale is affected by different interlinked processes and factors (Liramo Mengistu, 2020). Major factors affecting soil erosion are climate, soil properties, vegetation characteristics, and topography. Human disturbances, such as tillage and construction, and natural disturbances, such as severe weather or fire, dramatically increase erosion levels. A mong these, the vegetation and some disturbances, and, to a lesser extent, the soil and topography can be managed to reduce erosion (Fang Meier et al., 2006).

2.3.1 Climatic factors

Erosion by water is the most predominant in terms of its contribution to soil degradation (Girmay Gebirehana et al., 2020). The basic energy input required to drive erosion processes is provided by rainfall and runoff. Soil erosion by water occurs when raindrops act upon the soil particles. Soil loss is closely related to rainfall, partly through the detaching power of raindrops striking the soil surface and partly through runoff (Abate Shiferaw, 2012). The potential ability of rain to cause erosion is known as the erosivity (R) factor (Moisa Mitiku, 2021). Raindrops, while falling, acquire kinetic energy, and on impact, the kinetic energy is used up in detaching the soil particles. Energy is required to break the soil aggregates, splashing them and subsequently carrying them with runoff (Saavedra, 2005). Soil movement by rainfall is usually greatest and most noticeable during short- duration, high-intensity thunderstorms.

2.3.2 Soil factors

Physical properties of the soil affect the infiltration capacity and the extent to which particles can be detached and transported. The susceptibility of soil to erosion agents is generally referred to as soil erodobility (Renard et al., 1997). The erodobility of the soil is the resistance of the soil to both detachment and transport by the eroding agent. Hudson (1996) defines erodobility as the specific property of soil that can be quantitatively evaluated as the vulnerability of the soil to erosion under specific circumstances. The soil erodobility (K) factor shows the mean long-term soil and soil profile response to the erosive power associated with rainfall and runoff(Tesema et al., 2024)

2.3.3. Topographic factors

Soil erosion by water is a function of steepness (gradient), slope length, and shape, which modify the energy of the hydrologic inputs (Abate Shiferaw, 2012). Naturally, the steeper the slope of a field, the greater the amount of soil loss from erosion by water (Morgan, 2005). Soil erosion by water also increases as the slope length increases due to greater accumulation of runoff. Topographic features that influence erosion are slope length, steepness and shape (including concave, uniform, or convex), and size and shape of the watershed. The slope factors (LS) refer to topographic and/or relief factors.

2.3.4. Ground cover factors

Cover includes plant canopy, mulches, plant residues, or densely growing plants in direct contact with the soil surface. Vegetation cover including plant canopy, mulches, and plant residues signif icantly reduces soil erosion by protecting the soil from rain, increasing water infiltration, reducin g surface runoff speed, binding the soil mechanically; maintain soil surface roughness, and impro ving soil properties (Morgan, 2005). The C-factor is defined as the ratio of soil loss from land cropped under specified conditions to the corresponding clean tilled continuous fallow (Wischme ier and Smith, 1978). For deriving and mapping ground cover factor, or C factor, various approac hes have been used.

2.3.5. Conservation practices

Specific cultivation practices affect erosion by modifying the flow pattern and the direction of runoff and by reducing the amount of runoff (Renard et al., 1997). Especially in agricultural areas, conservation practices such as contouring, strip cropping, or terracing reduce soil losses. For instance, in areas where there is terracing, runoff speed could be reduced with increased infiltration, ultimately resulting in lower soil loss and sediment delivery. The effectiveness of such practices is often analyzed with a support practice factor (P-factor), which is defined as the ratio of soil loss with the practice applied to that of up-and downslope cultivation (Wischmeier and Smith, 1978). P-values have been assigned to land-use classes using ranges from 0 to 1 (Kaltenrieder, 2007).

2.4. The Concept of Soil and water Conservation Practices

Soil conservation is the preservation and careful management of the environment and natural resources and Soil conservation is the prevention and reduction of the amount of soil lost through erosion, while water conservation is a way of tapping as much water as possible and storing it in tanks or reservoirs (Ayalew Haweni, 2015). There are three types of soil conservation measures: physical, biological, and agronomical (Ayalew Hewani, 2015). Physical measures include variou s engineering techniques and structures. These practices aim at the following objectives: to divide a long slope of land into a series of shorter ones in order to reduce the velocity of runoff water, to retain the water on the soil for a long period so as to allow maximum water to be absorbed and held in the soil and less water to flows down the slope of the land at non-erosive velocity, and to protect the soil against erosion by water. Soil conservation as a way of solving problems of land degradation has been viewed through a single decision of conservation practices that utilized a single model of adoption in most research work (Tesfaye Gizaw et al, 2019).

Soil and water Conservation practice (SWC) is defined as the rational use of land resources, the application of erosion control measures and water conservation technologies, and the adoption of appropriate cropping patterns to improve soil productivity and prevent land degradation and thereby enhance the livelihood of the user communities(Beyene Yaron,2016). Soil and water conservation measures are more effective when integrated at catchment scale (Yaregal Biadigilig n, 2022). The isolated or single-case conservation approach so far observed from field experience has not satisfied the social, economic, and environmental needs. For instance, the construction of physical SWC measures on farmland or placing check dams inside gullies or planting tree specie s was considered as conservation intervention (Yaregal Biadigilign, 2022) However, this approac h is understood as an individual approach that cannot solve the problem effectively, and an integrated approach should be used to solve the problem sustainably in a combined and integrated way (Mekonnenet Kindu al., 2014a).

Information on SWC methods and techniques are action-oriented summaries for the different SWC measures commonly applied in various parts of the country (MoARD, 2005). The guidelines aimed to provide practical information on work norms and technical standered for development agents and experts at woreda level, that covers technology implementation phases,objectives,ecology,landuse,technicalprepardnes,sustainable productivity, environmental p rotection, surveying tools and management requirement(MoARD, 2005).

2.5. Soil and Water Conservation Principles

Effective implementations of SWC measures need to be guided by basic principles. According to MoARD(2005), BoA, (2011) and Makonnen Kindu et al.(2014a): (1) SWC measures should start from hilltop and proceed downhill to safely handle and protect concentrated surface run-off (ridge to valley approach); (2) SWC measures should be simple to understand and easy to implement by land owners; (3) SWC measures should get acceptance by the implementers for its sustainability; (4) SWC structures should be located at appropriate area in the land escape, properly designed and constructed based on accepted techniques, (proper location, design, layout and construction); (5) most conservation structures constructed on cultivated lands may take 10 % of farmland out of production which may create hardship on farmers to accept physical structures; (6) recognizing the role of women in SWC activities and ensuring their active participation in decision-making; (7) build on traditional practice(Kebede Wolka, 2018).

2.6. Soil and Water Conservation Practices in Ethiopia

Prior to the 1974 revolution, soil degradation did not get the policy attention it deserves (Olana, 2014). The famines of 1973 and 1985 provided an impetus for conservation work through a large increase in food aid, mainly using imported grains and oil. Following these severe famines, the government launched an ambitious program of soil and water conservation supported by donor and non-governmental organizations (MOA, 2012). The use of food aid as a payment for labor replaced voluntary labor for conservation campaigns. The roles of soil and water conservation measures in reducing nutrient and soil losses (Gadisa Negasa and Midega Tesfaye 2021).

Almost all the soil and water structures and practices were destroyed shortly after the construction in almost many places of the country(Yaregal Biadgilign, 2022). The project expected that the local people would bear all the costs of maintenance. Yet, farmers had few incentives to maintain structures or continue with practices (Woldeamlak Bewuket, 2003). Durin g the 1980s, the government of Ethiopia launched a massive program of soil and water conservat ion and rehabilitation. After 1989, soil and water conservation practices have mainly been undert aken in the form of campaigns and quite often farmers have not been involved in the planning process(Wildemeersch Jasmein et al., 2013) .

Between 1976and 1990,food for work(FFW) program incentives led to the completion of 71,000 ha of soil and stone bunds,233,000 ha of hillside terraces, 12,000 km of check dams in gullied lands, and 390,000 ha of closed areas for natural regeneration 448,000 ha of tree planting (USAI D, 2000). Nevertheless, the achievements fell far below expectations, the country still loses a tremendous amount of fertile topsoil, and the threat of land degradation is alarmingly broadening (Gebremedhin Birhanu, 2004). The difficulties encountered by the programmers during their initial stage of implementation led to the realization of the need for beneficiaries' participation in the planning and implementation of conservation programs and projects, including the adaptation of conservation technologies to local conditions (Masresha Baile, 2014).

2.7. Soil and water conservation practices in Amhara Region

Soil and water conservation(SWC) in amhara region of Ethiopia is crucial due to regions high population density, rugged train, and susceptibility of land degradation and drought (Yemata Demise etal, 2024).various SWC practices are employed to improve land productivity and food security, which includes physical structures, agronomic methods residue management (Sibuh Gebeyew,2020). Amhara region started to implement land rehabilitation measures through a massive soil and water conservation (SWC) program in the 1970s (Beyene Yaron, 2016). The region has been realized the treatment of vast degraded areas (both cultivated land and hillside government lands of the highlands) through mass movement of the community in line with different projects run by governmental and nongovernmental organizations(Yaregal Biadgilign,2 022). It comprises structural conservation measures (physical earthworks like construction of terracing, cut -off drains, bunds) followed by biological measures (plantation of grasses and forage plants to stabilize physical measures) that take place during the rainy season (Assefa Belay, 2010).

Whereas, in 2010, the effort was very much strengthened and taken as a priority objective, with the political leaders and experts conducting SWC campaigns every year (BoA, 2013). In those campaigns, it has been observed that a huge number of resources (labour and finance) have been mobilized and a large tract of land has been covered. At the regional level, before the commencement of the SWC activities, through public awareness is effective in motivating collective action and involving all active labor forces (elders, women, men and youth) that are expected to participate in catchment development activities as planned (BoA, 2013).

The community mobilization arrangements have allowed all concerned bodies to play their parts according to their ability. The active workforces include both men and women who are engaged in physical hard work (digging, excavation, and stone transport), while the elders look after children and animals as well as guard villages from theft. The initiative is well taken by the farming community and is becoming a common objective (BoA, 2013). The campaign gives due emphasis to SWC measures that are to be constructed on communal lands, gully rehabilitation, and drainage management such as cut-off drains, waterways, and graded bunds, particularly in the highland areas where there is high rainfall and the drainage management structures have paramount importance (BoA, 2013).soil and water conservation implementation often involves community participation, with farmers selecting and applying practice based on watershed principles(Hassen seid et al,2024).

2.8. Soil and water conservation techniques

Many workers define the effect of contour bunds to check soil erosion, but Subduhi et al. (2004) reported that renovation of terraces and plantation of fruit plants, and timber plants improved biomass production, net returns, growth of crops, productivity, reduction of runoff in the range of 1.5-10.8 times, soil loss in the range of 20 times, and soil loss in the range of 1.2 to 5.2 times, as well as water table rise. (Brenner et al., 2013) have reported that the effect of vegetative barriers like vetiver has increased the rice yield, decreased the soil loss, and decreased the runoff compared to farmer's practices.

(Arora and gupta,2002) reported that there is a growing need for rainwater management since 96 m/ha out of 142 m/ha of net cultivated land in the country is rain-fed. Scientific use of this resource will definitely increase the productivity and conservation of resources like soil and water. Various conservation techniques have been used or are being used to reduce soil loss and increase soil fertility and conserve soil moisture for enhancing soil productivity (Masresha Baile, 2014). Terracing reduces the soil slope, which ultimately reduces soil loss; a steep slope also enhances the erosive power of running water and the sediment- carrying capacity of the stream. By converting sloppy lands into terrace these lands become useful for agriculture, livestock, and society. Therefore, terraces have been indicated as suitable techniques for water conservation in order to improve the soil fertility (Gardner and Gerrard, 2003).

2.9. Agro-Ecological Zone for Soil and Water Conservation

Agro-ecological zone is one important variable in selecting and implementing PSWC measures. Classifying areas into dry, moist, and wet helps in understanding what types of water harvesting and SWC structures could be used(Hassen Getahunet al., 2021). What is designed for dry area may not serve sufficiently for wet and moist areas. To avoid such technical mistakes, identification of the agroclimatic zone of the working area is important. The simplest method by which an agro-climate of an area can be identified is by using rainfall, altitude, and temperature. According to MoA (2001), areas with annual rainfall less than 900 mm, 900–1,400 mm, and greater than 1,400 mm are considered as dry, moist, and wet agro-climatic zones, respectively. In

Ethiopia, for natural resource development and conservation purposes, SWC methods are selected based on agro-ecological zones (Hurni, 1995; MoARD, 2005; BoA, 2011)

2.10. The Impact of Physical Soil and Water Conservation Measures on Soil Erosion

Soil erosion in the form of water erosion is the main threat and concern in the highlands of Ethiopia, particularly in the Upper Blue Nile (UBN) basin (Dagnew Dessalegn et al., 2015). Physical soil and water conservation structures have great potential to reduce soil loss by decreasing overland flow of water and increase yield by reducing moisture stress on plant growth through retention of rainwater that would otherwise be lost to runoff (Damtie Sisay, 2017). PSWC measures had a positive impact on sustainable agriculture through reduction of runoff and soil loss. Various studies in the highlands of Ethiopia have reported that physical soil and water conservation measures reduced soil loss due to trapping sediment behind the structures and forming benches. Terrace has the lowest soil loss (23 tons per hectare per year) in conserved cultivated land, while the highest soil loss (119 tons per hectare per year) is in non-conserved land (Lakew Desta et al., 2020). And also in the northwestern highlands of Ethiopia, in the Geleda watershed of the Blue Nile basin, the soil loss in the steep areas of the watershed extends up to 237 tons per hectare per year (Gashaw Temesgen et al., 2017). Habtamu et al. (2020) also revealed that the maximum soil loss, which is 100.62 tons per hectare per year, was found in steep-slope cultivated land, and the average soil loss in the Yasir Watershed was 50.31 tons per hectare per year. Likewise, Belayneh Mengie et al. (2019) also found a total of 9.683456 million tons of gross surface soil lost annually, with an average soil loss of 42.67 tons per hectare per year, of which 62.1% was generated from cultivated land, and high spatial variability of soil erosion within the Gumara watershed. Among the physical SWC practices, level soil bunds were effective in reducing soil loss up to 88% (15.9 t ha^{-1}) (Adimassu Zenebe et al., 2017). This is because level bunds retain soil and water across the slope. Physical soil and water conservation with soil bunds on croplands in northern Ethiopia in the Debremawi watershed reduced the annual soil loss to 46 tons per hectare per year (Tadele Girma, et al., 2018), and trenches in the May Leiba watershed reduced it to 4 tons per hectare per year (Taye Getachew, et al., 2013).

2.11. Physical Soil and Water Conservation Practices

Physical soil conservation structures are permanent features made of earth, stones, or masonry, designed to protect the soil from uncontrolled runoff and erosion and retain water where needed

(Beyene Yaron, 2016). Physical SWC measures used to reduce surface runoff velocity trap water and sediment and thus control soil erosion. There are various physical land management practices that are applied to control erosion in the highland parts of the country. These measures include stone bunds, soil bunds, check dams, cutoff drains, and bench terraces. Water harvesting pond, eyebrow basin, microbasin, etc. (Beyene Yaron, 2016). Bunds are simply embankment like structures made of soil and/or stone with a basin at their upper side constructed across the slope (Kassa Dawit, 2021). Generally, it is used on cultivated lands with slopes above 3% based on the soil type, intensity, and amount of rainfall. In wet and moist regions and where the permeability of the soil is low, graded channel terraces are used with the purpose of draining runoff from the arable land at non-erosive velocity to a site where it can safely be discharged (MoARD, 2005).

2.12. The major constraints to implementing physical soil and water conservation measures

In Ethiopia, even though numerous studies have been conducted on the impact of individual SWC measures on soil erosion control, soil properties, and crop productivity, little information is available regarding the effects of integrated watershed management on the reduction of continued soil erosion and livelihood improvement (Gurebiyaw Kassa, 2019). The low adoption of sustainable land management practices is the main constraint for the unsuccessful implementation of physical soil and water conservation in the reduction of continued soil degradation and the inability to bring the expected result in livelihood improvement (Tilahun Kefialew & Desta Gizaw, 2021). Currently, sustainable land management is a valuable new approach for sustainable soil, water, and other natural resource management as well as for the improvement of livelihoods in Ethiopia (Bantider Amare et al., 2019). Furthermore, lack of integration of different disciplines and sectors is the main challenge/constraint for the failure of implemented physical soil and water conservation and the inability to bring expected improvement in the livelihood of households (Tilahun Kefialew & Desta Gizaw, 2021). Besides, the top-down approach of physical soil and water conservation intervention was the main governmental policy in the past and might have been sustained later.

2.12 .1 Limited Awareness on SWC

Less awareness of the nature and technical requirements of physical and soil and water conservation practices, as well as a lack of awareness of agricultural knowledge and physical soil and water conservation measures, are the major challenges that are limiting households from adopting and implementing physical soil and water conservation practices at their farmlands (Gurebiyaw Kassa, 2019). Higher education levels are hypothesized to be associated with improved awareness and knowledge regarding conservation measures and productivity, and the effects of erosion may persuade them to choose particular SWC practices (Fikirie Kalkidan et al., 2020). In addition to the approach and inappropriateness of the physical soil and water conservation practices, changing the mindset of farmers and convincing them to adopt the appropriate SWC technology are still the main constraints to success in soil erosion control and livelihood improvement (Asnake Belay & Elias Eyasu, 2017). Similarly, lack of participation of the community at all stages in physical soil and water conservation intervention brought less sense of ownership of soil and water conservation structures constructed in the area that imposed negative impacts on its sustainability (Wildemeersch, Jasmein, et al., 2013).

2.12.2 Labour Shortage

Labour shortage, specially the number of family size of the households, largely influences the participation in physical soil and water conservation measures (Asnake and Elias Eyasu, 2017). The construction and maintenance of physical SWC structures require intensive human labour for which machinery has not been developed or introduced in most developing countries (Gurebiyaw Kassa, 2019). The labor demand appears much more than the requirement for most ordinary farming businesses (Fikre Kalkidan et al, 2020).

2.12.3 Inappropriate/poor quality of the physical soil and water conservation technologies

The inappropriateness of implementing PSWC practices is the main constraint to bringing expected change in erosion control and livelihood improvement via land management practices in Ethiopia (Tilahun Kefialew & Desta Gizaw, 2021). Lone implementation of pits and half-moon physical soil and water conservation technologies in degraded hillside areas is effective only for the short rainy season, while after a long season the structures are filled with sediment, and the effectiveness of physical soil and water conservation declines quickly. The combination of stone bund and trench was more effective in reducing runoff and soil loss for hydrological response improvement and soil productivity (Olana Habitamu, 2014).

2.12.4 Physical factors of land

In Ethiopia, small landholding size is the main problem in adopting and using sustainably the SWC technologies. This implies that farmers having large farm sizes were more able to adopt the PSWC measures on cultivated land than farmers having small farm sizes (Asnake Belay & Elias Eyasu, 2017). Studies in a different part of Ethiopia indicated that landholding size was found to have a positive effect on farmers' perception of investing in SWC technologies (Gurebiyaw Kass a, 2019). Besides, physical SWC measures are challenged by frequent maintenance requirements , which are highly labor-demanding, loss of land to conservation, and unsuitability to the farming system (Gurebiyaw Kassa, 2019). On the other hand, various studies indicated that farmland distance from the homestead was found to have a negative and significant effect on farmers' perception of investing in SWC technologies in different parts of the country.

2.12.5 Institutional factors

Unstable institutional frameworks and a weak link between research and extension are major policy constraints that discourage farmers from making any sort of investment in the land and using it in a more suitable way. Lack of and rare extension services and training by the developmental agent are a very important constraint for the success of any SWC intervention (Adimassu Zenebe et al., 2017). This is because landowners with frequent visits to the farmer training center and demonstration sites are more voluntary to maintain soil conservation works b ecause it gives them a chance to learn technical skills and principles of natural resource manage ment (Asnake Belay & Elias Eyasu, 2017).

CHAPTER 3. MATERIAL AND METHODS

3.1. Description of the study area

Yilmana Densa District is one of the fifteen District in the West Gojjam Zone of the Amhara National Regional State. It is 42 km southeast of Bahir Dar, the capital of the Amhara National Regional State. It is bordered on the south by Quarit District, on the southwest by Sekela, on the west by Mecha woreda, on the north by Bahirdar zuria, and on the east by the Abay River, which separates it from the Debub Gonder Zone, and on the southeast by the Misraq Gojjam Zone. According to YDWAO (2022), the total population of the district was 235,250, of which males accounted for 114,274 and females accounted for 120,976 of the total population. The average annual rainfall of the area ranges from 1270 mm with an average temperature of 8.825.2°C. The district is characterized by 24% highland (Dega), 64% midland (Weynadega), and 12% (Kola) ag ro-ecological zones (YDWOA, 2023). Among the district population, 7490 are from Enegadie kebele, of which males account for 3992 and females 3498. From the total population of the Enegadie DebirWonz watershed, there are796 males and 396 females; 400 are accounted for in the study area where they live.

3.1.1 Location

DebirWonz watershed is located mainly in Enegadie kebele in Yilmana Densa District, West Gojjam zone of Amhara Region. It is located approximately 22 km north of Adet town. Debir Wonz watershed is located in the northern part of the Amhara region, Ethiopia. The watershed covers an area of 301.5 hectares and is geographically located between 11.17° and 11.2° North latitude and 37.05° to 37.5° East longitude. The elevation of the area ranges from as low as 2423 to as high as 2733 m a.s.l (YDWAO, 2023).

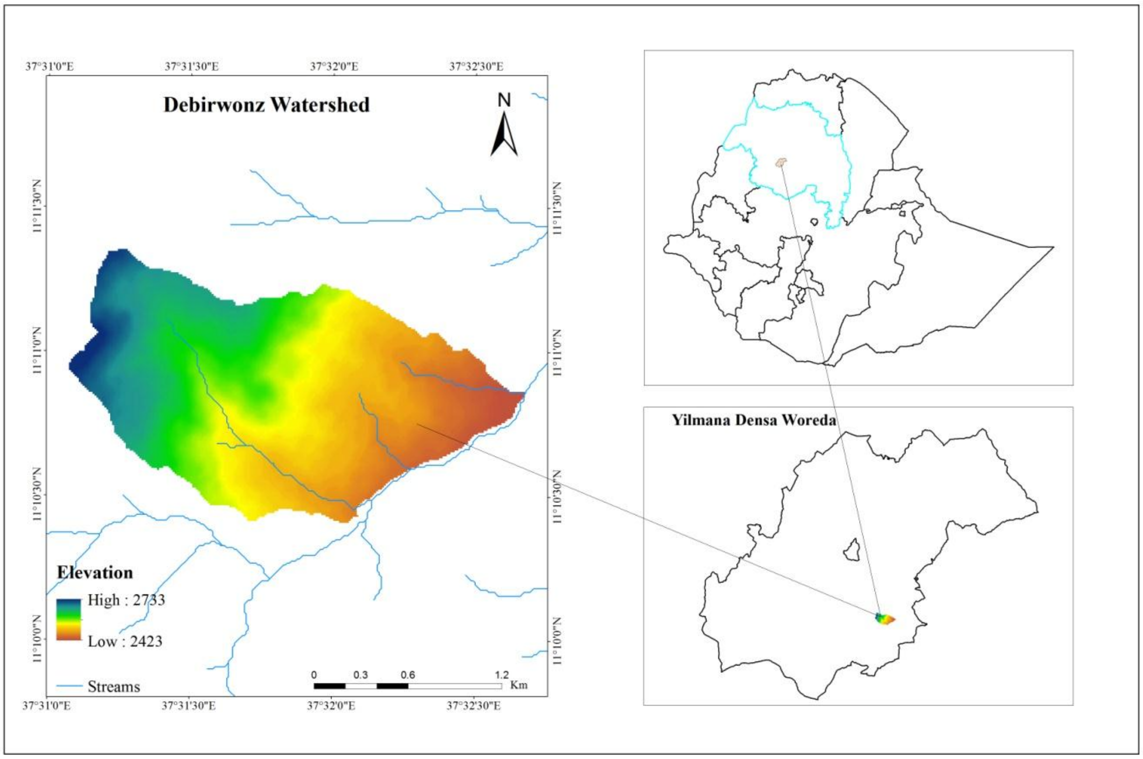

Figure 3.1 location map of study area

3.1.2. Topography and agro-climatic conditions

The Debirwonz Watershed has diverse characteristics of topographical formations. Covers slopes that range from flat (0%) to extremely steep (50%), as presented in Table 3.1. Therefore, its physical feature is characterized by flat to very gentle, moderate, steep, very steep, and extreme; this classification was developed from FAO slope classification. The agroclimatic conditions were dominantly moist weynadega (moist mid-highland) agroclimatic zone. Debir wonz watershed; the altitude ranges from 2423 to 2733 m above mean sea level (Masl). Annual mean temperature ranges from 15°C to 24°C, and annual mean rainfall (RF) ranges from a minimum of 1200 mm to a maximum of 1600 mm (YDWAO, 2023).

Table 3. 1 FAO slope classification in % of the study watershed

Slope class (%)	Area (ha)	Coverage (%)
0 – 3	3	1.03
3 – 8	33.4	33.4
8 – 15	121	38.28
15 – 30	133	44.13
30 – 50	11	3.65
	301.45	100.00

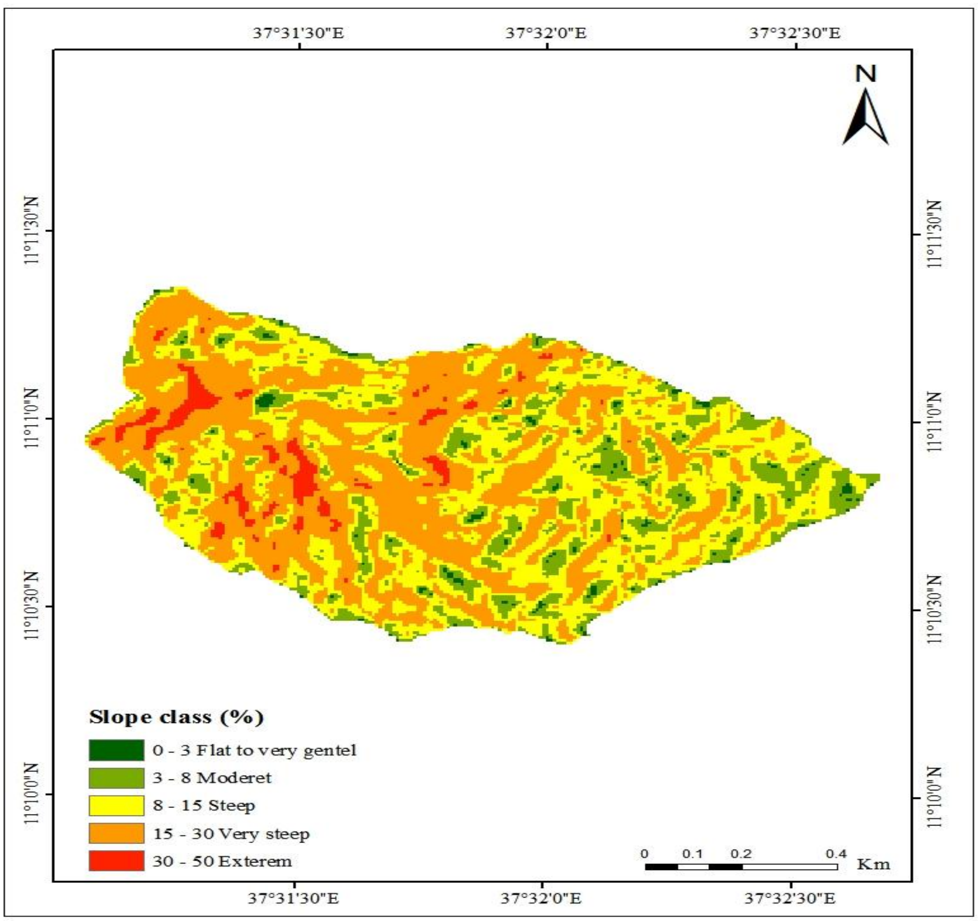

Figure 3.2 Slope classification map of the study watershed

3.1.3 Vegetation and land use

The farming system of the watershed is a mixed farming system where crop production is the most important component of the livelihood of the farmers. The major crops grown in the study area are maize (Zea mays), Barley (Hordeum Vulgare L), wheat (Triticum aestivum), Teff (Eragr ostistef Teff), beans, peas, Niger seeds etc are the important crops cultivated. Livestock production is another component of the watershed mixed farming system. From the total Livestock production, cattle and small ruminants are the dominant ones. In addition, beekeeping is traditionally practiced in the watershed.

In the study area, several indigenous and exotic tree species are found even if their abundance is very limited. A few are found, on some farmers' farmlands, river basins, around churches, homesteads, and government forests. The most dominant tree species in the study area was Eucalyptus globulus. This is because it grows very fast and has high economic value, such as house construction and fuel wood, and can also be sold on the market as a cash crop. Regarding in the land use pattern of the study watershed, major land use types were cultivated land (241.11ha), forestland (18.30ha), grazing land (14.06 ha), area for settlement (7.9 h), a total of 301.5 hectares (YDWAO, 2023).

3.1.4 Soil type

The dominant soil classifications found in the Yilmana Densa district were Vertisols (20%), Nito sols (65%), and Leptosols (15%) (YDWOA, 2023). Mostly the agroecology of the Yilmana Dens a district is weynadega. Vertisols soils developed from expanding clay. The dominant soil colors that were found in the Debirwonz watershed were black, brown, red, and grey, and Nitosols are red, well-drained soil. So the dominant soil type in the study area is Nitosols (YDWOA, 2023 and FAO soil map, 2006).

3.1.5 Physical soil and water conservation practices in Debir wonz watershed

Land and water management activities focusing on introduced measures were underway in the Debir wonz watershed beginning in 2013. The woreda agricultural offices were carrying out the work with financial and material support from community mobilization. The approach pursued was an integrated watershed management (IWM) type, where PSWC was given a central place. Different types of physical soil and water conservation measures were introduced to the study area. The introduction was aimed at conserving, developing, and rehabilitating degraded agricultural lands and increasing food security through increased food production/availability (MoARD, 2005). The majority of PSWCP effort made in the study area was directed to controlling soil loss from cultivated fields, as Woreda expert technical support. Among the variety of PSWCP implemented on farmlands, graded soil bund, trench and cut-off drains, waterways,, and stone check dams were the common ones. According to information obtained from the Yilimana Densa woreda agriculture office, the main PSWCP constructed in the study watershed includes a total of 186.5 ha of soil bund, 1.375 km (1650 m^3) of) of waterway, 1.3889 km (1250 m^3) of^3) of cutoff drain, 1450 trenches of, 0.55 ha of stone and stone-faced soil bund, and 2370 $m^3$of different check dams.

3.2. Sampling Procedure, Data Collection and Analysis

3.2.1. Sampling Technique

Debirwonz watershed was selected using a purposive sampling method based on accessibility to the field with all treatments of trench, soil bund, and waterway, and cut off drain and check dams and the control within the study area.

Assessments of soil conservation practices were made in three sections separately to account for the variation due to slope as well as agricultural practices variation and soil depth. Different parameters of the selected structures were measured starting from the hill to the bottom. The mean of those variables was computed for each structure and compared with the recommended (standard) value using a T-test to evaluate the quality of the structure to compare measurements of structure against a standard value, determining if there is stasticaly significant difference. This helps to assess whether structures were performing as an intended, according to established norms or design specification.t-test is a statistical method us used to compare means of two groups. In this case, one group represents the measurements taken from the constructed structure, and the standered or targeted value.

$$\text{Tcal}=x - x^{-} / _{s/\sqrt{n}}$$

Where, x- is the recommended standard value,

$\bar{x}$-is the mean of the data set,

s- is the standard deviation of the data set, and n- is the total number of each data.

3.2.2. Watershed community sample survey and analysis

A community-level survey was conducted in DebirWonz watershed. Data were collected through open-ended and close ended questionnaires to assess the community based watershed management practices in DebirWonz watershed. Sample farmer households who live in villages of the study area were determined following Yamane's formulated equation and selected using simple random sampling techniques. Data recorders were appointed to go to each household, and formats were filled by asking respondents orally. The data collected through the questionnaires were analyzed using the statistical package for the social sciences (SPSS Version 16). The number of respondents in the sample size was determined using the formula developed by Yamane (1967). A formula used for sample size determination was

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

Where: n= number of sample size; N= is population size; e= is the level of precision (5%, 7% and 10%), but 8% precision level will used for this study. Accordingly, the sample size required (n) in the study area from the total population was 112 households (HH). Because of a homogeneous type of HH population in terms of their livelihood and conservation technologies implementation, households were selected randomly. Lists of household heads recorded at the Village (locally called Kebele) administrative office were used as a sample frame for random selection of the households for face-to-face interviews. Besides, focused group discussions (FGD) supplement the information acquired from household surveys. The FGD participants include farmers, experts, administrators, and development agents. The aim of the FGD was to obtain important qualitative information concerning the ideas of the participants about PSWC technologies, design, acceptance, and constraints to implement the conservation work.

3.2.3. Methods of Data Collection

For this study, quantitative and qualitative data were collected from primary and secondary sources. Primary data were collected through transact walks, filed measurements, sample households including information on age, sex, family size, educational level, and land holding size, type and area coverage of SWCP, questionnaire interviews, and focus group discussions. Secondary data like population, age structure, farming systems, infrastructure situation, annual rainfall, station locations, etc. were collected from different sources. Development agents (Das) were recruited and trained on the techniques of data collection, including how they should approach farmers, conduct the interview, and convince the respondent to give relevant information on participation of PSWCP. After they were made aware of the objective of the study and content of the questionnaire, a pretest had been conducted under the supervision of the researcher. Some adjustments were made to the questionnaire, and the data were collected under continuous supervision of the researcher.

3.2.4.1. Transect walks

Transect walks across the watershed were conducted in order to obtain all the necessary extra biophysical information of the watershed. A group of eight people and the researcher were involved in the transect walk. The farmers were selected based on willingness, knowledge about the area, and duration of stay in the watershed. Three transect walks were made: one along the upper stream part and the second between middle and downstream sections of the watershed. Identification of types of conservation practices and field measurements was made during the transect walk. Moreover, the informal discussions with the farmers helped to acquire detailed information. During the transect walks, the types and year of construction of the PSWCP were identified, coded by features in the farms, and the owner of the farmland recorded using a format developed for this purpose.

3.2.4.2. Field Measurement

Direct field measurements of PSWCP (details of graded soil bunds, waterway, cutofdrain, check dam and trench) implemented government campaigns were measured and used to assess technical fitness with standards set by Ethiopian ministry of agriculture 2005 manual in the watersheds. The measured graded soil bunds were located first by dividing the whole area of the watershed into three parts depending on slope classes based on FAO (2006). Then based on reconnaissance field measurement the watersheds were categorized into downstream (3-8) % middle stream (8-15) % and upper stream (15-30) % and the soil depths were assessed at >50 cm and <50 cm for the respective slope categories to make convenience for the assessment of targeted technological characteristics such as design and layout of PSWCP. 18 soil bunds, 9 trench ,3 waterway ,3 cutofdrain and 3 check dam in the watershed (i.e. a total of 36 pswc) were taken for detail design investigation.

A detailed field measurement of the selected graded soil bunds such as embankment height, embankment width (both top and bottom), spacing between bunds, vertical interval, bund length, ditch depth, ditch width, berm width, bund gradient, embankment gradient and Spillway, Side ke y, Width of spillway, Bottom key, Height, Apron length and base width of check dam was measured at three points from each structure using a tape meter, water level, string (rope), and graduated poles. Then the mean of 18 graded soil bunds from each separate slope class of the study area was measured to make comparisons against the minimum standards set by Ministry of Agriculture (MoARD, 2005) manual based on slope and soil depth.

All of the constructed soil bunds, trenches waterways, and cutoffdrain and checks dam in the watersheds were selected for the detailed measurement of respective design and layout characteristics to evaluate against the minimum technical standards. Moreover, it presents general layout and design specifications for each type of method. The specification of soil bunds are shown in the (table3.2).

Table 3.2 Standard value of graded soil bund and trench

Soil bund Component	stable soil	Trench
Length of bund	60m for moderate and steep slopes, 60 m to 80m for gentle slops	2-3
Bund gradient	1%	
Ditch depth	0.50 m	50
Ditch width	0.60 m	50
Embankment height	0.60 m	-
Embankment top width	0.30 m	-
Embankment bottom width	1m-1.2m	-
Berm width	0.25 m	-
Spacing	1m slope <15	3-5

Source: MoARD, 2005

Slope of the watershed is the steepness of the slope. It is given as the height in percentage of length. It is calculated as

Slope in % = $\frac{VI\ (m)}{HD(m)}$*100……………………………………………Equation (1)

Where: VI - The vertical interval is the elevation difference between two points in (m).

HD- horizontal distance between two points.

Table 3.3 Vertical interval (VI) and bund spacing or horizontal distance (HD)

Slope%	Soil depth>75(cm)		Soil depth 50-75(cm)		Soil depth 25-50(cm)	
	VI(m)	HD(m)	VI(m)	HD(m)	VI(m)	HD(m)
3	1	33	-	-	-	-
4	1	25	-	-	-	-
5	1	20	0.7	15	0.5	10
6	1	17	0.7	12	0.6	10
7	1	14	0.8	12	0.7	10
8	1	12	0.8	10	0.7	9
9	1	11	0.9	10	0.8	9
10	1	10	0.9	9	0.8	8
11	1.1	10	1	9	0.9	8
12	1.1	9	1	8	0.9	8
13	1.2	9	1.1	8	1	8
14	1.2	8	1.1	8	1	7
15	1.2	8	1.1	7	1	7
16	1.3	8	1.1	7	1	6
17	1.3	8	1.2	7	1.1	6

18	1.3	7	1.2	7	1.1	6
19	1.3	7	1.2	6	1.1	6
20	1.4	7	1.2	6	1.1	6

Source: MoA, 2001; BoA, 2013

Waterways should be constructed one year before the graded SWC measure. The channel can have a gradient up to a maximum of 1% with an embankment height of 60 cm after compaction. The base width ranges from 1 to 1.2 m in stable soils and 1.2–1.5 m in unstable soils. It is a mistake to design waterway structures to discharge runoff if there is no suitable outlet, such as a natural waterway, artificial waterway, or grassed or forested area (MoARD, 2005).

Table 3.4 Nationally recommended standards of check dams (wood, loose stone)

Component	Recommended standards
Spillway	0.25-0.3M
Side key	0.7-1m
Bottom key	0.5m
Width of spillway	0.75-1.2m
Height	1-1.5m
Base width	1.5-3.5m
Apron length	1.5-3m w*1m length

Source: MoARD, 2005

3.3. Data Analysis

As stated above, a wide array of data collection strategies were employed together with a vast amount of evidence during a case study for analysis. Simple descriptive statistics were applied to analyze data. The data analysis on field measurement was made by comparing field results with the technical standards specified for different topographic, land use, agro-ecological conditions, and soil depths. The quantitative data was summarized, tallied, and coded by using Microsoft Excel 2016 and then entered into SPSS software version 2023 by using the one-sample T-test, and ArcGIS software version 10.8 was used to analyze the annual soil loss of the study area by entering the six parameters, such as the rainfall erosivity factor, soil erodibility factor, slope length and slope steepness factor, cropping and cover management factor, and conservation support practice factor, by using the RUSLE model. Tables were used to assess the effect of slope and soil depth on the technical aspects of soil and water conservation practices with their dimensions. Qualitative data were analyzed and described through opinion interpretations after being organized and categorized.

3.4. Data Sources and Methods in Determining RUSLE factor Values

ARCGIS 10.8 version of software were used in order to analysis the five factors to estimate average annual soil loss of study area watershed. The mean annual rate of soil loss due to sheet and rill erosion was estimated by using the Revised Universal Soil Loss Equation developed (RUSLE) by Renard et al. (1996), using six factors that directly and indirectly affect soil erosion rate (Eq. 3).

A= R*K*S*L*C*P…………………………………………………..Equation (2)

Where, A is the computed spatial annual soil loss (t/ha/yr); R is the rainfall erosivity factor (MJ mm/ha/h/yr); K is the soil erodobility factor (t ha h/MJ/mm); LS is the slope length and slope steepness factor (dimensionless); C is the land surface cover management factor (dimensionless); and P is the erosion control or conservation practice factor (dimensionless).

3.4.1. Rainfall erosivity factor (R)

This study used the following empirical equation adopted by Hurni (1985) to estimate R-factor values from annual total rainfall (P mm) (Eq. 4). For Ethiopian conditions used as (e.g. Amsalu Tadesse & Mengesha Abebe, 2014; Kebede Abebe 2014; Haregeweysn Nigussie et al., 2017; Sewnet Amare & Abebe Gebeyehu, 2017), based on the easily available mean annual rainfall (P).

R = -8.12 + (0.562×P) …………………………………………………..Equation (3)

Where, R is the erosivity factor in (MJ mm/ha/h/yr) and P is the mean annual rainfall depth in (mm).The annual rainfall data was obtained from west Amhara meteorological agency (WAMA) to compute the erosivity factor. Rainfall data from 5 in/nearby weather stations were collected from 2013 to 2022. To compute R factor, mean annual rainfall of 10 years were collected from five metrological stations (Adet, Bahirdar Motta, Merawi and Feresbet) were taken from neighboring woreda .After calculating average 10 years of rainfall for each station, the R factor was computed using the above formula and converted in to raster surface using IDW (Inverse Distance weighted) interpolation methods in ArcGIS software.

3.4.2. Soil Erodibilty factor (K)

For this study, due to the difficulty of finding parameters at local level and cost constraints of experimenting with soil samples erodobility factor (K) estimation based on soil color proposed by Hurni (1985) for Ethiopian condition is adopted. Based on the collected ground control point data of each soil color their corresponding soil erodobility factor (K) value was derived based on Hurni (1985) and Hellden (1987).

3.4.3. Slope length and slope steepness factor (LS)

The LS factor was calculated by using SRTM DEM with a resolution of 12.5 x 12.5 m spatial resolution. DEM (digital elevation model) was used to generate slope “Spatial Analyst Tool Surface Slope” in the ArcGIS 10.8 environment. The flow accumulation and slope steepness were computed from the DEM using ArcGIS. Flow accumulation was derived from hydrologically corrected DEM after conducting FILL and flow Direction processes by Arc Hydro tools, GIS software. Hydrologically corrected DEM is an adjusted elevation raster in which the source DEM is filled (it is a modified version of the raw DEM that has been processed to accurately represent water flow). Flow accumulation and slope maps were multiplied by using the Spatial Analyst Tool Map Algebra Raster Calculator” in ArcGIS to calculate and map the slope length (LS factor) as shown in equation (5) and defined by Wischmeier and Smith (1978).

$$\mathrm{L}S = \left[Flow\ accumulation * \frac{Cell\ size}{22.13}\right]^{0.4} * \left[\frac{Sin\ slope}{0.0896}\right]^{1.3} \text{……………………Equation (4)}$$

LS=Flow accumulation∗cell size

Where LS are the slope length and the slope steepness factor, cell size is the size of the grid cell, and the sin slope is the slope degree value in sin.

3.4.4. Cropping and Cover Management Factor (C)

The C factor was obtained from the land use land cover classification of the study catchment derived from Hurni (1985) in the Upper Blue Nile River. The raster land use/land cover map was converted to a vector format, and a corresponding C-factor value was assigned to each land use /land cover class. The study used four types of land use. Finally, using the conversion tool in ArcGIS software 10.8, the land use land cover type map was converted to a C factor map.

3.4.5. Conservation Support Practice Factor (P)

The P factor indicates the rate of soil loss according to the various cultivated lands on the earth. It represents the soil loss ratio after performing a specific support practice to the corresponding soil loss, which can be treated as the factor to represent the effect of soil and water conservation practices (Wischmeier and Smith (1978)). The constructed soil and water conservation structures were poorly maintained. The value of the support practice factor is assigned by considering the cultivation methods and slope in line with Shin (1999). P values range from 0 to 1. For this purpose, determining the slope map from the DEM was used to drive the spatial distribution maps of the P factor. The P-factor for this study was determined using an alternative method that utilizes slope and land cover data as suggested by Wischmeier and Smith (1978).

To estimate soil loss using the RUSLE model the methodological framework used for this study, as shown in (Figure 3.3).

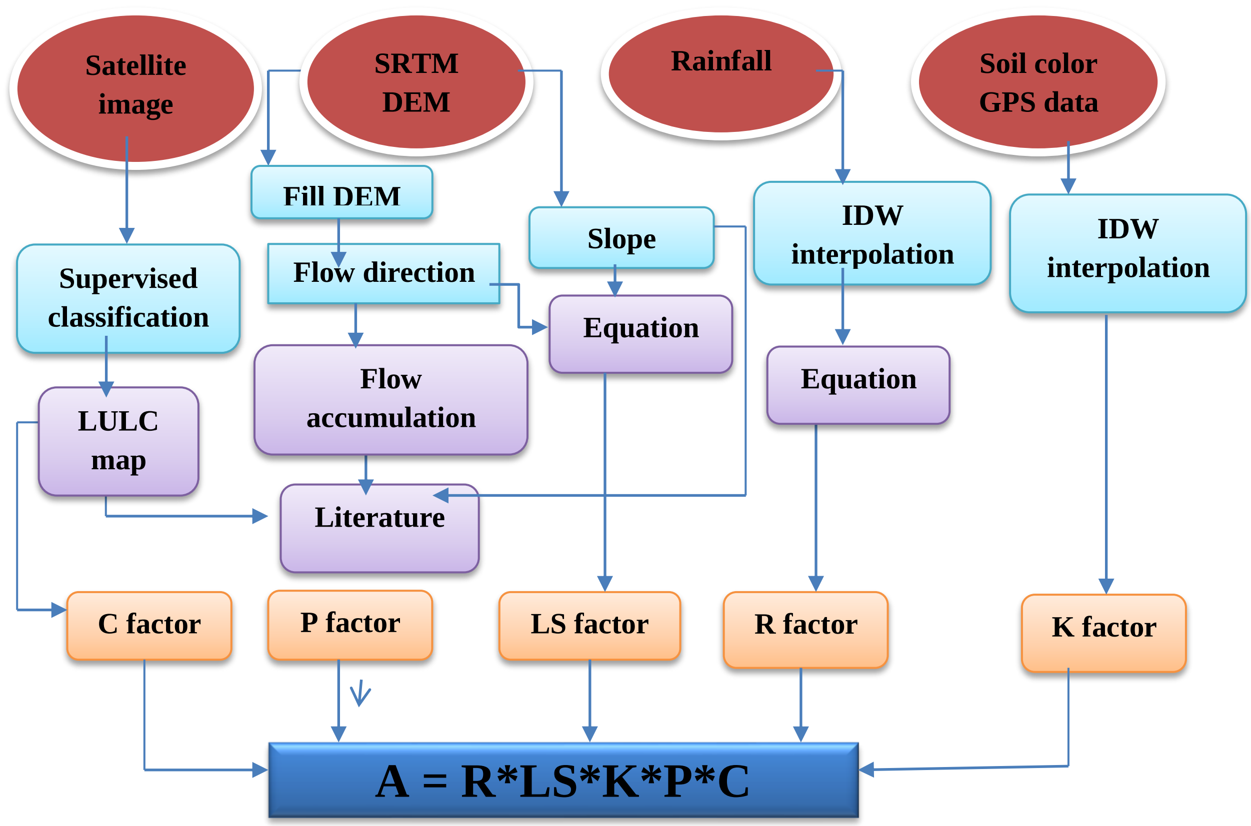

Figure 3.3 Flow chart showing the methodology adopted for soil loss

CHAPTER 4. RESULTS AND DISCUSSION

4.1. Technical Evaluation of Physical Soil and Water Conservation Practices

The evaluated existing soil bund indicated that the majority of variables of layouts, such as length of bund, depth of bund, width of bund, height of embankment, length of berm, and bottom width of embankment, were significantly lower than the standards (Table 4.1) Implementation of these structures considers agroecology, topography, and farmer participation factors (Atoma Habitamu, 2017). Moreover, land use and availability of construction materials are important. Based on the land use system and agro-ecology in the existing year in which they were installed, PSWC techniques introduced to the area can be categorized into two: PSWCP on farmlands (mainly on soil bund) and PSWCP on degraded grazing lands (mainly on trench and checkdam). A similar result was reported by Bewket Woldeamlak (2007), and both of them indicated soil erosion as an important agricultural problem, and yet the majority of the farmers were not willingly participating in the construction of different bunds.

Table 4.1 The main PSWCP in the study area

Major PSWC practice	Frequency	Percent
Stone & stone faced soil bund	3	2.7
Soil bund	58	51.8
Trench	28	25
Waterway	9	8
Cutoff drain	8	7.1
Check dam	6	5.4
Total	112	100

4.1.1 Evaluation of soil bund components against design specification

Soil bund depth

The standard of 0.5 m (50) cm was compared to the measured mean value of soil bund depth, wh ich was 0.48752 ±0.059499 m below the table (Table 4.2). The analysis result showed that t calc ulated was less than t-tabulated and the null hypothesis was accepted. This implied that in the existing soil bund, the mean depth of the bund ditch was a little bit lower (filled with soil) than the recommended standard. Implemented bund channel depth in the study area was not statistically significantly different but a little bit less than the calculated depth to hold the peak discharge generated and to remove the excess runoff at a non-erosive velocity (Gojjam Amare, 2023). This can also be a cause for overtopping, and it is hard to reverse the problem. This finding was similar to that of Fikirie Kalkidan et al., (2020) Central Rift Valley of Ethiopia; the main reasons for soil bunds implemented below the standards are knowledge and skill gaps in soil and water conservation structures. This was not only farmers but also development agents who had knowledge and skill gaps in designing the structures.

Soil bund width

The soil bund ditch width was compared to the recommended width according to MoARD (2005), which was 0.6 m (60 cm). The measured mean soil bund ditch width was 0.53911 ± 0.026562 m where T test was conducted to confirm this. However, from the T table at the 0.05 level of significance, the T value is 1.740. Therefore, a T calculated was greater than T t abulated, and thus, the null hypothesis was rejected (table 4.2).

The result showed that the mean ditch width of the soil bund was less than the recommended standard, whereas the measured mean values of width were statistically different, so less than the recommended dimensions set in the guideline. So bunds were not been in use for long time because of less width; bunds were simply full for a short period of time. The result was similar with Masresha Bailes (2014) Choke Mountain, but contradicted by Tesfay Gizaw, et al., (2019) Jimma Agricultural Research Center in southwestern Ethiopia.

Soil bund embankment height

Soil bund embankment and related specifications are indicated in different sources after repeated field observations and experiences. As the Table 4.2 below indicates, the standard height recomm ended by MoARD (2005) 0.6 m (60 cm). In the watershed, the average mean embankment height of the structure varied between 0.37456 ± 0.094458 m. The suitability of the existing average soil bund height against the standard was checked using a statistical table's t-test, as the number of samples was less than 30 and the population was not known. From the t-table, the p-value at the 0.05 level of significance was 1.740. Therefore, t- calculated was greater than t- value, and the null hypothesis was rejected. This showed that the average height of the soil bund in the catchment was significantly lower than the standard (MoARD, 2005).

As compared to the recommended ones,there were statistically significant difference in the measured watershed; the height of the embankment was maintained smaller than the recommended values. This result was similar to (Fikirie Kalkidan et al, 2020) in Central Rift Valley of Ethiopia and (Tsegaye Bekele and Awudengist Moges, 2018) in the Donbi Watershed, Wolaita Zone, Southern Ethiopia. Implemented structures lack the ability to hold the peak discha rge that can be generated in between two consecutive bunds when the implemented structure em bankment dimensions are less than the standard. This may cause serious damage to the field via initiating rill and gully erosion. Therefore, there might be an overtopping problem in the farm plots constructed with the soil bund terrace due to the short embankment height. So, lack of compaction is creating quality problems on SWCP (Daniel Danano, 2001).

Berm

In the table below (Table 4.2), the measured mean values of berm width (the free space between the ditch and embankment) of the soil bund were slightly less than the recommended dimension in all slope classes of both watersheds; the comparison did not show significant differences with the recommended dimensions. In Hurni (1985), it was recommended that the space between the ditch and the berm is at least 25 cm. Regarding the space between the ditch and the berm (berm size),in all the three parts of the watershed, the berm size was maintained at the recommended range. However, in most of the farm plots, its size was around the lower limit that might result in returning of the excavated soil into the ditch, which in the return shortens the life of the bund, because the soil embankment is nearest to the excavated bund soil, which is simply back in the ditch due to different factors and results in frequent maintenance. The result of the berm was high; the embankment of soil was enormous, so it lost more space of land, which the community has not accepted (Tsegaye Bekele and Awudengist Moges, 2018) Wolaita Zone, Southern Ethiop ia.

Embankment top width

The measured mean value the Embankment top width of this study was 33.0 cm (0.33 m). This result was higher than the standard value (0.3). This might be due to the slope factor; increased slope soil has shrunk down. This result was in agreed with the research finding of Gojjam Amare (2023), who showed that embankment top width was (0.34 m) in Sekela, Layguder Watershed, Source of Blue Nile, Northwest Ethiopia. However, the current study disagreed with Tesfaye Gizaw et al, (2019), who indicated that the embankment top was (25 cm) in Jima Zone, in Jimma Zone, southwestern Ethiopia. Also showed greater values in Debir Wonz watershed which a statistically significant difference from the standard. In the study area, the slope between the lower and middle parts was matched with the standards. In the upper slope embankment height was higher than the standard because of the slope factor; increasing the slope caused, soil to shrink down. The field measurement was taken immediately after the construction work (February and March 2022) and as observed in the field, the embankment was poorly compacted; its height would be shrinking gradually, which could create more quality problems on the structures (Table 4.2). This greater mean value of the measured embankment top width could be related to the lesser measured mean value of the embankment front height.

Bund layout, gradient

The gradient of the practices was the other factor that was considered for the evaluation. In all three parts of the watershed, the practices were not constructed along the contour, and it was graded with an average slope gradient of 3-30%. The table 6 indicates the recommended gradient was 0.5-1%, but the mean gradient of the bunds in the study area was 1.0556. The comparison result of the implemented PSWCP layout with its test values shows that there were significant differences between the soil conservation dimensions (measured variables) and its design standards. The evaluation of the lateral bund gradient of graded soil bunds indicated that greater mean values were obtained in the field. These bunds considered for evaluation are claiming to be level, made on the contour. However, it is common that due to poor layout, bunds deviate from being level. The field measurement indicated that the same selected bunds constructed were not laid along the contour (Tsegaye Bekele and Awudengist Moges). Hence, there may be unexpecte d flow following the gradient during intense rainfall. This implies that the farmlands are susceptible to being damaged by soil erosion caused by runoff channeled through the ditch. Because of this study, an excess amount of runoff accumulated through the ditch below.

Table 4.2 Comparison of an average value of existing soil bund components

Variable	Standard(m)	existing Mean(m)	SD	t-test	Tabulated t-value	DF	Decision
Depth(m)	0.5	0.48752	.059499	-0.890ns	1.740	17	Ho accepted
Width(m)	0.6	0.53911	**.026562**	9.72684*	1.740	17	Ho rejected
Berm(m)	0.25	0.21457	.043173	3.481*	1.740	17	Ho rejected
Embankment height(m)	0.6	0.37456	.094458	10.1257*	1.740	17	Ho rejected
Embankment top width(m)	0.3	0.33022	.030243	-4.2396ns	1.740	17	Ho accepted
Bund gradient(m)	0.5-1	1.0556	.250482	17.686*	1.740	17	Ho rejected

Bottom embankment width and bunds length

Though that percentage of measured soil bund embankment bottom width was found within the standards in the watershed and did not show a clear trend in the three slope classes, the majority of the mean was within the recommended bottom embankment width (1 m to1.2 m). There was some deviation;, the embankment bottom width in the lower and middle streams of the watershed was maintained around the recommended values. In the upper stream, measured value was 83% and 17% bunds were out of the standard and within the standard respectively. It means increase the recommended value because of slope increase and soil-strap down. As shown in the table, out of 18 soil bunds, about 50.2% of the total three slope classes in the watershed were fit with the Standard recommendation, and 49.8% of the three slope classes were out of the standard. The finding was disagreed with graded soil bunds in Lemo district and (Tesfaye Gizaw, et al., 2019) in Jimma Agricultural Research Center southwestern Ethiopia. Which embankment bottom width was within the standards set by the Ministry of Agriculture 2005 guideline (Mafkereseb Kasahun et al, 2018).

Length of soil bund

The average length of the bund was 62.0028 m with a maximum of 90 m and a minimum of 33 m. Out of 18 farm soil bunds, 64% have a length above 80 m and below 60 m, which is outside the technical recommendation (max 60–80 m) ,and 36% have a length between 60 and 80 m which in is with the standard. The major basis factor to determine the length of the bund was the availability of natural waterways or suitable boundaries between farms to construct artificial waterways. This was because farmers did not want to construct waterways on their plots since it takes a large area of land. As a result of such long bunds, were creating a distraction of the structure and the formation of new rills and gullies, which in turn aggravate soil erosion (land degradation). The guideline recommends increase channel cross-section towards the end because of water concentration (from 25 cm depth and 50 cm width to 50 cm depth and 100 cm width), but fixed channel dimension throughout the length was observed. The result presented in Table 7 shows that the length of soil bund was significantly out of the standards.

The results agree with Masresha Baile (2014) and Engdayehu Getachew et al., (2016) in the Dejil and Debremawi watersheds respectively. Their findings showed that ditch width, embankm ent height, and also depth were slightly lower than the standard. But top width and bund gradient were below the recommended standards. This reduced the effectiveness of the measures in reducing soil erosion. On the other hand, the higher values of the measured values of stone-faced soil bund than the recommended ones are found in Koga watershed (Jemberu wale, 2018).The gu ideline recommends to increasing channel cross-section towards the end because of water concentration (from 25 cm depth and 50 cm width to 50 cm depth and 100 cm width), but fixed channel dimension throughout the length was observed in all parts of watersheds, which leads the actual design dimensions far from the recommended ones, which creates ineffectiveness.

Table 4. 3 Percentage of measured soil bund embankment bottom width and length of bund

Variables	Slope %	Standard	No of bund	Bund with standard	Bunds out of standard
Embankment bottom width(m)	Lower 3-8%	1-1.2	6	67%	33%
	Medium8-15%	1-1.2	6	66.7%	33.3%
	Upper 15-30%	1-1.2	6	17%	83%
Total	3-30%	1-1.2	18	50.2%	49.8%
Length of bund(m)	Lower 3-8%	60-80	6	50%	50%
	Medium 8-15%	60	6	17%	83%
	Upper 15-30%	60	6	40%	60%
Total	3-30%	60-80	18	36%	64%

Evaluation of Vertical Interval (VI) and bund Spacing

The recommended standard spacing between consecutive bunds depends on slope and soil depth (MoARD, 2005). The spacing between existing soil bunds ranged from 10.7 m to 32.0 m in the study watershed in all slope classes, with an average of 10.33 m on 3-30 % slope lands. A greater number of soil bunds that are below the recommended VI and wider spacing were found in the 3-15% slope ranges where the soil depth was greater than (>50 cm) in the watershed. As shown in the table below, from field measurements, 77.7% of soil bund spacing constructed in the study area meaningfully wider than the recommended standards and unfit to the standard. The result of the study agrees with (Gebremariam Yabiyo, 2018) in Maego watershed North Ethiopia.

Especially, the widest spacing between hillside terraces on the 20 to 30% slope of the cultivated land was above the standards. But, technically, the spacing between bunds should decrease when the slope gradient increases (Tesfaye Gizaw et al, 2019).

The majority, 88.9% of the vertical intervals between soil bunds in Debirwonz watershed was greater than the minimum technical standards; this could facilitate surface runoff and destruction

(Tsegaye Bekele, and Awudengist Moges, 2018) Wolaita Zone, Southern Ethiopia.As rainwater accumulated inside the structures, soil erosion and runoff damaged the constructed structures. When the vertical interval between graded soil bunds was higher than the required standard, a huge amount of runoff could be generated and cause damage to bund embankments and croplands (Bekele Amanual et al, 2018). In focused group discussions in the watershed, the farmers stated that the main reasons for the presence of wider space between bunds were lack of sufficient technical support during bund design and layout, misunderstanding on the importance of space between bunds, and focus on quantity (i.e. area coverage with bunds) rather than quality of the work. In addition, wider spaces between bunds were preferred by farmers to minimize cultivable areas occupied with physical practices. Different studies revealed that when the space between bund structures was wider than the required spacing, the risk of soil erosion on cropland increased (Molla Tegegne and Sisheber Biniam, 2017).

The guideline recommends graded soil bunds were applied generally on cultivated lands with slopes above 3% and below 15% gradient with deep soil depth (MoARD, 2005). However, in-field measurements graded soil bunds were constructed on a steep slope (15-19%) and shallow soil depth on the watershed. As a result, it creates destruction of bunds to enhance soil erosion in the farmland. SWCP was implemented with less spacing large area of land can be lost, and farmers are not interested in implementing the structure, and when it was implemented with large spacing, more runoff can be generated, causing overtopping. Wider space between bunds may cause the formation of rills and gullies in cropland and needs more labour for maintenance of bunds (Meshesha Yericho and Birhanu Belay, 2015). Due to this over toping serious problems like rill or gully erosion could be initiated, which requires more labor and budget to overcome the problem (Tesfaye Gizaw etal, 2019).

Table 4. 4 Comparison of recommended and measured values of soil bund VI and HD

Slope (%)	Recommended for soil depth >50(cm)		No of bund	Existing average		No of bunds unfit to the standards	
	VI	HD		VI	HD	VI	HD
3	-	33	1	0.75	22	1	1
4	-	25	2	1.45	25	2	-
6	0.7	12	1	2.31	30	1	1
7	0.8	12	1	1.76	32	1	1
8	0.8	10	2	1.19	24.3	2	2
9	0.9	10	1	1.15	27	1	1
10	0.9	9	1	1.75	21	1	1
11	1	9	1	2.02	9	-	-
12	1	8	2	1.74	17.05	2	2
15	1.1	7	2	2.32	15	2	2
	Soil depth <50(cm)						
16	1	7	2	2.03	12	2	2
18	1.1	7	1	1	7	-	-
19	1.1	6	1	3.30	15.8	1	1
Total			18			16	14
%						88.9%	77.7%

4.1.2. Technical Evaluation of Trench Component against Design Specification

Trench depth

Trench depth was the other parameter measured with respect to this PSWCP. According to the Table 4.5 the mean trenches depth were 0.3678 m ± .03193 m. The standard trench depth recommended by MoARD (2005) was 0.3-0.5 m (30-50 cm). The value of t- tabulated at 95% confidence limits and n-1 degrees of freedom is 1.860 (one-tailed test), and the analysis result showed that t- calculated was greater than t- tabulated. These, the null hypothesis, were rejected. This means that the existing depth of the trenches was significantly different from the recommended standard (Table 4.5). The result was agreed with (Masresha Baile, 2014) in Dejiel watershed Choke Mountains, East Gojjam, who reported when the implemented trench depth was less than the standard value.

Trench's Width (Collection Ditch)

In another measurement, Table 4.5 shows the mean width of trenches was 0.45022 m ± 0.043002 m. The minimum standard trench width recommended by MoARD (2005) was 0.5 m. According to the analysis, t-calculated was greater than t-tabulated, and thus, the null hypothesis was rejected. This result depicted that the mean trench width (collection ditch) was narrower than the recommended standard. The suitability of the existing average trench against the recommender was undergone using the student t-test. Trench width was an important criterion for drainage capacity to hold the runoff and enhance water percolation that in turn improves soil moisture for planted seedlings during the dry season. The findings of the study were agreed with (Masresha, 2014) Dejiel watershed choke mountains, East Gojjam. Trench length

Trenches were constructed at an interval of 2-3 meters, depending upon the suitability of the land. The value of the existing average trench length was determined by comparing it with the recommended standard using the student t-test. According to (Table 4.5) the value of the constructed trenches was weighed up in terms of minimum standards already recommended by MoARD (2005). A mean value of 2.5811±0.35456 m trench length was recorded in this PSWCP. The student t-test was chosen because sample trenches were less than 30 and the population was not known. The t-value at 95% confidence limit and n-1 degrees of freedom is 1.860 (one-tailed test). Therefore, since t-calculated was less than t-tabulated, the null hypothesis was retained.

The result presented in (Table 8) shows that the lengths of trenches were not significantly less than the standards. Similarly, the majority of layouts have a negative mean difference, and the variation was statistically not significant or it is in the range of recommended values. These findings were agreed with (Masresha, 2014) in Dejiel Watersheds, Choke Mountains, East Gojja m Zone of Amhara Region, Ethiopia (Yericho Berhanu, 2019) in Lake Hawassa Watershed, sout hern Ethiopia.

Trench Spacing

In principle, the spacing between trenches should decrease as the slope gradient gets steeper. The recommended standard vertical interval between consecutive trenches ranges from 3 to 5 m. In areas where a high amount of rainfall is available, a 3 meters vertical interval was appropriate, and 5 meters was the recommended in dry areas. In Debirwonz study area, the recommended ver tical interval between consecutive trenches was 3 meters. This breaks and holds the runoff veloci ty of rainwater for percolation. However, trenches installed in the study area on an average slope of 11.6% grazing land had a spacing of 9 m at maximum and 2 m at minimum with an average of 4.4 m between consecutive trenches. According to MoARD, (2005) the distance between bunds depends upon the slope and agroecology and may range from 3 to 5m.

The vertical interval between successive trenches was wider than the recommended value. As a result of such wide spacing, huge amount of runoff with high velocity was accumulated on the bund, leading to the destruction of the embankment and the formation of new rills and gullies, which imprison and aggravate soil erosion (land degradation).Even though that problem was the real fact about field conditions, farmers did not accept narrow spacing, as they believed it reduced considerable agricultural production. Nonetheless, additional field-based assessments and long discussions with farmers were necessary to determine the critical spacing for different sets of conditions (MoARD, 2005).

Table 4.5 Comparison of average values of the existing trench component

Variable	Recommended standard	Existing mean	SD	Calculated t-value	Tabulated t-value	DF	Decision
Depth (m)	0.5	0.3678	.03193	12.4	1.860*	8	Ho rejected
Width(m)	0.5	0.45022	.04300	3.47	1.860*	8	Ho rejected
Length(m)	2-3	2.5811	.35456	0.000354	1.860ns	8	Ho accepted
Spacing(m)	3-5	4.4444	0.9597	0.850	1.860ns	8	Ho accepted

Note: SD-standard deviation, DF-degree of freedom=n-1, *- are significant at 95%. ^{ns}- Not significant

4.1.3. Technical Evaluation of waterway Component against Design Specification

Top width and bottom width of waterway

The measured mean value of waterway width with the mean value of 1.2467 ± 0.25007 m below the table (Table 4.6) was compared against the standard was 3m (300cm). The analysis result showed that t- calculated was greater than t-tabulated and the null hypothesis was rejected (as shown table 10). This implied that in the existing top width, the mean top width of waterway was significantly different from the recommended, and standard or a little bit lower (filled with soil) than the recommended standard and the measured mean value of the bottom width with the mean value of 0.65±0.0500 below the table was compared against the standard of 1-1.2 at a level of significance of 0.05 (one tailed test) n-1 degree of freedom showed that t-calculated was greater than t-tabulated so the null hypothesis was rejected. This implies that there was significant difference. In field observation, waterways had been constructed at the end of other PSWC practices (soil bund and cutoff drain) along farm boundaries, and these waterways were not lined by grasses or paved with stones. Thus, they may create gullies on farmlands. The guideline recommends increasing channel cross-section due to the amount of runoff increasing (Gojjam Amare, 2023).

Table 4.6 Technical Evaluation of waterway Component against Design Specification

Variables	Recommended standard	Implemented mean	SD	DF	Calculated t- value	Tabulated t-value	Decision
Top width	3m	1.2467	0.25007	2	9.92	2.920	Ho rejected
Bottom width	1-1.2m	0.65	0.0500	2	9.8870	2.920	Ho rejected
Depth	0.3-0.5m	0.4667	0.12583	2	0.03743	2.920	Ho accepted

Figure 4.1 Measured waterway from study area (field survey, 2022)

4.1.4. Technical Evaluation of Cutofdrain Component against Design Specification

Top width, bottom width, and depth of cutofdrain

According to MoARD (2005) the top width was compared to the recommended width, according which was 1.2-2.8 m. The measured mean top width was 1.0176 ± 0.07638 m where T-test was conducted to confirm this. However, from a T-table at the 0.05 level of significance, the T-value is 2.920 at degree of freedom 2. Therefore, t-calculated was greater than T-tabulated and thus, the null hypothesis was rejected (table 4.7). The result shows that there was a significant differen ce among the top width of cutofdrain against the recommended standered. So, the implemented cutoff drains could not accommodate the discharge from the respective upstream areas (MoA, 2005).

Table 4.7 Technical Evaluation of cutofdrain Component against Design Specification

Variable	Recommended standard	Existed mean	SD	DF	Calculated t- value	Tabulated t-value	Decision
Top width(m)	1.2-2.8	1.0176	0.07638	2	3.3772	2.920	Ho rejected
Bottom width(m)	0.6-1.4	0.6333	0.07638	2	-0.616563	2.920	Ho accepted
Depth(m)	0.3-0.7	0.400	0.18028	2	0.78444	2.920	Ho accepted

4.1.5. Technical Evaluation of check dam Component against Design Specification

Proper land management and slope treatment measures such as retention and infiltration ditches above the gully area are required to reduce the rate and amount of surface runoff (MOA, 2014 and Engdayehu Getachew, 2016). Such measures can be constructed before starting gully treatm ent check dam construction. In the study area, to retain runoff from rangelands and forest lands on the upper part of the gully, different physical soil and water conservation (PSWC) measures were put in place. But all of these structures were done after the construction of different wooden, gabion, and loose stone check dams, which did not follow the guideline. The measured mean value of the side key and base width of the check dam lies within the standard, and others were below the recommended standard.

Table 4.8 Technical Evaluation of checkdam Component against Design Specification

Variable	Recommended standard	Existed mean	SD	DF	Calculated t-value	Tabulated t-value	Decision
Spillway(m)	0.25-0.3M	0.1767	0.02517	2	5.047	2.920	Ho rejected
Side key(m)	0.7-1m	0.6567	0.12897	2	0.47478	2.920	Ho accepted
Bottom key(m)	0.5m	0.4167	0.07638	2	0.4517	2.920	Ho rejected
Height(m)	1-1.5m	0.9833	0.25166	2	9.3846	2.920	Ho rejected
Base width(m)	1.5-3.5m	1.667	0.29297	2	-0.8061	2.920	Ho accepted
Apron length(m)	1.5-3m w*1m length	1.2833	0.28431	2	1.07810	2.920	Ho rejected

Figure 4. 2 checkdam structure from study area (field survey.2022)

4.2. Farmers Participation in Physical Soil and Water Conservation Practices

4.2.1. Farmer's Contribution to Soil Erosion

Farmers had a different interest in PSWCP. The majority of farmers showed high interest in conserving their soil, while a limited number of farmers were reluctant. Most of the time, farmers whose lands were gravely degraded by erosion were highly interested in conserving the soil. These farmers were those residing in the upper part of the watershed. According to Table 4.9, the majority of the respondents (80%) of the total generally believed that erosion can be controlled by different PSWCPs, and the introduced PSWC technologies were effective in arresting soil erosion. Similarly, 89% of the respondents in the study watershed supposed that the introduced PSWC technologies had the potential to improve land productivity. Most of the respondents identify the indicators for the erosion, such as yield decline (52.9%), soil structure and color change (33.9%), and increased input demand (13.4%) in the study area. FGD also responded that the main causes of soil erosion in the study area were slope, the easily erodible nature of soils (high rainfall), unrestrained grazing (overgrazing), inappropriate farming systems (improper tillage), deforestation, and the absence of protective measures (deprived watershed management). This result was in line with the result of Kibemo (2011).

Table 4.9 Farmer’s contribution on Physical soil and water conservation practices

Farmers response		Percent (%)	Frequency
Does pswc have long term benefit?	Yes	89	79.5
	No	29	20.5
	Total	112	100
Does soil erosion can be controlled?	Yes	80	71.4
	No	32	28.6
	Total	112	100
Is there soil erosion problem in your farm land?	Yes	79	70.5

	No	33	29.5
	Total	112	100
If yes to the question 1, what indicators did you observe?	yield decline	59	52.7
	Soil structure & Soil color change	38	33.9
	Increased input demand	15	13.4
	Total	112	100

Table 4.10 Farmer's response the main causes of erosion in farm land

Farmers response	Causes of soil erosion	Frequency	Percent
What are the main causes of erosion in farm land?	improper tillage	27	24.1
	Slope	14	12.5
	Deforestation	23	20.5
	high rainfall	9	8.0
	Absence of protective measure	25	22.3
	over gazing	14	12.5
	Total	112	100

4.3.2. Design Aspect of Physical Soil and Water Conservation Technologies

In the study watershed, the PSWC technologies under implementation were physical soil and water conservation practices such as soil bunds, trenches, waterways, cutoff drains, and check dams. Among these, farmers were more willing to participate in soil bunds and trenches. As indicated in the focus group discussion, stone & stone-faced soil bund, check dam, and gully rehabilitation technologies were less preferred by respondents 'since these conservation practices need skilled manpower and intensive labor. The majority of respondents perceived soil bunds and trenches as effective to control soil erosion, while some proportions of apparent check dams make them more effective to control erosion. It was identified that conservation practices are not well designed and farmers' knowledge and experiences are not well recognized in the designing and implementation of the practices.

Farmers' awareness about the design of PSWCP was a very important aspect of sustainable PSWC uses. Since the structure was constructed on farmers' plots, it is necessary to accept the dimensions of those structures in their farmland. In the study area, usually, communities perceived that implementing soil bunds in narrow spacing may create difficulty in plowing activities and reduce farm size at the same time; it needs large labor force to implement. Traditionally, farmers were using traditional drainage ditches on their farmlands to dispose of excess runoff during high rainfall. Nonetheless, this type of conservation practice was out of the standard, which incapacitated soil erosion control since the drainage ditches have on average a high slope gradient, which leads to erosion along traditional drainage ditches and creates excess siltation on the lower part. Similar findings by (Gizaw Desta, 2010) reported that farmers construct drainage ditches every year, and sediments eroded from the ditches and accumulated down the slope were common indicators of erosion on farmer's farmlands.

Table 4.11 Farmer's participation in PSWC technologies layout

Farmers response		Frequency	Percent
Which components of the bund are not accepted?	Spacing of bunds	37	33
	Length of bund	58	51.8
	Height of embankment	17	15.2
	total	112	100

4.3.3. Major Constraints Farmers Faced during Soil and Water Conservation Practices Implementation

As the result showed, that major challenges such as 37.5% lack of labor (high labor demand), 22.3% technically difficult to implement, 18.8% physical factors, 19.6% lack of awareness, and 1.8% institutional factors were the major challenges in the study area that farmers came into view to face such problems as (table 4.12).

4.3.3.1. Lack of labor

The technological options are less available in the study area to ease humans. Thus, farm implementation of most farms-related works requires human labor, among others. PSWCP implementation and maintenance require concentrated labor. The toughness of PSWCP was mainly based on the slope of the area, rainfall intensity, soil constancy, and land use type and management, but it needs frequent maintenance such as desilting and repairing out-of order parts (Lakew Desta et al., 2005 and Fikirie Kalkidan, 2020).In the study area, usually, PSWCPs are approved out in the dry season when no or little labor is needed for agricultural activities. Because labor for the organization constitutes the largest part of the investments in PSWC Labour shortage, especially the number of family size in the households, largely influences the adoption of SWC measures. In this case, labor may stay a challenge for undertaking human labor based PSWCP in the area. That was also what was explained by (Kebede Wolka, 2014) which indicated that labor demand appears much more than the requirement for the most common place farming business. A guideline by the Ethiopian Ministry of Agriculture estimates 150-250 PD for the construction of a kilometer of commonly practiced soil and water conservation structures, such as soil bunds, fanyajuu, and stone-face soil bunds.

4.3.3.2. Lack of awareness

Less awareness of the technical requirements of SWC practices as well as a lack of awareness of agricultural knowledge and SWC measures were the major challenges that are limiting households from implementing SWC practices at their farmlands. Higher education levels are hypothesized to be associated with improved awareness and knowledge regarding conservation measures and productivity, and the effects of erosion may persuade them to choose particular SWC practices (Atinafe Addisu, etal, 2015).

4.3.3.3. Physical factor

Physical factors like the distance of farmland from residential areas of farm land negatively affect continued use of soil and water conservation work. Landowners who have land far from their homestead have a lower probability of sustainably implementing conservation work, due to the increased time effort and cost associated with managing them. This will lead the conclusion that farmers give higher conservation attention to nearby farmland than distant plots. Therefore, the greater the distance between farm land and farmer the lower the attention that would be given to sustainable soil conservation work (Birhanu Adegnaw and Meseret Desalew, 2013). Farmland size was one of the constraints to implement pswc, as farmers with greater farm sizes and farm lands are not interested in the continual use of SWC structures because of the expensiveness and labor-demanding nature of soil and water conservation works. Slope of land was one of the constraints to implement PSWCP.

4.3.3.4. Institutional factor

Farmers who obtained SWC knowledge from development agents were more likely to implement successful SWC techniques compared to those without this option. The absence and scarce extension services and training by the developmental agent are a very important constraint for the success of any SWC intervention. This is because Landholders with frequent visits to farmer training centers and demonstration sites are more voluntary to maintain soil conservation works because it gives them chance to learn technical skills and principles of natural resource management (Antonio, 2016). As focus group discussion indicated, less training on natural resource management and poor SWC design were another barrier. The top down approach in SWC intervention is the main constraint for the sustainability of implemented technologies. This indicated that planning and implementing SWC measures through a top-down approach without the agreement and willingness of landowners and farmers ideas and experience affects the continuous use of SWC measures.

4.3.3.5. Technically difficult to implement

Improper implementation SWC was the main constraint to bringing about expected change in erosion control and livelihood improvement via land management practices. The implementation of appropriate and recommended SWC in standard layout and design is important to the sustainability of SWC intervention for soil erosion control. As a result, proper quality and compatible SWC to the biophysical characteristics of the watershed are necessary to bring the expected result in the implementation of SWC.

As focus group discussion, there were also other constraints to the implementation of PSWC. Lack of maintenance and renewal of SWC practices, which Physical constructions designed to conserve water and soil require regular upkeep and follow-up after construction, and animal grazing on cultivated and grazing lands means animal trumping poses a serious risk of damaging the SWC structures physically. Damaged structures are more susceptible to unexpected erosion hazards. One of the primary causes of the lower performance of SWC activities in the watershed has been determined to be free and open animal grazing, especially on cultivated and grasslands (Mekuriaw et al., 2018).

Table 4.12 Major constraints farmers faced during PSWC implementation

Major constraints	Frequency	Percent
technically difficult to implement	25	22.3
physical factor	21	18.8
limited awareness	22	19.6
high labor demanding	42	37.5
institutional factor	2	1.8
Total	112	100.0

4.4. RUSLE Factors Generation

4.4.1. Rainfall Erosivity Factor (R) the years 2013-2022

Based on the result (Table 4.13), indicated that the R_factor ranged from 622.11 to 1190.57.1 MJmm t/ha/yr (Figure 4.3). The highest R-factor value was observed in the southeast part of the watershed, whereas the lowest R-factor value was observed in the northwest part of the watershed.

Table 4.13 Mean annual rainfall depth (mm), elevation (m a.s.l.) and calculated values of rainfall erosivity factor (R)

Stations	Locations			Mean annual Rainfall(mm) (2013-2022)	R_factor (MJmm t/ha/yr)
	Latitude	Longitude	Elevation (m)		
Adet	37.493	11.275	2179	1121.4	622.11
Bahir Dar	37.36	11.6	1800	1609.6	896.48
Motta	37.89	11.074	2417	1366.7	759.97
Merawi	37.164	11.411	2000	2005.8	1119.14
Feres Bet	37.608	10.85	3000	2132.9	1190.57

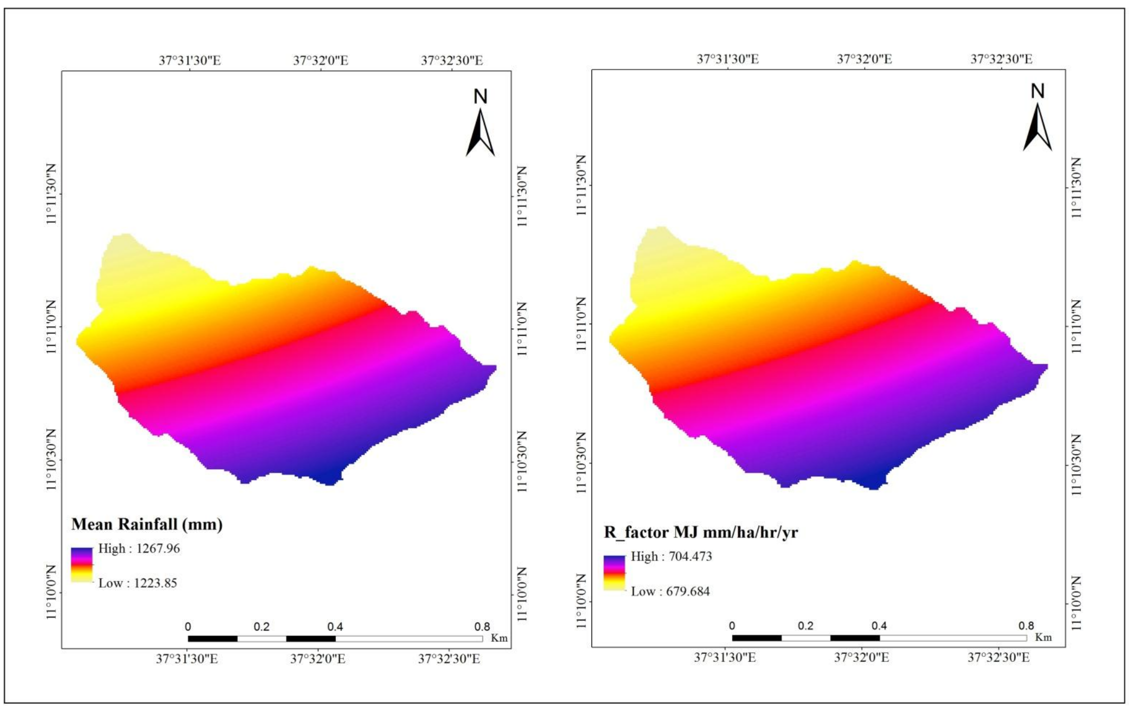

Figure 4.3 DebirWonz watershed average rainfall depth (mm) map and rainfall erosivity factor (R) map based on interpolated

4.4.2. Slope Length and Slope Steepness Factor (LS)

The result shows that the slope length factor values of the study area ranged from 0.03 to 14.1746 (Figure 4.4). The slope length factor values were found to be high in the drainage of the catchment. The steepness values were found to be high in the upper catchment of the study watershed. Soil loss is likely to be high in the steeper areas; on the other hand, the steeper the slope, the higher the soil loss rate. The LS-factor map was generated from a digital elevation model with 12.5 m resolution.

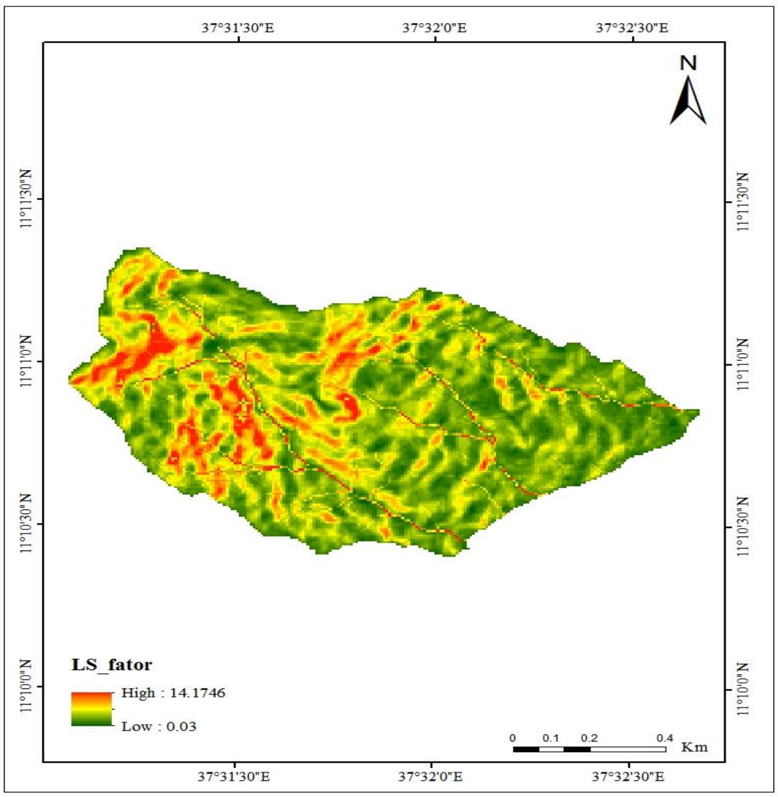

Figure 4.3 Slope Length and Slope Steepness factor map of Debirwonz watershed

4.4.3. Soil Erodobility Factor (K)

Figure 4.9 shows that the K-factor ranges from 0.15076 to 0.249974 t /ha/MJ/mm. The higher the K-factor values, the higher the soil erodibility. As well as the lowest the K-factor value, the lowest soil erodibility (Figure 4.5).

For this study, due to the difficulty of finding parameters at the local level and such cost constraints of experimenting with soil samples, the erodobility factor (K) estimation based on soil color proposed by Hurni (1985) for Ethiopian conditions is adopted. Based on the collected ground control point data of each soil color, their corresponding soil erodibility factor (K) value was derived based on Hurni, (1985) and Hellden, 1987) (Table 19). After giving the K value of each soil color, interpolation for the whole catchment is made in ArcGIS 10.8 software using inverse distance weighted overlay (IDW) interpolation from the 3D analysis tool. The interpolated K value was converted into a raster format with 12.5 m resolution and extracted for the studied catchment area (Figure 4.5).

Table 4.14 soil erodobility (k) (MJ mm/ha/hr/yr)

Soil color	Black	Brown	Red	Gray
K_ value	0.15	0.2	0.25	0.35

Source**:** Adopted from Hurni (1985); Hellden (1987)

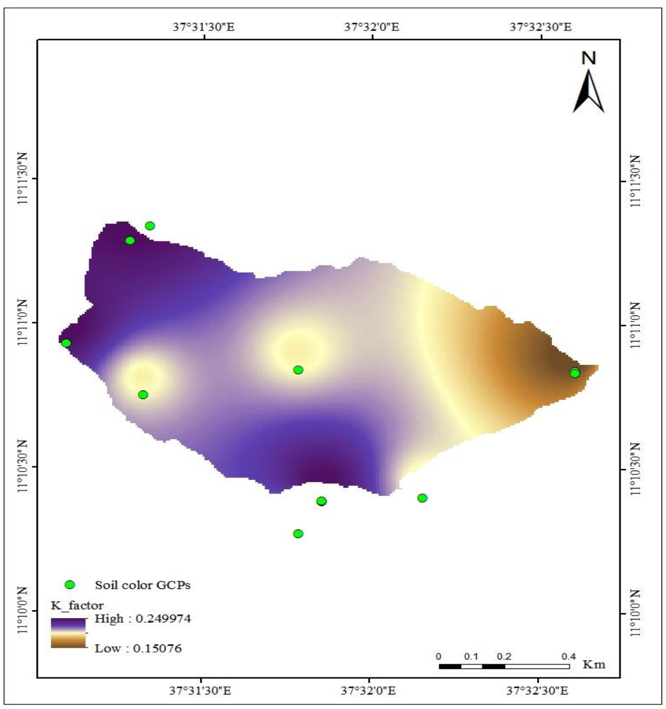

Figure 4.4 Soil erodobility factor (K) map in the study catchment

4.4.4. Conservation Support Practice Factor (P)

Support practice (P) factor refers to "the ratio of soil loss with a specific support practice to the corresponding loss with up- and- down slope tillage (Wischmeier and Smith 1978; Renard et al. 1997). Soil/level/ graded), stone-faced soil bunds, trenches, cut-off drains and waterways, and stone and check dams on gully areas have been implemented in the watershed ,but these were poorly maintained. The P-factor in the RUSLE model encompasses various agricultural management practices aimed at reducing water runoff and erosion. There are also contour farming and soil bund contouring as a method and as an important factor that can control the soil loss. The raster land use/land cover map was converted to a vector format, and a corresponding P-value was assigned to each land use class based on cover values proposed by Wischmeier and Smith (1978) and Shin (1999).Finally, using the conversion tool in ArcGIS software 10.8, the land use land cover type map was converted to a P factor map. P-factor value ranges from 0.55 to 1. (Figure 4.6 and Table 4.15).

Table 4.15 conservation support practice factor (p) value with each land use cover class

Land Use Type	Slope	Soil bund contouring	Contouring(P_factor)
Agricultural land	<5%	0.1	0.55
	5-11	0.12	0.6
	11-18	0.16	0.8
	18-27	0.18	0.9
Non- Agricultural land	all	0.2	1

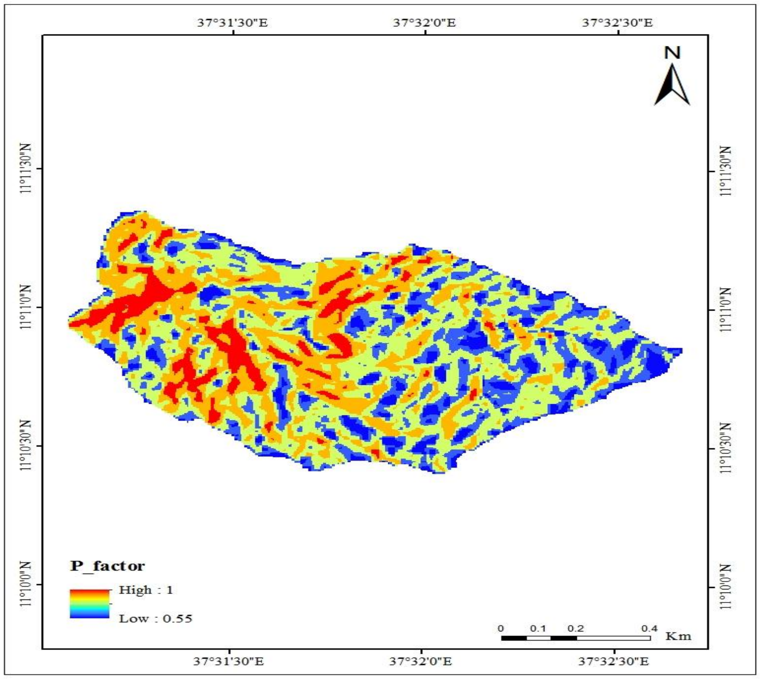

Figure 4.5 Conservation support practices factor map of Debirwonz watershed.

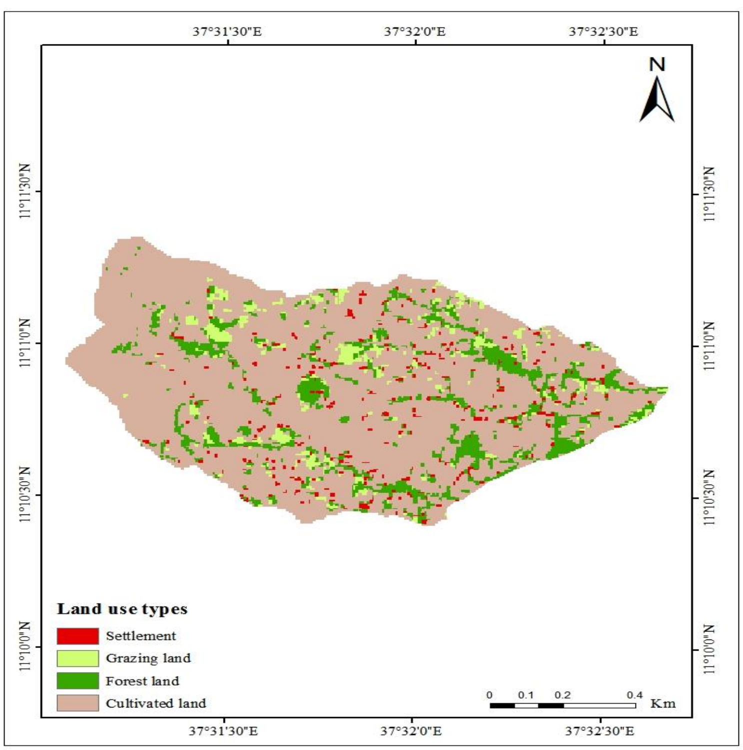

Figure 4.6 land use land cover map watershed

Table 4.16 Land use land cover types and area coverage of the Debir wonz watershed

S/N	Land use types	Area (Ha)	Coverage (%)
1	Settlement	7.97	2.65
2	Grazing land	14.06	4.66
3	Cultivated land	241.11	79.98
4	Forest land	38.30	12.71
		301.45	100.00

4.4.5. Cropping and Cover Management Factor (C)

The cover management factor (C) was obtained from the land use land cover classification of the study catchment derived from P-values, suggested by Hurni (1985) in the Upper Blue Nile River. The raster land use/land cover map was converted to a vector format, and a corresponding C-factor value was assigned to each land use/land cover class. Finally, using the conversion tool in ArcGIS software 10.8, the land use land cover type map was converted to a C factor map. The result shows that the C_factor value ranges from 0.01 to 0.63. (Figure 4.8 and Table 4.17).

Table 4.17 cover management factor (C) values with each land use cover class

S/N	Land use types	C-factor
1	Settlement	0.63
2	Grazing land	0.05
3	Cultivated land	0.15
4	Forest land	0.01

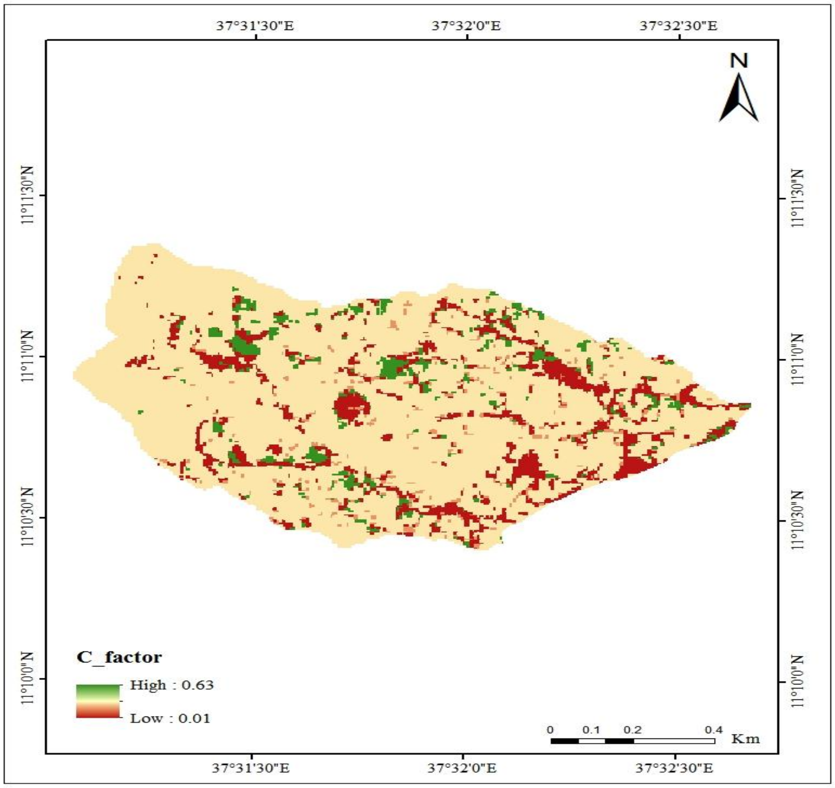

Figure 4.7 Cover management factor map of the Debirwonz watershed

4.5. Soil erosion estimation

Soil erosion estimates for the study watershed with RUSLE ranged from 0.00417741 to 815.99 tons, with a mean annual soil loss of 52.25 t ha^{-1} yr^{-1}. The entire catchment was divided into three sub-watersheds in order to identify the critical sources of soil erosion within the catchment. This result is similar to Tamene Lulseged & Le Quang. (2015), who found an estimated annual soil loss rate range between 0 to 650 t/ha/yr (the mean soil loss rate was 75 t/ha/yr) in the Nile basin in sub-Saharan Africa and Tesema Mekonen et al. (2024) reported that the average annual soil loss was 50.2 ton hactare per year, and the overall rate of soil erosion can reach 820.6 t ha 1 yr1. In contrast, Haregeweyn Nigussieet al. (2017) reported that the estimated annual soil loss rate ran ges from 0 to 200 t/ha/yr (mean soil loss rate 27.5 t/ha/yr) in the Upper Blue Nile, Ethiopia. The r esults of this study are somewhat lower than those of the Tashat Watershed, which had an estimate of 64.2 tons per hectare yearly (Mengie Mequanent et al. 2022), the Koga Watershed, which had an estimate of 47.0 tons per hectare yearly (Gelagay Habitamu & Minale Amare

2016), and the Gumara Watershed, which had an estimate of 42.7 tons per hectare yearly (Belayneh Mengie et al. 2019).

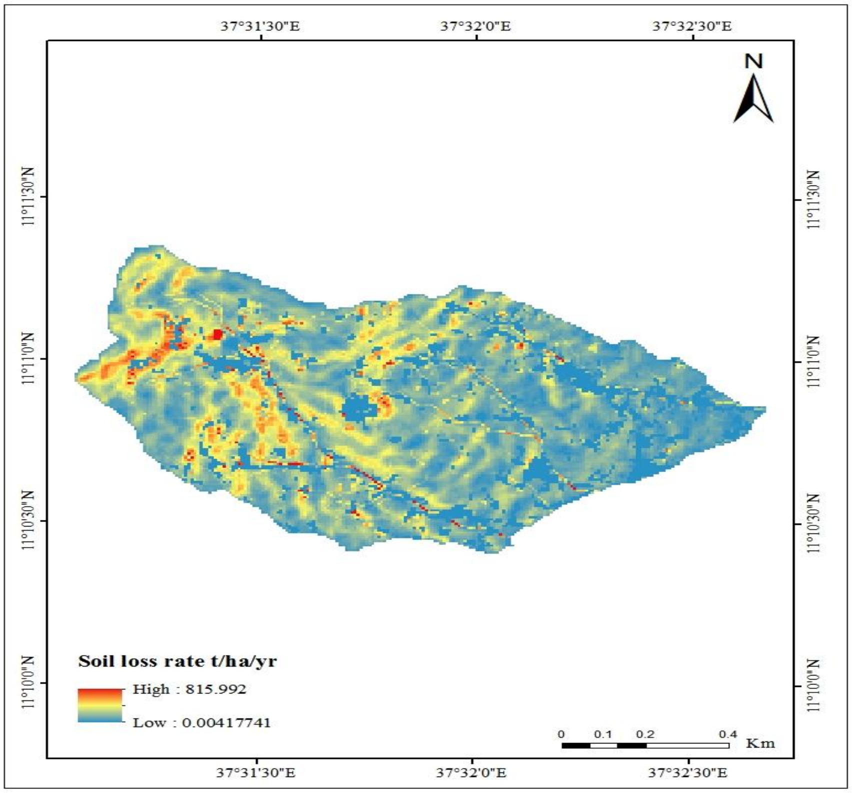

Figure 4.8 Annual soil loss map of the Debirwonz watershed

4.6. Soil erosion severity classes

Erosion severity maps were typically classified into categories based on the amount of soil loss or erosion depth. The average annual soil erosion rates were classified into the five priority classes, namely, very slight (0-5), slight (5-15), moderate (15-30), severe (30-50), and very severe (>50) t/ha per year to develop soil erosion severity maps, as shown (table 4.18 and figure 4.10). The map revealed 27.40%, 43.83%, and 28.77% of the watershed area experienced severe, severe, and very severe soil erosion rates, respectively (Table 4.18). Their respective average soil loss was 49.78, 38.55, and 69.4 t ha^{-1} $year^{-1}$, which is very high as compared to soil loss tolerance (2 to 18 t/ha/yr) proposed by Hurni (1985) for Ethiopia; therefore, it needs immediate action. This is also due to hilly topography, soil conditions (i.e., fine texture, low organic matter, poor plant coverage due to climate), absence of widespread and well designed PSWC measures, and inappropriate agricultural practices (excessive soil tillage and cultivation of steep lands).

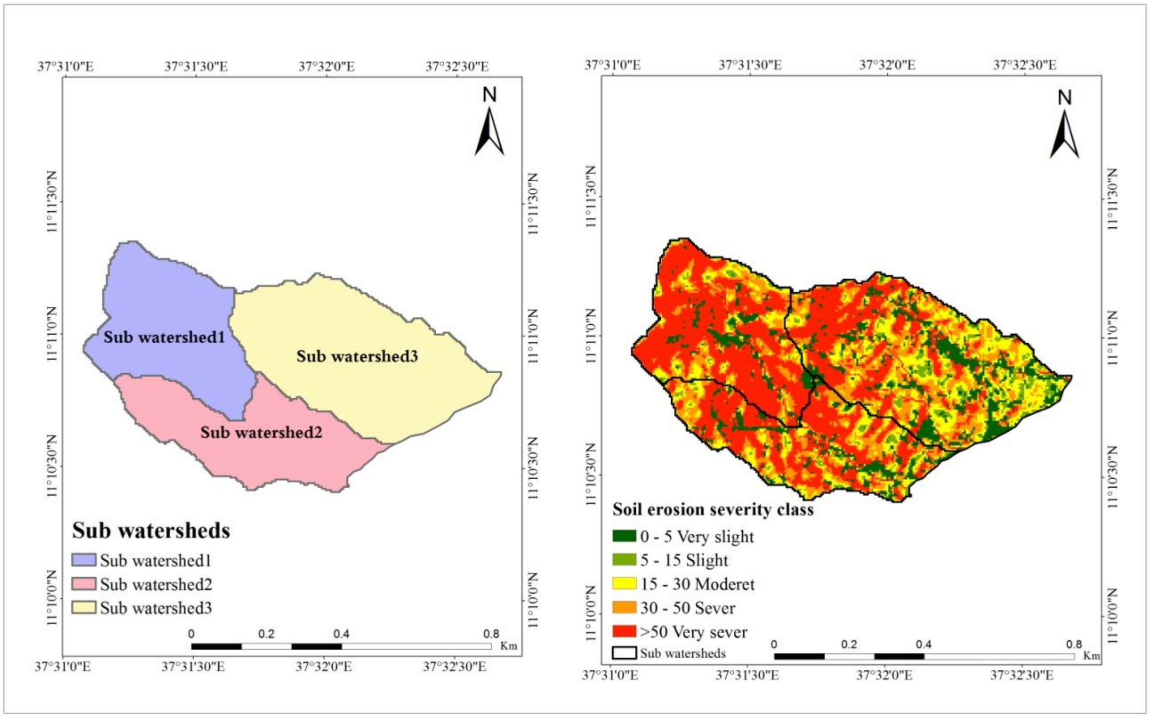

Figure 4.9 Mean annual soil loss rates (t/ha/yr) and severity class in the Debirwonz watershed

Table 4.18 Soil erosion severity classes and corresponding rates (t/ha/yr) in the study watershed

Sub watershed name	Area (ha)	Coverage (%)	Soil loss per sub watershed /ton/ha/yr	Mean soil loss t/ha/yr	Severity class	Priority Class
Sub watershed 1	86.72	28.77	709.71	68.4	Very sever	1
Sub watershed 2	82.59	27.40	815.97	49.78	Sever	2
Sub watershed 3	132.11	43.83	293.87	38.55	Sever	3
Average mean soil				**52.25**		

loss

Source: Derived from Haregeweyn Nigussie et al. (2017)

Where Very slight = 0 - 5, Slight = 5 – 15, Moderate = 15 –30, Sever = 30–50 and Very sever = >50 t ha^{-1} yr^{-1}.

Overall, from the soil loss rate results observed, the Debirwonz watershed had a high soil loss rate during the period of 2013 to 2022. Because in the past years all the PSWC activities were carried out using food aid or projects in the form of food for work, through which the farmers developed livelihood dependency. As the results of different types of PSWC conservation measures showed, the structures built existed in place for a short period of time. From the field observation, most of the implemented SWC structures were inappropriate, filled by siltation, and lost their structures in the study watershed as a result of the watershed not being strengthened with biological structures, continuous maintenance, free grazing, and expansion of cultivated lands on a steep slope due to the unimplemented land use planning proclamation. In this regard, there is no continuous assessment and evaluation of the effectiveness of SWC structures.

The study conducted by Haregeweyn Nigussie et al. (2015), reported in Ethiopia, integrated SWC started during the period from 1973 up to now by the governmental and nongovernmental bodies, but still there is a high soil loss rate. However, the northern and northeastern parts of Ethiopia experienced SWC programs, mostly focused on social protection in frequently drought-affected areas, despite the fact that natural resources conservation was not getting more policy attention (Haregeweyn Nigussie et al., 2015). In Ethiopia, this is evidence for our results of the soil loss rate analysis in the Debirwonz watershed.

4.7. Soil erosion for each land use land cover types

This study reveals considerable effects of LULC class on the extent of soil erosion in the watershed. The result presented in Table 4.19 indicates the total and mean annual soil loss rates for each land use land cover type. The highest soil loss rate was observed from the grazing land area, which is the mean soil loss rate of 97.69 t/ha/yr during the years 2013 to 2022. Similarly, the estimated annual soil loss rate at the cultivated land is 74.56 t/ha/yr. Likewise; settlement land was estimated at a mean soil loss rate of 36.48 t/ha/yr. These land use land cover types have a higher soil loss rate than other land use land cover types. In contrast, the lowest soil loss rate observed from forest land was 0.27 t/ha/yr. According to the RUSLE model, results estimated soil losses by water erosion were highest for grazing land, followed by cultivated lands of the watershed. Higher soil loss in grazing land is associated with intensive grazing, which results in removal of vegetation cover and soil compaction caused by trampling of livestock. Likely Higher soil loss is caused by cultivation on steep slopes, intensive plowing, and monocropping practices. This result, however, contradicts the plot level finding of Asnake Yimam and Amare Bantider (2019). Similarly, Nyssen et al (2009) documented higher soil erosion values for grazing lands as compared to that of croplands in Tigray. The differences may be due to variations in the prevaili ng environmental conditions (slopes, vegetation composition, climate, soil characteristic and lan d management practices) and adoption of different modeling approaches by the researchers while calculating C-factor values in their specific study areas.

Table 4.19 Soil erosion for each land use land cover types

S/N	Land use types	Area (Ha)	Coverage (%)	Mean soil loss t/ha/yr	Soil Erosion severity
1	Settlement	7.97	2.65	36.48	Sever
2	Grazing land	14.06	4.66	97.69	Very sever
3	Cultivated land	241.11	79.98	74.56	Very sever
4	Forest land	38.30	12.71	0.27	Very slight
Average soil loss				**52..25**	

During the 2013-2022 periods, grazing land (4.66%) and cultivated land (79.98%) have been at very severe soil erosion risk as compared to other land use land cover types. This result is similar to Haregeweyn Nigussie et al. (2017), who reported that bare lands, moderately cultivated land, and intensively cultivated lands had a high soil loss rate compared to other land use land cover types within the Upper Blue Nile River. Gidey Eskinder et al. (2017) mentioned that the expansion of cultivated land may accelerate the rate of water erosion. This is due to the rapid expansion of cultivation on marginal and steep slope lands, some inefficient and without physical conservation measures. These in turn affect accelerating soil erosion rates by water in the study catchment.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Implemented PSWC in Debirwonz watershed were identified and technically evaluated with fiel d measurements. From this study it can be concluded that field investigation in the studied watersheds of built waterways and cutoff drains and improved (soil bunds and trenches) and check dams dimensions varied widely and that they were often not according to the national guid elines as described in the Ethiopian Ministry of Agriculture (MoARD, 2005). Inappropriate drain age management activities and poorly selected, designed, and constructed gully treatment activiti es aggravate soil erosion and land degradation. Trenches implemented on grazing sloping areas in general were in good condition as compared to the standard, but the width, length, and spacing of trench demission was significantly difference. Trench bunds in the degraded area helped to retain water and increase percolation into the soil which in turn increases the ground water. However, constructed PSWCP of soil bund parameters implemented on farm land where bund spacing, bund width, bottom embankment width, berm width, height of embankment was significantly different from the recommended dimensions in watershed. In some areas, there was very narrow bund spacing that competes with farmable land and creates difficulty for ploughing. Also, wider spacing of bunds causes high runoff concentration and damages farmland by creating rill erosion. With regard to PSWC technology preferences, soil bund and trench are mostly preferred while, other practices are the least preferred, while technology to implement in the study area.

The study results shown that PSWC implementers are challenged by constraints like shortage of labor, lack of technical skills, physical factors, lack of awareness, and institutional factors. Most of the respondents confirmed that extension contact and training of farmers on PSWC were very low and weak. Debir wonz watershed is aff ected by soil erosion and water problems, and prioritized PSWC measures can be taken through integrated RUSLE, GIS, and remote sensing quantitative soil loss modeling. The RUSLE model has been a very easy tool to estimate the mean annual soil loss, especially in small areas such as watershed and district levels, and is eff ective planning soil conservation measures. RUSLE model analysis reveals high soil loss rate, particularly in areas with steep slopes inadequate vegetation cover. This study estimates the soil loss in the Debir Wonz watershed and prioritizes the areas based on erosion severity levels. The result shows that the watershed loses a mean annual soil loss of 52.25 t $ha^{-1}yr^{-1}$ with different risk levels.

5.2. Recommendation

- Based on the findings of the study and frequent field measurements, the following recom mendations are forwarded.
- It is important to enhance farmers awareness of the importance of PSWCP since most farmers believe that implementation of practices is minimizing their land area of cultivation.
- Capacity building for development agents is also important since poor design alignment of implemented practices was associated with the skill gap.
- The study suggests that well-organized training should be given for experts at different levels to fill the technical gap in their skills, and extension services like demonstrations should be held for all stakeholders before implementing the PSWCP.
- Implement soil and water conservation measures in high risk erosion areas, focusing on integrated watershed management combining physical, agronomic and biological measures to enhance soil and water conservation.
- To lessen the effects of soil erosion, local residents, stakeholders and specialists should be required prioritized conservation efforts in most degraded areas.
- Cultivated land and Grazing land accounts high soil erosion rate in comparison with other land use types, as a result soil and water conservation measures (i.e. soil bunds combined with trenches, modern agricultural activities) should be done in the study area.
- Furthermore, RUSLE does not take into account gully erosion, which how severely separates and divides grazing farmland; further study on estimating gully erosion and sedimentation is recommended.
- Experts at watershed levels should develop PSWC strategies based on the actual characterstics of the land, involving farmers in decision making process, rather than relying solely on plans developed at regional or zonal levels. Because this localized approach is essential ensuring the sustainability and effectiveness of SWC practice.

REFERENCE

Abate Shiferaw. (2012).Estimating Soil Loss Rates for Soil Conservation Planning in Borena Woreda of South Wollo Highlands of Ethiopia: The Case from the Legemara Watershed, EJBE. 2(2):1−34.

Abebaw Legesse, Nagy, and Kendie Hailu. (2022) Soil loss estimation and severity mapping using the RUSLE model and GIS in Megech watershed, Ethiopia', 8(April). Availableat:https://doi.org/10.1016/j.envc.2022.100560.

Abebe Tilahun, Tesfaye Mebirate, Fikrey Tesfay, Lemma Yitea.,&Getahun,Yibru.(2024).Effectiveness of physical soil and water conservation measures under simulated and observed dataset. In Ethiopia: Meta analysis. Land Degradation & Development, 35, 3302 3313. https://doi.org/10.1002/ldr.5131.a

Abera Bereket .(2024) Assessment and quantification of average soil erosion using RUSLE and geospatial modeling for sustainable Land management over Melka-Sedi Catchment, Ethiopia.

Addisu Zelalem, (2011) Pattern of ocular trauma seen in grarbet hospital, butajira, central Ethiopia. Ethiop J Health Dev 25(2):150–155.

Adimassu Zenebe, Langan, S., Johnston, R., Mekuria Wolde., & Amede Tilahun. (2017). Impacts of Soil and Water Conservation Practices on Crop Yield, Run-off, Soil Loss and Nutrient Loss in Ethiopia : Review and Synthesis. Environmental Management, 87 101.https://doi.org/10.1007/s00267-016-0776-1.

Alemu Biniam, Garedew Efrem., Eshetu Zewudu., & Kassa, Habtemariam. (2015). Land Use and Land Cover Changes and Associated Driving Forces in North Western Lowlands of Ethiopia, 5(1), 28–44.

Alemu Wubetu. (2019).Role of Soil and Water Conservation Measures to Ecosystem Services at Anjeni Watershed, Northwest Ethiopia.

Amsalu Akililu and De Graaff Jan., (2007).Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed.Ecological economics, 61(2-3), pp.294-302.

Amsalu Tadsse and Mengaw Abebe. (2014) GIS Based Soil Loss Estimation Using RUSLE

Model : The Case of JabiTehinan Woreda ’, pp. 616–626.

Antonio, S. 2016. Adoption and impact of soil conservation practices on farm income : Evidence from Northern Haiti Selected Poster prepared for presentation at the Southern Agricultural Economics Association’s 2016 Annual Meeting, San Antonio, Texas, February 6, pp.1–14. 4

Arora D, Gupta K.(2002).Effect of water conservation measures in a pasture on the productivity of Buffer grass. Proceeding of Indian association of soil and water conservation, Deheradun conference held in2001 PP65-66.

Asnake Belay &Elias Eyasu.(2017). Challenges and extents of Soil and Water Conservation measures in Guba-Lafto Woreda of North Wollo,. 7(2), 103–110.

Asnake Yimam and Amare Bantider (201 9) soil erosion mapping and severity analysis based on RUSLE model and local perception in the Beshilo catchment of Blue Nile basin of Ethiopia.

Assefa Belay. (2010). The effect of rural land certification in securing land rights: A case of Amhara Region, Ethiopia. MSc Thesis submitted to the International Institute of Geo Inform ation science and Earth Observation.

Assefa,Melesse, Wossenu Abitew & Shimelis Gebire. (2014). Nile River Basin. Ecohydrological Challenges, Climate Change and Hydropolitics. Switzerland.

Atnafe Adisu, Ahmed Husen,Adane Demeku.,(2015).Determinants of adopting techniques of soil and water conservation in Goromti Watershed, Western Ethiopia.ss.

Atoma Habitamu,. (2018) Assessment of Soil Erosion by RUSLE Model Using Remote sensing and GIS Techniques : A Case Study of Huluka Watershed, Central Ethiopia’,(May).

Awulachew Sileshi, (2010).Improved water and land management in the Ethiopian highlands and its impact on downstream stakeholders dependent on the Blue Nile.

Ayalew Haweni.(2015) .Effect Of Soil And Water Conservation On Selected Soil Characteristics In Dimma Watershed, Central Ethiopia ‘College Of Natural Science School Of Graduate Studies Environmental Science Program’.

Azizi Khalkheili, Zamani Gholam (2009) Farmer participation in irrigation management: the case of Doroodzan dam irrigation network, Iran. J Agric Water Manag 96(5):859–865.

Bantider Amare, Gete Zeleke GD, Alamirew T, . (2019) From Land Degradation Monitoring to

Landscape Transformation: Four Decades of Learning, Innovation and Action in Ethiopia. Shaping Sustainable Socio-Ecological Landscapes in 19.

Bekele Amanual (2017) evaluating community based physical soil and water conservation practices emphasis on technical fitness and its effect on soil properties in the case of lemo district, southern Ethiopia.

Bekele Shiferaw, Holden Stein (1999) Soil erosion and smallholders' conservation decisions in the highland. Ethiopia. World Dev 27(4):739–752.

Bekele Amanual, Aticho Abebayehu and Kissi Endalkachew. (2018) Assessment of community based watershed management practices : emphasis on technical fitness of physical structures and its effect on soil properties in Lemo district ', Environmental Systems Research [Preprint]. Available at: https://doi.org/10.1186/s40068-018-0124-y.

Belay Simane, Benjamin, F. Z. and Mutlu, O, (2013).Agro ecosystem Analysis of the Choke Mountain Watersheds, Ethiopia. Sustainability ISSN 2071-1050, pp. 596-598.

Belayneh Mengie,Yirgu Teshome & Tsegaye Dereje.(2019).Potential soil erosion estimation and area prioritization for better conservation planning in Gumara watershed using RUSLE and GIS techniques'.Environmental Systems Research, 8(1).https://doi. org/ 10. 1186/ s40068-019-

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

Beyene Yaron,(2016) Analyzing Performances of Selected Sustainable Land Management Practices in Gina Beret Watershed, North Shoa .

Birhanu Adugnaw and Meseret Dessalew (2013). Structural soil and water conservation practices in Farta District, North Western Ethiopia : An investigation on factors influencing continued use. Sci. Technol. Arts Res. J. 2(4): 114-117.

BOA (2013) Growth and transformation plan achievement report.Bahir Dar, Ethiopia by the rural poor.Centre for Development Cooperation Services, Free University, Amsterdam development and land use department. MORDA, Addis Ababa.

Brenner, C., Strohmeier, S., Ziadat, F., & Klik, A. (2013). Soil conservation measures in the Ethi opian Highlands: The effectiveness of stone bunds on soil erosion processes. 15, 5392.149-x

Carucci V (2000) Guidelines on water harvesting and soil conservation for moisture deficit areas in Ethiopia: the productive use of water and soil, manual for trainers, first draft.Ministry of Agriculture, Addis Ababap, p 383.

CSA (Central Statistical Agency). 2007. National population and housing census of the Federal Democratic Republic Ethiopia: Addis Ababa, Ethiopia.

Dagnew Desalegn, Guzman Chrsitian, Zegeye Asesfa., Tibebu Tigist, Getaneh Menelik, Abate, Solomon, Zemale Fasikaw, Ayana, Esiyas, Tilahun Seyifu & Steenhuis, T. S. (2015). Impact of conservation practices on runoff and soil loss in the sub-humid Ethiopian Highlands : The Debre Mawi watershed. 1998, 210–219. https://doi.org/10.1515/johh-2015-0021.

Damtie Sisay,(2017)Effects of Soil and Water Conservation Measures on Bio-Physical Attributes, Livestock Feed Resources Availability and People's Livelihood Condition of Debre-Mewi Watershed, North West Ethiopia.

Daniel Danano, (2001).Soil and water conservation manual/guideline for Ethiopia. Soil and water Conservation Team, Natural Resources Management and Regulatory Department, Ministry of agriculture, Addis Ababa, Ethiopia.Link:https://goo.gl/6CXavp.

Deore, Sachin.J. (2005).Prioritization of Micro-watersheds of Upper Bhama Basin on the Basis of Soil Erosion Risk Using Remote Sensing and GIS Technology. PhD thesis, University of Pune, Pune.

Desta Gebremicheal,(2006).Stone bunds for soil conservation in the northern Ethiopian highlands. dimentary Environments, 7(3), 617–631.https:// doi.org/ 10. 1007/ s43217- 022-00112-8.

Engdayehu Gatachew ,Fisseha Gatachew, Mekonnen Mulatie and Melesse Asmare (2015). Evaluation of Technical Standards of Physical Soil and Water Conservation Practices and Their Role in Soil Loss Reduction : The Case of Debre Mewi. 789 818. https://doi.org/10.1007/978-3-319-18787-7.

FAO,(2004) Methodological framework for land degradation assessment in dry-lands, Ethiopia.

Fikirie Kalkidan, Bezu Abebe, Eshetu Melat, Bekele Daniel, Mohamed Rebo (2020) 'Evaluate Technical Standards of Implemented Soil Bund in Central Rift Valley of Ethiopia :The Case of Adama ,Lume and Dodota Districts', 7(1), pp. 51 57. Available at: https://doi.org/10.20448/journal.512.2020.71.51.57.

Gadisa Negasa and Midega Tesfaye,(2021) Soil and Water Conservation Measures in Ethiopia: Importance and Adoption Challenges.

Gardner, R. A. M. A. J Gerrard. 2003. Runoff and soil erosion on cultivated rain fed terraces in the mid hills of Nepal.Applied Geography. 12:23-45.

Gashaw Temesgen, Taffa Tulu, Mekuria Aragaw (2017). Erosion risk assessment for prioritization of conservation measures in Geleda watershed, Blue Nile basin, Ethiopia. Environ System Res 6: 1-14. 58.

Gebeyehu Taye, Poesen, J, Van W, Vanmaercke, M, Daniel Teka, Deckers, J, Goosse, T, Maetens, W, Nyssen, J, Hallet, V, NigussieHaregeweyn, (2013). Effects of land use, slope gradient, and soil and water conservation structures on runoff and soil loss in semi-arid northern Ethiopia. Physical Geography, 34(3), 236-259.

Gebremariam Yabiyo, (2018).Technical evaluation of soil and water conservation measures in Maego Watershed, North Ethiopia.African Journal of Environmental Science and Technology, 12(5), pp.177-185.

Gebremedhin Birhanu, 2004. Collective action for grazing land management in crop–livestock mixed systems in the highlands of northern Ethiopia. Agricultural Systems, 82(3), pp.273-290.

Gelagay Habitamu & Minale Amare.(2016).Soil loss estimation using GIS and remote sensing techniques: A case of Koga watershed international soil and water conservation research Northwestern Ethiopia. Int Soil Water Conserv Res., 4(2), 126–136.

Gidey Eskinder, Zeleke Tesfaye, Assefa Engidawork and Ahimed Jemal.(2017) Modeling the Spatio-temporal dynamics and evolution of land use and land cover (1984–2015) using remote sensing and GIS in Raya, Northern Ethiopia. Modeling Earth Systems and Environment

Girmay Gebirehana, Moges Awudengist and Muluneh Alemayehu.(2020) Estimation of soil loss rate using the USLE model for Agewmariayam Watershed , northern', Agriculture & Food Security, pp. 1–12. Available at: https://doi.org/10.1186/s40066-020-00262-w.

Gizaw Desta, (2010) Conceptualizing rill erosion as a tool for planning and evaluating soil conservation in Angered watershed, Ethiopia: Methodological development Research Report for Q505 project supported by Eastern and Southern Africa Partnership Program (ESAPP).

Gojjam Amare, (2023) Evaluation of Technical Standards of Selected Physical Soil and Water Conservation Practices and Community Participation in Sekela, Layguder Watershed.

Gurebiyaw Kassa. (2019). Major constraints in Sustaining Soil Conservation System and Ethiopi an Major Constraints in Sustaining Soil Conservation System and Ethiopian Experience.July

Habtamu Ertiro,(2006) Adoption of physical soil and water conservation structures in Anna Watershed, Hadiya zone. MSC Thesis, Addis Ababa University, Ethiopia.

Haregeweyn, Nigussie. Tsunekawa, Atsush., NyssenJan., Poesen, Jean., TsuboMitsuru., Meshesh a, Dereje. T.Tegegne,F(2015). Soil erosion and conservationin Ethiopia: A review. Progress in Physical Geography, 1–25. https://doi.org/10.1177/0309133315598725.

Haregeweyn, Nigussie., Tsunekawa, Atsush., Poesen,Jean., Tsubo,Mitsuru., Tsegaye, Dereje., Almaw,Ayele,Adgo,Eneyew. (2017). Comprehensive assessment of soil erosion risk for better land use planning in river basins : Case study of the Upper Blue Nile River. Science of the Total Environment, The, 574, 95–108. ht

Hassen, Gatahun., Bantider, Amare., Legesse, Abiot., & Maimbo, Malesu. (2021). Assessment of Design and Constraints of Physical Soil and Water Conservation Structures in respect to the standard in the case of Gidabo sub-tps://doi.org/10.1016/j.scitotenv.2016.09.019

Hellden, Ulf. (1987). An Assessment of Woody Biomass, Community Forests, Land Use and Soil Erosion in Ethiopia: A Feasibility Study on the Use of Remote Sensing and GIS-Analysis for Planning Purposes in Developing Countries.Lund University Press, Lund, Sweden.

Herweg, Karl.,1991.Major constraints to effective soil conservation experiences in Ethiopia. Proceedings 7th ISCO Conference Australia.

Herweg, Karl., 1993. Problems of Acceptance and Adaptation of Soil Conservation in Ethiopia: Topics in Applied Resource Management. 3, 391-411.

Hudson, Norman. (1996).Soil conservation second edition.B.T,Batsford.

Hurni,Hans,Abate Solomon,BantiderAmare.,DebeleBerhanu.LudiEva.PortnerBrigitte.Yitaferu Bi ru.and Zeleke Gatie.(2010).Land degradation and sustainable land management in highland of Ethiopia.

Hurni, Hans.(1985).Erosion productivity conservation systems in Ethiopia. In: IV International Conference on Soil Conservation. Soil Conservation and Productivity:Proceedings.Maracay, Venezuela.03-09/11/1985.

Hurni, Hans., 1995. Climate, Soil, and Water: Degradation and Conservation of the Resources in the Ethiopian Highlands. Mountain Research and Development Vol.8, pp 123-130

Hurni,Hans.(1985a).Soil Formation Rates in Ethiopia, Soil Conservation Project,Working paper 2, Ministry of Agriculture,Addis Ababa,Ethiopia.

Jemberu Wale. (2018) Effect of soil and water conservation measures on hydrological processes and sediment yield in the highlands of North-Western Ethiopia.

Kaltenrieder, J. (2007). Adaptation and Validation of the Universal Soil Loss Equation (USLE) for the Ethiopian Eritrean Highlands.MSc Thesis,University of Berne,Centre for Development and Environment.pics in Applied Resource Management. 3, 391-411.

Kassa Dawit,Bekele Tsegaye, Dawit Tesfaye and T/yehonans(2021) Assessment and Documentation of Indigenous and Introduced Soil and Water Conservation Measures in Some Parts of Southern Ethiopia'.

Kebede Wolka. (2018) Effect of Soil and Water Conservation Measures and Challenges for its Adoption : Ethiopia in Focus', (January). Available at: https://doi.org/10.3923/jest.2014.185.199.

Kibemo D, "Farmers' perception on soil erosion and their use of structural soil conservation measures in Soro District, Southern Ethiopia," MSc Thesis, Addis Ababa University, Ethiopia, 2011.

Kidane Dessale & Alemu Biniam. (2015). The Effect of Upstream Land Use Practices on Soil Erosion and Sedimentation in the Upper Blue Nile, 4(2), 55–68.

Lakew Desta, Menale Kassie, Benin S. and Pender J., (2005).Land Degradation and Strategies for Sustainable Development in the Ethiopian Highlands Amhara Region.

Lakew Wale, Baartman Jantiene, Fleskens Luuk., Selassie Yihenew & Ritsema Coen. (2020). M easuring and modelling the impacts of soil and water conservation measures on soil erosion and sediment yield in North-Western Ethiopian highlands. 1–22.

Mafkereseb Kasahun.,Pierdicca R., Frontoni E., Malinverni E.S. and Gain J, 2018.A survey of augmented, virtual, and mixed reality for cultural heritage.Journal on Computing and Cultural Heritage (JOCCH), 11(2), pp.1-36.

Masresha, Baile. (2014) 'Evaluation of Soil and Water Conservation Measures in Dejiel Watersheds, Choke Mountains, East Gojjam Zone of Amhara Region, Ethiopia'.

Megersa Terefe,(2021) 'Factors Influencing Soil Erosion Management Practices in Ejersa Lafo District, West Showa Zone, Oromia, Regional State, Ethiopia.

Mekonen Kassahun, Tesfahunegn Gebereyasus, (2011). Impact assessment of soil and water conservation measures at Medego watershed in Tigray, northern Ethiopia.

Mekonnen Kindu, Keesstra SD, Baartman JEM, Stroosnijder L, Maroulis J (2014a) Soil conserv ation through sediment trapping: a review. Land Degrad Dev. doi:10.1002/ldr.2308.

Mekonnen Mulatie, Melesse Assefa,(2011) Soil erosion mapping and hotspot area identification using GIs and remote sensing in Northwest Ethiopian highlands, near lake Tana. Nile River Basin; hydrology, climate & water use. Springer, Berlin, pp 207–2.

Mekuriaw Asnake., Heinimann, Andreas., Zeleke, Gete. & Hurni Hans. (2018). Factors influenci ng the adoption of physical soil and water conservation practices in the Ethiopian highlands. International Soil and Water Conservation Research, 6(1), 23–30.

Melaku Nigus., Renschler, Chris. S., Holzmann, Hubret., Strohmeier, Stefan., Bayu Wondimu., Zucca, Cludio ,Ziadat Feras & Klik Andreas. (2017). Prediction of soil and water conservati on structure impacts on runoff and erosion processes using SWAT model in the northern Ethiopian highlands.

Melese Asmare and Mebrate Tesfaye.(2018). Assessment of spatial soil erosion hazard in Ajema ', 8(23), pp. 552–558. Available at: https://doi.org/10.15406/apar.2018.08.00384.

Mengie Mequanent, Hagos Yonas, Sebhat Mesenbet & Andualem, Tesfa. (2022).Assessment of soil loss rate using GIS RUSLE interface in Tashat Watershed, Northwestern Ethiopia.Journ al of Se Merrit, W.S.,Letcher,R.A.and Jakeman, A.J.(2003).A review of erosion and sedime nt transport models.Environmental Modelling and Software.18:761−799.

Meshesha Yaricho, Birhanu Belay (2015) Assessment of the effectiveness of watershed manage ment intervention in Chena Woreda, Kaffa Zone, Southwestern Ethiopia. J Water Resource Protect 7(15):1257–1269.

Mitiku Haile., Karl H. and Brigitta S.(2006).Sustainable land management.A New Approach to Soil and Water Conservation in Ethiopia, Land Resources Management and Environmental Protection department Mekelle University, Ethiopia, and Swiss National Centre of Competence in Research (NCCR) North-South University of Bern, Switzerland.

MoA (Ministry of Agriculture),(2001).Soil and water conservation Guide line for Ethiopia.

MoA Ministry of Agriculture (2012) soil and water conservation Training material module 7

MoARD (2005) Community based participatory watershed development: a guideline.Ministry of Agriculture and Rural development, Addis Ababa, Ethiopia.

Moisa Mitiku, Daniel Asesfa, Biratu Babo and Dessalegn Obisi,(2021) Impact of land-use and land-cover change on soil erosion using the RUSLE model and the geographic information system: a case of Temeji watershed, Western Ethiopia.

Molla Tegegne, Sisheber Biniam,(2017). Estimating soil erosion risk and evaluating erosion control measures for soil conservation planning at Koga watershed in the highlands of Ethiopia. Solid Earth, 8(1), p.13.

Morgan RPC 1995.Soil erosion and conservation.Longman London and New York.Morgan,R.P. C. (1995).Soil erosion and conservation (Second edition ed.). Harlow: Longman.

Morgan, R.P. (2005).Soil erosion and conservation.Oxford Black well science Ltd. Soil erosion and conservation / R. P. C. Morgan. – 3rd ed. 316 pp.

Mulu Abirham, Enyew Adigo and Zerihun Nigusie, (2016) ‘evaluation of physical soil and water conservation structures with respect to standard package in Enebsie Sarmidir district: the case of Guansa and Shola watersheds, Ethiopia.

Mulugeta Demelash,Stahr K(2010)Asssements of integerated soil and water conservation measures on key soil properties in south gonder zone,North western highlands of Ethiopia soil ScEnviorn mang1(7):164-176.

Nyssen Poesen Jan, Mitiku Haile, Moeyersons Jan,Jozef Deckers and Hans Hurni(2009) the effect of land use land cover on sheet and rill erosion rate in the Tigray high land of Ethiopia

Olana Habitamu,(2014) Challenges Of Soil And Water Conservation Practices and Measure To Be Undertaken the Case of Wuchale District North Shewa Zone, Oromia Regional State, Ethiopia.

Renard, K.G., Foster, G.R., Weesies, G.A., Mccool, D.K., & Yoder, D.C.(1997).Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). Agriculture Handbook703, 404.Washington: United States Department of Agriculture.col. Econ.Wello, Ethiopia.Environmental Management.

Saavedra, C. (2005).Estimating spatial patterns of soil erosion and deposition in the Andean region using geo-information techniques: a case study in Cochabamba, Bolivia Ph.D.

Sertsu, S. (2000). Degraded soils of Ethiopia and their management. Proceedings of the FAO/IS CW expert consultation on management of degraded soils in Southern and East Africa, 2nd Network Meeting, 18-22 September 2000.Pretoria. South Africa.

Sewnet Amare., & Abebe Gebeyehu. (2017). Land use and land cover change and implication to watershed degradation by using GIS and remote sensing in the Koga watershed , North Western Ethiopia, (Hussein 2009). https://doi.org/10.1007/s12145-017-0323-5.

Shiferaw Bekele. and, Holden Stein. (1999) Soil erosion and smallholders' conservation decisions in the highlands of Ethiopia.World Dev 27(4):739–752.

Shin, K. (1999). The soil loss analysis using GIS in watershed. Dissertation, Kangwon National University, South Korea.

Sibuh Gebeyew (2020) soil protection in Amhara national regional state: the legal and practical assessment, Bahirdar Ethiopia

Subudhi,C. R, Behera B, Sethi P K Sharma K N and Swain S N.(2004).Creation temporary structure across drainage line in degraded watershed. Indian Journal of power and River Valley Development. Vol. July – Aug: 164-167.

Tadesse Lemelem, Suryabhagavan, K. V, Sridhar, G., & Legesse Gizachew. (2017). Internationa l Soil and Water Conservation Research Landuse and landcover changes and Soil erosion in Yezat Watershed , North Western Ethiopia. International Soil and Water Conservation

Research. https://doi.org/10.1016/j.iswcr.2017.05.004.

Tamene Lulseged & Le Quang Baole. (2015). Estimating soil erosion in sub Saharan Africa base d on landscape similarity mapping and using the revised universal soil loss equation (RUSL E).Nutrient Cycling in Agro ecosystems,102, (1), 17 31.https://doi.org/10.1007/s10705-015 9674-9.

Taye Getachew, Adgo Enyew, Erkossa Tilahun (2013) On-site financial costs of soil erosion by runoff from the Mizewa catchment of the Blue Nile basin. ILRI.

Tesema Mekonen, Feyessa Fikadu, Kebede Adisu, & Geresu, Bezu. (2024). Evaluation of soil erosion rate using geospatial techniques for enhancing soil conservation efforts.

Tesfaye Gizaw, Fikirie Kalikidan, Debebe Yalemtsehay& Hailu Leta. (2019). Evaluating Techni cal Standards of Implemented Soil and Water Conservation Technologies in. 19(4).https://do i.org/10.19080/ARTOAJ.2019.19.556100.

Tilahun Kefialew & Desta Gizaw.(2021).Impact of Physical Soil and Water Conservation Measures on Soil Erosion Reduction and Associated Constraints in the Highland of Ethiopia . 5(1), 171–183. https://doi.org/10.36959/624/442.

Tsegaye Bekele and Awudengist Moges(2018).Technical evaluation of selected soil conservation practices and farmers' perception about soil erosion in Donbi Watershed,Wolaita Zone, Southern Ethiopia.Int J AgricSc Food Technol, 4(2), pp.016-023.

USAID (United State Agency International Development), (2000).Amhara National Regional State food security research assessment report. Available at:http://crsps.org/amhara/Amhara rpt.PDF.

Wasie Dessale, Yimer Fentaw & Alem, S. (2020). Effect of Integrated Soil and Water Conservati on Practices on Vegetation Effect of Integrated Soil and Water Conservation Practices on Vegetation Cover Change and Soil Loss Reduction in Southern Ethiopia.September.https://d oi.org/10.11648/j.ajep.20200903.12.

Wildemeersch Jasmein. C. J., Timmerman, E., Mazijn, B., Sabiou, M., & Ibro, G. (2013). Assessing The Constraints To Adopt Water And Soil Conservation Techniques In Tillaberi , Niger.

Wischemeier, W.H.and Smith, D.D.(1958).Rainfall energy and its relationship to soil loss. Trans.

AGU. 39:285–291.

Wagayehu Belay, Lars D.,(2003). Soil and Water Conservation Decision of Subsistence Farmers in the Eastern Highlands of Ethiopia: A case study of the Hunde-Lafto.

Wischmeier, W.H. and Smith, D.D.(1978).Predicting rainfall erosion losses, a guide to conservat ion planning. Agric. Hand B. No. 537, US Department of Agriculture, Washington, DC.

Wogayehu Worku A, Skjelvag AO (2006) The effect of different moisture and light regimes on productivity, light intercception and use eciency of common bean. SINET: Ethiop J Sci 29(2):95–106

Woldeamlak Bewket (2003).Land degradation and farmers acceptance, and adoption of conserva tion technologies in the Digil watershed, north western highlands of Ethiopia.Social science research report.Ossera; addisababa, Ethiopia.

Yaregal, Biadgilign (2022). Impact of Soil and Water Conservation Practices on Sediment Trap Ping , Soil Moisture Conservation , Slope Gradient Change and Crop Yield in Dembecha District Gosho Watershed Northwest Highlands of Ethiopia.

Yazie Tsegaye Mulatie Mekonenn, Assefa Derebe, and Tadele Melese.(2020). Investigating long year gully erosion and its impacts on soil loss, land competition and crop yield reduction, north-west Ethoipia.

Yericho Birhanu,(2019)Technical viability of physical soil and water conservation structures imp lemented in Lake Hawassa watershed, southern Ethiopia.Journal of Soil Science and Enviro nmental Management.

Yemata Demise, Alem Meta and Mare Addis(2024)assessing the impact of productive seftent program on soil and water conservation practice in Amhara region Sayint woreda

Yilmana Densa Woreda Agricultural office (2023) The Annual Basic Information of Yilmana Densa.Unpublished Document.

Zerihun Nigussie,Atsushi Tsunekawa,Nigussie Haregeweyn,EnyewAdgo,Makoto Nohmi Mitsur u Tssubo,Dagnachew Aklog,DeregeTsegayeMeshessha,Steffen Abele.(2017) farmers percep tion about soil erosion in Ethiopia.

APPENDIX

Appendix 1

Masters of Science thesis Survey

Name Ayenew Wudu

Bahirdar University

Code__________Date of interview____

Name of enumerator_____________________________

General demographic information of the respondent

Name of head of Household/Respondent: ___________________ Age ____ Sex____

Woreda Yilmana Densa kebele Enegadie watershed Debir Wonz

Sex: 1, Male 2, female

1. Age of household:

1. 15-30

2. 30-64

3.>64

2. Marital status of house hold

1. Marriage
2. Single
3. Divorced Education level

3. Education level

1. Illiterate
2. read and write
3. above read and write

4. Family size

1. 2-4 2. 5-8 3. >8

Appendix 2

Questioners

PHYSICAL SOIL AND WATER CONSERVATION PRACTICES

4. From the following physical conservation structure which one was mostly practiced in study watershed?

A. stone and stone face soil bund

B. soil bund

C. trench

D.waterway

E .Cutofdrain

F.checkdam

7. Do you think physical soil and water conservations have long term benefit?

a. Yes
b. b.no

8. Do you believe that soil erosion can be controlled?

a. yes

b. No

9. I s there soil erosion problem in your farm land?

a. yes

b. no

10. If yes to question 1, what indicators did you observe?

a. yield decline
b. soil structure and color change
c. increased input demand

11. What are the main causes of erosion in your farm land?

a. improper tillage
b. Slope
c. Deforestation
d. high rainfall
e. absence of protective measure
f. over gazing

12. Which design component of the bund are not accepted?

a. spacing of bunds
b. length of bunds
c. width of ditch
d. bottom width of embankment
e. height of embankment

13. Do the following constraints the degree of your participation to implement PSWC?

a. technically difficult to
b. physical factor
c. Limited awareness
d. High labor demanding
e. Institutional factor

Appendix 3

Guiding question for interview and focus group discussion (local elders, community leaders and Development agents)

1. If there is soil erosion problem in your area what is the cause of soil erosion?
2. What are the consequences of soil erosion problem of the area?
3. Describe the physical soil and water conservation measures in the area?
4. What are the major physical soils and water conservation measures are there?
5. Is there PSWC guideline? A/Yes B/No C/ Not known
6. How is the applicability of the SWC guideline?
7. Do you get technical knowledge about the PSWC practices?
8. What constraints are there to implement PSWC measures in the area? Do you have additional issues to forward pertaining points for discussion?

Appendix Table Socio-economic charactestics of the respondent

Variables	Frequency	Percent
Sex of respondent		
Male	75	67
Female	37	33
Total	112	100
Age of the respondents		
15-30	22	19.6
31-64	73	65.2
Above 64	17	15.2
Marital status		
Marriage	75	67
Single	14	12.5

Divorced	23	20.5
Total	112	100
Educational status		
Illiterate	53	47.3
read and write	47	42
above read and write	12	10.7
Total	112	100
Family size		
2-4	43	38.4
5-8	55	49.1
>8	14	12.5
Total	112	100

Appendix Table 1: Measured data of soil bund component in study watershed

Bund no	Slope %	VI (m)	HD (m)	Length of bund	bund gradient %	Depth av (m)	Width av(m)	Berm (m)	EH av(m)	ET av(m)	Bwav (m)
1	3	0.75	22	53	1.3	0.49	0.553	0.233	0.356	0.353	1.07
2	3.5	1.4	20.5	90	1	0.48	0.52	0.153	0.31	0.32	0.963
3	4	1.5	26	33	1	0.53	0.55	0.226	0.317	0.323	1.103
4	6	2.31	30	79.5	1.1	0.56	0.52	0.205	0.42	0.356	1.23
5	7	1.76	32	67	0.95	0.533	0.56	0.2	0.363	0.34	1.1
6	7.5	1.13	27	80	1.2	0.533	0.53	0.2423	0.306	0.31	1.15
7	8	1.25	21.6	85	0.9	0.5833	0.49	0.206	0.45	0.316	1.24
8	8.8	1.15	25.7	63	0.8	0.6	0.52	0.21	0.426	0.346	1.14
9	10.2	0.75	21	70	0.25	0.55	0.59	0.15	0.366	0.393	1.06

10	11	2.02	18	44	1	0.49	0.513	0.23	0.363	0.266	0.07
11	11.5	1.74	16.8	52	1.2	0.44	0.523	0.202	0.42	0.323	1.11
12	12	1.74	17.3	53	1.3	0.483	0.52	0.186	0.45	0.32	1.14
13	15	2.4	16	42.55	1.3	0.6	0.546	0.17	0.256	0.33	1.233
14	15.5	2.24	14	85	1	0.536	0.58	0.216	0.25	0.356	1.36
15	16	2.36	13.5	46	1.3	0.57	0.512	0.23	0.26	0.363	1.3
16	16.7	1.8	10.7	52	1.2	0.526	0.55	0.23	0.32	0.273	1.366
17	18.5	3	14	60	1.1	0.566	0.57	0.223	0.626	0.33	1.24
18	19	3.3	15.8	61	1.1	0.533	0.556	0.35	0.483	0.326	1.14

Appendix Table 2: data of trench components in Debir Wonz watershed

trench no	Slope (%)	length(m)	depth(m)	width(m)	spacing(m)
1	9	3	0.3	0.45	2
2	10.5	2.5	0.4	0.5	4
3	11	3	0.4	0.4	5
4	10.8	2.43	0.36	0.523	4.5
5	9.45	2.7	0.39	0.44	3
6	12.6	2.2	0.37	0.403	5
7	13	2.2	0.34	0.416	9
8	11.56	2.2	0.37	0.44	3.5
9	11	3	0.38	0.48	4

Appendix Table 3: measured data of waterway in Debir Wonz watershed

Waterway	Slope (%)	Bottom width(m)	Depth(m)	Top width
1	10	1.50	0.45	1.25
2	10.5	2	0.40	1.2342
3	9.5	1.80	0.30	1.256

Appendix Table 4: Measured data of cutofdrain

Cutoff drain No	Slope (%)	Bottom Width(m)	Top width(m)	Depth(m)
1	12.5	0.7	1	0.6
2	10.5	0.65	1.1	0.25
3	16	0.55	0.95	0.35

Appendix Table 5: Measured data of Stone check dam

Check dam No	Slope (%)	Side key(m)	Width(m)	Height (m)	Apron (m)	Spill way(m)	Bottom key(m)	Spacing (m)
1	8	0.62	1.45	0.95	1.2	0,25	0.4	13
2	9.5	0.8	1.55	1.25	1.6	0.3	0.5	13
3	15	0.55	2	0.75	1.05	0.2	0.35	6

Appendix Table 6: Result of soil bund dimensions in study watershed

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
D av (m)	18	.48752	.059499	.014024

One-Sample Test

	Test Value = 0.5					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
D av (m)	-.890	17	.386	-.012483	-.04207	.01710

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Wav (m)	18	.53906	.026620	.006274

One-Sample Test

	Test Value = 0.6					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Wav (m)	-9.713	17	.000	-.060944	-.07418	-.04771

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
EH av (m)	18	.37456	.094458	.022264

One-Sample Test

	Test Value = 0.6					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
EH av (m)	-10.126	17	.000	-.225444	-.27242	-.17847

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
ET av(m)	18	.33022	.030243	.007128

One-Sample Test

	Test Value = 0.3					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
ET av(m)	4.240	17	.001	.030222	.01518	.04526

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Length of bund	18	33.00	90.00	62.0028	16.67783
Valid N (listwise)	18				

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Slope %	18	3.0	19.0	10.733	5.1503
Valid N (listwise)	18				

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
HD (m)	18	10.7	32.0	20.106	6.0634
Valid N (listwise)	18				

Appendix Table Table 7: Rainfall stations and its mean annual rainfall in study area

Name of Stations	Latitude	Longitude	Elevation (m)	Mean annual RF
Adet	37.493	11.275	2179	1121.4
Bahir Dar	37.36	11.6	1800	1609.6
Motta	37.89	11.074	2417	1366.7
Merawi	37.164	11.411	2000	2005.8
Feresbet	37.608	10.85	3000	2132.9

Appendix Table 8: Rainfall data of Bahirdar

Year	Jan	Feb	May	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	0.0	0.0	1.4	1.4	88.0	148.6	594.0	350.3	137.9	169.1	16.6	0.0
2014	0.0	0.0	65.9	66.6	163.7	178.4	378.4	480.8	260.0	117.4	0.0	0.4
2015	0.0	0.8	0.4	0.0	136.8	89.3	302.2	248.9	223.9	116.7	12.2	31.8
2016	0.0	0.0	23.8	8.5	171.2	248.8	409.6	259.9	274.4	104.8	0.5	0.0
2017	0.0	25.9	2.6	41.9	136.8	50.0	528.7	485.7	189.2	128.9	9.6	0.0

2018	0.0	91.8	17.0	66.8	54.1	290.6	307.3	222.7	123.4	73.7	83.0	0.0
2019	0.0	4.3	9.2	71.8	75.3	353.2	418.4	331.8	248.1	52.1	139.6	83.0
2020	0.0	0.4	0.0	0.0	108.1	295.1	571.1	427.5	441.4	79.3	0.5	4.0
2021	0.0	8.2	2.9	19.2	117.4	129.3	786.0	358.5	407.9	68.0	8.0	3.9
2022	0.0	2.0	5.8	39.3	14.5	168.5	702.3	313.6	257.5	131.9	13.3	11.1

Appendix Table 9: Rainfall data of adet

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	0.0	3.5	114.2	85.6	188.3	130.6	210.8	200.2	151.8	108.5	21.7	0.0
2015	0.0	1.8	22.3	0.0	139.3	141.7	181.1	188.5	124.3	313.3	0.0	26.0
2016	0.0	0.0	73.8	21.4	176.2	161.2	294.8	146.3	98.7	85.4	0.2	0.0
2017	0.0	40.9	15.9	122.4	115.5	77.8	392.6	168.3	143.4	78.5	53.4	0.0
2018	0.0	0.0	37.9	15.8	107.3	159.9	307.8	244.6	224.6	154.2	172.5	7.2
2019	0.0	29.9	29.2	65.9	105.7	301.6	362.7	306.8	235.5	57.2	76.3	21.0
2020	0.0	3.4	0.0	0.2	226.2	145.8	334.6	270.0	148.5	75.5	23.9	0.0
2021	0.0	21.1	10.4	16.1	155.7	24.5	407.6	184.5	114.2	85.4	35.6	6.7
2022	1.1	5.6	7.3	28	147.4	143.4	275.7	365.6	145.7	117.7	31.8	11.2

Appendix Table 10: Rainfall data of Feresbet

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	16.2	10.9	71.3	66.2	906.44	148.6	650.1	489.2	164.8	192.6	66.1	2.2
2014	62.3	6.6	120.61	157.1	362.2	261.4	493.8	403.1	221.7	181.1	83.3	25.0
2015	0	40.3	67.9	10.1	303.7	310.6	276.2	388.9	271.2	104	119.7	63.4
2016	7.8	41.0	78.3	37.7	391.1	201.5	556.3	428.1	175.6	132.0	15.0	0.0

2017	1.4	76.4	44.2	91.6	242.9	141.6	522.5	470.6	170.7	79.7	49.4	0.0
2018	11.0	18.3	21.7	49.7	154.0	265.8	480.9	371.6	247.5	172.1	120.5	25.2
2019	28.6	25	53	78.3	323.1	329.5	529.2	477.4	317.2	42.4	231.5	39.7
2020	3.3	0.0	23.1	73.5	178.8	213.6	434.5	510.4	257.2	131.3	62.8	5.5
2021	0.0	6.7	22.4	158.4	287.3	197.8	628.5	368.3	231.5	163.0	23.9	27.6
2022	79.3	24.9	27.2	60.1	81.7	358.2	428.9	309.1	225.3	115.2	60.4	61.9

Appendix Table 11: Rainfall data of Motta

year	Jan	Feb	Marc	Apr	Ma	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	16.2	10.9	71.3	66.2	906.44	148.6	650.1	489.2	164.8	192.6	66.1	2.2
2014	62.3	6.6	120.61	157.1	362.2	261.4	493.8	403.1	221.7	181.1	83.3	25.0
2015	0	40.3	67.9	10.1	303.7	310.6	276.2	388.9	271.2	104	119.7	63.4
2016	7.8	41.0	78.3	37.7	391.1	201.5	556.3	428.1	175.6	132.0	15.0	0.0
2017	1.4	76.4	44.2	91.6	242.9	141.6	522.5	470.6	170.7	79.7	49.4	0.0
2018	11.0	18.3	21.7	49.7	154.0	265.8	480.9	371.6	247.5	172.1	120.5	25.2
2019	28.6	25	53	78.3	323.1	329.5	529.2	477.4	317.2	42.4	231.5	39.7
2020	3.3	0.0	23.1	73.5	178.8	213.6	434.5	510.4	257.2	131.3	62.8	5.5
2021	0.0	6.7	22.4	158.4	287.3	197.8	628.5	368.3	231.5	163.0	23.9	27.6
2022	79.3	24.9	27.2	60.1	81.7	358.2	428.9	309.1	225.3	115.2	60.4	61.9

Appendix Table 12: Rainfall data of Merawi

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	0.0	0.0	0.0	1.8	154.4	220.7	510.9	239.9	159.6	135.6	31.6	0.0
2014	0.0	3.5	74.0	157.2	183.1	243.7	243.2	361.5	181.3	105.4	5.0	0.0
2015	0.0	0.0	8.4	0.0	226.1	244.4	282.2	229.0	128.5	0.0	0.0	0.0

2016	0.0	0.0	50.6	10.3	185.5	418.2	227.1	229.0	300.7	144.8	43.7	0.0
2017	0.0	51.0	12.2	75.5	198.8	217.8	147.5	766.9	179.9	31.8	0.0	0.0
2018	0.0	51.0	16.7	72.5	226.3	374.1	399.9	433.1	300.7	144.8	43.7	2.0
2019	0.0	18.1	4.9	89.3	61.4	732.9	743.6	665.3	555.2	150.1	130.5	2.0
2020	0.0	0.0	0.0	0.0	378.4	468.2	465.6	378.1	381.9	73.6	0.0	2.0
2021	0.0	0.0	0.0	285.6	529.4	273.0	495.3	401.6	304.8	343.8	96.5	0.0
2022	0.0	0.0	0.0	32.8	119.7	548.0	483.6	422.1	514.5	318.6	86.0	14.1

Appendix Table 13: Soil color survey points and their respective K_ factor values (soil erodibility factor)

S/N	X	Y	Soil color	K_factor value
1	340962.4	1236347	Black	0.15
2	339596.7	1235515	Red	0.25
3	338630.8	1236198	Brown	0.2
4	339467.9	1236355	Brown	0.2
5	338561.7	1237184	Red	0.25
6	338668.2	1237280	black	0.15
7	338216.5	1236530	Red	0.25
8	340962.4	1236333	Black	0.15
9	341232.1	1236269	Red	0.25
10	339595	1235518	Red	0.25
11	340142	1235538	Brown	0.2
12	339472	1235308	Brown	0.2
13	337959	1236568	Red	0.25

BIOGRAPHICAL SKETCH

The author Ayenew Wudu Aragie was born on June 9, 1995 G.c in Simada woreda, South Gonder Zone of Amhara National Regional State, Ethiopia. He attended elementary education from (1-8^{th} Grade) at Saf primary school. He attended his secondary and preparatory education (9- $12t^{h}$) at Tagel secondary and Preparatory school. After he successfully passed the Ethiopian higher education entrance qualification exam, He joined Debre Markos University in 2014 and graduated with a BSc degree in Natural Resource Management in June 2016. Following his graduation, then after he has joined the school of postgraduate studies of Bahir Dar University to follow his MSc degree in Soil Conservation and Watershed Management.