EFFECTIVENESS OF VEGETATION IN SUSTAINABLE SOIL AND WATER CONSERVATION FOR SOIL QUALITY ENHANCEMENT IN BERA-SALAYISH WATERSHED, CENTRAL ETHIOPIA

MSc. Thesis

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May 2023/24
Debre Berhan, Ethiopia

EFFECTIVENESS OF VEGETATION IN SUSTAINABLE SOIL AND WATER CONSERVATION FOR SOIL QUALITY ENHANCEMENT IN BERA-SALAYISH WATERSHED, CENTRAL ETHIOPIA

A Thesis Submitted to Department of Natural Resources Management College of Agriculture and Natural Resource Sciences, School of Graduate Studies
DEBRE BERHAN UNIVERSITY

In Partial Fulfilment to the Requirements for Degree of Master of Science in Soil and Water Conservation

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EXAMINERS APPROVAL SHEET – I

(Submission Sheet-1)

We, the undersigned members of the boarded of the examiners of the final open defense by Belaynesh Zeyede have read and evaluated her thesis entitled Effectiveness of Vegetation in Sustainable Soil and Water Conservation for Soil Quality Enhancement in Bera-Salayish Watershed, Central Ethiopia, and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of **Master of Science** in Natural resource management with specialization in **Soil and Water Conservation**.

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College of Agriculture and Natural Resource Sciences

Department of Natural Resource Management

(Submission Sheet-2)

As members of the Board of Examiners of the final Masters open defense, we certify that we have read and evaluated the thesis prepared by **Belaynesh Zeyede** under the title **"Effectiveness of Vegetation in Sustainable Soil and Water Conservation for Soil Quality Enhancement in Bera-Salayish Watershed, Central Ethiopia"**, and recommend that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in **Natural resources management** with Specialization in **Soil and Water Conservation.**

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College of Agriculture and Natural Resource Sciences

Department of Natural Resource Management

(Submission Sheet-3)

As members of the Board of Examiners of the final Masters open defense, we certify that we have read and evaluated the thesis prepared by **Belaynesh Zeyede** under the title **"Effectiveness of Vegetation in Sustainable Soil and Water Conservation for Soil Quality Enhancement in Bera-Salayish Watershed, Central Ethiopia"**, and recommend that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in **Natural resources management** with Specialization in **Soil and Water Conservation.**

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Certification of the Final Thesis

I hereby certify all the correction and recommendations suggested by the board of Examiner are incorporated in the final thesis **"Effectiveness of Vegetation in Sustainable Soil and Water Conservation for Soil Quality Enhancement in Bera-Salayish Watershed, Central Ethiopia" by**

______________________________	_______________	_____________
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DEDICATION

I would like to dedicate this thesis to my committed and hardworking father, Mr. **Zeyede Gosa**, and my mother, Mrs. **Mulunesh Tadesse**.

STATEMENT OF THE AUTHOR

I hereby declare that this thesis is my genuine work, and that all sources of materials used for this thesis have been profoundly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for Master of Science (MSc) at Debre Berhan University and it is deposited at the University library to be made available for users under the rule of the library. I intensely declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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Name: Belaynesh Zeyede Gosa **Signature**: ________________

Place: College of Agriculture and Natural Resource Sciences, Debre Berhan University.

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BIOGRAPHICAL SKETCH

The author, Mrs. Belaynesh Zeyede, was born on May 27, 1999 in ‘’Secoru Kebele’’ North Shewa Zone, Amhara National Regional State, Ethiopia. She attended primary education at Secoru Primary School, and Secondary education at Asagrt Secondary and Preparatory School.

In September 2018, Mrs. Belaynesh Zeyede joined Debere Berhan University to pursue a Bachelor of Science (BSc) degree in Natural Resource Management. Immediately after completing her undergraduate studies, she was hired as a Graduate Assistant at Debre Berhan University, where she began serving the institution. In February 2022 she joined the School of Graduate Studies at Debre Berhan University to attend her Master of Science (MSc) degree program in Soil and Water Conservation.

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ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
BA	Basal Area
CEC	Cation exchange capacity
DBH	Diameter at Breast Height
FAO	Food and Agriculture Organization
GERD	Grand Ethiopian Renaissance Dam
GLM	Generalized Linear Models
GPS	Global Positioning System
ISRIC	International Soil Reference and Information Centre
IVI	Important Value Index
LSD	Least Significant Difference
SKAO	Salayish Kebele Agricultural Office
SOC	Soil Organic Carbon
SWC	Soil and Water Conservation

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EFFECTIVENESS OF VEGETATION IN SUSTAINABLE SOIL AND WATER CONSERVATION FOR SOIL QUALITY ENHANCEMENT IN BERA-SALAYISH WATERSHED, CENTRAL ETHIOPIA

ABSTRACT

This study aimed to evaluate the effectiveness of vegetation in promoting sustainable soil and water conservation and enhancing soil quality in the Bera-Salayish Watershed. The study used both quantitative and qualitative data collected from primary and secondary sources. Vegetation data was collected using a systematic sampling design with three transect lines/replication across upper, middle, and lower elevation zones, each containing three land use categories (exclosure, open grazing, and agricultural land), with 60 plots established along transect lines to measure vegetation parameters such as species composition, structure, and diversity. Soil data was also analyzed to assess the effectiveness of the vegetative soil and water conservation (SWC) measures across different land use categories (exclosure and open grazing land) and slope classes (upper, middle, and lower). The study followed a randomized complete block design (RCBD) so that vegetation and soil data were statistically analyzed using two-way ANOVA to determine the effects of the independent factors. The results show that a total of 125 plant species were identified, with 59.2% woody species (49 shrub and 25 tree species) and 40.8% herbaceous species. Fabaceae was the most dominant woody plant family, while Poaceae was the most dominant herbaceous family. The upper and middle elevation zones exhibited greater species richness and diversity. Certain species, like Euclea racemosa, had the highest importance value index (IVI) in the watershed. While the exclosure area had better soil properties, such as higher soil depth, SOC, TN, Av-P, Mg^{2+} and K^{+} the vegetation regeneration was not effective in the watershed. Recommendations include implementing effective vegetation management strategies, expanding exclosure areas, adopting sustainable land management practices, and conducting further research to understand the complex soil-vegetation interactions. Implementing these measures can help rehabilitate the vegetation cover, conserve soil and water resources, and improve the overall sustainability of the Bera-Salayish Watershed.

Keywords: Land use categories, Elevation zones, Shannon diversity, Soil organic carbon

1. INTRODUCTION

1.1. Background of the study

Land degradation is one of the largest environmental problems that human society is currently facing and started in ancient times of human history (Prăvălie, 2021). As part and parcel of this history, Ethiopia's main ecological and agricultural problems are caused by land degradation (Sinore *et al*., 2018). The reported causes of land degradation include clearing forest for agriculture, repeated cultivation, wood extraction, deforestation, population growth, overgrazing, heavy wind, drought and landslides, high intensity of rainfall and lack of land use plans (Jinger *et al*., 2021; Borsali1 *et al*., 2017; Bartnik, 2013). Amhara Region is very prone to land degradation resulting in the depletion of land resources, which in turn causes a decline in agricultural output, the deterioration of water quality, the extinction of species, instability in society, poverty and food insecurity (Meseret, 2016).

A problem that affects the entire planet is soil erosion, which results in an annual loss of more than 36 billion tons of soil and destruction of about 10 million ha of cropland in each year (Gachene *et al*., 2019). Soil degradation is caused by a number of important processes, including soil erosion, which is one of the most common environmental problems (Mulat, 2013). The rate of soil erosion, the loss of soil fertility, the fall in crop output, and the level of food insecurity are all being accelerated by the on-going change in land use (Tsegaye *et al*., 2012). Soil erosion, the main land degradation processes, might involve, splash, sheet, rill, and/or gully erosion types. This happens when energetic water movement displaces soil from where it originally formed (Vanmaercke *et al.*, 2021). Degradation of one natural resource has an impact on the other since they are interdependent. In Ethiopia, soil erosion is a significant contributor to land degradation that affects the physical, chemical, and biological characteristics of soils, leading to on-site nutrient loss and off-site sedimentation (Sinore *et al*., 2018). Soil erosion in all land uses is a serious problem by which in Ethiopia, Abay basin contributes the highest (30%) soil loss of the countries (Fenta *et al.*, 2021). This problem encourages the use of a wide range of conservation measures.

Ethiopian farmers practice a variety of coping mechanisms for soil degradation, including terracing, crop rotation, mixed cropping, irrigation, and a variety of conventional soil conservation techniques (Megerssa and Bekere, 2019). For farmers to make any effort at addressing a degradation problem, they must be well-informed of the existence, severity, and contributing factors. Based on their information and evidence farmers believe that conserved farmland is more productive (Borsali1 *et al*., 2017). Besides, farmers are being forced to give up or resist to appling soil and water conservation techniques due to a fear of productive area competition by the measures since they have a shortage of land resulting from land fragmentation. Adoption of these techniques is still below expectations, despite the introduction of several soil and water conservation measures to address land degradation, mostly due to high construction costs and a shortage of experienced labour (Terefe, 2011). The loss of these conservation methods will significantly affect soil quality unless farmers adopt alternative sources of nutrients (Corbeels *et al*., 2000). However, several studies show that land users have their own reasons for acting as they do, which cannot be disregarded in the achievement of a more effective soil and water conservation (Michael and Herweg., 2000).

Evaluating the status of vegetation informs natural resource (soil, water, etc.) conservation priorities in the targeted area (Jewitt, 2018). Typically, measurements or estimations of vegetation structure and composition are made based on plant communities (Tegegne, 2016). This knowledge helps in developing effective conservation and management strategies. Furthermore, vegetation management to lower erosion and runoff rates is known as the vegetative method in soil and water conservation (SWC) strategies (Agustina and Saputra, 2015). Therefore, vegetation recovery and restoration are well-known results that effectively prevent land degradation (Fusun *et al*., 2013; Zhang *et al*., 2021). By increasing vegetation cover, one may lessen the rate and amount of water that flows over the soil, preventing soil nutrients from being removed from the soil and reducing land degradation (Megerssa and Bekere, 2019). The large-canopied tree plants can capture rainwater and retain it by intercepting, decreasing direct flow, and forming a layer of litter (Agustina and Saputra, 2015). Plant species enhance the soil's ability to retain moisture, its hydraulic conductivity, and its ability to store rainwater during both dry and wet seasons. Additionally, afforestation has fewer maintenance costs than structural interventions (Singha, 2019). Rain splash erosion is lessened by trees because they reduce the impact of raindrops on the soil's surface. In addition to lowering soil temperature and minimizing water evaporation into the atmosphere, trees provide shade for the soil. And also because trees slow the wind, wind erosion is reduced (Gachene *et al*., 2019). Trees may hinder the flow of water evaporating from the surface when placed along contours. Further, the restoration of vegetation greatly aids in soil and water conservation (Descheemaeker *et al*., 2006). Therefore, it makes sense to promote the growing and management of vegetative soil and water conservation measures for tackling land degradation due to soil erosion.

1.2. Statement of the problem

In the Amhara Region North Shewa Zone Ensaro Woreda, where this study was undertaken, soil erosion and ensuring SWC sustainability is a major problem (Tesfaye, 2019). In Ethiopia as well as in the Region, building physical structures has long been given priority over vegetative conservation measures to combat soil degradation (Woldeamlak, 2003). However, vegetative measures are easier and less expensive than physical structures, and effective to rehabilitate areas, safeguards against upcoming degradation, and long-term stabilization of physical structures (Abinet, 2011). Further, little research has been done on vegetative soil conservation practices that can improve biomass accumulation and restore degraded lands in the Region and not in the Bera-Salayish watershed.

The Bera-Salayish Watershed has a critical natural resource that supports the livelihoods of local communities. However, the watershed has faced significant challenges related to soil degradation and water scarcity, threatening the long-term sustainability of the ecosystem. The conversion of natural vegetation to agricultural lands and overgrazing has led to soil erosion, loss of soil fertility, and reduced water infiltration, contributing to a decline in overall soil quality and water availability (Tsegaye, 2019). Despite the importance of vegetation in maintaining soil and water resources, there is limited understanding of the specific mechanisms by which different plant species and their management can promote sustainable soil and water conservation in this watershed. The effectiveness of various vegetation types and their spatial distribution in enhancing soil quality and water conservation remain largely unexplored.

This study aims to address this knowledge gap by investigating the role of vegetation in promoting sustainable soil and water conservation, and its impact on improving soil quality within the Bera-Salayish Watershed. Vegetation plays a crucial role in maintaining soil and water resources through various mechanisms, but the current status and spatial distribution of vegetation within the watershed, and its effectiveness in promoting sustainable soil and water conservation, remains poorly understood. There is a need to systematically assess the vegetation status and its contribution to soil and water conservation in the study area. The findings from this research will provide critical insights to guide the development of informed land management strategies that can enhance the resilience of the ecosystem and improve the livelihoods of the local communities.

1.3. Significance of the study

The study's findings will help for improved understanding of the status of vegetation and its effectiveness to conserve soil and water resources in Bera-Salayish watershed. Besides, the study provides crucial information on vegetation status as an input to the nation's programs of sustainable land management, which is a top priority for overall agricultural development. Likewise, it may assist local and district agricultural specialists to organize their plans for efficient land management techniques. Besides, the study can convey messages through its generated data and information about the role of vegetative SWC practices, especially integration with physical methods to boost agricultural productivity in a sustainable manner. As an immediate benefit, the watershed community as well as the district society and the economy will get evidence to manage their vegetation cover to enhance their soil quality and increase their control over the soil and water resources conservation.

1.4. Objectives of the study

1.4.1. General objective

To evaluate the effectiveness of vegetation in promoting sustainable soil and water conservation and enhancing soil quality in the Bera-Salayish Watershed

1.4.2. Specific objectives

- ✓ To identify the structures and compositions of vegetation present in the Bera-Salayish Watershed and their respective roles in soil and water conservation;
- ✓ To measure key soil quality parameters in areas with different vegetation of land use category to determine their impact on soil health.

1.5. Research questions

1. What are the structures and compositions of vegetation and their respective roles in soil and water conservation in Bera-Salayish watershed?
2. What are the effects of vegetation on soil quality parameters in areas with different vegetation of land use category to determine their impact on soil health?

1.6. Scope of the study

For conserving the soil and water resources in the Bera-Salayish watershed, the primary goal of this study was to evaluate the effectiveness of vegetation in promoting sustainable soil and water conservation and enhancing soil quality. Beside, how well vegetation functions for maintaining soil and water resources were also a focus of the study, on the other hand it was not interested in how any particular plant species impacts on the soil and water resource.

1.7. Limitation of the study

The key limitation of the study resulted from the unability to collect the undisturbed soil samples for measuring soil bulk density. Given that soil bulk density was initially identified as the most effective soil quality indicator that the researcher wanted to quantify, but unable to collect the necessary undisturbed soil samples due to a lack of security in the study area after the rest of the data was collected, which posed a risk to the integrity of the samples, despite the researchers' ability to collect all other necessary data for the study, the omission of soil bulk density represents a notable limitation that will need to be acknowledged in the interpretation of the study's findings.

2. LITERATURE REVIEW

2.1. Soil degradation

Approximately 95% of the food produced worldwide is grown on soil, which also provides ecosystem services (Ferreira *et al*., 2022). Soil degradation, which includes physical, chemical, and biological degradation, is a major factor in land degradation (Dagnachew *et al*., 2019). Ethiopia's high population as well as animal density and intense crop production, leads to soil degradation and decreasing agricultural productivity (Borrelli *et al*., 2017). It is obvious that infertile soils are unable to produce sufficient agricultural growth to support life. The soil's capacity to hold moisture and infiltration water is further diminished by soil erosion; compaction and poor humus content (Arora *et al*., 2022).

The factors that affect soil quality and crop yield in Ethiopia are soil erosion and the resulted nutrient depletion. Due to present rates of soil erosion magnitude higher than the natural soil formations, poses a serious danger to both food security and ecological survival (Wuepper *et al*., 2019). Soil erosion is the most dangerous ecological process that can be noticed in Ethiopia, which affects the valuable soil resources that are the foundation of agricultural production and the country's food supply (Negessa and Tesfaye, 2021). Good moisture content, no erosion, strong plants, green crops, black soil, speedy plant development, high germination, and soft soil are qualities of healthy soil (Hermans *et al*., 2021).

Significant negative externalities associated with soil erosion include water contamination, river bed sedimentation, and a decrease in the soil's water-carrying capacity, all of which might impact the surrounding flora and fauna as well as create sedimentation in dams (Singha, 2019). As a result, all across the world, governments are attempting to solve the problem of soil erosion. However, it is unknown how much actually influence nations have over soil erosion (Wuepper *et al.*, 2019). Soil and water conservation techniques are one way to reduce erosion and the associated nutrient loss, which minimises the risk of production. Therefore, various strategies of soil and water conservation should be introduced and implemented while taking into account the agro ecology, socioeconomic status, and climate of the intervention zone in order to prevent soil erosion in a sustainable manner (Anteneh, 2022). Recognizing the factors that influence farmers' choice of various soil and water conservation techniques can help in identifying the advantages and disadvantages of the different SWC methods. It can also help in finding the scientific aspects of strategies that are both economically viable and socially acceptable (Ellis-Jones and Tengberg, 2000).

2.2. Vegetation degradation and deforestation

Vegetation degradation/decline can be considered as another major pathway of land degradation, given its diverse ecological consequences, global spatial footprint, and the effects it generates in climate system dynamics (Prăvălie *et al.*, 2021). A serious environmental issue that could cause degradation of soil is the loss of natural vegetation cover (Zoungrana *et al.*, 2018). The loss of vegetation is a global environmental issue that affects many different parts of the world. For instance, vegetation performs the task of absorbing carbon dioxide, therefore without it, earthly life is reduced. Human activities lead to considerable amounts of damaged vegetation. Mining, logging, burning and the creation of urban centers are a few of these activities. Deforestation and vegetation degradation have significant direct and indirect effects on the agricultural sector in Africa, particularly in Ethiopia (Oljirra, 2019). Monitoring the spatial patterns of vegetation dynamics and determining their driving forces are crucial due to the large regional and local variability in vegetation dynamics (Peng *et al*., 2015).

With more than 60% of the world's biodiversity found in forests, they are one of the most precious ecosystems on the planet. In addition, forests contribute to a sustainable environment that benefits society and the economy in a variety of ways (Oljirra, 2019). Sustainable development eventually disappears as a result of deforestation. It accelerated land deterioration and soil erosion. Numerous factors, including logging, population increase, urbanization, the lack of appropriate benefit-sharing and tenure issues, grazing, the building of dams and reservoirs, habitat fragmentation, policy failures, burn method of farming, wildfires, global warming, and hydropower projects, contribute to deforestation (Tariq and Aziz, 2015). Over the past few decades, there has been an increase in efforts to slow down, halt, and reverse deforestation in the tropics in recognition of the scope and expense of these consequences. This can involve a broad range of initiatives operating at various scales, including legal requirements and regulations (restrictions around land use and vegetation clearing), voluntary sustainability commitments from businesses and industries, the establishment of protected area networks, financial incentives such as payments for ecosystem services, and demand-side initiatives that aim to shift consumer preferences and behavior (Austin *et al*., 2019).

2.3. Cause and status of land degradation in Ethiopia

Land degradation is defined differently by various authors. Others also provide an explanation for the difficulties in defining it due to its larger range and extent (Meseret, 2016). Destructive processes that modify the values of the biophysical environment and the characteristics of the land are brought on by land degradation. These include modifications to the geography, soil, water, vegetation, and climate (Mohamed *et al*., 2019). A natural process or human action that makes the land temporarily or permanently unable to perform the intended functions is known as "land degradation" (Meseret, 2016). Agriculture is the backbone of Ethiopia's economy. On the other hand, land degradation is wholly controlling the economy's production (Megerssa and Bekere, 2019). A common occurrence, land degradation has an influence on society, the economy, the environment, and other areas (Meseret, 2016). Land degradation is frequently thought to be the outcome of excessive use of natural resources or population growth (Lanckriet *et al*., 2015). The rural poor own few productive assets, and the majority of their households are involved in agriculture, making land one of their few productive assets (Barbier and Hochard, 2018).

The rapid population growth, deforestation, cultivating on steep slopes, rugged topographical features, political unrest and civil wars, low vegetative cover, and unbalanced agricultural and livestock production are the main causes of land degradation in Ethiopia (Megerssa and Bekere, 2019). The political-ecological system and its associated conservation policies are fundamentally responsible for the land degradation in Ethiopia, which should not solely or even mostly be considered to be a result of poor management, overpopulation, or technical-environmental factors (Lanckriet *et al*., 2015). Inadequate land-use systems and land-tenure laws further accelerate desertification and the loss of agricultural biodiversity (Taddese, 2001). Changes in land policies and cycles of land degradation appear to be closely related (Lanckriet *et al*., 2015).

It is impossible to evaluate land degradation in isolation from its spatial, temporal, economic, environmental, and cultural contexts. Evaluations are thus nearly endlessly changeable and extremely dynamic (Warren, 2002). The interaction between natural and human activities, which results in land degradation, is complicated and is influenced by important economic, social, and environmental aspects (Barbier and Hochard, 2018).

2.4. Practice of soil and water conservation in Ethiopia

Ethiopia's soil and water conservation methods are very old, as shown by the use of conventional practices in several regions of the country (Osman and Sauerborn, 2001). Historical evidence reveals that in the 1930s, significant rates of soil erosion were occurring over most of the world, which led to a decrease in agricultural production. Moreover, one of the primary causes of low agricultural production in tropical and subtropical countries continues to be the loss of soil quality brought on by soil erosion (Zinn, 2011). As a result, several international organizations made investments in this field. Also, the Ethiopian government and people have put in significantly more resources, including cash, time, expertise, and labour (Kanito, 2021). The sustainability of agriculture and the environment depends on the conservation of soil and water resources (Meseret, 2016).

Without paying much consideration to the ecological and environmental balance, Ethiopian agriculture is unquestionably exploitative. As a result, several regions of the nation developed local soil and water conservation mechanisms (Osman and Sauerborn, 2001). However, in the east and central African area, developing sustainable soil management practices is still a significant problem (Gachene *et al.*, 2019). In addition, the results of soil and water conservation techniques in Ethiopia's highlands have been uneven and unreliable (Adimassu *et al.*, 2017).

Farming in ecologically vulnerable areas may require the adoption of several types of soil conservation techniques (Singha, 2019). According to an economic feasibility study, the integration of physical, agronomic and biological soil and water conservation practices made them economically more feasible and improved ecosystem services (Adimassu *et al.*, 2017). However, because of their cheap adoption costs compared to the structural SWC measures, agronomic and vegetative SWC techniques have gained significant application, especially in sub-Saharan Africa (Gachene *et al.*, 2019). The primary contributing element for decreasing runoff is vegetation cover. It is determined that enclosures serve as significant sediment and water sinks and, as a result, aid in soil and water conservation (Descheemaeker *et al.*, 2006).

In degraded regions, soil and water conservation refers to local efforts to avoid or lessen soil erosion, compaction and salinity and also to conserve water or drainage in order to retain or increase the land's productive capacity (Abiye, 2022). Some researchers categorized SWC as agronomic, physical, and vegetative techniques (Anteneh, 2022). To increase soil quality, agronomic practices SWC options would be crucial (Dagnachew *et al*., 2020). Additionally, agroforestry is the practice of planting trees or shrubs or preserving naturally occurring trees. By lessening the effects of the raindrops on the soil, such trees reduce the severity of splash erosion (Sustainet, 2010). As a result, researchers have been interested in agroforestry because of its potential to decrease poverty and land degradation, increase food security, and slow down climate change (Ahmad *et al*., 2017). Moreover, farmers use strips of grass along the slope to build barriers that reduce soil erosion and runoff on farmland. It also integrates the characteristics of both structural and biological measures (Gachene *et al*., 2019). At the beginning, the plot's thin strips are left unploughed to allow for spontaneous growth of the plant cover. The farmers use such practices as figure 1 below (Michael and Herweg., 2000).

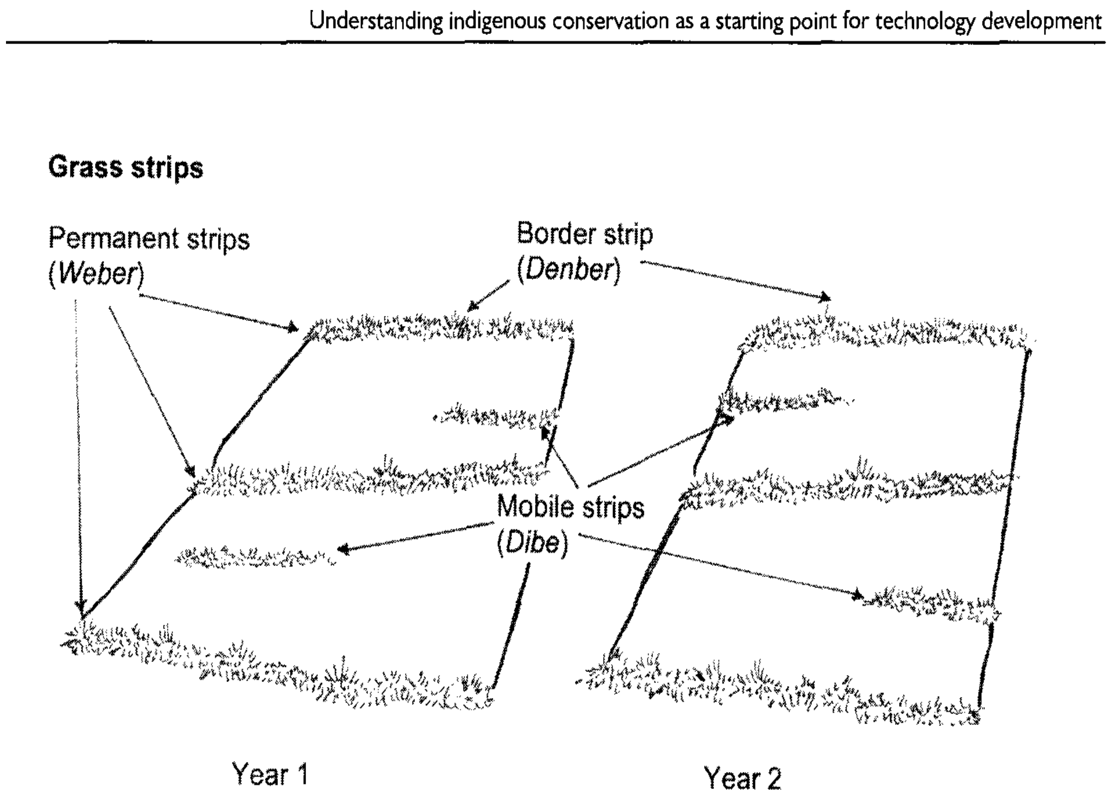

Figure 1. Indigenous biological SWC and their dynamic

2.4.1. Vegetative soil and water conservation measures

The biological approach mainly entails promoting the growth of vegetation (such as grass, shrubs, or trees) in the barren site. Moreover, the roots of this vegetation firmly attach to the ground while the tops of shrubs and forests create obstacles to the movement of air or water streams (Asfaw, 2022). Using biological techniques can improve the general condition of the soil by increasing its organic matter content, enhancing its physical properties, and boosting its nutrient levels (Terefe, 2011). Increased vegetation supplies natural matter to the ground, which consequently enhances soil arrangement and productiveness (Abinet, 2011). Trees shade the ground, lowering soil temperature and minimizing water evaporation into the atmosphere (Gachene *et al*., 2019).

In addition to providing many environmental and social advantages including timber and biomass supplies, clean water, wildlife habitat, and leisure, forests also store carbon and give other benefits (Tariq and Aziz, 2015). Furthermore, the vegetation captures the precipitation, enhancing infiltration and minimizing runoff. The hydrology is improved as a result of the infiltrating water's percolation into the soil (aquifer). Additionally, the risk of flooding has decreased, and gravel and stone deposition on productive farmlands has decreased (Shiene, 2012).

Natural vegetation of the strips: Planting trees and other non-crop plants like eucalyptus along the contour is a highly effective method for conserving soil and water. These plants act as filters for eroded soils, reduce water flow rates, and promote water infiltration, often in combination with other conservation practices (Mushir and Kedru., 2012). Trees may hinder the flow of water flowing from the surface when placed along contours (Gachene *et al*., 2019).

2.5. Farmers perception towards soil and water conservation measure in Ethiopia

Africa's farmers have long been aware of local environmental changes and evaluated the challenges they face. Moreover, they are familiar with the causes of soil erosion and the resulting decline in land production (Kanito, 2021). The farmers have a lot of local knowledge in managing and sustaining watersheds, as well as established land use systems (Meseret, 2014). As a result, they believe that putting SWC measures in place is insurance for watershed sustainability. Terracing, check dam construction, closing and fencing of agricultural plots, manuring, crop rotation, and the use of agronomic and other structural measures are some of the most significant conservation proactive practices used by farmers as coping mechanisms to restore the degraded and eroded lands (Adimassu *et al.*, 2017; Hurni *et al.*, 2016; Shiene, 2012). These conservation efforts are crucial for the environment's and agriculture's sustainability. Therefore, as many historically used practices across the country would suggest, farmers are not unfamiliar with the concept of soil conservation.

According to the results of Meseret (2014), the majority of farmers believe that appropriate soil and water conservation techniques may be used to reduce soil erosion. Specifically, the farmer's perception of SWC has a positive relationship with the number of trees on the farm (Sinore *et al*., 2018). Despite the fact that socioeconomic, institutional, attitudinal, and biophysical variables significantly influenced farmers' perceptions about investing in SWC technologies (Moges and Taye, 2017). Therefore, when promoting soil and water conservation technologies to farmers, consideration must be given to the farming environment, the institutional and socioeconomic makeup of the target populations, and the significance of developing and putting into action suitable policies and programmes that will influence farmers' attitudes towards incorporating these conservation measures into their farming practises (Meseret, 2014).

2.6. Implication of vegetative soil and water conservation for land restoration

Long-term agricultural sustainability is facilitated by methods that conserve soil and water (Abiye, 2022). Practices to conserve soil and water are one way to lower the risk of production by reducing erosion and the nutrient loss that goes along with it. In comparison to the adjacent cropland without vegetative soil and water conservation measures, it increased the soil's physical and chemical fertility compared to the nearby cropland that isn't protected from soil and water loss (Adugna, 2019). Also, it reduces the amount of fertile topsoil that is removed and increases soil moisture, both of which promote crop development and raise the grain yield of the crops (Anteneh, 2022).

In enclosure sites with restored vegetation, the chemical characteristics of the soil are improved (Descheemaeker *et al*., 2006). Moreover, with the protection of soil and water on sloping areas, agroforestry contributes to the ecological restoration and preservation of the environment. Because tree canopies function to shield the soil from the erosive impacts of precipitation, during the rainy season tree roots serve to hold the soil together, avoiding erosion and eventually the appearance of floods. Further, because trees slow the wind, wind erosion is reduced (Gachene *et al*., 2019). Major improvements in the grassland/woody grassland cover show the effectiveness of restoration efforts (Shiene, 2012).

In general, today's best method for conserving soil and water is one of the best land use systems that support land restoration in a way that is beneficial to both the current generation and future generations. So, cattle must be completely excluded from the area year-round in order to revegetate with grasses and shrubs in arid areas as well as use area closure on agricultural land that has been deteriorated and has shallow soil. And also with the farmer's agreement, convert land that has a slope gradient more than 50% into grassland or forest (Hurni *et al*., 2016).

3. MATERIALS AND METHODS

3.1. Description of the study area

3.1.1. Location

The study was conducted in the Bera-Salayish watershed, which is located at Salayish Kebele in Ensaro District. The district is one of the 24 districts found in the North Showa Zone of Amhara Region, Ethiopia. The district has one urban and 12 rural kebeles (the lowest administrative level). The capital town of the district is Lemmi; it is 85 kilometers from Debre Berehan and 130 kilometers from Addis Ababa.

Salayish kebele was specifically chosen for the study due to the availability of vegetation and practices for conserving soil and water through vegetation. Bera-Salayish watershed was selected for the study from Salayish kebele; it covers 1490.51ha and located 12 km from Lemmi Town. Geographically, the study area is situated between 9^0 49'- 9^0 54' North latitude and 38^0 54' - 38^0 57' East longitudes.

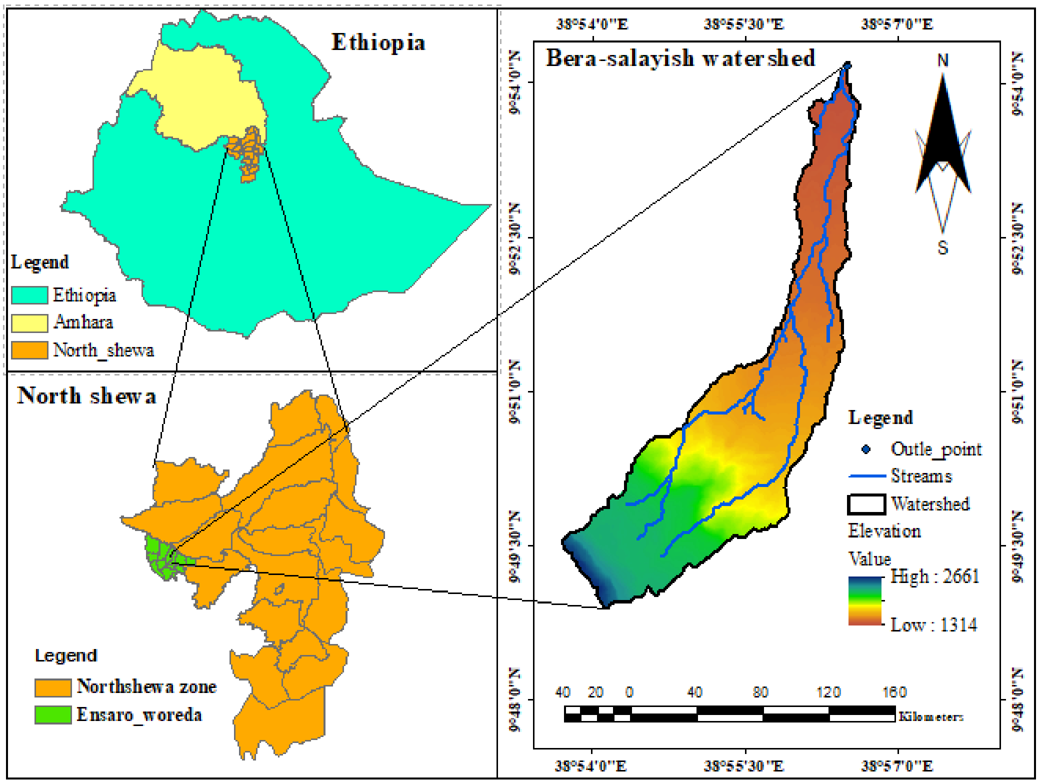

Figure 2. Map of the study area

3.1.2. Climate and drainage

The study area received minimum and maximum annual RF of 800 mm and 1100mm and temperature of 24°C and 29 °C, respectively (Figure 3). The rainfall exhibits a bimodal pattern, with the major rainy season occurring from June to September and the dry season lasting from November to February (SKAO, 2023). The agroecology of the study watershed includes Dega, Woina Dega and Kolla climates, according to Hurni's (1998) Ethiopian agro-ecological categorization.

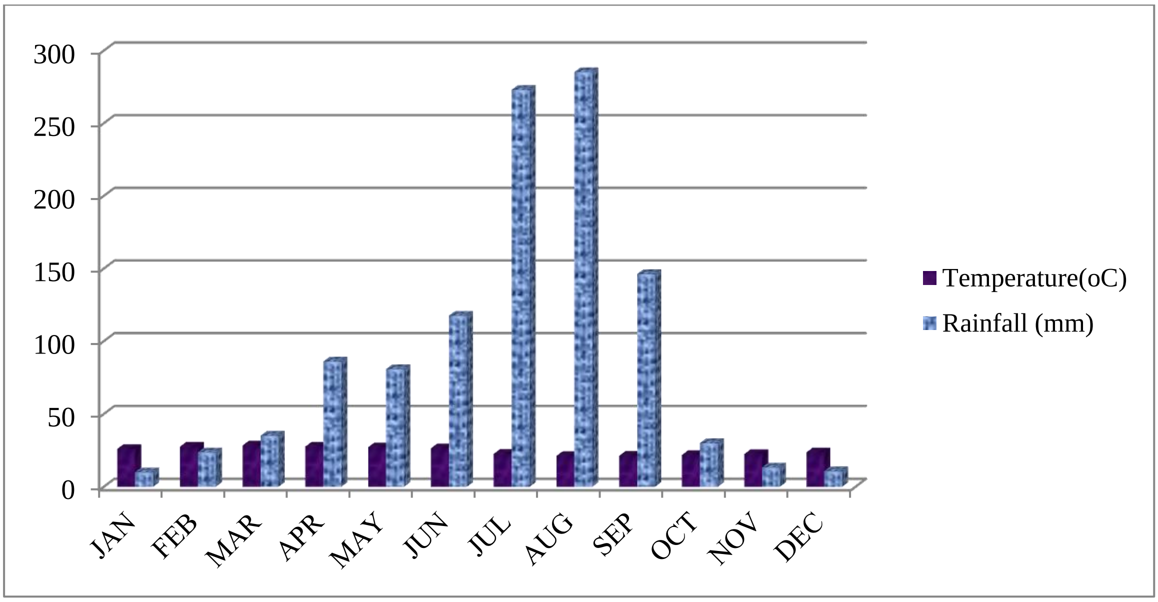

Figure 3. The study areas mean monthly rainfall and temperature of 2000 – 2022

The Bera-Salayish watershed drains directly into the Bersina River, which then flows into the Jemma River, ultimately ending at the GERD. The main drainage of the watershed is Bera River which has a seasonal flow (Figure 4) with a few streams that are suitable for irrigation development.

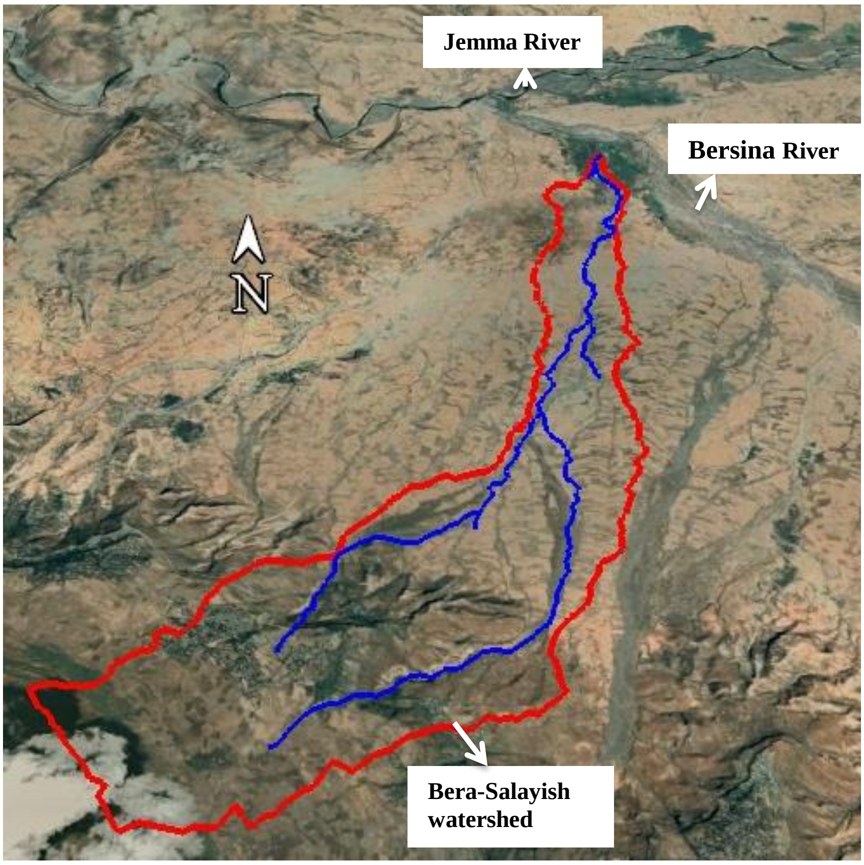

Figure 4. Study watershed drainage

3.1.3. Soil types

The study watershed's predominant soil type, as determined by the FAO (from ISRIC), is Haplic arenosols (69.02%). Which have high permeability and poor nutrient concentration due to their sandy-texture (Hartemink and Huting, 2008). Therefore, these soils need careful management when used for agriculture. It’s mostly found in the flat area (0-8% slope class) of the study watershed. Moreover, the remaining area is covered by Leptosols, Regosols and Vertisols soil type (Table 1) and the spatial distribution presented in Figure 5. The soil type in the upper site of the watershed is relatively heterogeneous. Moreover, the lower site is flat and covered by Arenosols and Regosols soil type.

Table 1. Soil class of Bera-Salayish watershed

No	Soil unit	Area (ha)	Area (%)
1	Haplic Vertisols	28.65	1.92
2	Eutric Regosols	193.36	12.97
3	Eutric Leptosols	239.76	16.09
4	Haplic Arenosols	1028.74	69.02
	Total	1490.51	100.00

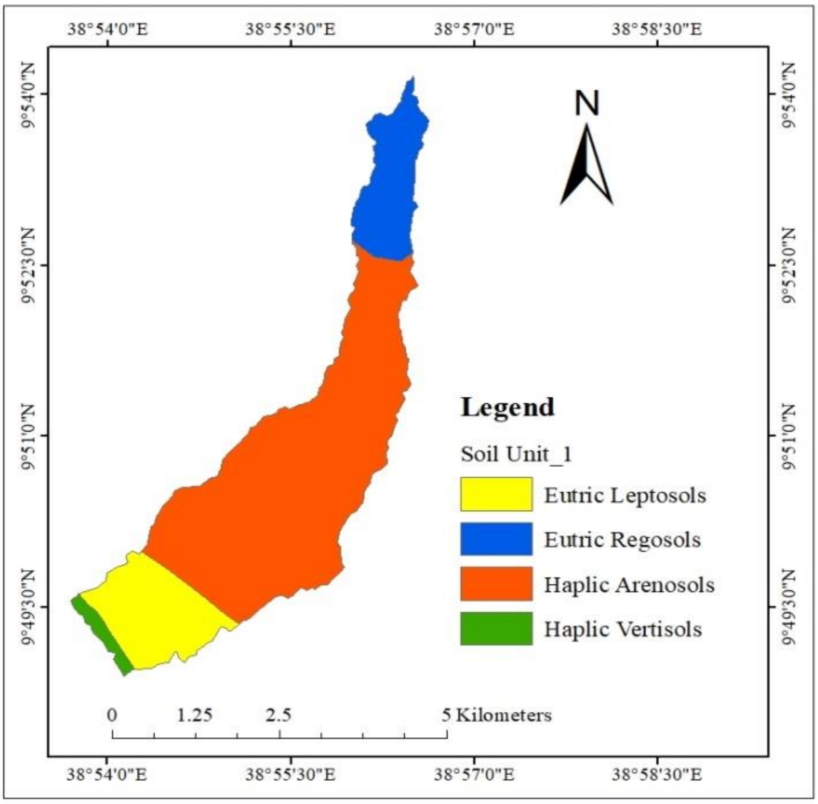

Figure 5. Soil type of the study watershed

3.1.4. Topography

The watershed's altitudes range from 1314 m to 2661 m above sea level. Moreover, most of the study area (65.73%) is found under the slope ranging from 0 to 8%, it covers 959.67ha of land. Whereas the remaining area (34.27%) is found greater than 8% slope, the details are shown on Table 2 (Figure 6).

Table 2. Slope class of Bera-Salayish watershed

No	Slope	Area (ha)	Percent
1	0 - 8%	959.67	65.73
2	8 - 15%	250.65	17.17
3	15 - 30%	170.31	11.67
4	30 - 45%	65.84	4.51
5	>45%	13.48	0.92

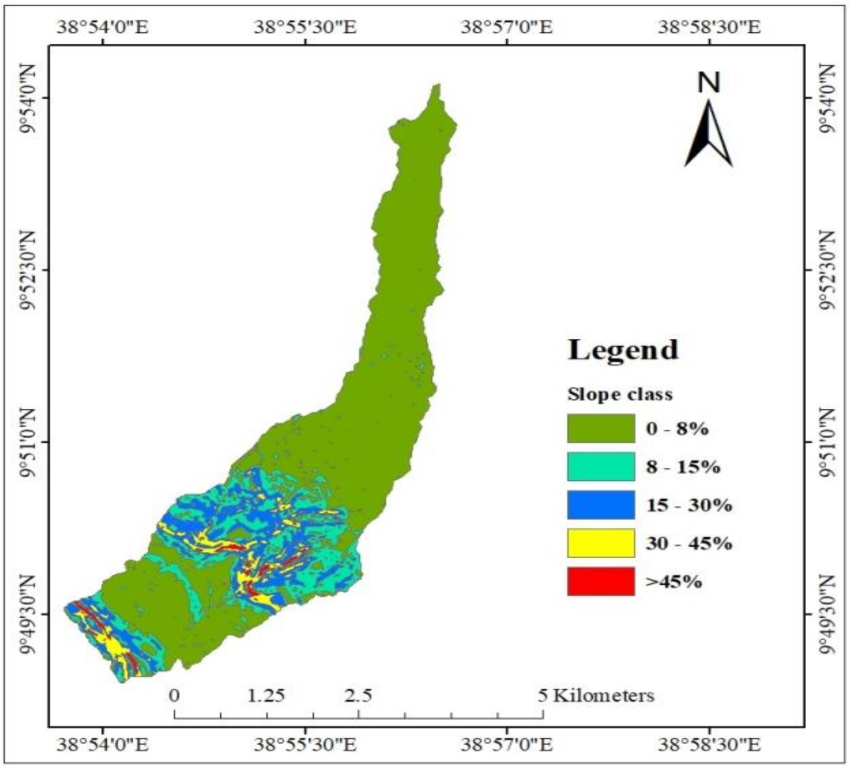

Figure 6. Slope of the study watershed

3.1.5. Population and socio-economic condition

There are 905 households overall, with 801 males and 104 female's household heads in Salayish kebele. From these total households, 400 households live in Bera-Salayish watershed.

Additionally, Teff (17%) and sorghum (70%) are the two main agricultural crops produced in large amounts and also cereal crops, cash crops, and vegetables are the primary crop types growing during the rainy season. Moreover, different types of vegetation cover the study area to various extents. These areas were determined with the help of agricultural experts, as well as a direct field observation.

3.1.6. Land use and land cover

The study watershed recent LULC of 2018 – 2023 raster data were downloaded from Esri Portal 2022 with 10m resolution and supervised classification was performed by ArcGIS10.8 environment (Table 3, Figure 7).

Table 3. Land use land cover of Bera-salayish watershed

No	LULC	Area (ha)	Percentage (%)
1	Agricultural land	807.33	54.18
3	Bare land	136.89	9.19
2	Exclosure area	97.43	6.54
4	Open grazing land	195.58	13.13
5	Settlement	235.27	15.79
6	Water body	17.54	1.18
	Total	1490.04	100.00

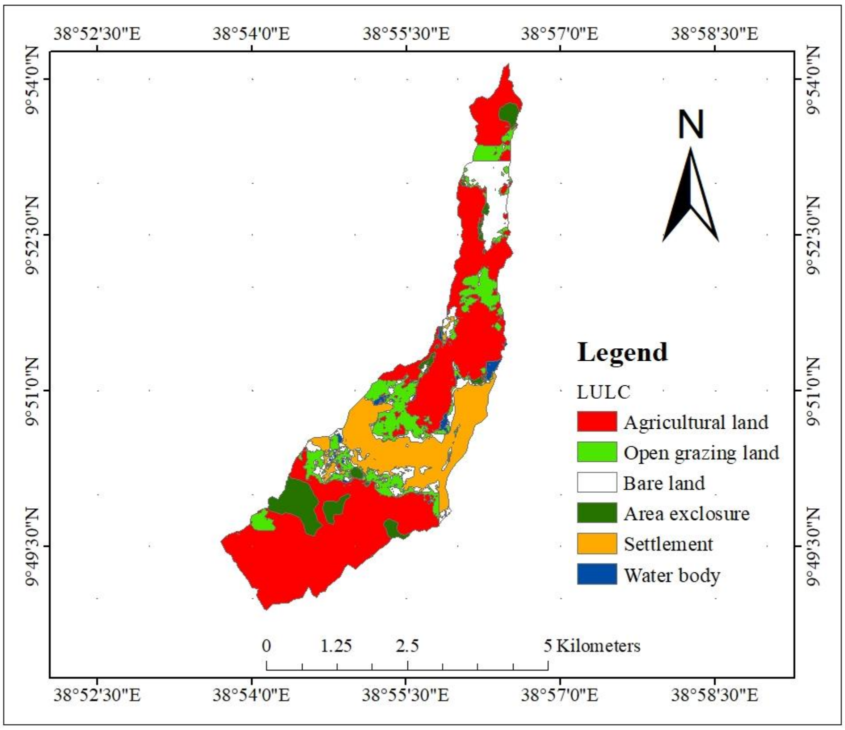

Figure 7. Study watershed land use land cover

The land use land cover of the watershed was dominated by Agricultural land, Exclosure area, Bare land, Open grazing land, Settlement and Water body. The larger area of the watershed is used as agricultural land. Some of the key land use categories in the study area that were the focus of this study are discussed in Table 4.

Table 4. Description of land use category identifed in the Bera-salaysh watershed, Ethiopia

No	Land use category	Descriptions
1	Agricultural Land	In addition to cultivation land, agricultural land in the area used for Pastures and rangelands used for grazing livestock, production of annual, perennial, and permanent fruit trees,
2	Exclosure/protected land	Exclosures in the study area refer to areas that are protected from grazing by livestock or other forms of human-induced disturbance. It is mostly made up natural vegetation of undisturbed evergreen, deciduous, and semi deciduous trees, shrubs and grass
3	Grazing land or open grazing land	An area of grassland utilized for grazing, mostly for short grasses, 10% or more of the land is covered in shrubs and trees.

3.2. Experimental/Research design and data collection method

The study used both quantitative & qualitative data types and also both primary & secondary data sources. The primary data were collected from sample plot, field observation and measurement and key informant interview (agricultural experts). Further, secondary data were gathered from journal articles, governmental and non-governmental sources, and reports.

3.2.1. Vegetation data collection

The vegetation status investigation was carried out in the upper, middle and lower site with relatively different elevation categories of the study watershed as <1500, 1500 – 2300, >2300m a.s.l (Hurni, 1998). The three categories of land use were investigated in each site of the study watershed, as protected/exclosure area, agricultural land and open grazing land with the three transect lines as a replicate for each, forming a Randomized Complete Block Design (RCBD) for data analysis.

The study site's vegetation was investigated using a systematic sampling design. A total of nine transect lines (thee in each land use category) were used, along the transect lines, a total of 60 systematically selected study plots (24 in upper site, 18 in middle site and 18 in lower site). At 100 m interval, a 20m x20m (400m^2) sampling plot for measuring and counting matured species, 5m x5m (25m^2) sub plot for seedling and sapling counting per species and 1m x1m (1m^2) sub plot for herbaceous cover determination were set up along transect line in each site and land use category (Figure 8) (Hussein and Temesgen, 2021).

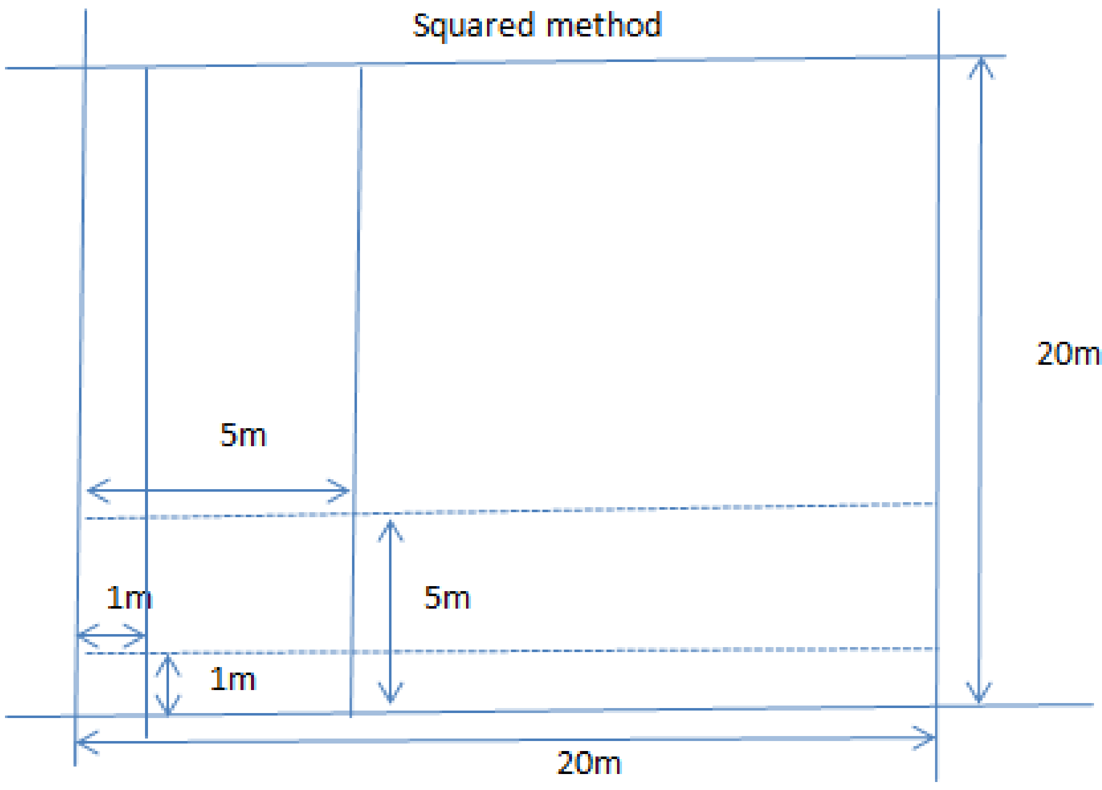

Figure 8. Plot size for observation of vegetation

Each site's plant species were noted and coded with scientific and/or local names in each plot. Clinometers were used to measure slope up and down by pointing at the center of plot and also a handheld Global Positioning System (GPS) was used to mark the location of each sampling plot. A hypsometer and a calliper were used to measure in each plot the height and diameter at breast height (DBH) of vegetation respectively (Nzunda *et al.*, 2007). Height and DBH were measured and recorded for woody vegetation such as trees and shrubs with DBH >2.5 cm (Hasani, 2021). DBH had been measured with a calliper at a height of around 1.3 meters from the ground. Individual trees and shrubs with several stems or forks below 1.3 m in height had been evaluated (Sahle and Yeshitela, 2018). It had been measured and average the diameter of each tree and shrub that branches at breast height. On the research sites, vegetation species were identified. For species that could not be recognised in the field, specimens were prepared and brought to Debre Berhan University herbarium.

3.2.2. Soil data collection

To quantify the status of the effectiveness of the vegetative SWC measures, an approach of comparative analysis of the selected soil properties improvement of the vegetative measures was designed for this study. The comparison was made between selected areas with the vegetative measure and with the nearby similar areas where no vegetative measures were available. The treatments had been ordered in a Randomized Completely Block Design (RCBD). A total of 18 (3 slope class x 3 replication x 2 land use category x1 depth (0-30cm)) composite soil samples were taken for analysis. A composite soil sample was prepared from the three positions of sampling plots (Figure 9).

After the most representative vegetation-covered area was identified, three sample areas were demarcated in slope class namely, lower (3–8%), middle (8–15%), and upper (15–30%), this was identified by purposefully leaving out slopes less than 3% with a consideration of these slopes invites minimum erosion (Hurni, 1988). Accordingly, three no vegetation-covered areas in the nearby location with similar other environments (relatively similar soil type, land use and farming practice) had been identified and demarcated. For each of the three replications, soil depth, soil texture, soil organic carbon (SOC), total nitrogen (TN), carbon to nitrogen ratio (C:N), soil pH, available phosphorus (Av-P), cation exchange capacity (CEC), exchangeable base (Na^+ and K^+), Ca and Mg had been analyzed.

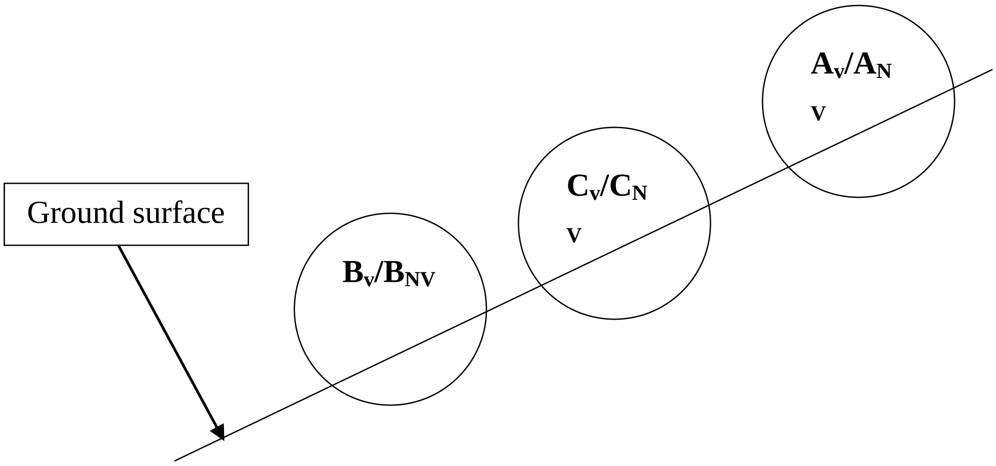

Figure 9. Sampling position of the effectiveness of the vegetative measures

The letters C_V means center of the vegetation, A_V means above the vegetation, and B_V means below the vegetation position. Similarly, the area where there is no vegetative measure has been designated as C_{NV} means center of the no vegetation, A_{NV} means above the no vegetation, and B_{NV} means below the no vegetation position. As a result composite soil was prepared by mixing soil samples from these three positions. Finally, the soil samples were brought to the Debre Berhan Agricultural Research Centre for analysis.

3.3. Methods of data analysis

3.3.1. Vegetation data analysis

In this study, Seedlings were defined as woody plants having a diameter at DBH of less than 2.5 cm and a height of less than 2 m. Saplings were defined as woody plants having a DBH of less than 2.5 cm, but a height of 2 m or greater. And also mature species were defined as woody plants having a DBH greater than 2.5 cm and a height greater than 2 m (Teshager *et al.,* 2018). To examine the population structure of the woody plants all the individuals encountered within the plots were divided into various height and diameter classes (Emiru *et al*., 2002). The density of seedling, sapling, and mature plant species was compared to assess the regeneration status of the watershed's vegetation. This approach allowed for an assessment of the distribution of the woody plant population across different size/age categories, which provides insights into the regeneration patterns and overall dynamics of the vegetation community.

A. Woody species diversity

The most popular criterion for assessing a site's ecological significance has been diversity. The Shannon diversity index is the most effective and popular diversity index (Hasani, 2021). The Shannon diversity index of a species had been used to assess the degree of richness in species and evenness of species distribution (Shannon, 1948). This had been determined as;

$$H' = -\sum_{i=1}^{s} Pi \ln pi \quad (1)$$

$$Pi = \frac{ni}{N} \quad (2)$$

Where: H' = Shannon diversity index, S = total number of species in the sample plot, Pi = the proportion of individuals belonging to the ''i-th species, ni = number of individuals of a species ''i'' and N= Total number of individuals of all species.

Evenness or equitability (measures of species balance) is a measure of how closely the abundances of different species in a given location are identical (Krebs, 1989). The following formula used to calculate evenness:

$$E = \frac{H'}{\ln S} \quad (3)$$

Where: E stands for evenness, H' for Shannon-Wiener diversity index, and S stands for total number of species.

The Jaccard similarity index (J) was used to determine the similarity coefficient between the different land cover types. This index was also used to assess the pattern of species turnover among the various community types in the study area.

The Jaccard similarity index is calculated as follows (Chidumayo, 1997):

Jaccard Similarity Index (J) = c / (a + b + c) (4)

Where:

a = number of species in only community A

b = number of species in only community B

c = number of species common to both communities A and B

This formula provides a quantitative measure of the similarity between two communities based on their shared species composition.

C. Important value index of woody species

The ecological value of woody species was compared using Importance Value Indices (IVI) based on three criteria (relative frequency (RF), Relative abundant (*R*A), and Relative dominance (RD) (Ajayi and Obi, 2016) .

The sum of individuals per species was determined in terms of species density per convenient area unit such as m^2 (Ellenberg *et al.*, 1974).

$$\text{Density of a species} = \frac{\text{The number of individuals of a species}}{\text{Sample Size in m2}} \quad (5)$$

$$\text{Relative abundant} = \frac{\text{No .of individuals of the species}}{\text{Total no .of individuals in all species}} \times 100 \quad (6)$$

Frequency of the species were calculated using plots and expressed as the number of plots occupied by a given species per total number of plots (Hussein and Temesgen, 2021). It is calculated as follows.

$$\text{Frequency of a species} = \frac{\text{Number of plots in which a species occur}}{\text{Total number of plots}} \times 100 \quad (7)$$

$$\text{Relative Frequency} = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} \times 100 \quad (8)$$

The basal area (BA) refers to a measure of the cross-sectional area of a tree or plant stems at a specified height (1.3m) above the ground. It calculated using the following formula and serves as a measure of dominance (Ajayi and Obi, 2016):

$$\text{BA} = \frac{\pi \text{d2}}{4} \quad (9)$$

Where BA = basal area in square meters, d = breast/stump height diameter in metres, and π= 3.14

$$\text{Relative dominance} = \frac{\text{Dominance of a species}}{\text{Total dominance of all species}} \times 100 \quad (10)$$

The significance of value index (IVI) had been generated for each woody species using the formula below.

$$\text{IVI} = \text{RF} + R\text{A} + \text{RD} \quad (11)$$

3.3.2. Soil data analysis

Soil samples were air-dried, crushed, and sifted through a 2 mm mesh sieve for analysis. The selected soil fertility parameters considered in this study were soil depth, soil texture, soil organic carbon (SOC), total nitrogen (TN), carbon to nitrogen ratio (C:N), soil pH, available phosphorus (AP), Cation exchange capacity, exchangeable base (Na^+ and K^+), Ca and Mg.

The soil depth was measured through the excavation of a soil pit; it is a valuable approach for assessing soil quality (Rhoton and Lindbo, 1997). Particle size analysis was determined by Bouyoucos hydrometer method (Bouyoucos, 1962). Soil reaction (pH) was measured in an aqueous soil extract in distilled water (1:2.5 soil: water) using a pH meter (Thomas, 1996). SOC was determined by the Walkley and Black method (Nelson & Sommers, 1982). TN was determined by the Kjeldahl method (Bremner & Mulvaney, 1982). C: N was calculated by dividing the organic carbon by the total soil Nitrogen. Available phosphorus (AP) was determined following the Olsen procedure (Olsen and Dean, 1965). Sodium acetate extract was used to determine the cation exchange capacity (CEC) (Chapman, 1965). Exchangeable potassium (K) and sodium (Na) were determined from the extraction of 1 M ammonium acetate (NH_4OAc) solution buffered at pH 7.0. and read by using flame photometry (Albert *et al*., 1982). Further, calcium and magnesium were determined by EDTA titrations (Tucker and Kurtz, 1961).

3.4. Statistical analysis

Following data collection, vegetation data was coded and organized for analysis. Both descriptive and inferential statistical methods were then employed to analyze the quantitative data. Statistical differences in vegetation data (three sites with three land use categories and three replications/transect lines for each) was analyzed by two-way analysis of variance (ANOVA). Similarly, the selected soil fertility parameter among treatments (protected area and open grazing land) in upper, middle and lower slope class with 0-30 cm of soil depth were tested using two-way analysis of variance (ANOVA). An analysis using Generalised Linear Models (GLMs) with SAS 9.0 statistical software was performed to determine the impact of independent, fixed factors on the response variables. The Least Significant Difference (LSD) at the 0.05 level of significance was used to compare the mean value.

4. RESULTS AND DISCUSSION

4.1. Composition of vegetation in the Bera-Salayish watershed

A total of 125 plant species were identified across the elevation (upper, middle, and lower sites) and land use (agricultural, open grazing and exclosure) categories of the study watershed. Of these 125 species, approximately 59.2% were woody species and 40.8% were herbaceous species. Further analysis revealed that the 74 woody species belonged to 41 families, and were 49 shrub species and 25 tree species. Fabaceae was the most dominant family in woody plant species with 11 (14.86%) species followed by Euphorbiaceae and Lamiaceae with 4(5.41%) species. Anacardiaceae, Apocynaceae, Celastraceae, Myrtaceae and Verbenaceae with 3(4.05%) species were the third dominant families. And also Aloaceae, Asteraceae, Ebenaceae, Oleaceae, Ranunculaceae, Sapindaceae and Tiliaceae were the forth dominant families with 2(2.70%) species. The remaining 26 last ranked families were 1.35% with one species for each (Appendix Table 1).

Moreover, 51 species of herbaceous plant consist of 22 families. The results show that the most dominant family were Poaceae with 9(17.65%), Asteraceae 8(15.69 %) and Cyperaceae 5(9.80%) followed by Lamiaceae 3(5.88%) and the other 18 families were <5% (Appendix Table 1).

4.2. Vegetation structure in upper, middle and lower sites with different land use

A. Herbaceous cover

In the study watershed, there were different herbaceous plant species from the highest cover per plot of *Cynodon dactylon* with 29.82% to the lowest cover of *Merendera schimperiana, Schoenoplectus lacustris, Sporobolus africanus, Phagnalon abyssinicum, Rumex nepalensis and Brassica carinata* with 1.00% (Appendix Table 3). However, the highest cover species have a good restorative impact that helps lessen soil erosion and surface runoff while also promoting the establishment of fertile soil and improving the stability of subsurface soils (Fusun *et al*., 2013). Worldwide there has been an increase in the use of herbaceous vegetation as vegetative barriers to lessen soil erosion from both farm and non-farm fields (Dass *et al*., 2011).

The herbaceous cover per plot did not differ significantly ($p > 0.05$) across the upper, middle, lower sites or land use categories (agricultural, open grazing, exclosure). Conversely, the mean herbaceous cover was relatively higher in the middle site (13.31%) and the exclosure area (13.96%), though the differences were not statistically significant ($p > 0.05$) (Table 5). According to the study by Zisadza-Gandiwa *et al.* (2013), the key reasons why protected areas are relatively higher in herbaceous cover compared to non-protected areas are lower levels of human-caused disturbances like grazing and trampling in the protected areas.

B. DBH and height class distribution

The mean maximum DBH value in the study area was recorded for *Ficus vasta* with an average DBH value of 75.00cm followed by *Ziziphus spina-christi* and *Entada abyssinica* with the average DBH value of 60.00 cm and 26.00 cm, respectively. The least mean DBH were recorded for *Dichrostachys cinerea, Clerodendrum myricoides, Olea europaea etc* with a mean value of 3.00 cm (Appendix Table 4). To generalize, the DBH distribution of Bera-Salayish watershed woody vegetation was classified into five classes (Teshager *et al*., 2018) (Figure 10). The highest number of species was in the ≤5 cm DBH class with 19 (55.88%) number of species. This information indicates that smaller trees or shrubs with a DBH of 5 cm or less contributed the most to the overall species richness. Furthermore, *Eucalyptus camaldulensis, Ziziphus spina-christi*, *Ficus vasta* and *Eucalyptus globulus* with its' height of 24.21m, 20.00m, 20.00m, and 18.25m respectively were the highest mean height of plant species in the study area (Appendix Table 5). Like that of DBH distribution of plant species, the height distribution of plant species also was classified into five classes (Figure 10).

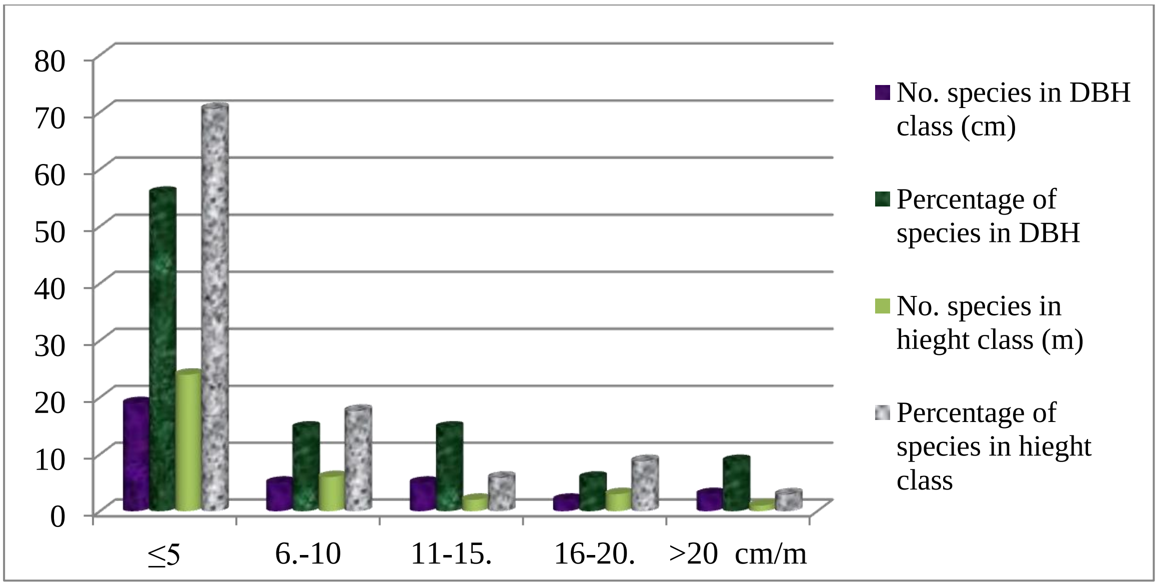

Figure 10. DBH and height class distribution

The old trees are found in the height class over 20 meters, which may be used as an indication of the age of the watershed vegetation (Teshager *et al.*, 2018). According to Agustina and Saputra (2015), plant height has a beneficial effect on the size and distribution of roots, which means that such species have the capacity to conserve the soil and increase soil fertility because of their widespread rooting systems. Large-root trees help to retain a lot of water, prevent erosion, and protect the soil. However, the result suggested that in higher plant height class, there was a lower number of species observed in the study watershed. This indicated that the plant species were recently grown in the study sites and may have shallower-root regarding its height. Beside, soil nutrient and moisture may be unavailable to those shallow-rooted plants. As a result, based on DBH and height of vegetation information, the watershed vegetation has less contribution to nutrient cycling and uptake and also less influence in soil fertility (Abdulahi *et al*., 2016).

The woody plant species DBH was significantly different across the site, with the upper site (12.61 cm) having the largest DBH, followed by the middle site (10.11 cm) and the lower site (4.39 cm). Regarding land use categories, the exclosure area (12.49 cm) had significantly higher DBH compared to the agricultural (7.27 cm) and open grazing (7.34 cm) land use categories (Table 5). These findings indicate that both site and land use have a significant influence on the growth and development of tree/shrub, with the upper site and exclosure area being more favorable for larger tree/shrub diameters in the study area. Tree/shrub height did not differ significantly across the different sites. However, tree/shrub height was significantly taller in the exclosure (7.64 m) and open grazing (6.82 m) land use categories compared to the agricultural land use category (4.26 m) (Table 5). Similarly the previous finding by Zisadza-Gandiwa *et al.* (2013), indicate that the height of shrubs were relatively higher in protected areas. This suggests that the exclosure and open grazing land use categories provide better conditions for the growth and development of taller trees/shrubs compared to the agricultural land use category.

C. Density of seedling, sapling and matured species

The investigation of the vegetation data in the study watershed across elevation and land use categories revealed that the density of mature species was 199.17/ha, saplings was 1759.17/ha, and seedlings were 1557.08/ha (Figure 11). Similarly, the ratio of seedlings to saplings individuals of woody species was 1:1.13, ratio of seedlings to mature individuals was 1:0.13, and sapling to mature individuals was 1:0.11. The vegetation cover of a watershed in number and density of seedlings, saplings and matured plant species indicate the status of regeneration of the plant towards effective ground coverage and other benefits (Tegegne, 2016). Beside, according to Pande *et al*. (2014), it seemed possible that a reverse J-shaped curve in the figure of seedling sapling and matured species distribution indicated good regeneration status. It suggested that the densities of seedlings > densities of saplings > the densities of matured species. In this study, however, because there were not more seedlings than saplings in terms of number and density, the regeneration was not effective. The gap between the seedlings and saplings was recognized since some saplings lack seedling species. This finding implies a need to develop and implement effective vegetation management strategies, as outlined in the Teshager *et al*. (2018) study. Consequently, in order to successfully cover the ground in space and time to conserve soil and water resources in the watershed by vegetative means, the vegetation should be rehabilitated and restored (Zhang *et al.*, 2021).

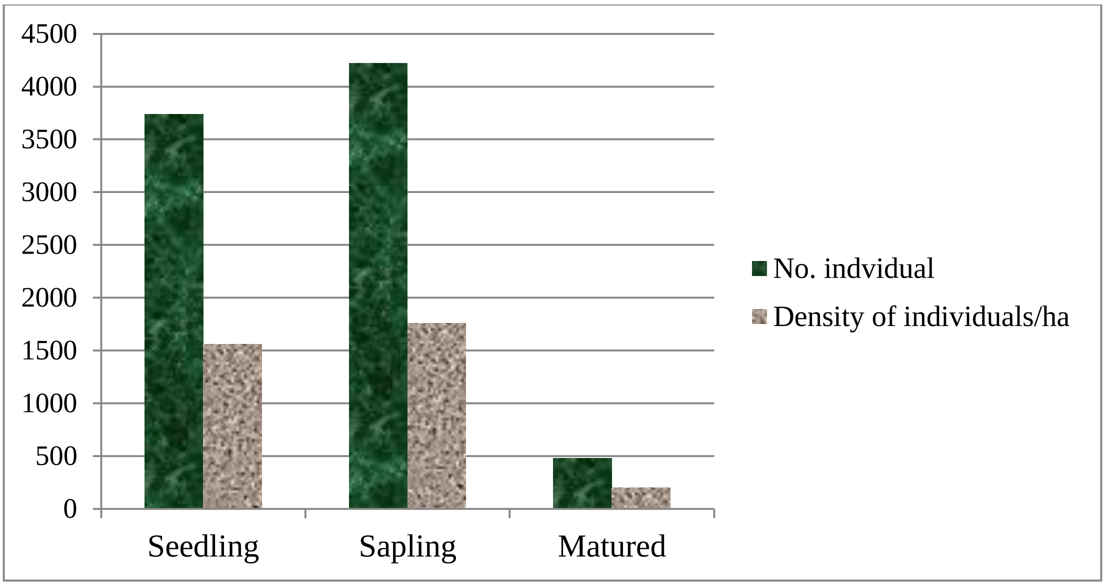

Figure 11. Seedling, sapling and matured woody species distribution in the study area

From the statistical analysis, seedling density was significantly higher (P < 0.001) in the upper site (0.50 seedlings/m2) compared to the middle and lower sites. Seedling and sapling densities were also significantly higher in the open grazing (0.42seedlings/m2, 0.46saplings/m2) and exclosure (0.40 seedlings/m2, 0.41saplings/m2) land use categories compared to the agricultural land use category (Table 5). Similarly, Zisadza-Gandiwa *et al*. (2013) observed higher species densities in protected/exclusion areas compared to more actively used land. Mature tree/shrub density did not differ significantly across the different site or land use categories. The vegetation structure across various types of land uses indicates that habitat loss may be long-term affected by anthropogenic disturbance (Álvarez-Yépiz *et al.,* 2008). In summary, the analysis suggests that site/elevation zone and land use category have significant influences on the vegetation structure, with the upper site and exclosure land use category generally supporting larger tree/shrub diameters, taller tree/shrub, and higher seedling and sapling densities compared to the other sites and land use categories.

Table 5. Attributes of vegetation for sample plots across different land use areas in each site

Factor	**Class**	**Vegetation parameter**					
		Herb. cover/plot	**DBH (cm)**	**Height (m)**	**Seedling density/m 2**	**Sapling density/m 2**	**Matured density/m 2**
Sites	Upper site	12.64^{a}	12.61^{a}	6.96^{a}	0.50^{a}	0.52^{a}	0.01^{a}
	Middle site	13.31^{a}	10.11^{b}	6.41^{a}	0.38^{b}	0.42^{a}	0.02^{a}
	Lower	12.83^{a}	4.39^{c}	5.34^{a}	0.22^{c}	0.24^{b}	0.01^{a}
	p-value	ns	***	ns	***	***	Ns
Land use category	Agricultural	10.94^{a}	7.27^{b}	4.26^{b}	0.28^{b}	0.30^{b}	0.01^{a}
	Open grazing	13.87^{a}	7.34^{b}	6.82^{a}	0.42^{a}	0.46^{a}	0.01^{a}
	Exclosure	13.96^{a}	12.49^{a}	7.64^{a}	0.40^{a}	0.41^{ab}	0.03a
	p-value	ns	**	**	*	*	Ns
	Site*LUC	ns	ns	ns	ns	ns	Ns
	CV %	22.60	25.56	29.67	24.57	28.24	21.69

Overall means followed by the same letter (s) across columns are not significantly different at p >0.05); * = significant at P < 0.05; ** = significant at P < 0.01; *** = significant at P < 0.001 for land use category (LUC) and sites (SC). (ns) = no significant variation

4.3. Diversity, richness, and evenness of vegetation

The results showed a significant difference (p< 0.01) on herbaceous species richness and woody species richness. Both herbaceous and woody species richness significantly higher in the upper site compared to the middle and lower sites. Regarding land use categories, the exclosure area had significantly higher (p< 0.01) and (p< 0.05) herbaceous and woody species richness respectively (Table 6). This finding is similar to the previous study by

Zisadza-Gandiwa *et al.* (2013), where the protected area had higher grass species richness per plot than the communal area.

Woody species evenness did not differ significantly ($p > 0.05$) across the different site or land use categories. This indicates that the distribution of abundance across the woody species was relatively similar across the various site positions and land use types. Woody species diversity, as measured by the Shannon-Weiner diversity index (H'), was significantly higher in the upper site (2.28) compared to the lower site (1.79). However, woody species diversity did not differ significantly across the different land use categories.

According to Kent and Coker (1992), as cited by Tegegne (2016), the Shannon diversity index (H') is commonly used to calculate species diversity and evenness. It typically ranges from 1.5 to 3.5 and rarely exceeds 4.5. Inline with, the results of the present investigation demonstrated that the Bera-Salayish watershed has medium to low species diversity in its upper middle and lower sites. According to Agustina and Saputra (2015), Shannon-Wiener index illustrates the richness (number of species) and evenness (distribution) of the species in a given area. The distribution and diversity of species in an area are higher with a higher H' value. Fachrul (2007) explained the basis for the interpretation, which states that: 1) a value of $H' > 3$ indicates a high diversity; 2) a value of H', $1 \leq H' \leq 3$ shows medium diversity; and 3) a value of $H' < 1$ specifies low diversity. Sharma (2009) explains that habitat types with a higher species diversity index are probably those with a higher species number and distribution.

In general, upper and middle sites had the medium vegetation diversity index, whereas lower sites had lower vegetation diversity index. In the three sites of observation, this is closely associated with environmental factors. That means, variations in the environmental conditions can have an impact on the lives of vegetation (Sharma, 2009). Addtionally, the diversity and composition of the vegetation in the Bera-Salayish watershed can be used as indicators of the watershed's sustainability, particularly with regard to soil and water conservation. By increasing the amount of vegetation cover, land degradation can be minimized. This practice is crucial to prevent the loss of soil nutrients, which lowers the volume and speed of water flowing over the soil (Senbeta et al., 2014).

Table 6. Effect of elevation zone/site and land use category on vegetation diversty

Factor		Vegetation parameter			
		Herb. R	**R**	**E**	**H'**
Sites	Upper site	14.44^{a}	18.00^{a}	0.84^{a}	2.28^{a}
	Middle site	10.55^{b}	11.77^{b}	0.80^{a}	2.13^{a}
	Lower	8.66^{b}	9.22^{b}	0.79^{a}	1.79^{b}
	p-value	**	**	ns	**
Land use category	Agricultural	7.44^{b}	11.22^{b}	0.82^{a}	1.96^{a}
	Open grazing	7.88^{b}	12.00^{b}	0.81^{a}	2.08^{a}
	Exclosure	10.22^{a}	15.77^{a}	0.79^{a}	2.16^{a}
	p-value	**	*	ns	Ns
	Site*LUC	ns	ns	ns	Ns
	CV %	20.82	23.45	7.77	10.03

Where, Herb.R= herbaceous species richness, R =Shannon richness of woody species, E = Shannon evenness of woody species and H' = Shannon-Weiner diversity index of woody species. Overall means followed by the same letter (s) across columns are not significantly different at p >0.05); * = significant at P < 0.05; ** = significant at P < 0.01; *** = significant at P < 0.001 for land use category (LUC) and sites (SC). (ns) = no significant variation

4.4. Jaccard coefficient of species similarity

The similarity in species composition across the three sites and land use categories within the watershed was calculated using the Jaccard's coefficient of similarity. The results showed that the upper and middle sites had a 64% similarity in woody species composition. The similarity was lower between the upper and lower sites, at 51%. Meanwhile, the middle and lower sites exhibited a 67% similarity. In contrast, the land use categories showed a higher degree of similarity. Between the agricultural and open grazing land areas, the similarity was 76%. For the agricultural and exclosure land, the similarity was 68%. The open grazing land and exclosure land had a 63% similarity. These findings indicate that the woody species composition had a significant overlap between the geographically closer upper and middle sites, as well as the middle and lower sites. Furthermore, the land use types exhibited a higher degree of similarity in their woody plant communities, likely due to the shared environmental conditions and management practices associated with each land use (Hussein and Temesgen, 2021).

4.5. Important value index (IVI) of species

The number of species making up the watershed in three observation sites is presented in Tables 7. Comparing the ecological relevance of a particular species is crucial. As a result, IVI is a useful index for classifying species in order of importance for management and conservation strategies and summarizing vegetation characteristics (Tegegne, 2016).

At upper and middle study sites, *Euclea racemosa* revealed the highest 'RA%' and 'RF%' (Table 7) and are found to be the dominant species with a greater numerical abundance and occurrence in sampling plots compared to other species. The species *Olea europaea* and *Faidherbia albida* revealed the lowest value of 'RA%' 'RF%' and 'RD%' in upper and middle sites respectively, and had lowest impact on the watershed processes and functions (Gaury and Devi, 2017). At lower sites, *Ziziphus spina-christi* plant species have the highest value of 'RF%' and 'RD%' but lowest 'RA%' from other species. *Ziziphus spina-christi species* was found at a lower site of the watershed with less number of individuals per area but it has significant ecological value with its highest IVI relative to others.

Based on their IVI value, *Euclea racemosa* (27.56), *Carissa spinarum* (24.49), *Eucalyptus camaldulensis* (18.10), *Calpurnia aurea* (17.53), *Buddleja polystachya*(16.50), *Eucalyptus globulus* (16.43), *Juniperus procera* (16.23), and *Osyris quadripartite* (15.14), respectively were the dominant woody species in the upper Bera-Salayish watershed, with the highest IVI and ecological significance (Nigatu *et al.,* 2019). Further, in the middle site the dominant species were *Euclea racemose* (100.28), *Ficus vasta* (90.97), *Carissa spinarum* (35.04) and *Anogeissus leiocarpa* (32.88). And also *Ziziphus spina-christi* (85.75), *Anogeissus leiocarpa* (76.00), *Entada abyssinica (*62.61) and *Faidherbia albida* (32.29) were the dominant species in lower site respectively. As a result those plants with the highest Important Value Index (IVI) can be used for vegetative soil and water conservation (Agustina and Saputra, 2015). Those species have the potential to conserve soil moisture and decrease water evaporation from the soil. In that the majority of vegetation's beneficial effects on soil quality are directly related to soil moisture retention (Gachene *et al*., 2019).

Table 7. IVI of woody species found in the upper, middle and lower sites of the watershed

Species name	RA%	RF%	RD%	IVI
		Upper site		
Acacia decurrens	0.03	0.80	9.43	10.25
Acacia saligna	0.13	2.40	6.37	8.90
Albizia gummifera	1.90	1.20	2.92	6.03
Allophylus abyssinicus	2.33	1.60	0.85	4.78
Bersama abyssinica	0.11	0.80	1.12	2.03
Buddleja polystachya	12.94	1.60	1.96	16.50
Calpurnia aurea	4.36	12.00	1.17	17.53
Carissa spinarum	11.76	11.60	1.13	24.49
Clerodendrum myricoides	0.48	0.80	0.49	1.77
Croton macrostachyus	3.01	5.20	3.20	11.41
Dichrostachys cinerea	1.39	0.40	0.49	2.28
Dodonea angustifolia	9.15	3.20	0.87	13.22
Eucalyptus camaldulensis	2.81	3.20	12.09	18.10
Eucalyptus globulus	0.29	2.80	13.34	16.43
Euclea racemosa	12.96	13.60	1.00	27.56
Euphorbia tirucalli	3.32	0.40	7.85	11.57
Faidherbia albida	4.38	2.40	7.16	13.95
Grewia ferruginea	2.00	2.40	0.67	5.07
Jacaranda mimosifolia	1.93	0.80	1.66	4.39
Juniperus procera	0.09	0.40	15.74	16.23
Maytenus arbutifolia	3.17	5.60	1.74	10.51
Maytenus gracilipes	6.88	3.60	0.69	11.17
Maytenus obscura	0.17	0.40	1.10	1.67
Olea europaea	0.03	0.40	0.49	0.92
Osyris quadripartita	5.21	8.80	1.13	15.14
Rhus glutinosa	2.15	4.40	1.57	8.12
Rhus natalensis	4.23	6.40	0.93	11.56

Senna singueana	2.57	2.40	0.87	5.85
Syzygium cumini	0.20	0.40	1.96	2.56
Total	100.00	100.00	100.00	300.00
Middle site				
Anogeissus leiocarpa	13.21	13.89	5.78	32.88
Carissa spinarum	18.25	16.67	0.13	35.04
Croton macrostachyus	2.79	13.89	0.92	17.60
Eucalyptus globulus	0.41	2.78	9.76	12.95
Euclea racemosa	63.81	36.11	0.36	100.28
Faidherbia albida	0.14	8.33	1.80	10.27
Ficus vasta	1.40	8.33	81.24	90.97
Total	100.00	100.00	100.00	300.00
Lower site				
Acacia etbaica	4.97	17.65	0.42	23.03
Anogeissus leiocarpa	46.22	17.65	12.14	76.00
Dichrostachys cinerea	8.39	11.76	0.15	20.31
Entada abyssinica	32.49	17.65	12.48	62.61
Faidherbia albida	5.57	11.76	14.96	32.29
Ziziphus spina-christi	2.37	23.53	59.85	85.75
Total	100.00	100.00	100.00	300.00

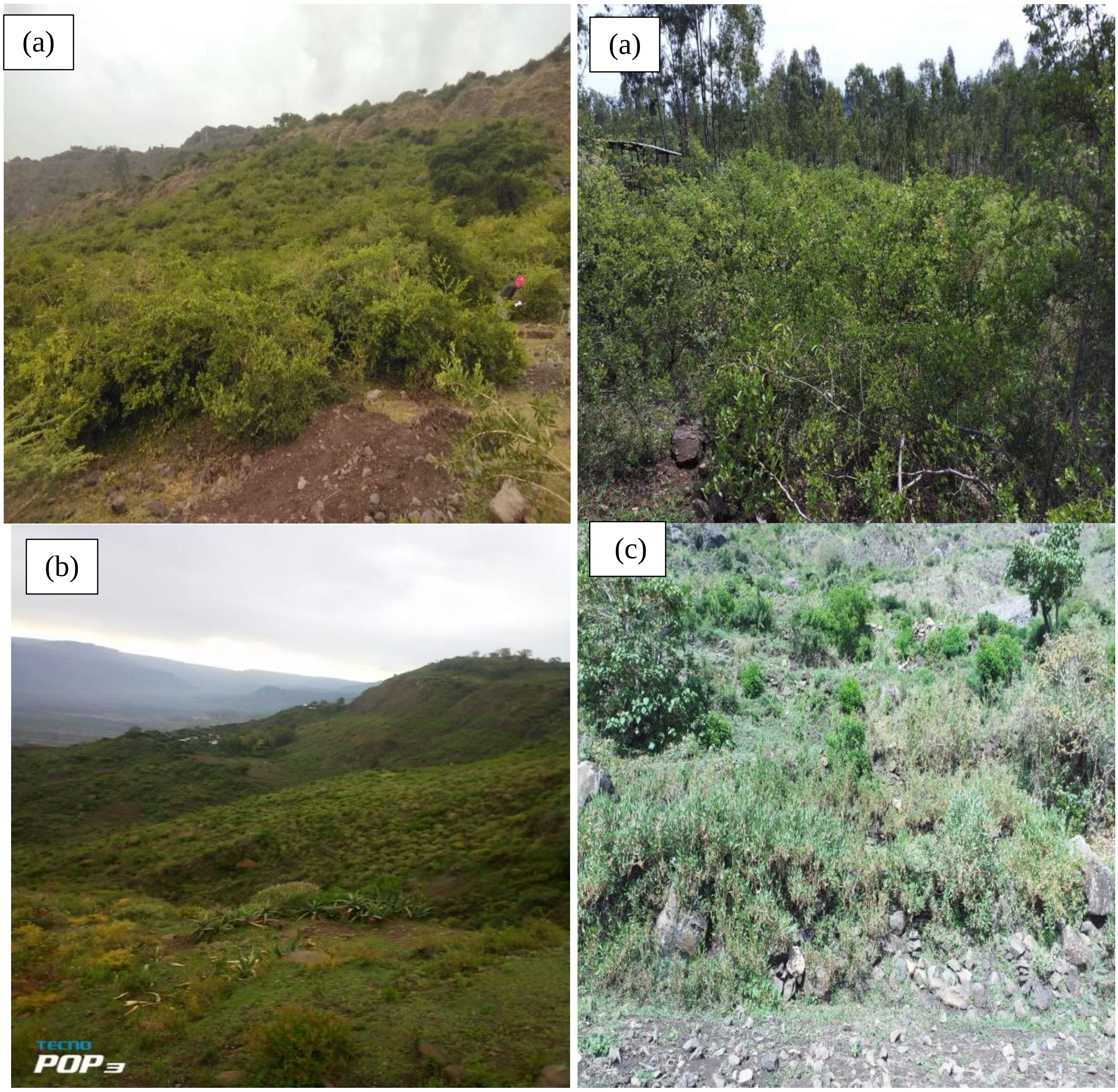

Figure 12. Some areas (a= upper site, b= middle site & c= lower site) of Bera-Salayish watershed (Photo by researcher, May, 2023 G .C).

4.6. Effectiveness of vegetative measure on soil properties

Ecosystems cannot survive or recover from disruptions without healthy or high-quality soils (Kamal *et al*., 2023). Understanding the relationships between vegetation and soil properties is crucial for developing effective soil conservation strategies through vegetative measure. Given that the main aim of the study was to examine the influence of vegetation on selected soil physicochemical parameters across different slope classes within the watershed.

4.6.1. Soil depth and soil texture in relation to land use category (LUC) and slope class

The results of soil physical properties are presented in Table 8. There were no significant differences in the sand, silt, and clay percentages between the exclosure and open grazing land. Both the exclosure and open grazing land had a Clay Loam (CL) textural class. Further, sand and clay show significant variation with slope class. The upper slope had significantly higher sand content (56.00%) compared to the lower (35.66%) and middle (36.66%) slopes. This result coincides with the report of Khan *et al*. (2013) and Magdić *et al*. (2022) with the implication that silt particles are more susceptible to moving down a slope than coarser particles. One possible explanation for the high sand content in upper slope class is the selective nature of soil erosion, which removes small particles from the soil and leaves behind coarse sand particles (Schoonover and Crim, 2015). The upper slope had a Sandy Loam (SL) textural class, while the lower and middle slopes were Clay Loam (CL).

The exclosure area had significantly greater soil depth compared to the open grazing land. The interaction between land use category and slope class was significant for soil depth, indicating that the effect of land use on soil depth was influenced by the slopes. The mean value of soil depth was significantly higher in exclosure area than open grazing land. Vegetation in exclosure area contributes to the accumulation of organic matter in the soil, which in turn promotes soil development to a deeper soil layer (Abdulahi *et al.*, 2016). This contribution of vegetation is through its roots, stems, leaves, and fallen plant materials. Further, in lower and middle slopes soil depth mean values were significantly higher than upper slopes. Erosion can remove the topsoil layer and reduce soil depth. As a result, the upper slopes tended to have shallower soil depths compared to the lower and middle slopes. Deeper soils have a greater capacity to store and infiltrate water, reducing the risk of surface runoff and erosion. This is because deeper soils have a larger pore space and a more developed soil structure, which allows for greater water storage and infiltration rates (Smith *et al*., 2020). As a result, the vegetation on soil depth showed a positive effect towards soil and water conservation. The CV% values ranged from 8.07% for soil depth to 23.76% for clay content, suggesting moderate to high variability in the soil properties (soil depth and soil textural fraction) measured.

Table 8. Effect of land use category and slope class on soil depth and soil texture

Factors	Attribute of factors	Soil depth (cm)	Particle size distribution (%)			Textural class
			Sand	Silt	Clay	
Land use category	Exclosure	26.55[a]	45.55[a]	18.66[a]	41.55[a]	CL
	Open grazing land	23.66[b]	40.00[a]	18.44[a]	35.77[a]	CL
	p-value	*	ns	ns	ns	
Slope class	Lower	27.50[a]	35.66[b]	20.66[a]	45.33[a]	CL
	Middle	25.33[a]	36.66[b]	18.00[a]	43.66[a]	CL
	Upper	22.50[b]	56.00[a]	17.00[a]	27.00[b]	SL
	p-value	**	***	ns	**	
	LUC*SC	*	ns	ns	ns	
	CV %	8.07	16.00	23.76	18.39	

Overall means followed by the same letter (s) across columns are not significantly different at p >0.05); * = significant at P < 0.05; ** = significant at P < 0.01; *** = significant at P < 0.001 for land use category (LUC) and slope class (SC). CL=clay loam, SL= sandy loam, (ns) = no significant variation

4.6.2. Soil pH, SOC, TN, C: N and Av-p in relation to the land use types and slope class

There was no significant difference in soil pH between the exclosure and open grazing land, in both area pH values were found within neutral pH rating (Hazelton and Murphy, 2016). The lower slope had significantly higher pH (7.80) compared to the middle (6.49) and upper (6.34) slopes (Table 9). This result was in agreement with Rezaei and Gilkes (2005) in that, the runoff water that comes from the upper slopes may have led to increased leaching and a decrease in soluble base cations, which caused higher H^+ activity and lower pH values in the soil at the upper and middle slopes.

The exclosure area had significantly higher SOC (1.66%) compared to the open grazing land (0.79%) (Table 9). In agreement with this study, significantly higher SOC was measured in the exclosure as compared to the open grazing land by Abay *et al*. (2020). Because of unrestricted grazing by livestock and human vegetation clearance, which may have exposed soil materials to erosion, there may be a decreased SOC and SOC stock in the grazing field

(Itanna *et al.,* 2011). Besides, Gebreselassie *et al.* (2009) also reported that the SOC of the no-vegetation area was significantly lower than that of the vegetated area. This is also supported by the fact that plant residues are the main supplier of soil organic matter, the distribution of soil organic carbon is determined by the context of vegetation (Rezaei *et al*., 2015). Moreover, the lower (1.46%) and middle (1.57%) slopes had significantly higher SOC compared to the upper slope (0.65%). A higher mean value of SOC in the lower position is due to the downward movement of runoff water from the upper slope and accumulated there (Khan *et al*., 2013). The higher SOC levels are associated with improved soil structure, water-holding capacity, nutrient availability, and cation exchange capacity (Lal, 2016). These qualities contribute to soil fertility, which are essential for sustaining soil and water resources.

The exclosure area had significantly higher TN (0.24%) compared to the open grazing land (0.14%) (Table 9). This could be due to the nitrogen fixation property of the plant species in exclosure area which have a direct impact on the soil TN. As indicated by Yimer *et al*. (2015), the greater TN content in the exclosure is the result of higher soil organic matter content and the presence of leguminous plants which have the potential to fix nitrogen from the atmosphere through the roots' nodules. The lower slope (0.34%) had significantly higher TN compared to the middle (0.13%) and upper (0.10%) slopes. The result agrees with the finding of Khormali *et al*. (2007), as total nitrogen showed a similar trend across slopes as SOC. The lower slope receives a greater accumulation of organic matter due to lower prevalence of soil erosion and high biomass production (Dagnachew *et al.*, 2020).

There was no significant difference in the C:N ratio between the exclosure and open grazing land. However, the their was relatively lower carbon to nitrogen ratio in open grazing land relative to the exclosure, it could result from the addition of cow dung, which is higher with total nitrogen, and the low amount of organic matter that accumulate through the litter fall from growing grasses and bushes (Yimer *et al*., 2015). The C:N ratio did not differ significantly across the slope classes.

Available phosphorus (Av-P) was significantly higher in the exclosure (29.38 ppm) compared to the open grazing land (15.49 ppm) (Table 9). Sharma (2009) also argued that available phosphorus is significantly available in vegetative-covered areas. This might be because the conserved areas with vegetation exhibit larger organic matter content than the non-vegetated ones (Hailu *et al*., 2012). Moreover, Av- P was significantly higher in the lower and middle slope classes compared to the upper slope class. It is due to the upper slope class may have reduced as a result of erosion hazards and a decrease in the organic matter content of the soil (Khan *et al*., 2013).

Generally, the exclosure area had significantly higher SOC, TN, and Av. P compared to the open grazing land, likely due to the absence of disturbance and increased organic matter inputs. Soil properties generally improved (higher pH, SOC, TN, Av. P) in the lower and middle slope classes compared to the upper slope class, reflecting the influence of topography and associated processes.

Table 9. Effect of land use category and slope class on soil pH, SOC, TN, C: N and Av-p

Factors	**Attribute of factors**	**pH(1:2.5)**	**SOC (%)**	**TN (%)**	**C: N (%)**	**Av. P (ppm)**
Land use category	Exclosure	6.96[a]	1.66[a]	0.24[a]	10.65[a]	29.38[a]
	Open grazing land	6.79[a]	0.79[b]	0.14[b]	5.70[a]	15.49[b]
	p-value	ns	***	*	ns	**
Slope class	Lower	7.80[a]	1.46[a]	0.34[a]	6.82[a]	34.25[a]
	Middle	6.49[b]	1.57[a]	0.13[b]	9.36[a]	28.67[a]
	Upper	6.34[b]	0.65[b]	0.10[b]	8.34[a]	4.40[b]
	p-value	***	***	**	ns	***
	LUC*SC	ns	ns	ns	ns	Ns
	CV %	7.70	25.74	29.70	26.55	24.99

Overall means followed by the same letter (s) across columns are not significantly different at p >0.05); * = significant at P < 0.05; ** = significant at P < 0.01; *** = significant at P < 0.001 for land use category (LUC) and slope class (SC). (ns)= no significant variation

4.6.3. CEC and exchangeable bases (K^+, Na^+, Ca^{2+} and Mg^{2+}) in relation to the land use category and slope class

Cation exchange capacity (CEC) did not differ significantly (p> 0.05) between the exclosure and open grazing land and slope class (Table 10). The numerical differences among slopes were very small but relatively higher mean value was observed in the exclosure area than in the open grazing land. This is possibly due to the higher concentration of soil organic carbon in the exclosure areas (Yimer *et al*., 2008). Organic matter contains negative charge that can attract and retain cations leading to increase the overall CEC of the soil. As a result, soils enriched with organic matter often exhibit higher CEC values (Rezaei *et al*., 2015). Overall, soils with higher CEC levels tend to have better soil structure, which improves water infiltration, reduces surface runoff, and enhances the soil's resistance to erosion (Berhe *et al*., 2018). This is especially important in vegetation areas where soil conservation is a priority, as it helps prevent the loss of valuable topsoil and nutrients (Turrión *et al*., 2007). Additionally, the ability of soils with higher CEC to retain and supply essential plant nutrients helps to maintain soil fertility, even in the face of nutrient losses through leaching, erosion, or plant uptake (Havlin *et al*., 2016). Therefore, in this study CEC showed relatively higher value in vegetation covered/exclosure areas since vegetation contributes to the overall soil fertility and sustainability, which is crucial for soil and water conservation.

Exchangeable K^+, Na^+ and Mg^{2+} showed significant variations with the exclosure and open grazing land; higher mean value of ex. K^+ and Mg^{2+} in the exclosure area whereas higher mean value of Na^+ in open grazing land. The total mean value of Ca^{2+} was relatively high in exclosure area and lower slope but it didn't show significant variation (Table 10). This is attributed to the process of breakdown and release of K^+, Ca^{2+} and Mg^{2+} to the soil accelerated through the increased microbial activity in the soil due to the presence of organic materials in areas with vegetation cover (Khan *et al*., 2013). Soil exchange properties did not vary significantly across the different slope classes, suggesting that slope class may not be a major driver of these soil characteristics in the study area.

Generally, other base cations except the exchangeable Na^+ overall mean value in exclosure area were higher than open grazing land; also its variation was significant except Ca^{2+}. The increased levels of these key cations suggest that vegetation improves soil quality and effective soil and water conservation.

Table 10. Effect of land use category and slope class CEC and Exchangeable bases (K+, Na+, Ca2+ and Mg2+)

Factors	**Attribute of factors**	**CEC(meq/100g)**	**ex.K (cmol/ kg)**	**ex.Na (cmol/ kg)**	**Ca(meq/100g)**	**Mg(meq/100g)**
Land use category	Exclosure	71.23^a	1.54^a	0.25^b	45.21^a	25.58^a
	Open grazing land	58.99^a	0.90^b	0.70^a	41.90^a	18.91^b
	p-value	ns	**	*	ns	*

Slope class	Lower	69.26 [a]	1.43 [a]	0.53[a]	47.66 [a]	25.35 [a]
	Middle	64.47 [a]	1.12 [a]	0.50[a]	42.90 [a]	21.60 [a]
	Upper	61.59 [a]	1.10 [a]	0.40[a]	40.10 [a]	19.80 [a]
	p-value	ns	ns	ns	ns	Ns
	LUC*SC	ns	ns	ns	ns	Ns
	CV %	23.79	27.73	26.78	14.18	22.58

Overall means followed by the same letter (s) across columns are not significantly different at p >0.05); * = significant at P < 0.05; ** = significant at P < 0.01; *** = significant at P < 0.001 for land use category (LUC) and slope class (SC). (ns)= no significant variation

4.6.4. Correlation of soil quality indicator

The strong negative correlation between sand and organic carbon (OC) (r = -0.695, p<0.01) indicates that soils with higher sand content tend to have lower organic matter (Table 11**)**. Conversely, the positive correlation between clay and OC (r = 0.630, p<0.01) suggests that soils with higher clay content are associated with higher organic matter. This implies that soil texture plays a significant role in the accumulation and retention of organic matter in the soil. Moreover, the positive correlation between TN and Av-P (r = 0.776, p<0.01) suggests that soils with higher TN also have higher Av-P. This indicates a generally good soil fertility status (Abay *et al*., 2020). Exchangeable K^+ also shows positive correlations with TN (r = 0.739, p<0.01) and Av-P (r = 0.578, p<0.05), further supporting the notion of overall soil fertility (Table 11).

The negative correlation between CEC and exchangeable Na^+ (r = -0.492, p<0.05) implies that soils with higher CEC tend to have lower exchangeable Na^+. This is a desirable characteristic, as high Na^+ can lead to soil degradation. The positive correlation between CEC and exchangeable Mg^{2+} (r = 0.478, p<0.05) indicates that soils with higher CEC also have higher Mg^{2+} availability, which is an essential nutrient for plant growth. These findings provide a comprehensive understanding of the relationships between various soil properties and their implications for soil quality and fertility.

Table 11. Pearson correlations for soil quality indicators (* Correlation is signifcant at the 0.05 level, ** Correlation is significant at the 0.01 level)

	Soil depth	Sand	Clay	Silt	OC	TN	C:N	Soil pH	Av-P	CEC	K+	Na+	Ca	Mg
Soil depth	1													
Sand	-0.187	1												
Clay	0.095	-.932**	1											
Silt	0.274	-0.388	0.027	1										
OC	0.339	-.695**	.630**	0.314	1									
TN	0.386	-0.334	0.233	0.328	0.424	1								
C:N	0.111	-0.269	0.249	0.108	.512*	-0.452	1							
Soil Ph	0.208	-0.355	0.277	0.274	0.061	.709**	-.530*	1						
Av- P	0.192	-.697**	.675**	0.206	.734**	.776**	-0.145	0.462	1					
CEC	0.169	-0.288	0.444	-0.332	0.139	0.234	-0.015	0.141	0.295	1				
K+	0.244	-0.245	0.131	0.342	0.449	.739**	-0.07	0.359	.578*	0.34	1			
Na+	-.631**	-0.012	-0.01	0.059	-0.245	-0.367	0.033	0.003	-0.242	-.492*	-.501*	1		
Ca	.585*	-.581*	0.456	0.442	.476*	0.299	0.287	0.172	0.337	0.144	0.131	-0.161	1	
Mg	0.006	-0.339	0.405	-0.095	0.363	-0.048	0.455	-0.241	0.256	.478*	0.366	-0.253	0.102	1

5. CONCLUSION AND RECOMMENDATIONS

The study conducted in the Bera-Salayish watershed identified a total of 125 plant species, with 59.2% being woody species (49 shrub and 25 tree species) and 40.8% being herbaceous species. Fabaceae and Poaceae were the most dominant woody and herbaceous families, respectively. The herbaceous cover did not differ significantly across the upper, middle, lower sites or land use categories, with the middle site and exclosure area having relatively higher herbaceous cover. The DBH and height distribution showed the highest number of species in the ≤5 cm/m class, indicating that smaller trees or shrubs contributed the most to the overall species richness. The analysis suggests that elevation and land use categories have significant influences on the vegetation structure, with the upper site and exclosure land use category generally supporting larger tree/shrub diameters, taller trees/shrubs, and higher seedling and sapling densities compared to the other sites and land use categories. However, the regeneration of the vegetation is not effective, as the density of seedlings is not higher than the density of saplings, indicating a need to develop and implement effective vegetation management strategies to rehabilitate and restore the vegetation in order to successfully cover the ground and conserve the soil and water resources in the watershed.

The study found significant differences in plant species richness across the watershed. The upper site had notably higher herbaceous and woody species richness compared to the middle and lower sites, and the exclosure area exhibited greater herbaceous and woody species richness compared to the agricultural and open grazing land use categories. However, woody species evenness did not differ significantly across sites or land use types. The Shannon-Weiner diversity index indicated medium to low species diversity, with the upper site having significantly higher woody species diversity than the lower site. Similarity analysis showed greater overlap in woody species composition between geographically closer sites, as well as higher similarity among the different land use types. The important value index analysis identified dominant woody species, with *Euclea racemosa*, *Carissa spinarum*, and *Ziziphus spina-christi* emerging as key species. These findings highlight the relationship between environmental conditions, land management, and vegetation diversity and composition within the Bera-Salayish watershed, with implications for soil and water conservation efforts.

The results of the study indicate that the exclosure area had significantly higher SOC, TN and Av-P compared to the open grazing land, likely due to the absence of disturbance and increased organic matter inputs in the exclosure. Soil properties generally improved (higher soil depth, pH, SOC, TN, Av-P) in the lower and middle slope classes compared to the upper slope class, reflecting the influence of topography and associated processes. CEC did not differ significantly between the exclosure and open grazing land or across slope classes, but the exclosure area showed relatively higher CEC values, potentially due to the higher concentration of SOC. Exchangeable K^+, Mg^{2+}, and Na^+ showed significant variations between the exclosure and open grazing land, with higher mean values of K^+ and Mg^{2+} in the exclosure. The strong negative correlation between sand and SOC, along with the positive correlation between clay and SOC, suggests that soil texture plays a significant role in the accumulation and retention of organic matter. Additionally, the positive correlations between TN and Av-P, as well as between exchangeable K^+ and TN and Av-P, indicate a generally good soil fertility status. Furthermore, the negative correlation between CEC and exchangeable Na^+, and the positive correlation between CEC and exchangeable Mg^{2+}, demonstrate desirable characteristics for soil quality and fertility. These findings provide a comprehensive understanding of the relationships between various soil properties and their implications for soil and water conservation in the studied watershed.

Based on the research findings, the following recommendations are made to enhance ongoing conservation efforts and reduce the risks of land degradation in the Bera-Salayish watershed:

- Develop and implement effective vegetation management strategies to rehabilitate and restore the vegetation cover in the watershed. This could involve measures such as controlled grazing, tree planting, and promoting natural regeneration.

- Expand the exclosure areas to improve soil fertility and quality, as the study showed higher soil depth, SOC, TN, Av-P, K^+ and Mg^{2+} in the exclosure areas compared to the open grazing lands. Beside, adopt sustainable land management practices, such as contour farming, terracing, and agroforestry, to conserve soil and water resources, considering the influence of topography (slope) on soil properties

- Conduct further research to understand the complex interactions between soil and vegetation, which could provide valuable insights to guide the development of more effective land management practices. Further, encourage the adoption of integrated watershed management approaches to address the interplay between soil, vegetation, and land use, and optimize the use of natural resources in the study region.

6. REFERENCES

Abay, K., Tewolde-Berhan, S., & Teka, K. (2020). The effect of exclosures on restoration of soil properties in Ethiopian lowland conditions. *SN Applied Sciences*, *2*, 1-12.

Abdulahi, M. M., Ebro, A., & Nigatu, L. (2016). Impact of woody plant species on soil physio-chemical properties along grazing gradients in rangelands of Eastern Ethiopia. *Tropical and Subtropical Agroecosystems*, *19*(3).

Abinet, T. (2011). The Impact of area enclosure on soil quality and farmers' ‘perception: The case of Tachignaw Gimbichu enclosure in Shashogo Woreda, Southern Ethiopia M.Sc. thesis. Addis Ababa, Ethiopia: Addis Ababa University.

Abiye, W. (2022). Soil and Water Conservation Nexus Agricultural Productivity in Ethiopia. *Advances in Agriculture*, *2022*, 1–10. https://doi.org/10.1155/2022/8611733

Adimassu, Z., Langan, S., Johnston, R., Mekuria, W., & Amede, T. (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*, *59*(1), 87–101. https://doi.org/10.1007/s00267-016-0776-1

Adugna, O. (2019). Evaluation of Vetiver Grass (Vetiver zizanodes) Potential to Soil Erosion Control at Assosa, Benishangul Gumuz, Ethiopia. *International Journal of Environmental Sciences & Natural Resources*, *16*(1). https://doi.org/10.19080/IJESNR.2019.16.555930

Agustina, P., & Saputra, A. (2015). Potential vegetation for soil and water conservation*:* case study in Samin Watershed, *Central Java*.

Ahmad, F., Goparaju, L., Qayum, A., Vindhyan Ecology and Natural History Foundation, Mirzapur, Uttar Pradesh, India, & Department of Environment and Forest, Govt. of Arunachal Pradesh, Itanagar, India. (2017). Agroforestry suitability analysis based upon nutrient availability mapping: A GIS based suitability mapping. *AIMS Agriculture and Food*, *2*(2), 201–220. https://doi.org/10.3934/agrfood.2017.2.201

Ajayi, S, & Obi, R. L. (2016). Tree Species Composition, Structure and Importance Value Index (IVI) of Okwangwo Division, *Cross River National Park, Nigeria*. *5*(12).

Albert, L., Miller, R., & Keeney, D. (1982). *METHODS OF SOIL ANALYSIS Part 2 , Second Edition*. *Chemical and Microbiological Properties*.

Álvarez-Yépiz, J. C., Martínez-Yrízar, A., Búrquez, A., & Lindquist, C. (2008). Variation in vegetation structure and soil properties related to land use history of old-growth and secondary tropical dry forests in northwestern Mexico. *Forest Ecology and*

Management, *256*(3), 355-366.

Anteneh, A. (2022). Review on the role of soil and water conservation practices on soil properties improvement in Ethiopia. *International Journal of Agricultural Science and Food Technology*, *8*(3), 225–231. https://doi.org/10.17352/2455-815X.000168

Arora, S., Bhatt, R., Sharma, V., & Hadda, M. S. (2022). Indigenous Practices of Soil and Water Conservation for Sustainable Hill Agriculture and Improving Livelihood Security. Environmental Management, 1. https://doi.org/10.1007/s00267-022-01602-1

Asfaw A (2022). Review on the role of soil and water conservation practices on soil properties improvement in Ethiopia. Int J Agric Sc Food Technol 8(3): 225-231. DOI: https://dx.doi.org/10.17352/2455-815X.000168.

Austin, K. G., Schwantes, A., Gu, Y., & Kasibhatla, P. S. (2019). What causes deforestation in Indonesia? *Environmental Research Letters*, *14*(2), 024007. https://doi.org/10.1088/1748-9326/aaf6db

Barbier, E. B., & Hochard, J. P. (2018). Land degradation and poverty. *Nature Sustainability*, *1*(11), 623–631. https://doi.org/10.1038/s41893-018-0155-4

Bartnik, A. (2013). Hydrological Effects of Urbanization: the Experience from the Sokołówka Catchment (Łódź). European Spatial Research and Policy, 20(2), 113-131.

Berhe, A. A., Barnes, R. T., Six, J., & Marín-Spiotta, E. (2018). Role of soil erosion in biogeochemical cycling of essential elements: carbon, nitrogen, and phosphorus. *Annual Review of Earth and Planetary Sciences*, *46*, 521-548.

Borrelli, P., Robinson, D. A., Fleischer, L. R., Lugato, E., Ballabio, C., Alewell, C., Meusburger, K., Modugno, S., Schütt, B., Ferro, V., Bagarello, V., Oost, K. Van, Montanarella, L., & Panagos, P. (2017). An assessment of the global impact of 21st century land use change on soil erosion. *Nature Communications*, *8*(1). https://doi.org/10.1038/s41467-017-02142-7

Borsali, S., Baaloudj, A., & Kerfouf, A. (2017). Ukrainian Journal of Ecology. *Ukrainian Journal of Ecology*, *7*(2), 96–103.

Bouyoucos, G. J. (1962). Hydrometer Method Improved for Making Particle Size Analyses of Soils1. *Agronomy Journal*, *54*(5), 464–465. https://doi.org/10.2134/agronj1962.00021962005400050028x

Bremner, J. M., & Mulvaney, C. S. (1982). Nitrogen-Total. In A. L. Page, R. H. Miller, & D.

R. Keeney (Eds.), *Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties* (2nd ed., pp. 595–624). ASA, SSSA. https://doi.org/10.2136/sssabookser5.3.c37

Chandra, L. R., Gupta, S., Pande, V., & Singh, N. (2016). Impact of forest vegetation on soil characteristics: A correlation between soil biological and physico-chemical properties. *Biotech*, *6*(2), 188. https://doi.org/10.1007/s13205-016-0510-y

Chapman,H. D.. (1965). "Cation Exchange Capacity". In: Black, C.A. (ed.), Methods of Soil Analysis. Agronomy 9, American Society of Agronomy. Inc., Madison, Wisconsin, pp. 891-901.

Chidumayo, E.N., 1997. Miombo ecology and management: an introduction. Intermediate Technology.

Corbeels, M., Shiferaw, A., & Haile, M. (2000). Farmers' Knowledge of Soil Fertility and Local Management Strategies in Tigray, Ethiopia. *Managing Africa's Soils*, *10*, 30.

Dagnachew, M., Moges, A., Kassa, A. K., & Castellini, M. (2019). Effects of land uses on soil quality indicators: The case of geshy subcatchment, Gojeb River Catchment, Ethiopia. *Applied and Environmental Soil Science*, *2019*. https://doi.org/10.1155/2019/2306019

Dagnachew, M., Moges, A., Kebede, A., & Abebe, A. (2020). Effects of Soil and Water Conservation Measures on Soil Quality Indicators: The Case of Geshy Subcatchment, Gojeb River Catchment, Ethiopia. *Applied and Environmental Soil Science*, *2020*, 1–16. https://doi.org/10.1155/2020/1868792

Dass, A., Sudhishri, S., Lenka, N. K., & Patnaik, U. S. (2011). Runoff capture through vegetative barriers and planting methodologies to reduce erosion, and improve soil moisture, fertility and crop productivity in southern Orissa, India. *Nutrient Cycling in Agroecosystems*, *89*(1), 45–57. https://doi.org/10.1007/s10705-010-9375-3

Descheemaeker, K., Nyssen, J., Poesen, J., Haile, M., Muys, B., Raes, D., Moeyersons, J., & Deckers, J. (2006). *Soil and water conservation through forest restoration in exclosures of the Tigray highlands*.

Ellenberg, D. and Mueller-Dombois, D., (1974). Aims and methods of vegetation ecology. New York: Wiley.

Ellis-Jones, J., & Tengberg, A. (2000). The impact of indigenous soil and water conservation practices on soil productivity: examples from Kenya, Tanzania and Uganda. *Land Degradation & Development*, *11*(1), 19-36.

Emiru, B., Demel, T. and Barklund, P., 2002. Actual and potential contributions of enclosure to enhance biodiversity in drylands of Eastern Tigray, with particular emphasis on woody plants. SLU (Swedish University of Agricultural Sciences), Sweden.

Erenso, F., Maryo, M., & Abebe, W. (2014). Floristic composition, diversity and vegetation structure of woody plant communities in Boda dry evergreen Montane Forest, West Showa, Ethiopia. *Int. J. Biodivers. Conserv*, *6*(5), 382-391.

Fachrul, MF. (2007). Bioecology Sampling Method. Bumi Aksara, Jakarta.

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

Ferreira, C. S. S., Seifollahi-Aghmiuni, S., Destouni, G., Ghajarnia, N., & Kalantari, Z. (2022). Soil degradation in the European Mediterranean region: Processes, status and consequences. *Science of the Total Environment*, *805*, 150106. https://doi.org/10.1016/j.scitotenv.2021.150106

Fusun, S., Jinniu, W., Tao, L., Yan, W., Haixia, G., & Ning, W. (2013). Effects of different types of vegetation recovery on runoff and soil erosion on a Wenchuan earthquake-triggered landslide, China. *Journal of Soil and Water Conservation*, *68*(2), 138–145. https://doi.org/10.2489/jswc.68.2.138

Gachene, C. K. K., Nyawade, S. O., & Karanja, N. N. (2019). Soil and Water Conservation: An Overview. In W. Leal Filho, A. M. Azul, L. Brandli, P. G. Özuyar, & T. Wall (Eds.), *Zero Hunger* (pp. 1–15). Springer International Publishing. https://doi.org/10.1007/978-3-319-69626-3_91-1

Gairola, S., Rawal, R.S., Todaria, N.P. (2008). Forest vegetation patterns along an altitu dinal gradient in sub-alpine zone of West Himalaya India. African J. Plant Sci. 2 (6), 42–48.

Gaury, P. K., & Devi, R. (2017). Plant species composition and diversity at the Aravalli Mountain Range in Haryana, India. *Journal of Biodiversity*, *8*(1), 34-43.

Gebreselassie, Y., Amdemariam, T., Haile, M., & Yamoah, C. (2009). Lessons from upstream soil conservation measures to mitigate soil erosion and its impact on upstream and downstream users of the Nile River. *International Water Management Institute*, 170-183.

Hailu, W., Moges, A., & Yimer, F. (2012). The Effects of Fanya juu Soil Conservation Structure on Selected Soil Physical & Chemical Properties: The Case of Goromti

Watershed, Western Ethiopia. *Resources and Environment*, *2*(4), 132–140. https://doi.org/10.5923/j.re.20120204.02

Hartemink, A. E., & Huting, J. (2008). Land Cover, Extent, and Properties of Arenosols in Southern Africa. *Arid Land Research and Management*, *22*(2), 134–147. https://doi.org/10.1080/15324980801957689

Hasani, M., Pielesiak, I., Mahiny, A. S., & Mikaeili, A. (2021). Regional ecosystem health assessment based on landscape patterns and ecosystem services approach. *Acta Ecologica Sinica*, *43*(2), 333–342. https://doi.org/10.1016/j.chnaes.2021.11.004

Havlin, J. L., Tisdale, S. L., Nelson, W. L., & Beaton, J. D. (2016). *Soil fertility and fertilizers*. Pearson Education India.

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

Hermans, T. D. G., Dougill, A. J., Whitfield, S., Peacock, C. L., Eze, S., & Thierfelder, C. (2021). Combining local knowledge and soil science for integrated soil health assessments in conservation agriculture systems. *Journal of Environmental Management*, *286*(February), 112192. https://doi.org/10.1016/j.jenvman.2021.112192

Hurni, H. (1988). Principles of soil conservation for cultivated land. *Soil Technology*, *1*(2), 101–116. https://doi.org/10.1016/S0933-3630(88)80013-8

Hurni, H. (1998). Agroecological belts of Ethiopia. Explanatory notes on three maps at a scale of, 1(1,000,000).

Hurni, H., Berhe, W. A., Chadhokar, P., Daniel, D., Gete, Z., Grunder, M., & Kassaye, G. (2016). Guidelines for development agents on soil and water conservation in Ethiopia.

Hussein, A., & Temesgen, T. (2021). Comparison of woody species diversity and population structure status across different management practice in the *GOLA NATURAL VEGETATION, EASTER HARARGHE, OROMIA OF ETHIOPIA* [Preprint]. Ecology. https://doi.org/10.1101/2021.09.17.460790

Itanna F, Olsson M, Stahr K (2011). Efect of land use changes on soil carbon status of some soil types in the Ethiopian Rift valley. J Dry Lands 4(1):289–299

Jewitt, D. (2018). Vegetation type conservation targets, status and level of protection in KwaZulu-Natal in 2016. *Bothalia*, *48*(1). https://doi.org/10.4102/abc.v48i1.2294

Jinger, D., Kakade, V., Kaushal, R., Dinesh, D., & Bhatnagar, P. R. (2021). *Rehabilitation of degraded lands through different planting techniques in Melia dubia Cav. 2*(1), 7.

Kamal, A., Mian, I. A., Akbar, W. A., Rahim, H. U., Irfan, M., Ali, S., Alrefael, A. F., & Zaman, W. (2023). Effects of soil depth and altitude on soil texture and soil quality index. *Applied Ecology and Environmental Research*, *21*(5), 4135–4154. https://doi.org/10.15666/aeer/2105_41354154

Kanito, D. (2021). Assessment and Documentation of Indigenous and Introduced Soil and Water Conservation Measures in Some Parts of Southern Ethiopia. 1–15.

Khan, F., Hayat, Z., Ahmad, W., Ramzan, M., Shah, Z., Sharif, M., Mian, I. A., & Hanif, M. (2013). *Effect of slope classon physico-chemical properties of eroded soil*.

Khormali, F., Ayoubi, S., Foomani, F. K., Fatemi, A., & Hemmati, K. (2007). Tea yield and soil properties as affected by slope classand aspect in Lahijan area, Iran. *International Journal of Plant Production*.

Krebs, C.J., (1989). Ecological methodology (No. QH541. 15. S72. K74 1999.). New York: Harper & Row.

Lal, R. (2016). Soil health and carbon management. *Food and Energy Security*, *5*(4), 212-222.

Lanckriet, S., Derudder, B., Naudts, J., Bauer, H., Deckers, J., Haile, M., & Nyssen, J. (2015). A Political Ecology Perspective of Land Degradation in the North Ethiopian Highlands. *Land Degradation & Development*, *26*(5), 521–530. https://doi.org/10.1002/ldr.2278

Li, W., Yan, M., Qingfeng, Z., & Zhikaun, J. (2012). Effects of Vegetation Restoration on Soil Physical Properties in the Wind–Water Erosion Region of the Northern Loess Plateau of China. *CLEAN – Soil, Air, Water*, *40*(1), 7–15. https://doi.org/10.1002/clen.201100367

Magdić, I., Safner, T., Rubinić, V., Rutić, F., Husnjak, S., & Filipović, V. (2022). Effect of slope classon soil properties and soil moisture regime of Stagnosol in the vineyard. *Journal of Hydrology and Hydromechanics*, *70*(1), 62–73. https://doi.org/10.2478/johh-2021-0037

Megerssa, G. R., & Bekere, Y. B. (2019). Causes, consequences and coping strategies of land degradation: Evidence from Ethiopia. *Journal of Degraded and Mining Lands Management*, *7*(1), 1953–1957. https://doi.org/10.15243/jdmlm.2019.071.1953

Meseret, D. (2014). Determinants of Farmers' Perception of soil and water Conservation Practices on Cultivated Land in Ankesha District, Ethiopia. *Agricultural Science*, *2*(5).

Meseret, D. (2016). Land Degradation in Amhara Region of Ethiopia: *Review on Extent, Impacts and Rehabilitation Practices*.

Michael, Y. G., & Herweg., K. (2000). From Indigenous Knowledge to Participatory Technology Development.

Moges, D. M., & Taye, A. A. (2017). Determinants of farmers' perception to invest in soil and water conservation technologies in the North-Western Highlands of Ethiopia. *International Soil and Water Conservation Research*, *5*(1), 56–61. https://doi.org/10.1016/j.iswcr.2017.02.003

Mohamed, E., Belal, A.-A., Ali, R. R., Saleh, A., & Hendawy, E. A. (2019). Land Degradation. In H. El-Ramady, T. Alshaal, N. Bakr, T. Elbana, E. Mohamed, & A.-A. Belal (Eds.), *The Soils of Egypt* (pp. 159–174). Springer International Publishing. https://doi.org/10.1007/978-3-319-95516-2_9

Mulat, Y. (2013). Indigenous knowledge practices in soil conservation at Konso people, south western Ethiopia. Journal of Agriculture and Environmental Sciences, 2(2), 1-10.

Mushir, A., & Kedru, S. (2012). Soil and Water Conservation Management Through Indigenous and Traditional Practices in Ethiopia: A Case Study. Ethiopian Journal of Environmental Studies and Management, 5(4), 343–355. https://doi.org/10.4314/ejesm.v5i4.3

Negessa G., & Tesfaye M. (2021). Soil and Water Conservation Measures in Ethiopia: Importance and Adoption Challenges. World J Agri & Soil Sci. 6(3): WJASS.MS.ID.000636. DOI: 10.33552/WJASS.2021.06.000636.

Nelson, D. W., & Sommers, L. E. (1982). Total Carbon, Organic Carbon, and Organic Matter. In A. L. Page, R. H. Miller, & D. R. Keeney (Eds.), *Methods of Soil Analysis, Part 2. Chemical and Microbiological Propertie* (2nd ed., pp. 593–579). ASA, SSSA. https://doi.org/10.2134/agronmonogr9.2.2ed.c29

Nigatu, D., Firew, K., & Mulugeta, K. (2019). Floristic composition, vegetation structure and regeneration status of Wabero forest, Oromia Regional State, Southeastern Ethiopia. *International Journal of Biodiversity and Conservation*, *11*(9), 272–279. https://doi.org/10.5897/IJBC2018.1241

Nyssen J, Poesen J, Moeyersons J, Deckers J, Mitiku Haile, Lang A (2004). Human impact on the environment in the Ethiopian and Eritrean highlands - a state of the art. EarthScience Reviews 64: 273-320.

Nzunda, E. F., Griffiths, M. E., & Lawes, M. J. (2007). Multi-stemmed trees in subtropical coastal dune forest: Survival strategy in response to chronic disturbance. Journal of Vegetation Science, 18(5), 693-700.

Oljirra, A. (2019). The causes, consequences and remedies of deforestation in Ethiopia. *Journal of Degraded and Mining Lands Management*, *6*(3), 1747–1754. https://doi.org/10.15243/jdmlm.2019.063.1747

Olsen, S. R., & Dean, L. A. (1965). Phosphorus. In A. L. Page, R. H. Miller, & D. R. Keeney (Eds.), *Methods of Soil Analysis, Part 2. Chemical and Microbiological Propertie* (pp. 1035–1049). ASA, SSSA. https://doi.org/10.2134/agronmonogr9.2.c32

Osman, M., & Sauerborn, P. (2001). Soil and water conservation in ethiopia: Experiences and lessons. *Journal of Soils and Sediments*, *1*(2), 117–123. https://doi.org/10.1007/BF02987717

Pande, R., Bargali, K., & Pande, N. (2014). Impacts of disturbance on the population structure and regeneration status of tree species in a Central Himalayan Mixed-Oak Forest, India. *Taiwan Journal of Forest Science*, *29*(3), 179-192.

Pärtel, M., Helm, A., Ingerpuu, N., Reier, Ü., & Tuvi, E.-L. (2004). Conservation of Northern European plant diversity: The correspondence with soil pH. *Biological Conservation*, *120*(4), 525–531. https://doi.org/10.1016/j.biocon.2004.03.025

Peng, J., Li, Y., Tian, L., Liu, Y., & Wang, Y. (2015). Vegetation dynamics and associated driving forces in eastern China during 1999-2008. *Remote Sensing*, *7*(10), 13641–13663. https://doi.org/10.3390/rs71013641

Prăvălie, R. (2021). Exploring the multiple land degradation pathways across the planet. *Earth-Science Reviews*, *220*, 103689.

Prăvălie, R., Patriche, C., Borrelli, P., Panagos, P., Roșca, B., Dumitras¸cu, M., Nita, I.A., S˘ avulescu, I. (2021). Arable lands under the pressure of multiple land degradation processes. A global perspective. Environ. Res. 194 https://doi.org/ 10.1016/j.envres.2020.110697.

Rezaei, H., Jafarzadeh, A. A., Alijanpour, A., Shahbazi, F., & Kamran, K. V. (2015). Effect of Slope classon Soil Properties and Types Along an Elevation Gradient of Arasbaran Forest, Iran. *International Journal on Advanced Science, Engineering and Information Technology*, *5*(6), 449. https://doi.org/10.18517/ijaseit.5.6.589

Rezaei, S.A & Gilkes, R.J. (2005) The effects of landscape attributes and plant community on soil physical properties in rangelands. Geoderma 125, 145–154.

Rhoton, F. E., & Lindbo, D. L. (1997). A soil depth approach to soil quality assessment. *Journal of Soil and Water Conservation*, *52*(1), 66-72.

Sahle, M., FÃ rst, C., & Yeshitela, K. (2018). Plant diversity analysis for conservation of Afromontane vegetation in socio-ecological mountain landscape of Gurage, South Central Ethiopia. *International Journal of Biodiversity and Conservation*, *10*(4), 161-171.

Salaysh Kebele Agricultural Office (SKAO), (2023). Agricultural development extension.

Schoonover, J. E., & Crim, J. F. (2015). An Introduction to Soil Concepts and the Role of Soils in Watershed Management. *Journal of Contemporary Water Research & Education*, *154*(1), 21–47. https://doi.org/10.1111/j.1936-704X.2015.03186.x

Senbeta, F., Schmitt, C., Woldemariam, T., Boehmer, H. J., & Denich, M. (2014). Plant diversity, vegetation structure and relationship between plant communities and environmental variables in the Afromontane Forests of Ethiopia.

Shannon, C. E. (1948). A Mathematical Theory of Communication. *The Bell System Technical Journal*, 27(3), 379-423.

Sharma, C. M. (2009). Vegetation structure, composition and diversity in relation to the soil characteristics of temperate mixed broad-leaved forest along an altitudinal gradient in Garhwal Himalaya. *Indian Journal of Science and Technology*, *2*(7), 39–45. https://doi.org/10.17485/ijst/2009/v2i7.11

Shiene, S. D. (2012). Effectiveness of soil and water conservation measures for land restoration in the Wello area, northern Ethiopian highlands.

Singha, C. (2019). Impact of the adoption of vegetative soil conservation measures on farm profit, revenue and variable cost in Darjeeling district, India. *Environment and Development Economics*, *24*(5), 529–553. https://doi.org/10.1017/S1355770X19000226

Sinore, T., Kissi, E., & Aticho, A. (2018). The effects of biological soil conservation practices and community perception toward these practices in the Lemo District of Southern Ethiopia. *International Soil and Water Conservation Research*, *6*(2), 123–130. https://doi.org/10.1016/j.iswcr.2018.01.004

Smith, W., Grant, B., Qi, Z., He, W., VanderZaag, A., Drury, C. F., & Helmers, M. (2020). Development of the DNDC model to improve soil hydrology and incorporate mechanistic tile drainage: A comparative analysis with RZWQM2. *Environmental Modelling & Software*, *123*, 104577.

Sugihara, S., Shibata, M., Mvondo Ze, A. D., Araki, S., & Funakawa, S. (2014). Effect of vegetation on soil C, N, P and other minerals in Oxisols at the forest-savanna transition zone of central Africa. *Soil Science and Plant Nutrition*, *60*(1), 45–59. https://doi.org/10.1080/00380768.2013.866523

Sustainet, E. (2010). Technical Manual Soil And Water Conservation. *Technical Manual for Farmers and Field Extension Service Providers*.

Taddese, G. (2001). Land degradation: A challenge to Ethiopia. *Environmental Management, 27*(6), 815–824. https://doi.org/10.1007/s002670010190

Tariq, M., & Aziz, R. (2015). *An Overview of Deforestation Causes and Its Environmental Hazards in Khyber Pukhtunkhwa*.

Tegegne, S. (2016). Vegetative structure, floristic composition and natural regeneration of a species in Ylat Forest in Meket Woreda, North Eastern Ethiopia.

Terefe, T. (2011). Farmers' perception on the role of vetiver grass in SWC in Southwest Ethiopia: The Case of Tubule Peasant Association, Metu District (M. A. Thesis). New Delhi, India.

Tesfaye, G. A. (2019). *C*ontribution of soil and water conservation practices to household food security in *Ensaro Woreda, Amhara National Regional State, Ethiopia.*

Teshager, Z., Argaw, M., & Eshete, A. (2018). Woody Species Diversity, Structure and Regeneration Status in Weiramba Forest of Amhara Region, Ethiopia*: Implications of Managing Forests for Biodiversity Conservation*.

Thomas, G. W. (1996). Soil pH and Soil Acidity. In Methods Soil Anal Part 3—Chemical Methodss-SSSA Book Series no. 5. (pp. 475–490). Soil Science Society of America and American Society of Agronomy. https://doi.org/10.2136/sssabookser5.3.c16

Tsegaye, B. (2019). Effect of land use and land cover changes on soil erosion in Ethiopia. *International Journal of Agricultural Science and Food Technology*, *5*(1), 026-034.

Tsegaye, D., Tsunekawa, A., Tsubo, M., & Haregeweyn, N. (2012). Dynamics and hotspots of soil erosion and management scenarios of the Central Rift Valley of Ethiopia. International Journal of Sediment Research, 27, 84–99.

Tucker, B. B., & Kurtz, L. T. (1961). Calcium and magnesium determinations by EDTA titrations. *Soil Science Society of America Journal*, *25*(1), 27-29.

Turrión, M. B., López, O., Lafuente, F., Mulas, R., Ruipérez, C., & Puyo, A. (2007). Soil phosphorus forms as quality indicators of soils under different vegetation covers. *Science of the Total Environment*, *378*(1-2), 195-198.

Vanmaercke, M., Panagos, P., Vanwalleghem, T., Hayas, A., Foerster, S., Borrelli, P., Rossi, M., Torri, D. (2021). Measuring, modelling and managing gully erosion at R. Prav˘

alie ˘ Earth-Science Reviews 220 (2021) 103689 33 large scales: a state of the art. https://doi.org/10.1016/j. earscirev.2021.103637.

Warren, A. (2002). Land degradation is contextual. *Land Degradation and Development*, *13*(6), 449–459. https://doi.org/10.1002/ldr.532

Woldeamlak, B. (2003). Land degradation and farmers' acceptance and adoption of conservation technologies in the Digil Watershed, Northwestern Highlands of Ethiopia. Social Science Research Report Series, Addis Ababa, vol. 29, 65p

Wuepper, D., Borrelli, P., & Finger, R. (2019). Countries and the global rate of soil erosion. *Nature Sustainability*, *3*(1), 51–55. https://doi.org/10.1038/s41893-019-0438-4

Yimer, F., Alemu, G., & Abdelkadir, A. (2015). Soil property variations in relation to exclosure and open grazing land use types in the Central Rift Valley area of Ethiopia. *Environmental Systems Research*, *4*, 1-10.

Yimer, F., Ledin, S., & Abdelkadir, A. (2008). Concentrations of exchangeable bases and cation exchange capacity in soils of cropland, grazing and forest in the Bale Mountains, Ethiopia. *Forest Ecology and Management*, *256*(6), 1298-1302.

Zhang, J., Chen, H., Fu, Z., & Wang, K. (2021). Effects of vegetation restoration on soil properties along an elevation gradient in the karst region of southwest China. *Agriculture, Ecosystems & Environment*, *320*, 107572. https://doi.org/10.1016/j.agee.2021.107572

Zinn, J. A. (2011). Soil and water conservation: An overview. *Agricultural Conservation*, *January*, 115–142. https://doi.org/10.1007/978-3-319-95675-6_91

Zoungrana, B. J. B., Conrad, C., Thiel, M., Amekudzi, L. K., & Da, E. D. (2018). MODIS NDVI trends and fractional land cover change for improved assessments of vegetation degradation in Burkina Faso, West Africa. *Journal of Arid Environments*, *153*(March 2017), 66–75. https://doi.org/10.1016/j.jaridenv.2018.01.005

7. APPENDIX

Part I. List of Figures

Appendix Figure 1. During plot preparation

Appendix Figure 2. During vegetation identification

Appendix Figure 3. Vegetation in Bera Salayish watershed

Part II. List of tables

Appendix Table 1. Summary of number woody plant species and herbaceous plant species in family

Family	**Number of species**	**per cent**
Acanthaceae	1	1.35
Agavaceae	1	1.35
Aloaceae	2	2.70
Anacardiaceae	3	4.05
Apiaceae	1	1.35
Apocynaceae	3	4.05
Asclepiadaceae	1	1.35
Asparagaceae	1	1.35
Asteraceae	2	2.70
Bignoniaceae	1	1.35
Boraginaceae	1	1.35
Celastraceae	3	4.05
Combretaceae	1	1.35
Cupressaceae	1	1.35
Dracaenaceae	1	1.35
Ebenaceae	2	2.70
Ebenaceae	1	1.35
Euphorbaceae	1	1.35
Euphorbiaceae	4	5.41
Fabaceae	11	14.86
Lamiaceae	4	5.41
Loganiaceae	1	1.35
Malvaceae	1	1.35
Melianthaceae	1	1.35
Menispermaceae	1	1.35
Moraceae	1	1.35
Myrtaceae	3	4.05
Olacaceae	1	1.35

Oleaceae	2	2.70
Phytolaccaceae	1	1.35
Polygonaceae	1	1.35
Ranunculaceae	2	2.70
Rhamnaceae	1	1.35
Rosaceae	1	1.35
Rutaceae	1	1.35
Santalaceae	1	1.35
Sapindaceae	2	2.70
Solanaceae	1	1.35
Tiliaceae	2	2.70
Verbenaceae	3	4.05
Vitaceae	1	1.35

Appendix Table 2. Herbaceous plant species relative ground cover in percentage in Bera-Salayish watershed

Species name	**Per cent**	**Rank**
Achyranthes aspera	2.60	13
Ageratum conzoides	0.52	42
Amaranthus hybridus	0.78	37
Andropogon abyssinicus	4.04	7
Bidens biternata	3.91	8
Bidens pilosa	1.54	20
Bidens prestinaria	0.52	42
Brassica carinata	0.26	46
Commelina africana	1.01	32
Crinum abyssinicum	5.21	3
Cynodon dactylon	7.76	1
Cyperus fischerianus	2.26	17
Cyperus papyrus	1.30	23
Cyperus rigidifolius	0.78	37
Datura stramonium	2.60	13

Delphinium wellbyi	0.78	37
Eleusine floccifolia	1.54	19
Epilobium hirsutum	1.30	23
Erucastrum arabicum	1.45	21
Evolvulus alsinoides	2.60	13
Festuca abyssinica	5.21	3
Galinsoga parviflora	1.30	23
Hagenia abyssinica	1.26	31
Haplocarpha rueppelli	0.69	41
Hibiscus trionum	2.21	18
Hibiscus trionum	1.30	23
Hyparrhenia hirta	3.36	10
Lantana camara	0.91	34
Medicago polymorpha	0.91	34
Merendera schimperiana	0.26	46
Ocimum gratissimum	1.30	23
Ocimum urticifolium	0.91	34
Oplismenus hirtellus	6.97	2
Pavonia burchellii	4.58	6
Pelargonium multibracteatum	0.52	42
Phagnalon abyssinicum	0.26	46
Phalaris paradoxa	1.30	23
Plantago lanceolata	2.43	16
Rumex nepalensis	0.26	46
Satureja abyssinica	1.30	23
Schoenoplectus lacustris	0.26	46
Scirpus lacustris	0.52	42
Snowdenia polystachya	5.08	5
Solanum nigrum	0.78	37
Sporobolus africanus	0.26	46
Thalictrum rhynchocarpum	3.69	9
Torilis arvensis	1.01	33

Trifolium acaule	1.35	22
Verbascum sinaiticum	2.69	12
Xanthium strumarium	1.30	23
Other forb	3.03	11

Table 3. Summary herbaceous plant species mean cover per plot

Species name	**Family**	**Cover%/ plot av.**
Achyranthes aspera L.	Amaranthaceae	10.00
Ageratum conzoides	Asteraceae	2.00
Amaranthus hybridus L.	Amaranthaceae	3.00
Andropogon abyssinicus Fresen.	Poaceae	15.50
Bidens biternata (Lour.) Merr.and Sherff.	Asteraceae	15.00
Bidens pilosa	Asteraceae	5.90
Bidens prestinaria (Sch. Bip.) Cufod	Asteraceae	2.00
Brassica carinata A.Br.	Brassicaceae	1.00
Commelina africana L.	Commelinaceae	3.88
Crinum abyssinicum Hochst. ex A.Rich.	Amaryllidaceae	20.00
Cynodon dactylon (L.) Pers.	Poaceae	29.82
Cyperus fischerianus A.Rich.	Cyperaceae	8.67
Cyperus papyrus	Cyperaceae	5.00
Cyperus rigidifolius	Cyperaceae	3.00
Datura stramonium	Solanaceae	10.00
Delphinium wellbyi Hemsl.	Ranunculaceae	3.00
Eleusine floccifolia (Forssk.) Spreng.	Poaceae	5.92
Epilobium hirsutum L.	Onagraceae	5.00
Erucastrum arabicum Fisch. and Mey.	Brassicaceae	5.56
Evolvulus alsinoides	Convolvulaceae	10.00
Festuca abyssinica Hochst. ex A.Rich.	Poaceae	20.00
Galinsoga parviflora	Asteraceae	5.00
Hagenia abyssinica (Bruce)J.F.Gmel.	Rosaceae	4.86
Haplocarpha rueppelli (Sch.Bip.)Beauv.	Asteraceae	2.67
Hibiscus trionum	Malvaceae	8.50

Hyparrhenia hirta (L.) Stapf	Poaceae	12.92
Lantana camara L.	Verbenaceae	3.50
Medicago polymorpha L.	Fabaceae	3.50
Merendera schimperiana Hochst.	Colchicaceae	1.00
Ocimum gratissimum L.	Lamiaceae	5.00
Ocimum urticifolium	Lamiaceae	3.50
Oplismenus hirtellus (L.) P.Beauv.	Poaceae	26.76
Pavonia burchellii	Malvaceae	17.58
Pelargonium multibracteatum Hochst.	Geraniaceae	2.00
Phagnalon abyssinicum	Asteraceae	1.00
Phalaris paradoxa L.	Poaceae	5.00
Plantago lanceolata L.	Plantaginaceae	9.33
Rumex abyssinicus	Polygonaceae	5.00
Rumex nepalensis Spreng.	Polygonaceae	1.00
Satureja abyssinica	Lamiaceae	5.00
Schoenoplectus lacustris	Cyperaceae	1.00
Scirpus lacustris	Cyperaceae	2.00
Snowdenia polystachya (Fresen.) Pilg.	Poaceae	19.50
Solanum nigrum	Solanaceae	3.00
Sporobolus africanus (Poir.) Robyns and Tournay	Poaceae	1.00
Thalictrum rhynchocarpum Dill. & Rich.	Ranunculaceae	14.17
Torilis arvensis (Hudson) Link	Apiaceae	3.87
Trifolium acaule Steud. ex A.Rich.	Fabaceae	5.19
Verbascum sinaiticum Benth.	Scrophulariaceae	10.33
Xanthium strumarium L.	Asteraceae	5.00
Other forb	---	11.64

Appendix Table 4. Woody plant species mean DBH (cm) and height (m)

Sci.name	**DBH(cm)**	**Height(m)**
Acacia decurrens	13.00	9.00
Acacia etbaica	5.00	3.00
Acacia saligna	10.33	5.67

Albizia gummifera	7.00	5.67
Allophylus abyssinicus	3.75	2.75
Anogeissus leiocarpa	20.67	9.00
Bersama abyssinica	4.50	4.50
Buddleja polystachya	6.00	5.00
Calpurnia aurea	4.50	4.38
Carissa spinarum	4.28	4.47
Clerodendrum myricoides	3.00	3.00
Croton macrostachyus	7.35	5.31
Dichrostachys cinerea	3.00	2.75
Dodonea angustifolia	4.00	3.00
Entada abyssinica	26.00	9.00
Eucalyptus camaldulensis	14.21	24.21
Eucalyptus globulus	15.81	18.25
Euclea racemosa	4.13	3.03
Euphorbia tirucalli	12.00	5.00
Faidherbia albida	13.25	6.50
Ficus vasta	75.00	20.00
Grewia ferruginea	3.50	2.00
Jacaranda mimosifolia	5.50	7.00
Juniperus procera	17.00	10.00
Maytenus arbutifolia	5.33	3.58
Maytenus gracilipes	3.50	2.79
Maytenus obscura	4.50	3.00
Olea europaea	3.00	5.00
Osyris quadripartita	4.41	4.50
Rhus glutinosa	4.75	3.75
Rhus natalensis	4.00	4.09
Senna singueana	4.00	3.00
Syzygium cumini	6.00	3.00
Ziziphus spina-christi	60.00	20.00

Appendix Table 5. List of plant species with scientific name, family, local name and habit (indicated as T =Tree, H = Herb & S =shrub) recorded from Bera-Salayish watershed

Scientific name	**Family**	**Local name**	**Habit**
Acacia decurrens	Fabaceae	Dikerence grar	T
Acacia etbaica Schweinf.	Fabaceae	Dere	T
Acacia saligna	Fabaceae	Saligna grar	T
Acacia seyal	Fabaceae	Wachu	S

Achyranthes aspera	Amaranthaceae	Telenji	H
Acokanthera schimperi (A.DC.) Schweinf.	Apocynaceae	Mrenz	S
Agave americana L	Agavaceae	Sete kacha	S
Ageratum conzoides	Asteraceae	Gomech	H
Albizia gummifera	Fabaceae	Sesa	T
Allophylus abyssinicus (Hochst.) Radlk.	Sapindaceae	Embus	T
Aloe debrana	Aloaceae	Wonde eret	S
Aloe pulcherrima Gilbert and Sebsebe	Aloaceae	Sete eret	S
Amaranthus hybridus	Amaranthaceae	Aluma	H
Andropogon abyssinicus	Poaceae	Gaja sar	H
Anogeissus leiocarpa Guill. and Perr.	Combretaceae	Kirkira	T
Asparagus africanus Lam.	Asparagaceae	Serte	T
Bersama abyssinica Fresen.	Melianthaceae	Azamir	T
Bidens biternata	Asteraceae	Adey abeba	H
Bidens pilosa	Asteraceae	Korefe	H
Bidens prestinaria (Sch. Bip.)	Asteraceae	Leko	H
Brassica carinata	Brassicaceae	Zerer	H
Buddleja polystachya Fresen.	Loganiaceae	Anfar	T
Calotropis procera	Asclepiadaceae	Qimbo	S
Calpurnia aurea (Ait.) Benth.	Fabaceae	Digita	S
Carduus nyassanus (S. Moore) R. E. Fr.	Asteraceae	Koshashila	S
Carissa spinarum L.	Apocynaceae	Agam	T
Cavratica gracilis (Guill. & Perr.)	Vitaceae	Aserkushtebetebkush	S
Clausenia anisata	Rutaceae	Kntsts	S
Clematis hirsuta Perr. and Guill.	Ranunculaceae	Azo hareg	S
Clerodendrum myricoides (Hochst.) Vatke	Lamiaceae	Misirch	S
Clutia abyssinica Jaub.and Spach.	Euphorbiaceae	Fiyelefeg	S
Commelina Africana	Commelinaceae	Wof ankur	H
Cordia monoica Roxb	Boraginaceae	Chewanza	S
Crinum abyssinicum	Amaryllidaceae	Yejb shnkurt	H

Croton macrostachyus Del.	Euphorbiaceae	Bsana	T
Cynodon dactylon	Poaceae	Serdo sar	H
Cyperus fischerianus	Cyperaceae	Engcha	H
Cyperus papyrus	Cyperaceae	Mamf	H
Cyperus rigidifolius	Cyperaceae	Muachera	H
Datura stramonium	Solanaceae	Shkoko sar	H
Delphinium wellbyi	Ranunculaceae	Gedel amuk	H
Dichrostachys cinerea	Fabaceae	Ader	S
Diospyros mespiliformis Hochst. ex A.DC.	Ebenaceae	Tkure	S
Dodonea angustifolia L.F.	Sapindaceae	Kitkta	T
Duranta erecta	Verbenaceae	Muatosh	S
Eleusine floccifolia	Poaceae	Akrma	H
Entada abyssinica A.Rich	Fabaceae	Sheferie	T
Epilobium hirsutum	Onagraceae	Yelamchew	H
Erucastrum arabicum	Brassicaceae	Yewof zer	H
Eucalyptus camaldulensis Dehnh.	Myrtaceae	Key bahrzaf	T
Eucalyptus globulus Labill.	Myrtaceae	Nech bahrzaf	T
Euclea racemosa	Ebenaceae	Dedeho	S
Euclea schimperi	Ebenaceae	Leglego	S
Euphorbia abyssinica Gmel	Euphorbaceae	Kulkual	S
Euphorbia tirucalli	Euphorbiaceae	Kinchib	T
Evolvulus alsinoides	Convolvulaceae	Fay	H
Faidherbia albida	Fabaceae	Grar	T
Ferula communis	Apiaceae	Mlasgolgul	S
Festuca abyssinica	Poaceae	Guasa sar	H
Ficus vasta Forssk	Moraceae	Wuarka	T
Galinsoga parviflora	Asteraceae	Zrtrt	H
Gomphocarpus frucosus	Apocynaceae	Tutye	S
Grewia bicolor Juss	Tiliaceae	Telench	S
Grewia ferruginea Hochst. ex A.Rich.	Tiliaceae	Lenkuata	S
Hagenia abyssinica	Rosaceae	Yahya kesso	H

Haplocarpha rueppelli	Asteraceae	Getin	H
Hibiscus trionum	Malvaceae	Seleklek	H
Hygrophila schulli (Hamilt.)	Acanthaceae)	Eshoh	S
Hyparrhenia hirta	Poaceae	Senbet	H
Jacaranda mimosifolia	Bignoniaceae	Yetemenja zaf	T
Jasminum grandiflorum L.	Oleaceae	Tembelel	S
Juniperus procera L.	Cupressaceae	Yehabesha tsd	T
Kosteletzkya begoniifolia (Ulbr.) Ulbr	Malvaceae	Nacha	S
Lantana camara	Verbenaceae	Yewofkolo	H
Lippia adoensis	Verbenaceae	Kessie	S
Maytenus arbutifolia (A. Rich.) Wilczek	Celastraceae	Nech atat	S
Maytenus gracilipes (Welw. Ex Oliv.)Exell	Celastraceae	Tkur atat	S
Maytenus obscura (A. Rich.) Cuf.	Celastraceae	Kumbel	T
Medicago polymorpha	Fabaceae	Amaqito	H
Merendera schimperiana	Colchicaceae	Gime sar	H
Ocimum gratissimum	Lamiaceae	Korkorche	H
Ocimum lamiifolium Hochst.	Lamiaceae	Damakese	S
Ocimum urticifolium	Lamiaceae	Besobla	H
Olea europaea L.subsp. Cuspidata (Wall.ex G. Don.) Cif.	Oleaceae	Woyra	T
Oplismenus hirtellus	Poaceae	Yekoksar	H
Osyris quadripartita Decn.	Santalaceae	Keret	S
Otostegia fruticosa (Forssk.) Schweinf. ex Penzig subsp. fruticosa	Lamiaceae	Tunjiti	S
Pavonia burchellii	Malvaceae	Wogel seber	H
Pelargonium multibracteatum	Geraniaceae	Demek abeba	H
Phagnalon abyssinicum	Asteraceae	Nbasl	H
Phalaris paradoxa	Poaceae	Asendabo	H
Phytolacca dodecandra L 'Herit.	Phytolaccaceae	Endod	S
Plantago lanceolata	Plantaginaceae	Gorteb	H
Premna schimperi	Verbenaceae	Chocho	S

Pterolobium stellatum (Forssk.) Brenan	Fabaceae	Kentfa	S
Ranunculus simensis Fresen.	Ranunculaceae	Hareg	S
Rhus glutinosa subsp. glutinosa	Anacardiaceae	Tilem	T
Rhus natalensis	Anacardiaceae	Takuma	S
Rosa abyssinica Lindley	Rosaceae	Kega	S
Rumex abyssinicus	Polygonaceae	Telehesh	H
Rumex nepalensis	Polygonaceae	Tult	H
Rumex nervosus Vahl	Polygonaceae	Embuacho	S
Salvia nilotica Jacq.	Lamiaceae	Ehul geb	S
Sansevieria ehrenbergii	Dracaenaceae	Wonde kacha	S
Satureja abyssinica	Lamiaceae	Lomi eshet	H
Schinus molle L	Anacardiaceae	Kundo berbere	S
Schoenoplectus lacustris	Cyperaceae	Knchesar	H
Scirpus lacustris	Cyperaceae	Kechemo	H
Senna singueana (Del.)	Fabaceae	Gufa	S
Snowdenia polystachya	Poaceae	Muja	H
Solanum marginatum L.f.	Solanaceae	Embuay	S
Solanum nigrum	Solanaceae	Yaytshnbra	H
Sporobolus africanus	Poaceae	Murie	H
Stephania abyssinica	Menispermaceae	Engochit hareg	S
Syzygium cumini (L.) Skeels	Myrtaceae	Zemato	T
Thalictrum rhynchocarpum Dill. & Rich.	Ranunculaceae	Wura	H
Torilis arvensis	Apiaceae	Chgogot	H
Trifolium acaule	Fabaceae	Wazma	H
Verbascum sinaiticum	Scrophulariaceae	Yahya joro	H
Vernonia hochstetteri	Asteraceae	Wuzgn	S
Xanthium strumarium L.	Asteraceae	Akenchra	H
Ximenia americana L.	Olacaceae	Enkoy	S
Ziziphus spina-christi (L.) Desf.	Rhamnaceae	Geba	T