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Effect of Different Soil Moisture Conservation Techniques for Degraded Land Rehabilitation in Geresse District, Gamo Zone, South Ethiopia

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ABSTRACT

Worldwide phenomena, land degradation puts people's livelihoods in jeopardy on a larger spatial scale. The research was conducted on degraded land situated in the midland agro-ecologies of Gerese District, within the Gamo Zone of South Ethiopia, for five consecutive years to evaluate moisture-conserving structures for degraded land rehabilitation and assess farmers' perceptions towards moisture conservation techniques. A randomized complete block design was used to arrange the study, and four different treatments were used: bench terrace, stone bund, stone-faced soil bund, and faanyajuu replicated three times. The study area experienced improvements in physical and chemical characteristics of soil following interventions, such as higher soil moisture content (31.46%) and improved soil pH than the untreated site(as a control). On a stone-faced soil bund, there were observations of a 5.34% soil organic matter content, an improved Cation exchange capacity (26 meq/100 g), and a moderate total nitrogen concentration (0.18%). Than other structures throughout the study years. The interventions also promoted species diversity and richness in treated sites with stone-faced soil bunds compared to untreated land. The biomass production of emerging grasses and shrubs, as well as the growth of test trees, was significantly higher in areas with soil and water conservation structures. The study suggests that midland farmers employ stone-faced soil bunds to raise the soil's moisture content, enhance biomass output, and encourage the growth of test trees and grass. As a result, for the purpose of land rehabilitation, all stakeholders involved should practice soil and water conservation.

INTRODUCTION

The livelihoods of people on a greater spatial scale are at risk due to the global phenomenon of land degradation (Gibbs and Salmon, 2015). Land degradation is occurring at a rate of 10 to 12 million hectares per year worldwide. Roughly 24% of the world's land area is either highly degraded or degrading at a rapid rate; consequently, 1.2 billion hectares of agricultural land have been affected by land degradation; of this total, 80% of the degradation has occurred in developing nations, the majority of which lack the resources necessary to restore degraded land (Thomas et al., 2018). Complex interactions between the human environment and climate, such as improper land use and management, overgrazing, excessive tillage, crop residue removal, and farming on hill slopes, lead to land degradation (Calicioglu et al., 2019). Land degradation increases vulnerability to the effects of predicted climate change, especially in Eastern Africa, by exacerbating droughts, flooding, deforestation, and the loss of ecosystem services. According to Haregeweyn et al. (2015), it is also a significant factor in low agricultural productivity and soil nutrient loss. In many nations, the issue of land degradation has hampered environmental sustainability and impeded efforts to improve agricultural output (Yonas et al., 2017). Particularly in rural communities practicing subsistence agriculture that completely rely on rainfall in sub-Saharan countries, changes in local climatic patterns can have a substantial impact on food production (Sintayehu, 2016). Similarly, Ethiopia has extremely high rates of land and natural resource degradation, particularly in its highlands, which negatively affects crop output, food security, and the preservation of natural resources (Erkossa, 2018).

Roughly one-third of the population lives in areas that are damaged or experiencing rapid deterioration in Ethiopia alone (Lemenih and Kassa, 2014). Soil erosion, a form of land deterioration, is one of Ethiopia's most significant environmental and socioeconomic issues. Water-induced soil erosion has a major effect on downstream flooding, crop productivity, ecosystem services, and reservoir sedimentation (Mokria et al., 2018). Reduced agricultural output, worsening food insecurity, and increased poverty are all consequences of land degradation in the nation. Farmers have been forced to cultivate ever-steeper slopes for the cultivation of small-scale food crops in an effort to find more productive farmland.

As a result, the land's potential for production was diminished, which continued to have an impact on the more than 80% of people who live in rural areas and practice subsistence farming. This made poverty and climate change vulnerability worse (Birhanu, 2014). The primary physical parameters affected by soil erosion include bulk density, infiltration rate, rooting depth, structure, texture, organic matter content, and water-holding capacity. Thus, for Ethiopia, to achieve sustainable development of its agricultural sector and the economy as a whole, the issue of soil conservation measures becomes crucial (Wolka et al., 2015). The most common restoration strategy is area closure, which is achieved by planting trees along with other physical conservation measures (Lemma, Tiki et al., 2015). Therefore, soil conservation techniques have been shown to have a certain impact and are an essential component of the system for preventing erosion at key periods of the year (Wolka et al., 2015).

Reforestation, grazing enclosures, and agricultural interventions to lessen detrimental practices like excessive tillage and overgrazing are just a few of the many strategies used in the long-term process of restoring degraded landscapes (Mokria et al., 2018). It also involves the construction of physical structures, including terraces, bunds, gully rehabilitation, establishment of enclosures, and afforestation of degraded landscapes (Mekuria et al., 2015). Therefore, in response to these threats, the government of Ethiopia has shown a great interest in strengthening efforts to restore degraded landscapes, thereby enhancing agricultural productivity and reducing vulnerability to a changing climate (Mokria et al., 2018). Most of Ethiopia has long used techniques like terracing and reforestation as a way to conserve water and soil. However, because there is less desire to accept and uphold the widely promoted techniques of soil conservation, efforts to conserve the soil have had limited effectiveness. Furthermore, a significant factor in the current state of food insecurity is soil erosion. The most common restoration strategy is area closure, which is achieved by planting trees along with other physical conservation measures (Lemma et al., 2015). The sustainability of the adopted interventions has been impacted by inadequate adoption, incorrect use of technology, and management of soil and water conservation (Nigussie et al., 2018). To address the issue of soil erosion, conservation of both soil and water is required (Wolka et al., 2015). Numerous studies have demonstrated the beneficial effects of physical soil and water conservation measures on sustainable agriculture, including decreased runoff and soil loss (Terefe et al., 2020), restored vegetation cover and diversity, altered slope gradient, improved soil quality, and increased moisture storage (Guadie et al., 2020). Therefore, this study aims to evaluate different moisture-conserving structures for degraded land rehabilitation and assess farmers' perception towards moisture conservation techniques.

MATERIALS AND METHODS

Study Area Description

The study was carried out on degraded land in the Gamo Zone in the midland agro-ecologies of Gerese district, South Ethiopia (Figure 1). The research area's geographic setting is determined by its closeness to the following surrounding districts: Arba Minch Zuria Woreda to the east, Kemba Woreda to the west, Derashe Special Woreda to the southeast, Ale Special Woreda to the south, and Bonke Woreda to the north (Woldu, 2010). The National Meteorological Agency (NMA, 2019) indicated that the research area sees an average annual rainfall of 980mm with minimum and maximum temperatures ranging from 12.6°C to 21.4°C, respectively. The region has a bimodal pattern of rainfall; the brief rainy season lasts from March to June, followed by the primary rainy season extending from July to November. This climatic variation plays a pivotal role in shaping the agro-ecological conditions of the area. This geographical and climatic variation provides the foundational context for investigating the impact of different soil and water conservation interventions on carbon sequestration in agricultural systems within this specific agro-ecological setting.

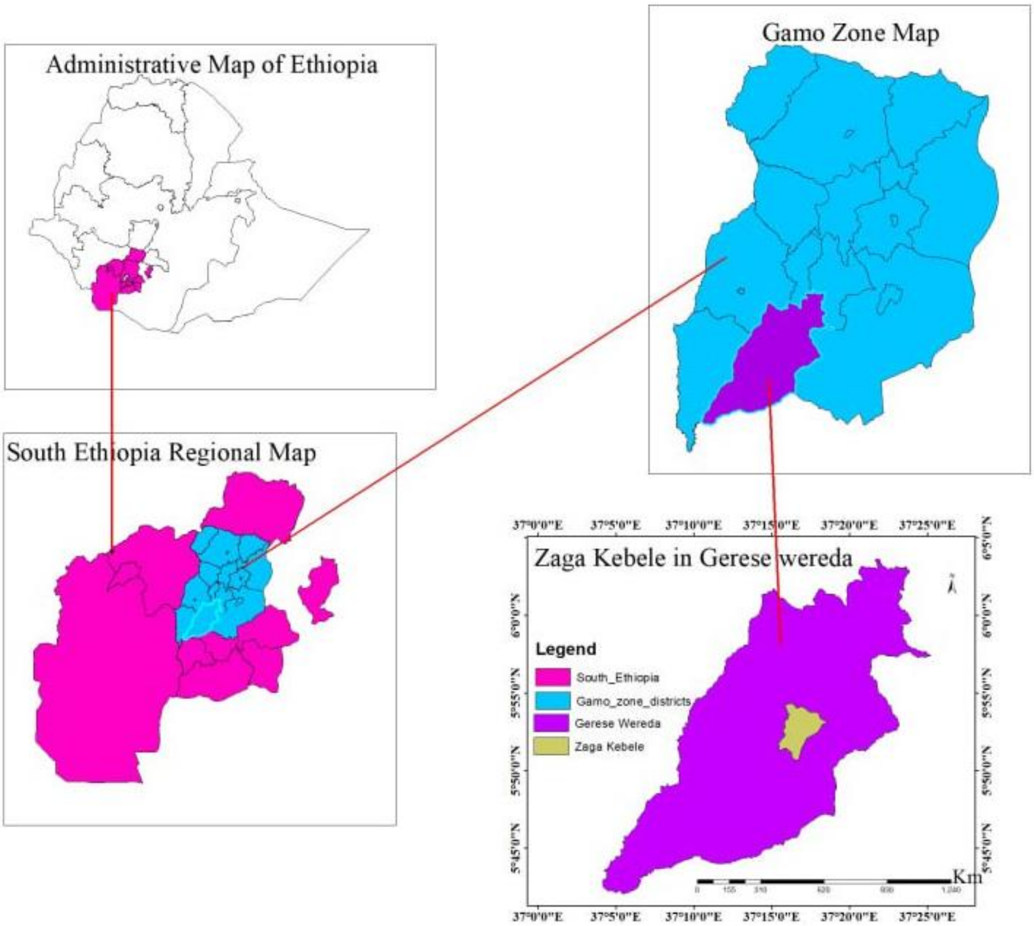

Figure 1. Location map of the study area

Soil of the Study Area

Before the implementation of any intervention, the soil exhibited properties falling within the ranges specified by Tekalign (1991). Specifically, the %OC values were observed to range between 0.5-1.5, %OM between 0.68-2.59, and total nitrogen (TN) between 0.05-0.12, all indicative of low rates. pH of the soil was identified as moderately acidic (Table 1). The entire mean sand fraction was determined to be high (46%) before the trial.

Table 1. Physico-chemical characteristics of the soil at the experimental site before the intervention

Bd (gm/ cm^3)	pH	EcµS	%OC	%OM	%TN	AP (ppm)	C:N	Av.K (ppm)	CEC (meq/ 100g)	%sand	%clay	%silt	Textural class
1.21	5.9	14.2	1.25	2.15	0.11	4.78	11.4	25	21.8	46	33	21	Sandy Clay Loam

Note: among the important indicators given are bulk density (Bd), electrical conductivity (Ec), power of hydrogen (pH), organic carbon (%OC), organic matter (%OM), total nitrogen (%TN), accessible phosphorus (AP), and Cation exchange capacity (CEC). The percentages of clay, silt, and sand, as well as the textural class, add to our understanding of the fundamental properties of the soil.

Research Design and Experimental Layouts

The experiment was laid out in a randomized complete block (RCBD) design utilizing four different treatments: bench terrace, faanyajuu, stone bund, and stone-faced soil bund. Plot sizes for each treatment were standardized to 10 m * 10 m, with a 2-meter gap between each plot. Each treatment was replicated three times. To maintain consistency and minimize variations between plots, particular attention was given to factors such as topography, level of degradation, slope steepness, and other elements known to influence plot variation. For uniformity across treatments, Gravilia Robusta trees and elephant grass were uniformly planted in all experimental plots. Recording and monitoring of newly emerging grass, shrub, and tree species were conducted, with a focus on minimizing variations between plots. Additionally, moisture content (%) was monitored quarterly, and the height of the test trees and grass was recorded at four-month intervals to track their growth progress. To gain insights into the community's perception of the interventions, farmer feedback was collected through focus group discussions, providing qualitative data on the local perspectives.

Soil Sampling and Laboratory Analysis

An auger was used to gather soil samples from the center and four corners of each sample plot, at a depth of 0–20 cm. After being labeled, the samples were taken to the soil laboratory for examination. After being allowed to air dry at room temperature, the samples were run through a 2 mm dirt sieve. The soil laboratory at Jinka Agricultural Research Center examined the samples. Each composite soil sample was subjected to physico-chemical tests that included measurements of bulk density, organic carbon, organic matter, soil textural class, total nitrogen, accessible phosphorus, electrical conductivity, cation exchange capacity, and pH. Utilizing the methodology described by Walker and Black (1934), soil organic matter was ascertained. The hydrometric approach was used to determine the soil textural fraction. Olsen (1954) used his approach to determine the amount of phosphorus that was accessible. The Kjeldahl technique was used to determine total nitrogen (Black, 1965). The sodium acetate method was used to assess potassium, while the ammonium acetate method was used to determine Cation Exchange Capacity (Chapman, 1995).

Data Analysis

The collected data underwent simple descriptive statistics to summarize key findings. Additionally, analysis of variance procedures and Least Significant Difference (LSD) multiple comparisons tests were applied to certain datasets. These statistical analyses aimed to uncover patterns, variations, and statistically significant differences among treatments, providing a robust foundation for the interpretation of the study's results. A thorough examination of both quantitative and qualitative data was ensured by the combination of descriptive and inferential statistical approaches, which helped to provide a nuanced knowledge of the effects of the interventions on the parameters under study.

To assess biodiversity, the Shannon diversity index (Greig-Smith, 1983) and richness were computed. The Shannon diversity index is particularly effective in determining the distribution of species in a given area. The calculation involved the use of the Shannon-Weiner index equation, a widely recognized method for quantifying biodiversity:

$$H'=-\sum i=1S(pi\cdot \ln (pi))$$

Where:

$'H'$: the Shannon diversity index,

S: the number of species in the community,

Pi: the proportion of individuals in the community belonging to the ith species. This methodology allowed for a comprehensive analysis of the diversity and richness of the emerging vegetation, providing valuable insights into the effectiveness of different treatments in promoting ecological diversity and health within the study area.

The Shannon Diversity index (H') was used to determine the Shannon evenness index (SEI). This index, ranging from 0 to 1, serves as a measure of the evenness of species distribution within a community. A value of 0 indicates complete unevenness, while a value of 1 signifies a perfectly even distribution where all species are equally abundant (Magurran, Anne, 2013). The evenness index (SEI) was calculated using the formula: $SEI=\ln(S)\ H'$

Where:

SEI: the Shannon evenness index,

$'H'$: the Shannon diversity index,

S: the number of species in the community,

ln (S): the natural logarithm of S.

This calculation provided a quantitative measure of how evenly distributed the species were within the study area. By incorporating the Shannon evenness index, the analysis aimed to capture not only the diversity of species but also the relative abundance and balance in their representation across different treatments, providing a more comprehensive understanding of the ecological dynamics within the experimental plots.

RESULTS AND DISCUSSION

Effects on Soil Physical Properties

Soil Texture

After the experiment, in terms of soil fraction variation, the stone-faced soil bund, faanyajuu, stone bund, and bench terrace had the highest average clay content (40%, 39%, 39%, and 37%), while the untreated site had the lowest (25%). The overall mean sand fraction was found to be low on stone-faced soil bunds, faanyajuu, stone bunds, and bench terraces (27%, 26%, 28%, and 27%), while non-conserved plots had the highest (58%), and the soil sampling was done from the lower position of the structure. One possible explanation for the comparatively greater sand concentration in the untreated plots is that the clay-rich subsurface was exposed as a result of topsoil erosion. While the sand fraction was lower in the treated than in the untreated areas, the treated fields had higher total mean percentages of silt and clay content (Table 2). In a similar study, research conducted by Yonas, A. et al. (2017) and Hishe et al. (2017) verified that the fields treated with SWC methods yielded increased clay content and lower sand.

Table 2. Mean values of soil texture under treated and untreated sites after intervention

Treatments	Soil texture			
	%Sand	%Silt	%Clay	Textural class
Fanyaajuu	26	35	39	Clay Loam
Stone-faced soil bund	27	36	40	Clay Loam
Stone bund	28	36	39	Clay Loam
Bench terrace	27	36	37	Clay Loam
untreated site	58	17	25	Sandy Loam

Soil Moisture Content

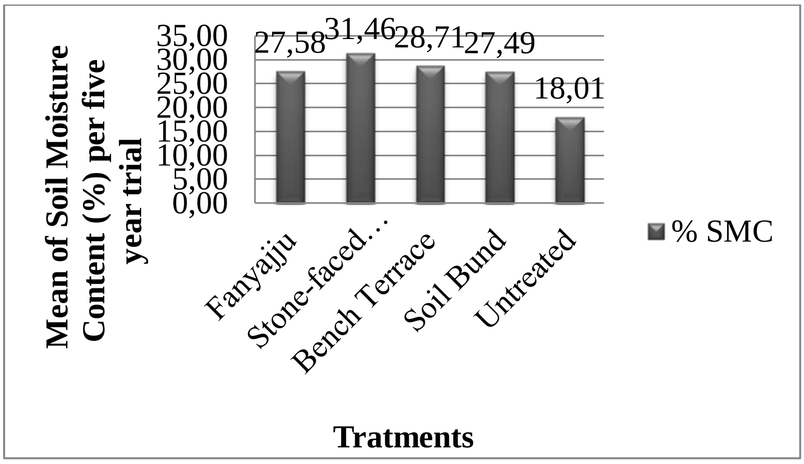

Figure 2. Mean average soil moisture contents (%) from (2018-2022) per treatments

According to (Figure 2) above, the stone-faced soil bund had the highest soil moisture contents (31.46%), followed by the bench terrace (28.71%), faanyajuu (27.58%), soil bund (27.49%), and that of the untreated site (18.01%). Over the course of the five-year trial period, the study found that stone-faced soil bunds consistently demonstrated superior soil moisture content. As a result, soil and water conservation practices may have contributed to the difference in moisture content between treated and untreated sites by reducing runoff and storing moisture in the field. Site-specific studies in Ethiopian highland areas have also highlighted the positive effects of soil and water conservation measures on enhancing moisture storage (Belay, A., & Eyasu, E., 2019).

Effects on Soil Chemical Properties

Table 3. Chemical properties of the soil after intervention (2022GC)

Soil physicochemical properties	Treatments				
	Fanyaajuu	Stone-faced soil bund	Stone bund	Bench terrace	untreated site
pH	6.03	6.18	6.03	6.11	5.08
%OC	2.65	3.1	2.01	2.57	0.85
%OM	4.56	5.34	3.46	4.44	1.46
%TN	0.13	0.18	0.12	0.16	0.10
Av.P ppm	5.03	7.84	5.33	6.37	4.12
Av.K ppm	31.24	78.36	29.63	68.10	25.37
CEC(meq/100g)	12.64	26	8.60	11.75	9.31
C:N	20.38	17.22	16.75	16.1	8.5

Soil pH

Soil pH is a vital indicator of soil quality, both in terms of nutrient availability and physical properties. Accordingly, following the intervention, the pH of the soil samples in this study indicated a slight variation between the treated sites, which included fanyaajuu, bench terrace, stone bund, and stone-faced soil bund. The soil pH increased in the treated sites with stone-faced soil bunds and bench terraces (6.18) compared to the untreated site (5.03), which had significantly acidic pH (Table 3). Overall, as per the ratings of Tekalign T. (1991) at the study location, after five trial years indicated that the pH of the soil was slightly acidic (6.0–6.6), which is good for crop production because most nutrients are available at pH values between 5.5 and 7.0 (Keesstra et al., 2016). Similarly, Dejene T. (2017) found that untreated farmland had a lower pH of soil than treated farmland.

Soil Organic Matter

The findings of the investigation shown in Table 3 above show that there are only minor mean average differences in soil organic matter between treatments. The area covered by stone-faced soil bunds had a high percentage of soil organic matter content (5.34%); this was because of the bench terraces (4.44%), faanyajuu (4.56%), and 3.46% with stone bunds, which Tekalign (1991) evaluated as medium. Additionally, the land had a high level of organic carbon (>3%). The percentage of soil organic matter content on untreated land was low (1.46%). This finding implies that the application of soil and water conservation strategies makes the addition of organic matter to the soil feasible. The accumulation of sediments in the soil and the breakdown of dead roots from grass, tree, and shrub species, which add organic matter to the soil and around soil bunds, could be the cause of the treated land's moderate mean soil organic matter content in the study site. Consequently, a deficiency in decomposed materials and plant litter may be the cause of the low mean value of soil organic matter content on the untreated field.

Cation Exchange Capacity (CEC)

The land treated with a stone-faced soil bund had the highest mean CEC (26 meq/100 g), which may be related to the higher amount of clay particles and soil organic matter, according to ratings provided by Hazelton and Murphy (2007). The land treated with faanyajuu had moderate ratings (12.64 meq/100 g). Guadie's (2020) study verified that the use of soil and water conservation practices had a considerable impact on CEC. This effect may have resulted from the build-up of soil organic matter behind these practices. The outcome is consistent with reports from the Weday watershed in eastern Ethiopia (Dejene Teressa, 2017) and the Adaa Berga district in central Ethiopia (Mihrete, 2014), in which treated fields had higher mean CEC values than untreated fields.

Total Nitrogen

The mean total nitrogen was 0.18% on the land treated with stone-faced soil bund, 0.13% on the land treated with faanyajuu, 0.16% on the land treated with stone bund, and 0.10% on the untreated land (Table 3). High availability of organic matter may be the cause of the comparatively moderate percentage of total nitrogen in the soil samples of treated land with stone-faced soil bunds. The outcome is in line with the findings of Challa et al. (2016) and Belayneh et al. (2019).

Effect of Mountain Rehabilitation Measures on Biomass Production of Emerged Shrubs and Growth of Test Tree

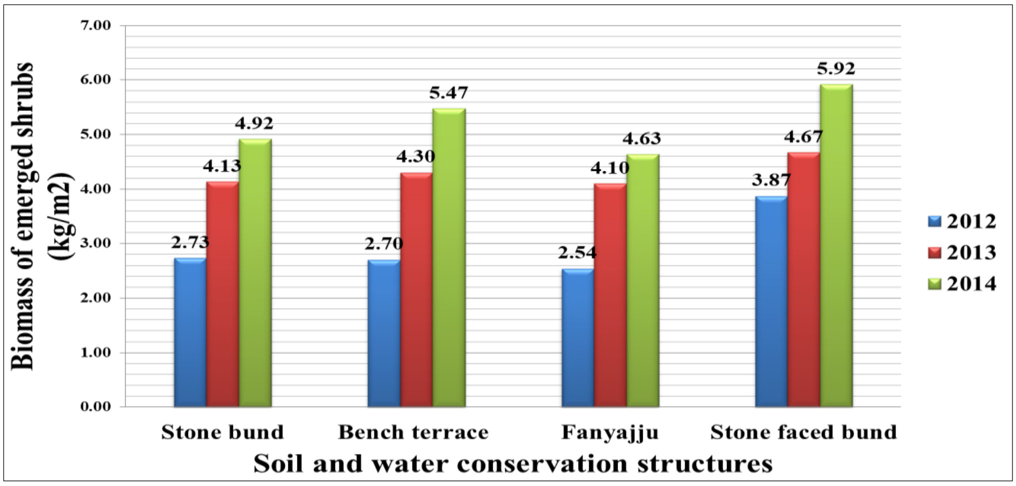

Figure 3. Biomass of emerged shrubs per treatment and trial years

Significant variation ($p<0.05$) was seen in biomass production, namely in emerging grass and shrubs, across trial years and soil and water conservation structures. Throughout the trial years, the biomass harvesting performance of the stone-faced soil bund continuously exceeded other interventions.

Table 4. Average Height of Gravilia tree and Elephant grass per four-month intervals in a trial years

Height of Gravilia(m)				Height of Elephant grass (m)	
Treatment	2020	2021	2022	2021	2022
Stone-faced soil bund	0.40^{a}	0.71	1.28	0.89	1.99^{a}
Bench terrace	0.39^{ab}	0.63	1.14	0.75	1.19^{b}
Fanyajuu	0.38^{b}	0.64	1.13	0.54	1.47^{ab}
Stone bund	0.29^{b}	0.61	1.16	0.71	1.57^{ab}
LSD (0.05)	0.1	ns	ns	ns	0.77
CV (%)	13.9	28	22.8	27.6	24.8

The biomass of emerging species per soil and water conservation structure in a one-meter square quadrant plot area was measured in the trial year of 2022 in the following structures: the stone bund (4.92kg/m^2), bench terrace (5.47kg/m^2), fanyajju (4.63kg/m^2), and the stone-faced soil bund (5.92kg/m^2) (Figure 3). Similar studies have shown that vegetation recovery and enhanced plant biodiversity result from the rehabilitation of degraded regions, which is aided by soil and water conservation structures (Singh et al., 2011).

Significant variations (P-value<0.05) were seen in the height of Gravilia trees between treatment groups in the 2020 trial year and the 2022 trial year when it came to Elephant grass. The average height measurements in Table 4 show that the stone-faced soil bund significantly supported the growth of test trees and grass.

Effect of Mountain Rehabilitation Measures on Species Diversity

As shown in Table 5, the species diversity indices for soil and water conservation structures are in comparison to other structures; the stone-faced soil bund demonstrated superior species richness and medium diversity (SDI > 1.5). According to the results in Table 6, the relative abundance and regeneration of different species were increased due to the intervention made in the study area. This showed that the plant species compositions recorded inside and outside of the interventions were different. Accordingly, “Shonna” (Guizotia scabra (Vis.) was the most dominant species in the area, “Shonna” (Guizotia scabra

(Vis.) Chiov), and it was found in relatively abundant quantities on stone bunds (75.21%), bench terraces (46.52%), fanyaajuu (34.21%), and stone-faced soil bunds (42.75%). Low levels of species richness and diversity were observed outside the intervention area. A few species that are poorly scattered outside of the intervention area were also identified by the study: "Eketelia" (Satureja abysinica (Benth.) Briq), "Lowla" (Triumfetta brachyceras K. Schum), and "Mercho" (Setaria incrassata) Hack.

The results of this investigation align with those of Ombega et al. (2017), who examined rangeland regeneration in Southwest Kenya by utilizing soil and water conservation structures. According to their findings, the repaired area produced more biomass and had higher levels of relative abundance, species richness, variety, and productivity than the degraded area. According to a study done in northern Ethiopia, watershed-based repaired regions using SWC structures had much more species variety and richness than untreated areas (Dimtsu, G. et al., 2018).

Table 5. Species diversity

Treatments	Shannon diversity index (SDI)	Shannon Evenness Index (SEI)	Species richness
Stone bund	0.85	0.37	10
Stone-faced soil bund	1.66	0.69	11
Fanyajuu	1.25	0.58	8
Bench terrace	1.26	0.57	9
Outside of the intervention area	0.41	0.25	3

Table 6. Identified species and their relative abundance per soil water conservation practices inside the intervention area

Treatments	Species local name	Species Family name	Species Scientific name	Relative abundance (%)
Stone bund	Eketelia	Lamiaceae	Satureja abyssinica (Benth.) Briq.	2.56
	Lowla	Tiliaceae	Triumfetta brachyceras K. Schum.	14.53
	Shonna	Asteraceae	Guizotia scabra (Vis.) Chiov.	75.21
	Susa	Asteraceae	Bothriocline schimperi Olivo & Hiern ex Benth.	1.71
	Amado	Asteraceae	Helichrysum stenopterum DC	0.85
	Echere hayita	Apiaceae	Centella asiatica (L.) Urban	5.14
	Mercho	Poaceae	Setaria incrassata (Hochst.) Hack.	-
Bench terrace	Lowla	Tiliaceae	Triumfetta brachyceras K. Schum.	3.21
	Shonna	Asteraceae	Guizotia scabra (Vis.) Chiov.	46.52
	Susa	Asteraceae	Bothriocline schimperi Olivo & Hiern ex Benth.	3.21
	Amado	Asteraceae	Helichrysum stenopterum DC	2.14
	Eketelia	Lamiaceae	Satureja abyssinica (Benth.) Briq.	6.95
	Echere hayita	Apiaceae	Centella asiatica (L.) Urban	37.97
	Mercho	Poaceae	Setaria incrassata (Hochst.) Hack.	-
Stone-faced soil bund	Lowla	Tiliaceae	Triumfetta brachyceras K. Schum.	4.35
	Shonna	Asteraceae	Guizotia scabra (Vis.) Chiov.	42.75
	Susa	Asteraceae	Bothriocline schimperi Olivo & Hiern ex Benth.	10.87
	Amado	Asteraceae	Helichrysum stenopterum DC	7.25
	Erka			7.97
	Shishita	Myricaceae	Myrica salicifolia	0.72
	Eketelia	Lamiaceae	Satureja abyssinica (Benth.) Briq.	3.62
	Unknown			21.74

	Echere hayita	Apiaceae	Centella asiatica (L.) Urban	0.73
	Mercho	Poaceae	Setaria incrassata (Hochst.) Hack.	-
Fanyajuu	Lowla	Tiliaceae	Triumfetta brachyceras K. Schum.	4.61
	Mercho	Poaceae	Setaria incrassata (Hochst.) Hack.	-
	Shonna	Asteraceae	Guizotia scabra (Vis.) Chiov.	34.21
	Eketelia	Lamiaceae	Satureja abyssinica (Benth.) Briq.	7.89
	Amado	Asteraceae	Helichrysum stenopterum DC	0.66
	Susa	Asteraceae	Bothriocline schimperi Olivo & Hiern ex Benth.	3.29
	Echere hayita	Apiaceae	Centella asiatica (L.) Urban	49.34

Plate 1. Taken to show the status of the field outside and inside the intervention site

Plate 2. Taken while species identification inside the intervention site

Community Perception Towards the Mountain Rehabilitation Measures

Causes and Impacts of Soil Erosion Problem in the Study Area

Before the implementation of soil and water conservation measures, focus group talks disclosed that the area experienced significant issues with soil erosion, resulting in severely degraded ground devoid of any vegetation, including shrubs or grass. Farmland and the means of subsistence for populations were damaged by flooding from higher alpine areas. Among the causes for soil erosion were (Figure 4), and the impacts soil erosion problem as mentioned by the community were (Figure 5).

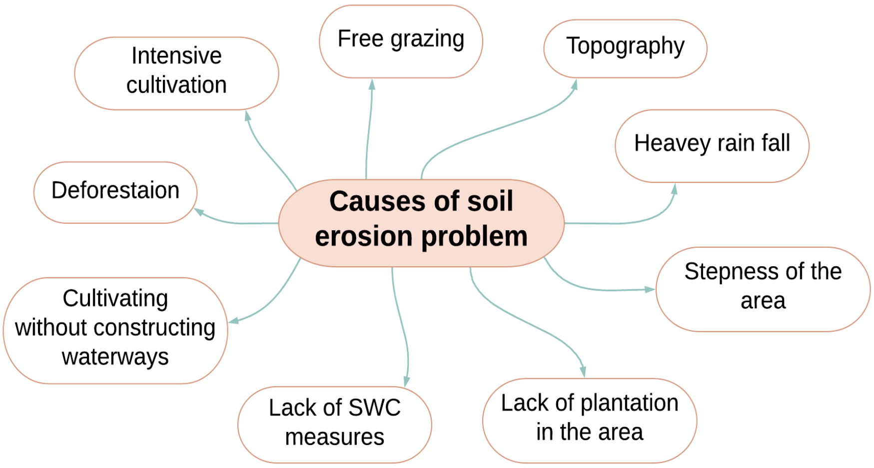

Figure 4. Communities' point of view on the causes of soil erosion

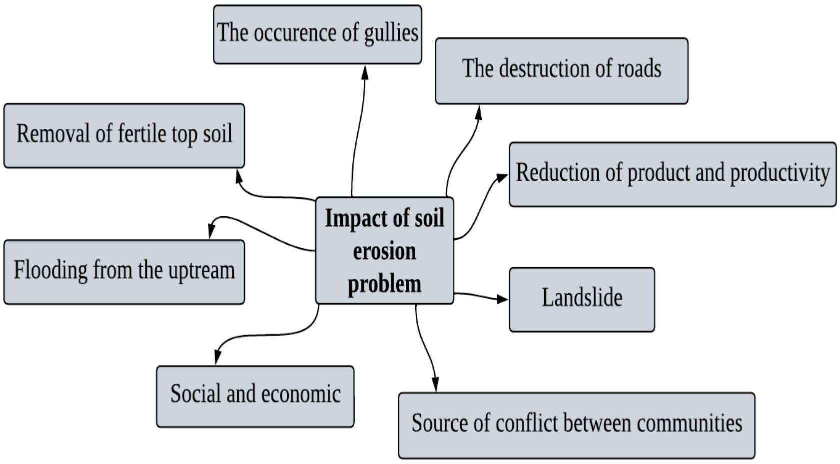

Figure 5. Views from communities regarding the impact of soil erosion

Interventions for Conserving Soil and Water Were Carried Out

Adoption of initiatives like soil bunds, stone bunds, waterways, and stone-faced soil bunds demonstrated the community's understanding of soil and water conservation techniques. The degree to which the community adopted these practices is seen in Table 7. They also practice contour cultivation, building drainage ditches, fallowing for three to four years, and intercropping maize with beans. In addition, they are putting grass strips on their farms and fertilizing it with compost and other materials.

Table 7. The level of soil and water conservation strategies implemented

How much do you utilize conservation techniques for soil and water on your farmland?				
Practices	Very much	Often	Rarely	Never
Soil bund	✓	X	X	X
Area closure	X	X	✓	X
Stone bund	✓	X	X	X
Bench terrace	X	X	✓	X
Making waterways	✓	X	X	X
Faanyajuu	X	✓	X	X
Stone-faced soil bund	✓	X	X	X

Changes Observed and Benefits Gained After Intervention

Respondents noted fewer issues with soil erosion, increased production, easier access to feed for livestock, and less sediment deposition following the intervention. Benefits included increased soil moisture, reduced soil erosion, improved species emergence, and fuel wood and livestock feed availability. Notably, the effort has raised community understanding of interventions and encouraged experience sharing so that people can initiate and spread the practice on their own land. Research has also shown that the implementation of integrated soil and water conservation practices has had a substantial impact on agricultural productivity, as evidenced by changes in crop production, food security, and household income as well as a decrease in soil erosion and sedimentation (Belay, Asnake and Elias, 2017), vegetation change, and biomass recovery (Tadese, Lemlem et al., 2017). Reducing soil loss may be possible by integrating land management through the use of various soil and water conservation measures along with the land cover (Shibire et al., 2024).

CONCLUSION

The soil properties of %OC, %OM, and TN were initially low, indicating degradation. Better soil moisture content and biomass production were consistently demonstrated by stone-faced soil bunds, which also promoted the growth of test trees and grass. The most prevalent species in the intervention area was found to be Shonna. Following the implementation of interventions, the community reported a decrease in difficulties related to soil erosion. Benefits to communities included improved soil moisture, decreased soil erosion, and access to feed for livestock. Encourage midland farmers to use stone-faced soil bunds to improve the soil's moisture content. To increase the production of biomass and the growth of test trees and grass, promote the construction of soil bunds with a stone face.

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