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Impact of Physical Soil and Water Conservation Structure on Selected Soil Physicochemical Properties in Gondar Zuriya Woreda

Worku Hailu

Department of Water resources and Irrigation Management, Ambo University, Ambo, Ethiopia

Abstract Land degradation is a major concern in Ethiopia since it leads to declining agricultural productivity, poverty and food insecurity. Soil degradation is one of the crucial issues in mountainous areas of Ethiopia which needs efforts to reduce it. In the last two decades, various soil and water conservation interventions had been introduced in to different parts of Ethiopia. However, the performance of s*oil and water conservation structures* has not been well studied. Therefore, this study was conducted in Ambachara watershed, Northern Ethiopia to evaluate the effect of soil and water conservation structures in reducing soil erosion and its effect on selected soil properties. Stone faced soil bunds (SFSB) and stone bunds (SB) have been widely implemented in the study area with GIZ support since 1994. Cultivated fields treated by SFSB and SB structures were compared with non-conserved cultivated land (control) and evaluated under three slope gradients {gentle: 3-15%, moderately steep:15-30% and steep slope:>30%}. A total of 27 soil samples were collected from the top 20 cm soil depth replicated three times. Composite soil samples were collected in '**X**' design square plot with length of 15 m x 15 m. Household survey, focus group discussions and field observations were also conducted to assess farmers' perceptions on the impact of soil and water conservation structures (SWC) on soil degradation. The results of the experimental study showed that soil organic carbons (SOC), total nitrogen (N), Avail_P, Exchangeable K and Bulk density (Bd) were significantly ($p \leq 0.05$) affected by the soil conservation measures. Sand and clay fractions significantly varied with both soil conservation measures and slope gradient. Soil organic carbon and total N were higher while bulk density was lower in soils of the conserved fields compared to fields without conservation structures. No significant difference was observed in SOC and N along the slope but the mean value of SOC and N increased with decrease in the slope percent and decrease in soil bulk density. Similarly, CEC, EC, and exchangeable Ca^{2+} and Mg^{2+} did not show any significant differences with respect to SWC measures and slope gradient. Most of the interviewees (83.3%) positive opinion on SFSB and SB on their cropland and its role in improving soil fertility based on their own indicators. From the interviewed farmer, 80% perceived change in crop yield within two years after implementation of the structures. Farmers had a positive attitude towards the SWC structures as they improve the soil productivity. Soil properties were in good conditions in the conserved areas with higher SOC, N and lower BD which are indicators of a fertile soil compared to the non-conserved plots. Further research is recommended to study the magnitude of the effects and for a better understanding ofsustainable land use systems.

Keywords Soil and water conservation, Stone faced soil bunds, Non-terraced, Stone bund, Water erosion

1. Background and Justification

Soil erosion is a major constraint to sustainable agricultural development in Ethiopia especially in sloppy agricultural lands and practically in all cultivated lands, though in varying scale. The magnitude and rate of soil erosion continue to increase despite considerable efforts made during the past three decades in conservation activities .The soil conservation research project estimate an average soil loss of 42t/ha/year on cultivated land and maximum of 300-400t/ha/year in highly erodible and intensively serial cultivated field [1]. Among the factors that have been identified as accounting for severe erosion loss in Ethiopia are; undulating topographic conditions, farming practice which do not consider conservation measure, seasonal intense rains, low soil fertility and lack of awareness on soil erosion problem and the willingness to adopt introduced conservation practices [2].

In Ethiopia, natural resources are under great pressure. Land degradation, including deforestation, soil erosion and biological soil degradation had been reported to be very rampant throughout the country. [3] Reported that because of its topographic nature, the removal of land cover leads to soil

* Corresponding author:
worku.ha@gmail.com (Worku Hailu)
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degradation. Environmental degradation, high population growth in developing countries, and the need to enhance sustainable agricultural productivity are interlocked issues that constitute a triple global challenge currently.

Soil conservation structures are an important part of most conservation plans. They provide a stable drainage network to transport excess rainfall, and are increasingly being supported by conservation tillage practices. Nowadays, there is much attention given to improve farm layouts in order to increase production efficiency and stability of soil conservation structures. The function of soil and water conservation is not only to protect the soil but to sustain its productive capacity while using it in a proper condition [1, 4, 5]. Most soil and water conservation efforts focused on highly degraded areas with limited production potential.

1.1. Significance of the Study

It is possible to say that the farm plots treated with conservation structure face similar run- off but less sediment loss than the ones which are not conserved. Hence, adequate emphasis should be given in selecting appropriate soil conservation techniques for a particular area. However, most developing countries undertake too little research on runoff management. Research done in many countries is often inadequate to provide proven alternative practices for erosion control and soil moisture conservation. Although some basic concepts in this field are potentially of universal application, conservation practices developed in one country need testing and verification, especially in relation to rainfall, soil and local cropping practices, before they are adopted elsewhere [6].

The study aims at assessing the variability of soil property between the conserved farm plot and control area where the conservation structures are not applied. This information can then be used to improve land management practices (e.g. tillage operations & fertilization) in the subtropical hilly areas in the study area as well as in similar areas in the country. The study should serve as a guidance and informative document for the people in the area, the GOs, the NGOs, and the agricultural experts who are engaged in SWC.

1.2. Objective of the Study

The study has two broad objectives. First, it

The objectives of this study are; 1. to assess the effect of SWC measures on selected physical properties (soil texture & bulk density) and chemical (soil organic carbon, phosphorus, potassium and nitrogen and other) properties of soil in conserved and non-conserved farm.2. To assess the attitude/perception of farmers towards the effect of SWC structure in relation to soil nutrient loss and soil degradation problem.

2. Methods and Materials

2.1. The Study Area

Ambachia Watershed is found in Gondar Zuriya Woreda, North Gondar Zone, Ethiopia (Figure 1). It is 45 km far from Gondar town, 698 km from A. A. Geographically, it is located between 120 23’ 53” to 120 30’ 49” N Latitude and 370 33’ 39” to 370 37’ 14” E Longitude (Figure 1). The total land area of the Ambachia Watershed is about 1622 hectares. The watershed has an altitude range of 1923 to 2851 m a.s.l. The area is characterized by undulating, rugged and hilly topography. About 25% of the total area is steep (more than 30% slope), 39% is moderately steep while the remaining 36% of the area is gentle to sloping relief.

The mean annual rainfall of the study area is 1103.4 mm while the lowest and the highest mean annual temperatures are 13.3 and 28.5°C, respectively. Although detailed soil description is lacking in the study area, two major soil types are dominant in the watershed: Red soil covers (Nitosol) and Black soil (Vertisol).

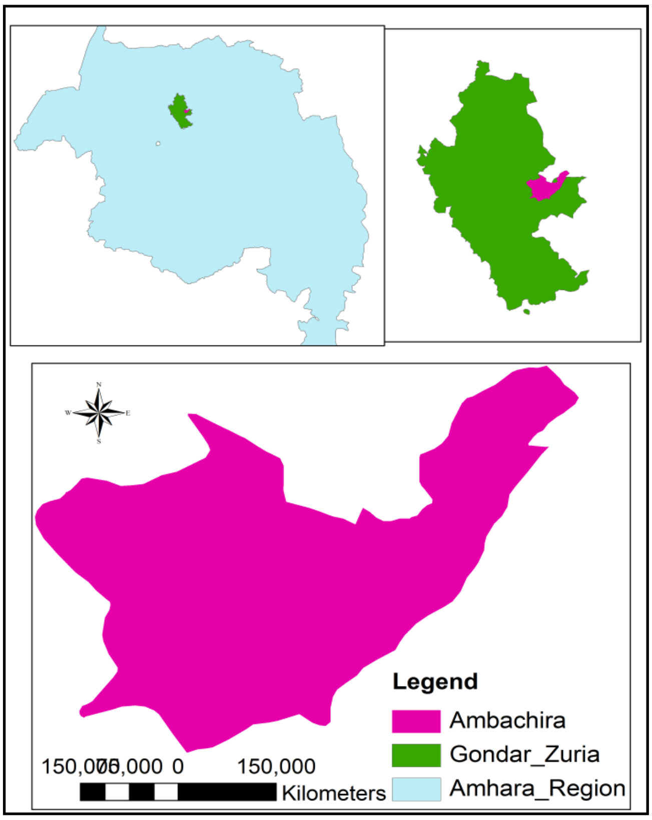

Figure 1. Location map of the study area

2.2. Method of Data Sampling

The research represents a field case study. A reconnaissance survey was carried out to identify representative soil sampling plots. Sampling sites are selected both from the farm plots where different SWC structures are practiced and in plots with no SWC practice in the catchments of the study area. In the case of conserved farm plot, the sampling plots refer to the area between the two successive structures. In the case of the non-conserved plots, the sampling plots refer to the area under cultivation which is found adjacent to each structural type.

Soil samples were collected from the top 0-20cm depth at four corners and center of a plot of 10m x 10m size using "X" sampling design as described by [7] with sharp edged and closed, circular auger pushed manually down the soil profile. The availed treatments were selected namely, different SWC structures and farm plot with no SWC measures as control was be used. Therefore a total soil samples were sated as (No treatments * 3slope gradient class *3 rps) were collected in a Complete block Design (CBD) from the top 20 cm depth for soil analysis. The samples were mixed thoroughly in a plastic bucket to form a composite sample. Collected soil samples were air-dried at room temperature, homogenized and passed through a 2mm sieve before laboratory analysis. Moreover, undisturbed samples were taken with a core sampler of height 10cm and diameter 7.2cm for soil bulk density determination.

Soil analysis procedure

The composite samples (< 2mm) were analyzed for selected soil properties. Physical property (soil texture and bulk density); Chemical property (Total Nitrogen (TN), Available Phosphorus (AP), Cation Exchange Capacity (CEC), Soil Reaction (pH), Soil Organic Carbon/matter, Available Potassium (AK+) and were analyzed following standard laboratory procedure. The soil for bulk density (BD) determination from all treatment plots using core sampler was taken from undisturbed center of "X" plot for each sample site to a depth of 20cm.

Surveys were conducted to assess farmer's perception on the problem of soil degradation and the effectiveness of the structures in reducing soil degradation. Of the total number of households residing in the study area (PA), only 5% of 603 household heads were randomly selected for questioner survey.

Data analysis

Soil and water conservation practice (stone faced soil bund and stone bund) and adjacent control farm plots and slope gradient were used as independent variables and the soil parameters as dependent variables. The significance difference of soil property due to SWC practice and slope gradient were tested using analysis of variance (ANOVA) following general Linear Model (GLM) procedure at $P \leq 0.05$ level of significance. The data collected in the HH survey were analyzed using Statistical Package of Social Science (SPSS) Software and data was organized, results will be presented in descriptive statistics (frequency tables showing the number of households corresponding to their responses usually expressed in percentages).

3. Result and Discussion

3.1. Soil Analysis

3.1.1. Soil Texture and Bulk Density

The result of soil physical properties analyses are presented in Table 1. There was a significant variation in the soil textural fractions of sand and clay with slope gradient. Whereas sand showed significant variation along the treatments and none was observed with clay. The mean sand content was higher (31.6±2.10) and lower (24.6± 2.15) when the slope gradient was greater than 30% and 3-15%, respectively (Table 1). This indicates that it is the inherent soil property and the position on the landscape (slope gradient) which cause the variation in texture rather than the age of structures. With steep landscapes, transportation and translocation of fine particles are expected. This result also confirms the presence of higher clay fraction in the lower slope gradient due to deposition from the upper slope. [8-11] also reported that on the steep cultivated hill slope, the most noticeable changes were a decrease in clay and a corresponding increase in sand and silt fractions as the slope gradient increases. This may be due to the fact that the high mean annual precipitation over the study area may be selectively transported and/or leached fine fractions leaving behind the coarser fraction [12].

The soil bulk density (Bd) showed significant variation with treatments although higher mean value was observed in control farm land compared to the stone bund and stone faced soil bund based SWC structures. [13-16] reported that soil under non-conserved treatments was found to have higher bulk density than those under SWC structures. The soil bulk density also showed significant difference with the slope gradients, indicating a direct relationship which might be attributed to the corresponding decline in soil organic carbon content with the increase in slope gradient/steepness. [17, 11] also indicated the decrease in bulk density on cultivated soils in the lower than in the higher slope gradients.

3.1.2. Soil Organic Carbon and Total Nitrogen

Soil organic carbon (SOC) showed significant variation with respect to treatment. The soil organic carbon content under the control farm was significantly lower than in the cultivated land under stone bund and stone faced soil bund structures (Table 2). The result agrees with the finding of [12] who reported that soil organic carbon content in soils under three terraced sites were higher compared to non-terraced sites with similar slopes. [16, 13] also reported that non-conserved fields had significantly lower SOC as compared to the conserved fields with different conservation measures.

Variations in SOC contents were also significant with slope gradient. Higher SOC (2.14±0.06) was observed in the lower slope (3-15%) than in the higher slope gradient >30% (1.88 ± 0.08). The results indicate that soil organic carbon is inversely related with slope gradient (Table 2). This may be due to the removal of organic matter (transportation) from the upper to the lower slope. [8, 14] had reported the dependence of SOC content on landscape position where the increasing soil water content and fertile soil deposition at lower slope favors higher crop biomass production and the resultant higher SOC content. According to [18, 14] SOC content at higher slope gradient are normally lower for different soil depths. The highest SOC contents were found at the lower slope positions for soil of the study area. All of the mean values of organic carbon of conserved and non-conserved farm plots are found very low. This might be due to the soil fertility management practice conducted by the respective farmers.

The result of soil total nitrogen showed a significant variation with respect to treatments. The overall total nitrogen content of soils under control farm plots was significantly lower than that of soils under stone bund and stone faced soil bund structures (Table 2). Similarly [15] also reported that farmland with physical SWC measures had higher total nitrogen compared to non-conserved land.

The non-variation in total nitrogen was observed along slope gradient, but higher mean value was observed in the lower slope than in the higher upper slope gradients. This might be due to the removal of organic matter (materials) from the steep slopes as a result of soil erosion. Similarly, [14, 8] also reported that SOC and total N contents were more or less similar (i.e. lower) in the higher slope gradients.

The average total nitrogen content for both conserved and non-conserved farm plots could probably rated to the rapid mineralization of existing low organic matter content. The other reason might be associated with the absence of incorporation of leguminous plants which have the capacity to fix nitrogen through the nodules in the land management practices.

3.1.3. Soil pH, Available Phosphorus (Av-P), EC and CEC

No significant difference is observed in soil pH with treatments as well as along slope gradient and. The mean values of soil pH were lower in control farm land and As compared to stone bund and stone faced soil bund (Table 3). This variation might be due to leaching of cations in controlled farm plot due to absence of SWC structure that trap soil as well as low ground cover in the farm as compared to the conserved farm plot. Soil pH was lower in slope >30% (5.88±0.02) and higher in 3-15% (5.97±0.05) slope. This could be due to the fact that increasing altitude increases rainfall and thus causing increased leaching and a reduction in soluble base cations leading to higher H+ activity and registered as decreased pH [12]. Similarly findings like [8] lower values of pH were observed in the valley than in the plateau. Generally the soil in the study area can be classified as moderately acidic soil.

Electrical conductivity (EC) of soil solution shows indirect measurement of salt content [19]. EC did not show significant variation (*P>0.05*) both in between the treatment and along the slope gradient. According to [20] the range of salinity classification, based on the result obtained the soil in the study area could be regarded as a non saline (salt free) soil.

The overall average CEC values were not statistically significant with respect to treatments and slope gradients, though the differences among treatments as well as slope gradients were very small (Table 3). The overall mean CEC (cmolc/kg) in the study area ranges from 34.05 to 35.03among the treatment and from 33.33 to 34.23 between slope gradient. The mean CEC value was lower (33.33±1.02) in slope >30% and higher (34.23±1.66) in 3-15% slope. Following [20] rating soils of the study area have higher CEC.

Table 1. Soil Physical properties (sand, silt clay and Bd fractions) in relation to the type of conservation practices and slope gradient (mean ± S.E.) of topsoil (0–20 cm) depth

Variable	Slope gradient	Conservation practice			
		Control	**SFSB**	**SB**	**Over all**
Sand (%)	3-15	24.18±1.34	24.85±1.72	24.85±3.96	24.6±2.15**a**
	15-30	24.85±2.31	25.52±0.94	34.18±0.38	28.1±0.91**ab**
	>30	26.18±0.62	33.52±1.31	35.28±4.76	31.6±2.10**b**
	Over all	25.1±1.23**a**	27.9±1.03**ab**	31.4±3.92**b**	
Silt (%)	3-15	38.80±1.25	38.13±1.37	38.13±8.14	38.35±2.41**a**
	15-30	37.46±0.33	39.46±1.28	40.13±1.21	39.0±1.91**a**
	>30	41.46±1.92	35.46±0.32	35.89±11.74	37.6±2.12**a**
	Over all	39.2±0.33**a**	38.1±1.00**a**	37.7±3.44**a**	
Clay (%)	3-15	37.01±3.02	37.01±1.35	37.02±8.12	37.0±4.35**a**
	15-30	37.68±4.25	35.01±0.49	29.01±1.71	33.9±1.00**ab**
	>30	32.34±1.89	31.01±1.20	28.82±1.11	30.7±1.02**b**
	Over all	35.6±1.74**a**	34.4±1.21**a**	31.6±7.22**a**	
Bd (g/cm^3)	3-15	1.13±0.01	1.03±0.02	1.17±0.04	1.11±0.02**b**
	15-30	1.33±0.04	1.11±0.02	1.14±0.02	1.19±0.02**a**
	>30	1.28±0.01	1.18±0.02	1.23±0.03	1.23±0.02**a**
	Over all	1.24±0.02**a**	1.11±0.02**b**	1.18±0.02**ab**	

Means within rows followed by different letters are significantly different (p < 0.05) with respect to treatment and slope gradient

Table 2. Soil chemical properties (OC and N) in relation to type of conservation practices and slope gradient (mean ± S.E.) of topsoil (0–20 cm) depth

Variable	Slope gradient	Conservation practice			
		Control	SFSB	SB	Over all
OC (%)	3-15	2.13±0.18	2.11±0.08	2.17±0.05	2.14±0.06**a**
	15-30	1.89±0.09	2.36±0.06	2.08±0.07	2.11 ±0.07**a**
	>30	1.72±0.07	2.00±0.03	1.93±0.24	1.88 ±0.08**b**
	Over all	1.91±0.10**b**	2.15±0.08**a**	2.06±0.1**ab**	
N (%)	3-15	0.17±0.019	0.19±0.03	0.21±0.05	0.196±0.02**a**
	15-30	0.15±0.024	0.23±0.05	0.20±0.04	0.173±0.01**a**
	>30	0.16±0.04	0.19±0.02	0.18±0.07	0.169±0.02**a**
	Over all	0.16±0.009**b**	0.20±0.0.01**a**	0.19±0.01**ab**	

Means within rows followed by different letters are significantly different ($p < 0.05$) with respect to treatments and slope gradients

Table 3. Soil chemical properties (pH, EC, CEC Ava_P, and Ava_ K) of soil in relation to type of conservation practices and slope gradient (mean ± S.E.) (0–20 cm) depth

Variable	Slope gradient	Conservation practice			
		Control	SFSB	SB	Over all
pH	3-15	5.81±0.043	5.89±0.038	6.21±0.135	5.97±0.05**a**
	15-30	5.75±0.013	5.77±0.112	6.11±0.082	5.87±0.09**a**
	>30	5.84±0.053	5.91±0.072	6.00±0.041	5.92±0.02**a**
	Over all	5.80±0.05**b**	5.85±0.07**b**	6.10±0.04**a**	
EC (ms/cm)	3-15	0.04±0.003	0.05±0.003	0.06±0.003	0.051±.004**a**
	15-30	0.05±0.008	0.04±0.003	0.08±0.00	0.053±0.003**a**
	>30	0.04±0.006	0.04±0.01	0.08±0.001	0.060±0.004**a**
	Over all	0.043±0.005**a**	0.047±0.004**a**	0.076±0.002**a**	
CEC (meq/100gm)	3-15	33.58±2.61	35.03±4.15	34.08±2.17	34.23±1.66**a**
	15-30	38.86±2.01	34.78±2.98	35.50±1.35	36.36±1.12**a**
	>30	32.64±2.44	34.72±1.48	32.57±1.78	33.33±1.02**a**
	Over all	35.03±1.32**a**	34.84±1.86**a**	34.05±1.13**a**	
Ava_p (gm)	3-15	12.36±10.69	19.30±4.28	25.26±2.62	14.230±4.81**a**
	15-30	4.82±8.84	15.64±16.20	22.22±5.47	18.977±5.70**a**
	>30	8.13±4.77	27.04±1.32	37.09±13.97	24.09±5.67**a**
	Over all	8.44±4.67**a**	20.66±5.25**ab**	28.19±6.17**a**	

Means within rows followed by different letters are significantly different ($p < 0.05$) with respect to treatment and slope gradient.

Table 4. Soil chemical properties of exchangeable bases (K^+, Ca^{2+}, and Mg^{2+}) in relation to type of conservation practices and slope gradient (mean ± S.E.) of topsoil (0–20 cm) depth

Variable	Slope gradient	Conservation practice			
		Control	SFSB	SB	Over all
K(meq/100gm)	3-15	0.63±0.75	0.95±0.19	1.06±0.06	0.74± 0.37**b**
	15-30	0.81±0.16	1.13±0.15	2.08±0.17	1.34±0.11**a**
	>30	0.73±0.95	0.74±0.08	0.75±0.11	0.88±0.30**b**
	Over all	0.72±0.38**b**	0.94±0.23**ab**	1.30±0.12**a**	
Ca(meq/100gm)	3-15	11.92±2.43	11.45±1.55	11.45±2.08	11.61±1.06**a**
	15-30	12.86±0.32	10.53±1.32	12.39±2.02	11.93±0.94**a**
	>30	11.29±1.52	10.35±1.81	11.14±0.50	10.93± 0.82**a**
	Over all	12.03±0.84**a**	11.66±0.89**a**	10.78±0.87**a**	
Mg(meq/100gm)	3-15	5.64±2.66	6.59±2.11	2.51±2.28	4.92±1.44**a**
	15-30	4.39±1.01	3.29±3.59	1.41±1.88	3.033±1.25**a**
	>30	1.88±1.57	3.14±2.15	3.92±0.86	2.98±1.22**a**
	Over all	3.97±0.99**a**	4.34±1.62**a**	2.62±0.95**a**	

Means within rows followed by different letters are significantly different ($p < 0.05$) with respect to treatment and slope gradient.

The results also indicated that available phosphorous did not significantly varied ($P > 0.05$) both with the treatments and slope gradients. The mean value of Av-P within treatments as well as slope gradients showed a slight difference. The mean Av-P in soil under conserved plots was relatively better than in the non-conserved plots. This could be due to higher organic matter content of the conserved plots than the non-conserved ones. According to [21] ratings, available P in soil of the study area can be described as medium to high.

3.1.4. Exchangeable K^+, Ca^{2+}, and Mg^{2+}

Except with the exchangeable K^+ other base cat-ions didn't show significant variation ($P> 0.05$) with treatments as well as slope gradients. Exchangeable K^+ under control farm plot was significantly lower compared to stone bund and stone faced soil bund structure. Under all SWC practices and slope gradient, the overall mean concentration of exchangeable cat-ions is in the order of $Ca^{2+}> Mg^{2+}> K^+$, which was similar with the report of [22].

3.2. Framers Perception on the Impact of SWC

3.2.1. Farmer's Perception on Soil Erosion and Its Extent Before and after Introducing SWC

Generally, perception of soil erosion problem is an important factor to suggest possible solutions for farmers and makes decisions on conservation investments. The perception of farmers in Ambachira watershed showed that soil erosion was perceived as a problem by more than 83% of the farmers All respondents recognized soil erosion as a problem in at least one of their plots, and were also able to identify indicators of the problem to include reduced soil depth (76.6%), 89.9% reported soil loss through mass movement, and 60% mentioned difficulty during plowing as indicators of soil erosion. Reduced productivity of land, declining soil fertility, formation of gully, and soil deposits on river bank were also indicated during focus group discussion.

In individual interviews and focus group discussions, farmers commonly indicated that they have witnessed the loss of soil from cultivated fields and the reduction of the depth of the topsoil through time which resulted in increasing the proportion of stones in their farmlands over time. They also revealed that, two decades ago, the soil in the area was generally fertile in nature and more productive but currently; it does not provide yields without the application of fertilizers.

The main causes of soil erosion mentioned by farmers included cultivation of steep slope without SWC measures, over cultivation, improper tillage practices (plowing across or diagonal to the slope) and poor drainage of excess water (Table 5). The farmers' perception on the indicators and causes of soil erosion reflect that farmers had understood the problem and able to evaluate if their actions are mitigating the right causes. Thus, farmers who declared soil erosion as a key problem were asked to list and rank the main causes of soil erosion. More than 75% of the farmers perceived slope/terrain as the main cause of soil erosion. Inappropriate tillage, lack of diversion ditch and damage of conservation structure were perceived to be the other causes of erosion on their farm plots (Table 5). Even though the causes of soil erosion listed above were perceived by most farmers, increase in livestock population and deforestation are also suggested as other causes during the group discussion. This indicates that most of them have got an understanding that soil erosion is caused by combined factors which include both natural and manmade factor.

Regarding the status of the soil erosion before and after introducing SWC, most farmers had their own mechanisms to identify this status (severe, moderate and slight). Accordingly, if the farm land face high removal of top soil, high distribution of sand with shallow depth, less productivity and large gully formed in the farm, erosion is considered as severe, if soil has better depth and better productivity with small gullies, farmers described it as moderate and land with deep depth soil with good productivity and low removal of soil, erosion is considered slight this result is consistent with [23] finding.

From the interviewed farmers, 75.7% confirmed that the extent of soil erosion before the introduction of conservation structures on their plots was severe and only 23.3% said that it was moderate (Table 5). Completely rating soil erosion from farm lands using SWC measures doesn't seem achievable. This might be the reason why farmers need short-term benefit and less awareness of the effectiveness of SWC measures. Additionally, lack of proper design of structures and selection of structures that best fit with the weather condition of the area may also reduce the effectiveness of SWC measure and leads to unconditional perception toward the structure by farmers. The result of the questionnaire survey indicated that most of respondents agreed with the presence of soil erosion problem under their field now treated with *stone bund, stone faced soil bund* and other SWC structures. Out of interviewed respondents, 49.9% indicate that the status of soil erosion after the introduction of SWC to their farm plots as slight whereas 33.3 and 16.6% of the respondent observe as moderate and sever respectively (Table 5).

Here, the question of how and what makes farmers to be aware of the problem and their views about the status arises. It could be noted that awareness maybe the result of the impacts on their resources and lives and/or the knowledge imparted as a result of active participation. Generally, awareness of soil degradation problems in Ethiopia is high. Participation in soil and water conservation (SWC) promotes a positive and significant effect on perception of farmers. [16] had reported that participation of different stakeholders during strategy development, policy formulation and technology selection to sustain agricultural productivities helps to identify the interests of the different stakeholders and to choose more acceptable and appropriate management options. With the help of organizations like the German GIZ and KFW, farmers had become active participants in trainings and/or the implementation of soil and water conservation. This result is consistent with the finding of [24] in Tanzania, who observed that training of farmers and their participation in extension workshops improved their perception of the soil degradation problem and facilitates the adoption of improved technologies. Even though they are well aware of soil erosion problem and its mitigation, the lack of SWC structure maintenance were observed during field visit.

3.2.2. Farmers Perception on the Impact of SWC and Factors Limit Their Use

Farmers were asked the positive and negative impact of SWC implemented on their land as shown in Table 6. Most of the farmers perceived the positive impact of SWC structure on their farm land. Out of the selected farmers more than 83.2% of them address that SWC structures improve their land through preventing erosion, increasing in land productivity and increase in fertility. Additionally, increase soil depth, moisture conservation and source of income were also addressed (Table 6). Only 36.1% of farmers recognize SWC structure development has negative impact through loss of land, difficulty during plowing and the need for additional time. While more than 72.9% have believed SWC structure do not have negative impact. This indicates that farmers has good awareness of SWC structure even the structure is time taking in maintaining soil through protecting soil from different degrading factor. [13, 25, 26] Address that farmers have the positive attitude toward soil and water conservation structures has improved crop yield when compared to non-conserved land.

Table 5. Perception of respondents for soil erosion as a problem

Issues	Response	Frequency	Percent (%) (n=27)
Occurrence of soil erosion	Yes	25	83.3
	No	5	16.6
Extents of soil erosion before you use SWC.	Severe	23	75.7
	Moderate	7	23.3
	Slight	0	0
Extent of soil erosion After SWC measure.	Severe	5	16.6
	Moderate	10	33.3
	Slight	15	49.9
Indicator of erosion observed by respondent	Reduction Soil depth	23	76.6
	Mass movement of soil	27	89.9
	Difficulty during plowing	18	60
	Fertility decline	17	56.6
	Gully formation	19	63.3
Cause suggested	Steepness of the slope	23	75.9
	Inappropriate tillage	16	53
	lack of diversion ditch	12	39.6
	Damage of conservation structure	8	26.64
	Increasing of livestock	9	30

Table 6. Farmers' reasons for not to use the newly introduced SWC measure

Issues	Response	Frequency	Percent (%) (n=27)
What are the positive impact of SWC you observe	Preventing erosion	25	83.2
	Increasing in land productivity	24	73.2
	Increase in fertility	16	53.3
	Increase soil depth	11	36.3
	Moisture conservation	8	26.6
	Source of income	4	13.2
Negative impact of SWC	No negative impact	21	69.9
	Lose of land	6	19.9
	Difficulty during plowing	4	13.2
	Take more time and labor	9	29.9
The limiting factor not to use SWC	Shortage of labor	19	63.3
	It reduces land	7	23.3
	No problem of soil erosion	18	59.4
	complexity of the technology	0	0

In the watershed, the introduced soil and water conservation measures are better. Though farmers showed willing to adopt the introduced SWC structures, they are willing to practice these measures to their farmlands. This is despite that from the interviewed farmers, 29.9% reported that some conservation measures like stone bund, stone faced soil bund and cutoff drain were time consuming and labor demanding for construction (Table 6). The other issue that affected their conservation practices is that the structure reduces their land (13.2%) and difficulties during plowing.

4. Conclusions and Recommendations

The use of SWC structure is promising in protecting the cultivated land from erosion and the associated nutrient depletion. Farmers seem to have a positive perception of the use of SWC to combat soil erosion and are generally aware of the problem. With regard to analysis of soil characteristics in treated and untreated plots, SOC and total N were higher while BD was lower under the conserved farm. The study showed that increase in slope gradient significantly increase soil BD and sand content while SOC, total N, and clay fractions were decreased. Generally, the soil physical and chemical properties were better in conserved farm plots than the non-conserved plots. Farmers' opinion indicated that the soil condition in relation to productivity is relatively better on conserved farm plots than on the non-conserved ones. This indicates that good agreement between assessment of soil fertility by farmers in the study area and scientific indicators of soil fertility.

The study's recommendations centers around the importance of enhancing participation in soil conservation measures and the need to explore further conservation strategies and methods. Clearly, a continuous awareness raising efforts through farmers' participation and a follow up process on the proper management (maintenance) of the structures is necessary. On the other hand, suitable conservation structures to climatic condition and slope gradient need to be implemented. Additionally, there should be an effort to improve soil fertility management practices (combined used of organic and commercial fertilizer) alongside the SWC structure. Finally, further research is required on effects of SWC measures on key soil properties, socio-economic development, environmental impacts, cropping and tillage systems.

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