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The Effects of '*Fanya juu*' Soil Conservation Structure on Selected Soil Physical & Chemical Properties: the Case of Goromti Watershed, Western Ethiopia

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Abstract Soil degradation is evident in the mountainous areas of Ethiopia, is often represented as results of human pressure. It can be improved through different Soil and Water Conservation (SWC) measures. The study was conducted in Goromti watershed, in western Ethiopia to evaluate the impact of Fanya juu structures on some soil physical & chemical properties. Cultivated fields treated by five years and ten years old fanyajuu structures were compared with non conserved cultivated land (control) and evaluated under three slope gradients. The slope gradients were; 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 and selected physical and chemical properties were analysed in the laboratory. The results of the study showed that soil pH, soil organic carbon (SOC), total nitrogen (N) were significantly ($p \leq 0.05$) different on farms treated by the fanyajuu compared to the non-conserved plots as well as under the different slope gradients. Bulk density (Db), sand and clay fractions were significantly varied with slope gradient. Soil organic carbon and total N were higher while bulk density was lower in soil under the non-conserved fields than in fields with fanyajuu structures. But no significant difference was observed in soil bulk density, sand and clay fractions among treatments. Similarly, CEC, available K and available P, and exchangeable K^+, Ca^{2+}, and Mg^{2+} didn't show any significant differences with respect to structures and slope gradient. The research indicates that structures could benefit farmers through improving the nutrient status better if integrated with agronomic measures by using vegetation suitable for the local environment in one hand, and properly maintained for longer period of time, on the other.

Keywords Fanya Juu, Cultivated Lands, Soil Fertility, Soil Properties, Western Ethiopia

1. Introduction

The most serious problem of African countries in the future can be that of land degradation[22]. To understand how and why land has become degraded or likely to become so, one needs to have some knowledge of the physical environment, population, land use history and farming systems. Different explanations can be forwarded as to this daunting problem of mainly the agricultural sector in developing country like Ethiopia.

The problem of soil degradation in Ethiopia is well established fact. The causes and consequences have been substantiated in different regions in the country.[29]noted 'soil degradation can be regarded as a direct result of the past agricultural practices in the Ethiopian highlands'.[39]also agreed that anthropogenic effects continue to be the main causes and driving factors for soil degradation in Ethiopia. Soil degradation is a term that encompassing processes that involve the physical, biological and chemical degradations.

Unwise land use change is one of the major causes of land degradation in Ethiopia. The most productive forest lands have already been brought into agricultural production. Further expansion of agriculture and grazing that takes place on marginal lands, even on steep slopes or on soils of poor physical structure or inherent property may accelerate land degradation. According to[3] only 25% of the land rehabilitation targets in terms of reforestation efforts and soil conservation schemes have been accomplished and most of the physical soil conservation measures and community forest plantations were destroyed in Ethiopia. Moreover, population growth in the country leads to deforestation and the conversion of pastureland to crops leading to overstocking and further degradation. Crop residues are increasingly used for fuel rather than mulch. Dung is also used as fuel rather than manure. All these factors lead to nutrient loss and increased erosion[32].

Soil erosion is one of the most important threats to the

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sustainability of agricultural systems in the Third World countries[18]. Ethiopia can be a good example where such depletion of the soil resources is enormous. Dominated by small-scale agricultural producers, Ethiopia is one of the most severely eroded countries in the world[31]. The average annual rate of soil loss in Ethiopia is estimated to be 12 t/ha /yr, and it can be even higher on steep slopes with soil loss rates reach up to 300 t/ha/yr, where vegetation cover is scant[25,46]. The average annual soil loss from croplands is estimated at 42 t/ha[1]. About 45% of the total annual soil loss in the country occurs from cultivated fields, which accounts for only 15.3% of the total area[16]. This is about six times the rate of soil formation and causes annual reduction in soil depth by about 4 mm[29].

Since 1980s, the Ethiopian Government has established the Soil and Water Conservation Department (SWCD) and the Forest and Water Conservation Department (FWACD), respectively, in the Ministry of Agriculture, to carry out soil and water conservation activities and has been active in conservation works. A package of conservation measures have been developed usually employing terraces, bunds, tree planting and closure of grazing areas. Between 1970s and 1980s food-for-work (FFW) programme funded the construction of 800,000 km of soil and stone bunds on cultivated land; 600,000 km of hillside terraces and 80,000 hectares were closed for regeneration and for afforestation of steep slopes[13,19,48].

Fanya-juu is a SWC structures that has been adapted and widely used in Africa especially in Kenya, Tanzania, Uganda, and in Ethiopia. The structure is an embankment made of soil and/or stone with a basin in the lower part[31]. The structure would eventually leads to the development of bench terraces over a period of time[37] if properly maintained. This happens as, the land between several of the embankments/bunds, levels off. The field then develops the characteristic "steps" of bench terraces. Soil and rainwater are conserved between the fanya-juu bunds. The objective is to keep rainfall where it falls and to keep soil in the field. The end result is creation of better growing conditions for the crop, both immediately, because of an increase in the amount of moisture available, and in the long term, because the soil is conserved.

Basically the objective of soil and water conservation (SWC) is both using the soil and maintaining the productive capacity[45]. Though, to recommend a viable and applicable SWC may seem simple, it is important to understand how different practices affect productivity and how to implement with less cost.[15] estimated that without soil conservation intervention, crop yields will decline approximately by 1.5 percent per year, being equivalent to 30 per cent decline over 20 years. SWC structures not only act as a partial barrier to water induced erosion, but also form a total barrier to tillage erosion[14].[44] in his finding at Afdeyu, Eritrea indicated that from different SWC structures fanya Juu and double ditch were more effective in reducing soil loss and runoff losses than farm land with no SWC and contour bund. In his report 48.65t/ha, 2.39t/ha, 0.13t/ha and 0.08t/ha of soil lost from control, contour bunds, fanya juu and double ditch respectively.[23]reported that on their results of the experiment indicated that organic carbon (OC), total nitrogen (N), bulk density and infiltration rate, are significantly affected by soil conservation measures. The non-conserved fields had significantly lower OC, total N, and infiltration rate; but higher bulk density as compared to the fields treated by different conservation measures.

Cultivation of the rugged topography and steep slopes is common in Ethiopian highlands, it is also the same in the study watershed. Such practices increase surface runoff and soil erosion. Even though the effects and extent of soil erosion vary with management and location, deterioration of the physical and chemical properties of soil by loss of organic matter, loss of minerals containing plant nutrient and exposes subsoil are generally accepted phenomenon.

Apart from agronomic and soil management practices; structures would be necessary as they are controlling excess runoff particularly for annual crops and no steeper slopes. Despite all these efforts, others reported that SWC projects had been neither effective nor sustainable. For example,[1]showed that SWC activities in the highlands of Ethiopia are faced with several challenges. Despite extensive conservation interventions for over a decade, sustained adoption of the recommended measures by the farmers has not been as expected.[47] also noted that in the past, the agricultural sector has failed to keep pace with growing demand for food which is partly attributable to erosion induced degradation of croplands ended up with disappointing results.

As in most western Ethiopia farm fields in the study area typically known for intensive cultivation that led to high runoff, soil erosion and sediment loss. In the past ten years, intensive soil and water conservation works have been started, one of which was Goromti watershed. Physical soil and water conservation structures were given emphasis mainly fanya juu and soil bund with support of NGOs and various government agencies. However enclosure and afforestation were also widely practiced. The adoption and sustained use of this measures have had mixed results. These practices reduce rate of land degradation and improve productive capacity of the land. On the other hand farmers were reluctant on maintenance of structures. Although it is recognized that SWC practices can sustainably contribute to reversing land degradation, the performance of past and present programs have in most cases been disappointing in terms of success and implementation in many countries[27]. As the most widely practiced intervention, the Fanyajuu's impact on productivity of the soil is more relevant to farmers. This issue is critical but no report / study available. Such knowledge will be important to give information that can be used to improve land management practices in Goromti as well as in similar areas in the country. The overall aim of the study was to evaluate the effects of fanya juu on selected physical and chemical properties of the soil in the study area. Further it explores why farmers are reluctant in adopting SWC practices.

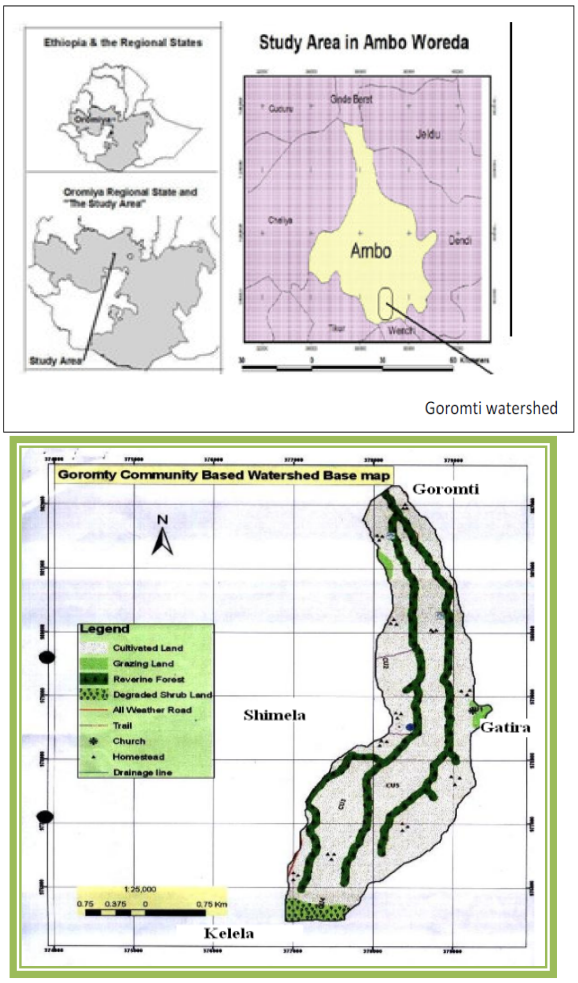

Figure 1. The location map and the study area

2. Materials and Methods

2.1. The Study Area

Goromti Watershed is found in Ambo Woreda, Oromia Region, western Ethiopia (Figure 1). It is 15km far from Ambo town and 130 km from Addis Ababa.

Geographically, it is located between 8049'26"-8055'22"N Latitude and 37051'57"- 37054'08"E Longitude (Figure 1). The total land area of the Goromti watershed is about 1091 hectares and composed of Goromti and Ya-ee Chebo villages[2].

The watershed has an altitude range of 2380 to 3170 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), 35% is moderately steep while the remaining 40% of the area is gentle to sloping relief.

According to the local agro-climatic classifications, the study area belongs to moist 'Dega' agro-climatic zone with two rainy periods; the main rainy season is locally known as "Genaa rains" which occurs from June to mid-September and the short rainy season is locally known as "Arfassa" extending from February to April. The mean annual rainfall ranges from 1500-1700mm while the lowest and the highest mean annual temperatures are 13℃ and 27℃, respectively.

Fifty nine percent of the total area of the watershed is cultivated land with arable crops, 6% covered by Enset (*Enset ventricosum*), plantation, 15% by shrubs and remnant natural forests, while 18% is occupied by villages/homesteads and 2% a grazing land. Natural vegetation in the Goromti watershed area is almost nonexistent and disappearing, although some indigenous trees like *Juniperus P, Hagenia A, Podocarpus F, Oelea abisinica, Maitenus ovastus and Acasia spps* are visible sparsely, only giving witness as dominant indigenous tree of the area. Some remains of Astha (ericaceous plant) are available on the top of Wenci mountain ridge[2]. Although detailed soil description is lacking in the study area, three major soil types are dominant in the watershed: brown soil locally 'biyyo boralee' which accounts 70% of the area followed by red soil locally known biyyo diimaa covering about 20% of the watershed, black soil (biyyo gurracha) covers 7% and others 3%[2].

2.2. Soil sampling and Laboratory Analysis

A reconnaissance survey was carried out to identify representative soil sampling plots. Sampling sites were selected both from the farm plots where fanya juu structures have been practiced and plots with no SWC practices as a control (cultivation land adjacent to each structure) in the study area. In plots where the fanya juu structures are practiced sampling was done between the two successive structures.

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[36] with sharp edged and closed, circular auger pushed manually down the soil profile. A total of 27 soil samples (3treatments * 3slope gradients * 3replications*1 depth: 0-20cm) were collected in a Randomize Complete block Design (RCBD) for laboratory 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.

Since the structure (fanya juu) availed in between 3- 45% slope in the area, accordingly the slope gradient was divided into three slope ranges: 3-15 % is considered as gentle slope, 15-30% moderately steep and slope 30-50% considered as steep slope[17].

Except the soil bulk density which was determined at Ambo University soil laboratory, the rest parameters were analyzed at the Water Works Design and Supervision Enterprise laboratory, Addis Ababa. Bulk density was determined by the core method[6]. Soil texture analysis was performed using Hydrometric method,[5]. The USDA particle size classes viz. sand (2.0–0.05 mm), silt (0.05–0.002 mm) and clay (<0.002 mm), were used when classifying the

textural classes. Soil organic carbon (SOC) was determined by the Walkley-Black oxidation method[43]. Total nitrogen (TN) was determined using the Kjeldahl digestion method[9] and Available Phosphorous (Av-P) was determined using Olsen's extraction method[40]. Available potassium (Av-K) and the exchangeable bases (Na+, K+, Ca2+, and Mg2+) were measured by atomic absorption spectrophotometer[5]. The Cation Exchange Capacity (CEC) was determined by extraction with Ammonium acetate method[10] and soil pH was determined by potesiometric Methods at a 1:2.5 soil-to water ratio.

Soil and water conservation practice (fanya juu 5 years and 10 years old) and adjacent control farm plots and slope gradient were used as independent variables and the soil parameters as dependent variables. The significance differences 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.

3. Results and Discussion

Soil texture and Bulk Density

The results of soil physical properties are presented in Table 1. The soil textural fractions of sand and clay showed significant variation with slope gradient (P=0.0250) and (P=0.0451), respectively While no significant variations were observed with the treatments. The mean sand content was higher (44.11±2.99) and lower (35.67± 1.95) 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 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.[42] 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[21,11].

The soil bulk density (Bd) didn't show a significant variation with treatments although higher mean value was observed in control farm land as compared to the 5 & 10 years aged fanya juu based SWC structures.[38]and[23]also reported that soil under non-conserved treatment was found to exhibit higher soil bulk density than treatments by SWC structures. The soil bulk density also showed significant difference (P=0.0451) with the slope gradients. The results indicate that soil Bd has a direct relation with slope gradient which might be attributed to the corresponding decline in soil organic carbon content with the increase in slope gradient/steepness.[35]also indicated the decrease in bulk density on cultivated soils in the lower than in the higher slope gradients.

Soil organic carbon, total nitrogen contents (%) and C/N ratio

Soil organic carbon (SOC) showed significant variation (P = 0.0408) with respect to treatment. The soil organic carbon content under the control farm was significantly lower than in the cultivated land under 5 and 10 years of aged fanya juu structures (Table 2). The result agrees with the finding of[37]in that soil organic carbon content in soils under three terraced sites were higher compared to the corresponding non-terraced sites of similar slopes.[23]also reported that the non-conserved fields had significantly lower SOC as compared to the conserved fields with different conservation measures.

Table 1. Soil Physical Properties of topsoil (0–20 cm depth); Soil Texture (sand, silt, clay, %) and Bd (g/cm^3) at Three Gradients Under the Three Treatments (mean ±S.E.)

Variable	Slope gradient	Conservation practice with age			
		Control	F- juu 5	F- juu 10	Over all
Sand (%)	3-15	40.42±2.39	36.0±2.72	30.6±2.96	35.67± 1.95a
	15-30	39.7±2.31	39.04±0.94	38.2±0.37	38.93± 0.75ab
	>30	44.42±0.57	38.6±1.27	49.3±8.76	44.11±2.99b
	Over all	41.5±1.23a	37.9±1.03a	39.4±3.92a	
Silt (%)	3-15	34.6±1.25	32.5±1.36	22.5±8.14	29.9± 3.05a
	15-30	34.4±0.33	30.3±1.28	35.1±1.28	33.3± 0.91a
	>30	33.0±2.47	37.2± 0.98	27.7±11.74	32.6±3.74a
	Over all	34.0± 0.84a	33.4±1.19a	28.41±4.3a	
Clay (%)	3-15	25.0±3.02	31.5±1.35	43.9±11.12	33.5± 4.35a
	15-30	26.1±4.25	30.6±0.49	28.3±0.71	28.3±1.00ab
	>30	22.6±1.89	24.2±1.20	26.5±1.93	24.4±1.02b
	Over all	24.7±1.35a	28.8± 1.27a	33.0±4.28a	
Bd (g/cm^3)	3-15	1.07±0.01	1.06±0.02	1.04±0.04	1.06± 0.02b
	15-30	1.12±0.04	1.11±0.02	1.09±0.02	1.10±0.02a
	>30	1.16±0.01	1.16±0.02	1.16±0.03	1.09±0.02a
	Over all	1.12±0.02a	1.10±0.02a	1.09±0.02a	

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

Variations in SOC contents were also significant (P =0.0003) with slope gradient. Higher mean SOC (2.35±0.06) was observed in the lower slope (3-15%) than in the higher slope gradient >30% (1.86±0.08). The results indicate that soil organic carbon is inversely related with slope gradient (Table 2). This may be due to the organic matter removal (transportation) from the upper slope to the lower one.[41],[20] and[24] also reported the dependence of SOC content with landscape position where the increasing soil water content and fertile soil deposition at lower slope position would favor higher crop biomass production and thereby higher SOC content. According to[25] SOC content at higher slope (steep) gradients are normally lowest 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.

Total nitrogen also showed a significant variation (P=0.0446) with respect to treatment. The overall total nitrogen content in soils under control farm plots was significantly lower than the content under fanya juu of 5 and 10 years old (Table 2). Similarly[38]also reported that farmland with physical SWC measures have high total nitrogen as compared to the non-conserved land.[37] and[23] also found that the mean total N content of the terraced site were higher as compared to the average total N contents of the corresponding non-terraced sites.

The variation in total nitrogen was also significant (P =0.0101) with slope gradient, higher in the lower slope than in the higher slope gradients. This might be due to the removal of organic matter (materials) from the higher or steep slopes as a result of soil erosion. Similarly,[42]also reported similarly for SOC and total N contents on steeper slopes from Southern America.

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

Carbon to nitrogen ratio (C:N) is an index of nutrient mineralization and immobilization whereby low C:N ratio indicates higher rate of mineralization[8]. The C:N ratio in the investigated soils didn't show any significant variation across treatments. However, variation was significant with slope gradients (P= 0.0494). The C:N ratio within treatments and slope gradients ranged from 9.35-11.42 and 9.44-11.81, respectively (Table 2). This indicates that organic matter is not fully mineralized[34].

Soil pH, Available Phosphorus (Av-P), Potassium (Av-K), EC and CEC

The soil pH significantly varied within treatments (P=0.0004), slope gradients (P=0.0011) and their interaction effect (P=0.0011). Soil pH was lower (5.56±0.05) in control farm land and higher (5.75±0.04) in fanya juu 10 years aged (Table 3). While there was no significant variation observed between fanya juu of 5 years of age and control farm plot. 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% (5.55±0.08) and higher in 3-15% (5.77±0.04) slope. This could be due to the fact that the high rainfall coupled with steeper slopes might have increased leaching, soil erosion and a reduction in soluble base cations leading to higher H+ activity and registered as decreased pH[21].[12]also indicated that soil in steeper slope had a significantly lower pH than those on other slope positions due to the accumulation of soluble cations on the level slope. Generally, the overall mean pH value (5.50–5.75; moderately acidic) in the study area was within the preferred range (ca. 5.5–7.0 pH) for most crops; lower end of range too acidic for some[34].

Table 2. Soil Properties of the Top Soil (0–20 cm Depth); OC, N and C:N ratio at Three Gradients Under the Three Treatments (mean ±S.E.).

Variable	Slope gradient	Conservation practice			
		Control	F juu 5	F juu 10	Over all
SOC (%)	3-15	2.24±0.18	2.38±0.08	2.37±0.05	2.35±0.06a
	15-30	1.94±0.09	2.31±0.06	2.18±0.07	2.15 ±0.07a
	>30	1.68±0.07	1.92±0.03	1.94±0.24	1.86 ±0.08b
	Over all	1.96±0.10b	2.21± 0.08a	2.17±0.1ab	
N (%)	3-15	0.19±0.019	0.24±0.03	0.28±0.05	0.24 ±0.02a
	15-30	0.16±0.024	0.20±0.05	0.19±0.04	0.20±0.01ab
	>30	0.17±0.04	0.19±0.02	0.24±0.07	0.18 ±0.02b
	Over all	0.17±0.009b	0.21±0.0.01ab	0.24±0.01a	
C:N (%)	3-15	11.86±0.41	10.06±0.56	8.43±0.70	10.11±0.57ab
	15-30	11.92±0.69	12.05±1.57	11.46±1.06	11.81±0.59a
	>30	10.49±2.22	9.56±0.46	8.16 ±0.98	9.44±0.79b
	Over all	11.42±0.72a	10.58±0.62a	9.35±0.70a	

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

Table 3. Soil Properties (pH, EC, CEC, Av P, Av K) of the Topsoil (0–20 cm depth); at Three Gradients Under the Three Treatments (mean ±S.E.)

Variable	Slope gradient	Conservation practice			
		Control	F juu 5	F juu 10	Over all
pH	3-15	5.71±0.063	5.80±0.038	5.80±0.115	5.77±0.04a
	15-30	5.41±0.072	5.25±0.112	5.79±0.043	5.48±0.08b
	>30	5.57±0.052	5.42±0.072	5.67±0.040	5.55±0.04b
	Over all	5.56±0.05b	5.49±0.09b	5.75±0.04a	
EC (ms/cm)	3-15	0.07±0.003	0.05±0.003	0.07±0.003	0.061±.004ab
	15-30	0.05±0.008	0.05±0.003	0.06±0.00	0.05±0.003b
	>30	0.07±0.006	0.07±0.01	0.06±0.001	0.06±0.004a
	Over all	0.062±0.005a	0.056±0.004a	0.062±0.002a	
CEC (cmolc/kg)	3-15	33.89±2.61	37.12±4.15	33.30±2.17	34.77±1.66a
	15-30	31.21±2.01	31.04±2.98	30.38±1.35	30.88±1.12a
	>30	29.97±2.44	30.66±1.48	28.65±1.78	29.77±1.02a
	Over all	31.69±1.32a	32.95±1.86a	30.78±1.13a	
Av_p (gm)	3-15	28.48±10.69	18.27±4.28	16.81±2.62	25.10± 4.81a
	15-30	29.35±8.84	31.37±16.20	22.84±5.47	27.85± 5.70a
	>30	17.20± 4.77	20.74±1.32	45.31±13.97	23.84±5.67a
	Over all	25.01±4.67a	23.47±5.25a	28.33±6.17a	
Av_K (gm)	3-15	1087.70±391.	553.8±56.47	753.5±34.4	798.35 ±138.64a
	15-30	914.19±206.2	786.9±63.1	616.5±11.5	772.57 ±75.81a
	>30	1057.2±302.9	1297.7±35.6	938.3±84.6	1097.7±105.58a
	Over all	564.08±21.72	540.06±32.72	618.36±34.14	

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

Table 4. Soil Properties (Na^+, K^+, Ca^{2+} and Mg^{2+}) of the Top Soil (0 -20cm depth); at Three Gradients Under the Three Treatments (mean ±S.E.)

Variable	Slope gradient	Conservation practice			
		Control	F juu 5	F juu 10	Over all
Na(cmolc/kg	3-15	0.46±0.07	0.21±0.04	0.23±0.02	0.30± 0.05a
	15-30	0.48±0.10	0.240±.05	0.38±0.04	0.36± 0.05a
	>30	0.53±0.18	0.49±0.02	0.35 0.03	0.46±0.06a
	Over all	0.49±0.06a	0.32±0.05b	0.32±0.03b	
K(cmolc/kg)	3-15	3.25±0.75	1.46±0.19	1.54±0.06	2.09± 0.37a
	15-30	2.22±0.16	1.70±0.15	2.07±0.17	2.001±0.11a
	>30	2.83±0.95	2.89±0.08	2.19±0.11	2.64±0.30a
	Over all	2.77±0.38a	2.02±0.23a	1.94±0.12a	
Ca(cmolc/kg)	3-15	12.60±2.43	13.65±1.55	14.46±2.08	13.57±1.06a
	15-30	11.83±0.32	11.25±1.32	15.27±2.02	12.79±0.94a
	>30	12.56±1.52	13.89±1.81	15.55±0.50	14.01± 0.82a
	Over all	12.33±0.84a	12.94±0.89a	15.1±0.87a	
Mg(cmolc/kg)	3-15	7.40±2.66	10.69±2.11	13.02±2.28	10.37± 1.44a
	15-30	8.65±1.01	10.37±3.59	10.95±1.88	9.10± 1.25a
	>30	6.59±1.57	5.19±2.15	11.23±0.86	7.01±1.22a
	Over all	7.55±0.99a	8.75±1.62a	11.73±0.95a	

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

Electrical conductivity (EC) of soil solution shows indirect measurement of salt content[8]. EC did not show significant variation ($P>0.05$) between treatments and control farm land. But the variation was significant ($P=0.0487$) with the slope gradient. According to[34] range of salinity classification, 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. Even 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 30.8 to 32.9 among the treatment and from 34.8 to 29.8 among slope gradients. The mean CEC value was lower (29.77±1.02) in slope >30% and higher (34.77±1.66) in 3-15% slope. Following[34] rating, the soils of the study area have higher CEC.

The results also showed that available phosphorous and available potassium did not significantly varied ($P > 0.05$) both with the treatments and slope gradients. The mean value of Av-P and Av-K within treatments as well as slope gradients showed a slight difference. The mean Av-P and Av-K in soil under conserved plots was relatively better than in the non-conserved plots. This could probably be due to higher organic matter content in the conserved plots than in the non-conserved ones. According to[4] ratings, there was medium to high concentration of available P in the soils

of study area.

Exchangeable Na^+, K^+, Ca^{2+}, and Mg^{2+}

Except with the exchangeable Na+ other base cations didn't show significant variations (P> 0.05) with treatments as well as slope gradients. Exchangeable Na+ under control farm plot was significantly higher compared to fanya juu of 5 &10 years of age. Under all SWC practices and slope gradients, the overall mean concentration of exchangeable cations is in the order of $Ca^{2+} > Mg^{2+} > K^+ > Na^+$, which was similar with the report of[7].

Generally, the SOC, N, Av-K and Av-P concentrations in farm plots with structures were found to be significantly higher than in the adjacent non-conserved farm plots. This indicates the positive impacts of SWC structures in improving the nutrient status of farms treated by structures.

According to[45] the aim of soil and water conservation is both addressing proper use of soil and maintaining its productive capacity by minimizing soil degradation rate.[47] based on a research in Afdeyu, Eritrea, reported that among the different SWC structures tested, fanya juu were more effective in reducing soil loss and runoff losses with estimated soil loss of 48.65 and 0.13 ton/ha from the control and fanya juu respectively.[23] also indicated that organic carbon (OC), total nitrogen (N) and bulk density were significantly affected by soil conservation measures.

4. Conclusions

The study revealed that, the use of Fanya juu as soil and water conservation structure in Goromti watershed had been found beneficial in protecting the cultivated land from erosion and the corresponding nutrient depletion. Further the results of the soil analysis showed that most of the soil physical and chemical properties had significant variations with respect to management practices and slope gradients. Bulk density in soil under conserved farm plots was lower than in the non-conserved farm plots. Bulk density and texture fractions of sand and clay also varied with slope gradients. The non significance differences in the physical properties (mainly in clay contents) in conserved and non- conserved farm plot suggested that differences in soil chemical properties were mainly results of soil management practices and not the inherent properties of the soils. Soil organic matter, total nitrogen and pH were found to vary with treatments and slope gradients. Generally, the SWC structures had shown positive impacts on the soil conditions, measured by the various soil physical and chemical properties. Considering the advantages of SWC structures towards improving the soil quality and thereby sustainable agricultural productivity, there should be a continuous awareness creation mechanism and a follow up process on the proper maintenance and management of the structures along with integrating agronomic measures using appropriate plant species.

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