The Effect of Soil and Water Conservation Structures on the Soil Physical and Chemical Properties in the Gidabo River Sub-basin, Ethiopian Rift Valley

Getahun Hassen, Amare Bantider, Abiyot Legesse, and Malesu Maimbo

Abstract—**Soil erosion is one of the global challenges noticed as a cause for unsustainable socio-economic and environmental conditions. Over the last half-century, various soil and water conservation (SWC) practices were introduced in Ethiopia, but the conservation work could not be fully achieved in many areas. Therefore, this study aimed to explore the effect and constraints of physical SWC on selected soil physical and chemical properties of the Ethiopian rift valley. The primary and secondary data sources were used to answer the intended objectives. The statistical analysis of variance showed that the soil texture of the study area was affected by the type of conservation practices than agroecology. However, soil bulk density was not significantly affected at all. The study also showed that the soil's physical and chemical properties were significantly affected by the variation of agroecology and soil management practices. The overall result of the study depicted that nearly half of the conservation work failed to maintain soil fertility because the farmers have constraints to adopt and adapt the SWC work. The constraints include small land size, dependency on food aid, less productivity of the soil, youth migration, shortage of fuel wood, (high energy demand) and long lasted effect of conservation works. These constraints were seen as causes for inferior agricultural products, food insecurity, famine, migration, and frequent drought in the area. The study concluded that the SWC work of the area should focus on variation of agroecology, SWC technologies, and local constraints. Also, the policy of natural resource conservation should consider local constraints to implement the national SWC guideline.**

Index Terms—**Community, food security, soil nutrients, soil and water conservation.**

I. Introduction

Natural resource degradation is one of the significant challenges that the world is facing today and is feared to risk future life all over the globe [1]. Though natural resource degradation processes do occur without interference by man, accelerated land degradation is most commonly caused as a result of human action in the environment [2]. Soil erosion is one of the causes of natural resource degradation and the socio-economic and environmental threat to agriculture's sustainability and productive capacity [3]. In developing countries, soil erosion is a severe problem because of their direct dependence on the soil resource [4]. Research results confirmed that soil erosion and nutrient depletion had been the main challenges in Ethiopia that adversely affect crop productivity and reduce agricultural production [5].

The poor performance of the agricultural sector, food-deficit, unsustainable subsistence agriculture, famine, starvation, frequent drought, and desertifications is common in Ethiopia that have been credited mainly to soil erosion [6]. Global effort on natural resource conservation work started before 5000 years [7]. However, special emphasis was given to watershed-based soil and water conservation (SWC) following the UN conference of 1972 to 2003 [8]. In Ethiopia, the traditional natural resource conservation has been applied since the Aksumite Kingdom from 400 BC to 800 AD [9]. Institutional-based and large-scale SWC work was begun in the 1970s [10]. Though research reports in Ethiopia showed inconsistent results on the effectiveness of SWC, the report by [5], [11], and [12] showed that in most areas of Ethiopia, the SWC was found relatively at a low level of success.

Therefore, this research work aimed:

1) To investigate the effectiveness of SWC works in improving soil fertility at different agroecology.
2) To evaluate the effectiveness of SWC in improving soil fertility at different soil conservation practices.
3) To identify the constraints of SWC.

II. Materials and Methods

A. Study Area Description

Gidabo river sub-basin is situated in the southeastern Rift valley region of Ethiopia. The area is specified in the limits of 6 °11'N to 6 °34'N latitude and 38 °12'E to 38 °32'E Longitude. The southeastern rift valley region of Ethiopia is part of the Great East African Rift Valley. The administrative boundary of the Gidabo river sub-basin is in the Southern Nations Nationalities and Peoples and the Oromia Regional States of Ethiopia (see Fig. 1).

The highest altitude of the river sub-basin is about 3029 m a.s.l in the south, and the lowest point is 1205 m a.s.l in the west part of the sub-basin. The highland occupies a narrow strip in the eastern part of the catchment forming a flat to the undulating landscape that is slightly dissected with some depressions characterized by seasonal drainage. The

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Getahun Hassen is with the Department of Natural Resources Management, Dilla University, Ethiopia (e-mail:getahunhassen5@gmail.com).

Amare Bantider is with the Water and Land Resource Centre of Addis Ababa University, Ethiopia. He is also with the Center for Food Security Studies, Addis Ababa University, Ethiopia (e-mail: amare.bantider@gmail.com).

Abiyot Legesse is with the Department of Geography and Environmental Studies, Dilla University, Ethiopia (e-mail: abiyottura@gmail.com).

Malesu Maimbo is with the Water Management Unit at the World Agroforestry Centre (ICRAF) based in Nairobi, Kenya (e-mail: M.MALESU@cgiar.org).

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escarpment is very steep and marked by major border normal faults. The mountainous escarpment is highly dissected terrain with a dense drainage system. The Gidab river sub-basin covers about an area of 102,738 ha. Although the main economic activity of the river basin is forest-based agriculture (agroforestry), mixed farming (livestock production and cultivation of crops) is the principal occupation of the people in the highland, and lowland area of the river basin. According to [13] the climate of the Gidabo river sub-basin ranges from humid to sub-humid in the highlands of the escarpment to semi-arid in the low land, which is characterized by warm and wet summer and dry, cold and windy winter. According to the information from the meteorological station, the average rainfall of the study area ranges from 900 to 1400 mm in the dry and rainy periods respectively, whereas the average monthly temperature of the area varies from 21^0C to 25^0C in the lowland and from 12^0C to 18^0C in the highland (see Fig. 2).

Hydrological conditions of the river sub-basin showed that the average annual recharge for 1998–2010 revealed a remarkable decrease from the highland (410 mm/year) towards the rift floor (25 mm/year). Both the spatial and temporal recharge variability is mainly controlled by the climate and land cover. In the rift floor, recharge is found to occur only when annual precipitation exceeds a threshold of approximately 800 mm. A sensitivity analysis reveals that annual recharge is very sensitive to variations in precipitation and moderately sensitive to temperature changes. The relative sensitivity increases from the highland to the rift floor across the watershed [13].

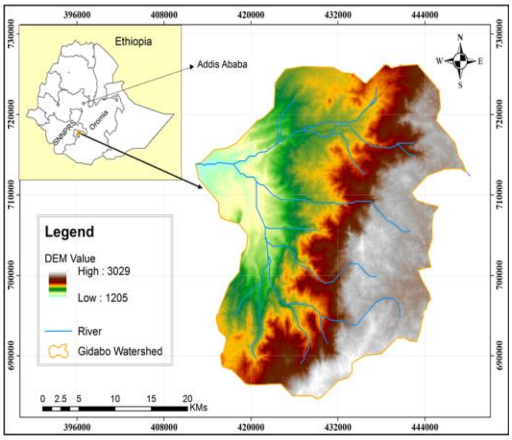

Fig.1. Location map of Gidabo river sub-basin.

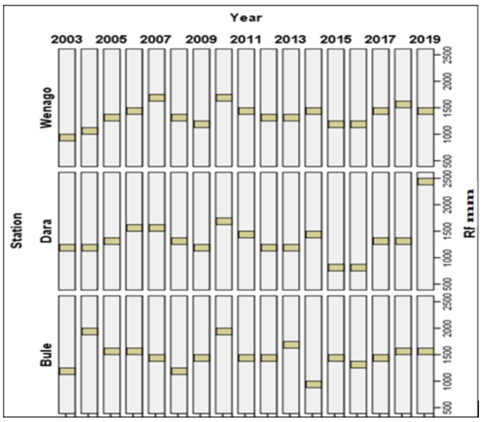

Fig. 2. Rainfall graphs for different stations.
Source; Ethiopian meteorological station (2020)

B. Research Method and Tools of Data Collection

This research was conducted using field observation, field works, interviews, group discussion, and lab work. The study site selection was carried out through a bio-sequential approach. Bio-sequential refers to the research site selection based on the variation of agroecology, landscapes, and soil management [14].

C. Key Informant Interview (KII)

Participants for key informant interviews were purposefully selected from the sampled watersheds at different agroecology/altitudinal belts. For the interview, 9 to 11 key respondents were selected considering gender proportionality, age (above 45 years) who perceived better information about historical data on LULCC, resource conservation experience, and social recognition. Based on this arrangement 70 interviewees were carried out in the whole agroecology. The KII aimed to obtain crucial qualitative information about their knowledge and perception of SWC work on soil fertility and constraints of the SWC technologies.

D. Focus Group (FG)

Focus group discussants of the study area were purposefully selected from the sampled watersheds, with a maximum of five to six participants, making it easy to manage the discussion. Based on the variation of population size the number of watersheds was selected proportionally from different agroecology. In the sampled watershed about 14 group discussions were carried out, which is eight FGD in the midland and three for each in the highland and lowland. FGD participants included model farmers, experts, administrators, and development agents from the highland, midland, and lowland agroecology The FG was intended to understand the stakeholders ‘perception of soil erosion, land management (soil fertility), and attitude on soil fertility management strategies.

E. Field Observation and Measurement

During field observations, a transect walk was carried out to collect data about different agroecology/altitudinal belt, soil management practices, age of conservation structures, and physical impact of conservation work.

1) Soil sampling technique

Though there is no common soil sampling approach, the technique, timing, and type of soil sample need to be considered for accurate results based on soil type and topography. For this research, the selection of a plot was carried out using the judgment/targeted sampling method which mainly focused on historical information, visual inspection, and professional judgment. Judgment/targeted sampling was used to select the plot site based on the similarity of agroecology, age of conservation structures, and soil management. In this method, the researchers judged the plot site based on the similarity of the conservation structures, age of SWC structures that has 3 years along different altitudinal belts that were considered as slope variation. Then zigzag sampling was used to select soil samples from the identified plot site. A total of about 36 composite soil samples were collected and coded for laboratory analysis.

This refers to 3 altitudinal belt x 3 conservation structures x 3 replicates x 1 soil depth (20 cm) = 27 for treated land. The same procedure was carried out for non-treated land of 3 agroecologies x 3 replications x 1 soil depth = 9, which is 27+9 =36. The treatments used for comparison were cultivated land treated by SWC structures, and adjacent non-conserved cultivated land, along different agroecological belts

2) Data analysis

The data analysis was made to test the significant difference between physical and chemical soil fertility indicators at the three agroecology (altitudinal belt), conserved and non-conserved land. .The variation was tested using an analysis of variance (ANOVA). Among the statistical tools ANOVA, and descriptive statistics (frequency and percentage) were employed. Analysis of variance (ANOVA) was used to test the difference of mean among different soil management practices. Content analysis was used to describe qualitative data.

III. Result and Discussion

A. Impact of SWC Structures, Agroecology/Altitudinal Belt on the Soil Physical Characteristics

Soil physical properties refer to the soil particle size proportions of sand, clay, and silt fractions in the soil .For this study, soil physical property indicators such as soil texture and bulk density were considered for different soil conservation practices and agroecology/ altitudinal belts

1) Soil texture

The ANOVA result showed no significant difference in soil texture across different soil management practices except the sandy soil in the highland, and silt soil in the lowland. The statistical result also showed no significant difference of sand, silt, and clay was observed along different agroecology (midland, lowland and highland). Nevertheless, a significant difference between silt and clay was observed along with different soil management practices. For instance, the greater mean value of silt soil was recorded in conserved land and clay in non-conserved plots of the study area (Table I and II).

The high concentration of silt soil in the conserved land is attributed to the comparative effect of SWC, which increased the deposition of fine soil particles. The high clay content in the non-conserved land might be related to the remaining resistant clay soil in the eroded land. This result agrees with the report by [15] and [16]; soils of the non-conserved land had the highest percent of clay compared to the soils of the conserved one.

2) Soil bulk density (SBD)

The overall mean value of SBD at $p \leq 0.05$ has no significant difference across agroecology/altitudinal belt and soil management practices. The ANOVA result showed that variation of land management practices, and agroecology, have no significant impact on the soil bulk density of the study area (see Table I, and II). Consistently, studies have reported that the soil bulk density was not statistically significant across different soil management practices [15].

Though there is no significant difference, the soil bulk density is relatively higher in the non-conserved landscape than conserved (Table I and II). The result was supported by [16] that reported non-conserved micro-watershed significantly exhibited the highest mean value of bulk density than the treated land with SWC structures. The high bulk density of the non-conserved land might be associated with the high soil density. This observation could be caused by soil compaction and fine soil organic matter by erosion. However, in the land treated with SWC structures, microbial development has a higher probability of reducing the compaction and density of soil. According to [18], soil bulk density higher than 1.6 g/cm^3 tends to restrict root growth. Therefore, the mean value of soil bulk density of the conservation structures of the study area that ranges between 1.45 to 0.65 g/cm^3 does not tend to restrict plant root growth and is ideal for plant growth.

TABLE I: Mean SD of Soil Texture and Bulk Density along with Different Soil Management of All Altitudinal Belts

Altitudinal belt	Land mgt.	Sand	Clay	Silt	BD
Highland (> 2,300 m)	SB	45.33 ±1.15	24.0 ± 2	34.66 ±1.15	.66 ±.068
	FN	38 ±2	32.0 ± 2	30 ±4	1.08 ±.56
	CD	49.66 ±4.72	21.33 ± 8.32	26. ±2	.65 ± .13
	NC	53 ±6.08	21.0 ± 2.64	26.66 ±5.5	1.24 ±.51
	F	7.787	3.735	3.647	1.775
	Sig	*.009 ***	*.060 ns*	*.064ns*	*.230 ns*
Mid land (1500 -2300 m)	SB	33.33 ±6.42	4 3.33 ±4.16	23.33 ±3.05	1.28 ±.03
	FN	39.33 ±11.01	40.66 ±11.7	20 ±3.46	1.12 ±.020
	CD	34.66 ±8.08	40.66 ±14.04	24.66 ±6.42	1.38 ±.44
	NC	50. ±7.21	29 ±6.55	18.66 ±2.08	1.45 ±.07
	F	2.451	1.245	1.406	1.212
	Sig	*.138 ns*	*.356 ns*	*.310 ns*	*.366ns*
Low land (5000 -1500 m)	SB	34.66 ±13.01	52.±15.09	13.33 ±2.30	1.22 ±.05
	FN	45.33 ±9.01	42.66 ±11.54	12 ±5.29	1.22 ±.04
	CD	45.33 ±3.05	32.66 ± 1.15	22 ±4	1.12 ±.12
	NC	53.66 ±3.21	30.00 ±1.73	11 ±4.35	1.30 ±.09
	F	2.691	3.316	4.454	2.332
	Sig	*.117 ns*	*.078 ns*	*.040 **	*.151 ns*

SB (Level soil bund), FN (Level Fanya Juu), CD (Cut off drain), NC (Not Conserved)

TABLE II: THE TWO-WAY ANOVA ANALYSIS OF SOIL PHYSICAL POSTHOC MULTIPLE COMPARISONS

Soil variable	Source	SS	DF	MS	F	Sig
	Ago ecology/altitudinal belt	.222	2	.111	.001	.999
	Soil management	196.528	3	65.509	.691	.565
	Error	2656.167	28	94.863		
	Total	71211.000	36			
Silt soil (%)	Ago ecology/ altitudinal belt	12.056	2	6.028	.156	.857
	Soil management	980.528	3	326.843	8.445	.000*
	Error	1083.667	28	38.702		
	Total	19325.000	36			
Clay soil (%)	Ago ecology/ altitudinal belt	22.222	2	11.111	.112	.895
	Soil management	1827.778	3	609.259	6.115	.002*
	Error	2789.833	28	99.637		
	Total	46732.000	36			
BD (g/cm3)	Ago ecology/ altitudinal belt	.319	2	.160	.876	.428
	Soil management	.608	3	.203	1.111	.361
	Error	5.102	28	.182		
	Total	47.775	36			

Agroecology/altitudinal belt (500 to 1500, 1500 to 2200 and above 2200); SWC structures, soil bund, Fanya Juu, and cutoff drain.

B. The Impact of Different Agroecology (Altitudinal Belt) and SWC practices on the Soil chemical Properties

Soil chemical properties are the most essential factors that govern the nutrient supplying power of the soil to the microbes and plants. The chemical property of the soil in the Gidabo river sub-basin at the different altitudinal belt, and soil conservation practices were assessed from the soil organic carbon, total nitrogen, soil pH, soil electrical conductivity, cation exchange capacity, available phosphorus, and available potassium.

1) Soil organic carbon (SOC)

In this study, the two ways ANOVA at $p< 0.05$ was used to test the SOC distribution along different agroecology and soil conservation type. The statistical analysis showed significant variation of SOC across different agroecology (midland, lowland and highland) ,and soil managements (FN, CD, SB ,and NC).This result refers to the distribution of SOC significantly affected by agroecology with different climatic characteristics and soil management practices (Table III). For instance, in the midland, the mean SOC has a greater value in the land treated with SWC structures than non-treated. In contrast, in the highland and lowland agrology, the mean value of SOC has no significant difference between treated and non-treated land. According to Table V, the statistical result showed that irregular distribution of SOC was observed between treated and non-treated land of the highland and lowland altitudinal belt. The result depicted that certain conservation structures are not successful in improving the SOC, which might be related to constraints limiting the effectiveness of the conservation structures. The effectiveness of any SWC could be determined by the type of land management, climate, cropping system, soil types, and access to resources [19], [20]. According to [21], soil organic carbon is highly determined by the level of land management practices. In this regard, the higher value of SOC on treated land of the midland altitudinal belt implies that agroecological conditions of the area have positively contributed to improving the SOC in the treated land. Also land tillage, grassland cover, and application of manure/ household waste could contribute to the variation of SOC along different agroecology of the study area.

2) Total nitrogen (TN)

For this study, TN was considered one of the macronutrients for plants. The combined effect of TN in Table V indicated that significant difference was observed across various agroecology and SWC structures. In this regard, agroecological differences showed that higher TN is found in the highland and the least is in the lowland. The high nitrogen content at high altitudes may be due to wet conditions, which enhanced the activity of nitrogen-fixing bacteria. Regarding variation of soil conservation relatively greater value of TN was recorded in the soil treated with SWC structures of the highland and lowland area. However, in the midland irregular distribution of TN was observed. For instance, the mean value of TN in the FN and CD structures was lower than the land not treated with SWC. Nevertheless, the mean value of TN in soil treated with SB structures is greater than in non-treated land.

The high mean value of TN in the soil treated with SWC structures of the highland and lowland area agrees with the report by [15] and [22] that showed the mean total nitrogen of the soil was greater in conserved land than non-conserved. The lower mean value of TN in the FN and CD structures than non-conserved land depicted that the conservation work was failed or did not succeed in improving the soil's total nitrogen content.

It might be due to failure to select the right conservation technology and or poor design/layout of the structures to keep soil erosion. According to the report by [17], appropriate conservation structures for ecological and socio-economic conditions are necessary for effective conservation work.

3) Soil pH

The soil pH value is the negative hydrogen ion concentration of soil that determines the availability of soil bacteria, nutrient leaching, nutrient availability, toxic elements, and soil structure. According to Table III, the two ways analysis of variance at $p \leq 0.05$ showed a significant difference in soil pH across different agroecology and soil management practices. The result depicted that variation of agroecology, and different soil management has a significant impact on the distribution of soil pH of the study area. For instance, in the highland, midland, and lowland agroecology, the highest mean value of soil pH was observed in the treated land than non-treated.

The result on the distribution of soil pH indicated the positive impact of conservation work. This result might be related to the SWC work that retains the basic cations and fine fraction, raising the soil pH. A report by [23] showed that a soil pH was significantly higher in the soil with management practice than soils with no management practices. Agroecological variation of soil pH showed a lower pH value in the highland than midland or lowland. The lower soil pH change in the highland may be increment of temperature that causes high molecular vibrations, which results in the ability of water to ionize and form more hydrogen ions. As a result, the soil pH will decrease.

4) Electrical conductivity (EC)

The ANOVA result revealed a significant difference in soil EC across various agroecology and conservation structures. For instance in the highland and midland agroecology's conserved soil, had a higher mean value of soil EC than non-conserved land (Table V). The higher mean value of soil EC in the conserved land might be related to household wastes, livestock manure, dung ash and other decomposable materials used on the conservation structures, which collectively enhance soil EC over a long time. A similar result was reported by [24] in the study area. The local farmers mostly throw wastes, residue, dung, wood, and other decomposable materials in the farmland that gradually increase soil EC.

Though the least value of the soil EC in the lowland was found in the non-treated land, statistically, the difference is not significant among various soil management practices. The study also showed the overall mean value of soil EC in the highland was lower than the midland or lowland. This might be due to temperature variation. When the temperature decreases, soil EC decreases slightly because when the temperature is below freezing, soil pores become increasingly insulated from each other and overall soil EC declines rapidly. This might be the cause in the study area for the value of soil EC was relatively lower in the highland when compared to the amount in midland/lowland.

5) Cation exchange capacity (CEC)

The total number of exchangeable cations a soil can hold is called its cation exchange capacity (CEC). The analysis of variance at $p < 0.05$ showed a significant difference in soil CEC across various agroecology and soil management practices (Table VI). For instance, the mean value of CEC is greater in conserved land compared with non-conserved land. The result indicated that the SWC practices significantly affected the soil CEC in the study area. The high CEC observed in the conserved land might be caused by conservation work that generates high biomass and control of erosion, consequently increasing CEC in the soil. A study report by [23] and [25] showed that the mean value of CEC content in soils under un-conserved farm plots was lower than the value recorded in conserved farm plots. The result also indicated that the SWC technologies significantly affected the soil CEC in the study area. The higher soil CEC indicates soil fertility improvement because it shows the soil's ability to supply essential plant nutrients, such as calcium and magnesium.

The agroecological difference of soil CEC showed a high mean value in the highland and the least in the lowland. The high CEC value in the highland might be due to the high contents of clay soil texture in the highland that holds or stores cation. But in the midland and lowland agroecology, the sand content of the soil is higher than the highland that has a low holding capacity of the soil CEC. Climate variability may be the other factor that has contributed to the agroecological variation of the soil CEC. For instance, an increase in soil temperature decreases organic matter through combustion, which leads reduction in clay size clay fraction and the cation exchange capacity of the soil [25].

6) Available phosphorus (Av.P)

The available phosphorus was significantly different in the study area at $p \leq 0.05$ along different agroecology and soil conservation structures (Table IV). For instance, in all agroecology or altitudinal belts, the soil's available phosphorus (AP) was greater in conserved land than non-conserved plots. The result in the Table IV revealed that the SWC structures have significantly contributed to the improvement of phosphorous in the soil than non-conserved soil. These results agree with the finding by [7] and [26] reported that the physical SWC measures caused a higher amount of available phosphorous on conserved land.

In the study area, the application of both organic and inorganic sources of AP was important for amending the agricultural land for better land productivity. The high concentration of AP in the treated land could be attributed to the application of chemical fertilizers (urea, CO, NH2), diammonium phosphate (DAP), and organic fertilizers (e.g., compost, manure, and household wastes) in the cultivation land. The data in (Table IV) show that the mean value of available phosphorus in the soil was increasing with the decreasing altitude in the midland and lowland agroecology. The lower mean value of AP in the midland area than lowland might have resulted from the variation of temperature, which is a lower temperature in the midland than lowland. But the contrary result was observed in the highland agroecology because there is high AP with low temperature than the midland or lowland area. The factors that contributed to high AP in the highland agroecology of the study area may be related to soil conservation and less tillage that reduced the removal of AP.

7) Available potassium (Av.K)

Potassium is essential for plant photosynthesis, metabolism, carbohydrate breakdown, drought resistance (reducing plant water loss), translocating nutrients within the plant, and increasing plant resistance to diseases. The ANOVA result showed a significant difference of available potassium (AK) across different agroecology and SWC structures (Table IV). For instance, the mean value of soil AK is high in the lowland and least in the midland. The exact mechanism by which factors influence the reaction of potassium in soil is not clearly understood. The lower value of AK in the midland might be related to the variation of soil management, soil texture, or soil temperature in the area. For instance the least value of AK in the midland may be related to frequent (over) cultivation of farmers in small plots of land that lead to both soil degradation and erosion of available potassium of the soil. Continued cultivation of the crops on the same soil without additional input reduces the marginal productivity of the soil due to exhaustion of nutrients, thus the land depreciates.

Though the irregular distribution of AK was recorded within different soil management practices of the midland and lowland agroecology, in the highland area, a greater value of AK was recorded in conserved land. The value of (AK) in the highland area was in line with the report by [27], in which higher soil potassium was observed on the treated land than non-treated. The high concentration of AK in the treated land of highland agroecology might be related to the application of plant cover in the treated land. However, in the midland and lowland area, plant material was frequently removed for household energy consumption and it might have facilitated leaching problems. This might contribute to the lower value of AK in the midland and lowland compared to in the highland agroecology of the study area.

TABLE III: TWO-WAY ANOVA ANALYSES OF SOIL CHEMICAL PROPERTIES POSTHOC MULTIPLE COMPARISONS

Soil variable	Source	SS	DF	MS	F	Sig
OC	Ago ecology/ altitudinal belt	116.341	2	58.170	107.747	.000*
	Soil management	5.727	3	1.909	3.536	.027*
	Error	15.117	28	.540		
	Total	416.302	36			
pH	Ago ecology/ altitudinal belt	8.006	2	4.003	34.758	.000*
	Soil management	6.295	3	2.098	18.218	.000*
	Error	3.225	28	.115		
	Total	1129.899	36			
TN	Ago ecology/ altitudinal belt	1.527	2	.764	65.731	.000*
	Soil management	.081	3	.027	2.324	.080*
	Error	.325	28	.012		
	Total	9.306	36			

Agroecology/altitudinal belt (500 to 1500, 1500 to 2200,and above 2200);

TABLE IV: TWO WAY ANOVA ANALYSIS OF SOIL CHEMICAL PROPERTIES POSTHOC MULTIPLE COMPARISONS

Soil variable	Source	SS	DF	MS	F	Sig
CEC(meq/100 gm)	Ago ecology/ altitudinal belt	2385.032	2	1192.516	274.462	.000*
	Soil management	39.725	3	13.242	3.048	.045*
	Error	121.658	28	4.345		
	Total	6097.076	36			
EC (µs/cm)/	Ago ecology/ altitudinal belt	21394.071	2	10697.035	8.481	.001*
	Soil management	26659.140	3	8886.380	7.046	.001*
	Error	35315.764	28	1261.277		
	Total	180026.020	36			
Av.K (mg/l)	Ago ecology/ altitudinal belt	318819.757	2	159409.879	7.479	.002*
	Soil management	171542.857	3	57180.952	2.683	.009
	Error	596788.963	28	21313.892		
	Total	2092214.300	36			
Av.P (mg/l)	Ago ecology/ altitudinal belt	49.567	2	24.783	49.986	.000*
	Soil management	11.809	3	3.936	7.939	.001*
	Error	13.883	28	.496		
	Total	1051.319	36			

TABLE V: MEAN DIFFERENCE OF SOIL BIOCHEMICAL PROPERTIES ALONG DIFFERENT AGROECOLOGY AND LAND MANAGEMENT

Agro ecology	Land mgt	N	% OC	CEC (meq)	% TN	PH	EC	AK	AP
Highland (> 2,300 m)	SB	3	5.71 ±.015	24.56 ±1.75	.82 ±.02	5.93 ±.09	27.86 ±5.48	130.7 ±108.6	7.39 ±.76
	FN	3	4.60 ±.87	20.71 ±1.65	.71 ±.05	5.48 ±.11	28.66 ±1.53	232.8 ±72.	6.51 ±.31
	CD	3	5.70 ±14	19.78 ±1.62	.77 ±.03	4.88 ±.18	42.96 ±7.22	82.8 ±23.88	7.19 ±.17
	NC	3	4.83 ±1.16	19.72 ±2.24	.59 ±.21	4.41 ±.19	21.53 ±1.62	72.83 ±46.43	6.18 ±.30
	F		1.884	4.671	2.345	24.960	11.272	5.724	4.760
	Sig		*.211 ns*	*.036**	*.149ns*	*.000 ***	*.003***	*.081**	*.035**
Mid land (1500 to 2300 m)	SB	3	3.51 ±.39	8.61 ±2.01	.47 ±.05	5.55 ±.38	21.5 ±.91	118 ±194.9	4.32 ± .48
	FN	3	2.09 ±.87	6.38 ±.81	.38 ±.08	6.10 ±.38	181.8 ± 68.98	114 ±83.5	5.32 ± .93
	CD	3	1.63 ±.39	5.40 ±.42	.34 ±.04	6.10 ±.17	82.13 ± 22.15	76 .26 ±15.40	4.02 ±.52
	NC	3	1.38 ±.38	4.46 ±1.62	.40 ±.15	4.94 ±.57	52.86 ± 30.61	175.5.13 ±131.2	3.98 ± 1.16
	F		8.766	5.028	.925	5.685	9.337	1.120	5.767
	Sig		*.007***	*.030**	*.472 ns*	*.022**	*.005***	*.136ns*	*.24ns*
	SB	3	.46 ±.39	1.90 ±85	.17 ±.05	6.23 ±.10	26.5 ±10.73	144 ±27.56	3.92 ±.50

Low land (5000 -1500 m)	FN	3	.93 ±.34	1.66 ± 1.30	.20 ±.08	6.78 ±.46	73.5 ±50.05	250.33 ± 83.75	5.25 ±.94
	CD	3	1.87 ±.54	5.46 ±2.08	.38 ±.06	5.76±.06	24.86 ±6.26	76.26 ±15.40	4.12 ±.44
	NC	3	.49 ±.48	1.19 ±1.78	.15 ±.07	5.48 ±.51	18.86 ±4.11	242.36 ±93.35	3.08 ±.02
	F		6.396	.016	6.959	8.049	2.860	9.471	7.122
	Sig		*5.463ns*	*.024**	*.013**	*.008***	*.104ns*	*.014**	*.012**

SB (Level soil bund), FN (Level fanya juu), CD (Cut off drain), NC (None Conserved)

C. Perception of Farmers on Soil Erosion

In the study area, about 90% of the farmers perceive that soil erosion problem is increasing in their farmlands that are related to deforestation (land degradation), shortage of land, steep slope cultivation, inadequate land cover, climate variability, inaccessibility of resources such as fertilizers, seeds and pesticides and land management problems. These are the causes for the decline of crop and livestock production of the area throughout the year. The link between soil erosion and decline in soil fertility levels appeared evident to the respondents. The declining soil fertility was the driving force to expand their farmlands to forestlands and marginal areas, characterized by rugged topography. According to [28], expanding cultivation land to the marginal lands, forest land, and grazing land are the major causes of the increasing vulnerability of agricultural land to soil erosion in Ethiopia. Because of this, large numbers of farmers of the study area are dependent on food aid; others are shifting their livelihood from farming to daily labor in the urban areas.

D. Farmers Attitude on Soil Fertility versus Soil Fertility Management Strategies

Farmers have the knowledge to identify soil fertility that developed through experience. According to the land users, soil color and depth, crop productivity, gully erosion, and runoff (blue color of the water) are the best indicators of soil fertility. Mainly soil color is highly influential in soil fertility; about 84% of farmers of the study area have perceived that reddish-brown soil is an indicator of poor fertility, and darker (black) soils are fertile soils.

They also perceive that low depth soil has lesser soil fertility than deep soil. This result agrees with the study report by [29] in southern Ethiopia. In the study area, the farmers have been applying different soil fertility management strategies, such as land rotation, crop rotation, applying residuals (dung), horizontal plow, mulching, and planting indigenous trees (agroforestry) that are the long-lasted approaches, which are referred to as the traditional strategies.

Besides these, from the time when 2002/3 watershed-based SWC technologies such as terracing, stone bund soil bund, check dam, micro basin, and cut of drain have been practiced in different areas. Parallel to the SWC works, the farmers use organic fertilizers for homestead products and mineral fertilizers for annual grain crops grown on distant fields and less fertile soils, which are essential for soil fertility management.

E. Impact of Farmers' Perception on Soil Fertility

Among several socio-cultural factors that influence soil management, farmers' perception is the most important in deciding on resource conservation work. If the land users failed to perceive soil management or SWC enhance agricultural productivity, they would feel reluctant to take action against soil erosion [30]. During household surveys and interviews, the farmers were asked about their perception of the importance of SWC. Of the total household survey, more than 85% were perceived that both traditional and introduced SWC works are important to improve agricultural productivity.

Based on the interview and household survey results, most respondents perceive that SWC has a significant impact on successful soil management practices. However, more than half of interviewed farmers have not adopted SWC practices in their farmland. Others gradually started to abandon certain SWC practices, such as fallowing, terracing, crop residues, and others introduced conservation measures related to the study area's current challenge (constraints).

F. Constraints to Adopt and Adapt the SWC Practices

The primary constraints of farmers to adopt/adapt SWC work are small land size, shortage of fuelwood, dependency on food aid, less productivity of the soil, the high price of chemical fertilizers, youth migration, and long lasted effect of conservation works. For instance, shortage of land had not allowed the farmers to fallow their land or apply physical SWC structures according to the standard because they perceived it consumes the land. On the other hand, the shortage of fuel wood and fodder forced the farmers to reduce the application of crop residuals on their farmland that has a higher probability of improving soil fertility. The other challenge of the farmers adopting SWC practices was the high price of chemical fertilizers and seeds. The farmers said that the implementation of SWC work without the application of chemical fertilizers was meaningless. This result agrees with the study report by [31] in the Gidabo watershed of southeastern Ethiopia.

Nevertheless, the price of chemical fertilizer is not affordable to many farmers. Therefore, most of them abandoned the adoption of SWC and are looking for non-cultivated land from marginal areas to feed their family, adversely affecting the farmers' role in soil management, agricultural production, and sustainable socio-economic and environmental system of the area. In general, the identified constraints were seen as severe problems for farmers to adopt and apply the standard dimension of SWC structures and soil management, which minimized the full effect of the conservation work on soil fertility.

IV. Conclusion and Recommendations

The ANOVA result at $p \leq 0.05$ showed no significant difference in soil texture along different agroecology. However, a significant difference in silt and clay texture was observed along with various soil management practices. For instance, the greater mean value of silt soil was recorded in conserved land and clay in non-conserved land. The high concentration of silt soil in the conserved land is attributed to the comparative effect of SWC, which increased the deposition of fine soil particles. The high clay content in the non-conserved land might be related to the resistant clay soil in the eroded land. Though no significant difference in soil bulk density was observed relatively higher mean value of SBD was recorded in non-conserved land. This observation might be associated with the high soil density that could be caused by compaction of the soil and removal of soil organic matter by soil erosion.

The land treated with SWC structures has the opportunity to develop microorganism that reduces the compaction and density of the soil. Regarding soil chemical properties, the statistical result showed that the soil properties such as OC, pH, TN, CEC, EC, and AP showed significant differences across various agroecology and soil conservation. In the case of AK, irregular distribution was observed along with different soil conservation practices. However, the results mainly indicate that soil fertility was strongly influenced by altitude and soil conservation practices. This refers altitudinal variation denotes the variation of climate variables such as temperature and rainfall that may have significant impacts on the distribution of soil properties.

Therefore the overall result indicated that about 40% of SWC activities was failed to maintain soil fertility. The identified constraints of SWC practices are small land size, lack of labor force, less agricultural product, lack of interest among youth for agricultural work, the prolonged effect of SWC and lack of access to chemical fertilizer. Though the farmers have a positive interest in the conservation work, the constraints were enforced the farmers to be reluctant to adopt/adapt the standard SWC work, which minimized the effort to enhance soil fertility. This attitude will cause unsustainable socio-economic and environmental development in the study area. The study concluded that the SWC work of the area should focus on variation of agroecology, SWC technologies, and local constraints that are important for sustainable ecosystem services. In addition, policymakers should set options for the constraints that hinder the implementation of nationally designed SWC practices.

Conflict of Interest

The authors declare no conflict of interest

Authors Contributions

GH contributed to the design of the work data acquisition, analysis, interpretation, and write-up of the manuscript. **AB** designed the work, supervised, and substantively revised the work. **AT** designed the work, supervised, and substantively revised the work. **MM** designed the work, supervised, and substantively revised the work.

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Getahun Hassen is a PhD candidate in the Department of Natural Resources Management at Dilla University, Ethiopia. He has more than six years of teaching experience in different government and non-government organizations. Getahun also worked as a Dilla University Research and Dissemination Support center coordinator until his current PhD study. Professionally he has five publications (research and review work) internationally peer-reviewed journals. Besides, he has more than ten certificates of participation in academic and social training at national and international forums. His research interest is physical geography and natural resource conservation.

Amare Bantider (PhD) is an associate professor of geography land resource management. He is a senior researcher in the Water and Land Resource Centre of Addis Ababa University and lectures at the Center for Food Security Studies, College of Development Studies, Addis Ababa University. Overall, he has more than 30 years of professional experience, of which 23 years are in higher learning institutions as a researcher, instructor and in several academic leadership positions. He obtained his first and second degrees from the Department of Geography and Environmental Studies at Addis Ababa University (Ethiopia) in 1987 and 1996. He obtained his PhD degree from Bern University, Switzerland, in 2007. He authored and co-authored papers and book chapters and published in peer-reviewed journals and books on thematic areas of land use and land cover changes, watershed management, climate change adaptations, soil and water conservation, resource governance and related fields.

Abiyot Legesse (PhD) is an associate professor of geography & land resource management. He served in several professional, academic and administrative positions. Notable ones include being Editor-in-chief of Journal of Environment and development, Vice president for Academic Affairs, Dilla University, Dean of School of Graduate Studies, Dilla University, vice-director for teacher development, Dilla University and others. He has 16 publications in international peer-reviewed journals. His research interest is Geographic information system (GIS) and remote sensing for Hazard mapping and environmental modeling, spatiotemporal analysis for physical geography and natural resource conservation.

Maimbo Mabanga Malesuis is an agricultural engineering expert with 32 years of experience in managing programmes and projects and facilitating sustainable small holder agricultural research and development in land management, conservation agriculture, soil and water conservation, small and large-scale irrigation and water harvesting and management. His contribution is mainly in bettering small-scale farmers' livelihoods and engineering and science through over 80 peer-reviewed publications. Eng. Malesu is head of the Water Management Unit at the World Agroforestry Centre (ICRAF) based in Nairobi, Kenya. In addition, he is the Leader of the Transformative Partnership Platform – TPP on Forests and Water in the merged CIFOR-ICRAF. He is a registered member of the American Society of Agricultural and Biological Engineers (ASABE).