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Review on Role of Soil and Water Conservation Measures on Soil Physico Chemical Properties and Its Implication to Climate Change Mitigation and Adaptation

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Abstract

Soil degradation is a global threat. Developing countries are more severely affected by soil degradation than developed countries. Ethiopia, one of the developing countries in eastern Africa, is highly threatened by soil degradation problems. The soil degradation problem has had serious consequences in Ethiopia such as occurrence of persistent food insecurity, economic losses and various environmental hazards such as recurrent drought and increases vulnerability of people to the adverse effects of climate variability and change. To overcome these problems, integrated soil and water conservation has been implemented in the country. Thus many studies have been conducted with regards to soil and water conservation which influences soil physical and chemical properties and on climate change adaption and mitigation. Therefore, this review papers was aimed to assess role of soil and water conservation on soil physical and chemical properties and it's implication to climate change adaptation and mitigation. Different studies showed that soil physical and chemical properties such as Soil texture (sand, silt, clay), Moisture volume (%), FC (%), PWP (%), AWC (%), OC, TN, pH, EC, CEC Ava_P, and Ava_ K, (EB: K^+, Ca^{2+}, and Mg^{2+}) were improved in different agro ecologies. In addition to this, soil treated with soil and water conservation stored more organic carbon as compared to non treated soil. Soil and water conservation also contributed to improve yield and yield component of crops in areas where serious soil erosion and also in moisture deficit areas. Thus, the studies have been showed that the people's ability to adopted in climate change. Therefore soil and water conservation could improve soil physical and chemical properties, climate change mitigation and adaptation in the country.

Keywords: Adaptation, Mitigation, Phyisco chemical properties, soil and water conservation
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1. INTRODUCTION

Soil degradation is a global threat (Cerdà *et al*., 2010; Mighall *et al*., 2012; de Souza Braz *et al*., 2013; Wang *et al*., 2013). It has been affecting about two billion hectares of land (Oldeman *et al*., 1991). While no region is immune, developing countries are more severely affected by soil degradation than developed countries. Ethiopia, one of the developing countries in eastern Africa, is highly threatened by soil degradation problems (Hurni, 1993; Shiferaw & Holden, 1999; Hurni *et al*., 2007). Soil degradation is a serious problem in Ethiopia, particularly in the highlands, where population density is high and the bulk of crop production occurs (Hurni, 1993; Shiferaw & Holden, 1999; Hurni *et al*.,2007; Haile and Fetene, 2012; Mekuria *et al*., 2012; Meshesha *et al*., 2012; Haregeweyn *et al*., 2013; Karltun *et al*., 2013;Belay *et al*., 2014). The pressure from human and livestock populations, coupled with biophysical, social, economic, and political factors, has caused severe degradation of resources (Hurni, 1993; Sonneveld, 2002; Girmay *et al.,* 2008). Depletion of soil organic matter (SOM) and nutrients, salinization, and soil erosion by water are the most critical forms of soil degradation (Bewket, 2003; Girmay *et al*., 2008) and are exacerbated by deforestation.

The severity of this land degradation process makes large areas unsuitable for agricultural production, because the topsoil and even part of the sub-soil in some areas has been removed, and stones or bare rock are left at the surface (Esser *et al.,* 2002). The land degradation problem has had serious consequences in Ethiopia such as occurrence of persistent food insecurity, economic losses and various environmental hazards such as recurrent drought (Bekele and Holden, 1999). As noted by Pimentel et al. (1995), erosion adversely affects crop productivity by reducing water availability, water-holding capacity of the soil, nutrient levels, soil organic matter and soil depth. Research results confirmed that soil nutrient depletion caused by erosion is the major cause for decline of agricultural production (Bekele and Holden, 1998; Abay *et al*., 2016). Deforestation and conversion of marginal land to agriculture has been followed by severe soil erosion that has caused crop production losses, which in turn result in economic losses (Bojö and Cassels, 1995). For example, due to soil and nutrient loss through erosion, Ethiopia has been annually losing about US$ 106 million (Bojö and Cassels, 1995).

Soil degradation also increases vulnerability of people to the adverse effects of climate variability and change, by reducing soil organic carbon (SOC) concentration and water holding capacity, which in turn reduces agricultural productivity and local resource assets (TerrAfrica, 2009). The downward spiral adversely affects the adaptive capacity of the people to climate variability and change (Girmay *et al*., 2008; TerrAfrica, 2009).

Soil organic carbon (SOC) plays a vital role within the overall carbon cycle (Van Oost *et al.,* 2007). Central to the present concept, soil sequesters averagely three hundred times of carbon created by industrial burning of fossil fuels (Lal, 2005). So any slight changes to SOC can have a negative effect on provision of system services. Being preferentially found on the surfaces, SOC has comparatively lower density, making it easier for it to be carried off by runoff. Several studies have shown that the typical loss of SOC by water erosion annually is 1-5 pentagram of carbon that is consequently deposited at the lower areas of a catchment (Berhe, 2012).

SOC includes organic compounds (i'e., plant, animal and microbial residues in any stage of decay) that are highly enriched in carbon (Lal, 2008). Consequently the role of SOC is important in edaphic factors like physical, chemical and biological properties of soil. Thus soil organic matter (SOM) determines soil quality, physical properties, crop nutrition and the link between these (Bergmann 1992; Loveland and Webb 2003). The soil physical properties affected by soil OM include aggregate stability, infiltration, water-holding capacity, soil workability, bulk density, aeration and water movement (Bergmann 1992; Loveland and Webb 2003). Soil carbon is affected on a spatial and temporal scale by climatical, edaphic, biotic and lithological factors which influence the balance between the gains and losses of soil carbon (Kurgat, 2011).

Girmay et al. (2008) estimated the historic SOC loss from rangelands and croplands of Ethiopia over the last 50 years to be 230–670 TgC (Tg = teragram = 1012 g = million metric ton). Therefore, soil degradation will continue to be a serious threat to the finite land resource if prudent land use and effective soil management strategies to increase SOC concentration and restore soil quality are not implemented.

Sustainable soil management technologies (e.g., appropriate soil and water conservation (SWC) measures, afforestation of degraded soils, water harvesting, crop rotations, crop residue mulching along with cover cropping, agroforestry, and integrated nutrient management) can enhance the SOC stock, reduce soil degradation, and decrease soil's vulnerability to climate change. In addition, judicious soil management can increase people's capacity to adapt and mitigate climate change through C sequestration and greenhouse gas (GHG) emissions reduction (Lal, 2004; Vagen *et al*., 2005; TerrAfrica, 2009). World croplands can sequester 0.02–0.76MgCha^{-1} year^{-1} by adopting recommended management practices (Lal, 2001). Girmay et al. (2008) estimated the historical SOC sequestration potential of croplands in Ethiopia through adapting soil restorative measures at 215 – 638 Tg C over a period of 50 years. Soil C sequestration can improve soil quality; restore degraded ecosystems, and increase agronomic/biomass productivity (Lal *et al.,* 2003). Thus, C sequestration is often termed as a win–win or no-regrets strategy (Lal *et al*., 2003; Girmay *et al*., 2008). However, it requires the selection and implementation of technologies that are appropriate to specific soils and eco regions (Girmay *et al*., 2008).

Therefore the objective of this review is to assess role of soil and water conservation on soil physical and chemical properties and it's implication to climate change adaptation and mitigation in Ethiopia.

2. METHODOLOGY OF REVIEW

To the success of this work, different sources such as journals, proceedings, thesis works and reports related to soil and water conservation and climate change adaptation and mitigation have been used.

3. EFFECT OF SOIL AND WATER CONSERVATION ON PROPERTIES OF SOIL

3.1 Effect of Soil and Water Conservation on Chemical Properties of Soil

Table 1 Effect of SWC on chemical soil properties

Type of SWC	**Studied chemical properties of soil**	**Improved chemical properties of soil**	**Studied area**	**Source**
Graded stone bund	OM, TN, pH, and CEC	OM, TN, pH, and CEC	Adaa Berga district	Abay *et al.,* 2016
Stone faced soil bund and soil bund	OC, TN, pH, EC, CEC Ava_P, and Ava_ K, (EB) (K^+, Ca^{2+}, and Mg^{2+})	OC, TN, pH, EC, CEC Ava_P, and Ava_ K, (EB) (K^+, Ca^{2+}, and Mg^{2+})	Gonder zuria district , Ambachia Watershed	Worku, 2017
Level soil bund and stone bund	SOC, TN, P_avai, K_avail, Ph, CEC,	TN	Dawuro zone, Loma district	Kebede *et al.,* 2011
Terraces	OM, TN, pH, CEC Ava_P, and (EB) (K^+, Na^+, Ca^{2+}, and Mg^{2+})	OM, TN, pH, , CEC Ava_P, and, (EB) (Na^+ K^+, Ca^{2+}, and Mg^{2+})	Dembecha district, Anjeni watershed	Tadele *et al.,* 2013
Lands treated with Sesbania and elephant grass	OM, TN, pH, CEC Ava_P, and (EB) (K^+, Na^+, Ca^{2+}, and Mg^{2+})	OM, TN, pH, CEC Ava_P, and (EB) (K^+, Na^+ , Ca^{2+}, and Mg^{2+})	Lemo district, Hadiya zone	Tamrat *et al.,* 2018
Manure, Soil bund, integrated manure and soil bund	TN, pH, CEC Ava_P, OM	TN, pH, CEC Ava_P, OM	Dembecha woreda, Zikri watershed	Yihenew et al., 2015

Several studies recognized that, physical SWC showed a significant difference on chemical properties of soil between conserved and non conserved plot of land. According to the study conducted by (Abay *et al*., 2016) the graded stone bunds have shown significant improvement in chemical soil properties such as soil OM, TN, pH, and CEC. Moreover, the high OM content of farm plots with SWC practices affect more positively the soil properties as compared to the non conserved farm plots. Also, variation was also significant along slope gradient for some chemicals properties. Worku, H (2017) indicated that, physical SWC (stone faced soil bund and soil bund) is promising in protecting the cultivated land from erosion and the associated nutrient depletion. 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. Yonas *et al*., 2017 also reported that, that the effectiveness of soil and water conservation improves significantly the soil chemical properties (soil pH, K^+, available P, SOC, TN, and CEC) than in the adjacent without SWC treatment. This indicates the positive impacts of SWC practices in improving the nutrient status. OM, TN, pH, CEC Ava_P, and EB also significantly improved by biological SWC. However, Kebede *et al*., 2011 reported that, less SOC, Pavai, pH is measured from conserved plot of land. These perhaps due to: the difference in the past land degradation resulting from continuous cultivation, extractive plant harvest and soil erosion. Alemayehu, A 2007 also confirm in Anjeni watershed that Pavail on non terraced land was higher than the terraced. The significantly low soil pH in level stone bund and soil bund compared to the respective adjacent-nonterraced cropland were probably due to loss of relatively more basic cation resulted from erosion before the structures built and did not restore yet after the structures. Under a continuous cropping system soil acidity increases due to the gradual replacement of basic cations by aluminum (Zougmore *et al.,* 2002).

SWC structures are practically used as support for agronomic and soil management (Morgan, 2005) and considered as the first defense line. Thus, they alone are less likely to improve soil properties significantly under similar management to non terraced. Zougmore *et al*., 2009 has reported that combining stone rows barriers to run-off with the application of compost was significantly controlled erosion and reduced organic C and nutrient losses than compost or stone row alone.

3.2 Effect of Soil and Water Conservation on Physical Properties of Soil

Various studies conducted to evaluate the structural and biological soil and water conservation and on physical soil properties. According to those studies, the percentage of clay content of soil increases with a soil treated with SWC structure, and decreasing sand particles of soil. The decrease in soil BD due to SWC practices at would result in greater water infiltration rates which in turn minimize runoff velocity, thus, sediments and organic matter removal. As a consequence OM accumulation improves a soil physical structure which promotes crop root abundance, crop stand, crop production and better crop residues at the conserved field plot. The land that treated with SWC measures improves the soil moisture content which is a key factor affecting agricultural production in water limited environments.

Table 2 Effect of SWC on physical soil properties

Type of SWC	**Studied physical properties of soil**	**Improved physical properties of soil**	**Studied area**	**Source**
Graded stone bund	BD, MC	BD, MC	Adaa Berga district	Abay et al., 2016
Level soil bund and stone bund	Soil texture (sand, silt, clay)	Soil texture (sand, silt, clay)	Dawuro zone, Loma district	Kebede *et al.,* 2011
Fanya Juu	Soil texture (sand, silt, clay), BD	Soil texture (sand, silt, clay), BD	Ambo district, Goromti watershed	Worku *et al.,* 2012
Fanya Juu	Soil texture (sand, silt, clay), Moisture volume (%), FC(%), PWP(%), AWC (%)	Soil texture (sand, silt, clay), Moisture volume (%), FC(%), PWP(%), AWC (%)	Dembecha woreda, Anjeni watershed	Daniel *et al.,* 2015
Lands treated with Sesbania and elephant grass	Soil texture (sand, silt, clay), BD	Soil texture (sand, silt, clay), BD	Lemo District of Southern Ethiopia	Tamrat *et al.,* 2018
Manure, Soil bund, integrated manure and soil bund	BD	BD	Dembecha woreda, Zikri watershed	Yihenew et al., 2015

According to (Abay, *et al*) Bulk density and moisture content of treated soil is increased. Similar results also reported by (worku *et al*., 2012) and increased the percentage of clay contents was observed. This result also confirms the presence of higher clay fraction of conserved soil due to deposition from the upper slope (Regina *et al.,* 2004). Soil moisture shows significance variation between treated and non treated land. SOM is positively correlated with MC while it is inversely correlated with soil BD. The recorded percentage of sand is lower for soil treated with SWC while higher percentage of clay for treated soil. Those results confirm the findings by Lemma et al. (2015).These may be due to soil particles resistance to detachment, and susceptibility to transportation. Gebremichael *et al*. (2005) reported that selective removal of soil particles to steeper slopes leave behind coarser materials (sand, gravel and stones), while the transported material is deposited as the slope steepness decreases. Sandy soils are less cohesive than clayey soils and thus aggregates with high sand content are more easily detached; silty soils derived from loess parent material are the most erodible type of soil (Blanco and Lal, 2008). Integrated application of manure and soil bund also improves soil bulk density (Yihenew *et al*., 2015)

There is an improvement in hydrological properties in soils of the conserved than those in the non-conserved land (Daniel *et al.,* 2015). The volumetric moisture content, field capacity, permanent wilting point and available water content of soils of the conserved land is higher than the non conserved land. A study by World Neighbors (2000) in Guatemala, Honduras, and Nicaragua reported a 3–15% increase in AWC by the adoption of ecologically sound SWC practices. Improvement in AWC is important because such soils buffer water during periods of water deficit and could significantly improve agronomic productivity of rainfed agriculture. However, the agronomic and economic performances of SWC measures in tropical regions are highly dependent on the amount and distribution of precipitation (Benites & Ofori, 1993). Daniel et al., 2015 reported that, the highest FC and AWC, and also the lowest PWP is recorded from a soil treated with SWC. These trends suggest a positive impact of SWC measures on MC, FC, PWP and AWC.

The highest quantity of clay fractions is recorded under lands treated with elephant grass and sesbania whereas the lowest was in the adjacent degraded grazing land. A similar amount of clay fraction was found at lands treated with elephant grass and sesbania. This indicates elephant grass and sesbania have equal potential to minimize rates of erosion, keep clay materials in its original place, and capture eroded clay materials. The highest value of bulk density is observed at degraded grazing land and lowest at land treated with elephant grass and sesbania. Further, elephant grass and sesbania had similar effects on soil bulk density. Perhaps, the achieved soil bulk density improvement is due to organic matter addition from the plants, reduction of physical soil loss, and exclusion of grazing practices and human interference.

4. ROLE OF SWC TO MITIGATE CLIMATE CHANGE.

There is much concern that the increasing concentration of greenhouse gases in general, and carbon dioxide in particular contributes to global warming by trapping long-wave radiation reflected from the earth's surface. Over the past 150 years, the amount of carbon in the atmosphere has increased by 30%. Most scientists believe that there is a direct relationship between increased levels of carbon dioxide in the atmosphere and rising global temperature (Stavins and Richards, 2005).

One proposed method to reduce atmospheric carbon dioxide is to increase the global storage of carbon in soils. Though, soil carbon storage is a win–win strategy. It mitigates climate change by offsetting anthropogenic emissions; improves the environment, especially the quality of natural waters; enhances soil quality; improves agronomic productivity; and advances food security (FAO, 2005; Lal, 2009; Adesodun and Odejim, 2010; Kumar *et al*., 2009). Soils store 1502 Gt carbon (Jobbagy and Jackson, 2000), an amount that is two times greater than the amount found in the atmospheric carbon pool (Battle *et al*., 2000; Lal, 2004). In addition to carbon storage, the turnover time of organic carbon is important in understanding the role of soils in the global carbon cycle. Thus, soil carbon sequestration through changes in land use and management is one of the important strategies to mitigate the global greenhouse effect. Important land uses and practices with the potential to sequester soil organic carbon include conversion of cropland to pastoral and forest lands, conventional tillage to conservation tillage or no-tillage, and no manure use to regular addition of manure. However, food security needs for the world teeming population make conversion of cropland to forestland unsustainable. Therefore, increased food demands call for management of croplands to ensure food security and at the same time enhanced soil organic carbon sink within the soil to minimized atmospheric emission of CO_2 (Adesodun and Odejimi, 2010). In this case, afforestation and conservation programs have been made in the last three decades (Badege, 2001). In addition to this there was a huge areal closure activity in the country for the purpose of rehabilitating degraded lands which have their own role in increasing soil carbon stock.

According to the study conducted in Anjeni watershed, higher soil organic carbon concentration and soil organic carbon stock recorded from a soil treated with SWC than non conserved soil (Daniel *et al.,* 2015). The soil and water conservation system reduce surface runoff and soil loss, retain water that enhances crop growth and contributes to SOC input. Thus several studies confirm that, SOM and SOC are increased because of conservation measures. However, Kebede *et al*., 2011 disagree with these results that, the concentration of SOC is decreased from conserved lands (treated with level soil bund and stone bunds). Thus he suggests that, SOC is less because of intensive tillage, continuous cropping, removal of crop residues, and low organic carbon input in croplands.

5. CLIMATE CHANGE ADAPTATION

Ethiopia is extremely vulnerable to the impacts of climate change (Aklilu *et al*., 2009). Similarly, Burnett (2013) reported that Ethiopia has been identified as one of the most vulnerable countries to climate variability and change, and is frequently faced with climate-related hazards, commonly drought and floods. Since the early 1980s, the country has suffered seven major droughts five of which have led to famines in addition to dozens of local droughts. Major floods also occurred in different parts of the country in 1988, 1993, 1994, 1995, 1996 and 2006 (World Bank, 2010). Vulnerability is not the same for populations living under different social, economic,political, institutional and environmental conditions. For example, pastoralists in Yabello district tend to bemore vulnerable to climate change than farmers (Oxfam international, 2010). Several studies indicate that soil and water conservation measures used as a climate change adaptation through encouraging crop yield, even in areas where moisture deficit affect crop yields. SWC used to save moisture in the soil and make conducive environment for plants. Therefore it provides a yield advantage.

Table 3 Effect of SWC on yield improvements

Type of SWC	**Studied crop**	**Improved parameters**	**Studied area**	**Source**
Terraces	Wheat and maize	Grain yield, biomass yield and plant height	Dembecha district, Anjeni watershed	Tadele *et al.*, 2013
Level soil bund	Maize and sorghum	Yield	Hawi Gudina district, Oromia region	Eshetu *et al.*, 2016b
Fanya juu and Fanya chin	Maize	Yield	Daro labu district, Oromia region	Eshetu *et al.*, 2016a
Negarim and semi circular structure with mulch	Banana	Yield and yield components	Daro labu district, Oromia region	Tadele *et al.*, 2016
Tied ridge	maize	Yield and yield components	Sankurra district SNNPR: Bako district, Oromia region	Dagnaw *et al.*, 2018; Solomon, 2015
Tied ridges with mulch	sorghum	Yield and yield components	Alamata district, tigray region	Berhanu and Kidane, 2013
Circular Pitting, Open Ridge, Tied Ridge, Half Moon	sorghum	Yield and yield components	Alduba district SNNPR	Tekle and Wedajo, 2015

Eshetu *et al*., 2016a and Eshetu *et al.,* 2016b reported that the adoption ofFanya juu and Fanya chin and soil bund moisture conservation structure improves crop production and increase the yield advantage as Soil moisture/rainfall decrease. Also considered conserving soil moisture recommended with early maturing and drought resistant maize variety or other annual crops to be further scaled up in moisture stress areas. Also Dagnaw *et al*., 2018 indicated that Open end tied ridge planting on the furrow showed a promising result on maize grain yield and soil moisture conservation as compared to traditional practice. Therefore, tied ridge as in-situ moisture conservation is effective measures in storing 33.7% additional soil water for the next cropping season as compared to traditional practice. It is recommended that, the practice should be demonstrated and scaled up in moisture stress areas of the country. Terraces improve the yield and yield components of maize and wheat (Tadele *et al*., 2013). The study of SWC also extends to fruit crops which is affected by moisture deficit due to recent climate change occurred. Therefore, Negarim and semicircular micro catchments with mulch increases the yield and yield components of banana in moisture deficit areas (Tadele *et al*., 2017). Tekle and Wedajo, 2015 reported that critical to use and apply soil moisture conservation practices in the current agricultural production system and in order to use the available in situ water efficiently and effectively to bring improved grain and biomass yield and also improved productivity and production of sorghum in a sustainable manner. Solomon, 2015 recommend that Water conservation techniques at farm level are essential options for the semi arid area for improving yield through better soil water storage. With the current change in global climate, adaptation methods like the use of conservation approaches are to be implemented if the agriculture sector is to continue to meet the ever increasing food demand especially in developing countries like Ethiopia.

Generally, the current condition of Ethiopian climate change has been changing from time to time which affects the crop production, livestock and all natural resources. The recurrent occurrence of drought in the country leads to famine in arid and semi arid areas. In order to adapt to the change, the farmers adopt SWC on their farm lands and also on area enclosure. Thus, according to the study conducted by many authors, application of SWC provides food and feed even if below of its potential.

6. SUMMARY AND CONCLUSION

Ethiopia, one of the developing countries in eastern Africa, is highly threatened by soil degradation problems. Depletion of soil organic matter (SOM) and nutrients, salinization, and soil erosion by water are the most critical forms of soil degradation. SWC measures, afforestation of degraded soils, water harvesting, crop rotations; crop residue mulching along with cover cropping, agroforestry, and integrated nutrient management can enhance the SOC stock, reduce soil degradation, and decrease soil's vulnerability to climate change. In addition, judicious soil management can increase people's capacity to adapt and mitigate climate change through C sequestration and greenhouse gas (GHG) emissions reduction.

In Ethiopia different SWC has been implemented under different land use system to rehabilitate degraded lands, enhance soil productivity, improve micro climate, and improve crop yields under moisture stress areas. In line with this, different researches have been conducted in different agro ecologies to assess the role of SWC on soil physico chemical properties and its role on to climate mitigation adaptation. Among physical SWC, soil bund, stone bund, stone face soil bund, Fanya juu, Fanya chin, terraces, and among biological SWC plantation of elephant grass and sesbania was implemented. Also integrated soil bund with manure demonstrated to improve soil fertility. According to the research conducted in the country, both biological and physical SWC has improved both physical and chemical soil properties. However the integrated SWC was more effective rather than individual conservation measures. According to the research reviewed, a few considerations were given to physical soil properties as affected by SWC. Physical soil properties affect chemical soil properties.

SWC is act as a climate change mitigation strategies through reduction of CO_2 emission to the atmosphere which is in particular contributes to global warming. According to the study conducted in the country, higher soil organic carbon concentration and soil organic carbon stock recorded from a soil treated with SWC than non conserved soil. But most studies have been conducted to determine SOM concentration of the soil, thus SWC increases SOM and in directly store more carbon in soil. However many studies disagree with such finds that only SWC cannot significantly increase SOM alone. Because, it needs an integrated approach of biological and physical SWC to enhance SOM

Ethiopia is the most vulnerable countries to climate variability and change, and is frequently faced with climate-related hazards, commonly drought and floods which lead to famine. SWC plays a major role on climate adaptation in order to produce yields especially under moisture deficit areas. The most effective SWC to harvest water were tied ridges with mulch, Circular Pitting, Open Ridge, Half Moon terraces, level soil bund, *Fanya juu and Fanya chin,* Negarim and semi circular structure with mulch were implemented with different commodities and gives yield advantages than un conserved water on the fields. Even if more consideration were given to physical SWC, soil physical and chemical soil properties were improved and indirectly mitigate climate changes in the country. In addition to this, small holder farmers produce crop yield under limited moisture content of soil by harvesting the limited rainfall. Therefore soil and water conservation could be demonstrated and popularized on all land uses

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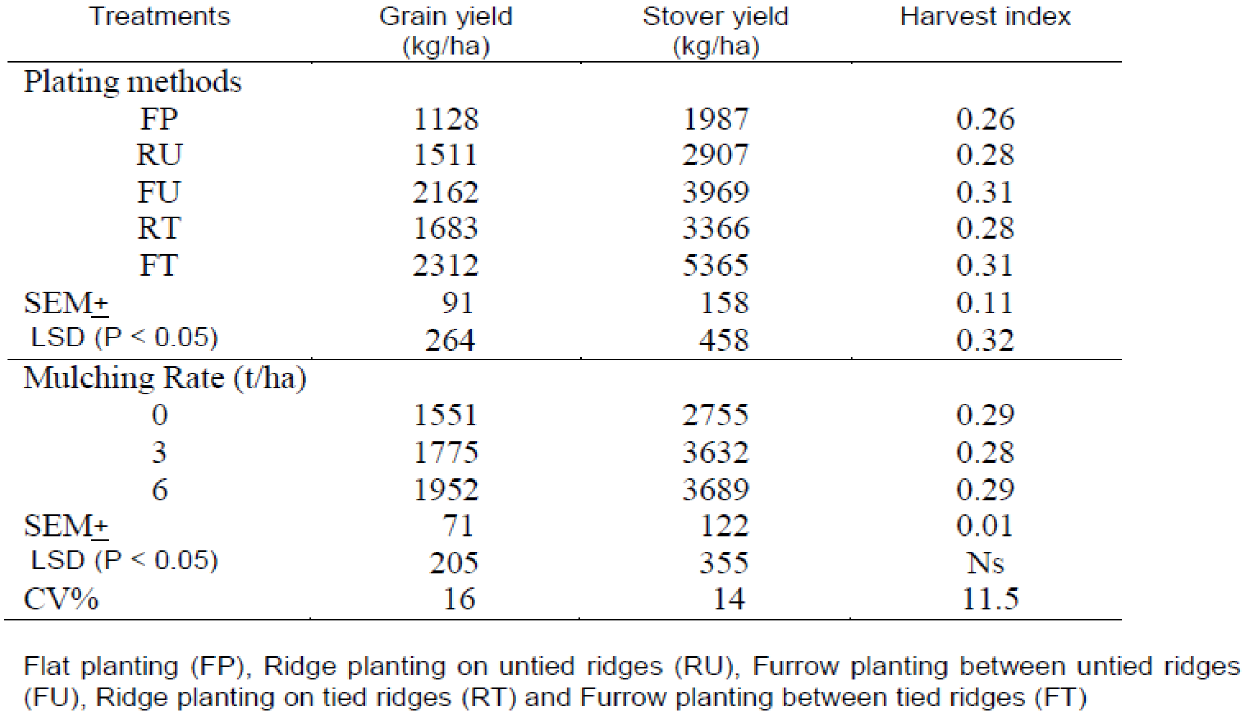
APPENDIX

Appendix Table 1. Effect of planting method and mulching rate of sorghum yield, Tigray region



Treatments	Grain yield (kg/ha)	Stover yield (kg/ha)	Harvest index
Plating methods			
FP	1128	1987	0.26
RU	1511	2907	0.28
FU	2162	3969	0.31
RT	1683	3366	0.28
FT	2312	5365	0.31
SEM±	91	158	0.11
LSD (P < 0.05)	264	458	0.32
Mulching Rate (t/ha)			
0	1551	2755	0.29
3	1775	3632	0.28
6	1952	3689	0.29
SEM±	71	122	0.01
LSD (P < 0.05)	205	355	Ns
CV%	16	14	11.5

Flat planting (FP), Ridge planting on untied ridges (RU), Furrow planting between untied ridges (FU), Ridge planting on tied ridges (RT) and Furrow planting between tied ridges (FT)

Appendix Table 2. Effect of Fanya Juu and Fanya chin on yield and yield components of maize, Western Hararghe zone, Daro Labu district

Treatment	Mean values of parameters during 2011 cropping season				
	STCH	NCpt	Yield (Qt/ha)	Days maturity	Yield advantage (%)
Level Fanya Juu	572	661	52.7	112.00	7.5
Level Fanya Chin	594	657	59.2	111.00	20.8
Control	649	658	49	111.00	
Mean	**605**	**658.1**	**53.64**	111.77	
LSD 0.05	175.3	118.25	5.1529	2.2031	
CV (%)	12.78	7.92	4.270345	0.869	

Table 2: Mean yield of maize variety (quintal ha^{-1}), stand count at harvest (STCH) & number of cobs per plot (NCpt) during 2012 cropping season

Treatment	Mean values of parameters during 2012 cropping season				
	STCH	NCpt	Yield (Qt/ha)	Days to maturity	Yield advantage (%)
Level Fanya Juu	665	655	54.09	115	87
Level Fanya Chin	709	694	41.9	115	45
Control	357	343	28.9	113	
Mean	**577**	**564**	**41.64**	114.222	
LSD 0.05	169.03	127.6	26.93	1.7722	
CV (%)	12.9	9.9	28.5	0.684	

Appendix Table 3. Effect of soil bund on yield and yield component of maize and sorghum, Western Hararghe zone, Hawi Gudina district

Parameters collected	Types of field crop used			
	Maize (Melkasa-4)		Sorghum (Abshir)	
	Conservation structure			
	Level Bund	Farmers practice	Level Bund	Farmers practice
Stand count at Harvest/ha	15,300	16,800	58,000	50,800
No. Cobs (heads)/ha	11,000	11,100	56,300	47,900
Days to maturity	115	112	120	119
Yield (Qt/ha)	8.5	6.7	23.5	15.32
Yield advantage (%)	26.8	-	53.3	-

Appendix Table 4. Effect of fanya juu on soil physico chemical properties, Ambo district, Goromti watershed

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	

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	

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.

Appendix Table 5. Effect of level soil bund and stone bund on soil physico chemical properties, Bokole watershed

Soil texture	LSB-4 year	NTU-1	*P*-value	LSB-6 year	NTU-2	*P*-value	LSB-9 year	NTU-3	*P*-value
Sand (%)	47.17 ± 0.75	43.83 ± 1.89	0.132	47.17 ± 1.76	47.83 ± 1.6	0.785	46.00 ± 2.7	47.8 ± 3.00	0.659
Silt (%)	17.17 ± 0.60	18.67 ± 0.80	0.166	25.67 ± 1.80	19.33 ± 0.95	0.011*	18.00 ± 1.00	18.17 ± 0.98	0.908
Clay (%)	35.67 ± 0.56	37.50 ± 1.31	0.227	27.17 ± 1.45	32.83 ± 1.72	0.030*	36.00 ± 2.58	34.00 ± 2.13	0.563
Textural Classes	Sandy clay	Clay loam		Sandy clay loam	Sandy clay loam		Sandy clay	Sandy clay loam	

*denotes significantly different values from each other at $P < 0.05$ by 2-tailed t-test

Soil texture	SB-4 year	NTL-1	*P*-value	SB-6 year	NTL- 2	*P*-value	SB- 8 year	NTL- 3	*P*-value
Sand (%)	55.67 ± 1.31	59.67 ± 1.43	0.066	49.17 ± 1.40	53.50 ± 1.63	0.071	48.67 ± 2.12	47.83 ± 1.64	0.763
Silt (%)	14.00 ± 1.39	16.83 ± 0.60	0.091	20.33 ± 0.67	17.33 ± 0.95	0.028*	23.67 ± 1.61	23.33 ± 1.20	0.871
Clay (%)	30.33 ± 1.10	23.50 ± 1.34	0.003*	30.5 ± 1.18	29.17 ± 1.51	0.503	27.67 ± 0.95	28.83 ± 1.05	0.429
Textural Classes	Sandy clay loam	Sandy clay loam		Sandy clay loam	Sandy clay loam		Sandy clay loam	Sandy clay loam	

*denotes significantly different values from each other at $P < 0.05$ by 2-tailed t-test

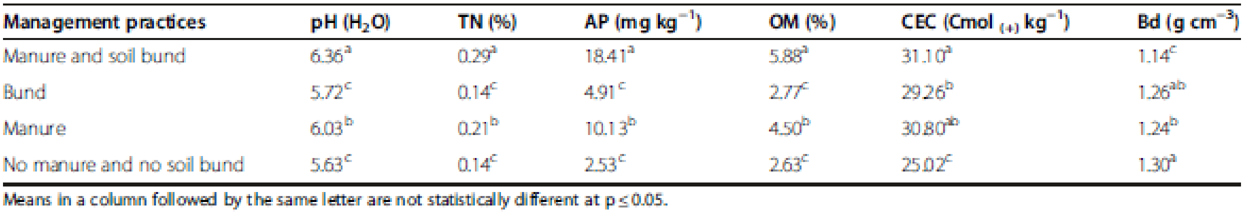
Soil parameters	LSB-4 year	NTU-1	*P*-value	LSB-6 year	NTU-2	*P*-value	LSB-9 year	NTU-3	*P*-value
SOC (%)	1.23 ± 0.15	1.32 ± 0.23	0.736	1.41 ± 0.28	1.18 ± 0.11	0.463	1.57 ± 0.27	1.68 ± 0.15	0.715
TN (%)	0.11 ± 0.02	0.07 ± 0.02	0.275	0.21 ± 0.13	0.12 ± 0.04	0.515	0.08 ± 0.02	0.17 ± 0.06	0.138
AP (ppm)	12.04 ± 0.56	16.87 ± 1.94	0.037*	5.86 ± 0.95	3.94 ± 1.66	0.131	10.5 ± 2.70	5.68 ± 0.39	0.105
AK cmol (+)/kg soil)	0.15 ± 0.003	0.21 ± 0.04	0.138	0.23 ± 0.06	0.31 ± 0.13	0.600	0.20 ± 0.06	0.14 ± 0.004	0.326
pH	5.26 ± 0.15	5.64 ± 0.04	0.034*	5.87 ± 0.10	5.34 ± 0.23	0.068	5.83 ± 0.07	5.93 ± 0.08	0.383
CEC cmol (+)/kg soil)	20.57 ± 2.63	29.75 ± 3.48	0.062	17.16 ± 2.10	21.27 ± 4.03	0.380	16.75 ± 1.57	18.33 ± 1.53	0.487

*denotes significantly different values from each other at $P < 0.05$ by 2-tailed t-test

Soil parameters	SB-4 year	NTL- 1	*P*-value	SB-6 year	NTL-2	*P*-value	SB-8 year	NTL-3	*P*-value
SOC (%)	1.57 ± 0.16	1.22 ± 0 .12	0.101	1.35 ± 0.14	1.10 ± 0.12	0.206	0.69 ± 0.11	1.01 ± 0.09	0.048*
TN (%)	0.28 ± 0.08	0.13 ± 0. 03	0.098	0.09 ± 0.06	0.06 ± 0.02	0.619	0.41 ± 0.13	0.26 ± 0.12	0.409
AP (ppm)	2.92 ± 0.65	4.41 ± 0.46	0.089	1.82 ± 0.13	7.33 ± 1.74	0.010*	10.62 ± 1.71	27.48 ± 6.20	0.026*
AK cmol (+)/kg soil)	0.45 ± 0.08	0.44 ± 0.02	0.906	1.39 ± 0.30	0.83 ± 0.15	0.123	0.59 ± 0.29	1.61 ± 0.32	0.039*
pH	7.06 ± 0.034	7.13 ± 0.02	0.090	6.34 ± 0.05	6.63 ± 0.087	0.014*	6.41 ± 0.08	6.64 ± 0.04	0.03*
CEC cmol (+)/kg soil)	25.70 ± 5.85	21.80 ± 5.19	0.629	30.43 ± 4.46	31.43 ± 3.52	0.864	31.57 ± 2.96	25.93 ± 6.85	0.468

*denotes significantly different values from each other at $P < 0.05$ by 2-tailed t-test

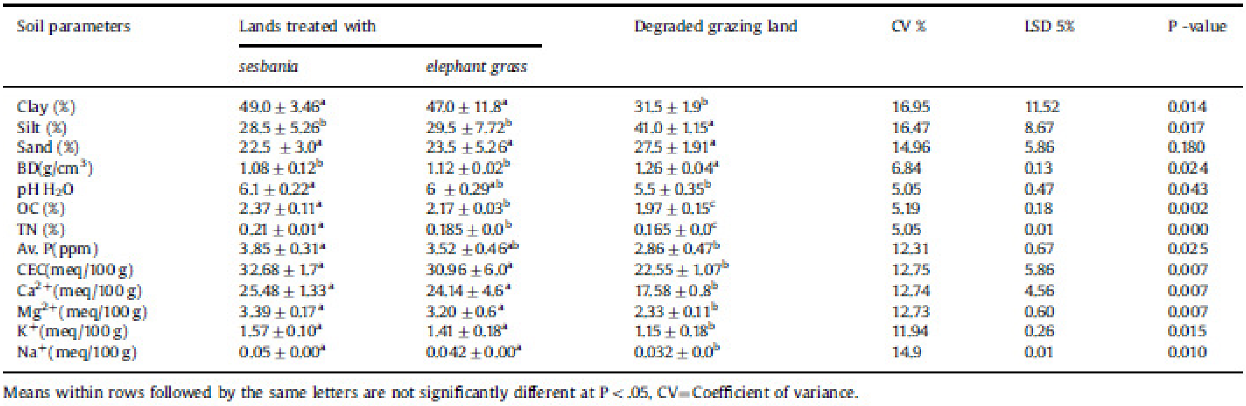
Appendix Table 6. Effect of Management practices on selected soil physico chemical properties Zikri watershed



Management practices	pH (H$_2$O)	TN (%)	AP (mg kg^{-1})	OM (%)	CEC (Cmol $_{(+)}$ kg^{-1})	Bd (g cm^{-3})
Manure and soil bund	6.36^{a}	0.29^{a}	18.41^{a}	5.88^{a}	31.10^{a}	1.14^{c}
Bund	5.72^{c}	0.14^{c}	4.91^{c}	2.77^{c}	29.26^{b}	1.26^{ab}
Manure	6.03^{b}	0.21^{b}	10.13^{b}	4.50^{b}	30.80^{ab}	1.24^{b}
No manure and no soil bund	5.63^{c}	0.14^{c}	2.53^{c}	2.63^{c}	25.02^{c}	1.30^{a}

Means in a column followed by the same letter are not statistically different at $p \leq 0.05$.

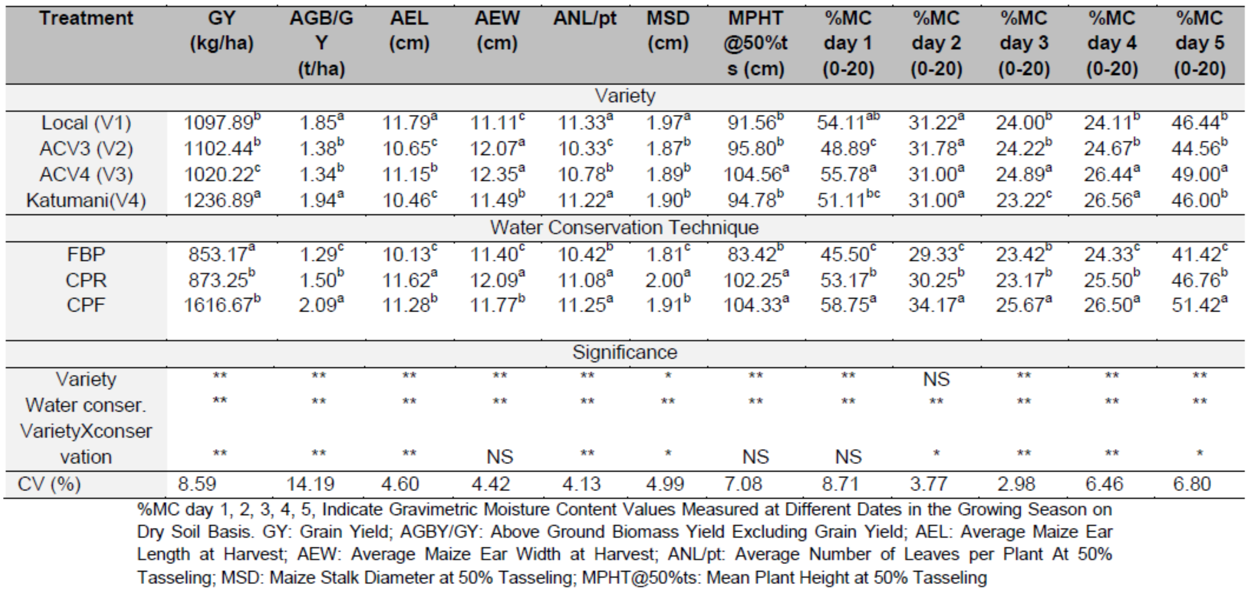
Appendix Table 7. Effect of Soil Conservation Practices on basic soil properties, Lemo District of Southern Ethiopia



Soil parameters	Lands treated with		Degraded grazing land	CV %	LSD 5%	P -value
	sesbania	*elephant grass*				
Clay (%)	49.0 ± 3.46^{a}	47.0 ± 11.8^{a}	31.5 ± 1.9^{b}	16.95	11.52	0.014
Silt (%)	28.5 ± 5.26^{b}	29.5 ± 7.72^{b}	41.0 ± 1.15^{a}	16.47	8.67	0.017
Sand (%)	22.5 ± 3.0^{a}	23.5 ± 5.26^{a}	27.5 ± 1.91^{a}	14.96	5.86	0.180
BD(g/cm^{3})	1.08 ± 0.12^{b}	1.12 ± 0.02^{b}	1.26 ± 0.04^{a}	6.84	0.13	0.024
pH H$_2$O	6.1 ± 0.22^{a}	6 ± 0.29^{ab}	5.5 ± 0.35^{b}	5.05	0.47	0.043
OC (%)	2.37 ± 0.11^{a}	2.17 ± 0.03^{b}	1.97 ± 0.15^{c}	5.19	0.18	0.002
TN (%)	0.21 ± 0.01^{a}	0.185 ± 0.0^{b}	0.165 ± 0.0^{c}	5.05	0.01	0.000
Av. P(ppm)	3.85 ± 0.31^{a}	3.52 ± 0.46^{ab}	2.86 ± 0.47^{b}	12.31	0.67	0.025
CEC(meq/100 g)	32.68 ± 1.7^{a}	30.96 ± 6.0^{a}	22.55 ± 1.07^{b}	12.75	5.86	0.007
Ca^{2+}(meq/100 g)	25.48 ± 1.33^{a}	24.14 ± 4.6^{a}	17.58 ± 0.8^{b}	12.74	4.56	0.007
Mg^{2+}(meq/100 g)	3.39 ± 0.17^{a}	3.20 ± 0.6^{a}	2.33 ± 0.11^{b}	12.73	0.60	0.007
K^{+}(meq/100 g)	1.57 ± 0.10^{a}	1.41 ± 0.18^{a}	1.15 ± 0.18^{b}	11.94	0.26	0.015
Na^{+}(meq/100 g)	0.05 ± 0.00^{a}	0.042 ± 0.00^{a}	0.032 ± 0.0^{b}	14.9	0.01	0.010

Means within rows followed by the same letters are not significantly different at $P < .05$, CV=Coefficient of variance.

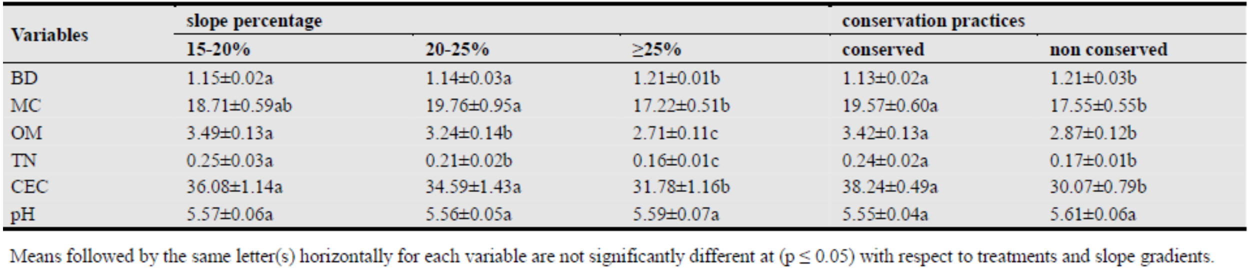
Appendix Table 8. Effect of moisture conservation on yield and yield components of maize, Western Oromia, Bako area



Treatment	GY (kg/ha)	AGB/GY (t/ha)	AEL (cm)	AEW (cm)	ANL/pt	MSD (cm)	MPHT @50%ts (cm)	%MC day 1 (0-20)	%MC day 2 (0-20)	%MC day 3 (0-20)	%MC day 4 (0-20)	%MC day 5 (0-20)
Variety												
Local (V1)	1097.89^{b}	1.85^{a}	11.79^{a}	11.11^{c}	11.33^{a}	1.97^{a}	91.56^{b}	54.11^{ab}	31.22^{a}	24.00^{b}	24.11^{b}	46.44^{b}
ACV3 (V2)	1102.44^{b}	1.38^{b}	10.65^{c}	12.07^{a}	10.33^{c}	1.87^{b}	95.80^{b}	48.89^{c}	31.78^{a}	24.22^{b}	24.67^{b}	44.56^{b}
ACV4 (V3)	1020.22^{c}	1.34^{b}	11.15^{b}	12.35^{a}	10.78^{b}	1.89^{b}	104.56^{a}	55.78^{a}	31.00^{a}	24.89^{a}	26.44^{a}	49.00^{a}
Katumani(V4)	1236.89^{a}	1.94^{a}	10.46^{c}	11.49^{b}	11.22^{a}	1.90^{b}	94.78^{b}	51.11^{bc}	31.00^{a}	23.22^{c}	26.56^{a}	46.00^{b}
Water Conservation Technique												
FBP	853.17^{a}	1.29^{c}	10.13^{c}	11.40^{c}	10.42^{b}	1.81^{c}	83.42^{b}	45.50^{c}	29.33^{c}	23.42^{b}	24.33^{c}	41.42^{c}
CPR	873.25^{b}	1.50^{b}	11.62^{a}	12.09^{a}	11.08^{a}	2.00^{a}	102.25^{a}	53.17^{b}	30.25^{b}	23.17^{b}	25.50^{b}	46.76^{b}
CPF	1616.67^{b}	2.09^{a}	11.28^{b}	11.77^{b}	11.25^{a}	1.91^{b}	104.33^{a}	58.75^{a}	34.17^{a}	25.67^{a}	26.50^{a}	51.42^{a}
Significance												
Variety	**	**	**	**	**	*	**	**	NS	**	**	**
Water conser.	**	**	**	**	**	**	**	**	**	**	**	**
VarietyXconservation	**	**	**	NS	**	*	NS	NS	*	**	**	*
CV (%)	8.59	14.19	4.60	4.42	4.13	4.99	7.08	8.71	3.77	2.98	6.46	6.80

%MC day 1, 2, 3, 4, 5, Indicate Gravimetric Moisture Content Values Measured at Different Dates in the Growing Season on Dry Soil Basis. GY: Grain Yield; AGBY/GY: Above Ground Biomass Yield Excluding Grain Yield; AEL: Average Maize Ear Length at Harvest; AEW: Average Maize Ear Width at Harvest; ANL/pt: Average Number of Leaves per Plant At 50% Tasseling; MSD: Maize Stalk Diameter at 50% Tasseling; MPHT@50%ts: Mean Plant Height at 50% Tasseling

Appendix Table 9. Effect of graded stone bunds on selected soil properties, Central highland of Ethiopia



Variables	slope percentage			conservation practices	
	15-20%	20-25%	≥25%	conserved	non conserved
BD	1.15±0.02a	1.14±0.03a	1.21±0.01b	1.13±0.02a	1.21±0.03b
MC	18.71±0.59ab	19.76±0.95a	17.22±0.51b	19.57±0.60a	17.55±0.55b
OM	3.49±0.13a	3.24±0.14b	2.71±0.11c	3.42±0.13a	2.87±0.12b
TN	0.25±0.03a	0.21±0.02b	0.16±0.01c	0.24±0.02a	0.17±0.01b
CEC	36.08±1.14a	34.59±1.43a	31.78±1.16b	38.24±0.49a	30.07±0.79b
pH	5.57±0.06a	5.56±0.05a	5.59±0.07a	5.55±0.04a	5.61±0.06a

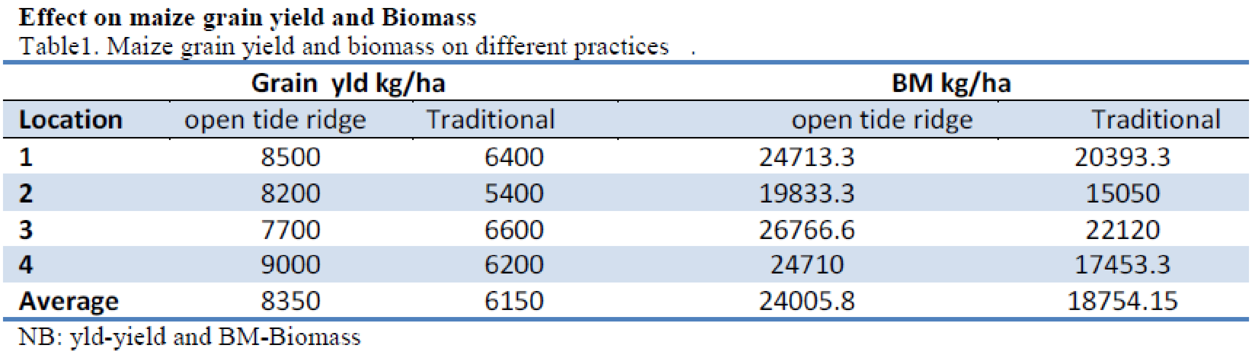
Means followed by the same letter(s) horizontally for each variable are not significantly different at ($p \leq 0.05$) with respect to treatments and slope gradients.

Appendix Table 10. Effect of Conservation terraces on soil organic carbon storage and soil properties, Anjeni watershed

Landscape positions	Relative location in the sub-watershed	Without conservation practice (*Zikrie*) SOC (%)	Without conservation practice (*Zikrie*) Carbon stock (Mg ha^{-1} in 30-cm depth)	With conservation practice (*Minchet*) SOC (%)	With conservation practice (*Minchet*) Carbon stock (Mg ha^{-1} in 30-cm depth)
Toe slope	Upper	1·24	37·60	1·34	50·54
	Middle	2·42	80·01	1·42	60·67
	Lower	2·06	81·94	1·51	54·46
	Average	1·90	66·52	1·42	55·22
	SD	0·95	33·33	0·44	16·65
Foot slope	Upper	0·83	31·79	1·12	42·67
	Middle	2·15	83·01	1·51	51·94
	Lower	1·02	36·58	1·96	81·81
	Average	1·33	50·46	1·53	58·81
	SD	0·69	26·21	0·61	25·88
Back slope	Upper	1·27	40·57	2·16	80·61
	Middle	1·77	63·45	2·00	72·34
	Lower	1·03	36·28	2·44	90·57
	Average	1·36	46·77	2·20	81·17
	SD	0·78	28·29	0·76	25·54
Shoulder slope	Upper	2·00	69·95	1·66	56·37
	Middle	1·43	51·72	2·37	79·48
	Lower	1·52	55·31	1·02	40·52
	Average	1·65	58·99	1·68	58·79
	SD	0·59	20·82	0·85	27·13
Crest slope	Upper	1·50	49·50	2·38	74·76
	Middle	2·29	75·55	1·51	52·95
	Lower	2·18	77·48	1·01	33·44
	Average	1·99	67·51	1·63	53·72
	SD	0·87	36·76	0·70	21·67
Average	Upper	1·37	45·88	1·73	60·99
	Middle	2·01	70·75	1·77	63·47
	Lower	1·56	57·52	1·59	60·16
	Average	1·65	58·05	1·70	61·54
	SD	0·78	28·96	0·71	24·64

		Without conservation practice (*Zikrie*)					With conservation practice (*Minchet*)				
			Texture					Texture			
Landscape positions	Relative location in the sub-watershed	Bulk density (g cm^{-3})	Sand (%)	Silt (%)	Clay (%)	Texture class	Bulk density (g cm^{-3})	Sand (%)	Silt (%)	Clay (%)	Texture class
Toe slope	Upper	1·01	20·56	28·28	51·16	C	1·26	15·89	25·95	58·16	C
	Middle	1·10	20·38	35·28	44·34	C	1·43	23·89	27·95	48·16	C
	Lower	1·33	27·56	26·28	46·16	C	1·21	17·56	24·28	58·16	C
	Average	1·15	22·83	29·95	47·22	C	1·30	19·12	26·06	54·83	C
	SD	0·15	10·15	6·89	12·91		0·12	5·85	5·66	9·77	
Foot slope	Upper	1·28	13·56	24·28	62·16	C	1·27	19·77	21·95	58·28	C
	Middle	1·29	31·56	36·28	32·16	CL	1·15	23·29	28·88	47·83	C
	Lower	1·20	20·38	32·28	47·34	C	1·39	22·56	28·28	49·16	C
	Average	1·25	21·83	30·95	47·22	C	1·27	21·87	26·37	51·76	C
	SD	0·17	9·14	7·09	13·77		0·11	8·00	4·99	9·11	
Back slope	Upper	1·06	19·56	24·28	56·16	C	1·24	23·47	30·78	45·75	C
	Middle	1·20	20·44	25·95	53·61	C	1·21	22·74	27·68	49·58	C
	Lower	1·17	23·89	25·95	50·16	C	1·24	27·56	25·28	47·16	C
	Average	1·15	21·52	25·39	53·31	C	1·23	24·59	27·91	47·50	C
	SD	0·08	6·46	2·91	8·78		0·08	6·82	5·59	10·20	
Shoulder slope	Upper	1·17	23·56	26·28	50·16	C	1·13	21·11	28·61	50·28	C
	Middle	1·21	14·38	27·28	58·34	C	1·12	25·11	27·95	46·95	C
	Lower	1·21	16·56	28·28	55·16	C	1·32	20·56	19·28	60·16	C
	Average	1·20	18·17	27·28	54·55	C	1·19	22·26	25·28	50·46	C
	SD	0·15	5·48	4·73	7·33		0·12	4·02	3·90	6·29	
Crest slope	Upper	1·10	22·44	36·61	40·95	C	1·05	29·56	25·28	45·16	C
	Middle	1·10	26·56	32·28	41·16	C	1·17	24·56	22·61	52·83	C
	Lower	1·18	25·38	28·28	46·34	C	1·10	24·56	25·28	50·16	C
	Average	1·13	24·46	32·39	42·82	C	1·11	26·23	24·39	49·38	C
	SD	0·15	3·14	5·09	4·05		0·06	3·88	6·65	9·24	
Average	Upper	1·12	19·94	27·95	52·12	C	1·19	21·96	26·51	51·53	C
	Middle	1·18	22·66	31·41	45·92	C	1·21	23·92	27·01	49·07	C
	Lower	1·22	22·75	28·21	49·03	C	1·25	22·56	24·48	52·96	C
	Average	1·17	21·78	29·19	49·02	C	1·22	22·81	26·00	51·18	C
	SD	0·14	7·00	5·78	10·20		0·12	6·32	5·05	9·02	

Appendix Table 11. Effect of Tied ridge on maize grain yield and biomass, Sankurra district SNNPR.



Effect on maize grain yield and Biomass

Table1. Maize grain yield and biomass on different practices .

	Grain yld kg/ha		BM kg/ha	
Location	open tide ridge	Traditional	open tide ridge	Traditional
1	8500	6400	24713.3	20393.3
2	8200	5400	19833.3	15050
3	7700	6600	26766.6	22120
4	9000	6200	24710	17453.3
Average	8350	6150	24005.8	18754.15

NB: yld-yield and BM-Biomass

Appendix Table 12. Effect of Terraces on selected soil properties, yield and yield components of Maize and Wheat, Dembecha district, Anjeni watershed

Terrace zone	pH	OM (%)	TN (%)	Available phosphorus (ppm)	Exchangeable bases †					CEC †	PBS (%)
					Na	K	Ca	Mg	SEB		
Deposition	5.7	3.05	0.20	7.79	0.09	1.44	8.49	2.00	12.02	21.57	58.33
Loss	6.0	1.74	0.15	6.83	0.17	1.27	8.38	2.12	11.94	20.35	55.66
Student's t-test	ns	**	*	ns	ns	ns	ns	ns	ns	*	*

** Significant at $p \leq 0.01$; * Significant at $p \leq 0.05$; ns = non-significant at $p \leq 0.05$

† $\text{Cmol}_C\ \text{kg}^{-1}$; SEB = Sum of Exchangeable Bases; PBS = Percent Base Saturation

Terrace zone	Wheat			Maize		
	Grain yield (kg/ha)	Biomass yield (kg/ha)	Height (m)	Grain yield (kg/ha)	Biomass yield (kg/ha)	Plant height (m)
Deposition	1077.2^{a}	5208.3^{a}	0.64^{a}	2695.1^{a}	17125^{a}	2.38^{a}
Middle	759.9^{b}	4183.3^{b}	0.59^{a}	1685.9^{b}	10250^{b}	2.16^{b}
Loss	656.2^{b}	3491.7^{c}	0.52^{b}	1072.9^{c}	9292^{b}	2.08^{b}
CV (%)	22.5	12.8	10.56	36.1	21	7.48

*Values in a column followed by the same letter are not statistically different at $p \leq 0.05$