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RESEARCH ARTICLE

# EVALUATION OF SOIL AND WATER CONSERVATION MEASURES ON SOIL PROPERTY AND WHEAT PRODUCTIVITY AT BORE DISTRICT, SOUTHERN ETHIOPIA

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**ABSTRACT**

In Ethiopia different soil and water conservation technologies with different approaches have been implemented focusing on the highlands of the country where the problem is more threatening. With the aim of decreasing land degradation problems, efforts are underway on the implementation of soil and water conservation (SWC) measures. The purpose of this study is to investigate Effect of Soil and Water conservation measures on Soil property and Wheat productivity at Bore District, Southern Ethiopia. Data were collected from six different measures through Non-conserved land, Vetivary grass hedge row conservation, Graded soil bund ($1^0$) conservation, Graded Fanyajuu ($1^0$) conservation, Integrated graded soil bund ($1^0$) with vetivar grass hedge row conservation, and Integrated graded Fanyajuu ($1^0$) with vetivary hedge row grass conservation. Agronomic analysis indicted that SWC measures significantly ($p < 0.05$) enhanced plant height, tiller formation, spike length and grain yield of wheat. Soil analysis also revealed that integrated soil bund increased soil pH (4.577 to 5.053), organic carbon (5.10 to 6.73%) and available phosphorous (5.77 to 25.18 mg $kg^{-1}$) by 90.6%, 75.8% and 229% compared to non-conserved cultivated land, respectively. Fanyajuu SWC measure increased cation exchange capacity (CEC) by 79.2% than control. It is concluded that SWC measures have positive impacts on soil and wheat productivity of cultivated lands; however, their effect is more pronounced when physical SWC measures are integrated with biological SWC measures



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## INTRODUCTION

All over the world today, depletion of natural resources is among the major problems facing human beings. Assessment of soil degradation by the World Resource Institute, United Nations Environment Programmed estimated that 9 million hectare of land are extremely degraded; with their original biotic functions completely disappeared and 1.2 billion hectares, that is, 10% of the earth's vegetative surface are moderately degraded (WRI *et al*., 1996). About 16% of the world's agricultural land is affected by soil degradation (UNEP, 2002). Of all the processes leading to land degradation, erosion by water is the most threatening. It accounts for 56% of the total degraded land surface of the world (Oldeman *et al*., 1990). In Africa alone, it is estimated that 5 - 6 million hectares of productive land are affected by land degradation each year (Stocking and Niamh, 2000). Obviously, erosion is a more serious problem to developing countries including Ethiopia because their dependence on the soil resource is more direct.

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The average annual rate of soil loss in Ethiopia is estimated to be 12 tons/hectare/year, and can be even higher on steep slopes with soil loss rates greater than 300 tons/hectare/year or about 250 mm/year where vegetation cover is inadequate (USAID, 2000). In Ethiopia different soil and water conservation technologies with different approaches have been implemented focusing on the highlands of the country where the problem is more threatening. With the aim of curbing land degradation problems, efforts are underway on the implementation of soil and water conservation (SWC) measures. Soil conservation activities can change the physical and chemical conditions of the soil like soil organic matter content, total N, available phosphorous (P), bulk density, infiltration rate and soil texture (Demelash & Stahr, 2010). Agricultural sector is the mainstay of Ethiopian economy contributing 54 % of gross domestic product (GDP), 90% of the national export earnings as well as supplying 70% of the raw materials for home agro-industries and supports 85 % of the population (CSA, 2007). Recognizing this Ethiopian government opted for Agricultural Development Led Industrialization (ADLI) economic development policy. Sustainable management and utilization of land resources is an essential requirement to realize the objectives of ADLI policy.

In spite of this fact, the agricultural potential has been threatened by soil erosion, nutrient depletion and deforestation which are taking place at a rapid pace affecting the country's biodiversity (flora and fauna) and deepening poverty (EC, 2000). Currently, about 85% of the land surface in the country is considered prone to moderate to very severe soil degradation. Comparing changes with key soil factors between two watersheds (treated with soil conservation measures and untreated) could contribute for further improvement of the integrated soil and water conservation (SWC) measures currently underway and to draw some recommendations. The purpose of this study is to investigate effects of different SWC measures on some soil physical and chemical properties so as to draw conclusions that contribute in future improvement of SWC measures implementation in improving soil for a better land productivity, erosion control and sustainable use of resources available in the country. Therefore, this project is proposed with the intention of alleviating these problems and shifting towards the more resource conserving system.

*Objective of the study*

- To evaluate effect of soil and water conservation measures on soil property and wheat productivity

**Statement of the component:** Soil erosion is a severe problem in Ethiopia, especially in the highlands where much of the population is living and agriculture is intensive (Gete, 2000).Sustainable management and utilization of land is an essential for country development. Biological and physical measures provide permanent erosion control, reduce water and nutrient losses. Thus, by having different conservation measures the problem can be mitigated. Therefore this project is proposed to evaluate the effect of conservation measures.

## MATERIALS AND METHODS

***Study Area:*** The study was conducted in Bore District of Guji zone of South Oromia regional state, Ethiopia (Figure 1). The study area is located at 385 kms South of Addis Ababa, capital city of Ethiopia and lies between the coordinates of 11°32' to 12°03' N latitude and 37°31' to 38°43' E longitude with an estimated area of 1284km$^2$.The altitude of the area is 1600-2900 meter above seas level. The rainfall pattern is uni-modal extending from February to October with mean annual rainfall above 1227mm. The monthly maximum temperature is between 16.8˚C and 21.3˚C, and the monthly minimum temperature is between 6.8˚C and 9.6˚C (District statistical abstract of 2014/15). The major soil types in the study area include Haplic calcisols, Haplic Gypsisols, Petric Gypsisols and Petric calcisols(extract from FAO soil classification, 2007). The farming system is a mixed one (growing of crops and rearing of animals). The major crops grown are cereal crops like maize, wheat, Barley; (District statistical abstract of 2014/15

***Experimental Plots and Design:*** Six different SWC measures were used as treatments in order to study their effects on soil properties and crop yield. These include: non-conserved land, Vetivary grass hedge row conservation, Graded soil bund ($1^0$) conservation, Graded Fanyajuu ($1^0$) conservation, Integrated graded soil bund ($1^0$) with vetivar grass hedge row conservation, Integrated graded Fanyajuu ($1^0$) with vetivary hedge row grass conservation. Each treatment was established on plot size of 25m x25m area arranged in contour line independently (Fig. 2). To control and distribute the effect of heterogeneity of the land, the treatments were arranged out as a randomized complete block design (RCBD) and replicated Three times per treatment. There were spacing of 1 m between the treatments or experimental plots that was used as water way to discharge surplus water drained from the conservation structures. The vertical interval between the structures was depends on the slope of the area.

***Soil sampling:*** A representative composite soil sample was taken using an auger from a plough layer of depth 0-30 cm from the whole experimental field before planting and after harvesting of the crops from each plot every year. These samples were randomly collected from 5 different locations of each plot and thoroughly mixed to form a representative sample. From these samples, selected soil chemicals (pH, N, P, CEC and OC) and physical property (texture) were analyzed following standard procedures at Zuway soil laboratory, Zuway, Ethiopia.

***Crop data sampling procedures:*** Wheat is one of major cereal crop grown in Bore District during the main rainy season (June–September). Consequently, improved bread wheat (variety Huluka) that was promoted by Bore Agricultural Research center was taken as a test crop to evaluate the crop response on above mentioned SWC measures (i.e., treatments). The crop was planted with package of recommendations such as fertilizer [121kg NPS (19-38-0-7SO4) and 50 kg Urea (46-0-0)], seed rate (125 kg ha$^{-1}$), broadcast planting and two hand weeding. At maturity stage of the crop, a square quadrant with 0.5 m × 0.5 m (0.25 m$^2$) size was randomly assigned to three random spots (top, middle and bottom) of each crop plot that was identified for soil data collection. The crop within each quadrant was harvested to record growth, yield and yield component parameters following standard agronomic data collection procedures. Plant height (cm) was determined from the base to the tip of the spike (from 12 randomly selected plants). Spike length (cm) is part of wheat plant which is the length occupied by seed. It is measured from 12 randomly selected plants. Number of productive tillers was determined by counting all spikes producing seeds of each quadrant then converted into m$^2$. Grain yield (kg ha$^{-1}$) was measured after threshing the seed yield from each quadrant, and then converted to kilogram per hectare.

***Statistical analysis:*** The effects of SWC measures on soil properties and wheat yield were evaluated using different statistical methods. Analysis of variance (ANOVA) was performed for crop data using Statistical Analysis System (SAS Institute Inc2008). Soil data was subjected to descriptive statistics.When the effects of treatments were significant, mean comparison was performed using least significance differences (LSD) at 5% probability level

## RESULTS AND DISCUSSION

***Yield and yield component of whea***

***Plant height:*** Table 1shows the effects of different soil and water conservation measures on selected growth parameters of wheat crop.

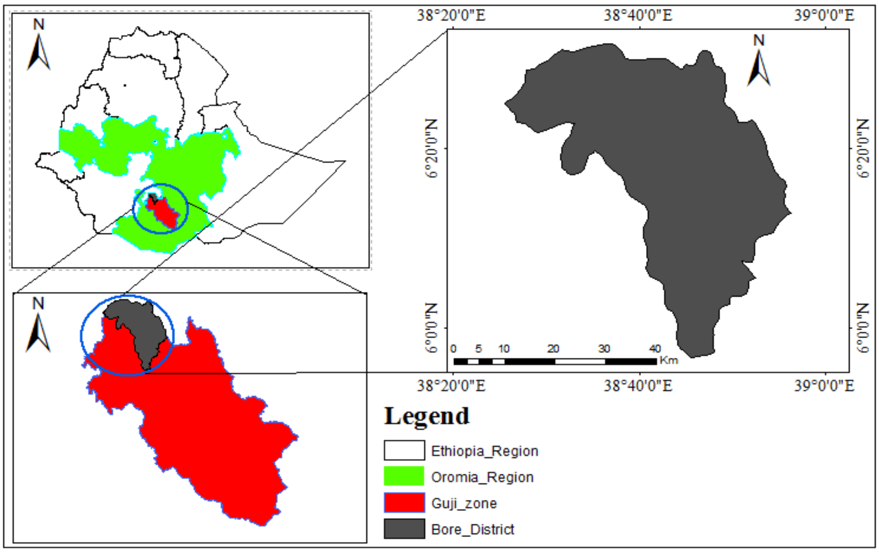


**Figure 1. Location Map of the study area**

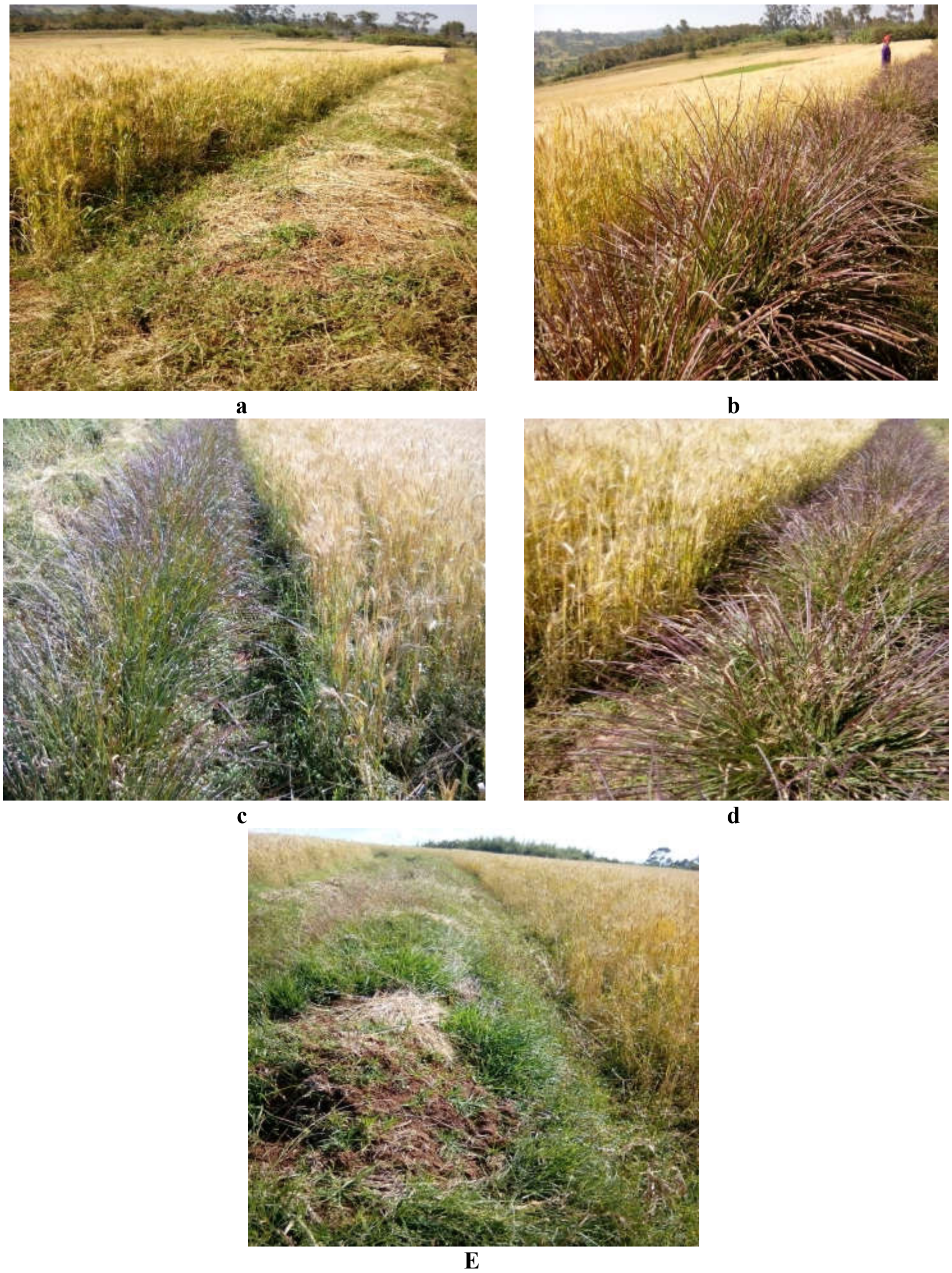


**Figure 2. (A)Soil Bund, (B) Integrated Soil Bund, (C) Fanyajuu, (D) Integrated Fanyajuu and (E) Veti vary grass hedge row**

**Table 1.Effect of soil and water conservation measures on wheat yield and yield component**

| Conservation measures | Plant height (cm) | Number of productive tiller(No./plant) | Spike length (cm) | Grain yield (kg ha$^{-1}$) |
|---|---|---|---|---|
| Integrated soil bund | 87.07a | 2.80a | 7.416a | 4261a |
| Vetivery grass | 79.98b | 2.64ab | 6.282bc | 3385ab |
| Integrated funya juu | 82.34ab | 2.208b | 7.187ab | 3507ab |
| Soil bund | 82.12ab | 2.526ab | 7.212ab | 3510ab |
| Funya juu | 79.94ab | 2.166b | 6.072cd | 3273ab |
| Control/no conservation | 76.80b | 2.15b | 5.146d | 2989b |
| $LSD_{0.05}$ | 6.958 | 0.5284 | 0.927 | 999.2 |
| CV (%) | 7.3 | 18.5 | 12.0 | 24.3 |

Means with the same letter in each column are not significantly different at $p<0.05$

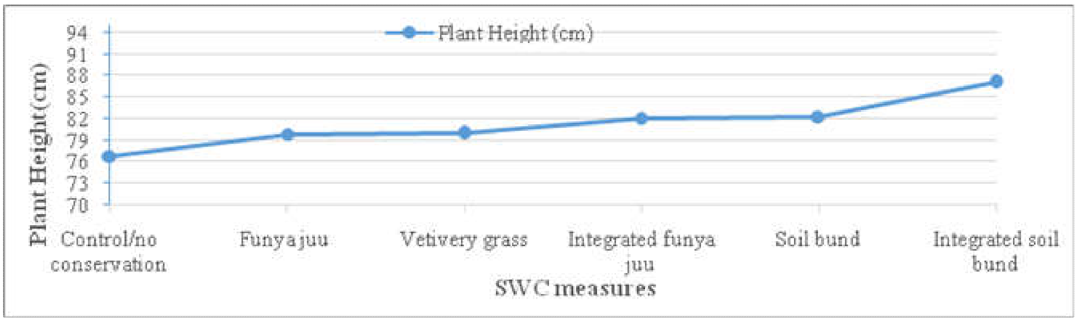


**Figure 3. Effects of SWC measures on plant height of wheat at Bore District**

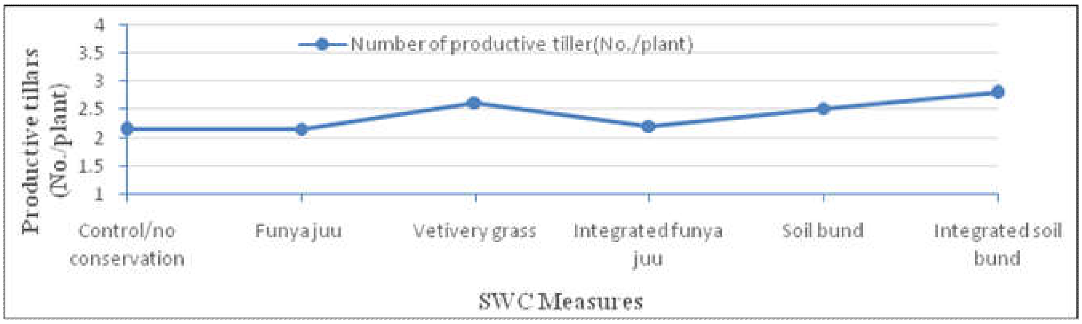


**Figure 4. Effects of SWC measures on number productive tiller of wheat at Bore District**

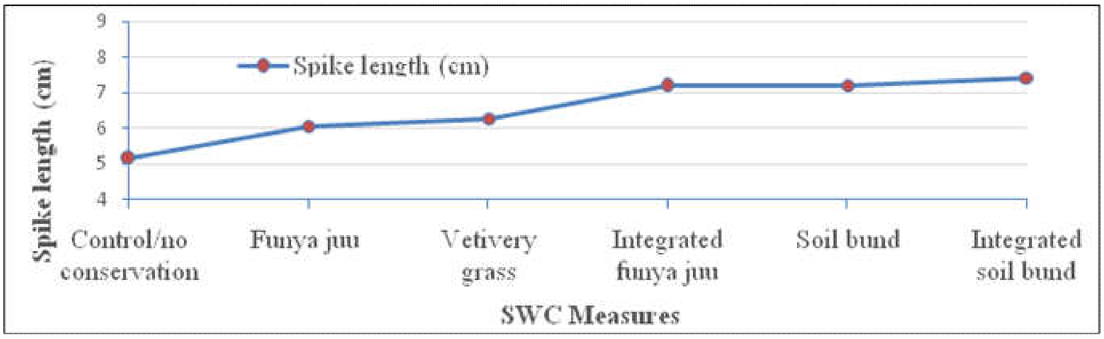


**Figure 5. Effects of SWC measures on spike length of wheat at Bore District**

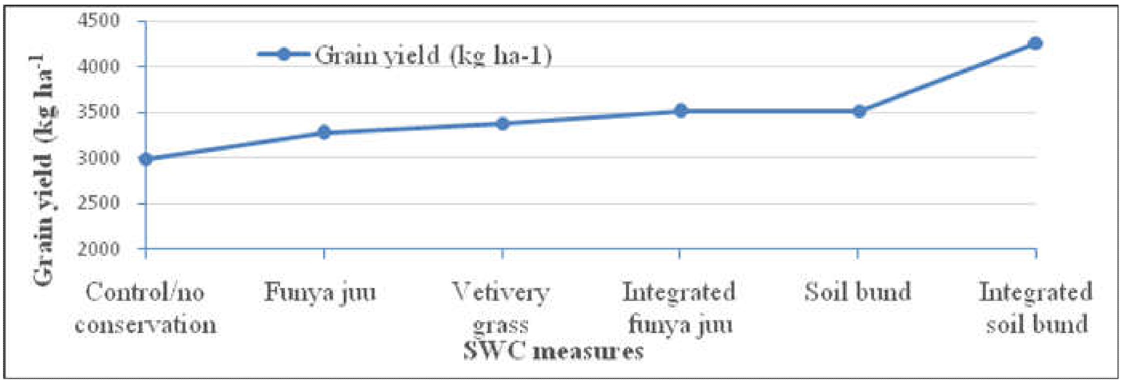


**Figure 6. Effects of SWC measures on grain yield of wheat at Bore District**

**Table 2. Effect of soil and water conservation measures on soil physical and chemical properties**

| Conservation measures | pH-$H_2O$ | Av.P (mg/kg$^{-1}$) | %OC | CEC(meq/100g soil) | %sand | %silt | %clay | Texture class |
|---|---|---|---|---|---|---|---|---|
| Integrated soil bund | 5.053 | 25.18 | 6.734 | 19.48 | 37.13 | 29.77 | 33.10 | Sandy clay loam |
| Vetivery grass | 4.933 | 9.29 | 5.012 | 16.69 | 39.33 | 30.11 | 30.55 | Sandy clay loam |
| Integrated funya juu | 4.932 | 17.47 | 5.15 | 17.23 | 39.11 | 31.01 | 29.89 | Sandy clay loam |
| Soil bund | 4.990 | 20.9 | 5.066 | 18.37 | 38.68 | 31.11 | 30.22 | Sandy clay loam |
| Funya juu | 4.792 | 6.65 | 5.734 | 20.47 | 38.46 | 31.54 | 29.99 | Sandy clay loam |
| Control/no conservation | 4.577 | 5.77 | 5.10 | 16.21 | 37.56 | 30.45 | 31.99 | Sandy clay loam |
| $LSD_{0.05}$ | 0.288 | 17.391 | 2.99 | 8.128 | 10.3 | 9.3 | 8.4 | |
| CV (%) | 5.0 | 103.6 | 48 | 38.1 | 27.7 | 25.7 | 23.0 | |

**Table 3. Correlation analysis between soil properties, yield and yield components**

| | Soil pH-H2O(1:2.5) | Av.P (mg/kg) | OC (%) | CEC (Meq/100g soil) | Plant height (cm) | Number of productive tiller (No/plant) | Spike length (cm) | Grain yield (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| Soil pH-H2O | 1.00 | | | | | | | |
| Av.P (mg kg$^{-1}$) | 0.83$^{*}$ | 1.00 | | | | | | |
| OC (%) | 0.38$^{ns}$ | 0.49$^{ns}$ | 1.00 | | | | | |
| CEC (Meq/100g soil) | 0.36$^{ns}$ | 0.28$^{ns}$ | 0.69$^{ns}$ | 1.00 | | | | |
| Plant height (cm) | 0.87$^{*}$ | 0.91$^{**}$ | 0.74$^{*}$ | 0.50$^{ns}$ | 1.00 | | | |
| Number of productive tiller (No./plant) | 0.76$^{*}$ | 0.65$^{ns}$ | 0.47$^{ns}$ | 0.14$^{ns}$ | 0.70$^{ns}$ | 1.00 | | |
| Spike length (cm) | 0.94$^{**}$ | 0.92$^{**}$ | 0.38$^{ns}$ | 0.37$^{ns}$ | 0.90$^{**}$ | 0.58$^{ns}$ | 1.00 | |
| Grain yield (kg ha$^{-1}$) | 0.83$^{*}$ | 0.78$^{*}$ | 0.79$^{*}$ | 0.46$^{ns}$ | 0.87$^{**}$ | 0.78$^{*}$ | 0.98$^{*}$ | 1.00 |

ns not significant.
**. Correlation is significant at the 0.01
*. Correlation is significant at the 0.05

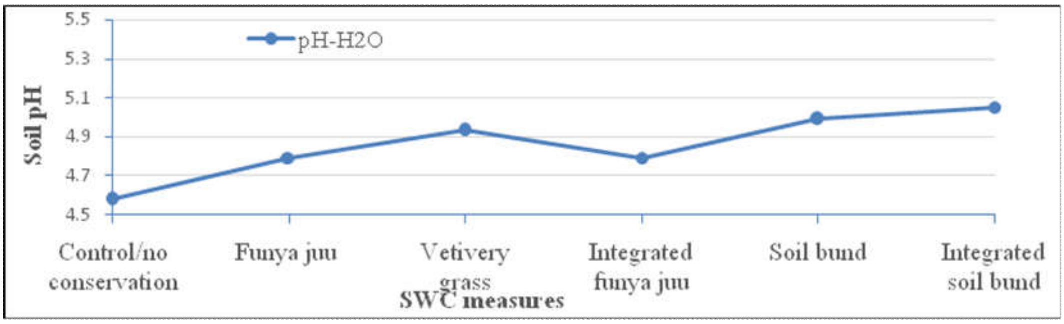


**Figure 7. Effects of SWC measures on soil pH at Bore District**

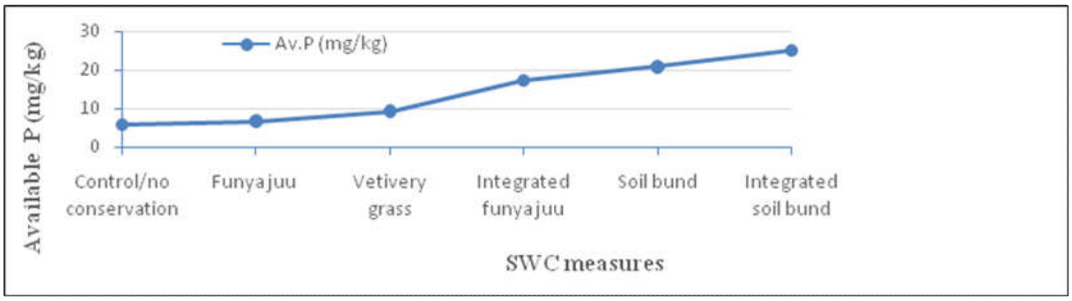


**Figure 8. Effects of SWC measures on available P at Bore District**

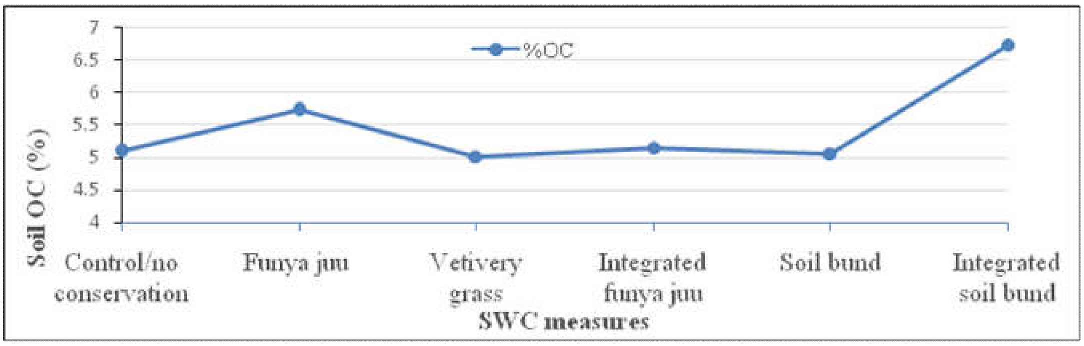


**Figure 9. Effects of SWC measures on soil OC at Bore District**

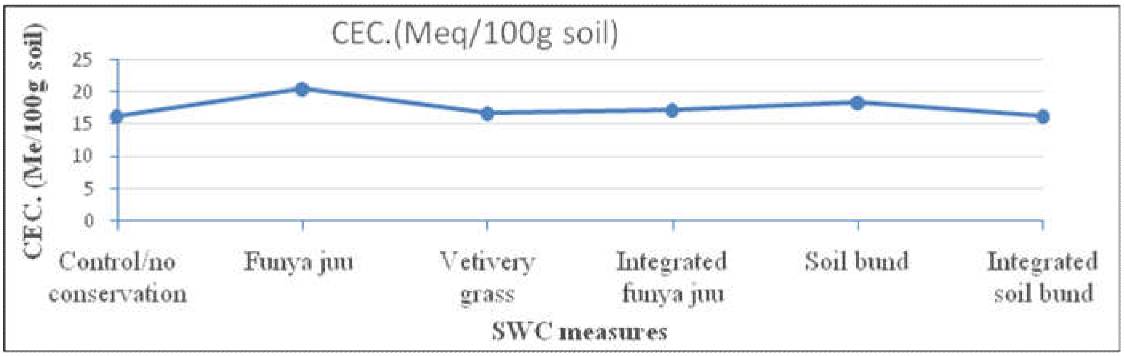


**Figure 10. Effects of SWC measures Soil CEC at Bore District**

SWC measurements significantly influenced ($p < 0.05$) plant height of wheat. The tallest plant (87.07 cm) was achieved under integrated soil bund with Vetivery grass treatment whereas the shortest plant (76.80 cm) was recorded from non-conserved cultivated land (Fig. 3). The probable reason could be related to the effect of SWC measurements on increasing soil moisture availability through increased infiltration and protecting washing away of essential soil nutrients as it was observed in soil analysis result (Table 2). The reduced limitation of water and nutrients allowed comfortable vegetative growth of crops grown on plots with integrated soil bunds, while those grown without integrated soil bund switched to early senescence and maturity due to the possible terminal moisture stress (Abay 2011; Ferede 2018; Teklu *et al.* 2018).

***Number of productive tiller:*** The yield of wheat crop is affected by different factors of which the number of tillers per plant has a vital position. The larger the number of tillers per plot area, the better will be the status of crop, which at the end results improved yield. Tillering capacity of wheat was significantly ($p < 0.05$) influenced by soil water conservation measurements. The number of productive tillers per plant was varying from 2.80under integrated soil bund to 2.15 on non-conserved cultivated land in which integrated soil bund measurement resulted 7.68% tillering advantage than non-conserved cultivated lands (Table 1). Data regarding number of productive tillers per plant showed the maximum value 2.80 that was obtained from integrated soil bund whereas the minimum 2.15number was recorded from non-treated cultivated land (Fig. 4). In general, tiller formation increases with SWC measurements.

***Spike length:*** The yield of wheat crop is affected by spike length of the plant. The longer the spike length of the plant, the better will be the yield of the crop. The spike length of wheat was significantly ($p < 0.05$) influenced by soil water conservation measurements. The spike length of the plant was varying from 7.42 under integrated soil bund to 5.15 on non-conserved cultivated land in which integrated soil bund measurement resulted 69.39% spike length advantage than non-conserved cultivated lands (Table 1). Data regarding spike length showed the maximum value 7.42 cm that was obtained from integrated soil bund whereas the minimum 5.15 cm was recorded from non-treated cultivated land (Fig. 5).

***Grain yield:*** The finale goal of crop production is maximizing yield, which is cumulative function of individual yield components in response to improved seed and management practices. Grain yield of wheat was significantly ($p < 0.05$) different due to different soil and water conservation measures that vary between 2989 kg $ha^{-1}$ (non-conserved cultivate plot) and 4261 kg $ha^{-1}$ (under Integrated soil bund) (Table 1) and (Fig. 6). The maximum grain yield was 70.15% more than the yield obtained from untreated plot. Construction of SWC with integration with biological activities result in a successive increase in grain yield of wheat compared to non-conserved plot (Fig. 6). The improvement in grain yield due to SWC measures might be related to the enhanced water availability until grain filling stage, reduced runoff, increased infiltration and enhanced nutrients availability that might give extended time for increased photosynthesis, nutrient uptake and grain filling, and finally resulted in better yield components and grain yield. The calculated Pearson correlation matrix between soil properties, grain yield and yield components are presented in Table 3. Grain yield showed high significant ($p<0.05$) correlation and positive association with plant height, spike length, number of productive tiller, organic carbon, available phosphorus and soil pH. The highest correlation coefficient in the research offered relationship between grain yield with number spike length (r=+0.98**) followed by correlations between spike length and soil pH (r=+0.94**). The results are in agreement with (Tanto & Laekemariam, 2019), Abay (2011), Ferede (2018), Teklu *et al.* (2018) and Adimassu *et al.* (2014) who found significant grain yield increment on lands with SWC measures compared to non-conserved land. Similarly, Eshetu *et al.* (2016) stated up to 87% maize grain yield advantage by using *fanyajuu* than without treatment.

## Soil properties

**Soil pH:** Even though the mean value of pH for the sampled soils in this study shows minor difference between the conserved and non-conserved plots, soil pH among conservation practices varied between 4.577 and 5.053. The minimum and maximum pH value was recorded from non-conserved plot and integrated soil bund practices (Table 2). From the result it was observed that the soil pH has shown an increasing trend with SWC measurements (Fig. 7). These might be associated to the decrease of the loss of soil organic matter and exchangeable bases through soil erosion and runoff; and thereby increase soil pH. The result is in agreement with different scholars who observed lower pH value from the non-conserved cultivated land as compared to conserved farms ((Demelash & Stahr, 2010); Meshesha *et al.* (2018), Worku 2017; Solomon *et al.* 2017) that was recognized to the high soil erosion, loss of basic nutrients, relatively lower base saturation percentage and lower soil organic matter content. Worku (2017) stated that land with stone bund had higher soil pH (5.89 ± 0.038) than control(5.81 ± 0.043). Solomon *et al.* (2017) also documented that soil pH in terraced cultivated land was higher (6.0) compared to non-terraced farm land (5.5).

**Soil organic carbon:** SWC measures influenced soil organic carbon (OC) of cultivated plots. The mean value of soil OC range between 5.10 and 6.73% in which Integrated soil bund had the highest value and the minimum was obtained on non-conserved plot (Table 2and Fig. 9). Overall, it was noted that the SWC measures and its integration with biological measures hadpositive impact on soil OC of cultivated lands. This might show that SWC measures have a positive role in improving soil OC. The finding was supported by Million (2003) who reported higher soil OC on land conserved with Fanyajuu for 5 years (2.21 ± 0.08) and 10 years (2.17 ± 0.1) compared non-conserved sites (1.96 ± 0.10)

***Available phosphorus:*** Available P among different SWC measures was highly variable. It varies from 5.77 to 25.18 mg $kg^{-1}$ (Table 2 and Fig. 8) that was recorded from Integrated soil bund and non-conserved plot, respectively. The result clearly illustrated that the establishment of SWC measures and its integration with biological measures positively influenced available P content of cultivated lands (Fig. 8). It is clear that changes recorded in soil pH, restoration of soil OC and maintenance of externally added P by reducing soil erosion and runoff could result an increased available P on integrated SWC measures. This is also supported by correlation matrix (Table 3) that showed positive and significant association of available P with soil pH (0.83*). According to Prasad and Power (1997), available P is more in the soil when soil pH range is 6.0–6.5.
The result was supported by the finding of Demelash and Stahr (2010) who reported that available P was observed to be significantly different in the treated cultivated land than non-treated cultivated lands.Tolera (2011) in addition confirmed that integration of physical and biological measures on cultivated lands resulted higher amount of available P than un-conserved cultivated lands. According to the author it was due to improved soil organic matter which increases P and protect from the removal and fixation.

***Cation Exchange Capacity:*** The cation exchange capacity (CEC) is a measure of number of observation sites per unit of soil at particular pH. The mean value of CEC in the soil samples collected and analyzed showed that the results obtained were statistically non-significant. The highest value of CEC 19.48 was obtained under integrated soil bund whereas the minimum result was under plot without conservation (Table 2 and Fig.10). This might be due to the fact that SWC measures reduced run off loss of nutrients due to improvements in soil properties such as infiltration rate, moisture retention and nutrient availability.

## Conclusion and Recommendation

It is concluded that SWC measures have positive impacts on soil fertility and crop productivity of cultivated lands. From agronomic view point, this is also justified by 70.15% grain yield advantage from integrated soil bund measures over non-conserved cultivate land. This might be attributed to reduced runoff, retained moisture and enhanced nutrients availability during growth time that is leading to improvement of soil properties and grain yield. It is fact that the changes on soil properties and yield become increasing when physical works are integrated with biological measures. Additionally, stabilizing physical SWC structures by planting multi-purpose grasses would also benefit farmers by providing fodder. Thus, this study recommends the use of integrated SWC measures. Nevertheless, further studies on other crops yield performance and cost effectiveness of SWC measures are recommended. Additionally, identification of best grass type that can stabilize the bund and provide added benefits to farmers should be investigated.

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