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# Effect of Soil and Water Conservation (SWC) Measures on Soil Nutrient and Moisture Status, a Case of Two Selected Watersheds

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**The study was conducted in Guba-Lafto Woreda of North Wollo to find out the effect of stone faced soil bund on soil macronutrients (N, P, and K), organic carbon content, soil pH, cation exchange capacity (CEC), and soil moisture status. From two case study kebeles, two watersheds were purposively selected representing Dega (highland) and Woina dega (midland) agro ecological zones. Sixteen composite surface soil samples (0 to 20 cm depth) were collected from selected watersheds. A statistical paired samples t-test showed that, mean value of some soil parameters were significantly different *at* t and p-value between conserved and non-conserved farmlands. These indicated that, conservation practices reduce runoff, and helps keep nutrients on the field. The study also revealed that stone faced soil bund is essential for soil moisture retentions through reducing run-off velocity, conserving and storing water, and then increasing infiltration and percolation rates. Therefore, implementation of soil and water conservation (SWC) practices should be encouraged by different governmental and non-governmental sectors of Ethiopia, and it should be followed up by other inputs like application of organic fertilizers.**

**Key words:** Soil and water conservation, soil and water conservation measures, stone faced soil bund, soil nutrients, soil moisture.

## INTRODUCTION

The economy of Ethiopia is based mainly on agriculture that provides employment for over 80% of the labor force, and 46.3% of the gross domestic product (GDP) (Gross domestic product). In fact, agriculture in Ethiopia is not only an economic activity but also a way of life for which agricultural land is an indispensable resource upon which the welfare of the society is dependent on. Such dependence obviously leads to increased vulnerability of the economy to problems related to land degradation (Wegayehu, 2005).

Land degradation resulting from soil erosion and nutrient depletion is one of the most challenging environmental problems in Ethiopia, which directly reduces soil fertility. The Ethiopian highlands have been

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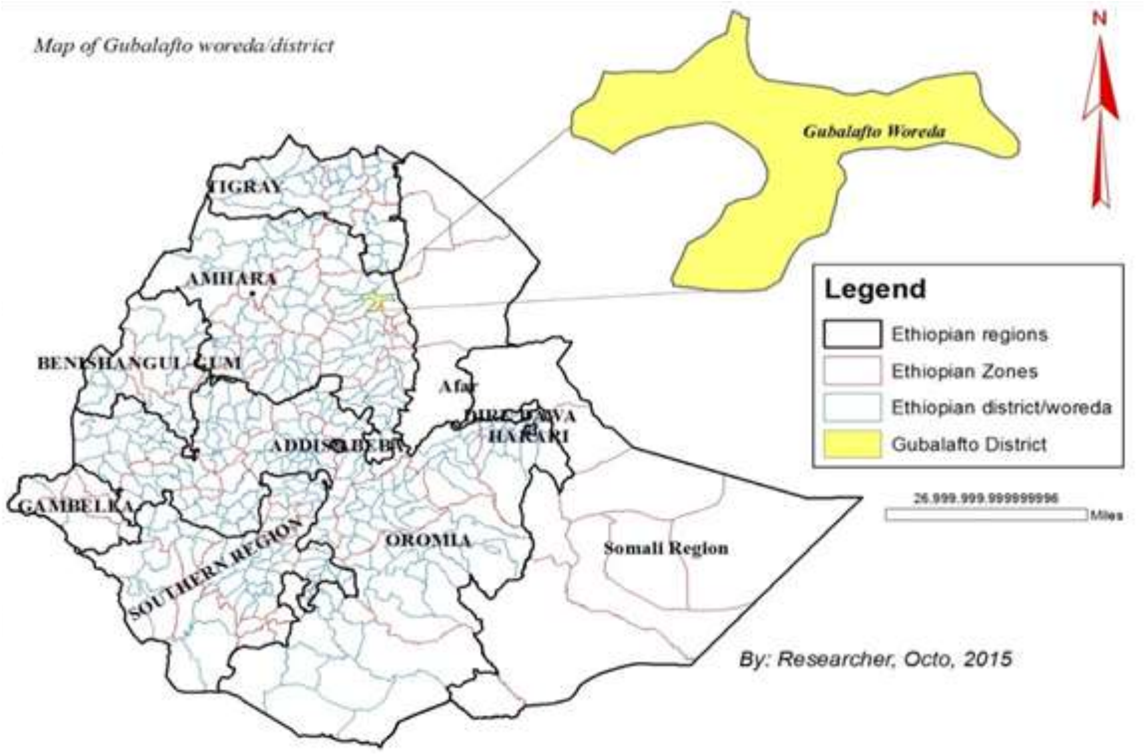

**Figure 1.** Location map of the study area.

experiencing declining soil fertility and severe soil erosion due to intensive farming on steep and fragile land (Amsalu, 2006).

The government of Ethiopia has made several interventions like mass mobilization, and soil and water conservation campaigns that have resulted in terraces, soil bunds, area closures, and planted with millions of tree seedlings. Nevertheless, the country still loses tremendous amount of fertile topsoil, and the threat of land degradation is broadening alarmingly (Teklu and Gezahegn, 2003).

According to FAO (2011), to reduce rural poverty and maintain food security, soil fertility need to be maintained, agricultural systems need to be transformed to increase the productive capacity and stability of small holder crop production. Greater attention is thus being given to alternative means of intensification, particularly the adoption[1] of soil and water conservation (SWC) practices.

Chemical fertilizers grow plants but for moisture deficiency periods do nothing to sustain the soil (Brady and Weil, 2002). This indicates that fertilizer application must be complimented with SWC practices to sustain agricultural production in rural livelihoods, where agricultural land is in short supply, where moisture is deficient, and/or where SWC practices has the potential to increase yields of high-value crops (Braun et al., 2003).

SWC practices are increasing food production without further depleting soil and water resources, adding high amounts of biomass to the soil, causing minimal soil disturbance, conserving soil and water, restoring soil fertility, and increasing the resilience of farming systems to climatic risk (FAO, 2009, 2010c). Thus, this study was designed to examine the effect of stone faced soil bund on soil macronutrients (N, P, and K), organic carbon content, soil pH, cation exchange capacity (CEC), and soil moisture status in Guba-Lafto Woreda.

## METHODOLOGY

### Description of the study area

Figure 1 presents the location map of Guba-Lafto Woreda within the Amhara Region of Ethiopia. The Woreda is bordered in the south by the South Wollo Zone, Delanta and Wadla Woreda in the west, Meket Woreda in the north-west, Gidan Woreda in the northeast by the Logiya River which separates it from Kobo, and on the southeast by Habru. Woldiya is an enclave inside this Woreda, and it is the major town in the area. Geographically, the area is located between 39°6’9” and 39°45’58’’East and 11°34’54’’and $11^0$58’59’’North.

Based on the 2014/2015 national census conducted by the Central Statistical Agency of Ethiopia (CSA), with an area of 900.49 square kilometers, Guba-Lafto Woreda has a population of 139,825. The major land use practices in the area includes arable

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[1] Adoption refers to a potential as technical feasibility, economic viability and social acceptability of a technology when managed at field scale by a target population of farmers (Franzel and Helen, 1992).

**Figure 2.** Average monthly temperature and rainfall at Woreda from 1990 to 2012.

land (34.1%), grazing land (17.9%), forest (27.1%), and water bodies (6%), rocky land (5%) and others (9.9%), respectively (Dereje and Desale, 2016).

Dominant soil types in the area are Eutric Leptosols, while Eutric Cambisols, Lithic Leptosols, and Vertic Cambisols are also observed in the Woreda (Mohammed, 2010). A bi-modal nature of rainfall characterizes most parts of Guba-Lafto Woreda. The short rainy season (Belg), occurs between February and April while the long rainy season (Meher), occurs between June and September. Figure 2 shows mean historical monthly temperature and rainfall for Guba Lafto Woreda during the time period 1990 to 2012.

## Methods of soil sampling and laboratory analyses

### *Soil sampling procedures*

Kebeles in the Woreda were stratified into two agro-ecological zones highland and midland. One kebeles from each agro ecological zone totally two kebeles; Shewat kebele (highland) and Amaymicha kebele (midland) have been selected purposively as SWC practices are more available in these kebeles. These kebele provide us an opportunity to find out different SWC practices and to investigate the roles of these practices on soil nutrient and soil moisture status.

From two selected kebeles which are Shewat and Amaymicha kebeles, soil samples were collected from two selected watersheds[2], which are Wege Alba watershed and Tikur Wuha watershed representing Shewat and Amaymicha kebeles respectively. In each watershed, four representative areas which are both the upper (loss zone) and lower streams (deposition zone) were selected purposefully to collect composite surface soil samples (0 to 20 cm).

From both watersheds, stone-faced soil bund is more available. Therefore, 8 composite soil samples were collected from farmlands with stone faced soil bund (>3 years old), and 8 composite soil samples from non-conserved farmlands giving a total sample size of 16 composite samples. Soil samples were taken by Auger to a depth of 20 cm from different sampling locations. The soil samples represent upper stream and lower streams of selected watersheds to explore variability in nutrient, and moisture contents as function of slope gradient and land use practice.

### *Soil laboratory analyses*

The soil samples were submitted to Dessie regional soil laboratory. Total Nitrogen (Tot N%) was analyzed using the Kjeldahl wet oxidation process as described by Blakemore et al. (1987). Available soil Phosphorus (mg/ kg of soil) was analyzed based on Olsen method (Olsen et al., 1954).

Exchangeable potassium (cmol (+)/kg) was analyzed through ammonium acetate extraction. Soil organic carbon content (Org C%) was determined according to the Walkley-Black titration method. Soil pH was measured in distilled water and potassium chloride (1M KCl) suspension in a 1:2.5 ml (soil: liquid ratio) using pH meter.

Cation exchange capacity (CEC) was estimated titrimetrically by distillation of ammonium that was displaced by sodium from NaCl solution (Van Reeuwijk, 2002). The percentage of soil moisture content was determined using Gravimetric method by using the formula:

$$\%\text{Moisture} =( ((Wf\text{-}Wod) /(Wod))* 100$$

Where: Wf = weight of fresh soil sample and Wod = weight of oven-dried soil sample.

## RESULT AND DISCUSSION

### *Effect of stone faced soil bund on some soil parameters*

*Soil pH*: Table 1 presents that treated plots with stone faced soil bund had significantly higher soil pH than non-treated soil. Though, statistical paired samples t-test showed that, there is no significant differences (t =2.222; p=0.062) between the mean of soil pH from treated plots

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[2] Watersheds or water catchments is an area where rainfall, surface runoff drains into one common stream, river or other water body. It can be a spatial unit which covers geographical surface that contributes to a major watershed (Sarah and Margaret, 2007)

**Table 1.** Effect of stone faced soil bund on soil pH.

| Sub-watersheds | Sample | pH –$H_2O$ | |
|---|---|---|---|
| | | Treated | Non-treated |
| Upper stream of Wege Alba watershed | 1 | 6.43 | 6.18 |
| | 2 | 4.43 | 3.05 |
| | Mean | 5.43 | 4.62 |
| Lower stream of Wege Alba watershed | 1 | 6.28 | 5.79 |
| | 2 | 5.28 | 5.4 |
| | Mean | 5.78 | 5.6 |
| Upper stream of Tikur wuha watershed | 1 | 8.23 | 5.15 |
| | 2 | 7.23 | 4.65 |
| | Mean | 7.73 | 4.9 |
| Lower stream of Tikur wuha watershed | 1 | 6.40 | 5.92 |
| | 2 | 5.43 | 4.84 |
| | Mean | 5.92 | 5.38 |
| Overall mean | | 6.2138 | 5.1218 |
| Std. D | | 1.18634 | 0.99058 |

Test statistics t-value =2.222; p-value =0.062 and d.f.=7 @ 95% Conf.In.

with stone faced soil bund and non-conserved farmlands. The mean soil pH value for treated plots was 6.2, compared to 5.1 for the non-treated plots. This is in agreement with previous studies elsewhere (Mulugeta and Stahr, 2010).

The higher pH values for the treated fields might be related to the higher organic matter content (Table 1) which is also confirmed by the works of Mulugeta and Stahr (2010) who reported that soils with high organic matter content have a higher soil pH which favors better exchange of bases, and increase availability of nutrients that are needed for the growth of plants in a given soil and ecology. Soil pH associated with the type of parent material and extent of soil erosion. For every half-unit drop in soil pH, percent base saturation declines by about 15% (Baruah and Barthakur, 1998).

Considering the soil pH difference along slope gradient, the plots in the upper sub-catchments have significantly lower soil pH compared to the foot slope positions (Table 1). This relates to the fact that the upper catchment is erosional area while the lower catchment is depositional where the finer soil particles, exchangeable bases, and organic humus are deposited. Therefore, farmers need to be encouraged to implement SWC measures for maximizing soil pH.

***Soil organic carbon:*** Table 2 presents the mean value of organic carbon content for treated plots with stone faced soil bund is 9.04% compared to 7.5% for the non-treated plots. A statistical paired samples t-test showed that, there is significant differences ($t$ =2.407; $p$ =0.047) between the mean of organic carbon content from treated plots with stone faced soil bund and non-treated plots.

This is in agreement with Mulugeta and Stahr (2010) that, soil organic carbon differences between the conserved and non-conserved micro-watersheds were statistically significant. The higher organic carbon content for the treated fields (Table 2) might be related to the higher organic matter content as total organic carbon is the carbon stored in soil organic matter (White, 1997).

Considering organic carbon content difference along slope gradient, the plots in the upper sub-catchments have significantly lower organic carbon content compared to the foot slope positions (Table 2). This relates to the fact that the upper catchment is erosional area while the lower catchment is depositional where the organic humus is deposited.

***Total nitrogen (N):*** Table 3 presents that the plots treated with stone faced soil bund had significantly higher total nitrogen content compared to that of non-treated plots. The mean total nitrogen content for treated plots with stone faced soil bund is 0.07 and 0.03% for untreated plots, which is significantly difference *(t =5.73; p=0.001)* in between.

This finding is in agreement with the findings of Million Alemayehu (2003) that the mean total nitrogen content of the terraced site with the original slope of 15, 25 and 35% were higher by 26, 34 and 14%, respectively, compared to the average total nitrogen contents of their corresponding non-terraced sloping lands. It is important to note that the pattern of the N-status of the soil follows

**Table 2.** Effect of stone faced soil bund on soil organic carbon content.

| Sub-watersheds | Sample | Organic carbon (%) | |
|---|---|---|---|
| | | Treated | Non-treated |
| Upper stream of Wege Alba watershed | 1 | 7.05 | 4.88 |
| | 2 | 8.9 | 7.85 |
| | Mean | 7.98 | 6.37 |
| Lower stream of Wege Alba watershed | 1 | 6.60 | 7.43 |
| | 2 | 11.27 | 7.26 |
| | Mean | 8.94 | 7.35 |
| Upper stream of Tikur wuha watershed | 1 | 9.16 | 6.94 |
| | 2 | 11.5 | 9.6 |
| | Mean | 10.33 | 8.27 |
| Lower stream of Tikur wuha watershed | 1 | 9.58 | 7.43 |
| | 2 | 8.3 | 9.40 |
| | Mean | 8.94 | 8.42 |
| Overall mean | | 9.0450 | 7.5988 |
| Std. Deviation | | 1.76519 | 1.47889 |

Test statistics t-value =2.407; p-value =0.047 and d.f.=7 @ 95% Conf.In.

**Table 3.** Effect of stone faced soil bund on total soil nitrogen (tot N) status.

| Sub-watersheds | Sample | Total Nitrogen (%) | |
|---|---|---|---|
| | | Treated | Untreated |
| Upper stream of Wege Alba watershed | 1 | 0.050 | 0.027 |
| | 2 | 0.047 | 0.040 |
| | Mean | 0.048 | 0.034 |
| Lower stream of Wege Alba watershed | 1 | 0.064 | 0.020 |
| | 2 | 0.070 | 0.054 |
| | Mean | 0.067 | 0.037 |
| Upper stream of Tikur wuha watershed | 1 | 0.087 | 0.034 |
| | 2 | 0.086 | 0.003 |
| | Mean | 0.0865 | 0.018 |
| Lower stream of Tikur wuha watershed | 1 | 0.084 | 0.034 |
| | 2 | 0.085 | 0.031 |
| | Mean | 0.0845 | 0.031 |
| Overall mean | | 0.072 | 0.033 |
| Std. Deviation | | 0.016 | 0.010 |

Test statistics t-value =5.73; p-value =0.001 and d.f.=7 @ 95% Conf.In.

that of the carbon content.

The soil nitrogen in both treated and non-treated plots along slop gradient is low in upper stream compared to lower stream of selected watersheds. The reason is that lower zones are deposition zones and upper streams area consists of most of the time soil loss zones in which, nitrogen is the most readily lost because of its high solubility in the nitrate form.

***Available phosphorus (P):*** Table 4 shows that mean value of available phosphorus (mg/kg) on treated plot with stone faced soil bund is 3.65 which is significantly higher than non-treated plots with mean value of 1.78. A statistical paired samples t-test showed that, mean of available phosphorus (mg/kg) is significantly difference [*t* =3.13*; p* =0.017] between treated and non-treated plots. It is in agreement that phosphorous (P) in the studied

**Table 4.** Effect of stone faced soil bund on available phosphorus (mg/kg).

| Sub-watersheds | Sample | Available phosphorus (mg/ Kg) | |
|---|---|---|---|
| | | Treated | Untreated |
| Upper stream of Wege Alba watershed | 1 | 3.86 | 2.06 |
| | 2 | 0.96 | 0.86 |
| | Mean | 2.41 | 1.46 |
| Lower stream of Wege Alba watershed | 1 | 5.16 | 5.66 |
| | 2 | 3.8 | 2.44 |
| | Mean | 4.48 | 4.05 |
| Upper stream of Tikur wuha watershed | 1 | 3.22 | 0.7 |
| | 2 | 5.12 | 0.02 |
| | Mean | 4.17 | 0.36 |
| Lower stream of Tikur wuha watershed | 1 | 3.52 | 1.12 |
| | 2 | 3.6 | 1.4 |
| | Mean | 3.56 | 1.26 |
| Overall mean | | 3.6550 | 1.7825 |
| Std. Deviation | | 1.3064 | 1.74269 |

Test statistics t-value =3.13; p-value =0.017 and d.f.=7 @ 95% Conf.In.

micro-watersheds were found to be significantly different between the conserved and non-conserved plots. It is also reported that available phosphorus is much higher in the conserved one (Mulugeta and Stahr, 2010). When we compare mean of available phosphorus (mg/kg) in both treated and non-treated plots along slop gradient, it is low in upper stream compared to lower stream of selected watersheds. The reason is that lower zones are deposition zones, and upper streams most of the time loss soil zones corresponding high erosion rate in soil particles.

***Exchangeable potassium (K):*** Table 5 shows that, the mean of exchangeable potassium from conserved plots with stone faced soil bund is 0.28 which is significantly higher than non-conserved farmlands with mean value of 0.26. A statistical paired samples t-test showed that, mean of exchangeable potassium *(cmol (+)/ kg)* is not significantly difference (*t* =1.03*; p =0*.34) between treated and non-treated plots. This study is in agreement with that of Wadera Lemma (2013) that, showed that adoption of SWC practices enhances the available soil potassium. It is reported that, plants deficient in potassium are unable to utilize nitrogen and water efficiently, and are more susceptible to disease (Shober, 2013). The mean of exchangeable Potassium *(cmol(+)/ kg)* along slop gradient is low in upper stream compared to lower stream of selected watersheds. The reason is that lower zones are deposition zones, and upper streams most of the time loss soil zones corresponding high erosion rate in soil particles in which, potassium is tightly held by soil particles, and so can be removed from fields by erosion.

***Cation exchange capacity (CEC):*** The cation exchange capacity (CEC) is a measure of the number of adsorption sites per unit weight of soil at a particular pH. CEC (cmol (+)/kg) is affected quite dramatically by pH changes. Soils with high in organic matter have a high CEC. In contrast, soils dominated by kaolinite and hydrous oxide clays generally have a low CEC (Mulugeta and Stahr, 2010).

Table 6 presents that, treated plots with stone faced soil bund with mean value of 24.4 has significantly higher CEC than non-treated plots with mean value of 19.7. A statistical paired samples t-test showed that, mean of CEC is significantly difference (*t* =2.807*; p* =0.026) between treated and non-treated plots. It is in agreement with Million Alemayehu (2003) that, terraced area with original slope of 25 and 35% had higher mean CEC value than that of the corresponding non-terraced slopes by 6 and 49%, respectively.

The mean of CEC along slop gradient in both treated and non-treated plots, is low in upper stream compared to lower stream of selected watersheds. The reason is that CEC content positively correlates with organic matter content, and soil organic carbon. The CEC of a soil can be reduced by soil erosion through the loss of soil organic matter, and clay particles (Brady and Weil, 2002).

***Effect of stone faced soil bund on soil moisture status:*** Table 7 presents that, mean value of soil moisture (%) on treated plots with stone faced soil bund is 33.5% which is significantly higher than non-treated plots with mean value of 25.6%. A statistical paired samples t-test showed that, mean of available soil moisture (%) is significantly difference (*t* =4.6*; p* =0.002)

**Table 5.** Effect of stone faced soil bund on exchangeable potassium.

| Sub-Watersheds | Sample | Exchangeable potassium (cmol (+)/ kg) | |
|---|---|---|---|
| | | Treated | Non-treated |
| | 1 | 0.28 | 0.31 |
| Upper stream of Wege Alba watershed | 2 | 0.24 | 0.23 |
| | Mean | 0.26 | 0.27 |
| | 1 | 0.29 | 0.25 |
| Lower stream of Wege Alba watershed | 2 | 0.26 | 0.21 |
| | Mean | 0.28 | 0.23 |
| | 1 | 0.31 | 0.33 |
| Upper stream of Tikur wuha watershed | 2 | 0.21 | 0.28 |
| | Mean | 0.26 | 0.31 |
| | 1 | 0.38 | 0.29 |
| Lower stream of Tikur wuha watershed | 2 | 0.30 | 0.19 |
| | Mean | 0.34 | 0.23 |
| Overall mean | | 0.28 | 0.26 |
| Std. D | | 0.051 | 0.049 |

Test statistics t-value =1.033; p-value =0.34 and d.f.=7 @ 95% Conf.In.

**Table 6.** Effect of stone faced soil bund on cation exchange capacity (CEC).

| Sub-Watersheds | Sample | CEC (cmol (+)/ kg) | |
|---|---|---|---|
| | | Treated | Non-treated |
| | 1 | 21.13 | 20.68 |
| Upper stream of Wege Alba watershed | 2 | 30.54 | 25.06 |
| | Mean | 25.84 | 22.87 |
| | 1 | 19.60 | 15.87 |
| Lower stream of Wege Alba watershed | 2 | 39.57 | 24.89 |
| | Mean | 29.59 | 20.38 |
| | 1 | 20.03 | 18.10 |
| Upper stream of Tikur wuha watershed | 2 | 21.08 | 13.74 |
| | Mean | 20.56 | 15.92 |
| | 1 | 22.78 | 19.45 |
| Lower stream of Tikur wuha watershed | 2 | 21.28 | 20.33 |
| | Mean | 22.03 | 19.89 |
| Overall mean | | 24.4975 | 19.7638 |
| Std. D | | 7.00055 | 3.96197 |

Test statistics t-value =2.807; p-value =0.026 and d.f.=7 @ 95% Conf.In.

between treated and non-treated plots. Joyce and Musiwa (1999) confirmed that SWC practices reduce the risks of total crop failure in drought years through enhancing soil moisture. Sutcliffe (1993) indicated that SWC practices are justifiable in moisture stressed areas of Ethiopian highlands, where moisture conservation plays an important role in increasing yield. The mean of available soil moisture (%) in both treated and non-treated plots along slope gradient is low in upper stream compared to lower stream of selected watersheds. The

**Table 7.** Effect of stone faced soil bund on soil moisture status.

| Sub-Watersheds | Sample | Available soil moisture (%) | |
|---|---|---|---|
| | | Treated | Non-treated |
| Upper stream of Wege Alba watershed | 1 | 34.84 | 22.05 |
| | 2 | 35.05 | 26.9 |
| | Mean | 34.95 | 24.48 |
| Lower stream of Wege Alba watershed | 1 | 38.17 | 26.7 |
| | 2 | 30.75 | 34.78 |
| | Mean | 34.46 | 30.74 |
| Upper stream of Tikur wuha watershed | 1 | 30.80 | 23.94 |
| | 2 | 32.39 | 21.69 |
| | Mean | 31.6 | 22.82 |
| Lower stream of Tikur wuha watershed | 1 | 35.04 | 23.62 |
| | 2 | 31.43 | 25.21 |
| | Mean | 32.24 | 24.42 |
| Over all mean | | 33.5588 | 25.6113 |
| Std. D | | 2.63819 | 4.17287 |

Test statistics t-value =4.611; p-value =0.002 and d.f.=7 @ 95% Conf.In.

reason is that lower zones are deposition zones corresponding with reduction in run-off velocity results in high levels of percolation and infiltration rate.

## Conclusion

The study showed that stone faced soil bund play a considerable role in enhancing soil nutrient and moisture status. Effect of stone faced soil bund on soil macronutrients, organic carbon content, soil pH, cation exchange capacity (CEC), and moisture status; as well as challenges to fully implement SWC practices were examined. A statistical paired samples t-test showed that, mean value of total nitrogen, available phosphorus, available potassium, organic carbon content, soil pH, cation exchange capacity (CEC), and moisture status were significantly difference (at t and p-value) between farm land with stone faced soil bund and non-conserved farmlands. That is why SWC practices are essential to enhance available soil nutrients by reducing runoff and soil erosion, helps keep nutrients on the field, and improves available soil moisture through storing water, and then increasing infiltration and percolation rates.

## RECOMMENDATIONS

Soil fertility decline and moisture stress were a significant crop production constraints in the Woreda. Thus, this study determined that stone faced soil bund improve soil characteristics including soil macronutrients (N, P, and K), organic carbon content, soil pH, cation exchange capacity (CEC), and moisture status. Above all, to solve soil nutrient depletion and moisture stress in Guba-Lafto Woreda, the following key recommendations should be taken in to account.

(1) The first recommendation is that, farmers need to be encouraged to implement SWC measures through the use of the productive safety net and Food-for Work payments.
(2) Construction of SWC practices should be followed up by other inputs (for example, organic fertilizer application).
(3) We should increase fallowing period, prevent cropland encroachment onto communal grazing areas, and control overstocking of dairy cows and oxen as it leads to overgrazing and further soil depletion.
(4) Finally, federal and local governments should support and encourage further studies in the Woreda to improve soil fertility, and to solve subsistence crop production problems, hence leads to increasing of production and productivity of farmlands.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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