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ARTICLE
Soil Bunds Effect on Soil Properties under Different Topographies of Southwest Ethiopia

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ABSTRACT

Soil erosion is a major environmental problem affecting development endeavors. Physical soil and water conservation (SWC) measures such as soil bunds are implemented to mitigate soil erosion. However, information on the effects of soil bunds on soil fertility is limited. This study aimed to evaluate soil quality in fields with soil bunds and with no soil bunds in steep, middle and lower sloping cultivated lands as well as spatial variation of soil properties in between bunds in southwest Ethiopia. About 7-15 years old bunds and nearby cultivated fields lacking bunds were assessed. From 0 cm-20 cm soil depth, 36 soil samples were collected. Soil texture, soil organic carbon (SOC), total nitrogen (N_{tot}) and exchangeable potassium (K_{exch}) were analyzed. Soil bunds showed significantly (p<0.0.5) greater clay but less sand than adjacent no-bund fields. In steep, middle, and lower slopes, concentrations of SOC and K_{exch} were greater in fields with soil bunds than without. Lower slope fields showed greater clay, SOC and nutrients than steep slopes. In between soil bunds, soil was more fertile at bunds than below the bunds. In Fanta watershed, soil bunds are a vital conservation measure to retain soil fertility in cultivated mountainous areas.

1. Introduction

Food security for the increasing human population relies on the quality of environment and sustainability of soil and water resources. Across the world, erosion removes as high as 75 billion tons of soil per annum [1] and is an alarming environmental problem with far-reaching impact. Soil quality decline due to erosion is a problem resulting in nutrient depletion and constraining the development of the agricultural sector and attainment of food security. About 65% of the total area is regarded as degraded, Sub-Saharan Africa is among the regions highly affected by soil quality loss that emanates from poor land management and excessive removal by erosion [2,3]. The geographic distribution of quality loss varies due to differences in topography, climate and land management. For example, east African highland is a soil degradation hot spot due to high annual soil loss,

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e.g., 420 tons per hectare in Uganda [4-6].

Ethiopia is among the countries most affected by soil erosion. The traditional and fragmented -agriculture dominating landscape of Ethiopia has been affected by soil erosion [7,8]. In Ethiopia, about 50% of the highlands, landscapes with an elevation exceeding 1500 meters from sea level, suffer from sheet and rill erosion [6], which is a severe problem in sloping areas, mainly in the northern and central highlands having little permanent vegetation cover and shallow soils. Every year, about 1.4-2 billion tonnes of soil are removed by erosion, about 50% of which is from cereal-growing landscapes [6,7]. Soil formation in Ethiopia varies between 2 tonnes/hectare/year and 22 tonnes/hectare/year [9], but several studies across the country reported soil erosion that exceeded soil formation rate [10-13]. This implied that the Ethiopian highlands have been experiencing a decline in soil fertility due to severe soil erosion. The traditional conventional farming system on shallow soil and sloping topography, excessive removal of plants by livestock and wood material extraction, crop residue removal, and shortened fallow periods due to increasing population and land scarcity have aggravated soil erosion and degradation [14,15]. Soil degradation due to erosion significantly contributes to food insecurity among rural households and poses a real threat to the sustainability of existing subsistence agriculture [16].

Traditional soil and water management practices have existed in Ethiopia for centuries [13]. However, expert-based efforts for controlling soil erosion were started in the past about four decades after recognizing the adverse effects of severe soil degradation and drought, particularly in Tigray and Wollo areas of northern Ethiopia. The modern erosion controlling efforts were implemented by constructing physical soil and water conservation techniques such as soil and stone bunds through resource support of international organizations [7,17,18]. The earlier incentives for controlling erosion and soil degradation were followed by food for work schemes [19]. In the recent two decades, the government emphasized environmental rehabilitation and protection using a participatory watershed management approach mainly in highlands, where population density is high and land degradation challenges agricultural production [18]. The government programs and development partners implemented watershed-based soil and water conservation measures. Productive Safety Net Program (PSNP) is one of the government-supported programs, involved in watershed-based soil and water conservation activities. The PSNP was initiated as social protection scheme in 2005 and supports food security issues resulting from environmental degradation and prolonged drought [20]. In food insecure areas, the PSNP has a public work scheme in which the beneficiaries receive cash or grain for, e.g., construction of soil and stone bunds [21].

Soil bunds, the physical barriers with about 50 cm deep and wide ditch, are constructed along contour to reduce surface runoff and soil loss [12,22,23]. On sloping cultivated lands, without soil bunds or sufficient vegetation cover, erosion could adversely affect soil quality. Research reported that, in plots treated with soil bunds, soil organic carbon and total nitrogen were greater than in plots without bunds on Nitisol of northern Ethiopia [24]. Studies reported positive effect of soil bunds on reducing soil erosion [12,13,25]. However, studies are rare on the effects of soil bunds on soil properties under different topographic set up [22,26,27]. Available literature on other related cross-slope barrier techniques such as *Fanya juu* reported insignificant differences in plant nutrients such as nitrogen and potassium, e.g., in Anjeni watershed of northern Ethiopia [28]. Alemayehu et al. [29] reported greater soil organic carbon in plots treated with stone bunds than without any physical measures. The erosion and subsequent deposition in the intra-*Fanya juu* area as well as in intra-terrace area reported spatial variation of soil organic carbon and nutrients in Ethiopia [30] and Uganda [31]. Effects of bunds may differ with climate, soil, and management practices [15], and the effect of bunds on soil properties is not well understood.

To combat soil erosion and associated soil degradation effect on food security, physical soil and water conservation measures including soil bunds were introduced to the Fanta watershed of the Omo-Gibe River basin, southwest Ethiopia, by government-supported programs such as PSNP. Thus, in this area, in the past 15 years, the PSNP has been supporting soil and water conservation activities. The program covers construction costs to the rural community and provides expert support. In addition to the PSNP, conservation measures were also implemented through state-initiated public campaigns since 2010 [32]. Even though the soil and water conservation practice has been promoted and implemented in a large area, its effects on soil properties are not understood. This study was aimed: (1) to evaluate the effect of soil bunds on soil quality at steep (> 25%), middle (15%-25%) and lower (3%-15%) slope areas of the cultivated landscape, and (2) to assess relative locational difference in soil properties in between two soil bunds of about 7-15 years old on Nitisol.

2. Methods and Materials

2.1 Description of the Study Area

The study was conducted in the Fanta watershed of the

Omo-Gibe River basin, Southwest Ethiopia. The Fanta watershed, located at 7°17'30''-7°20'30''N latitude and 37°17'10''-37°19'40''E longitude (Figure 1), drains to Gibe III hydro-electric dam on Omo River. The Omo-Gibe River basin is well recognized in East Africa due to the cross-border Omo River and Mega dams. Fanta watershed is one of the typical and important agriculture-dominating landscapes in the basin and is characterized by a range of elevation (1000 m-2860 m above sea level) and topographies (mountains, valleys, and plateaus). The mean annual temperature and rainfall of the area are 15.1 °C-27.5 °C and 1400 mm, respectively. Crop growing season in the area is between March and September. Nitisols and Leptosol are dominant soil types [33]. Smallholder crop-livestock farming is a major livelihood of the community. Annual crops such as maize (*Zea mays*), teff (*Eragrostis tef*), sorghum *(Sorghum bicolor),* and barley (*Hordeum vulgare*) are commonly cultivated, while the plots around the homestead are covered with enset (*Ensete ventricosum*). Enset is a perennial plant and important staple food in the region [13]. Livestock production is an essential part of the farming system as nearly seed bed preparations are done with oxen-drawn plough. Agriculture has replaced most of the forest and woodlands.

2.2 Soil Sampling and Analysis

To understand the effect of soil bunds, soil analyses were conducted for fields with and without soil bunds. Croplands with 7-15 years-old soil bunds (Figure 2) were selected in the steep, middle, and lower slope areas of cultivated Fanta watershed. In each slope area, near conserved fields, fields without any physical soil and water conservation measures were selected. Plots treated with soil bunds and those lacking soil bunds had a similar history of farm management, and soil group. The steep, middle, and lower slope areas had slopes of > 25%, 15%-25%, and 3%-15%, respectively. In each slope category, three fields treated with soil bunds and other nearby three fields with no physical conservation measures were selected. In plots having soil bunds, soil samples were collected from three relative locations in between two bunds. That is, near soil bund at ~1 m downslope side of the bund, middle point, and above soil bund at ~1 m. This was replicated three times per field. The samples were collected from soil depth of 0 cm-20 cm. A total of twenty-seven soil samples (3 slope categories * 3 fields per slope category * 3 samples per field in between soil bunds) were collected from croplands with soil bunds. In fields lacking soil bunds, a

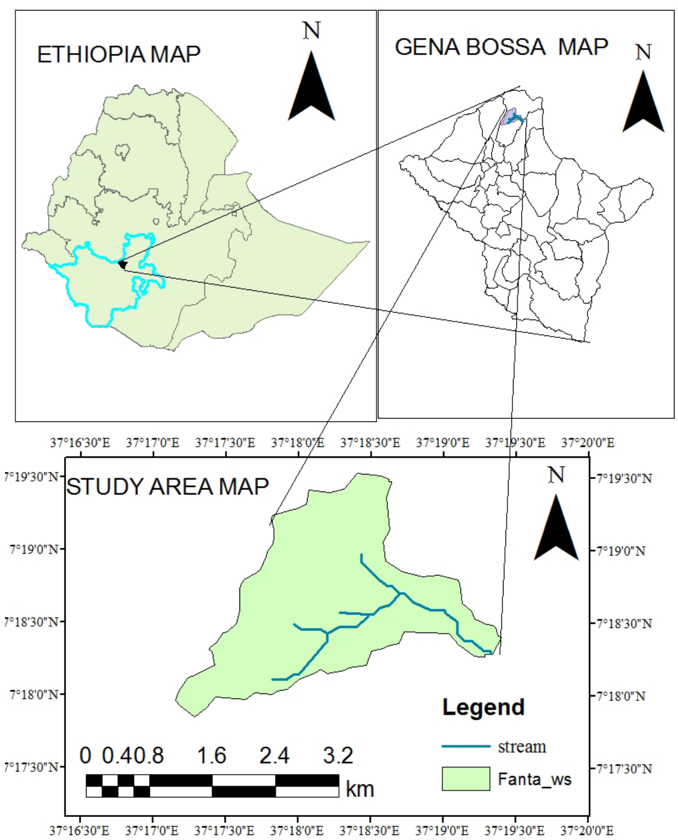

Figure 1. Location map of the Fanta watershed in Southwest Ethiopia.

Figure 2. Soil bunds on cultivated lands of the Fanta watershed, Southwest Ethiopia.

Photo: Wondimu Bekele.

total of nine soil samples (3 slope categories * 3 fields per slope category) were collected.

After sieving air dried soil samples with 2 mm steel mesh, texture, soil organic carbon (SOC), total nitrogen (N_{tot}), and exchangeable potassium (K_{exch}) were analyzed. Soil texture was determined following the hydrometric method [34]. The concentration of SOC was assessed following the Walkley and Black method [35], while total nitrogen (N_{tot}) was determined by wet-digestion, distillation, and titration procedures of the Kjeldahl method as described by Black et al. [36]. The exchangeable potassium (K_{exch}) was determined by a flame emission spectrophotometer [36].

2.3 Data Analysis

Data were analyzed using SPSS 20 computer software (IBM Co., Armonk, NY, USA). The differences in soil properties due to soil bunds compared with nearby non-conserved plots using a t-test. Variations in soil properties between slope categories as well as differences between the three sections (below a bund, middle point, and above a bund) within the soil bunds were assessed using analysis of variance (one-way ANOVA) at $p \leq 0.05$. The Least Significant Difference (LSD) was applied to evaluate differences between means.

3. Results

3.1 Variation of Soil Properties in between Fields with Soil Bunds and No Bunds

The texture analysis showed that fields without soil bunds showed significantly ($p<0.05$) greater sand and silt fractions and fewer fractions of clay than fields treated with soil bunds (Table 1). In the steep, moderate and lower slope areas, SOC was significantly greater ($p < 0.05$) in fields treated with soil bunds than no bund fields. The variations in SOC between bunds and no bunds were slight increased from steep slope to lower slope, where the fields with soil bunds in steep, middle and lower slope were greater by 25%, 39% and 42%, respectively, than those without bunds. The significant difference in N_{tot} was observed at steep slopes where fields with soil bunds had significantly ($p < 0.05$) greater values than no bunds. The K_{exch} was significantly ($p < 0.05$) greater in fields treated with soil bunds than without soil bunds at steep, middle and lower slopes. The K_{exch} was 63%-129% greater in fields with soil bunds than without, the highest difference at steeper slopes.

3.2 Spatial Variation of Soil Properties within Soil Bunds

In between two consecutive soil bunds, at steep slopes, concentrations of clay, SOC, and K_{exch} were significantly ($p < 0.05$) greater above a bund than middle and below a bund, and the opposite trend was observed for sand (Table 2). This was true for mid and lower slope categories. The significant differences in N_{tot} between above a bund, midpoint and below a bund were observed only at the lower slope category.

3.3 Effect of Slope and Bunds on Soil Properties

In fields with soil bunds and with no bunds, the fractions of sand and clay were significantly ($p < 0.05$) varied between steep and lower slopes. Sand fractions were greater at steep slope whereas clay was greater at lower slopes (Table 1). The differences were 50% and 14% of sand in fields with soil bunds and with no bunds, respec-

Table 1. Soil texture, soil organic carbon (SOC), total nitrogen (N_{tot}), and exchangeable potassium (K_{exch}) at 0 cm-20 cm depth soils of fields with and without soil bunds in steep, middle and lower slope positions of the Fanta Watershed (mean ± standard deviation), southwest Ethiopia.

Slope position	Soil bunds, n=9	Without soil bunds, n=3	*p*-value
Sand, %			
Steep	36.4 ± 0.84a^{a}	45.7 ± 3.05a^{b}	0.0
Middle	30.9 ± 1.69b^{a}	42.3 ± 0.57ab^{b}	0.0
Lower	24.3 ± 5.0c^{a}	40.0 ± 1.0b^{b}	0.0
p-value	0.0	0.028	
Clay, %			
Steep	36.9 ± 1.69a^{a}	29.0 ± 0.00a^{b}	0.0
Middle	41.1 ± 1.17a^{a}	30.7 ± 1.53a^{b}	0.0
Lower	55.8 ± 9.64b^{a}	33.00 ± 1.00b^{b}	0.003
p-value	0.0	0.01	
Silt, %			
Steep	26.66 ± 5.27a^{a}	25.33 ± 3.06a^{a}	0.233
Middle	28.1 ± 0.78a^{a}	26.67 ± 0.58a^{b}	0.016
Lower	19.9 ± 5.12b^{a}	27.0 ± 0.00a^{b}	0.043
p-value	0.0	0.55	
Soil organic carbon, %			
Steep	1.58 ± 0.04a^{a}	1.269 ± 0.018a^{b}	0.0
Middle	1.77 ± 0.03b^{a}	1.27 ± 0.02bc^{b}	0.0
Lower	1.97 ± 0.12c^{a}	1.39 ± 0.041c^{b}	0.0
p-value	0.0	0.0	0.0
Total nitrogen , %			
Steep	0.22 ± 0.05a^{a}	0.14 ± 0.03a^{b}	0.01
Middle	0.29 ± 0.04bc^{a}	0.20 ± 0.07ab^{a}	0.18
Lower	0.31 ± 0.05c^{a}	0.26 ± 0.05b^{a}	0.21
p-value	0.01	0.11	
$K_{exch,}$ Cmol (+)/kg			
Steep	0.278 ± 0.018a^{a}	0.118 ± 0.0549a^{b}	0.0
Middle	0.327 ± 0.018a^{a}	0.201 ± 0.0166bc^{b}	0.002
Lower	0.429 ± 0.059b^{a}	0.231 ± 0.008c^{b}	0.0
p-value	0.0	0.04	

Note: Mean and standard deviation followed by different small letters in the superscript indicate significant ($p < 0.05$) differences between soil bunds and no bund (row comparison). Significant ($p < 0.05$) variations between slope positions (column comparison) were shown by different small letters.

Table 2. Soil texture, concentration of soil organic carbon (SOC), total nitrogen (N_{tot}), exchangeable potassium (K_{exch}) in upper, middle and lower sections in intra-soil bunds in the steep, middle and lower slope position in the Fanta watershed of Omo-Gibe basin, Ethiopia (mean ± standard deviation, n = 3).

Slope position	Parameters	Location in between soil bunds				
		Upper section	Middle section	Lower section	Total	*p*-value
Steep slope position	Sand, %	38.0 ± 1.0a	37.0 ± 0.0a	34.3 ± 1.53b	36.4 ± 1.88	0.01
	Silt, %	27.0 ± 0.0a	26.0 ± 0.0b	26.7 ± 5.77a	26.6 ± 5.27	0.03
	Clay, %	35.0 ± 1.0a	37.0 ± 0.0b	38.7 ± 0.58c	36.9 ± 1.69	0.002
	SOC, %	1.51 ± 0.03a	1.56 ± 0.02ab	1.67 ± 0.03b	1.58 ± 0.03	0.001
	N_{tot}, %	0.19 ± 0.03a	0.22 ± 0.05a	0.25 ± 0.03a	0.22 ± 0.04	0.239
	K_{exch}, Cmol (+)/kg	0.26 ± 0.01a	0.28 ± 0.00b	0.29 ± 0.01b	0.28 ± 0.02	0.007
Middle slope position	Sand, %	33 ± 0.0a	30.3 ± 0.56b	29.3 ± 0.58c	30.9 ± 1.69	0.0
	Silt, %	27.3 ± 5.77a	28.7 ± 5.77b	28.3 ± 5.77ab	28.1 ± 7.83	0.07
	Clay, %	40.0 ± 0.0a	41.0 ± 0.0a	42.3 ± 1.15b	41.1 ± 1.16	0.015
	SOC, %	1.74 ± 0.01a	1.76 ± 0.01ab	1.81 ± 0.04b	1.77 ± 0.03	0.04
	N_{tot}, %	0.26 ± 0.04a	0.28 ± 0.04a	0.32 ± 0.03a	0.29 ± 0.04	0.29
	K_{exch}, Cmol (+)/kg	0.31 ± 0.01a	0.33 ± 0.01b	0.35 ± 0.00c	0.33 ± 0.02	0.0
Lower slope position	Sand, %	28.3 ± 1.12a	25.7 ± 1.12a	19.0 ± 5.29b	24.3 ± 5.00	0.03
	Silt, %	25.7 ± 2.08a	19.3 ± 1.12b	14.7 ± 3.06c	19.9 ± 1.72	0.0
	Clay, %	46.0 ± 2.65a	55.0 ± 2.00b	66.3 ± 7.02c	55.78 ± 9.64	0.004
	SOC, %	1.86 ± 0.04a	1.95 ± 0.01a	2.10 ± 0.12b	1.97 ± 0.12	0.018
	N_{tot}, %	0.27 ± 0.03a	0.31 ± 0.03ab	0.35 ± 0.04b	0.31 ± 0.05	0.069
	K_{exch}, Cmol (+)/kg	0.37 ± 0.01a	0.43 ± 0.02b	0.49 ± 0.04c	0.43 ± 0.06	0.006

Note: Mean and standard deviation followed by different small letters had significant difference (p<0.05) between sections in intra-bund area.

tively. Also, clay differed by 34% and 12% in fields with soil bunds and with no bunds, respectively. Unlike fields without soil bunds, significant difference in silt fraction between steep and lower slope was observed in fields with soil bunds. The SOC and K_{exch} were significantly ($p < 0.05$) greater at a lower slope than steep slopes, both at fields with soil bunds and with no bunds. In soil bunds, the lower slopes showed 20% greater SOC and 37% greater K_{exch} than steep slope, which was 9% of SOC and 49% of K_{exch} in fields without soil bunds. In fields with soil bunds, N_{tot} was significantly ($p < 0.05$) greater at lower slope areas than steep slopes, which was insignificant in fields with no bunds.

4. Discussion

4.1 Effects of Soil Bunds on Soil Fertility

Soil bunds, constructed along contour by digging a ditch and accumulating excavated soil at a down slope, are cross-slope barriers against surface runoff and thus, reduce soil loss. Studies reported soil bunds' effect in reducing erosion from 50%-90% [12,13,25]. The greater clay concentration and less sand in fields with soil bunds than no bunds in cultivated for more than seven years indicated that soil erosion has removed small-sized particles. The erosion-mitigating ability of the soil bunds has resulted in a greater concentration of clay fractions in fields with soil bunds. Due to its greater size, sand fractions remain behind while the finer materials are easily removed by erosion [37]. Studies by Bezabih et al. [27] in Dedo district of Southwest Ethiopia and Mengistu et al. [28] in northern Ethiopia reported that soils treated with soil bunds have higher clay fractions compared to no bund plots. Greater SOC in fields with physical SWC measures was reported in Silluh valley of northern Ethiopia [38]. However, Wolka et al. [22,26] and Hailu et al. [39] reported insignificant variation of soil sand and clay fractions in between fields with and without soil bunds in Goromti and Bokole areas. Differences in land management, length of intervention period and severity of erosion would have affected.

On slopping cultivated land, soil erosion removes SOC and thus, is a process of degrading soil quality [40,41]. The conservation measures are important to conserve SOC, which is a major soil property in determining soil quality, in cultivated sloping lands. In the Fanta watershed, the greater SOC in fields with soil bunds than with no bunds could be mainly due to the erosion controlling ability of the soil bunds. The retention of clay in fields with soil bunds could also imply the alongside retention of SOC, as associations between clay and SOC have been documented [42]. Our study showed that soil bunds could retain soil particles together with SOC in all slope categories (steep, middle and lower), indicating the need for such SWC practices in the different slope categories. The capacity of soil bunds to retain surface runoff could positively influence soil moisture and thus, crop yield as reported in Zimbabwe [43] and Ethiopia [28], which can partly enhance SOC concentration. Also, in fields with soil bunds, conservation of the dissolved SOC through surface runoff retention is an additional advantage [13]. The greater SOC in fields with soil bunds than with no bunds in the present study agreed with findings in Kenya [44] and Ethiopia [39]. The role of soil bunds in reducing soil erosion was also observed from its greater N_{tot} and K_{exch} than in fields with no soil bunds. However, Mengistu et al. [28] reported insignificant differences in N_{tot} and K_{exch} between fields with and without no conservation measures on different slope positions in Anjeni watershed, northern Ethiopia, which could be associated to severity of erosion and soil management activities. On sloping and conventionally cultivated land, the nutrient rich topsoil removal could affect cropland productivity. Thus, soil bunds are highly important to maintain cropland fertility and thus, food security of smallholders.

4.2 Soil Properties in Plots between Two Bunds

In Fanta watershed, more than seven years old soil bunds showed differences in soil properties between three locations (above bund, middle, below bund) in between bunds due to topsoil transfer to downslope. Soil bunds, a barrier against surface runoff, could accumulate soil above the bund. That means, the downslope side of soil bunds is a loser, while the upper slope side of next soil bund gains sediment. Van Oost et al. [45] reported that tillage erosion could also transfer 70 kg $m^{-1}yr^{-1}$-260 kg $m^{-1}yr^{-1}$ of soil when non-mechanized agriculture is practiced. That means, both water erosion and tillage could transport topsoil to downslope and deposit above the bund [46]. Thus, the sand fractions, due to their greater size, remain below the bund, while more clay accumulates at lower section, above soil bund. Our result agrees with the findings of Lin et al. [47], which reported greater clay fractions in lower section in purple-soil area of China. A related study by Siriri et al. [31] also reported greater clay at lower section of terrace in Uganda. In our study area, the downslope transfer of topsoil resulted in greater SOC, N_{tot} and K_{exch} at above soil bunds than below soil bunds. Studies on spatial variation of soil properties in intra-soil bund areas are rare. Wolka et al. [22] reported insignificant intra-bund soil properties in two years old soil bunds in Bokole watershed of Ethiopia. Studies on the other cross-slope barrier soil and water conservation measures such as *Fanya juu* and stone bunds in Ethiopia [29,30,48], plant hedgerow in Honduras and China [47,49], and bench terrace in Uganda [31] reported greater concentrations of SOC and nutrients at above the conservation measure than below the barrier. In the Fanta watershed, in the present study area, erosion below the bund and deposition above the bund, which resulted in spatial variation of soil quality, could have resulted in spatial variation of crop yield but not addressed in this study. Adaptive soil fertility management techniques in between bunds can improve soil quality below the bunds.

4.3 Effect of Slope Gradient on Soil Properties in Treated and Non-Treated Fields

In fields with soil bunds and no bunds, the steep slope showed greater sand and less clay than lower slope (Table 1), perhaps due to long time erosion and deposition. That means, the fine particles including clay are removed from upper slope position and deposited in lower slope area, while the large sized sand could remain behind. After physical soil and water conservation measures, less erosion is expected than in fields with soil bunds [12,15] than fields with no soil bunds. This implies a greater transfer of soil from steep slope to the lower slope in fields with no soil bunds, particularly on cereal dominating agricultural landscapes. Since soil erosion and sediment yields are a function of slope [50,51], steep slopes could have more erosion and thus, greater deposition at a lower slope.

Due to deposition of SOC and nutrient rich topsoil at lower slopes, greater SOC, N_{tot} and K_{exch} were observed at lower slopes than steep slopes. Our result supports Amare et al. [30] and Bezabih et al. [27], which reported greater SOC and nutrients at the slope position than steeper slope position in Anjeni watershed of northern Ethiopia and Dedo district of southwest Ethiopia. Hailu et al. [39] also reported the association of SOC with land slope positions where fertile soil deposits at lower slope positions. Due to surface runoff, the greater soil moisture at lower slopes could enhance plant growth and biomass production, which in turn can increase SOC. Insignificant variation in N_{tot} was observed along slope gradient, particularly in fields without soil bunds due to overall low soil N_{tot}. Implementing sufficient conservation measures is important to sustain soil quality of cultivated sloping land.

5. Conclusions

Soil and water conservation measures are practiced for controlling adverse effects of severe soil erosion on sloping cultivated lands. Soil bunds have been widely implemented to protect against erosion and soil degradation of sloping cultivated lands. Our study on more than seven years old soil bunds revealed that fields with soil bunds showed significantly greater clay fractions than fields with no soil bunds. The greater SOC and nutrients in fields with soil bunds revealed comparatively better soil fertility than in bunds than non-treated fields. The increase in clay, SOC, N_{tot}, and K_{exch} concentrations with decreasing slope gradients in fields with soil bunds and with no soil bunds showed long-term erosion from steeper slopes and deposition at foot slope fields. In intra-soil bund area, above soil bunds were more fertile than below soil bunds. Our study revealed that soil bunds are important cross-slope barriers which could support sustaining soil quality against erosion as differences in soil properties between fields with soil bunds and no bunds were revealed. In between bunds, soil fertility is better just above the bund. We suggest implementation of soil bunds in the study area and other areas with similar agro-ecology and soil type. The spatial variation of soil quality in between bunds could be compensated by applying selective soil fertility management techniques below the bunds to enhance nutrient concentrations and crop yield.

Conflict of Interest

There is no conflict of interest.

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