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Soil Fertility Status as Affected by Different Land Use Types and Topographic Positions: A Case of Delta Sub-Watershed, Southwestern Ethiopia

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Abstract
This study was aimed at assessing the status of soil properties under Enset (Enset ventricosum) farm, grazing and cultivated land from upper, middle and lower slope positions (15-25%, 8-15% and 3-8% slope) in Delta sub-watershed of Southwestern Ethiopia. Split block design was employed. A total of 54 soil samples, from 3 slope positions x 3 land use types (treatments) x 2 depths (0-20 and 20-40cm) x 3 replications, were collected and used to test for soil chemical properties. For soil physical properties assessment, 27 soil samples were collected from 0-20cm soil depth by using simple random sampling technique. The result from several soil chemical parameters revealed that OC, TN, C/N, AvP, CEC, exchangeable bases (K^+, Mg^{+2}, Ca^{+2} and Na^+), ESP, PBS were significantly lower ($p<0.001$) in both depths of cultivated land and upper slope position than in respective slope positions of the other two land use types. However, average soil EC and pH did not show variation with both slope positions and land use types. The result also showed that soil physical property parameters such as soil bulk density, soil moisture and clay content in grazing lands were significantly higher ($p<0.001$). In contrast, total porosity and silt content were relatively lower in grazing land. From this finding, it can be concluded that there needs to be a look into not only land use types but also slope positions in developing land use planning and soil management strategies in this region.
Keywords*:* slope gradient, land use change, soil depth, soil properties

Introduction

Soil is the most important resource required for Agricultural production (Khanif, 2010). That is why soil fertility depletion in smallholder farms has been cited as the fundamental biophysical root cause responsible for the declining per capita food production in Africa (Sanchez *et al*., 1996). In permanent agricultural systems, soil fertility can be maintained through applications of manure, organic materials, inorganic fertilizers, lime, and inclusion of legumes in the cropping systems and combination of these. Although the reliance on biological nutrient sources for soil fertility regeneration is adequate with low cropping intensity, it becomes unsustainable with more intensive cropping unless artificial fertilizers are applied (Mulongey and Merck, 1993). But in many parts of the developing countries the availability, use and profitability of inorganic fertilizers have been low whereas there has been intensification of land-use and expansion of crop cultivation to marginal soil. As a result, soil fertility has been declined and it is perceived to be widespread, particularly in sub-Saharan Africa including Ethiopia (Taye and yifru*,* 2010*)*. So, soil fertility maintenance is a major concern in the region to improve agricultural production in order to feed the growing population.

The fertility status of Ethiopian soils has also declined and continued to decline posing a challenge to crop production. This is due to, continuous cropping (abandoning of fallowing), reduced manure application, removal of crop residues and animal dung for fuel wood and erosion coupled with low inherent fertility of the soils (Yohannes, 1994; Tilahun *et. al,* 2007). According to Mesfin (1998) another challenges of soil fertility decline in Ethiopia are related to cultural practices like traditional cultivation, removal of vegetative cover (such as straw or stubble) or burning plant residues as practiced under the traditional system of crop production or the annual burning of vegetation on grazing lands. These are the major contributors to the loss of nutrients.

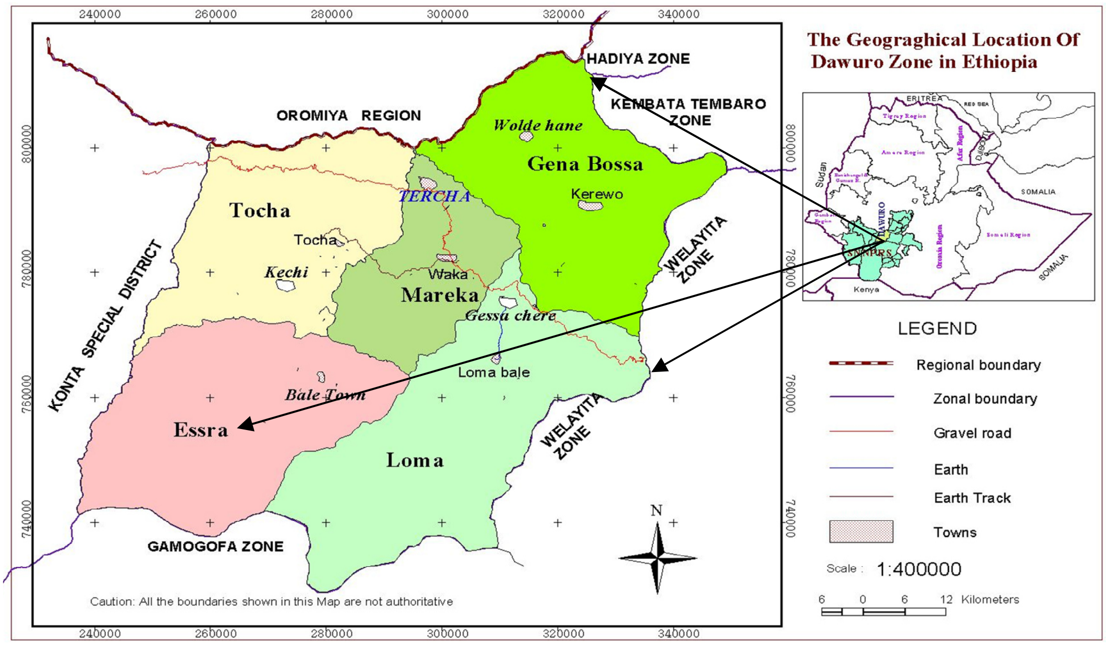
Southwest Ethiopia including dawuro zone, which is the focus of the present study, has also many natural resource management problems that combined to cause decline in soil fertility. According to Barry and Ejigu (2005) the main causes of fertility decline in southwestern Ethiopia are deforestation, removal of crop residues from fields, land fragmentation, reduction of fallowing periods, overgrazing, low fertilizer inputs, inadequate soil and water conservation practices and cropping of marginal lands. These have resulted in lowering of agricultural production, leading to food insecurity and increased poverty. Eventhough the consequence of soil fertility decline is very serious; it has not received as much research attention as soil erosion and other forms of land degradation. Most recently, only few studies (*e.g*. Mulugeta, 2004; Wakene and Heluf, 2004; Ashagrie *et al.,*

2005) have considered the effects of different land use systems and their associated soil management practices, on soil physical and chemical properties that influence soil fertility. These studies, however, were conducted to assess soil fertility status difference due to different land use types and topographic positions. The study area is densely populated with undulating topography, making it vulnerable for soil fertility decline, deforestation and causing soil erosion. On the other hand, shortage of grasslands (grazing areas) in the study area has forced the farmers to remove crop residues for animal feed. Manure and other home refuses are used mainly for specific land use type especially for homestead gardens to maintain soil fertility status of Enset *(Enset ventricosum)* farm. And also many farmers subjected to continuous cultivation of steeply slope lands without any adequate soil fertility amendments and soil and water conservation measures.

Materials and Methods

Description of the Study Area

The study watershed is situated in Southern Nations, Nationalities and Peoples Regional State (SNNPRS) of Ethiopia in the Essera *woreda* of Dawuro zone, southwestern Ethiopia (Figure1). It is situated in the Omo basin at about 507 km Southwest of Addis Ababa, the capital of Ethiopia. The area is topographically undulating and rugged. The Dawuro Zone covers total area of 4436.7sq.km^2 and lies between 6.59-7.34 degree north latitude and 36.68 to 37.52 degree east longitudes, with an elevation ranging 501-3000m (Mathewos, 2008). Regarding the Agro-Ecology, 55.6% is *kolla*, 41.4% is *Weinadega* and 3% is *Dega*. The annual mean temperature ranges between 15.1 to 27.5^{o}c. The rainfall is a bimodal type: the short rainy season is between (February to March) and the long between (May to September). The average annual rainfall ranges from 1201 to 1800mm. According to the land utilization data of the region, 38.4% is cultivated land, 13.39% grazing land, 16.81% forest bushes and shrub land, 17.09 % cultivable and 14.31 is covered by others. The livestock resource of the zone was estimated to be 313,094 cattle, 113,554 sheep, 45,703 goats, 7,081 horses, 1,934 mules, 5,064 donkey, and 157,996 chicken and 28,557 traditional hives (CSA 2006).



Source:-Dawuro Zone Development Association
Figure 2: Location map of the study area

Methods of Data Collection and Analysis

Soil sampling and laboratory analysis

Three representative land use types namely, cultivated land (cereal based land use type), Enset *(Enset ventricosum)* farm and grazing land (covered with grasses and some scattered agroforestry tree species) were selected from (lower, middle and upper) topographic position. Disturbed and undisturbed soil samples were collected from each land use type in three replicates from the three slope positions, lower (3-8%), middle (8-15%), and upper (15-25%) slope gradients. At each slope position the three land use types were selected from a more or less similar altitude, slope and soil types. For soil chemical property analysis, fifty four disturbed soil sample from 3 slope position (as block) x 3 land use types (treatments) x 2 depth (0-20cm and 20-40cm) x 3 replication were considered. From each slope positions and land use types a plot with 25 x 25m size was marked as sample plot following a method applied by (Chapman *et al.* 2009). The soil samples were then taken from five points in an 'X' design (from the middle and four corners of the plot) and from two subsequent depths (i.e.0-20cm and 20-40cm). Undisturbed soil samples were also taken by using core ring to investigate soil bulk density, soil moisture content and total porosity. For soil physical property analysis, twenty seven undisturbed soil samples were taken from top layers of soil (i.e. 0-20cm) through a steel core sampler of a 100 cm^3 volume.

The disturbed soil samples collected were air dried, mixed well and pass through a 2 mm sieve for chemical analysis. The soil physical parameters assessed were soil bulk density, total porosity; Gravimetric moisture content and soil texture. Soil texture was estimated using Hydrometer method (Day, 1965) after destroying organic matter by adding hydrogen peroxide (H_2O_2) and dispersing the soil through adding sodium hexametaphosphate $(NaPo_3)_6$. Bulk density of undisturbed soil sample was determined by using core sampler (cylindrical metal sampler). The mass of solids and the water content of the core was determined, by weighing the wet core, drying it to constant weight in an oven at 105^0C for 24 hours and calculated as oven dried mass per core volume. Gravimetric moisture content was calculated as the ratio of weight of water to weight of oven dry soil. And also total Porosity was calculated using Bd and particle density (Pd) as described in Hao *et al.* (2008).

$$P = 1 - \frac{Bd}{Pd}$$

Where, P = total porosity, Bd =bulk density, Pd = particle density (the assumed Pd is 2.65gm cm^{-3})

Soil chemical parameters assessed were soil pH, EC, Organic matter(OM), total nitrogen(TN), available phosphorous(AvP), CEC and exchangeable bases (K^{1+},Ca^{2+},Mg^{2+} and Na^{1+}). pH and electrical conductivity (EC) of soil samples were measured from a soil suspension solution prepared with 1:2.5 soil water ratios. Organic matter content was determined following the Walkey- Black (1934) procedure. Total nitrogen determined following the Kjeldahl (1883) procedure for converting organic nitrogen to ammonium-nitrogen that can be readily estimated. Available phosphorous of soil samples was determined following the Bray-2 method (Bray and Kurtz, 1945). Cation exchange capacity (CEC) and exchangeable bases (Ca^{2+}, Mg^{2+}, K^{1+} and Na^{1+}) were determined after extracting the soil samples by ammonium acetate (1N NH4OAc) at pH 7.0. Exchangeable Ca^{2+} and Mg^{2+} in the extracts was analyzed using atomic absorption spectrophotometer, while Na and K were analyzed by flame photometer (Chapman, 1965). Cation exchange capacity (CEC) was estimated titrimetrically by distillation of ammonium that was displaced by sodium from NaCl solution (Chapman, 1965). Percent base saturation (PBS) was calculated by dividing the sum of the base forming cations (Ca^{2+}, Mg^{2+}, K^{1+} and Na^{1+}) by the CEC of the soil and multiplied by 100. Similarly exchangeable sodium percentage (ESP) was calculated by dividing exchangeable Na^{1+} to catain exchange capacity (CEC) of the soil and multiplied by 100.

Data Analysis

The data obtained from the soil laboratory analyses were subjected to analysis of variance for each sample to detect whether differences in soil attributes that were analyzed shows significant difference due to land use type and different topographic positions. The effects of various land use types and topographic position on the physical and chemical properties of soils were tested by using SAS version 9.2 software packages. The treatments also arranged in split block design format as three way analysis with slope, land use type and soil depth as main factors. When the analysis of variance (ANOVA) show significant differences ($\alpha \leq 0.05$) among the various land use types, soil depths and slope position for each parameter, a mean separation for each parameter will be made using LSD (Least Significant Difference) test. Moreover, simple correlation analysis was carried out to determine the relationship between selected soil physicochemical properties using SPSS statistical software version 16.

Result and Discussion

Soil physical properties

Soil bulk density, Soil moisture content and total porosity

The mean bulk density varied significantly ($P<0.001$) between three land uses in the 0-20cm soil depths (Table 1). Accordingly, the bulk density of grazing land was significantly higher than the other two land use types. The possible reason for the difference might be due to cattle in the study area have been freely released to the grazing land and this most probably caused trampling effect and accounted for an increase in soil bulk density in the grazing land. The result is in harmony with the research finding of (Chaichi *et al.* 2005, Hamza and Anderson, 2005) reported as, Livestock trampling significantly increases soil bulk density and decreases porosity in the upper soil profile. The lowest soil bulk density observed in the Enset *(Enset ventricosum)* farm and cultivated land when compared to grazing land use. This, might be strongly linked with, the fact that free grazing in the

Enset *(Enset ventricosum)* farm is strictly forbidden in the study area and also it is not common in the cultivated land rather they use cut and carry system to use the grasses grown under the crops. In terms of topographic position, mean bulk density across the different slope category considered were 1.18, 1.26 and 1.24 (g/cm^3) for lower, middle and upper slope zones, respectively (Table 1), but the difference was not significant.

Gravimetric soil moisture content (GSM) was significantly higher (*P<0.001*) under grazing land and Enset *(Enset ventricosum)* farm. The result also revealed significantly higher variation of gravimetric soil moisture content (GSM) between upper and middle slope category compared with lower slope (Table 1). This may be attributable to the presence of different agroforestry practices, perennial crops and different trees species and shrub in the grazing and Enset *(Enset ventricosum)* farm lands of middle and upper slope position which might contributed to shading the soil and hence reduced evaporation water loss (soil desiccation). The result was in lined with Lal, 2004b who reported as, the presence of trees and shrub covers the soil from direct sun-light and which keeps the soil cool.

Table 1: The mean value (±) SEM of selected soil physical properties under different slope category, land uses and soil depths.

	BD (g/cm^3)	MC (%)	Porosity (%)	Clay (%)	Silt (%)	Sand (%)
	Slope position					
Lower Slope	1.18±0.17[a]	25.24±4.35[b]	55.460[a]	40.28±6.62[a]	35.95±9.57[a]	25.95±5.58[a]
Middle Slope	1.26± 0.10 [a]	30.14±4.68[a]	52.511[a]	41.55±6.55[a]	34.00±6.37[a]	23.74±67.87[a]
Upper Slope	1.24 0.15[a]	34.04±4.19[a]	53.416[a]	38.56±8.43[a]	34.39±9.75[a]	26.88±4.55[a]
LSD (0.05)	NS	4.59	NS	NS	NS	NS
Land use						
Cultivated	1.18±0.08 a	26.01±3.48b	55.67±3.08a	34.94±6.71b	36.5±8.61a	28.56±6.56a
Grazing land	1.39±0.07b	32.30±4.78a	47.54±1.92b	42.83±7.12a	32.56±5.68a	24.78±5.78a
Enset farm	1.11±0.05 a	31.11±6.49ab	58.17±2.88a	41.61±5.77a	35.61±8.65a	22.21±5.94a
LSD (0.05)	0.08	5.66	3.24	5.87	NS	NS
Soil depth						
0-20cm				41.07± 6.43a	34.37±7.84a	24.74±5.52a
20-40cm				38.52±7.13a	35.67±7.70a	26.63±6.6a
LSD (0.05)				NS	NS	NS

Values followed by different letters within column are statistically different at *P≤0.05*: NS-not significant.

The mean total porosities are 47.54 55.67 and 58.17 for grazing, cultivated and Enset *(Enset ventricosum)* land uses, respectively (Table 1). The porosity under Enset *(Enset ventricosum)* farm land and cultivated land were highest while grazing land was significantly lower (*P≤0.05*). Highest soil mean porosity under cultivation and Enset *(Enset ventricosum)* farm land may be attributed to the relatively lower animal trampling, while lowest porosity is the result of higher animal tracking in the grazing land use type. The result agree with Wakene (2001) stated that, the lowest total porosity (36.2%) was observed on the abandoned land and the highest (56.7%) was recorded on the farmer's field. Along with the increase in soil bulk density, soil total porosity showed marked declines in all land use types. The lowest total porosity was the reflections of the low organic matter content.

In all slope categories the total porosity was not significantly different. Similarly there was no significant difference in bulk density among the interaction of different slope category by different land use types (Table 2). The mean values from slope and land use interaction showed decreasing trend of total porosity of cultivated and Enset *(Enset ventricosum)* from lower slope to upper slope position for all land use types, while grazing land has highest total porosity in the middle slope position (Table 2). Thus, according to Brady and Weil (2002), ideal total pore space values, which are acceptable for crop production, are around 50%. Hence, the study area soils have an acceptable range of total porosity values for crop production.

Table 2: Interaction of slope by land use mean value (±) SEM of selected soil physical property

Soil property	Land use system	Slope category: Lower slope	Middle slope	Upper slope	LSD(0.05)
BD(gm/cm^3)	Cultivated land	$1.16\pm0.08b^{a}$	$1.24\pm 0.08b^{a}$	$1.18 \pm0.04b^{a}$	0.096
	Grazing land	$1.39\pm 0.03a^{a}$	$1.37 \pm0.07a^{a}$	$1.41 \pm0.09a^{a}$	
	Enset farm	$1.08 \pm0.0b^{a}$	$1.17 \pm0.03b^{a}$	$1.12\pm0.06b^{a}$	
Soil moisture content (%)	Cultivated land	$22.034\pm1.45a^{b}$	$26.58\pm1.83a^{b}$	$29.4\pm 1.1a^{a}$	19.82
	Grazing land	$26.5\pm 6.63a^{b}$	$35.30\pm4.11a^{a}$	$34.46 \pm2.83a^{a}$	
	Enset farm	$27.14\pm 2.48a^{b}$	$28.55 \pm2.13a^{b}$	$38.23\pm1.62a^{a}$	
Total porosity (%)	Cultivated land	$58.05\pm2.91a^{a}$	$53.28\pm 3.16a^{a}$	$55.69\pm1.57a^{a}$	35.25
	Grazing land	$47.43 \pm1.14a^{a}$	$48.49 \pm2.47a^{a}$	$46.70\pm2.20a^{a}$	
	Enset farm	$60.90 \pm1.04a^{a}$	$55.76 \pm1.25a^{a}$	$57.86\pm3.22a^{a}$	

Values followed by different letters (subscript) within row and different letters (superscript) within column are statistically different at *P≤0.05*.

Soil texture

The mean value of sand and silt content in all land use types, slope category and depth were not statistically significant. When we see also the interaction effect of different slope position by different land use types and soil depths, all land use types did not show a significant variation in sand and silt content (Table 3). But relatively there is highest proportion of sand and lowest proportion of clay content in the cultivated land compared to grazing and Enset *(Enset ventricosum)* farm land. A relative variation in proportion of sand and clay content in the cultivated land could be due to soil erosion because most of the cultivated fields in the study area lacks any soil and water conservation measures as well as management practices, thus resulted in removal of a smallest soil separates of clay which was easily transported by either water or wind erosion. Thus, contributed lowest proportion of clay in the cultivated and in opposite highest proportion of sand that could be due to it is not easily transportable relative to silt and clay.

The mean values of clay for three land use types are 34.94, 42.83, and 41.61% for cultivated, grazing and Enset *(Enset ventricosum)* farm land respectively. Similarly the mean values for the lower, middle and upper slope categories are 40.28, 41.55 and 38.56 % respectively, and also 41.07% and 38.52% for two depths 0-20cm and 20-40cm respectively. The mean value of cultivated land was significantly different compared with rest land use types at (*P<0.001*), while there was no significant variation across different slope zones and both depths (Table 1). The interaction effect result also revealed that, cultivated land has significantly lowest clay content compared to Enset *(Enset ventricosum)* and grazing land use type (3 & 4). But, Enset *(Enset ventricosum)* and grazing land in all slope zones and both soil depths were, almost not statistically significant in clay content. This could be due to the contribution of organic matter through addition of manures, mulching of its residue as well as crops residue from outfield and significance of different agroforestry trees that was commonly practiced with Enset *(Enset ventricosum)* farm in the study area. Similarly grazing land also occupied with some scattered trees that contributes in controlling the removal of soil clay content by erosion and improves soil structure. But most of the cultivated fields in the study area lack as such management practice and erosion controlling mechanism that is why clay content gets to be lowest in the cultivated field relative to the rest land use types. The overall textural class of the soils under the different land uses and slope category were found to be clay and clay loam (Table 3).

Table 3: Effect of land use, slope positions and soil depth on soil texture

slope	Land use	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class
Lower slope	Cultivated land	0-20	27.67±1.16a^{a}	36.00±3.46a^{a}	38.33±2.31a^{a}	CL
		0-40	29.51 ±7.81a^{a}	35.00±4.58a^{a}	34.00±2.00b^{a}	CL
	Grazing land	0-20	23.67 ±3.06a^{a}	32.00±6.08a^{a}	44.33 ± 4.04a^{a}	C
		20-40	24.33±5.86ab^{a}	34.00±8.19a^{a}	42.67± 1.53a^{a}	C
	Enset farm	0-20	23.00 ±3.61a^{a}	36.00±2.00a^{a}	41.00±1.00a^{a}	C
		20-40	22.00 ±6.25b^{a}	42.67±4.73a^{a}	35.33± 3.51b^{b}	CL
Middle slope	Cultivated land	0-20	27.00±6.20a^{a}	34.67±7.02a^{a}	38.33± 7.57b^{a}	CL
		20-40	29.34±10.79a^{a}	34.33±11.02a^{a}	36.33±2.52b^{a}	CL
	Grazing land	0-20	22.00 ±2.66a^{a}	32.33±1.16a^{a}	45.67±3.22a^{a}	C
		20-40	22.00±5.29ab^{a}	33.67±7.02a^{a}	44.33±9.24a^{a}	C
	Enset farm	0-20	21.33 ±5.69a^{a}	34.67±7.64a^{a}	44.00±1.73a^{a}	C
		20-40	20.67± 5.51b^{a}	38.66±5.03a^{a}	40.67±3.79a^{ab}	C
Upper slope	Cultivated land	0-20	28.67±3.51a^{a}	38.33±1.16a^{a}	32.66 ±4.93b^{b}	CL
		20-40	29.67±7.64a^{a}	38.67±2.89a^{a}	31.00 ±2.00b^{a}	CL
	Grazing land	0-20	27.00 ±4.36a^{a}	32.67±4.93a^{a}	40.33 ±4.62a^{a}	C
		20-40	29.67±4.16a^{a}	30.66±3.22a^{a}	39.67±2.52a^{a}	CL
	Enset farm	0-20	22.33±1.53a^{a}	32.67±3.22a^{a}	45.00 ±1.73a^{a}	C
		20-40	24.00±1.73a^{a}	33.33±8.51a^{a}	42.67±1.16a^{b}	C
LS(0.05)			9.19	9.73	6.33	

Values followed by different small letters represented in the subscript for comparison of different land use types within the same slope category and letters in the superscript for same land use types under different slope category that are statistically different at *P≤0.05*: C-clay, CL-clay loam.

Table 4: The mean value (±) SEM for Soil texture through Interaction of slope by land use

Soil property	Land use system	Slope category			LSD(0.05)
		Lower slope	Middle slope	Upper slope	
Sand(%)	Cultivated land	28.85±5.01	28.17±8.85	29.17±5.98	NS
	Grazing land	24.00 ±4.28	22.00±7.09	28.34±4.08	
	Enset farm	22.50±7.56	21.00±5.02	23.14±3.43	
Silt (%)	Cultivated land	35.50±13.48	34.50±5.87	38.50±3.83	NS
	Grazing land	33.00±4.94	33.00±4.51	31.67±5.48	
	Enset farm	39.34 ±6.26	34.50±8.57	33.00±6.09	
Clay (%)	Cultivated land	35.67±3.50b^{a}	37.33±5.74b^{a}	31.83±5.82b^{a}	5.22
	Grazing land	43.50±2.74a^{a}	45.00±8.76a^{a}	40.00±6.41a^{a}	
	Enset farm	41.67±7.33a^{a}	42.33±3.20a^{a}	43.84±6.52a^{a}	

Values followed by different letters (subscript) within row and different letters (superscript) within column are statistically different at *P≤0.05*: NS-not significant

Soil Chemical Properties

Soil pH and EC

The mean value of soil pH (H_2O) and EC did not show a significant difference between the slope categories and land use types in both depths (Table 5). The similar low pH in all cases of the study area, could be due to high rainfall of the area that removes or leaches basic cations (Ca^{2+} and Mg^{2+}) from the surface to downwards so as to reduce pH of the study area. Person's correlation matrix also revealed that, basic cations, CEC, Ca^{2+}, K^{1+}, Mg^{2+} and pH have had a strong positive relation with each other. This might be also interpreted as, when CEC and exchangeable cations leached down, the exchangeable site occupied with acid forming cations such as, Al^{3+} and H^{1+}, which results in increasing soil acidity through lowering soil pH value. This, in line with (Eylachew, 1999; Brady and Weil, 2002) who stated as, in acid soils, Al^{3+} becomes soluble and increase soil acidity while in alkaline soils; exchangeable basic cations tend to occupy the exchange sites of the soils by replacing exchangeable H^{1+} and Al^{3+} ions. Based on (Foth and Ellis, (1997), pH between 5.3-5.9 and 6.0-6.6 is classified as moderately and slightly acidic respectively. Accordingly, the pH of the study sub watershed falls under slightly and moderately acidic soil.

Table 5: The mean value (±) SEM of selected soil chemical properties under different slope categories, land uses and soil depths

	pH	EC(mmhos)	OC(%)	TN(%)	C/N	AvP(ppm)
			Slope position			
Lower slope	5.88±0.48	0.043±0.007	4.31±1.17 [a]	0.23±0.06[a]	18.56±2.91[a]	9.55±5.03 [a]
Middle slope	5.97±0.63	0.040±0.012	4.05±1.22 [a]	0.23±0.06[a]	18.04±2.68[ab]	9.97±4.72[a]
Upper slope	5.76±0.43	0.039±0.009	2.42±0.58 [b]	0.16±0.03 [b]	15.55±3.36 [b]	4.05±1.98[b]
LSD (0.05)	NS	NS	0.67	0.05	2.55	2.86
			Land use			
Cultivated land	5.70±0.34	0.042±0.013	2.70±1.03b	0.17±0.05b	16.09±3.26b	4.81±2.52c
Grazing land	5.83±0.5	0.041±0.011	3.83±1.15b	0.22±0.05a	16.95±2.92ab	7.89±4.73b
Enset farm	6.08±0.55	0.039±0.01	4.24±1.30a	0.22±0.06a	19.11±2.87a	10.88±5.1a
LSD (0.05)	NS	NS	0.67	0.05	2.55	2.86
			Soil depth			
0-20cm	5.74±0.57	0.038±0.012	3.97±1.50a	0.22±0.07a	18.01±3.06a	8.99±5.52a
20-40cm	5.99±0.52	0.043±0.010	3.21±0.99b	0.19±0.05b	16.75±3.41a	6.72±3.96b
LSD (0.05)	NS	NS	0.58	0.03	0.06	5.82

Values followed by different letters within column are statistically different at $P \le 0.05$: NS-not significantly different.

The consistently low EC value under different land use types, slope positions and soil depths might be due to the low exchangeable Na^{1+} content in the soils. Result from Pearson's correlation matrix table revealed that EC is positively and significantly correlated with exchangeable Na^{1+}(r=0.31*), exchangeable sodium percentage ESP(r=0.35*). According to FAO (2006) and Landon (1991) rating electrical conductivity (EC) values of the sub-watershed were considered to be very low for all land uses, slope position and both soil depths, which is also consistent with US salinity laboratory staff (1954), classifying EC value <2 as non saline soil.

Available phosphorus (AvP)

The mean values of available phosphorus (ppm) are 4.81, 7.89, and 10.88 (ppm) for cultivated, grazing and Enset *(Enset ventricosum)* farm land respectively. For the slope position the values were 9.55, 9.97, and 4.05 (ppm) for lower, middle and upper slope zones respectively (Table 5). There was a significant difference in available phosphorus between land use types, slope categories and soil depths ($P<0.001$). The mean value of available phosphorus in the upper slope zone was significantly lower at ($P<0.001$) compared to lower and middle slope zones while middle and lower slope zone had no significant variation at $P \leq 0.05$ level.

According to Landon (1991), available soil phosphorus level of < 5 ppm is rated as low; 5-15ppm as medium and > 15 ppm is rated as high. Accordingly, except Enset *(Enset ventricosum)* farm, the rest land use types in the upper slope category of the study area have less than 5ppm available phosphorus, qualifying for the low range (Table 6). The cause of thus, low available phosphorus content for cultivated and upper slope zone of the study area might be in line with the results reported by Eylachew (2001), that the availability of phosphorus under most soils of Ethiopia decline by the impacts of fixation, abundant crop harvest and erosion. Phosphorus is normally strongly bonded to soil particles and is therefore easily transported down slope during erosion. The result also in harmony with Hawando (1997) reported that, the most pervasive loss of phosphorus in Ethiopia is due to soil erosion especially in the highland areas. According to his report, 1.17–11.7million tons of phosphorus are lost from 780,000 km^2 of highland per year due to soil erosion. The result also in lined with Pavinato *et al.* 2009 reported as, lower soil organic carbon (SOC) affected by crop residue removal and frequent tillage. This is due to the fact that decomposing residues produce organic anions which may compete with phosphorus for sorption sites (Easterwood and Sartain 1990).

Soil organic carbon (SOC)

The mean values of soil organic carbon across the different land use types and slope zones were 2.70, 3.83 and 4.24 percent for cultivated, grazing and Enset *(Enset ventricosum)* farm land and 4.31, 4.05 and 2.42 percent for lower middle and upper slope category respectively (Table 5). Thus, soil organic carbon in the upper slope zone was significantly different compared with middle and lower slope zones at 5% significant level. However, there was no significant variation of soil organic carbon at 5% significant level between the lower slope and middle zones of the sub-watershed. The overall mean values of the two depths are 3.97 and 3.21 percent. Soil organic carbon (OC) concentrations in surface layers (0-20 cm) and subsurface layer (20-40cm) differed significantly at ($P<0.001$) and also there is a significant variation across different land use types in all slope category at ($P<0.001$) (Table 7).

According to the classification of soil organic matter as per the ranges suggested by Landon (1991), the soils of cultivated fields are in the range of low where as Enset *(Enset ventricosum)* and grazing land fall under medium rating class (Table 6). Thus, highest proportion of organic carbon in the grazing and Enset *(Enset ventricosum)* farm might be attributed to nutrient recycling through manure application or litter falls from the scattered trees of the study site. The other reason that could be explained for the significant difference in organic matter content for cultivated field is the removal of organic residues i.e. crop residues. The results of this study were in agreement with the finding of different researchers (Eylachew, 2001; Yihenew, 2002), who reported that most cultivated soils of Ethiopia are poor in organic matter contents due to low amount of organic materials applied to the soil and complete removal of the biomass from the field, and due to severe deforestation, steep relief condition, intensive cultivation and excessive erosion hazards.

The implicit of this finding is also consistent with a number of studies that compared soil organic carbon (SOC) under different land use types and management practices. An experiment made at Ohio State, USA, by Duiker and Lal (2001) revealed that crop residue increased soil organic carbon (SOC) by 10.5% and 11.29% per year in no till land and tilled land, respectively. Bostick *et al.* (2007) also compared residue management practices and cropping systems impact on soil organic carbon (SOC) in Burkina Faso, and reported that crop rotation and residue input significantly affected soil organic carbon (SOC). Thomsen and Christensen (2004) also assessed impact of long term application of barley straw on soil organic carbon (SOC) contents, and found that a soil receiving more straw has more soil organic carbon (SOC).

Table 6: Soil fertility class of the sub-watershed under different land use types and slope position based on Landon (1991) and FAO (2006) rating

Soil Characteristics	Lower slope	Middle slope	Upper slope	Cultivated land	Grazing land	Enset farm
Organic carbon	M	M	L	L	M	M
C:N ratio*						
Exchangeable sodium percentage ESP	L	L	L	L	L	L
Total nitrogen %	H	H	M	M	M	M
Available phosphorus (ppm)	M	M	VL	VL	M	M
CEC cmol (+) kg^{-1}	H	H	H	M	H	H
Base saturation %	H	H	H	H	H	H
Exchangeable Ca cmol kg^{-1}	H	H	H	H	H	VH
” Mg ”	M	M	M	M	M	M
” K ”	M	M	L	L	M	M
” Na ”	VL	VL	L	VL	VL	VL
pH	L	L	L	L	L	L
Salinity (EC dS/m)	VL	VL	VL	VL	VL	VL

L-Low-Medium-High, VH-Very High, VL-Very low

As described in the table above, upper slope zone of the watershed satisfies in the range of low while lower and middle slope position falls under medium rating class of soil organic carbon. This might be because erosion detaches and transports particles that have the highest content of organic matter from the upper slope zones of the sub-watershed.

Total nitrogen (Tn)

Between the different land use types, slope category and soil depths, it is noted that, significant differences were also observed in terms of total nitrogen (TN). Cultivated land was significantly differed from grazing and Enset *(Enset ventricosum)* farm land in the lower and middle slope zones where as there was insignificant variation among different land use types in the upper slope zones. When comparing different slopes for different land use types and soil depths, there was a significant variation. Upper slopes showed significantly lowest than middle and lower slope zone for all land use types in both depths at *0.05* level (Table 5). The overall mean values of two depths were also significantly differed, that is, top layers of 0-20cm soil was significantly higher than sub layers of 20-40cm soil depth (Table 5).

When we see land use and slope interaction, only cultivated land of lower slope and upper slope and similarly cultivated land of lower slope and middle slope were significantly different (Table 7). As per the rating of total nitrogen (> 1% as very high, 0.5 to 1% high, 0.2 to 0.5% medium, 0.1 to 0.2% low and < 0.1% as very low) as indicated by Landon (1991), lower and middle catchment zones qualify for medium while upper catchment zone qualify for low rating. Similarly, cultivated land qualifies for low status, while the Enset *(Enset ventricosum)* farm and grazing land qualify for medium rating of total nitrogen. This might be attributed to the contribution of organic matter. As the organic matter and total nitrogen contents showed strong association(r=0.88**), the reduction in the total nitrogen contents of the soils is affected among others by, the reduction of soil organic matter content and top soil loss by erosion. This, agrees with Hawando (1997), reported that, the most pervasive loss of nutrient in Ethiopia is due to erosion especially in the highland areas. For example, according to his report, 1.17–78million tons of organic matter and 0.39–5.07 million tons of nitrogen were lost from 780,000 km^2 of highland per year due to soil erosion.

The mean total nitrogen (TN) value was relatively higher under Enset (*Enset ventricosum*) and grazing land than cultivated land. This result agrees with the finding of Havlin *et al. (*2005). This probably happened due to continuous mulching of Enset (*Enset ventricosum*) garden with organic matter which is the potential source of soil N. similarly the highest total nitrogen (TN) in the grazing land might be attributed to the contribution of organic matter added through litter from the scattered trees, include acacia species which contributes nitrogen fixation and urine and animal feces during grazing time. Contrary to this, the lower total nitrogen (TN) could be on account of the minimum organic matter content due to absence of litter fall and crop residue removal. Advantages of crop residues in immobilizing N thereby reducing N mineralization have been reported elsewhere (Thomsen and Christensen 2004, Wivstad *et al.* 2005).

Table 7: The mean value (±) SEM of the interaction of slope by land use for Soil AvP, OC,TN and C/N

Soil property	Land use system	Slope category			LSD(0.05)
		Lower slope	Middle slope	Upper slope	
AvP(ppm)	Cultivated land	6.34±2.26b^{a}	5.94±1.89b^{ab}	2.16±0.31a^{b}	4.12
	Grazing land	10.30±5.79a^{a}	9.54±3.32b^{a}	3.82±1.20a^{b}	
	Enset farm	12.01±5.21a^{a}	14.44±4.18a^{a}	6.18±1.42a^{b}	
OC(%)	Cultivated land	3.26±1.04b^{a}	2.93±1.06b^{a}	1.92±0.50b^{b}	0.93
	Grazing land	4.59±0.80a^{a}	4.38±0.71a^{a}	2.53±0.49a^{b}	
	Enset farm	5.07±0.90a^{a}	4.85±1.04a^{a}	2.82±0.40a^{b}	
TN(%)	Cultivated land	0.20±0.05b^{a}	0.17±0.06b^{ab}	0.14±0.03a^{b}	0.039
	Grazing land	0.25±0.03a^{a}	0.25±0.04a^{a}	0.17±0.04a^{b}	
	Enset farm	0.25±0.07a^{a}	0.26±0.03a^{a}	0.16±0.016a^{b}	
C/N	Cultivated land	16.62±2.53b^{ac}	17.91±3.05a^{ab}	13.74±3.07b^{c}	3.40
	Grazing land	18.29±2.91ab^{a}	17.81±2.65a^{ab}	14.76±2.15ab^{b}	
	Enset farm	20.77±1.89a^{a}	18.41±2.81a^{a}	18.15±3.40a^{a}	

Mean values followed by different letters in the subscript within column and letters in the superscript within row are statistically different at *P≤0.05*.

Carbon to Nitrogen Ratio (C/N)

Carbon to Nitrogen ratio (C/N) in soils is good indicator of the freshly added residues. In this finding, the average mean value for different land use type ranges from 20.77 in Enset (*Enset ventricosum)* farm to 13.74 in cultivated land (Table 7). C/N was significantly different (*P<0.001*) among land uses. It was higher in the Enset *(Enset ventricosum)* farm land, followed by grazing lands in all slopes except in the middle slope. Lower values C/N were also observed in cultivated lands in all slope categories (Table 5 & 7). With regard to slope variation and soil depth, the C/N value of all land uses decreased from lower slope to upper slope and 0-20 to 20 40cm soil depth (Table 5).

The over all mean value of top layers of 0-20cm soil has higher C/N ration than 20-40cm soil depth. When it is seen separetely for different land uses in diffent slope catagoy it also showed a siginificant variation betewen two soil depths at *0.05* siginificance level (Table 5). The lower C/N cultivated land could imply that the soil of cultivated land has lower organic matter as compared to grazing and Enset *(Enset ventricosum)* farm land. This may be also due to the fact that the microenvironment under cultivated land may favor the existence of soil microbes that feed on organic carbon in soil solutions where litter and fresh residues are added to soils more often compared to grazing and Enset *(Enset ventricosum)* farm land contributed, lower C/N ratio due to the depleted organic carbon. While the highest C/N ratio in grazing and Enset farm land might be attributed highest organic matter through addition of manure, crop residue and litter fall from woody species. The result of Pearson's correlation matrix also revealed that there is strong association between C/N ratio and OC at (r=0.58**) (Table 8).

Table 8: Pearson's correlation matrix for selected soil physico- chemical properties

Soil property	EC	OC	TN	CN	CEC	$Ex.K^{1+}$	$Ex.Ca^{2+}$	$Ex.Mg^{2+}$	$Ex.Na^{1+}$	ESP	PBS	Clay
EC	1											
OC	0.23	1										
	0.09											
TN	0.18	0.88**	1									
	0.20	0.00										
CN	0.20	0.58**	0.14	1								
	0.15	0.00	0.30									
CEC	0.05	0.62**	0.53**	0.40**	1							
	0.74	0.00	0.00	0.00								
$Ex.K^{1+}$	0.09	0.62**	0.58**	0.34*	0.66**	1						
	0.52	0.00	0.00	0.01	0.00							
$Ex.Ca^{2+}$	-0.01	0.29*	0.25	0.25	0.51**	0.28*	1					
	0.92	0.03	0.07	0.08	0.00	0.04						
$Ex.Mg^{2+}$	-0.01	0.17	0.10	0.25	0.39**	0.24	0.69**	1				
	0.95	0.22	0.47	0.07	0.00	0.07	0.00					
$Ex.Na^{1+}$	0.31*	-0.06	-0.17	0.21	-0.00	-0.11	0.12	0.19	1			
	0.02	0.65	0.22	0.12	0.98	0.42	0.37	0.17				
ESP	0.15	-0.45**	-0.48**	-0.12	-0.69**	-0.50**	-0.26	-0.06	0.69**	1		
	0.28	0.00	0.00	0.40	0.00	0.00	0.06	0.65	0.00			
PBS	-0.10	-0.15	-0.12	-0.05	-0.22	-0.16	0.70**	0.57**	0.15	0.30*	1	
	0.48	0.27	0.38	0.71	0.11	0.24	0.00	0.00	0.28	0.03		
clay	0.18	0.64**	0.55**	0.43**	0.62**	0.67**	0.09	0.01	-0.13	-0.52**	-0.41**	1
	0.21	0.00	0.00	0.00	0.00	0.00	0.52	0.95	0.35	0.00	0.00	

**. Correlation is significant at the 0.01 level.
*. Correlation is significant at the 0.05 level.

Cation exchange capacity (CEC)

The overall mean values of CEC were 24.65, 33.83, and 35.96 cmol (+) kg-1 soil for cultivated, grazing and Enset *(Enset ventricosum)* farm land respectively and also the mean value of two depths are 32.39 and 29.39 cmol (+) kg-1 soil) for 0-20 and 20-40cm soil depth respectively (Table 9). Grazing and Enset *(Enset ventricosum)* farm land had significantly higher while cultivated land had significantly lower ($P<0.001$) values across all land use types at all slope zones. Therefore, the depletion of organic matter as a result of intensive cultivation has reduced the CEC (Mesfin 1980; Gao and Chang, 1996). The lowest mean CEC observed in the cultivated lands might be also due to loss of basic cations (Mg and Ca) by crop harvest and soil erosion. The CEC also decreased almost consistently from the surface to the subsurface horizons across three land use types at all slope zones. This decrease in CEC with depth is attributed to a decrease in organic matter content.

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Cation exchange capacity (CEC) is used as an overall assessment of the potential fertility of a soil and to assess the possible response of crops to fertilizer application. The highest CEC was found in the Enset *(Enset ventricosum)* farm land followed by Grazing land. This may be due to a significant difference of clay content combined with management effect as a main factor for CEC difference. According to Landon (1991), the top soils having CEC of > 25, 15-25 Cmol (+) kg^{-1}, 5-15 Cmol (+) kg^{-1} and < 5 cmol(+) kg^{-1} are classified as high, medium, low and very low, respectively. Based on the above ratings, cultivated lands of the sub-watershed qualify medium status of cation exchange capacity (CEC), where as high for grazing and Enset *(Enset ventricosum)* farm land of the top soil (0 up to 40cm). This might be attributed to low basic cations due to leaching, soil erosion and low proportion of clay content in the cultivated land resulted in lower CEC value than the rest land use types. This was also confirmed by Pearson's correlation matrix which revealed that there is a strong relationship between CEC and (Ca^{2+} at r=0.51**,Mg^{2+} at r=0.39**,K^{1+}at r=0.66**, and clay at r=0.55**). But in contrast different scattered tree species, perennial crops combined with different management practice that improves soil organic matters and increase the proportion of clay content through addition of manures and mulching of residue. Thus, could reduce the risk of erosion, leaching of cations, improved soil structure. Thus, resulted in high CEC in the Enset *(Enset ventricosum)* farm and grazing land. The mean values of lower, middle and upper slope category are, 33.50, 32.67 and 28.28 Cmol (+) kg^{1} soil respectively. CEC in the lower slope zone was significantly greater than upper slope zone (Table 9). Nevertheless, there was no significant difference at 5% significance level in CEC between the lower slope and middle zones of the watershed.

Table 9: Main effects of land use, slope position and soil depth on some soil chemical properties

	CEC mmhos	Ex.K^{+} (cmol(+)/kg)	Ex.Ca^{2+} (cmol(+)/kg)	Ex.Mg^{2+} (cmol(+)/kg)	Ex.Na^{1+} (cmol(+)/kg)	PBS	ESP
		Slope position					
Lower	33.50±5.89 ^{a}	0.380.12 ^{a}	19.19±5.86 ^{a}	2.86±0.69 ^{a}	0.054±0.009 ^{a}	67.35±15.57^{a}	0.17±0.043 ^{ab}
Middle	32.67±5.82 ^{a}	0.430.11 ^{a}	19.35±6.39 ^{a}	2.68±0.90 ^{a}	0.048±0.013^{a}	68.98±17.59^{a}	0.15±0.055^{b}
Upper	28.28±6.20 ^{b}	0.290.08 ^{b}	15.54±3.43 ^{b}	2.43±0.82 ^{b}	0.051±0.012^{a}	66.76±16.12^{a}	0.19±0.06 ^{a}
LSD (0.05)	3.30	0.06	2.99	0.20	0.008	8.56	0.04
		Land use					
Cultivated	24.65±3.36c	0.26±0.07b	13.75±2.46b	2.19±0.73b	0.052±0.01ab	66.98±14.22a	0.22±0.052a
Grazing land	33.83±4.39b	0.40±0.10a	19.86±5.23a	2.83±0.91a	0.043±0.009b	69.34±18.28a	0.13±0.04b
Enset farm	35.96±4.08a	0.43±0.10a	20.46±5.85a	2.94±0.59a	0.06±0.01a	66.78±16.55a	0.17±0.03b
LSD (0.05)	2.11	0.06	2.99	0.20	0.009	5.65	0.05
		Soil depth					
0-20cm	32.39±6.09a	0.39±0.13 a	14.67±2.48a	2.17±0.63a	0.047±0.009b	54.08±8.38b	0.15±0.042b
20-40cm	29.39±6.69b	0.34±0.09b	21.38±5.80b	3.14±0.68b	0.055±0.012a	81.31±8.78a	0.19±0.06a
LSD (0.05)	1.30	0.12	8.44	0.86	0.005	3.56	0.02

Values followed by different small letters within column are statistically different at $P \leq 0.05$.

Basic exchangeable cations

As in most agricultural soils, Ca was the dominant cation (Wild, 1993) in the exchangeable complex, followed by Mg and K. Enset *(Enset ventricosum)* farm land and grazing land had significantly higher Ca^{2+}, Mg^{2+} and k^{1+}under all slope categories and at both soil depths compared with cultivated land (Table 9 and 10). Generally, Enset *(Enset ventricosum)* farm land and grazing areas of the farms in the sub-watershed had better nutrient status than cultivated land. Managing the Enset *(Enset ventricosum)* farm land with soil amendments is important because it contributes an important proportion of food requirement in the study area. Likewise the grazing land receives dung and urine from grazing animals and also existence of different woody species which enhanced soil organic matter, thus maintaining slightly better fertility. While the soils of cultivated land in Delta sub-watershed is inherently suitable for subsistence agriculture, as evidenced by dominant textural class of clay loam and supply of basic cations (Ca and Mg), despite the low OC, TN values, and available phosphorus, indicate that the cultivated land in the sub-watershed were subject to an excessive pressure for food supply. This pressure is possibly leading to a spiral of soil fertility decline.

From the interaction result of slope by land use and soil depth, almost all exchangeable bases , percent base saturation and exchangeable sodium percentage of the sub-watershed were significantly different (*P<0.001*) across all slope categories and land uses (Table 10). Ca^{2+} = Exchangeable calcium (cmol /Kg soil), K^{1+}=Exchangeable Potassium (cmol/Kg soil), Mg^{2+} (exchangeable magnesium (cmol /Kg soil), PBS and ESP showed a significant variation almost in all land use types at all slope category. But exchangeable sodium only showed a significant variation in bottom layers soil depth 20-40cm (Table 9 and 10).

Table 10: The mean value (±) SEM of the interaction of slope by land use for CEC and exchangeable cations

Soil property	Land use system	Slope category			LSD(0.05)
		Lower slope	Middle slope	Upper slope	
CEC	Cultivated land	26.00±1.61a^{a}	26.78±1.77c^{a}	21.18±3.24b^{b}	3.51
	Grazing land	36.53±3.05a^{a}	32.30±4.46b^{ab}	32.67±4.82a^{b}	
	Enset farm	37.96±1.95a^{a}	38.93±1.83a^{a}	31.00±2.13a^{b}	
Ex.K^{+}	Cultivated land	0.25±0.040b^{ab}	0.32±0.06b^{a}	0.22±0.07b^{b}	0.086
	Grazing land	0.44±0.09a^{a}	0.46±0.09a^{a}	0.31±0.07a^{b}	
	Enset farm	0.45±0.10a^{a}	0.50±0.07a^{a}	0.34±0.06a^{b}	
Ex.Ca^{2+}	Cultivated land	14.34±2.85b^{a}	14.27±3.00b^{a}	12.65±1.18b^{a}	2.32
	Grazing land	20.80±4.42a^{a}	22.32±6.06a^{a}	16.27±3.39a^{b}	
	Enset farm	22.43±6.71a^{a}	21.25±6.78a^{a}	17.70±3.29a^{b}	
Ex.Mg^{2+}	Cultivated land	2.39±0.25b^{a}	2.14±1.05b^{a}	2.05±0.76a^{a}	0.68
	Grazing land	3.04±0.82a^{a}	2.84±0.83a^{a}	2.62±1.16a^{b}	
	Enset farm	3.15±0.68a^{a}	3.06±0.64a^{a}	2.62±0.37a^{a}	
Ex.Na^{1+}	Cultivated land	0.053±0.009a^{a}	0.055±0.014a^{a}	0.048±0.009a^{a}	0.011
	Grazing land	0.049±0.009a^{a}	0.037±0.009b^{a}	0.05±0.02a^{a}	
	Enset farm	0.06±0.09a^{b}	0.053±0.007a^{a}	0.062±0.012a^{a}	
PBS	Cultivated land	65.59±11.03a^{a}	62.49±12.3b^{a}	72.84±18.41a^{b}	7.95
	Grazing land	67.87±19.28a^{b}	79.86±15.48a^{a}	60.28±17.05b^{b}	
	Enset farm	68.60±18.02a^{a}	64.59±20.91b^{a}	67.15±12.61ab^{a}	
ESP	Cultivated land	0.21±0.48a^{a}	0.21±0.06a^{a}	0.23±0.06a^{a}	0.05
	Grazing land	0.14±0.03b^{a}	0.11±0.03b^{a}	0.14±0.04b^{a}	
	Enset farm	0.16±0.02ab^{b}	0.14±0.02b^{b}	0.20±0.05a^{a}	

Values followed by different letters (superscript) within column and letters (subscript) within row are statistically different at *P≤0.05*.

The exchangeable K^{1+} was significantly different (*P≤ 0.01*) among land use types with the higher K^{+1} (0.50 cmol (+) kg-1 soil) obtained under Enset *(Enset ventricosum)* farm land followed by grazing land (cmol 0.46 (+) kg-1 soil) and the lower (0.22cmol (+) kg-1 soil) (Table 10). The higher exchangeable K^{1+} in the Enset *(Enset ventricosum)* farm land could be due to application of ashes and presence of different types of tree species in the grazing land which pumps the cation through their deeper roots. While the lower K^{1+} in the cultivated land probably due to a large K^{1+} removal by the soil erosion and continuous cultivation. The soils under the three land use types significantly differed in Ca^{2+} content (*P≤ 0.001*) with the highest value (22.43cmol(+)kg^{-1}), being in the Enset *(Enset ventricosum)* farm land and lowest (12.65cmol(+)kg^{-1}) in the cultivated land (Table 10). Similarly Exchangeable Mg^{2+} was significantly higher under grazing and Enset *(Enset ventricosum)* farm land than cultivated land (Table 10). This is because of the presence of different woody species, perennial plants and different agro forestry trees in woody grazing and Enset *(Enset ventricosum)* farm land, which might have maintained soil $Mg^{2+}$and Ca^{2+} content through trapping and accumulating in their leaves, stems and barks. The result in lined with (Finzi *et al.*1998 and Saikh *et al.* 1998) findings who stated as, a significant increase in Mg^{2+} in soil might be due to pumping of Mg^{2+} by perennial plants where they take it by their deep roots, and release it to the soil through litter fall decomposition. It may also be due to management difference and relatively lower soil erosion, one of the main deriving forces for loss of $Mg^{2+}$and Ca^{2+}.

When comparing three slope position, exchangeable Ca^{2+}, Mg^{2+} and K^{1+}in the upper slope position showed significant difference (*P<0.001*) compared with middle and lower slope position with values in the order lower slope>middle slope>upper slope. In contrast, exchangeable sodium percentage (ESP) showed a higher mean value in the upper slope position where as Exchangeable Na and percent base saturation (PBS) was not significantly affected by slope position. All exchangeable cations except K^{1+} in all land uses across all slope category were significantly (*P<0.001*) higher in sub surface soil (20-40cm) than in the surface layer of soil depth (0-20cm), and showed an abrupt increase down the depth. This may be attributed to the leaching effect. This finding was also in line with that of Yimer and Abdelkadir (2010).

Based on Landon (1991) and FAO (2006) soil fertility classification, the study sub-watershed rated as, high to very high exchangeable Ca^{2+}, medium exchangeable Mg^{2+}, low to medium exchangeable k^{1+} and very low exchangeable Na^{1+} under different land use types and slope categories (Table 9). Percent base saturation (PBS) and exchangeable sodium percentage (ESP) also showed a significant variation with respect to depth. The differences in percent base saturation (PBS) and exchangeable sodium percentage (ESP) in depth are mainly associated with differences in cation exchange capacity (CEC) (e.g. high exchangeable bases and high cation exchange capacity (CEC) may give low percent base saturation (PBS) and exchangeable sodium percentage (ESP), while the higher exchangeable bases and lower cation exchange capacity (CEC) may give higher percent base saturation (PBS) and ESP. The higher percent base saturation (PBS) in lower soil depth of (20-40cm) than in upper soil depth (0-20cm) was due to low CEC values in the former. The increasing trend in percent base saturation (PBS) and exchangeable sodium percentage (ESP) down the depth may be also associated with the leaching of exchangeable bases, especially Ca^{2+} and Na^{1+}. In the study area, percent base saturation (PBS) ranges from moderate to high, 52.5% to 83.8%, (Landon 1991).The finding did not agree with the findings of Biyensa (2011), who found percent base saturation (PBS) decrease down the soil depth in an open and protected grazing and farmlands. But, in contrast it was consistent with the finding by Yimer and Abdelkadir (2010).

CONCLUSIONS

Result from Soil laboratory analysis and farmers perception on soil fertility of Delta sub-watershed revealed that soil fertility status is influenced by land use change, topographic position and management practice. Soil depth variation was also found to be another factor which affects soil fertility status. The soil analysis result emphasizes that land use change could result in differences in soil physical and chemical properties that are believed to be an important soil fertility parameters. The study clarified that almost all soil physicochemical parameters, namely OC,TN,C/N, available phosphorous, CEC, K, Mg, Ca, Na, ESP, PBS and proportion of clay showed lowest mean values in the cultivated land and upper slope position but relatively highest values for grazing and Enset *(Enset ventricosum)* farm lands. However soil EC, pH, proportion of silt and sand are not significantly varied due to different land uses, slope categories and soil depths. With regard to depth, also the mean values of soil parameters, including clay content, OC, TN, AvP, C/N, CEC, K are decreased with increasing soil depth from 0-20cm to 20-40cm. In contrast, the mean value of Mg, Ca, Na, ESP and PBS increased with increasing soil depth from 0-20 cm to 20-40cm.

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REFERENCES

AACMC, 1987. Assessment of agricultural land suitability in south-eastern, southern, south-western and western Ethiopia. Volume: I Main Report, Addis Ababa, Ethiopia.

Ashagrie, Y., Zech, W. & Guggenberger, G. 2005. Transformation of *Afrocarpus falcatus* dominated natural forest into a monoculture *Eucalyptus globules* plantation at Munesa,Ethiopia: soil organic C,N and S dynamics in primary particle and aggregate-size fractions.*Agriculture,Ecosystems and Environment.* **106**: 89-98**.**

Barry Pound and Ejigu Jonfa, 2005. Soil Fertility Practices in Wolaita Zone,Southern Ethiopia:28p

Bernoux, M., C.C. Cerri, C. Neill and J.F.L. De Moraes, 1998. The use of stable carbonisotopes for estimation of soil organic matter turnover rates. *Geoderma*. **82**: 43**-**58**.**

Biyensa, G., 2011.Impact of land use/land cover on soil organic carbon and nitrogen stock in Adami Tulu, Central Rift Valley of Ethiopia.M.sc thesis submitted to Hawassa College of Agriculture, Hawassa Universty**.**46p**.**

Bostick, W.M., V.B. Bado, A. Bationo, C.T. Soler, G. Hoogenboom and J.W. Jones, 2007. Soil carbon dynamics and crop residue yields of cropping systems in the Northern Guinea.

Bray, R.H., Kurtz LT., 1945. Determination of total organic andavailable forms of phosphorus in soils. *Soil Sci*. **59**: 39-45.

Cochran, W., 1977. Sampling Techniques. 3rd ed. John Wiley and sons. USA.

Chapman, H.D., 1965. Cation Exchange Capacity by ammonium saturation. 891-901p. In: C.A. Black (ed.). Methods of Soil Analysis. Agron. part II, No. 9, Am. Soc. Agron. Madison, Wisconsin, USA.

Chapman, David J., Richard C. Bishop, W. Michael Hanemann, Barbara J. Kanninen, Jon A. Krosnick, Edward R. Morey, and Roger Tourangeau. 2009. Natural Resource Damages Associated with Aesthetic and Ecosystem Injuries to Oklahoma's Illinois River System and Tenkiller Lake.

Chivenge, P.P., H.K. Murwira, K.E. Giller, P. Mapfumo and J. Six. 2007. Long-term impact of reduced tillage and residue management on soil carbon stabilization: Implications for conservation agriculture on contrasting soils. *Soil & Tillage Research* **94**:328–337

Conant, R.T.J.six and K.Paustian,2003.Land use effects on soil carbon fractions in the south eastern united states.management incentive versus extensive grazing. *Biol.fertile soils*.**38**:386-392.

CSA(Central Statistical Agency), 2006. Agricultural sample survey of livestock and livestock characteristics. Addis Ababa, Ethiopia. *Statistical Bulletin*. **388(2)**.

Davidson, A. and Rex, D. C., 1980. Age of volcanism and rifting in southwestern Ethiopia. *Nature* **283**:657–658.

Davidson, A., compiler, 1983. The Omo river project, reconnaissance geology and geochemistry of parts of Ilubabor,Kefa, Gemu Gofa and Sidamo, Ethiopia. *Ethiopia. Inst. Geol.Surv. Bull*. **2**: 1–89.

Day, P.R., 1965. Particle size analysis. In: Black CA (ed) Methods of soil analysis. Part 1: Physical and mineralogical methods, vol. 9.Am. Soc. Agro. *Inc., Madison*, WI. 545–566

Duiker, S.W. and R. Lal. 2001. Crop residue and tillage effects on carbon sequestration in Luvisol in central Ohio. *Soil & Tillage Research*.**52**: 73-81.

Easterwood, G.W. and Sartain, J.B. 1990. Clover residue effectiveness inreducing orthophosphate sorption on ferric hydroxide coated soil. *Soil Science Society of America Journal* **54**: 1345–1350.

Eylachew, Z., 2001. Study on physical, chemical and mineralogical characteristics of some Vertisols of Ethiopia. 87-102p.

FAO, 2006. World reference base for soil resources*:* a framework for international classification, correlation and communication. Rome: FAO. 103p.

Finzi, A.C., van Breemen N, Canham CD., 1998. Canopy tree-soil interactions within temperate forests: Species effects on soil carbon and nitrogen*. Ecological Application*.**8**: 440–446.

Gao, G., and C. Chang, 1996. Changes in cation exchange capacity and particle size distribution of soils associated with long-term annual applications of cattle feed lot manure. Soil Sci. **161**: 115-120.

Hao, X., B.C. Ball, J.L.B. Culley, M.R. Carter and G.W. Parkin, 2008. Soil Density and Porosity. In: M.R. Carter and E.G. Gregorich (Eds.) Soil Sampling and Methods of Analysis, *Canadian society of soil science, Taylor & Francis Group*, LLC., U.S.A. 743-760.

Havlin, J. L., J. D. Beaton, S. L. Tisdale , and W. L. Nelson, 2005. Soil Fertility and Fertilizers: An Introduction to Nutrient Management. 7^{th} Ed. Prentice Hall, Upper Saddle River, NJ.

Ishaq,M.I.and R.Lat,2002. Tillage effects on soil properties at different levels of fertilizer application in Punjab, pakistan.*soil till.res*.**68**:93-99.

Khanif, Y.M., 2010. Improvement of Soil Carrying Capacity for Better Living Department of Land Management, Faculty of Agriculture University Putra Malaysia, 43400, Serdang Selangor Malaysia.

Kjeldahl, J.Z., 1883. A new method for the determination of nitrogen in organic bodies analytical chemistry.**22**: 366p.

Lal, R. 2004b. Carbon sequestration in dry land ecosystems. *Environmental Management* **33(4):** 528-544.

Mathewos, A., 2008. Ethno botany of Spices, Condiments and Medicinal Plants in Loma and Gena Bosa Woredas of Dawuro Zone, Southern Ethiopia. A Thesis Submitted to the School of Graduate Studies in Addis Ababa University in Partial Fulfilment of the Degree of Masters in Biology (Dryland Biodiversity),120p.

Mesfin, A., 1980. State of soil science development for agriculture in Ethiopia. Eth. J. Agric. Sci **2**: 139-157.

Mulongey, K.and R. Merck (Eds.), 1993. Soil organic matter dynamics and sustainability of tropical agriculture. *John Wiley and Sons, Inc*., New York. 392p.

Mulugeta, L., 2004. Effect of Land Use Changes on Soils Quality and Native Flora degradation and restoration in the Highlands of Ethiopia, Implications for sustainable land management. Doctoral thesis. Acta Universitatis Agriculturae Sueciae, Uppsala,Sweden.

Pavinato, P.S., A. Merlin and C.A. Rosolem. 2009. Phosphorus fractions in Brazilian Cerrado soils as affected by tillage. *Soil & Tillage Research* **105**: 149–155.

Saikhe, H., C. Varadachari and K. Ghosh. 1998. Changes in carbon, N and P levels due to deforestation and cultivation. A Case study in Simplipal National Park, India. *Plant Soil.* **198**:137-145.

Sanchez, P.A., Izac A-MN, Valencia I & Pieri C., 1996. Soil fertility replenishment in Africa. In: Breth SA (ed) Achieving Greater Impact from Research Investments in Africa. Sasakawa Africa Association, Mexico City.

Taye, B. and Yifru, A., 2010. Assessment of Soil Fertility Status with Depth in Wheat Growing Highlands of Southeast Ethiopia.525p.

Tefera, M., Chernet T., Haro, W., 1999. Explanation of the geological map of Ethiopia,, 2nd ed. Addis Ababa: *EIGS technical publication team*, Addis Ababa.79p.

Tilahune, A., Endrias, G. and Takele, B., 2007. Reversing the degradation of arable land in Ethiopian highlands, Managing Africa's soil. No. 23, IIED-London.

Thomsen, I.K. and B.T. Christensen. 2004. Yields of wheat and soil carbon and nitrogen contents following

long-term incorporation of barley straw and ryegrass catch crops. *Soil Use and Management* **20**:432–438.
U.S. Salinity Laboratory Staff; 1954.Diagnosis and Improvement of Saline and Alkali Soils. *L. A. Richards, Ed*. U.S. Dept. of Agriculture, Washington, D.C. **2**:160.
Wakene, N. and Heluf, G., 2004. Impact of Different Land Use Systems on Soil Quality of Western Ethiopian Alfisols. A Paper presented on International Research on Food Security, Natural Resource Management and Rural Poverty Reduction through Research for Development and Transformation in Tropentag 2004, October 5 - 7, 2004,Berlin, Germany.
Walkey, A., and Black,I.A.1934. An examination of the degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method soil science .**37**: 29.
Wild, A., 1993.Soils and the environment: an introduction. Cambridge University Press, Cambridge, UKWoomer, P. and M.J. Swift. 1994. The biological management of tropical soil fertility. *John Wiley, Chichester*, U.K., 243p.
Wivstad, W., A.S. Dahlin and C. Grant .2005. Perspectives on nutrient management in arable farming systems. *Soil Use and Management* **21**: 113–121.
Yihenew, G., 2002. Selected chemical and physical characteristics of soils Adet research center and its testing sites in North-Western Ethiopia. *Ethiopian Journal of Natural Resources*. **4(2)**: 199-215.
Yimer, F. and Abdelkadir, A., 2010. Soil water property variations in three adjacent land use types in the Rift Valley area of Ethiopia .*Journal of Arid Environments*. **75(11):**1067-1071
Yohannes, U., 1994. The effect of nitrogen, phosphorus, potassium, and sulphur on the yield and yield components of Ensete (*Ensete ventricosum* W.) in Southwest of Ethiopia. PhD dissertation, Gießen, Germany.