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Soil Fertility Status and Productivity Trends Along a Toposequence: A Case of Gilgel Gibe Catchment in Nadda Assendabo Watershed, Southwest Ethiopia

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Abstract: The Impact of landscape positions and land use type on properties as well as land productivity are commonly observed in Ethiopia. The study was therefore conducted to quantify soil fertility and productivity trends under three land uses along the gradient (lower, middle and upper slope positions) of Nadda Assendabo watershed, Southwest Ethiopia. Thus field survey was covered a total of 54 composite soil samples using split plots (for soil physical properties) and split-split factorial arrangements with randomized complete block design from woodlot, grazing and crop land following topographic positions then different parameters were analyzed. The highest mean soil moisture content (56.68%) and porosity (71.09%) were observed for woodlot at the lower slope while the highest soil bulk density (1.74 g/cm^3) was observed for soil crop land at the upper slope where as the lowest (0.94 g/cm^3) was for woodlot at the lower slope. Sand, silt and clay fractions were significantly affected by interaction effects of slope and land uses (P≤0.01). Soil pH, electrical conductivity, organic carbon, cation exchange capacity, total nitrogen, available phosphorus, base saturation percentage and exchangeable basic cations for all land uses were increased down slope while they were affected significantly by slope steepness, land use and soil depth (P≤0.01). Therefore, electrical conductivity at middle and upper slope in grazing land and woodlot; total nitrogen, available phosphorus in crop land at lower slope was significantly different (P≤0.05) due to interaction effect. Furthermore, above ground biomass and grain yields of sorghum, maize and teff were also calculated on farm fields using split plots arrangements. Thus both yields were significantly affected by interaction effect of slope and crop type. Finally, based on the results woodlot, grazing and crop land were recommended for upper, middle and lower slopes respectively.

Keywords: Toposequence, Biomass and Grain Yield, Productivity Indicators

1. Introduction

Land is an essential resource particularly for agrarian society like Ethiopia. It is also a scarce resource with a carrying capacity that can be stretched only to a limited extent with the help of technology. As population grows rapidly, imbalance between supply for land resource and demand for it emerges. The consequences of imbalanced relationship are brought about either by natural or human factors such as deforestation, land degradation, soil erosion and conflict over land uses as a result of limited care of the resources and lack of awareness of the long-term effects (Buzuayehu *et al.,* 2002). Some of the conservation measures

like terracing, bunds and counter cultivation could be used for sustaining land productivity (Desta, 2003). In addition, small holder farmers use woodlot as means for reducing soil loss and resolving boundary conflict that may be raised due to land fragmentation into patch (Chris *et al.,* 2004). The trees planted for this purpose could be used for construction, fuel wood and reducing pressure on utilizing crop residues (Bezuayehu *et al.,* 2002).

A decline in soil fertility is becoming one of the major challenges for establishing sustainable agriculture in sub Saharan African countries (Muchena, 2008) This is enhanced by changes in land use, alteration of the ecosystem and susceptibility of the land to external pressure which

significantly affect soil physical, chemical, and biological properties. Due to these trends agricultural productivity per unit of land is declining through time and food production could not keep pace with population growth (Roy *et al.,* 2003).

Mostly, soil fertility parameters are influenced by rugged topography, steep slopes and land mosaic which results in exacerbating soil erosion rate through its morphological characteristics (Azene, 1997; Demel, 2001). On sloping lands, more than one-half of the soil particles that are dislodged by raindrops during rainfall are carried downhill (Brubaker *et al.,* 1993; Brady and Weil, 2002). Erosion increases dramatically because the increased angle facilitates water flow and soil movement. It is generally accepted that an increase in slope will increase soil erosion by water and landslide because they lead to an increase in overland flow volume and velocity. Runoff on lower slopes flows slowly and forms a water layer quickly deep enough to act as surface mulch (Wischmeier and Smith, 1978).

Beside, Ethiopia is a country where more than 85% of its labour force is engaged in agriculture (CSA, 2010). So working in the agriculture sector to improve the level of its productivity is a key issue to meet the requirements of the continued population growth. According to (FAO, 2010, as cited in Taffesse, 2011), the country population density per land area was 82.95 people per square kilometer and this resulted in the fragmentation of land into patch dynamics, which influences nutrient flow and further land productivity.

In sight of this, Southwestern Ethiopia has a strong potential for increased agricultural productivity due to high intense of woodlot which its tree species has less allellopathic effect on fragmented landscape (JZARDS, 2011). However, environmental challenges, mainly deforestation and the consequential soil erosion and nutrient depletion, have profound effects, and threatened the livelihoods of the farmers.

Poor land management practices coupled with the rugged topography, erosive rainfall and more intense of gully and rill formation in Omo Nadda Woreda (Mainly Nadda Assendabo watershed) affected the agricultural practices in the area (SLMP, 2010). As a consequence, an increase in sediment load in down slope and reduction of agricultural productivity is becoming a challenge for small holder farmers. Some research have been done in the study area covered the area of land use/land cover dynamics and its impact (Amanuel, 2011); comparative analysis of soil nutrient balance at farm level (Abebayehu *et al.,* 2011) reported that land use change and absence of nutrient balance brought low soil productivity. However, no study has been done on the land use planning, soil fertility and land productivity following the gradients. Therefore, the objective of this study was designed to investigate impact of topographic position and land use on soil fertility and its productivity in Omo Nadda woreda specifically Nadda Assendabo watershed, Southwest Ethiopia.
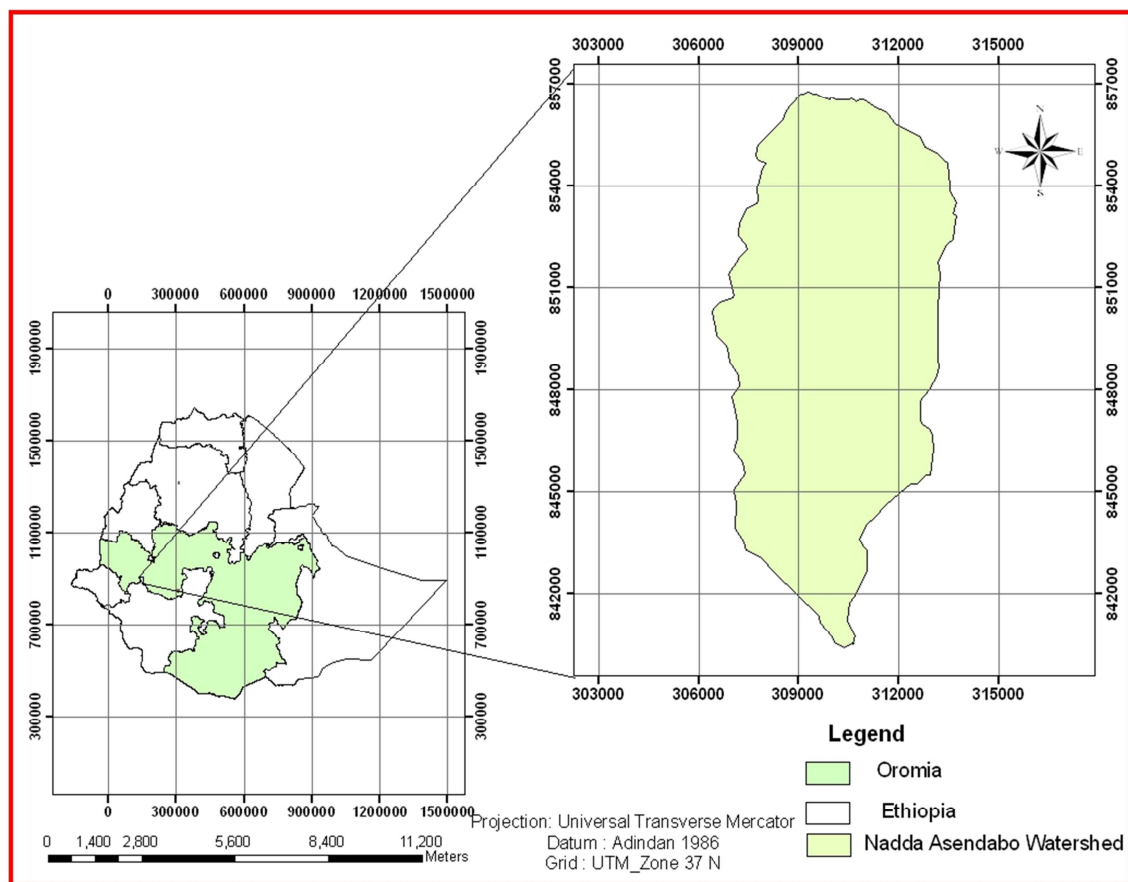

Figure 1. Location map of the study area.

2. Materials and Methods

2.1. Description of the Study Area

Nadda Asandabo watershed is located in Omo Nada Woreda, Jimma zone of Oromia Regional State. It is located close to Gilgel Gibe dam-I at about 260 km South West of Addis Ababa. Geographically it is located between 7^0 36' 00.87'' - 7^0 41' 05.72'' N latitude and 37^0 16' 55.88'' - 37^0 14' 40.73'' E longitude. It covers an area of 8,012 ha. This study was mainly focused on four kebels; Doyo yaya, Biso Gombo, Goro seden, Guddeta bula. The area is characterized by gentle, flat and undulating topography with the altitude ranging from 1650 – 2200 m a.s.l. According to Van Ranst *et al.,* (2010), the major reference soil groups in the Gilgel Gibe catchment are Nitisols, Acrisols, Ferralsols, Vertisols and Planosols. All these soils have a significant clay Bt level of dark reddish brown colour. They generally come from the alteration of the basaltic basement and are found on the hills and ridges. According to the surrounding elder's descriptions, 50 years ago the area was covered by indigenous trees such as *Poducarpus* and *Juniperus spps*. A later agricultural land expansion has resulted in destruction of forest trees and treats to wildlife (SLMP, 2009).

2.2. Methodology

This study was carried out immediately after cropping season specifically for soil sampling from the field in autumn and winter of 2013/2014. This was because of fall is the ideal time of a year to routine soil sampling of crop land. Additionally, cover crops were collected so that humidity standardized for surrounding environment. Furthermore, at this time soil and organic material were separable.

2.2.1. Experimental Design and Soil Sampling

Randomized complete block design with split-plot factorial conducted for soil moisture, bulk density and porosity whereas split-split plots for the left soil fertility parameters. The main plots, subplot and sub subplot were slope ranges, land uses and soil depth respectively. However, split plots arrangement was followed for surface soil moisture, bulk density and porosity. Prior to soil sampling, the landscape was divided into three gradients using GPS and clinometers namely; lower (0-15%), middle (15-25%) and upper slopes (≥25%) followed by selection of three land use types (i.e crop land, grazing land and woodlot) from each gradient. Each treatment was then replicated three times and the soil samples were collected from the depth of 0-20 and 20-40cm using auger. Five samples (in zigzag pattern) were collected to form composite soil samples (54), which were transported to the laboratory for further processing. Plant roots and shoots were handpicked and discarded. Then soil samples were air dried, mixed well before analyses.

2.2.2. Procedures for Soil Laboratory Analysis

(i). Soil Physical Properties

Soil moisture at the sampling time was determined by oven dried at 105ºc for 24 hrs. Then it was expressed by weight as the ratio of the mass of water present to the dry weight of the soil sample as described in Gravimetric method and bulk density was determined by core method (Blake, 1965) after drying a defined volume of soil in an oven at 105 °C for 24 hours. Finally, soil pore space was calculated from measured bulk density values using the following equation:

Soil porosity (PS) $= 1 - \frac{Db}{Dp}$ whereas, Db=Bulk density; Dp=Particle density

For soil texture, initially the soil sample was pretreated with H_2O_2 (30%) to remove any organic material and sodium hexametaphosphate to disperse complex Ca^{++}, Al^{3+}, Fe^{3+}, and other cations that bind clay and silt particles into aggregates. The density of the soil suspension was determined with a hydrometer method (Day, 1965) to read in grams of solids per liter after the sand settles out and again after the silt settles. A correction was made for the density and temperature of the dispersing solution. Percentage of particle size classes were identified according to the USDA textural triangle.

(ii). Soil Chemical Properties

The pH was measured in H_2O, in ratio of soil to water (1:2.5), using pH meter whereas Ec measured by conductivity meter using suspension of 1:5 soil: water ratio. Organic carbon was determined by following Walkley and Black method (1934). Then, percent soil organic matter was calculated by multiplying the percent organic carbon by a factor of 1.724. Total Nitrogen (TN) was determined by the micro-Kjeldahl digestion, distillation and titration method (Bremmer and Mulvane, 1982). Available phosphorus (AP) was determined using the standard Bray II. Cation exchange capacity was determined at soil pH level of 7 after displacement by using 1N ammonium acetate method in which it was, thereafter, estimated titrimetrically by distillation of ammonium that was displaced by sodium (Chapman, 1965). Total exchangeable bases were determined after leaching the soils with ammonium acetate (Thomas, 1990). Amounts of Ca^{2+} and Mg^{2+} in the leachate were analyzed by EDTA and K^+ and Na^+ were analyzed using flame photometrically. Percent base saturation was calculated by dividing the sum of the base forming cations (Ca, Mg, Na and K) by the CEC of the soil and multiplying by 100.

2.2.3. Biomass and Grain Yields Assessment

Three crop lands (Maize (*Zea mays*), Teff (*Eragrostis tef*) and Sorghum (*Sorghum bicolor*)) were selected for this study since they are commonly practiced in the watershed. These lands and varieties were selected following discussion with farmers, elders and experts. A plot of 2 m x 2 m was

temporary established using randomized complete block design with split plot factorial arrangement from the whole selected crop land considering its representativeness. Then for increasing precision of observation each crop land were replicated five times in anticipated ranges of elevation. Finally, the above ground biomass and yield was measured using spring balance in unit of kg after all grain yield was converted to kg/ha and biomass to t/ha for result presentation.

2.3. Statistical Analysis

Prior to statistical analysis treatments were arranged in factorial randomized complete block design format with slope steepness, land use and soil depth as factors. Three way analysis of variance (ANOVA) was performed to assess the significance of differences in soil parameters between slope steepness, land uses and soil depth, using the general linear model (GLM) procedure of the statistical analysis system (SAS Institute, 1996). A post hoc separation of means was done by LSD test after main effects were found significant at $P < 0.05$.

3. Results and Discussion

3.1. Soil Physical and Chemical Properties Along the Toposequence

3.1.1. Surface Soil Bulk Density, Moisture Contents and Porosity

The maximum mean of soil moisture content at the sampling time was observed in woodlot, whereas the minimum in crop land. Therefore, interaction effect of slope and land use significantly affected ($P \leq 0.01$) response of soil moisture and its mean comparison was significantly different ($P \leq 0.05$) in crop land at the middle slope, crop and grazing land at the upper slope (Table 1). Woodlot had high leaf cover while others land uses had little leaf cover. This can result in the larger differences in infiltration rate, drainage and evapotranspiration between different land uses. In addition, this was due to the flow of water is low at the lower slope as there is no elevation differences and, thus, it gets time to infiltrate. It is agrees with the findings of Yang (2001). On other hand, the highest mean of soil porosity in woodlot might be come from high organic matter and finer soil particle in this land use type (Table 1 and 2).

Therefore, interaction effect of slope, land uses and soil depths significantly affected ($P \leq 0.01$) bulk density and its mean comparison was significantly different($P \leq 0.05$) for all cases except in crop land at the middle slope, grazing land and woodlot at the upper slope (Table 1). Furthermore, soil total porosity affected by these interaction effect in grazing land and woodlot at the lower slope and crop land at the upper slope ($P \leq 0.01$) (Table 1).

Table 1. Interaction effects of slope and land use on soil MC, BD and porosity.

Slope (%)	Land use	MC	BD	Porosity
0-15	CL	29.75c	1.15f	56.6c
	GL	42.11b	1.06g	60b
	Wl	56.68a	0.94h	71.09a
15-25	CL	22.35e	1.52c	40.18f
	GL	28.35d	1.35d	48.89e
	Wl	39.96b	1.21e	55.27dc
≥25	CL	17.37g	1.74a	29.95g
	GL	20.72f	1.55bc	40.16f
	Wl	29.2cd	1.59b	46.31e
LSD (0.05)		1.21	0.05	4.8
CV (%)		8.48	7.28	6.77

GL=grazing land, CL=crop land, Wl=woodlot, MC=soil moisture content BD=bulk density; Means within a column followed by same letters in superscripts are not significantly different from each other at P=0.05.

Table 2. Interaction effects of slope, land use and soil depth on soil particle.

Slope (%)	LUT	Soil Depth	Sand	Silt	clay
0-15	Cl	0-20	13.37m	45.3a	41.33f
		20-40	11.7o	39.3d	49c
	Gl	0-20	15.16l	41.17c	43.67ed
		20-40	14.67m	26l	59.33a
	Wl	0-20	10.33p	39.3d	50.37b
		20-40	15.67k	24.33m	60a
15-15	Cl	0-20	28e	41c	31j
		20-40	13n	42.33b	44.67ed
	Gl	0-20	28.34d	36.33f	35.33h
		20-40	19j	37.33e	43.67ed
	Wl	0-20	28.67c	27k	44.33ed
		20-40	24.67i	30i	45.33d
≥25	Cl	0-20	39.36a	31.96h	28.68k
		20-40	27f	35.33g	37.67g
	Gl	0-20	26.67g	29.33j	33.75i
		20-40	27f	37.67e	35.33h
	Wl	0-20	35.67b	25.67l	38.66g
		20-40	26h	32.33h	41.67f
LSD (0.05)			0.24	0.41	1.02
CV (%)			11.32	9.45	3.28

Means within a column followed by same letters in superscripts are not significantly different

3.1.2. Soil Particle Distribution Along the Toposequence

Table 2 clearly shows that sand, silt and clay fractions differed significantly along three slopes, land use types and both soil depths ($P \leq 0.01$). Similarly, the sand and clay fraction strongly influenced by interaction effect of slope steepness, land use types and soil depth ($P \leq 0.01$) (Table 2). As a result, mean comparison of sand soil particle in woodlot at the lower slope (surface soil), crop land and grazing land (subsurface soil) at middle slope, crop land (surface), grazing land for both depths and woodlot (subsurface) at the upper slope was significantly different ($P \leq 0.05$). The values of silt/clay ratios were 0.63, 0.68 and 0.72 for crop land, grazing land and woodlot soils respectively (Table 2). The decreasing clay content can be used as an indicator for reducing degree of weathering. This finding agrees with the works of Van wambeke (1962) who used silt to clay ratio to estimate the degree of weathering of soil pedon, and postulate that the lower the ratio, the higher the degree of weathering. By increasing weathering, the silt fraction

changed into clay fraction so that clay content increased, thus the silt/clay ratio was to be lower. Furthermore, results of this study were showed that the ratio of clay contents in soil particle distribution for all land uses increased from surface to sub-surface along the gradient. This result agree with the works of Ashanafi *et al.* (2010); Esteban *et al.* (2000) and Sheleme (2011) who reported that the texture of the subsurface horizons became finer with soil depth, due to migration of clay from surface to lower horizons.

Silt fraction affected significantly by interaction of land use and soil depth ($P \leq 0.05$), slope and land use and slope and soil depth ($P \leq 0.01$) (Table 2) but mean comparison in grazing land and woodlot, surface and subsurface soil depth was not significantly different. In addition, clay fraction in crop land (surface soil), grazing land and woodlot (subsurface soil) at the lower slope, crop and grazing land (surface soil) at the middle slope as well as all land uses at the upper slope was significantly different ($P \leq 0.05$). This result agreed with the findings of Van wambeke (1962).

In addition it was supported by the works of (Ogeh and Ukodo, 2012) which revealed that sand fraction generally dominated the soils along the toposequence. Within the horizons, the sand content decreased with depth in all the

profiles, silt content increased with depth in all the profile.

3.1.3. Soil pH, EC, SOM, TN and AP, Exchangeable Bases, BS and CEC

Results of the present studies showed that soil pH increased down slope and with soil depth (Table 3). Statistically, pH was significantly affected by interaction of slope steepness, land use and soil depth in crop land, grazing land and woodlot (subsurface soil) grazing land (surface soil) at the upper slope (Table 3). Relatively lower pH values in the soil of the crop fields and grazing land, as compared to those under woodlot, might be due to depletion of basic cations by the harvested crop biomass, over grazing and leaching. Gebeyaw (2007) has also reported that a lower pH value in cultivated land was attributed to a high rate of organic matter oxidation. This is important to produce organic acids and provide H^+ to the soil solution, and thereby reduces soil pH values. This explanation was also partially supported by Tana (1996) and Butros *et al.* (2010) who reported that soil pH was increased with soil depth along the gradient due to carbonate content of the soil and high intensity of rain fall.

Table 3. Interaction effects of slope, land use and soil depth on soil physico-chemical properties.

Slope (%)	Land use	Soil depth (cm)	pH	Ec (dS-1m)	OM(%)	TN (%)	AP (ppm)	Ca	Mg	Na	K	CEC	BSP (%)
								cmol+Kg- of soil					
0-15	Cl	0-20	6.51f	0.042fgh	6.25cbd	0.39ed	4.56efg	12.61jik	5.04de	0.34fg	0.56eghf	25.33f	72.94fe
		20-40	6.6e	0.05ef	5.47cebd	0.32fheg	4.14g	16.07ef	5.67dc	0.44de	0.69ed	34.67c	66.57ijk
	Gl	0-20	6.78d	0.066d	8.98a	0.49cb	7.61a	16.93ecd	6.6c	0.52dc	0.75cd	33.44dc	74.74dce
		20-40	6.85c	0.079c	6.87b	0.4ced	6.28b	18.4bcd	8.96b	0.64ba	0.92cb	42.18b	68.67hgi
	Wl	0-20	6.91b	0.204b	9.63a	0.65a	5.29cd	19.9b	9.39b	0.61b	0.89cb	42.29b	73.16fe
		20-40	6.98a	0.355a	8.86a	0.5b	4.73defg	21.31a	12.23a	0.71a	1.75a	47.09a	76.81bc
15-25	Cl	0-20	5.53l	0.025jkl	4.62ef	0.23hi	2.71hij	13.19jih	3.1gf	0.24hi	0.43ih	17.84g	96.21a
		20-40	5.87j	0.028ijk	4.83efd	0.29fhig	2.37hij	14.23ihfg	4.13fe	0.3hg	0.51ghf	25.05f	77.44bc
	Gl	0-20	5.73k	0.037ghi	5.79cebd	0.33feg	4.92def	14.15jihfg	5.27dce	0.34fg	0.55eghf	25.93fe	78.79b
		20-40	5.93i	0.046fg	6.45cb	0.29fhig	5.89bc	15.54efg	5.82dc	0.48de	0.64egdf	30.28de	74.67dce
	Wl	0-20	6.2h	0.046fg	5.81cebd	0.37fe	4.17g	16.8ed	6.18dc	0.44de	0.68edf	33.3dc	71.68feg
		20-40	6.28g	0.061de	6.59b	0.47cbd	4.9def	19.04bc	8.7b	0.58bc	1.01b	39.39b	74.46dce
≥25	Cl	0-20	5s	0.014l	2.59g	0.13j	2.3hij	7.41k	2.49g	0.14j	0.18j	16.57h	61.68m
		20-40	5.13r	0.019kl	3.29gf	0.21ji	1.45jk	9.93jk	1.82g	0.18ji	0.26ij	18.45g	66.1o
	Gl	0-20	5.17qr	0.031hij	3.29gf	0.21ji	2.06jk	12.36jihg	2.94gf	0.23hi	0.29ij	21.47g	73.68ij
		20-40	5.23np	0.035ghij	4.54ef	0.27hig	3.26h	14.14jihfg	4.27fe	0.33fg	0.38ih	26.03fe	73.59lk
	Wl	0-20	5.2opq	0.037ghi	4.67ef	0.26hig	2.57hij	14.96ehfg	5.09de	0.28hg	0.39ih	29.67f	69.85n
		20-40	5.4m	0.043fg	4.94ced	0.29fhig	2.82hi	15.89ef	6.02dc	0.4fe	0.48gh	34.3dc	66.64ij
LSD (0.05)			0.05	0.011	1.56	0.09	0.68	2.22	1.36	0.08	0.18	4.37	3.04
CV (%)			3.1	8.1	13.82	10.95	13.55	6.02	13.75	8.83	14.77	4.86	7.56

Land use are the same as Table 3; BSP= Base Saturation Percentage; Means within a column followed by same letters in superscripts are not significantly different from each other at P=0.05

Interaction effect of slope and land use on Ec was significantly different in grazing land (surface) and woodlot (surface and subsurface) at the lower slope comparatively with others ($P \leq 0.05$) (Table 3). Following this scenario, Ec were higher in the woodlot with a mean of 0.355 dS^{-1}m, whereas the lowest 0.014 dS^{-1}m in the crop land at the upper slope (Table 3). Generally, Ec increased from surface to subsurface for all land uses, following sequential landscape gradients (Table 3). This result was in agreement with the findings of Doerge *et al.* (1999) and Butros *et al.* (2010) indicating greater clay particle percentage, loss of Calcium

(Ca), Magnesium (Mg), Sodium (Na) and Potassium (K) containing soluble salts after deforestation and cultivation and increased porosity of the soil under these land uses resulted in reduction of soil electrical conductivity. This result also supported by the works of (Alemayehu and Sheleme, 2013) which indicated crop with high biomass and large physiological activities assists soil erodibility.

SOM in crop land at the lower slope was significantly different ($P \leq 0.05$) from middle and upper slope due to interaction effects of slope with land use and soil depth (Table 3). The lower organic matter observed in crop and

grazing land comparing to woodlot could be explained by the seasonal cover in the former following over cultivation, free grazing and absence of soil nutrient balance. Removal of the surface soil rich in organic matter by soil erosion which undoubtedly could have accelerated with the removal of the plant cover is also expected to contribute to the lower organic matter contents observed in the crop and grazing land. The maintenance high levels of organic matter under woodlot are apparently attributed to the presence of vegetation and the associated high biomass and litter fall in the soils. This result was in agreement with the works of (Pan and Bhardwaj, 2013) forest has the highest carbon pool where as the agricultural crop had the lowest carbon pools in comparison.

Soil TN in woodlot at the lower slope (surface and subsurface) was significantly different (P ≤0.05) from other land use type at the three slopes due to interaction of these factors (Table 3). In line with soil organic matter contents, the highest mean soil total nitrogen (0.65%) was observed in the woodlot followed by the grazing land (0.5%), where as the lowest value (0.13%) of total nitrogen was recorded in the crop lands (Table 3). Reduced input of plant residues into the soils also has contributed to the depletion of organic matter thereby enhanced rate of nitrogen in crop land. As the area receiving high mean annual rain fall, leaching could be another reason for the decline in TN in cropped fields. Nitrate ions which are not adsorbed by the negatively charged colloids dominate in most soils and, thus, move downward with drainage water and are readily leached from the soil. Removal of crop residues and subsistence agricultural system affects nutrient balance more negatively (Fitsum et al., 1999).

AP was significantly different (P ≤ 0.05) in grazing land (surface) at lower slope comparatively with land use in all slope along a toposequence due to interaction effects of slope, land use and soil depth. Reduction of AP contents could be related to degree of its fixation which occurs at low pH levels where iron and aluminum activity actually increases (Brady and Weil, 2002). According to the reports of Maja (2011) for health vegetation, increase in elevation was associated with a decrease in soil NH_4^+ and PO_4^{3-} concentrations because the soil fungal: bacterial ratio was lowest at the lower elevations.

Exchangeable cations, Ca, Mg, Na and K were significantly different (P≤0.05) in woodlot (subsurface) at the lower slope due to interaction effects of slope, land use and soil depths (Table 3). This finding agreed with (Maja, 2011) reports, less amounts of soil erosion by water and high resistance of cations from leaching at foot slope and area covered by perennial vegetations improved level of exchangeable cations in the soil.

Cation exchange capacity was greater in woodlot land use type and at the lower slope (Table 3). This results supported by (Brady and Weil, 2002) cation exchange capacity increased with the ability of plant root to anchor soil mass and not rugged landscape which is less vulnerable to landslide due to elevation differences. Thus, this study was

revealed that interaction effects of slope, land uses and soil depths along a toposequence was indicated CEC was significantly different (P ≤0.05) in woodlot (subsurface) at the lower and middle slope from other values observed (Table 3)

Observed base saturation percentage in crop land at middle (surface) and upper (subsurface) slope was significantly different (P≤0.05) from others due to interaction effects of slope steepness, land use and soil depth (Table 3). This result was agreed with findings of Hikmatullah et al. (2003).

3.2. Crop Biomass and Grain Yield Along the Toposequence

Productivity of above ground biomass for sorghum and maize at the lower slope and teff at the upper slope was significantly different (P ≤0.01) from others due to the interaction effects of slope and crop type along the toposequences. Mean grain yields were ranged from 495-1070 kg (teff), 1890-5500 kg (maize), 2235-2360 kg (sorghum) along the landscape. This result was significantly different (P ≤0.05) in grain yield obtained from maize at all slope and teff yields at upper slope due to interaction effects of slope and crop type. It was agreed with works of Grabherr, 2009, as cited in Fabien, 2012).

Table 4. Interaction effects of slope and crop type on biomass and grain yields.

Slope (%)	Crop type	Biomass	Grain yield
	sorghum	32.95a	2250c
0-15	Teff	10.62f	1070e
	Maize	25.19b	5500a
	sorghum	19.99c	2235c
15-25	Teff	6.55g	895f
	Maize	19.27dc	3465b
	sorghum	13.7ef	2360c
≥25	Teff	4.16g	495g
	Maize	11.67ef	1890d
LSD (0.05)		3.71	139
CV (%)		19.85	13.67

Means within a column followed by same letters in superscripts are not significantly different

4. Conclusion and Recommendations

Based on this study results, most of soil nutrients significantly decreased due to soil erosion and landscape features with increasing slope steepness and unwise utilization of land. Thus higher organic matter, cation exchange capacity, soil moisture, finer soil particle, basic cation, nitrogen and phosphorus observed at foot slope and woodlot land use type. So that soil and water conservation measures like hillside trench, terracing, micro and macro basin should layout at the upper watershed side according to its suitability in the watershed. Therefore, lower slope watershed community should work cooperatively with upper and middle watershed since household in the lower watershed benefited from offsite nutrient movement to their

lands. This will be happened according to this research output through allocating woodlot land use type between fragmented crops and grazing land and empowering local community through training on how they can prepare organic fertilizer from locally available materials.

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