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Effects of Land Use, Soil Depth and Topography on Soil Physicochemical Properties along the Toposequence at the Wadla Delanta Massif, Northcentral Highlands of Ethiopia

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Abstract

The study was conducted to investigate the effects of land use, depth and topography on soil physicochemical properties at the Wadla Delanta Massif, northcentral Ethiopia. Four land uses (natural forest, shrub, grazing and cultivated land), three soil depths (0-20, 20-40, 40-60 cm) and three topographic positions (upper, middle and lower) in three replications were considered for this study. A total of 108 composite samples were collected for laboratory analysis. The results show that particle size distribution was affected by the main effects of land use and soil depth; bulk and particle densities, total porosity, organic matter and total nitrogen contents, C:N ratio and available phosphorus were significantly affected by the interaction of land use by soil depth only, whereas, soil pH, electrical conductivity, exchangeable bases, cation exchange capacity, percent base saturation and extractable micronutrients were affected by the interaction effects of the three factors. Highest clay and bulk density were recorded at the bottom layer of the cultivated land soils, while the utmost porosity, organic matter and nitrogen contents, and available phosphorus were recorded at the surface layers of the natural forest land soils. Highest pH was at the bottom layer of the cultivated land at the three topographic positions. Highest exchangeable bases and cation exchange capacity were observed in the bottom layers of soils under the four land use types at the lower topographic position, whilst extractable micronutrients were recorded at the surface layers of the forest land soils at the upper topographic position. In general, most of the measured soil properties were measured better in forest than in other land use soils and the lower topographic positions than the upper and middle ones. Interaction of land use with topography showed negative effects especially on cultivated and grazing land soils in all topographic positions. Therefore, integrated soil fertility management and soil conservation measures are required in all topographic positions to maintain soil physicochemical properties.

Keywords: chemical property, massif, physical property, soil depth, topographic position

1. Introduction

Topography plays a vital role in biogeochemical processes which performs key environmental, economic and social functions (Griffiths *et al.*, 2009). Any spatial patterns depend on soil forming processes, our understanding of which is still limited, especially in regards to topographic effects. As the landscape is undulating, soil characteristics at different topographic positions differ. Soils vary in their characteristics primarily because of topography (Amhakhian and Achimugu, 2011) which modifies soil water relationships and large extent influences on rainfall, drainage, soil erosion, textural composition and other soil properties that affect plant growth within a field (Atofarati *et al.*, 2012). Topographic variability associated with crop production is an integrated reflection on soil properties and factors affecting agricultural productivity (Dinaburga *et al.*, 2010).

The numbers of studies have publicized (Si and Farrell, 2004; Reuter *et al.*, 2005; Griffiths *et al.*, 2009) a clear association between land uses and topographical parameters (slope, soil surface curvature and elevation). Topography of agricultural fields can influence soil physicochemical properties (soil depth, texture, and mineral contents), biomass production, incoming solar radiation, precipitation and affect crop production. As an increased topography/elevation significantly increased soil moisture, precipitation, soil organic matter and labile carbon, whereas bulk density, pH and soil temperature were significantly lower at the higher elevations.

Heterogeneity by biophysical and socioeconomic factors makes to play a vital role in observed patterns of deforestation and reforestation. The conversion of natural forest into cultivated and grazing lands caused losses of soil nutrients. On cultivated land soils, cation exchange capacity, organic matter and total nitrogen contents are depleted by 50, 87 and 76%, respectively, whereas bulk density is increased by 21.42% (Nega and Heluf, 2009). The cultivation periods also influence soil physicochemical properties. As per cultivation periods various scholars (Mulugeta *et al.,* 2005; Eyayu *et al*., 2009; Mojiri *et al*., 2012) revealed that as the cultivation period increase the bulk density also increase, whereas soil organic carbon and total nitrogen contents are reduced by 50.4 and 59.2%, respectively. Soil texture is also an indicator of soil features vis-à-vis types of parent material, homogeneity and heterogeneity within the profile, migration of clay and intensity of weathering of soil material or age of soil (Aminu *et al.,* 2013). The highest clay content is found in subsoil layers of the cultivated land soils at the lower topographic position (Bahrami *et al.,* 2010; Fungo *et al.,* 2011; Aung *et al*., 2013).

As per high population growth and shortages of lands (Daniel, 2008; Diress, 2010; Abate, 2011; Messay, 2011) publicized that crop productions in Ethiopia are still being carried out by deforestation, on steep slopes, marginal lands and fragile soils with inadequate investments in soil conservation measures which also aggravates soil erosion. The effects may not be of equal magnitude on different topographic positions and soil depths. This implies different in management requirements. The way of the farming system is traditional; modern agricultural technology is not applied in most parts of the country. As a result, many agricultural land soils in Ethiopia have reached unreturned point. Nowadays, shortages of land for cropping and grazing have forced the farmers to eliminate the fallowing practice on the flatter areas and to remove crop residues for household fuels and animal feeds which in turn have led to the reduction of soil nutrients and crop productivity.

The situation at the study area is worse and the soil resource has degraded at an alarming rate. Consequently, the sustainability of agriculture and the livelihood of the community are under threat. To come up with sound management practices, investigating the impacts of the interaction of these factors is imperative. The main objective of this study was, therefore, to investigate the effects of different land uses, soil depths and topographic positions on soil physicochemical properties at the Wadla Delanta Massif, northcentral highlands of Ethiopia

2. Materials and Methods

2.1 Description of the Study Area

The study was conducted at the Wadla Delanta Massif in Delanta District, northcentral highlands of Ethiopia (Figure 1). The study area lies between 11° 29' 29.82" to 11° 41' 25.53" N and 39° 02' 19.19" to 39° 14' 05.04" E with elevation ranges from 2600 to 3500 meters above sea level and covering an area of 24,025 ha. It is located at about 499 km north of Addis Ababa and 98 km northwest of Dessie town, South Wello Zone.

According to WAOR (2013), the total area of the District is 105678 ha stretching from lowland to highland, much of it being in the mid-altitude ranges dominantly plateau plains. Average land holding size is one hectare per household (0.75 ha for crop production and 0.25 ha for grazing). Among the total area of the District, 24025 ha was covered by this study along toposequence which was mainly situated in plain areas with altitude ranges from 2600 to 3500 masl in the north, northwest and west from the center of the District town (Wegel Tena).

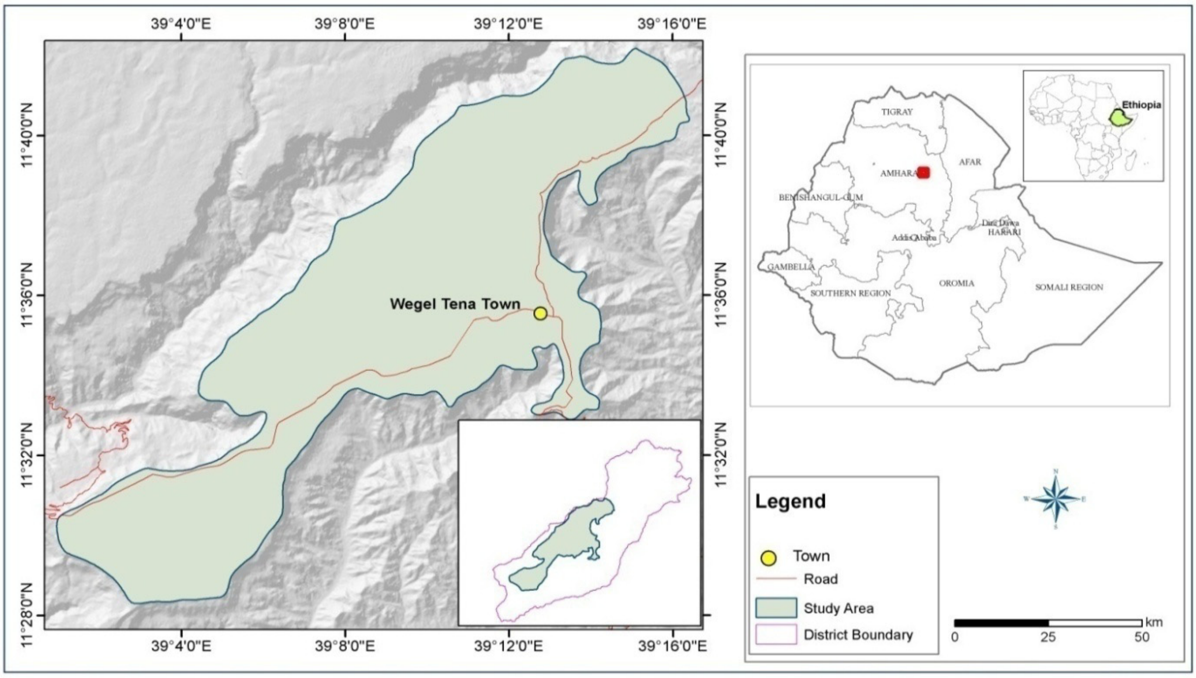

Figure 1. Location map of the study area

2.2 Geomorphology and Topography of the Study Area

The major landforms of the study area comprise extensive plateaus, chains of hills with mountainous ridge, oval in shape with dendritic drainage pattern, numerous convex hills at the plain area, river-valleys and very deep gorges at the boundary. About two-third of the area, embracing altitude ranges from 2100-3500 m, was highly populated. The remaining one third of the District is located mainly along the river valleys on the east, southeast, north and northwest location which range from 1500-2100 m. Topography of the highland plateaus especially; those are elevated above 3000 m which are dominated by chains of hills. According to WAOR (2013) reports, the general classification of the area is about 30% mountainous, 30% plains, 36.5% gorges and 3.5% other land features.

2.3 Climate and Land Use Systems of the Study Area

The traditional agro-ecological classification of the study area falls in all the categories that basically correlated with elevation. These are Kolla, Woina-dega, Dega and Wurch (Table 1). The climate of the area is characterized by dry seasons (October to February cold-dry and March to June hot-dry) and wet season (mid-June to September).

Table 1. Traditional agro-ecological zones (ACZ) of the northern ethiopian highlands

Traditional ACZ	Kolla	Woina-dega	Dega	Wurch
Elevation (m)	1500-1800	1800-2400	2400-3500	> 3500
Temperature (°C)	18-20	15-18	10-15	< 10
Rainfall (mm)	300-900	500-1500	700-1700	> 900
Dominant crop	Sorghum, maize	teff, maize, wheat	Barley, wheat	Barley

Adapted from Getahun (1984).

The rainfall pattern is bimodal with peak periods from mid-July to early September. For fifteen years (1999-2013) mean annual rainfall of the study area was about 812 mm of which 60-70% is received in summer (*Kiremt)* and 40-30% in the spring (*Belg*) seasons. The mean annual minimum and maximum temperatures are

6.8 and 19.6°C, respectively (Figure 2). People are living the upper topographic position and their farming activities primarily depend on spring (*Belg)* rains, whereas the middle and lower topographic positions rely on both the summer (*Kiremt)* and spring (*Belg)* rains. As a result, the small, erratic and unreliable rainfall, the area is prone to sporadic droughts.

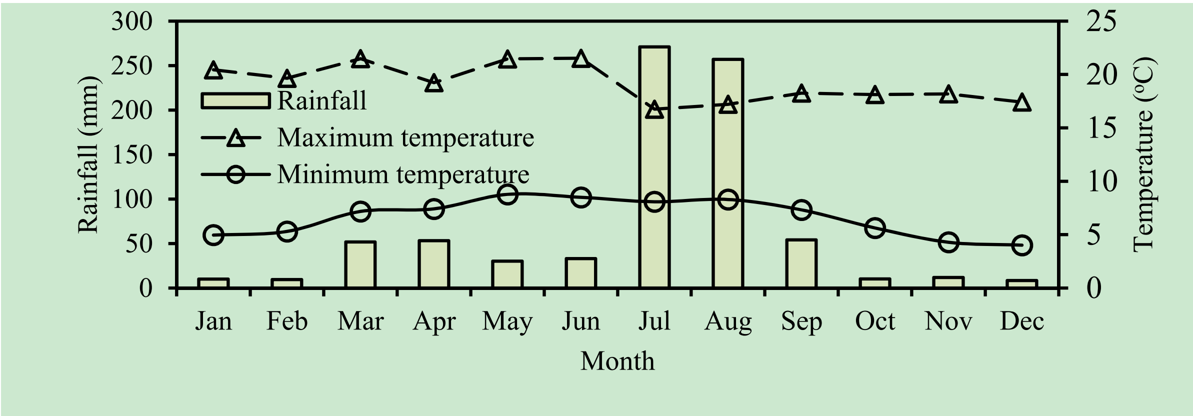

Figure 2. Mean monthly rainfall, maximum and minimum temperatures of the study area

The land use systems in the area are both private (farming) and communal (grazing) land holdings which can be identified through land use patterns. Cultivated and grazing lands are the major land use types in the area which account 22 and 8%, respectively. The largest proportion (45%) of the land in the study area is currently unutilized and the remaining (25%) is covered by shrub/bush, and natural and plantation forests. Agriculture is the predominant economic sector which is over 95% of the population engaged in this sector (WAOR, 2013). The farming system is both livestock and crop production which is characterized by subsistence agriculture. The overall farming system is strongly oriented on the way of crop production to sustain farmers' livelihoods. It is practiced using oxen and horses for land ploughing and threshing. Crop residues and intensive grazing are major livestock feed resources in the area.

The common rainfed crops grown in the area are bread wheat *(Triticum aestivum L.)*, food barley *(Hordenum vulgare* L.), faba bean (*Vicia faba L*.), lentil (*Lens culinaris L.*), grass pea (*Lathyrus sativus* L.), chickpea (*Cicer arietinum L.*) *teff* (*Eragrostis tef L.*) and sorghum (*Sorghum bicolor L.*). All these crops are managed using traditional techniques and equipment. Moreover, few types of vegetables, fruits, root crops and spices are also produced. Most of the arable land is under rainfed farming while very small area is under irrigation at the valley bottom or around riverbanks to produce vegetables and fruits (WAOR, 2013).

The natural woodland and vegetation of the study area has disappeared due to overgrazing, increasing demand for fuel-wood and conversion into cultivated lands. There are small patches of remnant natural forests are found on farm boundaries and around churches. Planted tree species like *Eucalyptus camaldulensis*, C*upressus lustanica, Acacia saligna* and A*cacia decurrens* are common around homesteads and conserved areas. The *Eucalyptus camaldulensis* plantations are replacing the arable/cultivated lands and expanding on backyards, stream banks and gully sides (WAOR, 2013).

2.4 Geology and Soils of the Study Area

Geology of the study area is characterized by the trap series of tertiary periods, similar to much of the central Ethiopian highlands (Mohr, 1971). As per Dereje *et al. (*2002), the area is covered by Oligocene rhyolite and very thick ignimbrite units encompassing predominantly of alkaline basalt with numerous inter-bedded flow of trachyte. The granite, gneisses and basalt rock types exist in the area forming part of the basement complex and most of the soils are basaltic parent material. Soils of the study area are greatly influenced by topography with high surface runoff during the main rainy season. There was no scientific studies in the area before this study except for FAO/UNDP (1984) small scale soil survey (1:1 000 000 scales) at the national level. The local people have traditionally classified the soils, namely *Walka or Mererie Afer* (Vertisols) in the plain area and *Nechatie or Gracha Af*er (Cambisols and leptosols) in steep slope or mountainous area.

2.5 Site Selection, Field Description and Soil Sampling

Before collecting soil samples, the existing land information were gathered from farmers and elders coupled with a visual observation in various parts of the district, obtaining base map (1:50,000 scale), preparing provisional map to identify mapping units and sites for the augur sampling. The survey technique was a free survey following a stratified sampling technique and transect was drawn from the crest to the foot along the toposequence. The altitude of the study site ranged from 2600 to 3500 masl and divided into three topographic clusters: upper (>3000 m), middle (2900 to 3000 m) and lower (<2900 m).The study area was covered by an approximately 1:50,000 scale topographic map produced by Ethiopian Mapping Agency to determine different land units on the basis of topography and other external land characteristics (roads, rivers, schools, faith sites). Topographic maps were also used for locating important land features to assist in soil mapping.

Thus, four land uses (natural forest, shrub, grazing and cultivated) were selected for assessing the influence of land uses on soil physicochemical properties at the three topographic positions. The previous land use history was gathered verbally from elder farmers. The natural forest which is owned by the Orthodox Church has no history of land use changes as it is well protected by the church. Some of the churches were established before the regime of Ahmed Ibrahim Aligazi ('Ahmed Giragn') like '*Kera Mariam', 'Tir Tiria Giyorgis'*, some of them have more than 100 years and others less than 100 years. The natural forests are found in the oldest churches and the recent churches have no natural forest. The cultivated land which was originally covered by natural forest has been continuously under cultivation for the rainfed farming. The grazing lands are communal livestock grazing fields which was dominated by grasses and some bush lands.

A total of 108 composite soil samples were collected from four land uses (natural forest, shrub, grazing and cultivated), three soil depths (0-20, 20-40 and 40-60 cm) and three topography (upper, middle and lower) using three replications. Representative plots (10 × 10 m) were located for each land use in *situ* along the toposequence. Within each plot soil samples were collected using augur from five different points (at the four corners and at the center of the plot). The soil samples were air dried and crushed to pass through 2 mm sieve for the physicochemical analysis except for total nitrogen and soil OC which was sieved through 0.5 mm. Moreover, undisturbed soil core samples of known volume were collected from each land uses to determine soil bulk density.

2.6 Laboratory Analysis

Particle size distribution was determined using hydrometer method (Bouyoucos, 1962). Bulk density (ρb) was determined by core-sampling method (Baruah and Barthakur, 1997). Particle density ($P\rho$) was measured with the liquid pycnometer method using de-aired water (Black and Hartge, 1986). Total porosity (f) was computed from the measurements of soil dry bulk density (ρb) and soil particle density ($P\rho$) as:

$$f = 1 - \left(\frac{\rho b}{P\rho}\right) \times 100 \qquad (1)$$

Soil pH was determined in H_2O (pH-H_2O) and 1M KCl (pH-KCl) using a glass electrode pH meter at the ratio of 1:2.5 soil to solution (Mclean, 1982). Electrical conductivity (EC) was determined using a conductivity meter in a soil-water extract method (Rowell, 1994). Organic carbon was analyzed by the wet digestion method (Walkley and Black, 1934). Soil organic matter was computed by multiplying soil OC by a factor of 1.724 (Baruah and Barthakur, 1997). Total nitrogen was determined by the micro- Kjeldahl digestion, distillation and titration method (Bremner and Mulvney, 1982). Available phosphorous was analyzed using the Olsen sodium bicarbonate extraction solution (pH 8.5) method (Olsen *et al.,* 1954) and the amount of available P was measured by spectrophotometer.

Cation exchange capacity and exchangeable cations were extracted by 1M ammonium acetate (pH 7) method (Van Reeuwijk, 1993). Exchangeable Ca and Mg were determined using atomic absorption spectrophotometer (AAS) and exchangeable K and Na by flame photometer. Percent base saturation was calculated as the sum of the base forming cations (Ca, Mg, Na and K) dividing by the CEC of the soil and multiplying by 100. Available micronutrients (Fe, Mn, Cu and Zn) were extracted by diethylenetriaminepenta acetic acid (DTPA) method and the reading was quantified using AAS (Lindsay and Norvell, 1978). The analyses were conducted at Haramaya University all parameters except exchangeable cations and micronutrients which were analyzed in Sirinka Agricultural Laboratory Center, all in Ethiopia.

2.7 Data Analysis

Land uses, soil depths and topographic positions were considered as main factors. The various data on soil physicochemical parameters were subjected to three-way analysis of variation (ANOVA) using the general linear model (GLM) procedure of statistical analysis system (SAS) software, version 9.2 (SAS, 2008) to find out whether variations in the soil attributes among land uses, soils depths and topographic positions were significant or not. The mean comparison was done using fisher's least significant difference (LSD) test at $P \leq 0.05$ significant level.

3. Results and Discussion

3.1 Land Use, Soil Depth and Topography Effects on Soil Physical Properties

3.1.1 Particle Size Distribution

Results of the statistical analysis reveal that particle size distributions were varied significantly at ($P \leq 0.05$) as a result of the main effects of land use and soil depth only (Table.2). Accordingly, the highest sand and silt contents were recorded in soils of the forest land and the surface layers, whereas the highest clay was found in soils of the cultivated land at the bottom layers. Although the statistical analysis showed significant differences contents of the three separates, the textural class remained the same across soils of the four land uses and three soil depths. Absence of textural class difference with soil depth in soils of all the lands uses indicates that the existence of weak translocation of materials within the soil system. The highest clay content observed in soils of the cultivated land could be attributed to the mixing of soil during tillage activities as was also reported by Heluf and Wakene (2006), Tematio *et al*. (2011), Aminu *et al.* (2013) and Aung *et al*. (2013).

Table 2. Land use, soil depth and topography effects on particle size distribution

Treatment	Particle size distributions (%)			Textural class
	Sand	Silt	Clay	
Land uses				
Forest (N) land	26.37a	27.46a	46.17d	Clay
Shrub land	24.92b	25.18b	49.90c	Clay
Grazing land	23.02c	22.20c	54.78b	Clay
Cultivated land	20.81d	20.44d	58.75a	Clay
LSD (0.05)	1.87	1.74	2.32	
Depth (cm)				
0-20	26.55a	27.33a	46.12c	Clay
20-40	24.19b	23.47b	52.34b	Clay
40-60	21.46c	19.53c	59.01a	Clay
LSD (0.05)	1.62	1.51	2.01	
CV (0.05)	14.10	13.66	8.19	

Means within a column followed by the same letter are not significantly different from each other at $P > 0.05$; Forest (N) = Natural forest; CV = Coefficient of variation and LSD = Least significant difference.

3.1.2 Bulk and Particle Densities, and Total Porosity

Mean bulk and particle densities, and total porosity of soils in the study area were different ($P \leq 0.05$) due to the interaction effects of land use by soil depth, while variation as a result of the interaction effect of the three factors was not significant ($P > 0.05$) (Table 3). Consequently, the highest (1.32 g cm^{-3}) and the lowest (1.16 g cm^{-3}) mean bulk density values were recorded at the 40-60 cm layer of the cultivated land soils and surface layer of the forest land soils, respectively. The lowest bulk density recorded at the surface layer of the forest land soils could be attributed to the relatively high organic matter contents, whereas the highest bulk density in the bottom layer of the cultivated land soils might be the result of compaction from repeated cultivation, low organic matter and weight of the overlying soil material. The lowest bulk density observed in soils of the forest land could be attributed to the high organic matter contents as was also reported by Eyayu *et al*. (2009) and Mojiri *et al*. (2012). The bulk density of the studied soils was fallen with the specified range as was suggested by White (1997) who revealed that bulk density is < 1 g cm^{-3} in high organic matter soils to 1.2 and 1.8 g cm^{-3} in sands and compacted horizons in clayey soils and it is largely affected by land uses and soil depth.

Table 3. Land use, soil depth and topography effects on bulk and particle densities and pore spaces

Treatment	Land uses			
Depth (cm)	Forest	Shrub	Grazing	Cultivated
		Bulk density (g cm^{-3})		
0-20	1.16e	1.20de	1.23cd	1.27bc
20-40	1.24bcd	1.25bcd	1.27bc	1.29ab
40-60	1.27bc	1.27bc	1.28abc	1.32a
LSD (0.05)	0.05	CV (0.05) 2.34		
		Particle density (g cm^{-3})		
0-20	2.59cd	2.65ab	2.67ab	2.68a
20-40	2.55de	2.57de	2.62bc	2.64ab
40-60	2.53e	2.55de	2.57cde	2.57cde
LSD (0.05)	0.05	CV (0.05) 3.75		
		Total porosity (%)		
0-20	58.55a	55.12b	52.62c	51.69d
20-40	50.73ef	49.44gh	51.85cd	50.14fg
40-60	48.98h	51.44de	50.38f	49.25gh
LSD (0.05)	0.91	CV (0.05) 4.73		

The highest (2.68 g cm^{-3}) and the lowest (2.53 g cm^{-3}) mean values of particle density were registered at the surface soils of the cultivated land and at the subsurface (40-60 cm) layers of the forest land soils, respectively. The highest particle density recorded at the surface layer of the cultivated land could be attributed to the subsequent cultivation and low bulk density, whereas the lowest particle density in the bottom layer of the forest land soils might be due to low organic matter contents and high bulk density. The particle density of the studied soils was fallen with the specified range as was rated by Hillel (2004) who revealed that the mean particle density of most mineral soils ranges from 2.50 - 2.75 g cm^{-3}, however the presence of iron oxide and heavy minerals are increased, but the presence of soil OM is decreased it.

The highest (58.55%) and lowest (48.98%) values of total porosity were recorded at the surface and subsurface (40-60 cm) layers of the forest land soils, respectively. These differences might be occurred due to the differences in bulk density. The highest total pore space at the surface layers in general and the forest land could be accredited by high organic matter contents and low bulk density as was also reported by Gupta (2004) and Brady and Weil (2008) who revealed that the amount of pore spaces and soil organic matter have inversely related to bulk density. All factors that affect soil pore spaces will also have effects on bulk density.

3.2 Land Use, Soil Depth and Topography Effects on Soil Chemical Properties

3.2.1 Soil pH and Electrical Conductivity

The variation of mean soil pH-H_2O and KCl as a result of the interaction effect of land use X soil depth X topographic position was significant ($P \leq 0.05$) (Table 4). The lowest pH-H_2O was registered at the surface layer of the forest land soils in the upper topographic position, while the highest was recorded at the 40-60 cm layers of the cultivated land soils at the lower topographic position. The lowest pH at the surface layer of the forest land could be the result of high organic matter content, while the highest pH in the bottom layer of the cultivated land could be the result of accumulation of basic cations. The range of soil-water pH interpretation was suggested by Jones (2003), the pH of the studied soils found between slightly acidic to neutral.

Table 4. Interaction effect of land use, soil depth and topography on soil pH and electrical conductivity

Treatment	Topographic position											
	Upper				Middle				Lower			
Land uses	Forest(N)	Shrub	Grazing	Cultivated	Forest(N)	Shrub	Grazing	Cultivated	Forest(N)	Shrub	Grazing	Cultivated
Depth (cm)	pH-H_2O											
0-20	6.13o	6.33mn	6.48jkl	6.26no	6.29mn	6.42klm	6.59f-h	6.39k-n	6.34lmn	6.52h-k	6.64e-i	6.45jkl
20-40	6.43k-m	6.58f-j	6.52h-j	6.66efg	6.53g-k	6.64e-i	6.52ijk	6.76e	6.57f-j	6.68efg	6.58f-i	6.78e
40-60	6.95d	6.66e-h	6.98dc	7.13abc	7.04bcd	6.73ef	7.02bcd	7.15ab	7.04bcd	6.78e	7.12bcd	7.26a
LSD (0.05)	0.15	CV (0.05)	5.96									
	pH-KCl											
0-20	5.12s	5.23rs	5.56j-m	5.26qr	5.32pqr	5.59jkl	5.86efg	5.39op	5.52lmn	5.78gh	6.05bc	5.58jkl
20-40	5.42nop	5.52klm	5.26qr	5.38op	5.69hi	5.97cbd	5.46mno	5.64ij	5.79gh	5.92def	5.59jkl	5.87efg
40-60	5.62ijk	5.33pq	5.58jkl	5.83fg	5.95cde	5.34pq	5.73hi	6.06b	6.06b	5.66ij	5.94de	6.18a
LSD (0.05)	0.11	CV (0.05)	6.27									
	ΔpH											
0-20	1.01f-j	1.09efg	0.92h-l	1.00f-j	0.98g-j	0.92g-l	0.79l-o	0.99f-j	0.84k-o	0.64pq	0.54p	0.87j-n
20-40	0.99f-j	1.06e-h	1.25bcd	1.29abc	0.84k-o	0.71po	1.04e-i	1.12def	0.78m-p	0.73nop	1.00f-j	0.92i-m
40-60	1.34ab	1.33ab	1.40a	1.32ab	1.10efg	1.37ab	1.32ab	1.07efg	0.99f-j	1.12def	1.16cde	1.08efg
LSD (0.05)	0.14	CV (0.05)	21.75									
	Electrical conductivity (dS m^{-1})											
0-20	0.074h	0.076gh	0.085g	0.011r	0.098f	0.103ef	0.134c	0.02o-r	0.111de	0.115d	0.132c	0.022nop
20-40	0.021n-q	0.049jk	0.026mno	0.029mn	0.022o-q	0.08gh	0.035lm	0.156b	0.023nop	0.049jk	0.056ij	0.154b
40-60	0.053ijk	0.013pqr	0.013pqr	0.017o-r	0.062i	0.02n-r	0.028mn	0.158b	0.033m	0.012qr	0.043lk	0.187a
LSD (0.05)	0.01	CV (0.05)	9.25									

Forest (N) = Natural forest; △pH = pH (H_2O – KCl); EC= Electrical conductivity

Results show that the highest pH-KCl was recorded at the 40-60 cm soil depth of the cultivated land in the lower topographic position, whereas the lowest was observed at the surface layer of the forest land in the upper topographic position. The highest pH-KCl observed at the deeper layer of the cultivated land at the lower topographic position could be attributed to the leaching of basic cations and soil erosion through tillage as was also reported by Fungo *et al.* (2011) and Kumar *et al*. (2012). The basic cations, CEC and pH have strong positive relations with each other.

In the studied soils, the highest electrical conductivity (EC) was registered in the bottom layer of the cultivated land soils at the lower topographic position, while the lowest was recorded in the surface soils of the cultivated land at the upper topographic position. This might be associated with leaching and soil erosion caused by continuous farming and removal of crop residues. In accordance with USDA/NRCS (2002) soil ratings, the EC of the studied soils was non-saline.

3.2.2 Soil Organic Matter, Total Nitrogen, C:N Ratio and Available Phosphorus

The mean soil organic matter content was significantly ($P \leq 0.05$) affected by the interaction effect of land use X soil depth, but no by the interaction effect of the three factors (Table 5). Following this, the highest mean organic matter content was recorded at the surface layer of the natural forest land soils, whilst the lowest was observed in the bottom layers of the shrub, grazing, and cultivated land soils. The intensive cultivation, which removes crop residue and intensifies oxidation of organic matter, and over grazing, which removes the sources of organic matter, might have resulted in low organic matter content in the study area as was also reported by Nega and Heluf (2009).

Similar to organic matter content, the mean total nitrogen content of the soils was also significantly ($P \leq 0.05$)

different among soils of the three land uses and soil depths due to the interaction effect of land use X soil depth, while it was not affected significantly (P > 0.05) by the interaction of the three factors (Table 5). This is expected because organic matter is the major source of soil organic matter and total nitrogen contents. Results indicate that conversion of the natural forest into cultivated land has resulted in loss of 80.4% of total nitrogen from the soils. Considerable loss of total nitrogen from soils following conversion of land from forest to cultivated land has been reported in many studies (Mulugeta *et al*., 2005; Eyayu *et al*., 2009; Mojiri *et al*., 2012). In consent with the trends observed in this study, various studies (Bahrami *et al*., 2010; Heshmati *et al*., 2011; Taye, 2011) reported lower total nitrogen content in soils of cultivated lands as compared to soils of natural forest lands.

Ratings were stated by Tekalign (1991), the organic matter and total nitrogen contents of the studied soils fall in the range of very low to high and low to medium, respectively at various land uses and soil depths along the toposequence. Most of the studied soils were less than 0.5% of total nitrogen which might be due to high rates of microbial decomposition and nitrogen transformation took place at the cultivated lands.

Table 5. Interaction effect of land use and soil depth on soil organic matter, total nitrogen, C:N ratio and available phosphorus

Treatment		Land uses			
Depth (cm)		Forest	Shrub	Grazing	Cultivated
			Soil organic matter (%)		
0-20		10.85a	6.83b	5.07c	3.26e
20-40		3.98d	2.18fg	2.30f	1.49hi
40-60		1.76gh	1.32hi	1.28hi	1.07i
LSD (0.05)	0.72		CV (0.05) 11.46		
			Total nitrogen (%)		
0-20		0.55a	0.54a	0.22b	0.11d
20-40		0.54a	0.23b	0.16c	0.08de
40-60		0.22b	0.17c	0.09de	0.06e
LSD (0.05)	0.04	CV (0.05) 8.75			
			C:N ratio		
0-20		12.29b	11.10bc	12.10b	11.29bc
20-40		11.02bc	9.40c	10.93bc	12.08b
40-60		11.89b	14.82a	15.03a	15.69a
LSD (0.05)	2.42		CV (0.05) 12.40		
			Available phosphorus (mg kg^{-1})		
0-20		24.96a	23.46b	20.85c	21.72c
20-40		13.27d	12.16d	6.15e	4.96ef
40-60		3.29gh	4.17fg	2.16hi	1.80i
LSD (0.05)	1.36		CV (0.05) 9.46		

C:N= Carbon to nitrogen ratio; LSD = Least significant difference; CV = Coefficient of variation; Means within a column followed by the sme letter have no significant differences (P > 0.05)

Being a derived parameter, the C:N ratio was also affected by the interaction of land use X soil depth only (Table 5) in which case the highest ratio was observed at the bottom layers of the shrub, grazing and cultivated land soils. These were also soils with the lowest organic matter and total nitrogen contents, implying that the proportional decrease in total nitrogen with soil depth was more than that of the organic matter. Except at the bottom layers of the grazing and cultivated land soils, the C:N ratio was within the normal range reported for mineral soils.

In general, the results obtained in this study indicate the deleterious impacts of over grazing and intensive cultivation on soil organic matter and total nitrogen contents of soils. This will negatively affect the fertility status of the soils, and thus, the agricultural productivity and sustainability. Measures that restrict limit over grazing of the grazing lands and add more organic matter into soils of the crop land should be practiced in the study area. Nevertheless, the effects of land use changes on soil organic matter and total nitrogen content did not vary on the different topographic positions.

The interaction effect of land use X soil depth on mean available phosphorus content was significant ($P \leq 0.05$), while the variation in topographic position and interaction effect of the three factors did not affect it significantly ($P > 0.05$) (Table 5). The highest (24.9 mg kg^{-1}) and the lowest (1.8 mg kg^{-1}) mean available P values were recorded at the surface layer of the forest land soils, and the bottom layers of the grazing and cultivated land soils, respectively. This clearly shows the significant contribution of the soil organic matter content to the P pool of the soils in the study area. In line with this, the positive effects of soil organic matter on available P, by forming organophosphate complexes that are more easily assimilated by plants and anion replacement of H_2PO from adsorption sites, were reported in different studies (Abebe and Endalkachew, 2012; Nega and Heluf, 2013; Yihenew and Getachew, 2013).

As per available P ratings of Cottenie (1980), the available P content of the studied soils falls in the range of very low to medium across the different land uses and soil depth along the toposequence. Murphy (1968), Tekalign *et al*. (2002) and Abebe and Endalkachew (2012) also reported low availability of P in most Ethiopian soils including Vertisols and attributed this to the effects of copious crop harvest, erosion, fixation and low accumulation of soil organic matter content.

3.2.3 Cation Exchange Capacity, Exchangeable Bases and Percent Base Saturation

The variation of mean exchangeable bases as a result of the interaction effect of the three factors (land use X soil depth X topographic position) were significant ($P \leq 0.05$) (Table 6). In general, the highest mean exchangeable Ca was found in the bottom layers of soils under the four land use types at the lower topographic position, whilst the lowest values were recorded at the surface layers of soils under the four land use types at the upper and middle topographic positions. This shows the existence of some erosion from the upper topographic position and subsequent deposition at the lower position and downward leaching of this cation within the soil system. The trends observed for the other exchangeable bases, however, were not consistent.

In the studied soils, Ca and Mg were the dominant cations. This is in agreement with the finding of Fassil and Yamoah (2009) who indicated that in neutral Vertisols the exchangeable sites are mainly occupied by Ca and Mg and to small extent by K and Na. Following exchangeable bases ratings suggested by FAO (2006), the soils were high to very high in their K, Ca, and Mg and low to medium in exchangeable Na.

The variation of mean cation exchange capacity (CEC) as a result of the interaction effect of land use X soil depth X topographic position were significant ($P \leq 0.05$) (Table 6). Following this, the highest mean CEC was registered in the bottom layers of soils under the four land use types at the lower and middle topographic positions, whereas the lowest values were observed at the surface layers of soils under the four land use types at the upper topographic position. The highest CEC in the bottom layers of all land uses at the lower and middle topographic positions could be the result of the high clay content accumulation, whilst the lowest CEC at the surface layers of all land uses at the upper topographic position could be the result of leaching and downward movement of clay particles as was also reported by Fassil and Yamoah (2009), Nega and Heluf (2009) and Deekor (2012). As per the ratings were suggested by FAO (2006), the CEC of the studied soils qualified in the range of high to very high across the different land uses and soil depth along the toposequence.

Results of the statistical analysis reveal that percent base saturation varied significantly ($P \leq 0.05$) as a result of the interaction effect of land use X soil depth X topographic position (Table 6). The percent base saturation values ranged from 64.22 to 87.08% at the surface layers and 65.44 to 94.85% at the bottom layers. The trends showed for the percent base saturation, however, were not constant due to the effects of exchangeable bases and cation exchange capacity.

Table 6. Interaction effects of land use, soil depth and topographic position on exchangeable bases, CEC and percent base saturation

Treatment	Topographic position (altitudinal ranges)											
	Upper				Middle				Lower			
Land use	Forest	Shrub	Grazing	Cultivated	Forest	Shrub	Grazing	Cultivated	Forest	Shrub	Grazing	Cultivated
Depth (cm)	Exchangeable Ca (cmol (+) kg^{-1})											
0-20	19.02tu	21.27o-r	19.13stu	18.93u	20.22q-u	23.39k-n	20.86p-t	20.73p-u	22.09n-q	27.38def	24.42i-m	21.32o-r
20-40	22.93l-o	19.25stu	19.97r-u	20.95p-s	23.57j-n	25.86f-i	22.86mo	25.76f-i	25.08h-k	19.44r-u	26.38e-h	26.07e-i
40-60	24.93h-k	27.28d-g	24.55h-l	26.14e-i	25.42g-j	27.51c-f	27.83b-e	29.15a-d	30.26a	29.54ab	28.67a-d	29.30abc
LSD (0.05)	1.88	CV (0.05)	4.80									
	Exchangeable Mg (cmol (+) kg^{-1})											
0-20	7.48pq	7.56opq	8.12k-o	7.69n-q	8.37i-m	8.54h-l	8.87e-i	9.03c-h	9.65bc	9.40cde	9.60bcd	8.59g-l
20-40	8.07l-p	8.61j-l	7.31q	8.99d-h	8.72f-k	10.34a	7.89n-q	8.21j-n	9.32c-f	9.41 cde	9.58bcd	9.18c-g
40-60	7.84m-q	7.84m-q	7.35q	7.89m-q	8.04l-p	7.52opq	9.55bcd	8.11k-o	10.55a	8.75f-j	8.24j-n	10.16ab
LSD (0.05)	0.62	CV (0.05)	4.42									
	Exchangeable K (cmol (+) kg^{-1})											
0-20	0.95ab	0.89a-e	0.94ab	0.96a	0.92a-d	0.79f-i	0.90a-d	0.92a-d	0.94ab	0.84d-g	0.90a-d	0.95a
20-41	0.92abc	0.85c-f	0.70k-n	0.93ab	0.78f-j	0.75h-l	0.73i-m	0.82e-h	0.88b-e	0.74i-m	0.77g-k	0.76h-l
40-60	0.79f-i	0.73i-m	0.69lmn	0.67mn	0.77g-l	0.69lmn	0.71j-n	0.64no	0.49p	0.73i-m	0.72i-m	0.58o
LSD (0.05)	0.08	CV (0.05)	6.57									
	Exchangeable Na (cmol (+) kg^{-1})											
0-20	0.31n-r	0.26qr	0.27pqr	0.24r	0.28o-r	0.28o-r	0.26qr	0.30n-r	0.52h	0.54gh	0.52h	0.51hi
20-40	0.40j-m	0.33m-p	0.33m-q	0.39j-m	0.35l-o	0.32n-r	0.36k-n	0.42jk	0.64de	0.54gh	0.57e-h	0.56fgh
40-60	0.45ij	0.42jk	0.43jk	0.44ij	0.44ij	0.60d-g	0.66d	0.62def	1.11a	1.04a	0.90b	0.73c
LSD (0.05)	0.07	CV (0.05)	9.20									
	Cation exchange capacity (cmol (+) kg^{-1})											
0-20	37.99no	37.03o	36.78o	37.10o	40.59k-n	38.99mno	39.10l-o	41.26klm	47.80fgh	42.22jkl	45.18hij	47.43gh
20-40	41.42klm	39.12l-o	40.87k-n	39.73k-o	47.86fgh	42.88ijk	46.72gh	45.50hi	49.83b-g	49.14d-g	49.25c-g	50.67a-f
40-60	44.82hij	42.06j-m	42.62ijk	48.79efg	47.64fgh	50.72a-f	51.62a-e	51.81a-e	52.37abc	52.09a-d	53.50ab	55.40a
SD (0.05)	3.16	CV (0.05)	4.29									
	% base saturation (%)											
0-20	64.77m	64.58m	69.36i-m	67.63klm	75.23g-j	84.82c-f	85.09c-f	79.33fg	77.98gh	87.08b-e	80.65efg	64.22m
20-40	68.83j-m	72.77h-k	66.21lm	76.47gh	79.46fg	92.54ab	76.90gh	76.89gh	72.17h-l	75.74ghi	67.31klm	77.83gh
40-60	72.10h-l	78.58fgh	81.49d-g	87.87bcd	76.20gh	88.97abc	94.85a	72.35h-k	76.20gh	66.88klm	65.44m	67.36klm
LSD (0.05)	6.55	CV (0.05)	5.30									

The factors that affect the basic cations also affect percent base saturation. As per percent base saturation ratings was suggested by Hazelton and Murphy (2007), the percent base saturation content of the studied soils qualified in the range of high to very high across the different land uses and soil depth along the toposequence.

3.2.4 Extractable Micronutrients

The variation of mean extractable micronutrients as a result of the interaction effect of the three factors (land use X soil depth X topographic position) was significant ($P \leq 0.05$) (Table 7). As a whole, the highest mean extractable micronutrients were recorded at the surface layer of the forest land soils at the upper topographic positions, whilst the lowest values were observed in the bottom layers of soils under the grazing and cultivated land use types at the lower and middle topographic positions. The highest values of micronutrients at the surface layer of the forest land could be the result of the high organic matter content, while the lowest values of micronutrients in the bottom layers of the grazing and cultivated land use types could be associated to high soil pH which might be due to the accumulation of basic cations.

Extractable Fe ranged from 2.43 to 8.42 mg kg^{-1}. The highest Fe value was found at the 0-20 cm soil depth of the forest land at the upper topographic position, whereas the lowest Fe was found at the 40-60 cm soil depth of the cultivated land at the middle topographic position. Extractable Mn ranged from 3.75 -7.19 mg kg^{-1}. The highest Mn was recorded at the surface soil of the shrub land at the upper topography and lowest at the 40-60 cm soil depth of the grazing land at the lower topographic position (Table 7). It seems that the Fe the highest values were related to the presence of high organic matter content. As per the ratings were suggested by Lindsay and Norvell (1978), most of the studied soils were medium to high contents of Fe and Mn. They were adequate for plant growths which are above the critical limit 4.5 mg kg^{-1} for Fe and 1 mg kg^{-1} for Mn.

Extractable Cu varied from 1.10-4.47 mg kg^{-1}. The highest Cu was recorded at the surface soils of the forest land at the upper topography and lowest at the bottom layers of soils of the grazing land at the middle topography. Extractable Zn ranged from 1.43-4.87 mg kg^{-1}. The rating was proposed by Lindsay and Norvell (1978), the values of extractable Cu and Zn were found in the range of adequate for normal plant growth which are above the critical limits (> 0.5 mg kg^{-1}) for Cu and (> 1.5 mg kg^{-1}) for Zn.

Table 7. Interaction effect of land use, soil depth and topographic position on extractable micronutrients

	Topographic position (altitudinal ranges)											
Treatment	Upper				Middle				Lower			
Land use	Forest	Shrub	Grazing	Cultivated	Forest	Shrub	Grazing	Cultivated	Forest	Shrub	Grazing	Cultivated
Depth (cm)	Mn (mg kg^{-1})											
0-20	7.19a	6.28cd	5.78ef	5.19h-k	6.82ab	5.63e-h	5.25hij	5.68efg	5.89de	4.94j-m	5.53e-i	5.09ijk
20-40	6.54bc	5.63e-h	5.08jk	5.05jkl	5.82e	5.35f-j	4.97j-m	5.12ijk	4.92j-m	4.79k-n	4.34o-s	4.55m-q
40-60	5.22h-k	4.09q-u	4.78k-o	4.62l-p	5.08ijk	4.43n-r	4.04r-u	3.87tu	4.19p-t	3.97stu	3.84tu	3.75u
LSD (0.05)	0.45	CV (0.05)	5.44									
			Fe (mg kg^{-1})									
0-20	8.42a	6.34fgh	6.80de	5.80ijk	7.48bc	7.05cd	6.57efg	6.17ghi	6.67def	7.56b	5.60jkl	5.05m-p
20-40	6.57efg	5.87ij	5.25lmn	5.42klm	5.10m-p	6.22ghi	3.93st	4.36rs	5.93hij	5.23lmn	4.04st	3.70tu
40-60	5.27lmn	5.16mno	4.78o-r	4.87n-q	4.60qr	3.99st	2.43v	3.96st	4.72pqr	4.06st	3.46u	3.27u
LSD (0.05)	0.43	CV (0.05)	5.02									
			Cu (mg kg^{-1})									
0-20	4.47a	3.75bc	3.72bc	3.58cd	3.99b	3.72bc	2.65g-j	2.63g-j	3.80bc	3.30de	2.67f-i	2.46ijk
20-40	3.54cd	3.30de	2.94fg	2.89fg	2.99ef	2.82fgh	2.40ijk	2.14klm	2.72f-i	2.43ijk	2.04lmn	2.33jkl
40-60	2.52hij	2.70f-i	2.01mn	1.79no	2.69f-i	1.83no	1.10p	1.63o	2.43ijk	1.92mno	1.74no	1.13p
LSD (0.05)	0.32	CV (0.05)	7.37									
			Zn (mg kg^{-1})									
0-20	4.87a	3.14def	2.34j-n	2.92e-h	4.00b	3.48cd	3.10def	2.67g-j	3.75bc	3.07d-g	2.93e-h	2.60h-k
20-40	3.28de	2.92e-h	2.44i-m	2.47i-l	2.90e-h	2.76f-i	2.20k-o	1.92n-r	2.27j-n	2.47i-l	1.84o-s	2.28j-n
40-60	2.48i-l	2.09l-p	2.07l-p	2.04m-q	2.39i-m	2.07l-p	1.80o-s	1.83o-s	1.63qrs	1.74p-s	1.60rs	1.43s
LSD (0.05)	0.42	CV (0.05)	10.02									

Means within a column followed by the same letter are not significantly differences at P > 0.05

4. Conclusion

The results show that the soils of the cultivated land in all topographic positions require more attention in order to sustain the agricultural activity in the area. The level of basic nutrients of soil organic matter, total nitrogen and available phosphorus in all sites are extremely low at the cultivated land soils as compared to others. This studies reinforce the sustainable crop production on these soils will require the maintenance of the productive potentials of the soils by cautious use of fertilizers and continuous use of compost, crop rotation, fallowing and intercropping leguminous crops with cereals. Moreover, the removal of crop residues on farm, the free grazing system and the current cropping practices on rugged and hill slopes to be ceased and changed into other land use systems.

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References

Abate, S. (2011). Evaluating the land use and land cover dynamics in Borena Woreda of south Wello highlands, Ethiopia. *Journal of Sustainable Development in Africa, 13*, 87-107.

Abebe, N., & Endalkachew, K. (2012). The contribution of coffee agro-ecotype to soil fertility in Southwestern Ethiopia. *African Journal of Agricultural Research, 7*(1), 74-81.

Amhakhian, S.O., & Achimugu, S. (2011). Characteristics of soil on toposequence in Egume, Dekina Local Government Area of Kogi State. *Production Agriculture and Technology, 7*(2), 29-36.

Aminu, Z., Yakubu, M., Mohammed, A. A., & Kumar, N. (2013). Effect of land use on soil quality in Suleja, Niger State, Nigeria. *Indian Journal of Leisure Science, 2*(2), 1-7.

Atofarati, S. O., Ewulo, B. S., & Ojeniyi, S. O. (2012). Characterization and classification of soils on two toposequence at Ile-Oluji, Ondo State, Nigeria. *International Journal of Agricultural Science, 2*(7), 642-650.

Aung, Z. O., Win, K. T., Nguyen, L., & Kimura, S. D. B. (2013). Toposequential variation in soil properties and crop yield from double-cropping paddy rice in Northwest Vietnam. *Journal of Cereals and Oilseeds, 4*(5), 65-75. http://dx.doi.org/10.5897/JCO2013.0109

Bahrami, A., Emadodin, I., Atashi, M. R., & Bork, H. R. (2010). Land use change and soil degradation: A case study, North of Iran. *Agriculture and Biology Journal of North America, 1*(4), 600-605.

Baruah, T. C., & Barthakur, H. P. (1997). *A text book of soil analysis*. Vikas Publishing House. Pvt. Ltd. New Delhi, India.

Black, G. R., & Hartge, K. H. (1986). Bulk density: In methods of soil analysis part physical and mineralogical properties, 2nd Edition. *American Society of Agronomy Monograph, 9*, 363-376.

Bouyoucos, G. J. (1962). Hydrometer method improved for making particle size analyses of soil. *Agronomy Journal, 53*, 464-465. http://dx.doi.org/10.2134/agronj1962.00021962005400050028x

Brady, N. C., & Weil, R. R. (2008). *The nature and properties of soils* (14th ed.). The Iowa State, India: PVT. Ltd.

Bremner, J. M., & Mulvaney, C. S. (1982). Nitrogen total in methods of soil analysis. In Page A. L. (Ed.), *Method of soil analysis part 2. Chemical and microbial properties.* Soil Science Society of America, Madison, WI. USA.

Cottenie, A. (1980). Soil and plant testing as a basis of fertilizer recommendations. FAO soil bulletin 38/2. Food and Agriculture Organization of the United Nations, Rome, Italy.

Daniel, A. (2008). Remote sensing and GIS-based land use and land cover change detection in the upper Dijo River Catchment, Silte Zone, Southern Ethiopia. Working papers on population and land use change in central Ethiopia.

Deekor, T. N. (2012). Changes in soil properties under different land use covers in parts of Odukpani, Cross River State, Nigeria. *Journal of Environment and Ecology, 3*(1), 86-99.

Dinaburga, G., Lapins, D., & Kopmanis, J. (2010). Differences of soil agrochemical properties in connection with altitude in Winter Wheat. *Engineering for Rural Development*, 79-84.

Diress, T., Moe, S. R., Vedeld, P., & Ermias, A. (20100. Land use and land cover dynamics in Northern Afar rangelands, Ethiopia. *Agriculture, Ecosystems and Environment, 139*, 174–180.

Eyayu, M., Heluf, G., Tekaliign, M., & Mohammed, A. (20090. Effects of land use change on selected soil properties in the Tera Gedam Catchment and adjacent agro-ecosystems, Northwest Ethiopia. *Ethiopian Journal of Natural Resources, 11*(1), 35-62.

FAO (Foodand Agriculture Organization). (2006). Plant nutrition for food security: A guide for integrated nutrient management. Fertilizer and Plant Nutrition Bulletin16, Rome, Italy.

Fassil, K., & Yamoah, C. (2009). Soil fertility status and numass fertilizer recommendation of TypicHapluusterts in the Northern highlands of Ethiopia. *World Applied Sciences Journal, 6*(11), 1473-1480.

Fungo, B. S., Grunwald, M. M., Tenywa, B., Vanlauwe, & Nkedi-Kizza, P. (2011). Lunnyu soils in the Lake Victoria basin of Uganda: Link to toposequence and soil type. *African Journal of Environmental Science and Technology, 5*(1), 15-24.

Griffiths, R. P., Madritch, M. D., & Swanson, A. K. (2009). The effects of topography on forest soil characteristics in the Oregon Cascade Mountains (USA): Implications for the effects of climate change on soil properties. *Forest Ecology and Management, 257*, 1-7. http://dx.doi.org/10.1016/j.foreco.2008.08.010

Gupta, P. K. (2004). *Soil, plant, water and fertilizer analysis.* Shyam printing press, AGROBIOS publisher, India.

Hazelton, P., & Murphy, B. (2007). Interpreting soil test results: What do all the number means? Common wealth Scientific and Industrial Research Organization (CSIRO) publishing.

Heluf, G., & Wakene, N. (2006). Effect of land use and management practices on chemical properties of some soils of Bako areas, western Ethiopia. *Ethiopian Journal of Natural Resources, 8*(2), 177-197.

Heshmati, M., Abdu, A., Jusop, S., & Majid, N. M. (2011). Effects of Land use practices on the organic carbon content, cation exchange capacity and aggregate stability of soils in the Catchment Zones. *American Journal of Applied Sciences, 8*(12), 1363-1373. http://dx.doi.org/10.3844/ajassp.2011.1363.1373

Hillel, D. (2004). *Introduction to environmental soil physics.* Elsevier Academic Press, USA.

Jones J. B. (2003). *Agronomic handbook: management of crops, soils, and their fertility.* CRC Press, Boca Raton, Florida, USA.

Kumar, R., Rawat, K. S., & Yadav, B. (2012).Vertical distribution of physicochemical properties under different toposequence in soils of Jharkhand. *Journal of Agricultural Physics, 12*(1), 63-69.

Lindsay,W. L., & Norvell, W. A. (1978). Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of American Journal, 42*, 421-428. http://dx.doi.org/10.2136/sssaj1978.03615995004200030009x

Mclean, E. O. (1982). Soil pH and lime requirements. In Page A. L. (Ed.), *Method of soil analysis part 2. Chemical and microbial properties.* Soil Science Society of America, Madison, WI. USA.

Messay, M. (2011). Land use land cover dynamics in Nonno District, Central Ethiopia. *Journal of sustainable development in Africa, 13*(1), 123-141.

Mojiri, A., Aziz, H. A., & Ramaji, A. (2012). Potential decline in soil quality attributes as a result of land use change in a hill slope in Lordegan, Western Iran. *African Journal of Agricultural Research, 7*(4), 577-582.

Mulugeta, L., Karltun, E., & Olsson, M. (2005). Assessing soil chemical and physical property responses to deforestation and subsequent cultivation in smallholders farming system in Ethiopia. *Agriculture, Ecosystems and Environment, 105*, 373-386. http://dx.doi.org/10.1016/j.agee.2004.01.046

Murphy, H. F. (1968). A report on the fertility status and other data on some soils of Ethiopia, Experiment Station Bulletin No. 44, College of Agriculture Haile Sellassie I University, Dire Dawa, Ethiopia.

Nega, E., & Heluf, G. (2009). Influence of land use changes and soil depth on cation exchange capacity and contents of exchangeable bases in the soils of Senbete watershed, Western Ethiopia. *Ethiopian Journal of Natural Resources, 11*(2), 195-206.

Nega, E., & Heluf, G. (2013). Effect of land use changes and soil depth on soil organic matter, total nitrogen and available phosphorus contents of soils in Senbat watershed, western Ethiopia. *ARPN Journal of Agricultural and Biological Science, 8*(3), 206-212.

Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, L. A. (1954). Estimation of available phosphorous in soils by extraction with Sodium Bicarbonate. *USDA Circular, 939*, 1-19.

Reuter, H. I., Kersebaum, K. C., & Wendroth, O. (2005). Spatial and temporal variability of soil properties with respect to relief information. *Proceedings of Precision Agriculture 05*, Academic Publishers, the Netherlands.

Rowell, D. L. (1994). *Soil science method and application*: Addison Wesley Longman limited, England.

SAS (Statistical Analysis System). (2008). SAS user's guide: Statistical released version 9.2. SAS. Institute Int. Cary NC. USA.

Si, B. C., & Farrell, R. E. (2004). Scale-dependent relationship between wheat yield and topographic indices: A wavelet approach. *Soil Science Society America Journal, 68*(2), 577-587. http://dx.doi.org/10.2136/sssaj2004.5770

Taye, K. (2011). Chemical properties of wild coffee forest soils in Ethiopia and management implications. *Agricultural Sciences, 2*(4), 443-450. http://dx.doi.org/10.4236/as.2011.24057

Tekalign, M., Richter, C., & Heiligtag, B. (2002). Phosphorus availability studies on ten Ethiopian Vertisols. *Journal of Agriculture and Rural Development in the Tropics and Subtropics, 103*(2), 177-183.

Tekalign, T. (1991). Soil, plant, water, fertilizer, animal manure and compost analysis. *Working document No. 13. International Livestock Research Center for Africa*, Addis Ababa, Ethiopia.

Tematio, P., Tsafack, E., & Kengni, L. (2011). Effects of tillage, fallow and burning on selected properties and fertility status of Andosols in the Mounts Bambouto, West Cameroon. *Agricultural sciences, 2*(3), 334-340. http://dx.doi.org/10.4236/as.2011.23044

USDA/NRCS (United States Department of Agriculture/Natural Resources Conservation Service). (2002). Field indicators of hydric soils in the United States. In Hurt, G. W., White, P. M., & Pringle, R. F. (Eds.), *Version 5 in cooperation with the National Technical Committee for Hydric Soils, Fort Worth, TX.*

Van Reeuwijk, L. P. (1993). *Procedures for soil analysis* (4th ed.). International Soil Reference and Information Center, the Netherlands.

Walkley, A., & Black, T. A. (1934). An examination of digestion Jarett method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Science Society of American journal, 37*, 29-38. http://dx.doi.org/10.1097/00010694-193401000-00003

White, P. F., Oberthur, T., & Sovuthy, P. (1997). Soils used for rice production in Cambodia. A manual for their recognition and management. Manila (Philippines): International Rice Research Institute.

Yihenew, G., & Getachew, A. (2013). Effects of different land use systems on selected physicochemical properties of soils in Northwestern Ethiopia. *Journal of Agricultural Science, 5*(4), 112-120.

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