

Full Length Research Paper

Assessment of selected soil physicochemical properties on different land-use systems and landscape positions at Hamesa watershed, Wolayita zone, Southern Ethiopia

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The investigation was undertaken at Hamesa watershed of Wolayita Zone with the aim to assess the consequences of land-use systems and topography on the physical and chemical properties of selected soils. Surface soil samples taken at 0-15 and 15-30 cm depths from three land-use systems (enset, grassland and maize fields) were collected under three slope positions (upper, middle and lower). Both the clay and bulk density increased with depth, while total nitrogen (N), OC, available P and micro-nutrients (Fe, Zn, Mn, and Cu) decreased. On the landscape positions, increase in exchangeable Ca and K, pH, bulk density and available Mn down the slope was observed; whereas total N, OC, available P and available Fe showed decreasing trend down the slope. At 0-15 cm soil depth, grassland soils exhibited higher bulk density and lower porosity as a result of livestock movement which was compacted. Grasslands had higher OC and TN compared to the other two land-use systems, due to the accumulation of humus in the root system in the grassland. Application of household refuses and manure contribute to increasing available P, TN, Zn, Ca and K contents in enset farmland. On the contrary, maize land use had lower CEC, K, PBS, Mg, TN and OC, which might be due to crop removal, erosion phenomena, and excessive tillage activities. These results suggest that for sustainable crop production, proper management practices should be in place by considering different slope positions and land-use systems.

Key words: Land use system, slope position, physical, chemical soil properties.

INTRODUCTION

Soil is the most fundamental basis of life, as most of the requirements of life come from it. Copious expansion of life is found in an area that has fertile soil. Soil fertility has a connection with civilization in past history worldwide (Taffa, 2002). The quick rise in the world's population demands the increase in the production of fuel, food, and

fiber quantities from lands. Studies on the soil nutrient availability across landscapes have become a crucial point of ecological study (Benning and Seastedt, 1995). Landscape position and land use may be the dominant factors of soil properties under a hill-slope and small catchment scale, landscape positions influence runoff

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and soil erosion and consequently soil formation (Kosmas et al., 2000) Soil nutrient availability is a significant aspect of crop production control (Pastor and Post, 1986).

Soil properties mainly, soil texture and nutrient status, significantly differ along land use systems; whereas soil reaction (pH) do not vary, which is consistently affected by land use system (Lauber et al., 2008). For pasture land converted to cultivation, there was decrease in the soil OM, soil aggregation and the hydraulic conductivity; in terms of soil erosion, soils under cultivation were severely subjected to raindrops effects as compared to forest (Celik, 2005). The SOC, TN, and pH are low in agricultural land compared to rangeland and forest. Land reclamations and re-vegetation improve soil organic carbon and total nitrogen; there are higher SOC contents in afforested areas and natural forest (Lizaga et al., 2019).

Soil bulk density, available water content, organic matter, total nitrogen, available phosphorus, and CEC were major soil properties affected by slope positions in the central rift valley of Ethiopia (Yimer, 2017). In a similar way, soil moisture and soil chemistry could affect plant growth and distributions on certain ecosystems governed by topographic attributes (Yimer et al., 2006). Landscape positions were influenced by soil texture (clay content), organic carbon and CEC (Dessalegn et al., 2014; Negasa et al., 2017; Tellen and Yerima, 2018). In some cases, however, middle slope positions contain high levels of OC and TN in semi-arid small catchment on the loess plateau in China (Wang et al., 2001).

The study conducted at Delbo Atwaro watershed, Southern Ethiopia by Kiflu and Beyene (2013) shows that the highest values of soil pH, EC, phosphorus, Zn, K, Ca and PBS were obtained under enset farmland when compared to maize and grassland areas. Similarly, soils of cultivated lands have higher available phosphorus content; whereas exchangeable bases, OC and CEC were higher in grasslands (Beyene, 2017). Grasslands had higher Organic matter and nitrogen content as compared to agricultural land and agroforestry Soil P showed a significant variation between agroforestry and grassland (Panday et al., 2019). Reduction of OM, available phosphorus and porosity was observed as a result of the change of land use from forest to cultivation, while a reverse trend was examined for BD and pH (Bizuhoraho et al., 2018)

There were spatial distributions of soil properties influenced by topography and existed land uses. The study conducted by Hu et al. (2019) reveal that silt, OM and TN has higher values in cultivated lands; whereas shrublands has lower values in relation to topographic positions significant variations observed for clay, bulk density, organic matter, and total nitrogen. Forest land use has higher soil properties (OC, TN, and CEC), while relatively lower in cultivated land use system, along with toe-slope CEC, OM and TN values increased compared to the upslope position (Ezeaku and Eze, 2014). There are progressively increased inhabitants living in Southern

Ethiopia, which are difficult to feed with agrarian cultivation system. Landscape features in most parts of Ethiopia have influence on soil resources, including depth; thus, cultivation exercises aggravate the situation of reduced crop production. There is a need to improve these tendencies and this lies in the improvement of a long term development of the agricultural sector.

According to Ethiopia Mapping Authority (1998), classified soils in Wolayita zone is Nitisols, however, previous studies indicated that other soil orders, Ultisols, Inceptisols and Entisols (Mulugeta, 2006) do also exist in the Wolayita areas. In Ethiopia, Ultisols are some of the oldest, occupying most stable positions along with Oxisols, Alfisols, and soils of other orders on young or relatively less stable surfaces (Mesfin, 1998). The study of Hamesa watershed of South Ethiopia was characterized by undulated topography feature having varied slope conditions, and farmers practiced cultivation for long years directed to minimize the soil fertility and increased soil erosion. Hence, an integrated approach is needed for important soil nutrients in relation to topography and land use systems. Thus, this aim to assess identified physicochemical soil properties on different land use systems and topography.

MATERIALS AND METHODS

Description of the study area

Hamesa watershed is situated in Humbo Woreda, Wolayita Zone, Southern Nations, Nationalities and Peoples Regional State (SNNPRS) which was shown in Figure 1. The altitude of this Woreda is found between 1050 to 1500 meters above sea level and agro ecologically, it has Kola to Woinadega categories. Hamesa watershed has bimodal rainfall and its distributed peak months are between April and August for the last 30 years according to the national metrological agency report. The minimum and maximum temperatures are 25 and 32°C, respectively and average yearly rainfall ranges between 600 and 900mm. The major crops cultivated in the watershed are cereals (teff, maize, and sorghum), pulses (haricot bean and chickpea), and root crops (potato, sweet potato and enset).

The land use system selected for this research is enset (*Enset ventricosum*), since it has being cultivated for years in the watershed for major consumption crops, semi perennial that takes four to seven years to mature and requires continuous application of manure. In addition, it is drought-resistant. Household refuse and organic sweepings around the house are used on enset fields; this is to improve the physical structure and nutrient retention than for their nutrient content on homestead fields. Maize was selected as the second land use system since it is grown in most parts of the cultivated lands in the watershed. It is the major cereal in the watershed and it lacks application of cow dung and households refuses because the location is far from the homestead. Grassland was considered as the third land use system. It is kept for tethered feeding in the front yard and is used for the establishment of small private grazing plots at the edge of the farm is common.

Three slope positions (upper, middle and lower) were identified based on topography and altitude ranges: with each slope section, three land use categories were recognized (enset, maize, and grassland). These were taken into account with experiences of major farmers. Thus, there were nine sampling sites identified in

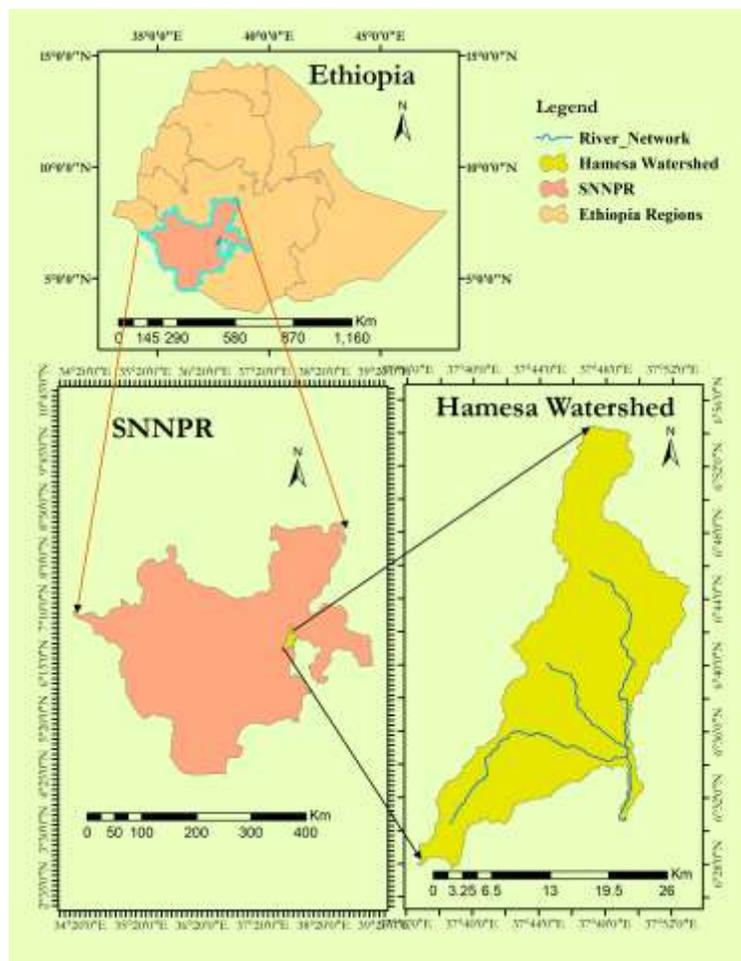


Figure 1. Hamesa Watershed Map.

order to collect soil samples from various land use and landscapes in Hamesa watershed. For each sampling sites, three soil samples were randomly collected from both depths (0-15 and 15-30cm), these samples were mixed in a plastic bucket to form a composite sample. All soil samples were air-dried, ground and to pass through 2 mm sieve for physicochemical analysis. Determine the total nitrogen and OC, a 0.5 mm sieve was used.

Laboratory analysis of soil properties

Soil particle size was determined using the hydrometer method (Sahlemedhin and Taye, 2000) and bulk density was determined by employing the core-sampling method (BSI, 1975). In order to determine total nitrogen content, Kjeldahl method was used as described by Jackson (1958) and the available phosphorus content of the soil was determined following the procedures of Olsen (Olsen et al., 1954)

Soil pH was measured following the procedures described by Sahlemedhin and Taye (2000) and wet digestion (Walkley and Black, 1934) was employed to determine organic matter content. Cation exchange capacity was extracted using ammonium acetate processes outlined by Van Reeuwijk (1993). Exchangeable bases were extracted with 1 M ammonium acetate, in the extract; exchangeable Ca and Mg were determined using atomic absorption

spectrophotometer (AAS) and exchangeable K and Na by flame photometer. The percentage base saturation (PBS) and exchangeable sodium percentage (ESP) were calculated using the Equations 1 and 2:

$$BS(\%) = \frac{Ca^{2+} + Mg^{2+} + K^{+} + Na^{+}}{CEC} \times 100 \quad (1)$$

$$ESP(\%) = \frac{Na^{+}}{CEC} \times 100 \quad (2)$$

Micronutrients (Cu, Fe, Mn and Zn) were determined following the procedures of diethylenetriaminepenta-acetic acid method; the extract was measured by AAS at different wavelengths (248.3, 279.5, 324.7, and 213.9 nm) respectively.

Statistical method

The soil data from three land use systems and three landscape positions were explored with SAS software (SAS, 1997) using a general linear model to separate mean differences (LSD) among

Table 1. Selected physical properties of soils (0-15 & 15-30cm depth) under three land use systems at Hamesa watershed.

Land use system	Particle size distribution (%)			Bulk density (g/cm ³)	Porosity (%)
	Sand	Silt	Clay		
0-15 cm depth					
Enset	61	26	13	1.007 ^a	62 ^a
Maize	50	31	19	1.087 ^b	58 ^{ab}
Grassland	54	25	21	1.173 ^b	55 ^b
15-30 cm depth					
Enset	63	29	18 ^b	1.160	56
Maize	52	25	23 ^a	1.187	55
Grassland	51	27	22 ^b	1.187	55

treatments at 5% and 1% significant levels, as per the requirements of statistical processes.

RESULTS AND DISCUSSION

Effects of land use types on soil physicochemical properties

Regarding soil textures variation recorded at both soils depths, in 0-15 cm depth enset farmland exhibited higher sand content followed by grassland and maize fields. Lower soil depth (15-30 cm depth) silt content was recorded in enset farmland had higher sand content followed by grassland and maize fields, on the contrary, higher clay content recorded in 15-30 cm of maize field (Table 1). The three land use systems had categorized as sandy loam textural class showed that land use system has no effect on soil texture since it is inherent soil physical property that might not change over a short period (Kiflu and Beyene, 2013). Continuous livestock movement for grazing purpose in grassland soils exhibit higher bulk density and lower porosity (Moges and Holden, 2008), whereas proper land management in homestead areas contributed to low bulk density and higher porosity in enset fields (Table 1)

At two soil depths, the soil pH ranged from very slightly acidic to slightly alkaline for the three land use systems at both depths described by London (1991). For the 0-15cm soil depth, enset field had higher soil pH followed by grassland and maize field (Table 2). This could be due to higher values basic cations owing to addition of household wastes; it is in agreement with the findings of Kiflu and Sheleme (2013).

The organic carbon content of grassland and maize fields were lower than enset field (Table 2). It varied from 1.93 to 3.07% for 0-15 cm and from 2.11 to 3.19% for 15-30 cm depth. Tillage frequency in maize field might be a possible reason for attaining lower OC on maize field (Kiflu, 2007). Grassland soils had higher OC compared to maize field. This might be due to the presence of humus

accumulation and roots in grassland (Elliot, 1986; Heluf and Wakene, 2006). Similarly, Woods and Schuman (1998) as well as Wakene (2001) found lower OC soils in cultivated land compared to grassland. Higher total nitrogen was recorded in the grassland compared to enset field at the 15-30 cm depth; this might be due to the strong relation of OM and TN (Ahn, 1993). At the 0-15 cm depth, on the other hand, enset field had the highest total N among other land use systems, which is in line with the finding of Boke (2004). There were significant differences ($P \leq 0.05$) of available P observed among various land uses. Enset field obtained higher values compared with grassland and maize fields (Table 2), this might due to the application of cow dung and household wastes and associated microbial activity (Boke, 2004; Fetene and Amera, 2018). The result is consistent with that of Kokate and Adilo areas according to Boke (2004), who found that available P was higher in enset field due to transformation processes of P, in another way application of P containing fertilizers also increase the availability of P on maize field (Van der Eijk et al., 2006). Regarding exchangeable K, enset field had higher values compared to grassland and maize fields; this might be due to the application of household refuse on the enset field; crop harvest and repeated tillage practices were responsible for the lower K in the maize field. Previous findings also indicated that weathering intensity and application K containing fertilizers influence the movement and circulation of K in the soil system (Saikh et al., 1998).

In a similar manner, enset field had the highest exchangeable Ca and Mg; while maize field has the lowest which might be due to crop removal and erosion phenomena ((Wakene, 2001) in the maize field. There were significant differences observed among land use types with regard to PBS of the soils ($P \leq 0.05$). For 0-15 cm depth, enset field has the highest PBS (79.3%) and the lowest recorded at maize field (63.5%); in 15-30 cm enset field had a higher value (80.6%), while grassland had the lower record (69.8%). In both soil depths, comparatively enset field had the highest PBS compared

Table 2. Selected chemical properties of soils (0-15 and 15-30 cm depth) under three land use systems at Hamesa watershed.

Land use system*	pH	OC	TN	Av.P	Exchangeable bases and CEC (cmol (+)kg ⁻¹)					ESP	PBS	Micronutrients (mg kg ⁻¹)			
					Na	K	Ca	Mg	CEC			(%)	(%)	Fe	Mn
0-15 cm depth															
Enset	7.08b	3.07 ^b	0.96	7.08 ^b	0.25	2.56	10.95	3.0 ^b	27.7	0.9	79.3 ^b	55.04 ^a	10.58	2.07	0.14
Maize	6.94a	1.93 ^a	0.49	2.82 ^a	0.11	2.28	10.05	2.8 ^a	20.0	0.6	63.5 ^a	16.79 ^c	9.17	1.90	0.05
Grassland	7.01b	2.35 ^a	0.55	4.91 ^a	0.28	2.35	10.29	2.9 ^b	28.3	1.0	57.1 ^a	32.97 ^b	10.76	2.15	0.07
LSD	0.240	0.290	0.310	11.760	0.337	0.456	0.124	0.256	3.906	0.148	11.070	0.250	0.150	0.226	0.413
15-30 cm depth															
Enset	7.00	2.62 ^a	0.54	6.51 ^b	0.17	2.42	10.83	3.01	20.7	0.8	80.6 ^a	35.13 ^a	12.52	1.94	0.08
Maize	7.01	2.11 ^a	0.42	2.08 ^a	0.26	2.60	10.15	2.96	24.1	1.1	64.3 ^b	23.83 ^b	9.49	2.18	0.09
Grassland	7.14	3.19 ^b	0.98	3.63 ^a	0.23	2.30	11.29	2.86	25.1	0.9	69.8 ^b	32.77 ^a	8.62	2.02	0.06
LSD	0.740	0.790	0.810	12.260	0.837	0.956	0.624	0.756	4.406	0.648	11.570	0.750	0.650	0.726	0.913

Means values within a column followed by the same letter (s) are not significantly different at $P < 0.05$. OC=Organic Carbon; TN= Total nitrogen; Av. P= available phosphorus; CEC= cation exchange capacity; PBS= Percent base saturation; ESP= exchangeable sodium percentage; LSD= least significant difference.

to other land use; indicating that enset field had better soil fertility status because of proper land management practices by local farmers. The CEC content recorded decrease in the order of grassland < enset < maize fields at 0-15 cm (Table 2); meanwhile several authors reported that CEC was positively correlated with organic carbon at surface soils (Kiflu and Sheleme, 2013; Kiflu, 2007; Wakene, 2001). To decrease depletion of land, the natural resources utilization appropriate land management in grasslands and maize fields has to be effective. Agricultural development work emphasized fertility parameters to boost crop production (Cade-Menun et al., 2017).

Various land use systems has affected soil micronutrients (Fe, Cu, Zn and Mn) in both soil depths ($P \leq 0.05$). For 0-15 cm depth, enset field has higher available Fe (55.04 mg kg⁻¹) followed by grassland (32.97 mg kg⁻¹). Similar result was achieved for 15-30 cm depth that is enset field (35.13 mg kg⁻¹) was higher compared to grassland

soils (32.77 mg kg⁻¹).

Reverse trends achieved in available Mn contents as compared to available Fe results in land use systems, had a greater value obtained in grassland compared to enset fields. In both depths, Mn concentration exceeds the critical values suggested by Lindsay and Norvell (1969), which were the deleterious level of the plants for three land use systems under study.

The highest concentration of available Zn (2.15 mg kg⁻¹) was found on the upper surface (0-15cm) of grassland followed by enset field (2.07 mg kg⁻¹); on the contrary, for maize, the lower depth (15-30 cm) had the highest available Zn (2.18 mg kg⁻¹) followed by grassland (2.02 mg kg⁻¹). The concentration of available zinc in enset, maize, and grasslands fulfilled the minimum requirements to support the plant growth (Havlin et al., 1999). At upper soil layer (0-15 cm) depth, available zinc concentration under maize filed was lowest when compared with the remaining two land uses; this

may possibly be due to continuous crop harvest and removal of topsoil by erosion that would be aggravated by tillage practices (Wakene, 2001). Enset fields had higher available Cu value attained. Compared with other land use systems (Table 2), there might be a strong positive relation copper with organic carbon. All land use systems in the study area were not sufficient to support plant growth based on values of available copper concentrations (Havlin et al., 1999).

Effects of slope positions on soil physicochemical properties

With regard to textural classification, clay content was consistently lowered when compared to silt and sand fractions in upper, middle and lower slope position. The middle slope position had higher sand content, but silt fraction recorded lower values (Table 3). Deposition of sediment

Table 3. Selected physical properties of soils (0-15 and 15-30cm depth) under different slope positions at Hamesa watershed (2010).

Slope positions	Particle size distribution (%)			Bulk density (g/cm ³)	Porosity (%)
	Sand	Silt	Clay		
0-15cm depth					
Upper	64 ^a	27	19 ^b	1.07 ^a	59
Middle	61 ^a	28	11 ^a	1.05 ^a	60
Lower	50 ^b	28	22 ^b	1.15 ^b	56
LSD	1.341	2.310	4.250	0.015	0.023
15-30cm depth					
Upper	51	30	19 ^a	1.15	57
Middle	59	23	18 ^a	1.22	53
Lower	46	28	26 ^b	1.16	56
LSD	2.120	3.420	5.150	0.034	0.041

Means values within a column followed by the same letter (s) are not significantly different at $P < 0.05$.

from the upper slope to middle slope contributed higher amounts of sand fraction. There was significant difference ($P \leq 0.05$) in clay; but silt and sand indicated clay fraction were easily transported to lower slopes resulting in sandy loam texture in the other two slope positions, while that of the lower slopes were sandy clay loam at both soil depths. For 15-30 cm depth, there is no significant difference on clay fraction at upper and middle landscape positions; however, great variations were observed in lower slopes. This result is in agreement with the previous study conducted at Umbulo catchment in Southern Ethiopia (Moges and Holden, 2008). The highest and lowest bulk densities were observed in lower and middle slope positions at 0-15 cm depth; this might be due to the variation in bulk densities, related to the contents of OC negatively and particle size distributions (Kiflu, 2007; Ellen and Yerima, 2018). Similar result was obtained in South Central Iowa of reconstructed prairies (Guzman and Al-Kaisi, 2011). Bulk densities of

surface soils decreased with increasing elevation, this is supported by Hanawalt and Whittaker (1976). Depth of 0-15 cm had higher bulk density (1.15 g/cm^3) measured at lower slope position, whereas lower BD (1.05 g/cm^3) in the middle slope position and significant variation is observed ($P \leq 0.05$). The attained bulk densities in the study area under three slopes position were lesser than the optimum ranges outlined in various researches (London, 1991). This could facilitate root growth and facilitate water and gas movements (Worku et al., 2017).

Soil pH has shown slight increment trends at 0-15cm soil depth from upper (6.6) to lower slope positions (7.2); indicating the removal of basic cations from the upper slope and laterally by runoff to down slope, increasing soil pH (Chen et al., 1997). Organic carbon and total nitrogen content significant differences ($P \leq 0.05$) were attained in the upper soil depth (0-15 cm) due to slope positions, and generally higher OC and TN were observed on the upper and middle slopes

compared to the lower slope position (Table 4). OC content increased with increase of elevation (Hanawalt and Whittaker, 1976); on the contrary, the research conducted by Guzman and Al-Kaisi (2011) indicated that organic carbon was lower at the middle slope compared to the summit and toe-slope positions. The highest available P (7.35 mg kg^{-1}) was recorded in the upper slope position, while the lowest (2.35 mg kg^{-1}) was recorded at the lower slope position of 0-15 cm depth. This increment may be attributed to the increment of OM content of soils along topo-sequence (Ahmed, 2002) and significant difference ($P \leq 0.01$) observed at 0-15 cm depth. CEC values of lower slopes were significantly ($P \leq 0.05$) different in the slope positions. The higher values were measured in the lower slope, followed by middle and upper slope positions (Table 4). This difference could be attributed to OC and clay (Moges and Holden, 2008). Generally, the highest exchangeable Na and K values were recorded in a lower slope position, whereas the lowest was measured in the

Table 4. Selected chemical properties of soils (0-15 and 15-30cm depth) under different slope positions at Hamesa watershed.

Slope positions*	pH	OC %	TN (%)	Av.P (mg kg ⁻¹)	Exchangeable bases and CEC (cmol (+)kg ⁻¹)					ESP (%)	PBS (%)	Micronutrients (mg kg ⁻¹)			
					Na	K	Ca	Mg	CEC			Fe	Mn	Zn	Cu
0-15 cm depth															
Upper	6.6	2.07 ^b	0.73 ^b	7.35 ^a	0.18	2.20	9.00	2.89	22.4 ^a	0.84	60	43.03 ^a	9.14 ^a	1.80	0.081
Middle	7.1	2.54 ^b	0.66 ^b	2.89 ^b	0.21	2.40	10.40	2.90	25.4 ^b	0.79	67	39.78 ^b	9.88 ^a	2.37	0.083
Lower	7.2	2.11 ^a	0.52 ^a	2.35 ^b	0.26	2.60	10.70	3.00	28.2 ^c	0.88	72	21.98 ^c	11.50 ^b	1.95	0.107
15-30 cm depth															
Upper	7.24	2.59	1.02 ^c	5.90 ^a	0.21	2.30	10.10	2.91	20.3	1.08	67	29.92	8.39	2.08	0.056
Middle	7.35	2.91	0.68 ^b	2.47 ^b	0.26	2.60	10.30	3.03	25.6	1.03	66	19.75	10.86	1.88	0.126
Lower	6.57	2.43	0.24 ^a	1.85 ^{ab}	0.18	2.70	10.60	2.88	24.2	0.78	80	21.98	11.38	2.18	0.062

*Means values within a column followed by the same letter (s) are not significantly different at $P \leq 0.01$; $P \leq 0.05$. OC=Organic Carbon; TN= Total nitrogen; Av. P= available phosphorus; CEC= cation exchange capacity; PBS= Percent base saturation; ESP= exchangeable sodium percentage; LSD= least significant difference.

upper slope positions; similar result was obtained in another area of Southwestern Ethiopia (Nigussie and Kissi, 2012). Regardless of slope positions and depths, the ESP values were lower than critical values (London, 1991). Higher amounts of exchangeable Ca and Mg were recorded at the lower slope positions of 0-15cm depth. The possible reason could be the movement of solutes from upper slopes and deposition on the lower slopes (Brubaker et al., 1993). PBS values followed the same trends as exchangeable cations concentrations at different slope positions. The highest available Fe content (43.03 mg kg⁻¹) was registered at the upper position, in contrast, the lowest available Fe (21.98 mg kg⁻¹) was observed at the lower positions of 0-15cm depth. On the other hand, the available Mn has shown an increasing trend from upper (9.14 mg kg⁻¹) to lower slope position (11.50 mg kg⁻¹) and significantly different ($P \leq 0.05$) at 0-15 cm depth (Table 4). The accumulation of manganese lower slope position might be due to the fact that it has easier reduction and solubility process than Fe. The lowest available Zn value (1.80 mg kg⁻¹) was measured in the upper slope position, while the highest (2.37 mg kg⁻¹) was recorded in the middle slope position at 0-15cm depth. The lowest available Zn value observed at upper elevation could be due to the removal of topsoil by sheet erosion. Considering available Cu, the distribution along with slope positions slight variations were observed (Table 4).

Conclusion

The results of this research achieved through representative surface soils collected under different land use indicate that most of the selected physical and chemical soil properties were impacted by types of land

uses in Hamesa watershed. Enset fields had higher values of pH, available Zn, exchangeable bases (K and Ca) and PBS when compared with the other two land use systems (Maize and grassland). Crop harvest and repeated tillage practices in maize fields were driving factors that contributed to having the lowest values of OC, TN, PBS, CEC, and exchangeable Mg. Moreover, the upper slope position had higher TN, OC, available Fe and P compared with other categories (middle and lower slope positions); whereas pH, available Ca, K, CEC, bulk density, and available manganese were higher at the lower slope positions in 0-15cm depth, suggesting the interaction effects of different land uses found in the three topographic positions considered in the study. The significant differences among soil properties in the study area indicates that land management practices should consider both land use changes and varied landscape features and for any natural resource management activities, soil properties should be considered. However, detailed studies on other areas should be conducted to examine the effects of climate, land management, soil types and other factors on soil properties, in spatial and temporal scales in addition to land use and topographic factors consideration.

CONFLICT OF INTERESTS

The author has not acknowledged any conflict of interest.

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