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Research Article

Effect of Land Use Types and Slope on Selected Soil Physicochemical Properties in Bubisa Watershed, Adea Berga District, Central Ethiopia

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Abstract

Soil physicochemical properties can be affected by different land use type in Ethiopia. The nutrient content of soil in the three sites was varied based on; soil management systems, organic inputs and other factors. Cognizant of this fact, research was conducted in Bubisa Watershed to evaluate the effect of different land use types and slope on selected physicochemical properties of soil. Accordingly, lands such as; crop, grazing and forest land were nominated and twenty seven (27) core and composite soil samples were collected from 0-20 cm layers. Soil analysis was done and the highest (1.29 g cm^{-3}) bulk density was recorded on the upper slope of crop land and lower (0.99 g cm^{-3}) on the lower slope of forest land. Total porosity and Available water holding capacity were high (60.02%; 172 mm/m) in forest land and lower (49.56%); 152 mm/m) in crop land respectively. Soil pH was high in forest land and low in crop land soils. The result of soil organic carbon and total nitrogen were also high (4.51%; 0.22%) in forest land and low (1.4; 0.15) crop land soils, respectively. Moreover, CEC and basic cations varied across the three sites and high in forest land and low in crop land in the study watershed. Based on the results, it was concluded that forest has high concentration of soil nutrients except bulk density than crop land. As recommendation, studies should be expanded to provide more conclusive recommendation to have qualified; productive soils and estimate the effect of land use types and slope on soil properties for sustainable agricultural productivity.

Keywords

Land Use, Slope, Soil Properties

1. Introduction

Land degradation leads to improper soil management practices and low soil fertility in large parts of Ethiopia [1]. The major causes are; deforestation, overgrazing, erosive rainfall patterns, no fallowing, removal of crop residues and low input of inorganic fertilizers and cultivation of crops on steep and fragile soils due to scarcity of land. The traditional farming practice that have been used during long term cultivations, limited awareness on soil and water conservation practice, inappropriate land use systems for crop production have aggravated the conditions [2].

The need of farming communities, environmental conditions, socioeconomic status, politics and cultural behaviors

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of the given area determine the land use types [3]. These influences the holder to choose the type of land uses to be used for different purposes. In the long run, soil degradation can be resulted in the decreasing of agricultural productivity, increasing of poverty and problem of attaining food security; which are key problems of the country in general and rural highlands as compared to the lowlands in particular [4].

Moreover, topography also plays a vigorous part in biogeochemical processes which achieves key environmental, economic and social purposes [5]. It modifies the soil-water content, amount of rainfall, drainage system, erosion, soil composition, and other soil properties that affect plant growth within a field and brought soil variability [6]. Topographic variability resulted in variable crop production systems through affecting land productivity by influencing soil properties [7]. In addition, exhaustive and incessant crop production without proper soil management resulted in decline soil fertility which exacerbates low production and food insecurity [8]. Furthermore, deforestation and cultivation of virgin soils often lead to exhaustion of essential plant nutrients such as N, P and S [9]. It also causes loss of soil OM and accelerated the rate of soil degradation. In such agriculture-based countries, reversing the declining of land productivity resulting from environmental dreadful conditions and ensuring adequate food supplies to the fast-growing population is a painful challenge.

Increasing crop production can be succeeded through improved soil fertility by addition of organic and inorganic inputs and optimal use of plant nutrients. Assessment of adequacy and requirement of plant nutrient is an imperative component of research for balanced use of nutrients from external sources [10]. Because of strong reliance of the country on agriculture as an economic driving force, soil resources should be managed in a maintainable way [11]. Hence, full consideration should be given to evaluate soil properties of the sites under different land use management systems.

The livelihood of communities at Bubisa watershed is based on agricultural activities. The watershed has low soil fertility status and less productive due to continuous crop production and deforestation associated with soil erosion and leaching which will make the efforts to increase crop production difficult. This problem may be improved through the inhibition of land degradation, restoration of the degraded areas and preparation of a rational land use planning for agriculture [12]. This indicate the importance of monitoring land use variations and estimate ecological replies of soils to land use fluctuations in Adea Berga district particularly at Bubisa watershed. In this esteem, little or no scientific information related to the size of land use type and its effect on soil properties in the study site. Therefore, the study was conducted with the objective of determining the effect of land use types and slope on selected soil physicochemical properties at Bubisa watershed.

2. Material and Methods

2.1. Description of the Study Area

2.1.1. Location and Area Coverage

The study was conducted at Bubisa watershed in Adea Berga district of West Shewa Zone, Oromia. The distance of the district is 67 km from Addis Ababa and bounded by Mulo and Sululta district on the East, Degem and Kuyu district on the North, Yaya Gulele district on the North East, Meta Robi district on the West and Ejere and Welmera district on the South. The geographical location of the study site is 9°12” to 9°37” North and 38°17” to 38°36” East and the total area coverage of Adea Berga district and Bubisa watershed are 94,995.5 and 206.3 ha, respectively.

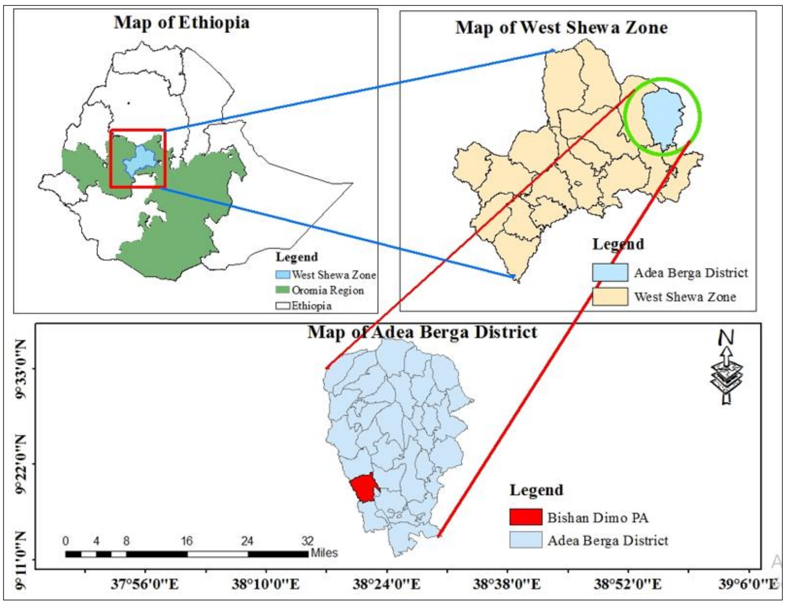

Figure 1. Location of Adea Berga district in Ethiopia.

2.1.2. Climate and Physical Features

Adea Berga district has three agro-ecological zones (Highland, Midland and Lowland). Midland dominates large areas of the study sites. The rainfall of the district is unimodal and its highest rainy season (80%) happens in summer starting from mid-June and ending in Mid-September whereas; the mean annual rainfall is 1180.5 mm. The minimum and maximum temperatures of the study area are 6.12 and 24.99 ℃, respectively. Bubisa Watershed is dominated by undulating land forms with diversified slope categories [13]. Its altitude ranges from 1160 to 3238 meters above sea level (masl).

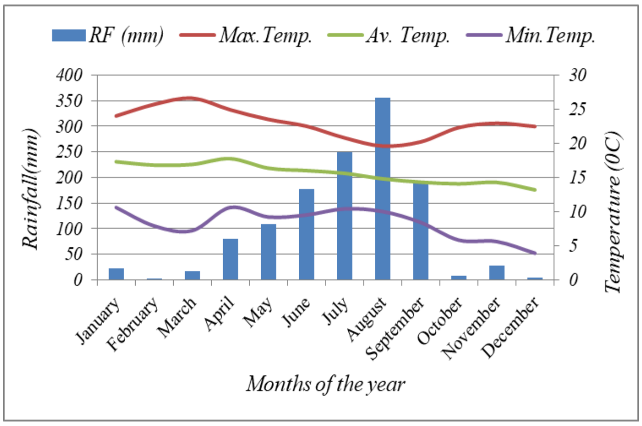

Figure 2. *Mean monthly rainfall and temperatures of Adea Berga district.*

2.1.3. Soil Types and Parent Materials

Vertisol is the major soil type covering large areas of Bubisa watershed and the parent material is basaltic [14]. These are heavy clay soils with high quantities of escalating clays (smectites). The smectite clays swell and shrink upon wetting and drying. During the dry season, the clay shrinks, becomes very hard and forms wide and deep cracks [15].

2.2. Study Approach and Source of Data

Spatial analogue method was designated to study the similarity and variability of different land uses types operating within a similar location and similar soil types for this study. Important data regarding to the study sites were collected. Primary data were collected through personal interviews with respondents and using questionnaire. Besides, secondary data were collected from various published and unpublished materials.

2.3. Site Selection and Soil Sampling

Three representative land use types (forest, grazing and crop lands) were identified in order to conduct the study in Bubisa watershed and each land use type was partitioned into three segments with their consecutive slopes [lower, middle and upper] for soil sample collection. A field area of 120 m x120 m size was assigned as sampling field for each slope positions of land use types based on a method applied by a study [16].

Hence, nine sampling sites for each land use types were randomly allocated and location of sampling sites were identified by using GPS. Core samplers and auger were used to collect core and composite soil samples from 0-20 cm respectively and a total of 27 composite and core soil samples were collected. One composite soil sample was made from the seventeen subsamples as shown in Figure 3 using ring or circle sampling method at 15 m radius from the center point.

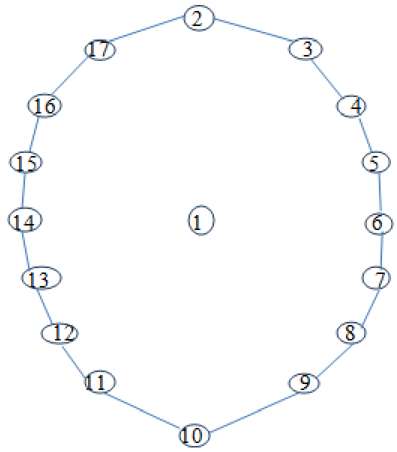

Figure 3. *Sub sampling positions.*

2.4. Soil Sample Preparation and Laboratory Analysis

Composite soil sample collected (500 g) were air dried; ground and laboratory analysis was done for both physical and chemical properties of soils at Oromia Engineering Corporation and Batu Soil Research Center. A 2 mm sieve and 0.5 mm sieve was used for total N and soil organic carbon content respectively, following standard laboratory soil analysis procedures.

2.4.1. Soil Physical Analysis

Soil particle size distribution was determined by the hydrometer method [17]. The soil was allocated to a textural class using the USDA soil textural triangle [18]. Bulk density was determined from core sample using core method [19]. Total porosity was computed from the values of bulk density and particle density [20]. To determine the AWHC of the soil, water content at FC and PWP were measured at -1/3 and -15 bars soil water potential, respectively, using the pressure plate apparatus [21]. The AWHC was obtained by subtracting water content at PWP from FC.

2.4.2. Soil Chemical Analysis

Soil pH was measured using pH meter at suspension of 1:2.5 (soil: liquid ratio) [22, 23] Soil organic carbon content was determined using wet digestion method. Total N was analyzed using the Kjeldahl digestion, distillation and titration method as described by [24]. Available soil P was extracted according to the standard procedure of Bray and Kurtz extraction method [25]. The P extracted with this method was measured by spectrophotometer following the procedures described by [26]. CEC and basic cations (Ca, Mg, K and Na) were determined after extracting the soil samples by ammonium acetate (1N NH4OAc) at pH 7. Exchangeable Ca and Mg in the extracts was analyzed using atomic absorption spectrophotometer, while Na and K were analyzed by flame photometer [27, 28]. Percent base saturation was calculated by dividing the sum of the charge equivalents of the base forming cations (Ca, Mg, K and Na) by CEC of the soil and multiplying by 100 [29].

2.5. Data Analysis

Descriptive statistics was used to analyze the data and comparisons of some soil physicochemical properties with their critical values were also done. Simple correlation analysis was also conducted by R statistical software version 3.5.3 [30] to identify useful relations between selected soil physicochemical properties.

3. Result and Discussions

3.1. Effects of Land Use Types and Slope on Soil Physical Properties

3.1.1. Particle Size Distributions

Soil texture is an intrinsic soil property less affected by management practices [31]. In this study, the highest (39.24%) and lowest (23.86%) values of sand content were obtained on the upper slope of crop land and forest land, respectively (Table 1). These high sand content of crop land might be related with no sand removal by erosion on the upper slope of cultivated land, where silt and clay contents were susceptible to erosion due to continuous cultivation down to the river and ponds. In agreement with this, [32] reported the highest sand percentage for crop land.

Silt content of the soil in the study area was high (41.64%) in forest soil and low (34.43%) in crop land soils (Table 1). This value might be recorded in forest land soils due to the shielding effect of forest to minimize soil erosion problems, the lowest mean of silt content in crop land might be due to soil loss as a result of erosion and high levels of soil weathering processes during tillage practices and subsequent conversion of silt fractions to clay through chipping (breaking) of silt by the effect erosion that could most possibly cause lower silt content in crop land. Agreement with the present result, [33, 34] also described the highest silt content in forest land than in cultivated land.

Moreover, the maximum (34.5%) and minimum (23.02%) value of clay was detected on the upper slope of the forest and crop land respectively (Table 1). This value recorded in crop land might be due to high leakage of clay down to the profile in cultivated site. This finding is similar with, [35, 36] who stated the highest clay content in forest land and the lowest in the cultivated land.

In terms of suitability for crop production (in cultivated land), loam soils are the most preferable soil for all farming communities due to its relatively proper composition of the three soil types sand (40%), silt (40%) and clay (20%) which is workable, moderately moisten and well aerated soil textural class [37, 38]. The dominant textural class of soils in the study area is clay loam based on the result of total surveyed sites (Table 1).

Table 1. *Mean of particle size distribution for the study area.*

Land use	**Slope (%)**	**Depth (cm)**	**Particle size distribution (%)**			***textural class***
			Sand	**Silt**	**Clay**	
Cultivated land	Upper	0-20	39.24	37.74	23.02	L
	Middle	0-20	36.4	35.77	27.83	L
	Lower	0-20	33.22	34.43	31.83	CL
Grazing land	Upper	0-20	35.3	35.28	29.42	CL
	Middle	0-20	32.53	35.92	31.54	CL
	Lower	0-20	31.92	37.22	30.86	CL
Forest land	Upper	0-20	23.86	41.64	34.5	CL
	Middle	0-20	29.06	40.3	30.64	CL

Land use	Slope (%)	Depth (cm)	Particle size distribution (%)			*textural class*
			Sand	Silt	Clay	
	Lower	0-20	35.28	34.95	30.29	CL

L= loam, CL = Clay loam

3.1.2. Bulk Density and Total Porosity of Soil

Soil bulk density is an indicator for compaction and soil health. It was considerably varied among the land uses in Bubisa watershed and the value ranges from 0.99-1.15 g cm^{-3} in forest land, 1.01-1.14 g cm^{-3} in grazing land and 1.21-1.29 g cm^{-3} in crop land (Table 2). Relatively, high (1.29 g cm^{-3}) and low (0.99 g cm^{-3}) mean value was obtained from the upper slope of crop and lower slope of forest sites respectively. This variation might be attributed to variation in their soil organic matter content, slope position and microbial activities. In general, forest soils with their comparatively highest soil OM content has lower bulk density.

The highest value observed on crop land might be due to low soil organic matter content as result of continuous cultivation (Table 2) and this can be confirmed by negative correlated (r= -0.77**) between soil BD and soil OC content in the study watershed (Table 5). In consistent with this finding, [39] reported the highest BD in plowing layer of crop land. The lowest soil BD obtained from forest land might be due to the fact that high addition of soil organic matter in forest land without fast decomposition processes as it was also reported by [40].

The ideal soil BD for plant growth was 1.1-1.2 g cm^{-3} for clay loam soils and 1.4 g cm^{-3} for loam soils as suggested by [41]. Thus, the highest BD value of cultivated site than these critical values indicates existence of soil compaction and strong bottleneck for most crop production in the watershed (Table 2).

In this study, the highest (60.02%) and lowest (49.56%) mean of TP was observed lower slope of the forest land and upper slope of crop soils, respectively (Table 2). The highest TP in forest land could be accredited by high OM, better aggregation and low BD of this land use. Agreement with this, [42, 43] also reported the highest TP of forest land due to its improved organic matter content than other land uses.

As suggested by [44], the ideal values of TP for crop production ranges from 50 to 60%. The TP of the soil was positively correlated (r = 0.78**) with soil OC and negatively correlated (r = -0.99**) with BD in the study watershed (Table 5). Similarly, [45] also reported the positive and negative correlation of TP with organic matter and BD, respectively.

3.1.3. Available Water Holding Capacity

The soil volumetric water content at field capacity and permanent wilting point as well as AWHC was found to be variable among the land uses considered for this study. Across the study sites, the soil volumetric water content at field capacity was ranged from 36.3-40.8% for crop site, 40.4-44.7% for grazing site and 44.8-46.8% for forest site. Similarly, the values of soil volumetric water content at permanent wilting point was ranged from 21.1-24.7% for crop site, 24.5-28% for grazing site and 28.5-29.6% for forest site. The computed values of available water holding capacity of soil under land uses were averaged between 152-161 mm/m, 159-167 mm/m, and 163 to 172 mm/m, respectively, for crop site, grazing site and forest site (Table 2).

The highest (46.8%, 29.6%) and lowest (36.3%, 21.1%) soil water content of this study were recorded at FC and PWP, respectively, from the lower slope of forest and upper slope of crop land uses (Table 2). Similarly, the highest (172 mm/m) and lowest (152 mm/m) AWHC was observed from the soils under forest and crop lands, respectively (Table 2). The highest AWHC for forest land might be due to high organic matter and clay content of forest land and the reverse for cultivated land. In agreement with this finding, [46] also observed the highest AWHC for forest land due to better accumulation of crop residues than other land uses. The lowest AWHC for crop land could be due to removal of plant residues from crop lands. Similarly, [47] reported that low available water holding capacity of crop land use due to removal of organic matter in different form from this land use.

As per rating by [48] the values of available water holding capacity of the watershed was categorized under medium class. Moreover, as suggested by [49] the optimal water holding capacity of soil for most crop production is greater or equal to 150 mm per meter depth.

Table 2. *Mean of BD, TP, FC and PWP of study area.*

Land use	SP	Depth (cm)	BD (gcm^{-3})	TP (%)	FC (%)	PWP (%)	AWHC (mm/m)
Cultivated land	Upper	0-20	1.29	49.56	36.3	21.1	152

Land use	SP	Depth (cm)	BD (gcm^{-3})	TP (%)	FC (%)	PWP (%)	AWHC (mm/m)
	Middle	0-20	1.23	53.59	39.5	23.7	158
	Lower	0-20	1.21	54.34	40.8	24.70	161
	Upper	0-20	1.14	56.98	40.4	24.5	159
Grazing land	Middle	0-20	1.04	57.63	42.5	26.1	164
	Lower	0-20	1.01	59.76	44.7	28.0	167
	Upper	0-20	1.15	56.73	44.8	28.5	163
Forest land	Middle	0-20	1.05	58.38	45.5	28.7	168
	Lower	0-20	0.99	60.02	46.8	29.6	172

BD= Bulk density, TP= Total porosity, FC= Field capacity, PWP= Permanent wilting point, AWHC= Available water holding capacity

3.2. Effect of Land Use Types and Slopes on Chemical Properties of Soils

3.2.1. Soil pH

Soil reaction (pH) characterizes the chemical properties of the soil and identifies the soil suitability for crop production. The soil pH varied with land use types and slope position. The pH values for this study were ranged between 5.65 and 6.51 on pH scale. The value under lower slope in forest site was highest (6.51 pH) and lowest (5.65 pH) value was noted on the upper slope of crop land surface soil, respectively (Table 3). The difference in soil pH could be due to variation in slope positions, organic residues, difference in vulnerability to surface erosion and difference in basic cations content.

The highest soil pH recorded for forest land attributed to the increase in soil organic matter and high accumulation of exchangeable bases and lowest value of soil pH under the crop land might be due to the diminution of basic cations in crop land and high microbial activities. This finding was similar to research finding by [50] who reported the highest soil pH in forest land. In line with this, [51] also reported highest rate of microbial activities in cultivated land that lower the organic matter content and pH of crop land.

As stated by [52] forest and grazing land uses were categorized under slightly acidic soil pH. According to [53] the ideal soil pH for crop production ranges from 5.6-7.5 and crop land is within the optimum pH for crop production.

3.2.2. Organic Carbon Content

Across the land uses, soil organic matter content was ranged from 1.4-2.43% in crop site, 2.23-3.02% in grazing site and 4.04-4.51% in forest site (Table 3). High (4.51%) and low (1.4%) content of soil OC was obtained from lower slope of forest field and upper slope of cultivated field respectively (Table 3).

As stated by [54], the soil OC of Bubisa watershed was categorized under low to medium class in crop site, medium class in grazing site and high class in forest site. Agreement with results [55] confirmed exhaustive cultivation results in fast oxidation of soil OM. Moreover, [56] informed the complete elimination of crop residues for animal feed caused low OM content in soils of Ethiopia. [57] Stated that most cultivated soils of Ethiopia are poor in OM content.

3.2.3. Total Nitrogen and Carbon to Nitrogen Ratio

In study area, the concentration of total N was differed among different fields (Table 3). Comparatively, high (0.22%) and low (0.15%) average of total N was observed on the lower slope of forest soils and upper slope of crop soils (Table 3). The ultimate source of variation among the land use type is soil OM content. The highest total nitrogen from forest soil could be attributed to relatively high OM and has positive correlation (r = 0.81**) soil OC (Table 5). Covenant with this [58] reported that, high mean of total N under forest site due to good microclimate, with moderate soil temperature and decreased loss of total N. Similarly, [59] also reported that soil OM is the source of total N content of soil which substitutes for about 95% of the total N.

Based on the ratings by [60], the total N under crop land was in medium class and [61] reported that the low OC input gained from the existence of crop production could not compensate N losses through OM mineralization, volatilization, de-nitrification and erosion in cultivated soils.

The soil TN varies not only with the land uses but also varied with the slope positions (Table 3). The TN of the soil increases from upper to lower slope in all the three land uses due to high removal of organic residues from upper slope and decrease in soil OM content. [62] Described that the highest mean of TN on lower slope positions.

C: N ratio is an important guide which shows either greater rate of nutrient mineralization (low C: N ratio) or immobilization (higher C: N ratio) [63]. It ranges from 9.33-11.57, 13.12-14.38 and 20.21-20.53, respectively, for crop field, grazing field and forest field (Table 3). Relatively, high

(20.53%) and low (9.16%) mean of C: N ratio was perceived in the soils of forest and crop land, respectively (Table 3). The highest and lowest C: N ratio might be due to high OC and rapid decomposition and improved aeration during tillage operation.

Moreover, narrow carbon to nitrogen ratio of crop land indicates high microbial activity. In agreement with this finding, [64] testified the lowest C: N ratio of crop field due to severe depletion of OM and continuous mining of soil N. Similarly, [65] also stated the highest value of C: N ratio for the forest land in the soils of Ethiopia. [54] Suggested the C: N ratio of crop site in the watershed was classified under low class.

The variation of C: N ratio with the slope position was observed among the study sites and high value of C: N ratio was verified under lower slope of forest soil, while, the lowest value was noted under the upper slope of crop land soil (Table 3). This might be due to high accumulation of soil OM content in forest land and accelerated rates of decomposition of organic residues in the cultivated land. [66, 67] also informed the highest and lowest C: N ratio under lower and upper slope of forest and crop land respectively (Table 3).

3.2.4. Available Phosphorus

Soil available P was fluctuated from 8.78-12.94 ppm (crop land), 5.08-6.95 ppm (grazing land) and 6.68-10.28 ppm (forest land). Accordingly, the highest (12.94 ppm) and lowest (5.08 ppm) available P was obtained from the crop land and grazing land, respectively (Table 3). High soil available P was noted for crop site might be the result of organic and inorganic fertilizers used in crop site. According to [68, 69] high available P for crop land might be because of fast mineralization from organic residues. As rating by [70] the available P of soil in the crop land and forest were varied from low to medium and low for grazing land (Table 3).

Consequently, the available P of the soil increases from upper to lower slope in all the three fields due to high accumulation in soil OC on lower slope (Table 3) and the relatively high clay content which might increase P fixation. In line with this, [71] reported that, the highest available P of crop land due to P containing fertilizer application, fast decomposition and mineralization of soil OM in crop land. Likewise, [72] testified the highest available P of cultivated soils due to p containing fertilizer applied to crop land.

Table 3. Mean values of pH, TN, OC, C: N and Av. P in the study area.

Land use	Slope positions	Depth (cm)	pH (H_2O)	TN (%)	OC (%)	C: N	Av. P (ppm)
Cultivated land	Upper	0-20	5.65	0.15	1.4	9.33	8.78
	Middle	0-20	5.75	0.17	1.76	10.35	11.01
	Lower	0-20	5.86	0.21	2.43	11.57	12.94
Grazing land	Upper	0-20	6.27	0.17	2.23	13.12	5.08
	Middle	0-20	6.39	0.17	2.26	13.29	6.16
	Lower	0-20	6.37	0.21	3.02	14.38	6.95
Forest land	Upper	0-20	6.22	0.20	4.04	20.21	6.68
	Middle	0-20	6.38	0.21	4.34	20.34	8.01
	Lower	0-20	6.51	0.22	4.51	20.53	10.28

pH= Power of hydrogen, TN= Total Nitrogen, OC= Organic Carbon, C: N= Carbon to nitrogen ratio, Av. P= Available phosphorus.

3.2.5. Cation Exchange Capacity

The study revealed that, soil CEC of the analyzed result shown dissimilarity among all land uses considered. The soil CEC of land uses were ranged from 19.47 to 22.39 Cmol $(_+)$ kg^{-1} (crop land), 21.49 to 21.66 Cmol $(_+)$ kg^{-1} (grazing land) and 22.85 to 23.22 Cmol $(_+)$ kg^{-1} (forest land) (Table 4). Relatively high (23.22 Cmol (+) kg^{-1}) and low (19.47 Cmol (+) kg^{-1}) value of CEC was observed for soils forest and crop land, respectively.

The highest soil CEC for forest land could be due to high clay percentage and OC confirmed by positive correlation (r=0.67**) with OM (Table 5). The research conducted by [73, 74] were in with this result and the highest CEC of forest land might be associated high OM content. Moreover, [75] stated that, CEC is high in forest land due to high soil OM, clay, pH and low in cultivated land.

The CEC of Bubisa watershed shown variation with slope and the highest and lowest mean values of soil CEC were recorded in lower slope of forest land and upper slope of crop land, respectively (Table 4). This might be due to high soil pH and OM content in forest land on lower slope and high removal of soil OM content by erosion as well as continuous leaching of basic cations and clay on upper slope in crop land as stated by [76].

3.2.6. Exchangeable Bases

Exchangeable bases are the most dominant cations present in many soils and surrounding the exchange sites of most soils. The basic cations of soil in study area exposed to variation for the land uses considered for this study. Relatively, the highest values of Ca (9.97 Cmol (+) kg^{-1}), Mg (2.98 Cmol (+) kg^{-1}), K (0.79 Cmol (+) kg^{-1}) and Na (0.25 Cmol (+) kg^{-1}) were recorded from forest land use soil, whereas the lowest values of Ca (7.51 Cmol (+) kg^{-1}), Mg (1.60 Cmol (+) kg^{-1}) and Na (0.13 Cmol (+) kg^{-1}) were registered from crop land use (Table 4).

The difference in OM, clay percentage, parent materials from which the soil is formed, slope and soil management practices used might be the reason for the variations in exchangeable basic cation content among the land uses under consideration (Table 4). Likewise, the highest soil basic cations (Ca, Mg, K and Na) verified at forest land might be due to relatively higher clay percentage and organic matter content of this land use. Similarly, [77] reported that high content of organic residues of forest land could protect loss of basic cations through leaching. In contrary, the lower bases recorded at crop land use might be attributed to lower organic matter contents and highest percentage of sand particle which contribute to rapid transport process of basic cations through leaching. Similarly, [78] reported lower concentrations of basic cations for soils under crop land due to low organic matter and high sand contents.

The exchangeable Na for soils under all land uses considered was categorized in low class. As suggested by [79], the ideal values of exchangeable Ca and Mg most preferable for crop production are ranged from 5 to 10 Cmol (+) kg^{-1} and 1 to 3 Cmol (+) kg^{-1}, respectively. With respect to this optimum value the values of Ca and Mg recorded for all land uses including crop land are found in this optimum value. Moreover, the optimum value of exchangeable K in the most for crop is 0.38 Cmol (+) kg^{-1}. In terms of this critical value, the content of exchangeable K under soil of crop land use is above this optimum for crop production.

From the fertility point of view, these three basic cations are not restricting nutrients to crop production. However, the results of this study indicating the existence of sufficient basic cations soil under crop land are for crop production. Similarly, [80] reported that crop responses to K fertilizations are rare in Ethiopia due to high exchangeable K content in many parts of the country. In contrary to this, [81] reported the low levels of exchangeable K in most acid soils of Ethiopia and the difference in these two findings might be due to difference in soil parent materials.

In all land uses the content of soil exchangeable basic cations increased with slope positions. Accordingly, high mean 9.97, 2.98, and 0.25 Cmol (+) kg^{-1} of bases (Ca, Mg and Na), are observed under the surface of lower slope of forest land. However, the lowest mean values 7.51, 1.6, 0.13 Cmol (+) kg^{-1} of bases (Ca, Mg, and Na), are recorded, respectively, from the upper slope of crop land. Similarly, [82] reported that the exchangeable bases were increased from upper to lower slope due to high accumulation of soil OM, clay content as eluviation of nutrients and organic material from upper slope to lower slope.

3.2.7. Percent Base Saturation

The soils under the three land uses at Bubisa watershed showed differences in percentage base saturation among the land uses. It was ranged between 51.52 to 54.62% in crop land, 55.79 to 57.25% in grazing land and 57.90 to 59.35% in forest land. The highest (59.35%) and the lowest (51.52%) mean of percentage base saturation were obtained from forest land and crop land, respectively (Table 4). The highest mean of percentage base saturation might be attributed to relatively high organic matter content and clay fraction which adsorbs basic cations against leaching. Similarly, [83] reported that high percentage base saturation due to high organic matter content.

Table 4. *Mean of CEC, Ca, Mg, K and Na of soil for study watershed.*

Units		cm	Cmol (+) kg^{-1}					%
			Means					
Land use	**Slope positions**	**Depth**	**CEC**	**Ca**	**Mg**	**K**	**Na**	**PBS**
Cultivated land	Upper	0-20	19.47	7.51	1.6	0.79	0.13	51.52
	Middle	0-20	20.69	8.3	2.1	0.70	0.15	54.37
	Lower	0-20	22.39	8.8	2.6	0.65	0.18	54.62
Grazing land	Upper	0-20	21.49	8.4	2. 61	0.84	0.14	55.79
	Middle	0-20	21.59	8.61	2. 62	0.66	0.16	55.81

Units		cm	Cmol $(_{+})$ kg^{-1} Means					%
Forest land	Lower	0-20	21.66	8.89	2. 81	0.51	0.19	57.25
	Upper	0-20	22.85	9.29	2.86	0.87	0.21	57.90
	Middle	0-20	23.12	9.68	2.93	0.64	0.23	58.31
	Lower	0-20	23.22	9.97	2.98	0.58	0.25	59.35

CEC= Cation Exchangeable Capacity, Ca= Calcium, Mg= Magnesium, Na= Sodium, K= Potassium, PBS= Percent Base Saturation

In general, soils in crop land of study area are fertile because many of the bases that contribute to higher percentage base saturation are essential macro plant nutrients as suggested by [84]. Based on the result obtained, the highest mean value of percentage base saturation was recorded in forest land and the lowest was recorded in cultivated land. This might be due to high OM and clay content of the forest field than grazing and crop field. [85] Reported the highest percentage base saturation in the forest land than crop land due to its higher basic cations. The percentage base saturation (PBS) followed the trend of exchangeable bases which varies with the slope positions. Percentage base saturation of the soil increased with increasing from upper to lower slope due to high accumulation of soil OM, clay content, basic cations and soil pH as eluviation of nutrients and organic material from upper slope to lower slope.

3.3. Pearson Correlation Matrix

Considering the Pearson correlation presented in Table 5, sand was highly and negatively correlated with organic carbon as well as, moderately and positively correlated with bulk density. Likewise, clay was moderately and positively correlated with available phosphorus and potassium whereas, BD was highly and negatively associated with TP, soil pH, total nitrogen, organic carbon, cation exchange capacity and calcium. Similarly, TP was highly and positively associated with OC and CEC.

Table 5. *Pearson's correlation matrix for soil properties.*

	Sa	Si	Cl	BD	TP	pH	TN	OC	Av. P	CEC	Ca	Mg	K	Na	PBS
Sa	1														
Si	0.71**	1													
Cl	-0.81**	-0.15	1												
BD	0.26	0.19	-0.21	1											
TP	-0.31	0.21	0.26	-0.99**	1										
pH	-0.44	0.07	0.56*	-0.76**	0.79**	1									
TN	-0.38	0.33	0.26	-0.74**	0.77**	0.65**	1								
OC	-0.61**	0.51*	0.43	-0.77**	0.78**	0.70***	0.81**	1							
Av. P	-0.31	0.23	0.24	-0.04	0.12	0.42	0.33	0.01	1						
CEC	-0.43	0.03	0.58*	-0.54*	0.58*	0.73**	0.67**	0.67**	0.02	1					
Ca	-0.41	0.04	0.54*	-0.57*	0.59*	0.72**	0.67**	0.78**	0.05	0.93**	1				
Mg	-0.36	0.51*	0.42	-0.31	0.33	0.53*	0.16	0.07	0.11	0.49*	0.42	1			
K	0.13	0.41	0.38	-0.87**	0.11	0.34	0.07	0.02	0.15	0.59*	0.45*	0.81**	1		
Na	-0.42	0.09	0.51*	-0.4	0.45*	0.56*	0.69**	0.63**	0.11	0.95**	0.89**	0.32	0.47*	1	
PBS	-0.44	0.02	0.60**	-0.37	0.40	0.60**	0.60**	0.67**	0.07	0.87**	0.95**	0.40	0.45*	0.89**	1

**Significant at P = 0.01 level; * significant at P = 0.05 level; Sa = sand; Si = silt; Cl = Clay

4. Conclusions and Recommendations

4.1. Conclusions

The result of this study has shown that, there was a variation in soil properties among the three land use types due to slope variations, management systems and tillage practices in the study area. In crop land, soil pH have shown lower mean value due to high leaching of basic cations down the profile and surface erosion as a result of continuous cultivation. Accordingly, forest land has higher soil nutrient content than other land use types due to high soil organic matter, high clay, low leaching and low soil erosion.

4.2. Recommendations

Based on the findings and conclusions of this study it can be recommended that, integrated soil fertility management, forest conservation and the use of conservation tillage increase soil productivity to feed the fast-growing population in the study area. Moreover, further studies are expected to have productive soils for sustainable agricultural productivity and feeding the fast-growing population.

Abbreviations

FAO	Food and Agriculture Organization
MASL	Meter above Sea Level
IUSS	International Union of Soil Science
WRB	World Reference Base
GPS	Geographical Positioning System
AWHC	Available Water Holding Capacity
FC	Field Capacity
PWP	Permanent Wilting Point
CEC	Cation Exchange Capacity
CL	Clay loam
OM	Organic Matter
BD	Bulk density
OC	Organic Carbon
TP	Total Porosity
SP	Slope Position
pH	Power of Hydrogen
TN	Total Nitrogen
C: N	Carbon to Nitrogen Ratio
AP	Available Phosphorous
PBS	Percent Base Saturation
Sa	Sand
Si	Silt
Cl	Clay

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Conflicts of Interest

The authors declare no conflicts of interest on the paper.

References

[1] Zajıcova, K. and Chuman, T. 2019. Effect of land use on soil chemical properties after 190 years of forest to agricultural land conversion. *Soil and Water Research*, 14: 121-131.

[2] Aytenew, M. and Kibret, K. 2016. Assessment of soil fertility status at dawja watershed in Enebse SarMidir district, Northwestern Ethiopia. *International Journal of Plant & Soil Science*, 11: 1-13.

[3] Abera, D. and Kefyalew, A. 2017. Assessement of physicochemical properties of soils as influenced by different land uses in Bedele area in Ilubabor Zone, Southwestern Ethiopia. *International Journal of Agriculture Innovations and Research*, 5: 319-473.

[4] Berhanu, S. 2016. Assessment of soil fertility status of Vertisols under selected three land uses in GirarJarso District of North Shewa Zone, Oromia National Regional State, Ethiopia. *Environmental System Research Journal*, 5: 1-16.

[5] Kibebew, K. and Mishra, B. B. 2017. Relevance of organic farming in Ethiopian agriculture: Mission and commitment with second green revolution. *Agriculture Research and Technology*, 10: 555-799.

[6] Zeleke, G., Agegnehu, G., Abera, D., and Rashid, S. 2010. Fertilizer and soil fertility potential in Ethiopia. Constraints and opportunities for enhancing the system. *International Food Policy Research Institute*, Addis Ababa, Ethiopia.

[7] Barua, S. K. and Haque, S. M. 2013. Soil characteristics and carbon sequestration potentials of vegetation in degraded hills of Chittagong, Bangladesh. *Land Degradation Development*, 24: 63-71.

[8] Habtamu, A., Heluf, G., Bobe, B. and Enyew, A. (2014). Fertility status of soils under different land uses at Wujiraba watershed, North-Western Highlands of Ethiopia. *Agriculture, Forestry and Fisheries*, 3: 410-419.

[9] Munoz, R. M., Jordán, A., Zavala, L. M., De La, R. D., Elmabod, S. K. and Anaya, R. M. 2015. Impact of land use and land cover changes on organic carbon stocks in Mediterranean soils. *Land Degradation Development*, 26: 168-179.

[10] Adesodun, J. K., Adeyemi, E. F. and Oyegoke, C. O. 2007. Distribution of nutrient elements within water-stable aggregates of two tropical agro ecological soils under different land uses. *Soil and Tillage Research*, 92: 190-197.

[11] FAO (Food and Agriculture Organization), 2017. Sustaining the future of agriculture in the land of a thousand hills. Food and Agriculture Organization of the United Nations (FAO).

[12] (12] Panwar, N. R., Ramesh, P., Singh, A. B. and Ramana, S. (2010). Influence of organic, chemical, and integrated management practices on soil organic carbon and soil nutrient status under semi-arid tropical conditions in central India Commun. *Soil Science and Plant Analysis*, 41: 1073-1083.

[13] FAO (Food and Agriculture Organization), 2006. Guidelines for soil description. 4rd Edition, Rome.

[14] IUSS and WRB, 2006. World Reference Base for Soil Resources: A framework for international Classification, Correlation and Communication. International Union of Soil Science, *World Soil Resource Reports*, No 103.

[15] Eylachew, Z. 2013. Properties of major Agricultural Soils of Ethiopia. Lambert Academic Publishing.

[16] Chapman, D. J., Richard, C., Bishop, W., Michael, H., Barbara, J. and *et al.* 2009. Natural Resource Damages Associated with Aesthetic and Ecosystem Injuries to Oklahoma's Illinois River System and Tenkiller Lake.

[17] Bouyoucos, G. J. 1962. Hydrometer method improvement for making particle size analysis of soils. *Journal of Agronomy*, 54: 179-186.

[18] Soil Survey Staff. 1999. A basic system of soil classification for making and interpreting soil survey. *Agricultural Handbook*. 436.

[19] Jamison, V. C., Weaver, H. H. and Reed, I. 1950. A hammer driven soil core sampler. *Soil Science*, 69: 487-496.

[20] Brady, C. N. and Weil, R. R. 2014. Soil Acidity. The nature and properties of soils, USA. 401-442.

[21] Klute, A. 1986. Water retention, Laboratory methods of soil analysis. Physical and Mineralogical Methods. Madison, WI, USA. *American Society of Agronomy*, 635-662.

[22] Peech, M. 1965. Hydrogen Ion Activity. In Black, C. A., *et al.*, Eds. Methods of Soil Analysis. *American Society of Agronomy*, 914-926.

[23] Walkley, A. and Black, C. A. 1934. An examination of different methods for determining soil organic matter and the proposed modification by the chromic acid titration method. *Soil Science*, 37: 29-38.

[24] Jackson, M. L. 1958. Soil chemical analysis. Prenstice Hall, Engle Wood Cliffs. New Jesey, 183-204.

[25] Bray, H. R. and Kurtz L. T. 1945. Determination of organic and available forms of phosphorus in soils. *Soil Science*, 9: 39-46.

[26] Murphy, J. and Riley, J. P. 1962. A modified single-solution method for the determination of phosphorus in natural waters: Analytical method of Chemical properties, 27: 31-36.

[27] Chapman, H. 1965. Cation exchange capacity by ammonium saturation. Black, C., Ensminger, L and Clark, F. (Ed.), Method of soil analysis, Madison Wisconsin, USA. *American Society of Agronomy*, 9: 891-901.

[28] Rowell, D. L. 1994. Soil science: Methods and applications. Addison Wesley Longman Limited. England. 350.

[29] Baruah, T. C. and Barthakur, H. P. 1997. A Textbook of Soils Analysis. Vikas Publishing *House Private Limited*, New Delhi. 256.

[30] R Core Team 2019. A language and environment for statistical computing; R Foundation for Statistical Computing, Vienna, Austria, http://www.R-project.org

[31] Lambin, E. F. and Meyfroidt, P. 2011. Global land use change, economic globalization, and the looming land scarcity. *Proceedings of the National Academy of Sciences*, 108: 3465-3472.

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

[33] Kundu, M. C., Das, T. and Biswas, P. K. *et al*. 2017. Effect of different land uses on soil organic carbon in new alluvial belt of West Bengal. *International Journal of Bioresource, Environment and Agricultural Sciences*, 3: 517-520.

[34] Mamo, Y. 2011. Influence of land use systems on selected soil physical and chemical properties at Agedit Watershed, South Gondar Zone, Amhara Regional State. MSc thesis, Haramaya University, Haramaya, Ethiopia.

[35] Eyayu, M., Heluf, G., Tekaliign, M. and Mohammed, A. 2010. Patterns of land use/cover dynamics in the mountain landscape of Tara Gedam and adjacent agro-ecosystem, northwest Ethiopia. *Ethiopian Journal of Science*, 33: 75-88.

[36] Tellen, V. A. and Yerima, B. P. 2018. Effects of land use change on soil physicochemical properties in selected areas in the North West region of Cameroon. *Environmental Systems Research*, 7: 3.

[37] Neris, J. 2012. Vegetation and land use effects on soil properties and water infiltration of Andisols in Tenerife. 98: 55-62.

[38] Miheretu, B. A. and Yimer, A. A., 2018. Spatial variability of selected soil properties in relation to land use and slope position in Gelana sub-watershed, Northern highlands of Ethiopia. *Physical Geography*, 39: 230-245.

[39] Tang, J., Davy, A. J. and Jiang, D. 2016. Effects of excluding grazing on the vegetation and soils of degraded sparse-elm grazing land in the Horqin Sandy Land, China. *Agriculture, Ecosystems and Environment*, 235: 340-348.

[40] Karltun, E., Tekalign, M., Taye, B., Sam, G. and Selamyihun, K. 2013. Towards improved fertilizer recommendations in Ethiopia; nutrient indices for categorization of fertilizer blends from Ethio-SIS woreda soil inventory data. *A discussion paper*.

[41] Hazelton, P. and Murphy, B. 2007. Interpreting Soil Test Results. What Do All the Numbers Mean? 2nd Edition. CSIRO Publishing.

[42] Rahman, M. R. and Hossain, M. B. 2015. Changes in land use pattern at ChakariaSundarbans mangrove forest in Bangladesh. *Journal of Bangladesh Research Publication*, 11: 13-20.

[43] Ezeaku, P. and Eze, F. 2014. Effect of land use in relation to slope position on soil properties in a semi-humid Nsukka area, Southeastern Nigeria. *Journal of Agricultural Research*, 52: 369-381.

[44] Chemada, M., Kibret, K. and Fite, T. 2017. Influence of different land use types and soil depths on selected soil properties related to soil fertility in Warandhab Area, Horo Guduru Wallaga Zone, Oromia, Ethiopia. *International Journal of Environmental Sciences and Natural Resources*, 4: 555-634.

[45] Patil, N., Pal, D., Mandal, C. and Mandal, D. 2012. Soil water retention characteristics of vertisols and pedotransfer functions based on nearest neighbor and neural networks approaches to estimate AWC. *Journal of Irrigation and Drainage Engineering*, 138: 177-184.

[46] Panday, D., Ojha, R. B., Chalise, D., Das, S. and Twanabasu, B. 2019. Spatial variability of soil properties under different land use in the Dang district of Nepal. *Cogent Food Agriculture Food Security*, 5.

[47] Damiani, M. L. 2016. Spatial trajectories segmentation, trends and challenges. *International Workshop on Mobile Geographic Information Systems*.

[48] Landon, J. R. 1991. Booker tropical soil manual: A Handbook for soil survey and agricultural land evaluation in the Tropics and Subtropics. *Longman Scientific and Technical, Essex*, New York.

[49] Mohanty, M., Sinha, N. K., Painuli, D. K., Bandyopadhyay, K. K., Hati, K. M. and Reddy, K. S. *et al*. 2015. Modelling soil water contents at field capacity and permanent wilting point using artificial neural network for Indian soils. *Natural Acadamic Science*, 38: 373-377.

[50] Takele, L., Chimdi, A. and Abebaw, A. 2014. Dynamics of soil fertility as influenced by different land use systems and soil depth in West Shoa Zone Gindeberet District Ethiopia. *Agricultural Forestry and Fisheries*, 3: 489-494.

[51] Lelisa, A. and Abebaw, A. 2016. Study on selected soil physicochemical properties of rehabilitated degraded bare land: the case of Jigessa rehabilitation site, Borana zone, Ethiopia. *Global Journal of Advanced Research*, 3: 354.

[52] Tekalign M. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. *International Livestock Research Center for Africa*, Addis Ababa.

[53] Gazey, C. and Davies, S. 2009. Soil acidity: A guide for WA Farmers and Consultants. Department of Agriculture and Food, Western Australia, Perth.

[54] FAO, (Food and Agriculture Organization), 2006a. Scaling Soil Nutrient Balances. Fertilizer and Plant Nutrition, Bulletin No. 15. FAO, Rome, Italy.

[55] Alemayehu, K. and Sheleme, B. 2013. Effects of different land use systems on selected soil properties in South Ethiopia. *Journal of Soil Science and Environmental Management*, 4: 107-117.

[56] Siraj, B., Mulugeta, L. and Endalkachew, K. 2015. Soil fertility status and productivity trends along a toposequence: A Case of Gilgel Gibe catchment in Nadda Assendabo watershed, Southwest Ethiopia. *International Journal of Environmental Protection and Policy*, 3: 137-144.

[57] Yihenew, G. S. and Getachew, A. 2013. Effect of different land use systems on select physicochemical properties of soils in Northwestern Ethiopia. *Journal of Agricultural Science*, 5: 114-117.

[58] Gelaw, A. M., Singh, B. R. and Lal, R., 2014. Soil organic carbon and total nitrogen stocks under different land uses in a semi-arid watershed in Tigray, Northern Ethiopia. *Agriculture, Ecosystems and Environment*, 188: 256-263.

[59] Tolessa, T. and Senbeta, F. 2018. The extent of soil organic carbon and total nitrogen in forest fragments of the central highlands of Ethiopia. *Journal of Ecology and Environment*, 42: 20.

[60] Murphy, H. F. 1968. A report on fertility status and other data on some soils of Ethiopia. *Collage of Agriculture*, 551.

[61] Gebreslassie, Y. and Ayanna, G. 2013. Effects of different land use systems on selected physico-chemical properties of soils in Applied and Environmental Soil Science, Northwestern Ethiopia. *Journal of Agricultural Science*, 5: 112.

[62] Tesfahunegn, G. B. 2016. Soil quality indicators response to land use and soil management systems in Northern Ethiopia's catchment. *Land Degradation Development*, 27: 438-448.

[63] Tesfaye, M. A., Bravo, F., Peinado, R. Pando, V. and Bravo, A. 2016. Impact of changes in land use, species and elevation on soil organic carbon and total nitrogen in Ethiopian Central Highlands. *Geoderma*, 261: 70-79.

[64] Moges, A., Dagnachew, M. and Yimer, F. 2013. Land Use Effects on Soil Quality Indicators: A Case Study of Abo Wonsho Southern Ethiopia. *Applied and Environmental Soil Science*, 20: 1-9.

[65] Lemma, G. and Smit, G. N. 2008. Relationships between plant and soil nutrient status and position in the landscape on Vertisols of Ethiopia. *Journal of Plant and Soil Science*, 25: 119-126.

[66] Gebreyesus, B. 2013. Soil quality indicators response to land use and soil management systems in Northern Ethiopia's catchment. *Land Degradation Development*.

[67] Zhang, K., Dang, H., Tan, S., Cheng, X. and Zhang, Q. 2010. Change in soil organic carbon following the 'Grain for Green' programme in China. *Land Degradation and Development*, 21: 16-28.

[68] Wang, J., Fu, B. Qiu, Y. and Chen, L. 2011. Soil nutrients in relation to land use and landscape position in the semi-arid small catchment on the loess plateau in China. *Journal of Arid Environment*, 48: 537-550.

[69] Elias, E., 2019. Selected chemical properties of agricultural soils in the Ethiopian highlands: a rapid assessment. *South African Journal of Plant and Soil*, 36: 153-156.

[70] 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.

[71] Abebe, N. and Endalkachew, K. 2012. The contribution of coffee agro-ecosystem to soil fertility in Southwestern Ethiopia. *African Journal of Agricultural Research*, 7: 74-81.

[72] Muche, M., Kokeb, A. and Molla, E. 2015. Assessing the Physicochemical Properties of Soil under Different Land Use Types. *Journal of Environment, Analytical Toxicology*, 5: 309.

[73] Kizilkaya, R. and Dengiz, O. 2010. Variation of land use and land cover effects on some soil physicochemical characteristics and soil enzyme activity. *Zemdirbyste Agriculture*, 97: 15-24.

[74] Abebe, S., Hans, H. and Gete, Z. 2013. A review on soil carbon sequestration in Ethiopia to mitigate land degradation and climate change. *Journal of Environment and Earth Science*, 3: 187-200.

[75] Achalu, C., Heluf, G., Kibebew, K. and Abi, T. 2012. Status of selected physicochemical properties of soils under different land use systems of Western Oromia, Ethiopia. *Journal of Biodiversity and Environmental Sciences*, 2: 57-71.

[76] Usmael, M. 2016. Soil fertility assessment and mapping of Becheke Sub-Watershed in Haramaya District of East Hararghe Zone of Oromia Region, Ethiopia. MSc thesis. Haramaya University, Haramaya, Ethiopia.

[77] Kedir, A., Muktar, M. and Kibebew, K. 2016. Soil fertility assessment and mapping of spatial variability at Amareganda-Abajarso SubWatershed, North-Eastern Ethiopia. *East African Journal of Sciences*, 10: 1-14.

[78] Achalu, C. 2014. Assessment of the severity of acid saturations on soils collected from cultivated lands of East Wollega Zone, Ethiopia. *Science, Technology and Arts Research Journal*, 3: 42-48.

[79] FAO, (Food and Agriculture Organization), 2006b. *Guidelines for Soil Description*. Rome, Italy.

[80] Dagne, C. 2016. Soil characteristics in maize based farming system of Western Oromia, Ethiopia. *Journal of Energy and Natural Resources*, 5: 37-46.

[81] Birhan, A. 2017. Land use/land cover changes and their environmental implications in the Gelana sub-watershed of Northern highlands of Ethiopia.

[82] Bore, G. and Bedadi, B. 2015. Impacts of land use types on selected soil physicochemical properties of Loma Woreda, Dawuro Zone, Southern Ethiopia. *Science, Technology and Arts Research Journal*, 4: 40-48.

[83] Getachew, F. and Heluf, G. 2007. Characterization and fertility status of the soils of Ayehu Research Substation, Northwestern Highlands of Ethiopia. *East African Journal of Sciences*, 1: 160-169.

[84] Havlin, J. L., Beaton, J. D., Tisdale, S. L. and Nelson, W. L. 2009. Soil Fertility and Fertilizers: *An Introduction to Nutrient Management*, USA.

[85] Abreha, K., Heluf, G., Tekalign, M. and Kibebew, K. (2012). Impact of altitude and land use type on some physical and chemical properties of acidic soils in Tsegede highlands, northern Ethiopia. *Open Journal of Soil Science*, 2: 223-233.