Impact of land use types and soil depths on selected soil physicochemical properties in Fasha District, Konso Zone, Southern Ethiopia

Mengistu Tumayro* and Dereje Tesgaye
Department of Plant Science, Arba Minch University, P. O. Box 21 Arba Minch, Ethiopia.

Received 23 March 2020; Accepted 30 December 2020

Agricultural activities such as deforestation, continuous cultivation and intensive grazing cause deterioration of soil properties. This study was conducted with the objective to investigate the influence of land use types (cultivated, grazing and forest lands) and soil depths (0-15 and 15-30 cm) on soil properties. Eighteen composite soil samples were collected and analyzed using standard procedures and the data was subjected to statistical analysis software (SAS). The result showed the highest mean values of pH, OC, TN, C:N, AP, CEC and exchangeable bases (Ca, Mg, K and Na) under forest and grassland soils while the lowest values of these parameters were observed in cultivated soil. Clay content and bulk density of cultivated soil were significantly (P < 0.05) higher than uncultivated lands. The result also showed the significant (P < 0.05) decline of sand fractions, OC, TN, C:N and AP with soil depth while clay content, bulk density, and exchange bases (Ca, Mg, K and Na) significantly (P < 0.05) increased with soil depth. In general, the soil properties under the cultivated land are deteriorating compared to the soils under forest and grass lands. Therefore, to improve soil properties of cultivated soil, integrated implementation of conservative tillage, crop rotation, application of manures and residue addition to the land was suggested for the study area.

Key words: Cultivated land, forestland, grassland, land use types, soil properties.

INTRODUCTION

Land use practices such as deforestations, overgrazing and cultivation are known to have noticeable effects on soil properties (Biro et al., 2013). The impact of these changes varies depending on the use and management practices employed on the lands (Javad et al., 2014). Several studies reported that deforestation and cultivation of forestlands leads to depletion of soil organic matter, plant nutrients such as N, Ca, Mg, K, etc. and increase soil bulk density (Girma et al., 2012; Ovie et al., 2013; Teshome et al., 2013). These impacts, in turn, reduce the fertility of the soils. In Ethiopia, land use changes such as conversion of natural vegetation to cultivated land results in rapid nutrient depletion from the soils (Alemayehu, 2016). Intensive and continuous cultivation without proper land management has resulted in deterioration of soil physical, chemical and biological properties (Ragassa and Bekele, 2016). Getahun and Bobe (2015) reported that the amount of OM, TN and CEC in cultivated land have declined by about 76, 61 and 39%, respectively. Tesfahunegn (2016) found the highest soil organic
Tumayro and Tesgaye

Figure 1. Map of the study area.

matter, pH, total nitrogen, available phosphorus and clay under forest land as compared to cultivated land. Alemayehu and Assefa (2016) also obtained the lowest soil OM content, total nitrogen, CEC, pH and exchangeable Ca and Mg in cultivated land as compared to forest and grass lands.

In the present study area, Konso, shortage of land for cultivation and livestock grazing, low fertility of the soil and increasing population pressure are major agricultural constraints. As a result, natural vegetation was converted to cultivated and grazing lands. Cultivation is also carried out on steep slopes which accelerate soil erosion and soil fertility decline. This in turn, has exacerbated soil degradation and led to deterioration of soil properties. Therefore, this study was initiated with the objective to investigate the influence of different land use types and soil depths on soil properties.

MATERIAL AND METHODS

Description of the study area

The study was conducted at Fasha watershed located in the Konso District, Southern Ethiopia (Figure 1). Geographically it is located between latitudes 5° 15’ 0″ to 5° 56’ 0″ N and longitudes 37° 01’ 0″ to 37° 69’ 0″ E. The altitude of the area varies from 500 m to 2,000 m a.s.l. Rainfall of the district has a bi-modal pattern. The average annual rainfall is 750 mm. Temperature of the area ranges from 16.5 to 31.3°C (Figure 2). The soil of the area is developed from volcanic-sedimentary rocks characterized by rockiness nature with little soil alone (Hailu and Yohannes, 2011). The soil of the area varies from place to place and comprises six major soil groups namely Eutric Regosols, Lithosols, Chromic Vertisols, Eutric Nitosols, Chromic Luvisols and Eutric Fluvisols (Tesfaye, 2003). Topographically, the area comprises of a rugged landscape which is predominantly composed of many hills and steep slopes.

Soil sampling and laboratory analysis

Three major land use types (cultivated, grazing, and forest lands) were selected from the watershed as major land use types of the study area. Eighteen composite soil samples (3 land use types x 2 soil depths x 3 replication) were collected from 0-15 and 15-30 cm soil depths using an auger. Disturbed soil samples were used for analysis of particle size distribution, soil pH, OC, total N, available P, exchangeable bases (Na, K, Mg and Ca) and CEC whereas undisturbed soil samples collected by sharp-edged steel cylinders forced manually into soil for the determination of soil bulk density.

Soil particle size distribution was determined by the Boyceous hydrometer method (Bouyoucos, 1962; Van Reeuwijk, 1992). Soil bulk density was determined by the undisturbed core sample method (Black, 1965). The pH of the soils was determined in 1:2.5
soil-to-water suspensions (Van Reeuwijk, 1992). The Walkley and Black (1934) wet digestion method was used to determine soil organic carbon. Total nitrogen was determined using the Kjeldahl digestion, distillation and titration method as described by Black (1965). Available soil phosphorus was analyzed according to the standard procedure of Olsen et al. (1954) extraction method. Cation exchange capacity (CEC) and exchangeable bases (Ca, Mg, K and Na) were determined after leaching the soil samples with ammonium acetate (1N NH₄OAc) buffered at pH 7.0.

Statistical analysis

The data was subjected to mean comparison and correlation analysis using statistical analysis system (SAS, 2004). The least significance difference (LSD) test was used at $P < 0.05$.

RESULTS AND DISCUSSION

Soil physical and chemical properties

The result showed that sand and silt contents of cultivated land were significantly ($P < 0.05$) lower than that of forest and grassland soils. The clay content was significantly ($P < 0.05$) different across all land use types. The highest (59.85%) and lowest (55.45%) clay contents were recorded in cultivated land and grassland, respectively (Table 1). This might be due to breakdown of soil particles during intensive cultivation. In agreement with this finding Alemayehu and Assefa (2016) reported the highest and lowest clay content in cultivated and forest lands, respectively. The result also showed the declines of sand and silt contents from 0-15 to 15-30 cm while clay content significantly ($P < 0.05$) increased with depth. The highest clay content in sub-surface soil may be due to leaching of clay particles down the soil profile with percolating water and parent materials of the study area.

The bulk density was significantly ($P < 0.05$) affected by land use types and soil depths interaction (Table 2). The highest (1.33 g/cm$^3$) and the lowest (1.20 g/cm$^3$) bulk density was recorded in the cultivated land and grassland, respectively (Table 1). The higher bulk density...
of cultivated soil was due to compaction resulting from intensive cultivation, low organic matter content and more disturbances of soils under cultivated land than uncultivated land. Soils in the current study area are tilled several times a year (at least six times per year) as farmers of the area work hard and this may indirectly have contributed to increase in bulk density in cultivated land. Similarly, Mostafa et al. (2008) reported that soil under cultivation had higher bulk density than soils under forest and pasture. The result also showed significant (P < 0.05) declines with increasing soil layer due to the decrease in OM content with soil depth.

The pH of the soils varies from 6.23 to 6.9 as indicated in Table 1. The highest (6.9) was observed in forest land followed by grass land (6.85) while the lowest (6.23) was recorded in cultivated land as shown in Table 1. According to the rating by Berhnu (1980), the TN of the study area was rated as low because of continuous cultivation accelerates OM oxidation which leads to decline of OM on cultivated soils. The current result was in agreement with several findings such as Achalu et al. (2012), Habtamu et al. (2014), Arasa et al. (2015), Alemayehu and Assefa (2016) and Mengistu et al. (2017) who reported the high organic carbon in grassland and forest land than cultivated lands. Generally organic carbon significantly (P < 0.05) declines with increasing soil depth.

The TN of cultivated land was significantly (P ≤ 0.01) affected by land use types and soil depth interaction (Table 2). The highest (4.86%) was founded in surface layer of forest land while the lowest (1.36%) was recorded in sub-surface layer of cultivated soil. According to the rating of OM by Berhnu (1980), the OC contents of the study area were rated as medium for grass and forest lands and low for cultivated land. In forest and grassland, high vegetation covers or above ground biomass, high root biomass and plant litter fall returned to the soil surface increases the fraction of OC in the soil of forest land. In cultivated land, cultivation enhances soil aeration which promotes rapid decomposition and oxidation of soil OM. Similarly, Alemayehu and Sheleme (2013) reported that continuous cultivation accelerates OM oxidation which leads to decline of OM on cultivated soils. The current result was in agreement with several findings such as Achalu et al. (2012), Habtamu et al. (2014), Arasa et al. (2015), Alemayehu and Assefa (2016) and Mengistu et al. (2017) who reported the high organic carbon in grassland and forest land than cultivated lands.

The pH of the soils varies from 6.23 to 6.9 as indicated in Table 2. Interaction effects of land use types and soil depths on soil texture, BD, pH, OC, TN, C:N and AP of the soil.

| Land use type | Depth (cm) | Soil texture (%) | BD (g/cm) | pH | OC (%) | TN (%) | C:N | AP (mg/kg) |
|---------------|-----------|------------------|-----------|----|--------|--------|-----|------------|
|               |           | Sand | Silt | Clay |           |         |     |            |
| Cultivated    | 0-15      | 31.93<sup>a</sup> | 10.97<sup>b</sup> | 56.10<sup>c</sup> | 1.31<sup>a</sup> | 6.20<sup>b</sup> | 2.58<sup>c</sup> | 0.14<sup>a</sup> | 17.92<sup>a</sup> | 3.12<sup>c</sup> |
|               | 15-30     | 26.00<sup>c</sup> | 9.47<sup>c</sup> | 63.60<sup>a</sup> | 1.34<sup>a</sup> | 6.27<sup>b</sup> | 3.16<sup>a</sup> | 0.12<sup>d</sup> | 11.70<sup>bc</sup> | 2.63<sup>c</sup> |
| Grass land    | 0-15      | 32.02<sup>a</sup> | 13.75<sup>a</sup> | 55.73<sup>cd</sup> | 1.21<sup>c</sup> | 6.83<sup>a</sup> | 3.66<sup>b</sup> | 0.30<sup>a</sup> | 12.10<sup>b</sup> | 4.06<sup>b</sup> |
|               | 15-30     | 31.00<sup>a</sup> | 12.33<sup>ab</sup> | 58.53<sup>b</sup> | 1.26<sup>b</sup> | 6.87<sup>a</sup> | 1.76<sup>d</sup> | 0.19<sup>b</sup> | 9.14<sup>d</sup> | 4.02<sup>b</sup> |
| Forest land   | 0-15      | 32.07<sup>a</sup> | 12.20<sup>ab</sup> | 54.23<sup>d</sup> | 1.19<sup>c</sup> | 6.90<sup>a</sup> | 4.86<sup>a</sup> | 0.29<sup>a</sup> | 16.35<sup>a</sup> | 5.47<sup>a</sup> |
|               | 15-30     | 28.47<sup>b</sup> | 13.00<sup>a</sup> | 56.67<sup>c</sup> | 1.22<sup>c</sup> | 6.93<sup>a</sup> | 1.91<sup>d</sup> | 0.19<sup>b</sup> | 9.96<sup>cd</sup> | 4.00<sup>b</sup> |
| LSD(0.05)     |           | 2.46 | 1.81 | 2.13 | 0.04 | 0.11 | 0.30 | 0.02 | 2.12 | 0.72 |
| CV (%)        |           | 4.46 | 8.31 | 2.04 | 1.59 | 0.93 | 6.11 | 4.70 | 9.05 | 10.25 |

Means with the same letters are not significantly different at P ≤ 0.05 LSD test; LSD=Least Significance Difference; CV=Coefficient of Variation; BD=bulk density; OC=organic carbon; TN=total nitrogen; C:N=carbon to nitrogen ratio and AP=available phosphorus.
comparing to uncultivated soils. Considering soil depth, the soil total nitrogen significantly (P < 0.05) decreased with increasing soil depth. This might be attributed to decrease in soil OM content with soil depth as shown in Table 4. The result also indicated highly significant (P ≤ 0.001) and strong positive associations (r=0.84) of TN with OC (Table 5). The current finding was in agreement with finding of Nega and Heluf (2013) who reported that the TN declines from surface to subsurface soils.

C:N ratio was significantly (P ≤ 0.05) affected by land use types and soil depths. The highest (14.81) was recorded in cultivated land followed by grassland (13.15) and forest land (10.62) (Table 1). Regassa and Bekele (2016) reported that when the C:N > 30:1, nitrogen is immobilized by soil microbes while if C:N < 20:1 there is a release of mineral nitrogen into the soil environment. Accordingly, the C:N of the soil of the study were below 20:1 range. This indicates the release of mineral nutrient to plant and soil environment. The result also indicated the significant (P ≤ 0.05) decline of C:N ratio with increasing soil depth. This attributed to the decline of OM and TN with soil depth as value of C:N ratio was calculated from the value of OC and TN. The result also showed significant (P ≤ 0.05) and positive correlation (r=0.57) of C:N ratio with OC (Table 5).

The result showed that AP was significantly (P ≤ 0.05) increases from cultivated land (2.87 mgkg⁻¹) to forest (4.04 mgkg⁻¹) and grassland (4.04 mgkg⁻¹). According to the rating by Landon (1991) AP of the study was less than 5 mgkg⁻¹, qualifying for the low range. This indicates the deficiency of P nutrient in the current study area. This might be due to low inherent P content of the parent material, and might also be due to high clay content which increases the retention capacity. Similarly, Brady and Weil (2002) reported that P in soil was constrained by the low total quantity and very low solubility. Contrarily, Mengistu et al. (2017) reported that AP was higher in cultivated land than other land uses due to continuous application of P. In the present study area there was no history of inorganic P fertilizer application. Considering soil depth, AP significantly (P ≤ 0.05) declines with increasing soil depth. This was probably due to type of parent material which may increase the fixation of the P beside the very small amount of the nutrient of soil. The result revealed that CEC of cultivated land was significantly (P ≤ 0.05) different from the CEC of grass land soil and forest soil. The low CEC in cultivated land was attributed to low OM, high leaching of basic cations and clay and uptake of basic cations like Ca and Mg by crops in cultivated land than uncultivated lands. According to the rating by Landon (1991) the CEC across land use types and soil depths were rated as medium. Nega and Heluf (2013) reported that soil CEC values in cultivated land uses decreased mainly due to the reduction in organic matter content. Similar finding was also reported by Woldeamlak and stroosnijder (2003), Habtamu et al. (2014) who reported the highest mean value of CEC in forest land and lowest in cultivated land. The finding also indicated positive and highly significant (P ≤ 0.01) correlation (r=0.65 and r=0.61) of CEC with exchangeable Ca and K, and significant (P ≤ 0.05) correlation (r=0.51 and r=0.55) with exchangeable Mg and Na.

The result showed that exchangeable bases (Ca, Mg, K and Na) of cultivated soils was significantly (P ≤ 0.05) lower than those of the forest and grassland soils (Table 4). This is mainly due to uptake of basic cations by crops, leaching and low organic matter in cultivated soils than uncultivated lands. Similar finding have been reported by Getahun and Bobe (2015). The result also showed the significant (P ≤ 0.05) increase of exchangeable bases (Ca, Mg, K and Na) bases from surface (0-15 cm) to sub- surface (15-30cm) soil depths as indicated in Table 3. This might be due to translocation of basic cations to lower layers. High clay content in the lower layer h increased the retention of

### Table 3. Main effects of land use types and soil depths on exchangeable bases (Ca, Mg, K and Na) and CEC.

| Land use types | CEC | Ca (Cmol(+)kg⁻¹) | Mg | K | Na |
|---------------|-----|-----------------|----|---|----|
| Cultivated land | 22.11<sup>b</sup> | 3.7<sup>c</sup> | 2.15<sup>b</sup> | 1.31<sup>c</sup> | 1.37<sup>b</sup> |
| Grass land | 28.71<sup>a</sup> | 5.41<sup>a</sup> | 3.10<sup>a</sup> | 2.70<sup>a</sup> | 2.26<sup>a</sup> |
| Forest land | 24.56<sup>ab</sup> | 4.5b<sup>a</sup> | 3.10<sup>a</sup> | 1.90<sup>b</sup> | 2.26<sup>a</sup> |
| LSD(0.05) | 6.06 | 0.16 | 0.27 | 0.41 | 0.32 |

Means with the same letters are not significantly different at P ≤ 0.05 LSD test, LSD = Least Significance Difference; SEM = Standard Error of Mean; CV = Coefficient of Variation; CEC = Cation Exchange Capacity.
Table 4. Interaction effects of land use types and soil depths on exchangeable bases (Ca, Mg, K and Na) and CEC.

| LUT | Depth   | CEC  | Ca    | Mg    | K     | Na    |
|-----|---------|------|-------|-------|-------|-------|
|     | (cm)    |      |       |       |       |       |
|     |         | (Cmol(+)kg\textsuperscript{-1}) |       |       |       |       |
| CL  | 0-15    | 18.83\textsuperscript{b} | 3.46\textsuperscript{f} | 1.84\textsuperscript{d} | 0.93\textsuperscript{d} | 1.22\textsuperscript{c} |
|     | 15-30   | 25.39\textsuperscript{ab} | 4.01\textsuperscript{e} | 2.45\textsuperscript{c} | 1.68\textsuperscript{c} | 1.52\textsuperscript{b} |
| GL  | 0-15    | 28.14\textsuperscript{ab} | 5.28\textsuperscript{d} | 2.83\textsuperscript{b} | 2.39\textsuperscript{c} | 2.01\textsuperscript{b} |
|     | 15-30   | 29.27\textsuperscript{ab} | 5.54\textsuperscript{c} | 3.36\textsuperscript{b} | 3.01\textsuperscript{c} | 2.49\textsuperscript{b} |
| FL  | 0-15    | 24.26\textsuperscript{a} | 4.25\textsuperscript{b} | 2.85\textsuperscript{a} | 1.75\textsuperscript{b} | 1.99\textsuperscript{a} |
|     | 15-30   | 24.86\textsuperscript{a} | 4.77\textsuperscript{e} | 2.39\textsuperscript{a} | 1.75\textsuperscript{b} | 2.53\textsuperscript{a} |
| LSD(0.05) | | 8.57 | 0.23 | 0.58 | 0.37 | 0.45 |
| CV (%) | | 18.76 | 2.80 | 16.34 | 7.46 | 12.65 |

Means with the same letters are not significantly different at P \( \leq 0.05 \) LSD test; LUT=Land Use Types; CL=Cultivated Land; GL=Grass Land; FL=Forest Land; CEC=Cation Exchange Capacity and LSD=Least Significance Difference and CV=Coefficient of Variation.

Table 5. Pearson's correlation matrix for selected soil physicochemical properties under different land use types and soil depths.

|      | BD    | pH    | OC    | TN    | C:N   | AP    | CEC   | Ca    | Mg    | K     | Na    |
|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| BD   | 1.00  |       |       |       |       |       |       |       |       |       |       |       |
| PH   | -0.88\textsuperscript{**} | 1.00  |       |       |       |       |       |       |       |       |       |       |
| OC   | -0.65\textsuperscript{*} | 0.37\textsuperscript{**} | 1.00  |       |       |       |       |       |       |       |       |       |
| TN   | -0.85\textsuperscript{**} | 0.72\textsuperscript{**} | 0.84\textsuperscript{***} | 1.00  |       |       |       |       |       |       |       |       |
| C:N  | 0.10\textsuperscript{NS} | -0.43\textsuperscript{**} | 0.57\textsuperscript{*} | 0.06\textsuperscript{ns} | 1.00  |       |       |       |       |       |       |       |
| AP   | -0.83\textsuperscript{***} | 0.75\textsuperscript{**} | 0.71\textsuperscript{**} | 0.78\textsuperscript{**} | 0.07\textsuperscript{ns} | 1.00  |       |       |       |       |       |       |
| CEC  | -0.29\textsuperscript{Ns} | 0.42\textsuperscript{**} | 0.06\textsuperscript{ns} | 0.22\textsuperscript{ns} | -0.30\textsuperscript{ns} | 0.26\textsuperscript{ns} | 1.00  |       |       |       |       |       |
| Ca   | -0.69\textsuperscript{**} | 0.84\textsuperscript{***} | 0.22\textsuperscript{**} | 0.44\textsuperscript{**} | -0.38\textsuperscript{**} | 0.06\textsuperscript{ns} | 0.63\textsuperscript{*} | 0.65\textsuperscript{**} | 1.00  |       |       |       |
| Mg   | -0.53\textsuperscript{*} | 0.83\textsuperscript{***} | -0.06\textsuperscript{ns} | 0.37\textsuperscript{ns} | -0.73\textsuperscript{**} | 0.41\textsuperscript{**} | 0.51\textsuperscript{*} | 0.81\textsuperscript{***} | 1.00  |       |       |       |
| K    | -0.59\textsuperscript{*} | 0.73\textsuperscript{**} | 0.06\textsuperscript{ns} | 0.34\textsuperscript{ns} | -0.50\textsuperscript{*} | 0.54\textsuperscript{*} | 0.61\textsuperscript{**} | 0.88\textsuperscript{***} | 0.71\textsuperscript{**} | 1.00  |       |       |
| Na   | -0.55\textsuperscript{*} | 0.80\textsuperscript{***} | -0.05\textsuperscript{ns} | 0.37\textsuperscript{ns} | -0.68\textsuperscript{*} | 0.47\textsuperscript{*} | 0.55\textsuperscript{*} | 0.76\textsuperscript{*} | 0.82\textsuperscript{***} | 0.78\textsuperscript{**} | 1.00  |       |

***= very highly significant; ** highly Significant at 1%; * Significant at 5%. Means with the same letters are not significantly different at P \( \leq 0.05 \) LSD test; LUT=Land Use Types; CL=Cultivated Land; GL=Grass Land; FL=Forest Land; CEC=Cation Exchange Capacity and LSD=Least Significance Difference and CV=Coefficient of Variation.

Conclusions

The result of this finding indicates that soil properties such as bulk density, soil pH, organic carbon, total nitrogen, available phosphorus, exchangeable bases (Ca, Mg, K and Na) and CEC are better under uncultivated (forestland and grassland) soils than cultivated soils in terms of soil fertility indicators. This indicates that conversion of natural forest and grasslands to cultivated soils diminishes soil quality. The changes in soil properties were not limited to surface soils but also the subsurface soils across the land uses. Integrated implementations of soil fertility improvement practices such as application of organic inputs, leaving crop residues after harvest and crop rotation of cereals with leguminous crops are also suggested to restore already degraded soil under cultivated lands. Finally, further researches addressing sustainable land management issues for the study area are needed.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

cations. In line with this finding, Mengistu et al. (2017) reported the increase in basic cation concentration with soil depth.

In line with this finding, Mengistu et al. (2017) reported the increase in basic cation concentration with soil depth.

Grassland and forest soils. The overall soil condition under the cultivated land is deteriorating and getting poor compared to the soils under the forest and grass lands. The changes in soil properties were not limited to surface soils but also the subsurface soils across the land uses. Integrated implementations of soil fertility improvement practices such as application of organic inputs, leaving crop residues after harvest and crop rotation of cereals with leguminous crops are also suggested to restore already degraded soil under cultivated lands. Finally, further researches addressing sustainable land management issues for the study area are needed.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

Grassland and forest soils. The overall soil condition under the cultivated land is deteriorating and getting poor compared to the soils under the forest and grass lands. The changes in soil properties were not limited to surface soils but also the subsurface soils across the land uses. Integrated implementations of soil fertility improvement practices such as application of organic inputs, leaving crop residues after harvest and crop rotation of cereals with leguminous crops are also suggested to restore already degraded soil under cultivated lands. Finally, further researches addressing sustainable land management issues for the study area are needed.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.
REFERENCES

Achalu C, Heluf G, Kibebeb K, 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(3):57-71.

Alemayehu A, Assefa A (2016). Effects of land use changes on the dynamics of selected soil properties. Soil 2:63-70.

Alemayehu A (2016). Effects of Land-use/Land-cover Changes on the Mean Differences of Soil Properties in the Western Nollegea, Ethiopia; degree of Doctor of Philosophy (PhD); Addis Ababa University, Addis Ababa, Ethiopia.

Alemayehu K, Sheleme B (2013). Effects of different land use systems on selected soil properties in South Ethiopia. Journal of Soil Science and Environmental Management 4(5):100-107.

Arasa F, Alemayehu A, Achalu C (2015). Effects of Different Land Uses (Forest, Grazing and Cultivated) on the Fertility Status of Acidic Soils of Dano District, West Shoa Zone, Oromia Region, Ethiopia. Arabian Journal of Biological Sciences 278:235-242.

Awdegeneest M, Melku D, Fantaw Y (2013). Land Use Effects on Soil Quality Indicators: A Case Study of Abo-Wonsho Southern Ethiopia. Applied and Environmental Soil Science 9:1.

Berhanu D (1980). The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land use planning and regulatory department, Ministry of Agriculture. Addis Ababa, Ethiopia.

Biro K, Pradhan B, Muchroithner M, Makeschin F (2013). Land use/land cover change analysis and its impact on soil properties in the northern part of Gadarif region, Sudan. Land Degradation and Development 24(1):90-102.

Black CA (1965). Methods of soil analysis. Part I, American Society of Agronomy. Madison, Wisconsin, USA 1572 p.

Bougoucos GJ (1962). Hydrometer method improvement for making particle size analysis of soils. Agronomy Journal. 54(5):179-186.

Brady NC, Weil RR (2002). The nature and properties of soils, 13th Ed. Prentice-Hall Inc., New Jersey, USA 960 p.

Foth HD, Ellis BG (1997). Soil fertility, 2nd Ed. Lewis CRC Press LLC., USA 290 p.

Getahun B, Bobe B (2015). Impacts of Land Use Types on Selected Soil Physico-Chemical Properties of Loma Woreda, Dawuro Zone, Southern Ethiopia. Journal of Science, Technology and Arts Research Journal 4(4):40-48 http://www.starjournal.org/

Girma A, Wolde-Meskel E, Bakken LR (2012). Carbon and nitrogen mineralization dynamics in different soils of the tropics amended with legume residues and contrasting soil moisture contents. Biology and Fertility of Soils 48(1):51-66.

Habtamu A, Heluf G, Bobe B, Enyew A (2014). Fertility Status of Soils under Different Land uses at Wujiraba Watershed, North-Western Highlands of Ethiopia. Agriculture, Forestry and Fisheries 3(5):410-419.

Hailu A, Yohannes G (2011). Some Examples of Best Practices by Smallholder Farmers in Ethiopia pp. 5-8.

Landon J (1991). Booker Tropical Soil Manual: A Hand Book for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. John Wiley and Sons Inc., New York 474 p.

Mengistu C, Kibebeb K, Tarekegn F (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, Oromiya, Ethiopia. International Journal of Environmental science and natural resource. Volume 4.

Mostafa E, Mehdi E, Mojiri B, Hamed F (2008). Effect of land use change on selected soil physical and chemical properties in Northern highland of Iran. Journal of Applied Science 8(3):496-502.

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. Journal of Agricultural and Biological Science 8(3):206-2012.

Olsen SR, Cole CV, Watanable FS, Dean LA (1954). Estimation of variable phosphorus in soil by extraction with sodium bicarbonate. USDA Circular 939:1-19.

Ovie S, Obanu AO, Okpata E (2013). Chemistry Division, Nigerian Institute for Oil palm Research. P.M.B 1030, Benin City. Agricultural Engineering Research Division. Nigerian Institute for Oil palm Research, P.M.B 1030, Benin City.

Regassa T, Bekele L (2016). Best Effect of Different Conservation Agricultural Practices On Soil Physical And Chemical Properties, In Bako Tibe District, West Shoa, Ethiopia: Best Journal of Humanities, Arts, Medicine and Sciences 2(1):49-56.

Statistical Analysis System (SAS) (2004). SAS/STAT user’s guide. Proprietary software version 9.00. SAS Inst., Inc., Cary, NC.

Tegenu AE, Kassahun HT, Collick AS, Adissu T, Ashagrie BB, Tessema ZK, Derebe A, Solomon D, Steenhus TS (2008). SoilProperties and Fertility Status Dynamics of North Western Ethiopia as Influenced by Land Use Changes: Case of Dibane https://www.researchgate.net/publication/258993430

Tesfahunegn GB (2016). Soil quality indicators response to land use and soil management systems in Northern Ethiopia’s catchment, Land Degradation Development 27(2):438-448.

Tesfaye B., (2003). Understanding Farmers: Explaining Soil and Water Conservation in Konso, Wolaita and Wello, Ethiopia. Tropical Resources Management Paper No. 41.

Teshome Y, Heluf G, Kibebeb K, Sheleme B (2013). Impacts of Land Use on Selected Physicochemical Properties of Soils of Abobo Area, Western Ethiopia. Agriculture, Forestry and Fisheries 2(5):177-183.

Ufot OU, Iren OB, Chikere NCU (2016). Effects of Land Use on Soil Physical and Chemical Properties in Akokwa Area of Imo State, Nigeria. International Journal of Life Sciences Scientific Research 2(3):273-278.

Van Reeuwijk LP (1992). Procedures for soil analysis, 3rd Ed. International Soil Reference and Information Center (ISRIC), Wageningen, the Netherlands 34 p.

Walikley A. and Black CA., (1934). An examination of the degjaireff method of determining soil organic matter and a proposed modification of chromic acid titration method. Soil Science 37:29-38.

Wasihun M, Muktar M, Teshome Y (2015). “Evaluation of the Effect of Land Use Types on Selected Soil Physico-Chemical Properties in Itang Ker Area of Gambella Regional State of Ethiopia”. Journal of Biological, Agriculture and Healthcare, Evaluation 5(11).

Woldeamblak B, Stroosnijder L (2003). Effects of agro-ecological land use succession on soil properties in the Chemoga watershed, Blue Nile basin, Ethiopia. Geoderma 111(1-2):85-98.

Yifruf A, Taye B (2011). Effects of Land use on Soil Organic Carbon and Nitrogen in Soils of Bale, Southeastern Ethiopia.Tropical and Subtropical Agro-ecosystems 14(1):229-235.

Yimer F, Ledini S, Abdulakdir A (2007). “Changes in soil organic carbon and total nitrogen contents in three adjacent land use types in the Bale Mountains, southeastern highlands of Ethiopia”. Forest Ecology Management 242(2-3):337-342.