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Nominated Characteristics of the Soils in Major Agro-Ecologies of Central Ethiopia

Eguale Tadesse*

Central Ethiopia Forestry Development Center (CEFDC), Ethiopian Forestry Development, Addis Ababa, Ethiopia.

Corresponding Author: Eguale Tadesse, Central (Ethiopia) Forestry Development Center (CEFDC), Ethiopian Forestry Development, Addis Ababa, Ethiopia.

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Abstract

Existence of flora and environmental disturbances had a pronounced influence on the soil characteristics. The objectives of this study were to determine the soil texture, bulk density (BD) and amount of organic carbon (OM and OC) in reserved forests and adjacent cultivated lands. Transect lines and plots were established to collect soil samples in the reserved forests and nearby cultivated lands. Soil horizon based soil sampling was administered on a transverse position from 2 ends of the diagonal line and from the center of each plot (mid of the diagonal) for soil texture and OC determination. For bulk density (BD) soil core samplers were used. The data was analyzed using one way ANOVA. The results revealed the %clay content was significantly higher in cultivated lands than reserved forests and the %sand content was higher in reserved forests than cultivated lands at (p=0.05). The BD is significantly higher in cultivated lands than reserved forests at (p=0.05). The soil OC was significantly higher in Soil-Horizon-1 than Soil-Horizon-2 and in reserved forests than cultivated lands at (p=0.05). The superior soil characteristics were obtained in reserved forests than in cultivated lands. Hence, it is recommended to conserve the reserved forests to maintain better property of the soil through enhancing OC and by decreasing soil BD since it has implications to improve the soil physical and chemical properties in cultivated lands adjoining the reserved forests. We also recommend application of green manure and compost to the cultivated lands to mend soil properties.

Keywords: Cultivated Land, Organic Carbon, Reserved Forest, Soil Horizons

1. Introduction

Land use change is the major problem that disturbs the physicochemical properties of soils in the highlands of Ethiopia [1]. Soil is composed of minerals, soil organic matter (OM), water, and air and the conformation and proportion of these components seriously influence soil physical properties, such as texture, structure, bulk density (BD) and porosity. Additionally, chemical properties of soils such as pH, nutrients, soil carbon, soil salinity and sodicity control nutrient availability and alterations and can affect physical properties and subsequently plant growth [2]. Soil BD is a basic soil property wavered by some soil physical and chemical properties such as OM . It is the oven-dried weight of a soil sample divided by the bulk volume of the same soil sample and is normally stated in gm/cm3. BD is a dynamic property that varies with the structural condition of the soil and can be altered by cultivation, trampling by animals, agricultural machinery, and raindrop effect [3].

Akin to this vegetation influences the physical properties of soil to a larger extent and mends the soil structure, permeation rate, water holding capacity, hydraulic conductivity and ventilation which are directly related to the BD [3]. On the other hand, high OM content increases the aggregate stability through solidity of aggregates which in turn reduces the forfeiture of fine soil particles. OM content also upsurges nitrogen mineralization and preserve the soil pH which in turn affect plant growth and soil quality [4]. Additionally, OC is considered a continuum of organic material in all phases of transformation and disintegration or stabilization. Nevertheless, these important properties of soils are degraded by different forms of soil degradation.

Soil degradation is a very serious problem in Ethiopia the high degree of deforestation, overgrazing, and over cultivation being the major factors accredited to the soil degradation [5]. As a result, land use change causes a decline in crop production owing to the depletion of vital soil nutrients [1]. Soil resources are determinate, non-renewable and disposed to degradation through exploitation and mismanagement [6]. Hence, the untenable land use and land cover changes are renowned as the main factors in the course of land resource degradation [6].

Agrarian cultivation is known to reduce carbon storage and results in a net fluidity of carbon to the atmosphere [7]. Thus, agricultural practice necessitates basic knowledge of sustainable use of the land. Contrariwise, there is evidence that primary forests and forests that are sufficiently managed for diversity and various benefits are more resilient to

disturbances and sustain healthy, firm soils, offer natural habitats for forest biodiversity and deliver a more stable stock of carbon [8]. This study is concerned with selected reserved forest areas and their adjoining cultivated lands that are facing a pronounced problem of deforestation and severe erosion. Hence, the study intended to assess some selected soil physical and chemical characteristics and the influence of land use type on the soil properties. Thus, the aim of the study is to determine and compare the soil Physico-chemical properties in the two land use types namely; cultivated and forested lands.

2. Materials and Methods

2.1. The Study Areas

The study areas were intentionally selected from Arsi zone and North-East Showa zone of Oromyia region and North Showa zone of Amhara region, Ethiopia. The major soil types in Arsi Zone are chromic and pellic vertisols. The geology of this area consists of pyroclastic rocks, mainly tuffs and ignimbrites of the recent volcanic eruptions. The upper soil layer consists of tephritic materials, whereas the substratum consists of calcareous material enriched through secondary precipitation over bedrock [9]. By and large, the fertility status of the soil of Arsi zone is good and conducive for crop production. In the North-East Showa zone the dominant soil types are pellic vertisols [10]. The geology is typically alkaline basalt and trachyte of the Cenozoic volcanic eruptions. In the North Shewa zone of Amhara region eluvium soil is commonly found on the plateau and the escarpment of the study area and near to the cliffs, occupying flat and gentle topography and was formed by the gradual weathering that are derived by in situ weathering or weathering plus gravitational movement or accumulation, of the basalt, ignimbrite (rhyolite) and previously formed soils. There are mixtures of rock fragments of basalt, ignimbrite and rhyolite within the eluvium soil. It is silt to clay sized, light/dark gray to reddish brown fertile soil. It forms the agricultural land and is used for the cultivation of different cereals, vegetation and fruits.

The specific study sites are selected areas of reserved forests and their surrounding Cultivated lands approximately 1km radius from the edge of the reserved forests. The first site (Asella Teklehymanot) is found in Tyio district, Arsi Zone and has elevations ranging from 2521-2581 m.a.s.l. As adopted from, the highland areas are found in altitudinal range of 2300-3200m a.s.l [11]. whereas; the midlands and lowlands take the altitude ranges from 1500-2300m a.s.l. and 500-1500 respectively. Based on this information site 1 is located under the highland agro climatic zone. The second site (Etisa Teklehymanot) is found in Mafud district, North-East Showa Zone, and has elevation ranges from 1500-2301m.a.s.l. and hence, it has a mixed midland and lowland agro climatic zone. The third site (Saramba Kidanemheret) is found in Gimbichu district, North Showa Zone and has elevations ranging from 2164-2251 m.a.s.l. which then put under midland agro climatic zone (Figure 1).

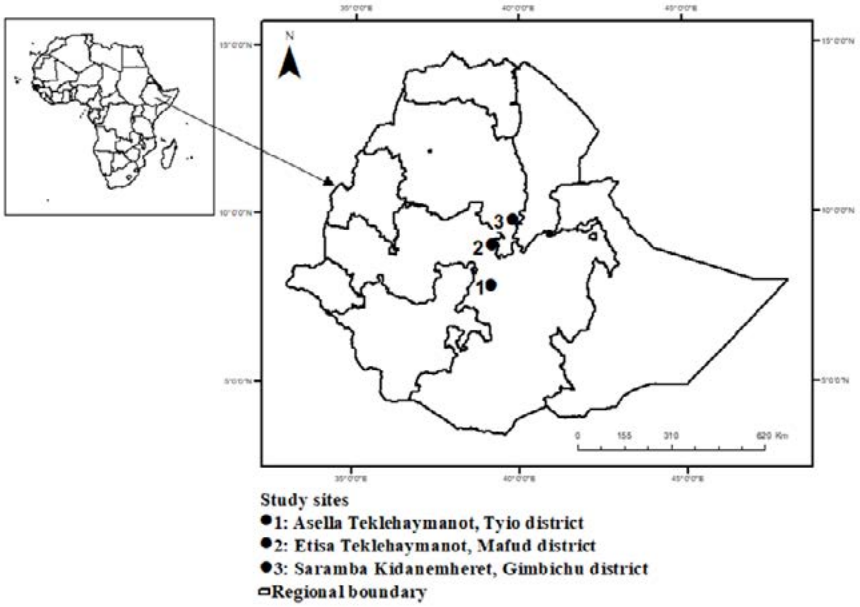

Figure 1: Location of the Study Areas

2.2. Methods

Transect lines were laid 100m apart along the slope from top to the bottom of the hills where the reserved forests are found. The distance between consecutive plots within transect lines was also 100m.Plots of 20m * 20m were established to collect soil samples in the reserved forests of the three sites. The same number and size of plots were also established on the cultivated lands surrounding each reserved forest. Digging shovel was used to collect soil samples and 50 centimeter plastic ruler was also used to measure the depth of the soil horizon. For soil bulk density assessment soil core samplers were used to collect soil samples. Finally, a plastic bag container was used to store each soil sample and tags made of paper were used to distinguish soil samples. For soil texture, OC analysis soil samples were collected from two soil horizons (H1: upper first and H2: Lower next to H1).

According to a vertical section of the soil in the land area exposes more or less distinct horizontal layers [12]. It shows the distinctive characters of the soil profile. The surface layer is darker in color because of its higher organic matter contents such as litter, humus, minerals, residues of the dead flora and fauna. Soil color is often a reliable indicator of soil though color alone does not affect all soil characteristics [12]. Hence, the different soil colors were used to identify the consecutive soil profiles and the depth of the soil from which the samples collected was determined by the depth of each horizon.

A transverse line inside each plot of 20m * 20m quadrant was used to collect soil samples at each terminal end of the diagonal and one at the center of the plot from each plot. Then, similar layers (horizons) from these three locations within the plot were mixed to form a soil composite. The composite sample for each soil layer was mixed splendidly and again divided into 3 equal parts among which one was selected randomly for the subsequent laboratory analyses consistent with [13]. The same procedure was undertaken on cultivated lands those are adjacent to sampled reserved forests to compare the soil properties. For soil BD analysis a soil core sampler was used to collect soil samples from 20m * 20m plots in the reserved forest and adjoining farm lands. For the determinations of OC content, the collected soil samples were spread on plastic sheet, air-dried in a dust-free room, cleaned from extraneous substances and crushed to pass through 2 mm sieve. A part of the 2mm sieved soil was further processed to pass through 0.5mm sieve. Then the OC was determined using wet digestion of method in which the carbon is oxidized under standard conditions with potassium dichromate in the presence of concentrated sulfuric acid as outlined by [14,15]. The SOM content was estimated from the OC content using the conventional factor of 1.72, assuming that OM contains 58% of OC [16]. The soil bulk density (gmcm-3) was calculated as the ratio of oven-dry weight of soil sample (dried at 105°C for 48 hours) to the volume of sampling cylinder. Finally, particle size analysis was carried out by the modified sedimentation hydrometer procedure according to [17].

2.3. Data Analysis

The differences in physical and chemical properties of soils for each soil horizon and between the two land-uses (reserved forests and their adjoining cultivated lands) and among the three sites were compared. The statistical analysis was carried out on the replicates by using analysis of variance (ANOVA).The result of the analysis was used to see whether the different land uses have significant differences on the mentioned soil properties. Mean separation was done by Least Significance Difference (LSD) for those attributes which produce a significant difference. Excel and statistical Package for Social Science (SPSS) v20 were administered. Hence, the variation in soil properties as affected by depth and land use type was calculated and analyzed.

3. Results

3.1. Soil Texture Analysis

Though it was assumed to get more than 3 soil horizons in both reserved forests and cultivated lands, the assessment obtained only two horizons (depending on change of soil color) in both land use types. More specifically under the reserved forests the stony layer comes within short soil depths. The mean %clay content was higher in farm lands than in the reserved forests and also in horizon 2 than horizon 1. The mean %sand content was consequently higher in reserved forests than farm lands. The %silt content has shown no difference both between land uses and between soil horizons (Table 1).

Land use type	Soil horizon	Soil texture class		
		% sand(Mean±Stdem)	%Clay(Mean±Stdem)	% Silt(Mean±Stdem)
Cultivated land	H1	21.39±2.25b	42.18±2.82e	32.27±1.73i
	H2	21.66±2.29b	47.28±2.61g	31.07±1.50i
Reserved forest	H1	36.01±2.15a	27.63±2.09f	36.40±1.53i
	H2	32.14±2.83a	34.08±2.51h	33.78±1.43i
Overall comparison(p<0.05)	H1 vs H2	0.508	0.048	0.227

Table 1: Percent Sand, Clay...) Before the Table? Most Articles Follow this Rule

Note

- Different superscript letters show the difference is significant between soil horizons and between land uses.
- According to the textural triangle, Farm (H1 and H2) have silty clay and Reserved forest (H1) have silt loam and Reserved forest (H2) silty clay loam textural class. Stdem=standard error of the mean.
- According to the result of the ANOVA table, the two soil horizons, H1 and H2 have a significant difference (P<0.05) in the mean %clay content.

Among the three studied sites similarly the result table showed the %sand content was higher in Site 3 and the %clay content was higher in Site 2. The mean %silt content was almost balanced in the 3 studied sites. Accordingly, the %sand content was significantly different between Site 3 and Site 1 and also between Site 3 and Site 2 but no significant difference between Site 1 and Site 2. Similar result found for Percent clay content. However, there was no significant difference in %silt content in all the three sites (Table 2).

Study site	Soil texture class		
	% sand(Mean±Stdem)	% clay(Mean±Stdem)	%Silt(Mean±Stdem)
Site 1(Highland)	23.27±1.55b	38.64±2.29d	35.82±1.26g
Site 2(Midland mixed lowland)	24.83±2.37b	42.70±2.75d	32.50±1.38g
Site 3(Midland)	39.56±2.49a	30.50±1.83e	29.94±1.12g
Overall Significance(P<0.05)	0.000	0.07	0.08

Table 2: Mean Bulk Density of the Two Land Use ...May be Taken Up Before the Table

Note

According to the textural triangle, Site 1 has silty clay loam soils, Site 2 has silty clay and Site 3 has clay loam soils.

3.2. Soil Bulk Density

The soil BD was determined for all the three sites in the two land use types. The mean BD is higher in cultivated lands than reserved forests and it was also highest in Site 3 reserved forest than Site 1 and Site 2 reserved forests. The result of the laboratory analysis and further analysis using SPSS v20 produced the results shown in table 3. Hence, there was a significant difference between land use types and among the three study sites at (p<0.05) (Table 3).

Study sites	Land use type	Bulk density
Site 1	Cultivated land	0.42±0.023
	Reserved forest	0.29±0.02
Site 2	Cultivated land	1.07±0.06
	Reserved forest	0.92±0.04
Site-3	Cultivated land	0.99±0.03
	Reserved forest	0.83±0.03
Overall significance (P<0.05)	Cultivated land vs Reserved forest	0.000
	Among sites	0.000

Table 3: Mean Bulk Density of the Two Land Use ...May be Taken Up Before the Table

3.3. Soil Organic Carbon

The OC content was analyzed both by the laboratory methods and using SPSS software v20. The ANOVA have shown OC was significantly different between the two soil horizons H1 and H2 at (F=10.724; P=0.001) with the topsoil (H1) showing higher values than the underneath soil (H2). The OC content was also compared between land use types and among the three study sites. The results have shown this soil chemical property was significantly different between land use types and among the three studied site. The OC value was higher in reserved forests than adjoining cultivated lands (farm lands) in all the three sites. The difference in OC content was highly significant among the three sites at (F=13.726; P=0.000), and between land use types at (F=33.139; p=0.000) (Table 4).

Sites	Soil horizon	OM	OC
Site 1	H1	7.76±0.62a	4.50±0.36a
	H2	6.21±0.56c	3.60±0.32c
Site 2	H1	5.27±0.61b	3.05±0.36b
	H2	3.51±0.46d	2.04±0.27d
Site 3	H1	5.28±0.84b	3.06±0.49b
	H2	2.69±0.39d	1.56±0.23d
Overall significance (P<0.05)	H1 vs H2	0.001	0.001

Table 4: Soil Organic Matter (OM) and Soil Organic Carbon (OC) Content in Site 1, Site 2 and Site 3, Central Ethiopia

4. Discussion

4.1. Soil Physical Properties

In the present study the mean %clay content was higher in cultivated lands than reserved forests.The present study results were in agreement with which identified on average clay content was higher in cultivated land by 2.1% from the forest land [18]. Another study by identified sand content of the three land use types, reserved forest (P1), Reserved forest (P2) and pasture land were greater than clay and silt content but clay content was greater in cultivated lands compared to forest and pasture lands. The physical properties of soil play important role in the control of erosion and to increase the soil fertility [19]. Accordingly, sandy soils allow a prompt entry and passage of water through them. On the contrary,

the high mean %clay content of the cultivated land in the present study may exacerbate soil erosion due to delayed infiltration rate but higher water holding capacity once the water is insinuated. Disproportionate moisture or anaerobic conditions resulting from elongated inundation may hinder the activity of soil flora and fauna and decomposition process. The soil texture, shape and size of particles in the soil and its physical condition, both of surface and profile layers affect vertical filtration and capability of soil to retain water. Therefore, the balanced % clay, % sand and % silt content of the reserved forest soils in all the three studied sites of the present study create favorable conditions for both the activities of soil organisms and for plant growth as described by [20].

The present study results also indicated the soil BD was higher in the cultivated lands than reserved forests with a significant difference at ($P<0.05$) asserting farming practices increase the compaction and expose soils to erosion. In a similar study in Ethiopia, highest BD (0-15 cm depth of soil) was found in the cultivated lands and the lowest under the reserved forest [21]. Higher BD may cause restrictions to root growth, and poor movement of air and water through the soil. BD can be changed by crop and land management practices that affect soil cover, organic matter, soil structure, and porosity and weaken the natural stability of soil aggregates making them susceptible to damage caused by water and wind [3]. The critical value of bulk density for plant growth at which root penetration is likely to be severely restricted is 1.4 gm cm-3 for clay soils [22]. Therefore, the results of the present study showed the maximum BD is 1.07gcm-3 which may not restrict root penetration.

The lower mean soil BD in the reserved forests (0.62gm/cm3) than cultivated lands (0.74gm/cm3) of the present study indicated the suitable characteristic of the forest soil due to high content of OC for plant growth and activity of soil fauna. A similar study in northern Ethiopia showed the cultivated land had the highest average BD and forest land the lowest of all land use types where the cultivated land had a 0.3 gm/cm3 higher BD than forest land and 0.2 gm/cm3 higher soil BD than grass land [18]. Generally, the lower BD in the present study in reserved forests than their adjoining cultivated lands have shown the contribution of the reserved forests in maintaining better soil characteristics.

4.2. Soil Chemical Properties

In the present study the comparison of OC content has shown a statistically significant difference among the three study sites. Accordingly, Site 1 (located in the highland area) comprised a vegetation of big trees and broad leaved shrubs and is well populated to cover the soil with enough litter fall and hence have shown the highest OM (8.83) content than the other two sites. A similar situation was observed in the cultivated lands of this site that showed a mean OM (5.13) content. This may also be attributed to a gradual decomposition and continuous accumulation of organic matter as the area is cooler than Site 2 and Site 3. The OM content in Site 2 and Site 3 seems almost similar, with Site 2 having a slightly higher mean OM of 5.45 than Site 3 which had 5.32 OM. A similar trend was seen on cultivated lands of Site 2 having mean values OM (3.33) and Site 3 having OM (2.65). These two sites had a nearly equal altitudinal ranges. Hence, the similarity in the mean OM content of these two sites may be attributed to their equivalent altitudinal range in addition to other factors which influence the amount of OM contents. The present study has also compared the OM content between the two land use types and as a result forest lands have higher values. A similar study by reported that conversion of reserved forest to continuous cultivation had resulted in a significant reduction of both the stock and concentration of OM [23]. Deforestation and subsequent cultivation decreased organic matter by 48.8% [23].

The study by found that OM content decreased down along the soil profile similar to the present study [23]. The same study by Jaiyeoba also reported the conversion of forest to cultivated land significantly decreased OM content. A number of similar studies also approved that forest soils contain higher OM than cultivated lands [25]. Generally, OM is a critical inlet in the carbon cycle and a storehouse of nutrients, and through its influence on many essential biological and chemical processes it plays a pivotal role in nutrient discharge and accessibility [25].

5. Conclusion

The findings of the present study asserted in all cases (i.e. soil texture, bulk density and OM content) the forest soil have much better soil characteristics than cultivated lands. The lower BD value in reserved forests is attributed to their higher organic matter and humus content. The mean OM content was higher in reserved forest than the cultivated lands indicating land use change from forest to cultivated land conveys a higher loss of organic matter. The highland site had higher mean OM content than the lowland and the midland sites which may be attributed to the slow rate of organic matter decomposition prevalent in the highland site (Site 1) which may be attributed to cooler soil temperature. Based on similar studies it can be concluded that organic matter content indicates the suitability of the soil for plant growth and other important processes in the soil. The mean %clay content and the mean OM content have shown a significant difference ($P=0.05$) between the two soil horizons (H1 and H2). H2 have shown higher %clay content than H1 and the mean OM content was higher in H1. The higher percentage of OM in the upper soil horizon (H1) indicates the presence of higher accumulation of litter and/or crop residues. There is also high OM in reserved forests than in adjacent cultivated lands. Therefore, from the results of the present study it is recommended to conserve the reserved forests for increasing the eminence of soil through enhancing OM and decreasing soil BD. It is also recommended to apply green manure and compost to the cultivated lands.

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