INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 18, No. 6, p. 38-47, 2021
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Selected soil properties under different land uses at Fasha District, Southern Ethiopia

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Article published on June 30, 2021

Key words: Cultivated Land, Fasha District, Forestland, Grassland, Land Uses.

Abstract

Land uses changes and agricultural activities (deforestation, cultivation and grazing) negatively affect soil qualities. This finding was initiated to evaluate soil properties under different of land uses. Nine composite soil samples were collected from three triplicated land uses (cultivated, grazing and forest lands) using auger at 0-150cm soil depth. The collected samples were analyzed using standard laboratory procedures and the data was subjected to statistical analysis software (SAS) for analysis. The result indicted the particle size distribution of the soils was clay, indicting similarity in parent materials. Soil parameters such as pH, OC, TN, AP, exchangeable bases (Ca, Mg, K and Na) and micro-nutrient cations (Fe, Mn, Cu, Zn) were significantly ($P < 0.05$) lower in cultivated than adjacent land uses. While bulk density and available phosphorus were significantly ($P < 0.05$) higher in cultivated soil than forest and grassland soils. This indicates that cultivated soils are poor in maintaining soil quality as compared to uncultivated soils. Therefore, integrated soil management practices such as conservative tillage, crop rotation, manures and residue addition are suggested for soils under cultivation.

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Introduction

Land use changes are a primary cause of global environmental changes (Li, 1996). This allows being major global change as its impacts on global biogeochemical cycles, climatic and hydrologic processes. Land use changes and agricultural activities, especially conversion of forest land to cultivated land immediately reduce soil quality (Girma *et al.*, 2012). Soil quality is ability of soil to function, to sustain plant growth. Change in land uses also causes variations in soil properties, terrestrial nutrient cycles and reduction of soil production under different land uses. They also cause soil erosion and leads to a reduction in soil organic matter content, loss of soil quality and deterioration of soil structure and its stability (Ovie *et al.*, 2013). Deforestations, overgrazing, conversion of forest and pasture land to crop land and cultivation are known to have noticeable effect on fertility of the soil (Biro, *et al.*, 2013). Mojiri *et al. (*2012) reported increase in bulk density, reduction in organic matter and cation exchange capacity (CEC), which in turn reduce the fertility status of the given soils, as main impacts of land use changes. Similarly, Getulio *et al. (*2014) reported that reduction of soil organic matter below the critical level leads to deterioration of soil structure, increases bulk density, reduce aggregation, decreases moisture storage and aeration of the soils.

In Ethiopia, land uses and agricultural activities such as, deforestations, grazing and cultivation results in rapid nutrient depletion from the soils (Alemayehu, 2016). Ragassa and Bekele, (2016) reported that cultivation without proper land management has resulted in deterioration of soil physical, chemical and biological properties. Cultivation on steep slopes and fragile soil with inadequate vegetation cover, limited recycling of residues to the soils and limited application of external plant nutrients are responsible for depletion of nutrients under cultivated land while deforestation and overgrazing are factors for soil fertility declines under forest and grassland soils, respectively (Habtamu, *et al.*, 2014). Soil management practices like intensive cultivation, no rotation of crops on the cultivated lands, removal of vegetation cover or burning of plant residue as practiced in traditional farming systems and annual burning of vegetation on grazing lands leads deterioration of soil properties (Tsegaye, 2011). Tesfahunegn, (2016) found the lowest soil organic matter, pH, total nitrogen, available phosphorus and clay under cultivated land as compared to uncultivated land. Several studies showed that deforestation and cultivation of virgin tropical soils often lead to depletion of nutrients (N, P, and S) present as part of complex organic polymers (Girma *et al.*, 2012; Ovie *et al.*, 2013 and Teshome, *et al.*, 2013).

In the present study area, increasing agriculture is happening from time to time on the limited land due to increasing population. Therefore, the previously lands occupied by natural vegetation is now day converted to cultivated and grazing lands. As result, cultivation is also carried out on slope areas which accelerate soil erosion and soil fertility decline. Thus, land use changes aggravate soil degradation and leads to decline in soil quality. Therefore, this study was conducted with objective to evaluate soil properties under different land uses in order to develop sustainable soil management options for study area.

Material and methods

Description of the Study Area

The study was conducted at Fasha District, Konso Zone, Southern Ethiopia (Fig. 1). It is geographically located between latitudes 5° 15′ 0″ to 5° 56′0″ N and longitudes 37° 01′ 0″ to 37° 69′0″ E.

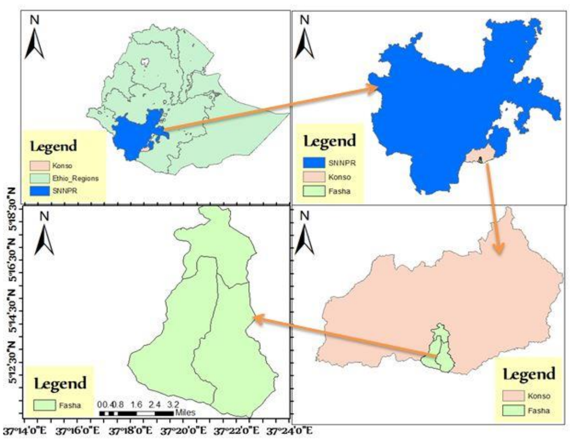

Fig. 1. Map of the Study Area.

The altitude of the area varies from 500m to 2,000m 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℃. 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.

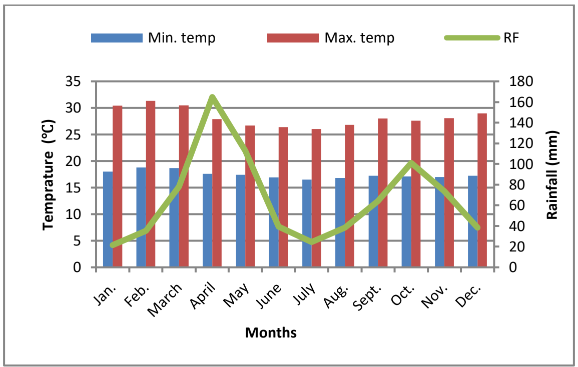

Fig. 1. Mean monthly temperature (°C) and rainfall (mm) of the study area from 2000 to 2020.

Soil Sampling and Analysis

Three land uses (cultivated, grazing, and forest lands) were selected, which are major land uses of the study area. Nine composite soil samples were collected from three triplicated land uses from 0-15 cm depth using an auger. Disturbed soil samples were used for analysis of Particle size distribution, soil pH, organic carbon, total nitrogen, available phosphorus, exchangeable bases (Na, K, Mg and Ca), CEC and micro-nutrient cations (Fe, Mn, Cu and Zn) whereas undisturbed soil samples collected by sharp-edged steel cylinders forced manually in to soil was used for the determination of soil bulk density.

Soil particle size distribution was determined by the Boycouos 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 NH_4OAc) buffered at pH 7.0. Micronutrient cations (Fe, Cu, Zn and Mn) were extracted by DTPA (Diethylene Triamine Penta-actic Acid) as described by Sahlemedhin and Taye (2000) and measured by atomic absorption spectrophotometer.

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 discussions

Soil Properties under different land uses

The particle size distribution across all land uses were dominated by clay followed by sand and silt fractions, this might be due to the geology of the soil or parent material from which soil was initially formed. The textural class across all land uses was clay, indicating similarity in parent material. Particle size distribution is the inherent soil physical properties less affected by soil management (Wakene, 2001).

The result showed that sand content of grazing land was significantly ($P < 0.05$) lower than that of forest and cultivated soils while silt content of cultivated land was significantly lower than that of grass and forest land. The clay content was not significantly ($P < 0.05$) different across all land uses. In line with this finding Javad *et al.* (2014) reported that percent of silt in agriculture land is lower than other land use types, whereas clay content is not significantly different across different land use types.

Table 1. Effects of land uses on particle size distribution (sand, silt and clay) and bulk density of the soil of Fasha District.

Land uses	Sand	Silt	Clay	BD (g/cm)
Cultivated land	24.93a	11.63b	63.77a	1.34a
Grass land	19.33b	17.20a	63.47a	1.21b
Forest land	27.02a	16.75a	58.57a	1.17b
LSD (0.05)	2.83	3.60	5.62	0.04
CV (%)	5.25	10.46	4.00	1.58

Means with the same letters are not significantly different at P ≤ 0.05 LSD test; LSD=Least Significance Difference; CV=Coefficient of variation and BD=Bulk Density

The bulk density of cultivated land was significantly ($P < 0.05$) higher than forest and grassland while there was no significance difference between grass land and forest land soils (Table 1). The highest (1.34g/cm^3) and the lowest (1.17 g/cm^3) bulk density was recorded in the cultivated land and forest land, respectively (Table 1). The highest 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 soils. These finding agrees with finding of Lechisa *et al. (*2014) who reported that bulk density of cultivated land were higher compared to the uncultivated lands. The lower and higher bulk density of forest and cultivated land may be attributed to the high soil organic matter, porosity and less disturbance of land under forest land than cultivated soils (Ararsa *et al.,* 2015). The result also showed significant ($P < 0.001$) and negative correlation of bulk density with most soil parameters such as OC (r= -0.93), pH (r= -0.94) and micro-nutrient cations (Table 5). This indicates increase in bulk density negatively affects soil quality. Similarly, Ufot *et al. (*2016) reported significant and negative correlation of bulk density with organic carbon.

The pH of the soils across all land uses ranges from 6.5 for cultivated soils to 6.9 for forest land as indicated in Table 2. Statistically, the pH value of cultivated soil was significantly ($P < 0.05$) lower than uncultivated soils. According to the rating of soil pH by Foth and Ellis (1997) the pH of the soils was rated as slightly acidic for cultivated lands and neutral for grass and forest lands. The removal of basic cations by harvested crops, erosion and leaching attributed for low pH in cultivated lands. Similarly, soils in the cultivated land were acidic than forestland and grazing lands (Alemayehu and Assefa, 2016). Correlation analysis showed significant ($P < 0.001$) and positive correlation (r=0.91) of pH with organic carbon (Table 5). Birhanu *et al. (*2016) reported that forest soil contains high organic matter content and less affected by pH changes, since it has high buffering capacity. Similarly, Abera and Kefyalew, (2017) reported the higher soil pH in the uncultivated land was due to the presence of relatively higher exchangeable bases and cation exchange capacity.

Soil organic carbon was significantly ($P \leq 0.05$) different across all land uses (Table 2). The highest (4.86%) was founded in forest land followed by grass land (3.67%) and cultivated land (2.58%). According to the rating of organic matter by Berhnu (1980), the organic carbon contents were rated as medium for grass and forest lands and low for cultivated land. This is due to the fact that in forest land, falling of plant materials could increase soil organic matter content. This result is in agreement with finding of Achalu *et al. (*2012) who founded high organic matter content in forestland as compared to other land uses. Yifru and Taye, (2011) reported that soil organic matter of forest soil were higher than other land uses most probably because of difference in management practices. The low organic carbon content in cultivated land was due to low of vegetation covers or above ground biomass, root biomass and plant litter fall as compared to uncultivated soils. Cultivation accelerates soil aeration which promotes rapid decomposition and oxidation of soil organic matter (Alemayehu and Sheleme, 2013). Similarly, Abebe *et al. (*2013) and Tuma *et al. (*2013) stated that in Ethiopia over cultivation depletes soil organic carbon.

The result showed that total nitrogen was significantly ($P \leq 0.05$) vary across all land uses (Table 2). The highest (0.29%) total nitrogen was recorded in forest land followed by grass land (0.20%) and cultivated land (0.17%) (Table 2).

The result agrees with several studies conducted in Ethiopia (Nega and Heluf *et al*., 2013 and Chemeda, 2017). According to the rating by Berhnu (1980), the total nitrogen of the forest land was rated as high and medium for cultivated and grasslands. The high total nitrogen in forest land was due to high organic matter content which is the main source for soil total nitrogen compared to grass and cultivated lands. Similarly, correlation result showed significant ($P \leq 0.001$) and strong positive associations (r=0.97) of total nitrogen with organic carbon (Table 5). In cultivated soils crop residues were continuously removed as source of fuel, livestock feed and source of incomes which are the source for the soil total nitrogen. Moreover, deforestation and conversion of natural forest to other land use type's (cultivated land) results in decline of soil organic carbon and which in turn reduced total nitrogen of soils. McDonagh *et al. (*2001) reported that the reduction of total nitrogen in cultivated lands was attributed to the rapid decomposition of the organic matters following intensive cultivation.

The results indicated that C:N of forest land (16.35) was significantly ($P \leq 0.05$) lower than cultivated (22.07) and grass lands (21.17). C:N of cultivated and grass land was not statistically different (Table 2). The highest C:N was recorded in cultivated land (22.08) followed by grass land (21.17) and forest land (16.35) (Table 2). Opposite finding was reported by Arasa *et al. (*2015); Teshome *et al. (*2013) who founded that the mean value of C:N ratio increased from cultivated land to grass and forest lands.

The distribution of C:N ratio across all land uses types follows similar pattern to organic carbon and total nitrogen distribution, except slight variation exist since organic matter are the main source for the soil nitrogen and C:N ratio. 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 soils were below 20:1 range, this indicates the release of mineral nutrient to plant and soil environment.

Table 2. Effects of land uses on pH, organic carbon, total nitrogen, C:N and available phosphorus of the soil of Fasha District.

Land uses	pH	OC (%)	TN (%)	C:N	AP(mg/kg)
Cultivated land	6.50a	2.58c	0.12c	22.07a	3.12b
Grass land	6.80b	3.66b	0.17b	21.17a	4.06b
Forest land	6.90b	4.86a	0.29a	16.35b	5.47a
LSD (0.05)	0.23	0.30	0.02	1.24	0.99
CV (%)	1.48	3.60	4.54	2.76	10.38

Means with the same letters are not significantly different at $P \leq 0.05$ LSD test; LSD=Least Significance Difference; CV=Coefficient of variation; OC=Organic Carbon; TN=Total Nitrogen; C:N=Carbon to Nitrogen Ratio and AP=Available Phosphorus.

The result of available phosphorus of forest land was significantly ($P \leq 0.05$) higher than cultivated and grassland soils. The value rises from cultivated land (3.12mgkg^{-1}) to grassland (4.06mgkg^{-1}) and forest land (5.47mgkg^{-1}) (Table 2). According to the rating by Landon, (1991) available phosphorus of cultivated and grassland soils was less than 5mgkg^{-1}, qualifying for the low range while medium range for forestland. This indicates the deficiency of P nutrient in cultivated and grass lands and it 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 (Brady and Weil, 2002). In line with this correlation result showed insignificant ($P \leq 0.01$) and negative association (r=-0.81) of available phosphorus with clay content of the soils of study area (Table 5). Similarly, Achalu *et al. (*2012) reported low available phosphorus in cultivated land as compared to soils of uncultivated soils.

The same author reported that continuous cultivation negatively affects phosphorus and nutrient levels in the soil. The lowest available phosphorus in cultivated land was attributed to no application of external source of P and the only P present in the soils is lost for their role (crop uptake, leaching loss and fixation). Forestland has higher available phosphorus than the grazing and cultivated lands this might be because; (i) in forest land, trees might remove a pool of available phosphorus; there was a probability of P return through litter fall to soil surface.

(ii) Microorganisms, which are abundant in the surface layers of the forest soils, may quickly add high amount of P source to the soil (Alemayehu and Assefa, 2016). Similar to this finding available phosphorus was significantly ($P<0.001$)) and positively correlated ($r=0.92$) with organic carbon (Table 5).

Exchangeable bases (Ca, Mg, K and Na) of forest and grassland soils were significantly ($P \leq 0.05$) higher than that of cultivated soils. This implies that exchangeable cations decline as conversion of forest lands to grassland and cultivated soils. In agreement with this, several researchers reported that exchangeable bases were higher in forest soil as compared to grassland and cultivated soils (Wasihun *et al.*, 2007; Alemayehu, 2016; Mengistu *et al.*, 2017). The low exchangeable bases in cultivated soils were associated with crop harvest loss, leaching and low organic matter content. Continuous cultivation deteriorates soil structures which facilitate organic matter decomposition and mineralization and leads depletion of exchangeable bases in cultivated soils. Arasa *et al.* (2015) reported the percent of exchangeable bases were high in the forest land as compared to other land uses due to more and continuous nutrient recycling in the forest. The exchange complex was dominated by Ca followed by Mg, K and Na, indicating productive agricultural soils (Bohn, 2001). The variation in basic cations in soil varies with amount of mineral present, soil texture, degree of weathering, soil management practices, climatic conditions, degree of soil development, the intensity of cultivation and the parent material from which the soil is initial formed (Heluf and Wakene, 2006).

Table 3. Effects of land uses on exchangeable bases (Ca, Mg, K and Na) and cation exchange capacity of soils of Fasha District.

Land uses	CEC	Ca (Cmol(+)kg^{-1})	Mg	K	Na
Cultivated land	22.16a	3.46c	1.84b	0.93c	1.22b
Grass land	24.26a	4.25b	2.70a	1.76b	1.99a
Forest land	28.47a	5.28a	2.85a	2.39a	2.15a
LSD (0.05)	7.78	0.22	0.34	0.22	0.39
CV (%)	13.75	2.24	6.07	5.82	9.62

Means with the same letters are not significantly different at $P \leq 0.05$ LSD test, LSD = Least Significance Difference; CV = Coefficient of Variation; CEC = Cation Exchange Capacity.

The result showed that CEC was not significantly ($P \leq 0.05$) affected by land uses. Numerically, it was lowest for cultivated land (22.16Cmol(+)kg^{-1}) while medium for grassland (24.26Cmol(+)kg^{-1}) and highest forest land (28.47Cmol(+)kg^{-1}) (Table 3). The numerical variation in CEC across land uses were attributed to variation in OM contents, leaching process and clay particles. The correlation matrix showed significant ($P\leq 0.05$) and positive correlation ($r=0.68$) of CEC with organic carbon and insignificant and negative correlation ($r=-0.60$) with clay particle (Table 5). According to the rating by Landon, (1991) the CEC of forest land was rated as high while medium for grass and cultivated lands.

Fe, Mn and Cu contents of cultivated soils were significantly ($P \leq 0.05$) lower than uncultivated soils (forest and grassland soils) while the same parameters were not significantly different in forest and grassland soils. The result also showed that Zn content was significantly ($P \leq 0.05$) affected by land uses. The highest Zn content was recorded in forest land (4.60mgkg^{-1}) followed by grassland soil (2.48mgkg^{-1}) and cultivated soil (1.91mgkg^{-1}) (Table 4). The content of micronutrient cations was high in forest soil followed by grassland and cultivated soils. This might be due to high organic matter content that is used as source such nutrients and supply soluble chelating agents which increase their solubility. The linear correlation analysis also showed significant ($P \leq 0.01$) and positive correlation of organic carbon with micro-nutrient cations as indicated in Table 4.

Table 4. Effects of land uses on Micro-nutrient cations (Fe, Mn, Cu and Zn) of soils of Fasha District.

Land use types	Fe	Mn (mgkg^{-1})	Cu	Zn
Cultivated land	4.34b	2.78b	1.91c	0.35b
Grass land	4.85a	3.67a	2.48b	0.44a
Forest land	4.93a	3.98a	4.60a	0.49a
LSD (0.05)	0.196	0.436	0.437	0.060
CV (%)	1.836	5.532	5.789	6.178

Means with the same letters are not significantly different at $P \leq 0.05$ LSD test, LSD = Least Significance Difference; CV = Coefficient of Variation.

The variation in content of micronutrient cations across land uses was due to the variation in amount and type of parent material, organic matter content and particle size distribution of the soil. In line with this finding Habtamu *et al.* (2014) reported that organic matter enhances the availability of micronutrients by providing soluble complexion agent or organic acids that prevent their fixation in forest land. According to Brady and Weil, (2002), intensive cultivation, in which greater amount of soil nutrients are lost by harvest accelerates the depletion of micronutrient in the soil and increases the deficiencies micronutrients in the soils.

Table 5. Pearson's correlation matrix for selected soil physicochemical properties under different land uses.

	Sand	Clay	bd	Ph	OC	TN	AP	CEC	Fe	Mn	Zn	Cu
Sand	1											
Clay	-0.54	1										
Bd	0.03	0.44	1									
Ph	0.01	-0.38	-0.94***	1								
OC	0.29	-0.65	-0.93***	0.91***	1							
TN	0.46	-0.70*	-0.86**	0.82**	0.97***	1						
AP	0.40	-0.81**	-0.81**	0.83**	0.92***	0.91***	1					
CEC	0.20	-0.60	-0.56	0.43	0.68*	0.69*	0.54	1				
Fe	-0.12	-0.48	-0.93***	0.89**	0.86**	0.77*	0.82**	0.52	1			
Mn	0.03	-0.65	-0.89**	0.87**	0.85**	0.79*	0.91***	0.44	0.93***	1		
Zn	0.16	-0.66	-0.94***	0.88**	0.98***	0.94***	0.90***	0.73*	0.91***	0.88**	1	
Cu	0.04	-0.62	-0.91***	0.80**	0.89**	0.86**	0.83**	0.73*	0.94***	0.88**	0.94***	1

*, ** and *** significant at 0.05, 0.01 and 0.001 probability levels, respectively; CEC=Cation Exchange Capacity and BD=Bulk Density

Conclusion

From the result, it is concluded that land uses such as deforestation, cultivation, grazing results in deterioration of soil properties. Soil properties such as soil pH, organic carbon, total nitrogen, available phosphorus, exchangeable bases (Ca, Mg, K and Na) and micro-nutrient cations (Fe, Mn, Cu and Zn) are low in soil under cultivation as compared to under uncultivated (forestland and grassland). Bulk density of cultivated soil was significantly higher than that of forest and grassland soils. This indicates land use changes especially, natural vegetation to cultivated soils seriously deteriorate soil properties. Particle size distribution (sand, silt and clay) are clay in textural class indicating similarity in parent materials under all land uses. 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 leaving crop residue to the land were suggested for the study area.

Acknowledgements

The author would like to acknowledge the Ethiopian Ministry of Education (MOE) for financing his studies at the Arba Minch University (AMU). The author also would like to thank his mother Shako Yaso and friend Tigist Katola for the support, encouragement and tolerance throughout the period of study.

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