academicJournals

Vol. 4(5), pp. 100-107, September, 2013
DOI 10.5897/JSSEM12.20
ISSN 2141-2391 ©2013 Academic Journals
http://www.academicjournals.org/JSSEM

Journal of Soil Science and Environmental Management

Full Length Research Paper

Effects of different land use systems on selected soil properties in South Ethiopia

Alemayehu Kiflu* and Sheleme Beyene

Soil Science Department, Hawassa University, Ethiopia

Accepted 21 August, 2013

A study was conducted to determine the effect of different land use systems on soil physical and chemical properties in Sodo Zuria Woreda of Wolaita zone Southern Ethiopia. Differences in soil properties in different land use types at two depths (0-15 and 15-30 cm) were observed on many soil properties important to crop growth. Enset (*Ensete Ventricosum*) fields had higher pH, electrical conductivity (EC), available P and Zn, exchangeable Ca and K which is attributed due to the addition of manure, whereas maize fields had lowest average K and Mg, cation exchange capacity (CEC), percentage of base saturation (PBS), total N and OC. These results suggest that land use has persistent, multi-decadal effects on the spatial heterogeneity of soil resources and also the need of land use and landscape research to determine ecologically sound and sustainable land use and management strategies.

Key words: Land use, Enset, grass land, manure, continuous cultivation, soil properties.

INTRODUCTION

Successful agriculture requires the sustainable use of soil resource, because soils can easily lose their quality and quantity within a short period of time for many reasons. Agricultural practice therefore requires basic knowledge of sustainable use of the land. A success in soil management to maintain the soil quality depends on the understanding of how the soil responds to agricultural practices over time. Recent interest in evaluating the quality of our soil resource has therefore been simulated by increasing awareness that soil is critically important component of the earths biosphere, functioning not only in the production of food and fiber, but also in the maintenance of local, regional, and worldwide environmental quality (Negassa, 2001). On the other hand, feeding the ever-increasing human population is most challenging in areas like southern Ethiopia, where there is a very high population density. In addition, the topography has also a great impact on the soil quality and depth due to the interaction impact of cultivation practices and slope. Revising these trends lies in the enhancement of sustainable development of the agricultural sector. However, the basis of this sustainable agricultural development is good quality of soil, since maintenance of soil quality is an integral part of sustainable agriculture.

According to Wang et al. (2001) climate and geological history are importance factors to affecting soil properties on regional and continental scales. However, land use may be the dominant factors of soil properties under small catchment scale. Land use and soil management practices influence the soil nutrients and related soil processes, such as erosion, oxidation, mineralization, and leaching, etc (Celik, 2005; Liu et al., 2010). As a result, it can modify the processes of transport and re-distribution of nutrients. In non-cultivated land, the type of vegetative cover is a factor influencing the soil organic carbon content (Liu et al., 2010). Moreover, soils through land use change also produce considerable alterations (Fu et al., 2000), and usually soil quality diminishes after the cultivation of previously untilled soils (Neris et al.,

*Corresponding author. E-mail: alemanchy@gmail.com.

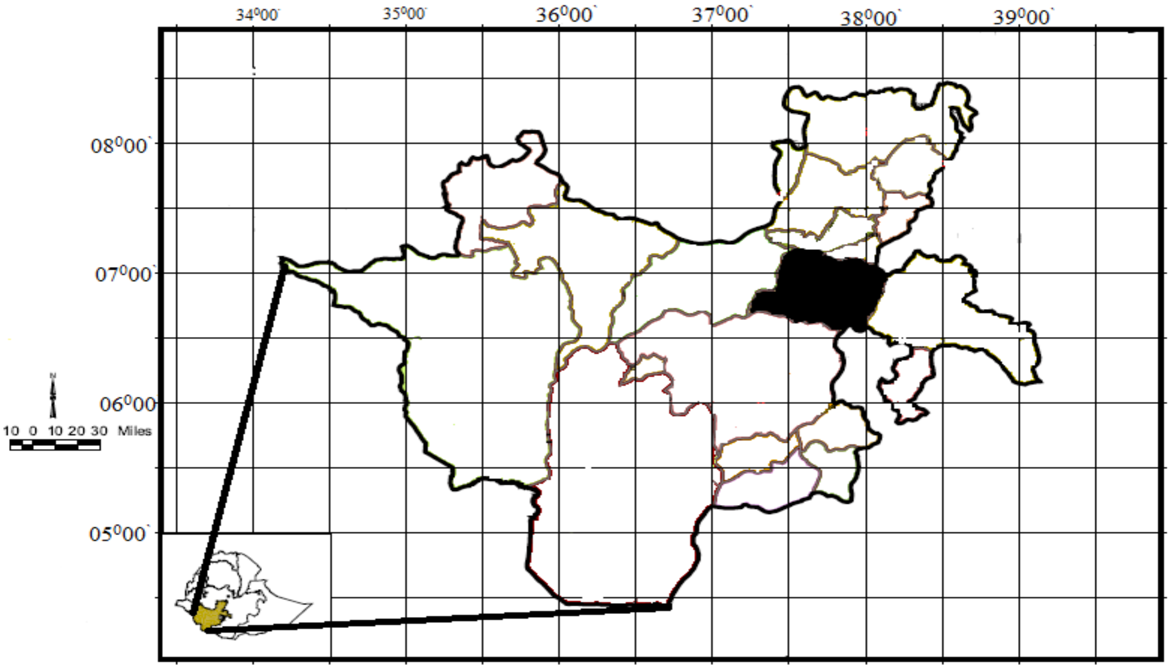

Figure 1. Location map of the study area (Sodo Zuria, Wolayita Southern Ethiopia).

2012). Thus, land use and type of vegetation must be taken into account when relating soil nutrients with environmental conditions (Liu et al., 2010). The particular nature of the typical rugged relief with slopes subjected to cultivation for many years in the study area had lead to decline in soil fertility. Therefore, there is special need for the analysis of soil nutrients in relation to land use. Such a local analysis is necessary to estimate nutrient storage in semi-natural and cultivated ecosystems (Wang et al., 2001), therefore this research was initiated to investigate the influence of different land use types on selected properties of the soil in southern Ethiopia.

MATERIALS AND METHODS

Description of the study area

The study was conducted at Delbo Atwaro watershed, which is located in Sodo Zuria Woreda of Wolayita zone, SNNP Regional State, Ethiopia. Delbo Atwaro is bounded by Damot Woyde on the east, Kindo Koysha on the west, and Bolosso Sore on the north and Humbo on the south. The altitude of Sodo Zuria Woreda ranges from 1500 to 3500 m above sea level, having a “Woinadega to Dega” climatic characteristic. The study area was selected as a representative watershed for high productivity potential in the Wolayita area to use as experimental site for the Sustainable Rural Agricultural Development project funded by CIDA/UPCD in 2003 (Figure 1).

Sodo Zuria Woreda has a total area of 48,125 ha, out of which 27,687 ha are being cultivated, and 4,020 ha are used for grazing and the rest is occupied by other land use types. The study area has a bimodal rainfall with peak rainy months in April and August. The mean seasonal temperature and the annual rainfall of the study area (Delbo watershed) are 20°C and 1296.6 mm, respectively. Soils of Wolayita area are grouped as Nitosols (Ethiopia Mapping Authority, 1998).

Land use and toposequence selection

Enset (*Enset ventricosum*) was selected as one of the land uses because it is as old as agriculture in the study area and used as a staple food. Moreover, maize is grown everywhere in the area and selected as the second land use, whereas grassland is selected as third land use system for the sake of comparison. To take a representative samples, a landscape facing west was selected in the watershed. The toposequence was divided into three slope positions: Upper N 06°54’ and E 37°50.589’ with 2161 m a.s.l, middle topographic position N 06°54.522’ and E 37°50.437 with altitude 2110 m a.s.l and lower topographic position N 06°54.628’ and E 37°50.388 and 2087 m a.s.l.

Soil sampling and preparation

All soil samples were air-dried, ground and passed through 2 mm sieve at the Soil Laboratory of the Awassa College of Agriculture. The physicochemical analyses of the soil samples were conducted at National Soil Research Center following standard laboratory procedures. The bulk density determinations were done at Soil Laboratory in Awassa collage of Agriculture. Duplicate soil samples from each topography (Upper, Middle and lower) and land use types (Enset, maize and Grass land) were collected.

Laboratory analyses

Total nitrogen content was determined following the Kjeldahl method (Jackson, 1958). The available phosphorus content of the

Table 1. EC, pH, sand, silt and clay properties of the soil at 0 to15 and 15 to 30 cm depth under different land use systems.

Land use	pH	EC (dS/m)	Sand (%)	Silt (%)	Clay (%)
			0-15 cm		
Enset	6.83	0.15	33.66	48.00^a	18.33
Grass	5.80	0.09	44.33	40.66^b	15.00
Maize	6.03	0.08	31.66	47.33^a	21.00
			15-30 cm		
Enset	6.4	0.10^a	29.66	46.00^a	24.33^b
Grass	5.63	0.06^{ab}	34.33	35.33^b	30.33^a
Maize	6.2	0.04^b	31.00	42.00^a	27.00^b

Mean values within a column followed by the same letter(s) are not significantly different at p ≤0.05.

soil was analyzed using 0.5 M sodium bicarbonate extraction solution (pH=8.5) following the method of Olsen et al. (1954). The organic carbon determinations were made following the wet oxidation method of Walkley and Black (1934). The exchangeable basic cations (K^+, Ca^{2+}, Mg^{2+}, and Na^+) were extracted with 1 M ammonium acetate at pH=7.0. The CEC of the soil was determined from ammonium acetate saturated sample. The excess ammonium acetate was removed by washing with ethanol. Finally, the exchangeable Ca^{2+} and Mg^{2+} in the ammonium acetate leachate were measured by atomic absorption spectrophotometry (AAS), and K^+ and Na^+ were determined by flame photometer. Hydrometer method was used for the determination of soil particle size distribution. The soil pH was measured using a glass combination pH meter in the supernatant solution of 1:2.5 soil to water solution ratio. The EC was measured by taking 10 g of soil in 25 ml of water with a conductivity meter. A commonly used procedure called diethylenetriaminepenta -acetic acid or DTPA (Lindsay and Norvell, 1978) extraction was used to extract Cu, Fe, Mn and Zn from the samples. The micronutrients extracted with this method were measured by atomic absorption spectrophotometer at 248.3, 279.5, 324.7 and 213.9 nm wavelength for Fe, Mn, Cu, and Zn, respectively.

Statistical analysis

Mean comparisons (LSD) were calculated for the different land uses systems and correlation analysis has been done for the different topographic positions and land uses systems using the SAS software (SAS, 1997), to see the relationship between parameters.

RESULTS AND DISCUSSION

Physico-chemical properties of the soil as influenced by different land use systems

Relatively higher sand content was recorded in grass land soils followed by that of enset and maize fields in the upper 0 to15 cm depth, whereas in the 15 to 30 cm depth silt was found to be higher in grass land soils followed by maize and enset fields (Table 1). On the other hand, higher content of clay was recorded in 0 to 15 cm depth of maize farms. Although texture is inherent property, this might be attributed to accelerated weathering as a result of disturbance during continuous cultivation, as was also concluded by Boke (2004) from the result obtained from the nearby site. The soil texture of the different land use types and the upper layers of the different horizons were found to be the same except for that of grassland soil (15 to 30 cm depth), which was clay loam. This suggests that the different land use types did not have effect on the soil texture of the study area, since texture is an inherent soil property that not influenced in short period of time.

The pH value under enset was found to be the highest followed by maize in both sampling depths. The soil pH could be categorized as slightly acidic under enset and maize fields whereas that of grassland was moderately acidic, following the classification described by Brady and Weil (2002). The higher values of pH under enset in both depths could be due to higher values of exchangeable bases as a result of application of house refuses and wood ash to enset fields. This is evident from the positively correlation between pH and the exchangeable bases in both depths. Relatively higher EC values at both depths were recorded in the enset farms followed by grassland soil. Although the EC values were negligible significant differences ($p \leq 0.05$) were obtained under the different land uses.

The organic carbon content of the soils varied from 2.08 to 3.25% for 0 to 15 cm depth. In 15 to 30 cm depth it ranged from 1.79 to 2.11% (Table 2). Significant differences ($p \leq 0.05$) in OC content of soils were observed among the different land use systems. The average content of soil OC along slope positions, were lower in maize and enset land use systems as compared to that of grassland. The difference could be attributed to the effect of continuous cultivation that aggravates organic matter oxidation. The roots of the grass and fungial hyphae in the grassland soils are probably responsible for the higher amount of total organic matter (Urioste et al., 2006). The results were in agreement with the findings of Negassa (2001) and Malo et al. (2005), who reported less organic carbon in the cultivated soils than grassed soils. At both depths enset farms had higher OC content as compared with the maize farms.

Table 2. Some chemical properties of the soil at 0-15 and 15-30 cm depth under different land use systems.

Land use	TN	OC	Av. P	Fe	Mn	Zn	Cu
	%		mg/kg				
			0-15 cm				
Enset	0.20^{b}	2.44^{b}	36.35^{a}	58.82	21.87^{b}	8.63	0.323
Grass	0.29^{a}	3.25^{a}	3.68^{b}	45.40	44.95^{a}	8.61	0.443
Maize	0.18^{b}	2.08^{b}	14.44^{b}	21.87	27.70^{b}	7.94	0.350
			15-30 cm				
Enset	$0.18a^{b}$	1.95	9.12^{a}	18.13^{b}	23.58	8.45	0.30
Grass	0.19^{a}	2.11	1.16^{b}	35.95^{a}	29.32	6.30	0.31
Maize	0.15^{b}	1.79	5.06^{ab}	26.91^{ab}	24.14	8.24	0.31

Mean values within a column followed by the same letter(s) are not significantly different at $p \leq 0.05$.

This could be due to the application of house refuse, which also increased total N content of enset farms. Zeleke et al. (2004) reported an increase in OC by 11 and 67% to incorporation of crop residues in Humbo and Alaba.

The mean available P content was significantly ($P \leq 0.05$) different among the land use systems. In all topographic positions and both depths, highest value of available P was found under enset farms followed by maize and grassland soils (Table 2). The higher available P content at both depths under enset is likely the consequence of long-term manure and house refuse applications and the associated increase in microbial activity. Materechera and Mkhabela (2001) have also reported that Organic matter influence P in soil solution by complexing P from adsorption site in ligand exchange and increase the mobility of inorganic P, particularly in acid soils, by decreasing chemical activity of iron and aluminum. The results were also in agreement with that of Boke (2004) who found high available P under enset in soils of Kokate and Adilo and concluded that transformation of organic P to available P through mineralization, addition of manure and crop residue to enset crop may have coated the reaction surfaces of the soil particles and prevent or delayed P sorption, and thereby increased P solubility. Relatively higher content of available P found under maize farms than that of grass land soils could be due to the continuous application of phosphorus fertilizer as was also reported by van der Eijk et al. (2006).

Available P content in all land use types was found to be higher than that of the surface horizons of the respective pedons (Table 2). This could be due to the application of manure, P fertilizers in the case of enset and maize farms, respectively. The difference between available P of grassland soils and surface soil pedons might be due to high number of samples taken from surface as compared to the single point sampling in the case of the pedons and depth of sampling.

Higher total nitrogen (TN) was observed in grassland fields followed by that of enset at both depths. This could be related to the higher organic matter content in the soils of grassland. There was also significant correlation (r=0.94***) and (r=0.50*) between organic carbon and total nitrogen at 0 to 15 cm and 15 to 30 cm depth, respectively. This shows that the contribution of OC to total N is high (Urioste et al, 2006). The results of the present study were in contrast to that of Boke (2004) who obtained relatively higher content of both organic carbon and total nitrogen from enset land use systems than that of the grasslands. The author attributed the higher concentration of total nitrogen under enset land use systems to the higher organic matter content as a result of manure addition.

The values of exchangeable Na were found to be highest under enset followed by grass in 0-15 cm depth (Table 3), while in 15 to 30 cm depth higher available Na was recorded in grass land soils followed by that of maize fields. Although there were differences in available Na concentration of the soils of the different land use systems, their ESP values were below the critical level (15%). For the three land uses and both depths the concentration of exchangeable potassium (K) followed trend of being enset field > grass land >maize farms. High exchangeable K in 0 to 15 cm under enset fields is likely the result of the addition of house refuse and wood ash supply, whereas low exchangeable K concentration in maize farms could be due to the effect of continuous cultivation and crop removal. This result is supported by previous findings that indicate intensity of weathering, cultivation and use of acid forming inorganic fertilizers affect the distribution of K in the soil system and enhance its depletion (Malo et al., 2005).

The exchangeable calcium (Ca) was highest under enset field (Table 3), whereas lower concentrations of exchangeable Ca were found under maize and grass in 0 to 15 cm and 15 to 30 cm depths, respectively. The exchangeable magnesium (Mg) concentrations followed similar trend as that of Ca under different land use systems. Higher and lower values of exchangeable Mg were found under enset and maize fields, respectively. The low exchangeable Ca and Mg observed under maize

Table 3. Some chemical properties of the soil at 0-15 and 15-30 cm depth under different land use systems.

Land use	Exchangeable cations				CEC	PBS
	Na	K	Ca	Mg		
	Cmol(+/kg)					%
			0-15 cm			
Enset	0.173	3.16	13.82	3.12a	23.73	84.66
Grass	0.133	2.35	10.56	3.33a	27.53	65.66
Maize	0.093	1.93	10.09	2.22b	21.80	59.00
			15-30 cm			
Enset	0.11	2.66	11.07	2.68	23.20	71.33^{a}
Grass	0.18	1.58	8.10	2.61	24.86	50.0^{b}
Maize	0.16	1.45	9.70	2.42	21.33	64.66^{a}

Means value within a column followed by the same letter(s) are not significantly different at $p \leq 0.05$

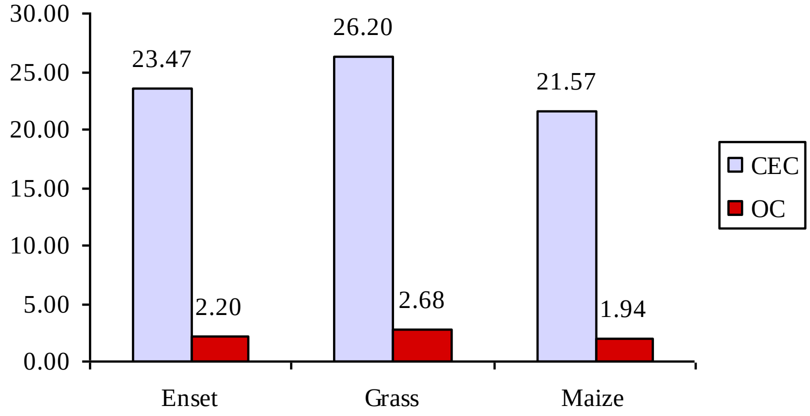

Figure 2. Organic carbon and CEC contents of soil under different land use systems

farms might be due to leaching, soil erosion and crop harvest, as was also reported by Negassa (2001).The percentage of base saturation (PBS) of soils under different land use systems showed significant differences. In 0 to 15 cm depth, the highest PBS was recorded under enset fields (84.66%) followed by grassland (65.66%), whereas in 15 to 30 cm depth, the highest value was found under enset (71.33%) followed by that of maize (64.66%) (Table 3). The highest PBS found under enset field at both depths indicates that the fertility status of enset field is higher as compared to that of the other land use systems. According to Urioste et al (2006), addition of organic matter increases the amount of exchangeable bases. Moreover, intensive cultivation and continuous use of inorganic fertilizers in the cultivated fields that enhance loss of base cations through leaching, erosion and crop harvest (Negassa, 2001).

Relatively, highest cation exchange capacity (CEC) values were observed under grassland (27.53 cmol (+)/kg) followed by that of enset (23.73 cmol (+)/kg) at both sampling depth (Table 3). In accordance with the organic carbon content, CEC values of the soil decreased consistently from grassland to enset and maize (Figure 2). This was also evident from the positively and highly correlation (r=0.91***) and (r =0.41) of CEC with organic carbon for 0 to 15 and 15 to 30 cm depths, respectively. The depletion of organic carbon as a result of intensive cultivation had, therefore, reduced the CEC of the soils under maize land use. These results were in agreement with pervious findings of Boke (2004) and Negassa (2001).

The micronutrients status of the soils was influenced by different land use systems (Table 2). Significant variations ($p \leq 0.05$) in available iron (Fe) at the 15 to 30 cm depth and manganese in 0 to 15 cm depth were observed among different land use systems. The highest available Fe was measured under enset (58.82 mg/kg) followed by grassland (45.40 mg/kg) at 0 to 15 cm depth. In 15 to 30 cm depth, highest Fe was obtained in grassland soils (35.95 mg/kg) followed by that of maize (26.91 mg/kg). In spite of the significant variation observed, available Fe was in a sufficient level for plant growth under all land use systems based on the Fe rating established by Havlin et al. (1999).

At both depths, available Mn concentrations were higher in grassland soils followed by that of maize fields (Appendix Table 1). According to the nutrient toxicity level suggested by Lindsay and Norvell (1978), the concentration of Mn was in the toxic level in all land use systems, as the concentrations of Mn in both layers were greater than 21.87 mg/kg compared to the critical level of 5 mg/kg. This higher content of Mn could be attributed due to pH of the soil where manganese becomes more available in acidic soils. Highest concentration of available Zinc (Zn) was found on the surface layer (0 to 15 cm depth) of enset field (8.63 mg/kg) followed by grassland soils (8.61 mg/kg), whereas in the lower depth (15 to 30 cm depth), the highest available Zn concentration under enset (8.45 mg/kg) was followed by maize land use (8.24 mg/kg). The concentrations of available Zn in all land use systems were within adequate level as indicated by Havlin et al. (1999). In the 0 to 15 cm depth the concentration of available Zn in the maize farms was the lowest as compared to the other land use systems. According to Negassa (2001), low Zn concentration in farm fields might be due to continuous harvesting of crop, organic matter oxidation, removal of the topsoil by sheet and rill erosion that is aggravated by tillage activities. Available cupper (Cu) values were not affected by the different land use systems. In 0 to 15 cm depth, however relatively highest available Cu content was observed in grassland soils (Appendix Table 2). This could be due to the relation of copper with organic carbon. According to Havlin et al. (1999) the concentrations of available Cu in all land use systems were in deficient range, except for grassland soils in depth of 0 to 15, where concentration falls under medium level.

Conclusion

In the southern region of Ethiopia, the growing population and more intensive land use have resulted in sharp declines of soil fertility by continuous removal of grain and vegetation, and erosion. Characterizing the spatial variability of soil nutrients in relation to site properties such as climate, land use, topography and other variables is important for understanding how the ecosystem works and assessing the effects of further land use change on soil properties (Wang et al., 2000). Findings of this study suggest that many soil properties are influenced by land use. At both depths, higher values of soil pH, EC, Av. P, Zn, K, Ca and PBS were obtained under enset fields as compared to the grassland and maize fields. Under maize fields the contents of Av. K, Mg, CEC, PBS, total N and OM were significantly lowest. These effects are attributed to the higher organic matter management in the enset fields and crop removal coupled with frequent disturbance of soil due to tillage practice under maize fields. The information generated from the present study will assist in developing sustainable and ecologically stable land use management strategies for the study area. Moreover, organizations, people living in the study area and others who intend to invest, transfer or introduce new agricultural technologies in the area will benefit from the study.

REFERENCES

Boke S (2004). Soil phosphorus fractions as influenced by different cropping systems in Andosols and Nitosols in Kembata-Tembaro and Wolayta Zones, SNNPRS. MSc Thesis. Alemaya University, (AU). P. 131.

Brady NC, Weil RR (2002). The nature and properties of soils. 13th ed. The Iowa state PVT. Ltd., India.

Celik I (2005). Land-use effects on organic matter and physical properties of soil in a southern Mediterranean highland of Turkey. Soil Tillage Res. 83:270–277.

Ethiopian Mapping Authority (1998). National Atlas of Ethiopia, Addis Abeba, Ethiopia.

Fu B, Chen L, Ma K, Zhou H, Wang J (2000). The relationships between land use and soil conditions in the hilly area of the loess plateau in northern Shaanxi, China. Catena 39:69-78.

Havlin JL, Beaton JD, Tisdale SL, Nilson WL (1999). Soil fertility and fertilizers: an introduction to nutrient management. 6th ed. Prentice Hall. Upper Saddle River, New Jersey. P. 499.

Jackson ML (1958). Soil Chemical Analysis. Prentice Hall, Inc., Engle Wood Cliffs. New Jersey. pp. 183-204.

Lindsay WL, Norvell WA (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci. Soc. Am. J. 42:421-428.

Liu XL, He YQ, Zhang HL, Schroder JK, Li CL, Zhou J, Zhang ZY (2010). Impact of land use and soil fertility on distributions of soil aggregate fractions and some nutrients. Pedosphere **20**(5):666–673.

Malo DD, Schumacher TE, Doolittle JJ (2005). Long-term cultivation impacts on selected soil properties in the northern Great Plains. Soil. Tillage Res. 81:277–291

Materechera SA, Mkhabela TS (2001). Influence of land-use on properties of a ferralitic soil under low external input farming in southern Swaziland. Soil Tillage Res. 62:15-25.

Negassa W (2001). Assessment of Important Physicochemical Properties of Nitosols under Different Management Systems in Bako Area, Western Ethiopia. M.Sc. Thesis, Alemaya University, Alemaya. p. 109.

Neris J, Jiménez C, Fuentes J, Morillas G, Tejedor M (2012). Vegetation and land-use effects on soil properties and water infiltration of Andisols in Tenerife (Canary Islands, Spain). Catena 98:55–62.

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

SAS (1997). SAS Institute Inc., Cary. NC. USA.

Urioste AM, Hevia a GG, Hepper EN. Anton LE, Bono AA, Buschiazzo DE (2006). Cultivation effects on the distribution of organic carbon, total nitrogen and phosphorus in soils of the semiarid region of Argentinian Pampas. Geoderma 136:621–630.

van der Eijk D, Janssen BH, Oenema O (2006) Initial and residual effects of fertilizer phosphorus on soil phosphorus and maize yields on phosphorus fixing soils A case study in south-west Kenya. Agric. Ecosys. Environ. 116:104–120

Wakene Negassa, (2001). Assessment of Important Physicochemical Properties of Nitosols under Different Management Systems in Bako Area, Western Ethiopia. M.Sc. Thesis, Alemaya University, Alemaya. pp 109.

Walkley A, Black CA (1934). An examination of Degtjareff method for determining soil organic matter and proposed modification of the proposed modification of the chromic acid titration method. Soil Sci, 37:29-38.

Wang J, Fu B, Qiu Y, Chen L (2001). Soil nutrients in relation to land use and landscape position in the semi-arid small catchment on the loess plateau in China J. Arid. Environ. 48:537–550.

Zeleke TB, Grevers MCJ, Si BC, Mermut AR, Beyene S (2004). Effect of residue incorporation on physical properties of the surface soi1 in the South Central Rift Valley of Ethiopia. Soil Till.Res. 77:35-46.

APPENDIX

Table 1. Correlation matrix of soil properties under different land uses of 0 to 15 cm depth at Delbo Watershed, 2006.

	pH	Clay	Na	K	Ca	Mg	CEC	TN	OC	Av. P	Fe	Mn	Zn	Cu
pH	1.0	-0.20	0.29	0.79*	0.85**	0.14	0.02	-0.28	-0.22	0.89**	0.02	-0.78*	0.10	-0.21
Clay		1.0	-0.16	-0.66*	-0.45	-0.49	-0.75*	-0.77*	-0.71*	0.05	0.073	-0.18	-0.70*	-0.34
Na			1.00	0.45	0.06	0.49	0.08	0.01	0.19	0.41	0.14	-0.31	0.33	-0.42
K				1.0	0.82**	0.42	0.49	0.24	0.30	0.57	0.07	-0.47	0.45	-0.10
Ca					1.0	0.33	0.45	0.12	0.16	0.55	0.24	-0.46	0.11	-0.09
Mg						1.0	0.75*	0.51	0.73*	-0.01	0.35	0.24	0.14	0.11
CEC							1.0	0.83**	0.91***	-0.33	0.23	0.44	0.24	0.20
TN								1.0	0.94***	-0.52	0.24	0.68*	0.58	0.36
OC									1.0	-0.46	0.32	0.64	0.43	0.25
Av. P										1.0	-0.01	-0.83**	0.13	-0.18
Fe											1.0	0.10	0.06	-0.19
Mn												1.0	0.11	0.54
Zn													1.0	0.31
Cu														1.0

*Significant at the < 0.05, ** < 0.01, and ***< 0.001 levels.

Table 2. Correlation matrix of soil properties under different land uses of 15 to 30 cm depth at Delbo Watershed, 2006.

	pH	Clay	Na	K	Ca	Mg	CEC	TN	OC	Av. P	Fe	Mn	Zn	Cu
pH	1.0	-0.62	0.002	0.80**	0.75*	0.25	-0.04	-0.57	-0.24	0.81**	-0.37	-0.84**	0.22	-0.21
Clay		1.0	0.37	-0.60	-0.42	-0.11	0.23	0.48	0.78*	-0.47	0.13	0.84**	-0.72	0.11
Na			1.0	0.10	-0.21	-0.45	0.19	-0.14	0.42	-0.39	-0.43	-0.03	-0.63	-0.59
K				1.0	0.47	0.30	0.17	-0.17	-0.04	0.60	-0.44	-0.73*	0.05	-0.34
Ca					1.0	0.03	0.17	-0.43	-0.13	0.73*	-0.43	-0.50	0.22	-0.22
Mg						1.0	0.21	0.17	0.10	0.39	0.53	-0.05	-0.06	0.52
CEC							1.0	0.33	0.41	-0.19	0.11	0.25	-0.47	-0.17
TN								1.0	0.50	-0.28	0.19	0.74*	-0.32	0.17
OC									1.0	-0.11	-0.21	0.55	-0.82**	-0.08
Av. P										1.0	-0.23	-0.54	0.38	0.20
Fe											1.0	0.35	0.18	0.78*
Mn												1.0	-0.41	0.30
Zn													1.0	0.38
Cu														1.0

*Significant at the < 0.05, ** < 0.01, and ***< 0.001 levels.