Developing Country Studies
ISSN 2224-607X (Paper) ISSN 2225-0565 (Online)
Vol.7, No.3, 2017

The Effect of Land Use Change on Soil Physicochemical Properties over Time in Ethiopia

Aklilu Bajigo
Department of Natural Resource Management, Wolaita Sodo University, Ethiopia
P.O. Box, 138 Wolaita, Ethiopia

Abstract

The study was conducted at Munesa Shashemane, Ethiopia to understand the long term effects of land use change on soil properties under different land use types. Comparison of change in soil properties over time was made by using samples from Mechanized farm (MF), Traditional farm (TF), plantations of Cupresus lusitanica (CL) and Euclayptus saligna (ES), and Natural Forest (NF), the data before ten years ago on the same site at this study was made. All data collected were subjected to ANOVA using the general linear model of SAS 9.0 at $p < 0.05$. Based on the result, under both plantation tree species, the total N, BS, and exchangeable Ca at 0-10 cm and 10-20 cm; available K and exchangeable K at 10-20 cm soil layer was increased significantly compared to the data before ten years ago. Under MF the bulk density, exchangeable Ca and exchangeable Na at 10-20 cm; total N, BS and available K at 0-10 cm and 10-20 cm soil depths increased significantly. Under TF, available K at 0-10 cm and 10-20 cm soil layer, BS and exchangeable Ca at 10-20 cm soil layer increased significantly. The CEC at 0-10 and 10-20 cm; the available P and exchangeable Na at 10-20 cm soil layer were decreased significantly compared to the data before ten years ago. Based on the results, the change in soil physicochemical properties is exacerbated by the land management practices, which may include selecting the right plantation species for restoring the site, and the plant residue management under different land use systems over time.

Keywords: Harvest, Macronutrient, Mechanized farming, Plantation, Traditional farming

1. INTRODUCTION

Inappropriate land use, agricultural productivity decline, and increasing population pressure are considered as the major driving factors of deforestation for millennia in Ethiopia (Elias, 2002). The rapidly growing human and domestic animal population created the need for expanding crop and grazing land (Teketay, 2001). The land pressure from increasing human population and domestic animals have had a negative impact on soil quality. Since many animals feed on the crop residue, little organic matter is returned back to the soil from continuous farmlands. Shortage of fuel wood, and increased dependency on crop residue and animal dung for household energy consumption leads to loss of the soil nutrients. Such practice for long period may cause severe soil degradation. The degradation is expressed in terms of loss of soil quality.

According to Lal (1997), soil degradation is the loss of actual potential productivity caused by the decline in soil physical, chemical and biological properties, including reduction in soil biodiversity. Land degradation can occur naturally, but human activities accelerate the process (Tefera, *et al.*, 2002). The rate of land degradation depends on the magnitude of deriving variables such as the land use change (Harrington CA, 1999). Conversion of forested land to crop cultivation in Bangladesh resulted in surface compaction and significant decreases in silt and clay contents of the soil. In relation to this, the soil quality such as soil porosity and aggregate stability, N, fulvic and labile C, microbial biomass C and deteriorated significantly (Islam and Weil, 2000).

The combined factors i.e., expansion of agricultural land, as well as increased demand of forest products are the threat on natural forests. In many areas, the harvest of timber products from Natural Forest (NF) is constrained in relation to diminishing natural forest. In response to this problem, use of tree plantations with fast growing native and exotic species to produce timber is becoming a common option (Laclau, 2003, Lemenih, 2006, Nambiar and Brown (Eds.), 1997, Tiarks *et al.*, 1998, Harrington, 1999). Fast growing exotic trees species, which have the ability to accumulate high amount of nutrients in their biomass and restore the soil physic-chemical properties. Tropical forest plantations are the most productive ecosystems in the world due to their fast growth (Binkley and Ryan, 1998). On the same study, *E. saligna,* which is fast growing compared to *Albizia facaltaria,* indicated that it has accumulated about 50% more aboveground biomass than *Albezia* at the same age. The trees shed part of their biomass to the soil, and release nutrients to the soil surface through decomposition and organic matter mineralization.

Although some researchers, for instance, (Binkley and Resh, 1999, Richter *et al.*, 1999) do not fully agree on the idea that a tree plantation can restore abandoned land and its nutrient resources, however the works of several researchers (Fisher, 1995, Lemenih *et al.*, 2004, Lugo, 1997, Schroth and Sinclair, 2003) indicate the positive contribution of plantation forestry established on previous crop lands. The study by Lemenih *et al.* (2004) also revealed the chance of reversed degradation with tree plantation based on careful species selection to achieve ecological restoration. Even though most of the studies encourage making tree plantation for restoration on degraded land, there are few studies that investigate the effect of continuous use of the same land either for tree plantation, or cultivation i.e. temporal change. Especially, studies that compare the change in soil conditions over time under different land use systems are important to predict the long term effects of the land use change.

To compare the change in soil properties over time under different land uses, i.e., *Eucalyptus saligna* (*E. saligna* Sm.), *Cupresus lusitanica* (*C. lusitanica* Mill.), Natural Forest (NF), Mechanized Farming (MF) and Traditional Farming (TF), the land uses were resampled after 10 years stay of the study by Lemenih *et al*. (2004) on the same site.

The objectives of this study were to: (1) assess differences in soil properties under five different land-uses assuming similar initial conditions (spatial analogue approach), (2) compare the soil property changes over time for five land-uses by repeated soil sampling (temporal analogue approach).

2. Materials and methods

2.1. Study site description

The study was made at warm sub-humid and humid eco-climatic zones of the elevation gradient part of the Munesa Shashemane forest, specifically at Lepis area, which is about 240 km south of the capital city, Addis Ababa close to the Rift Valley eastern escarpment. The plantations are in the Gambo district of the Shashemane Forest Industry Enterprise (SFIE) which is situated on latitude $7^{0}20'$N and longitude $38^{0}45'$E (Fig 1).

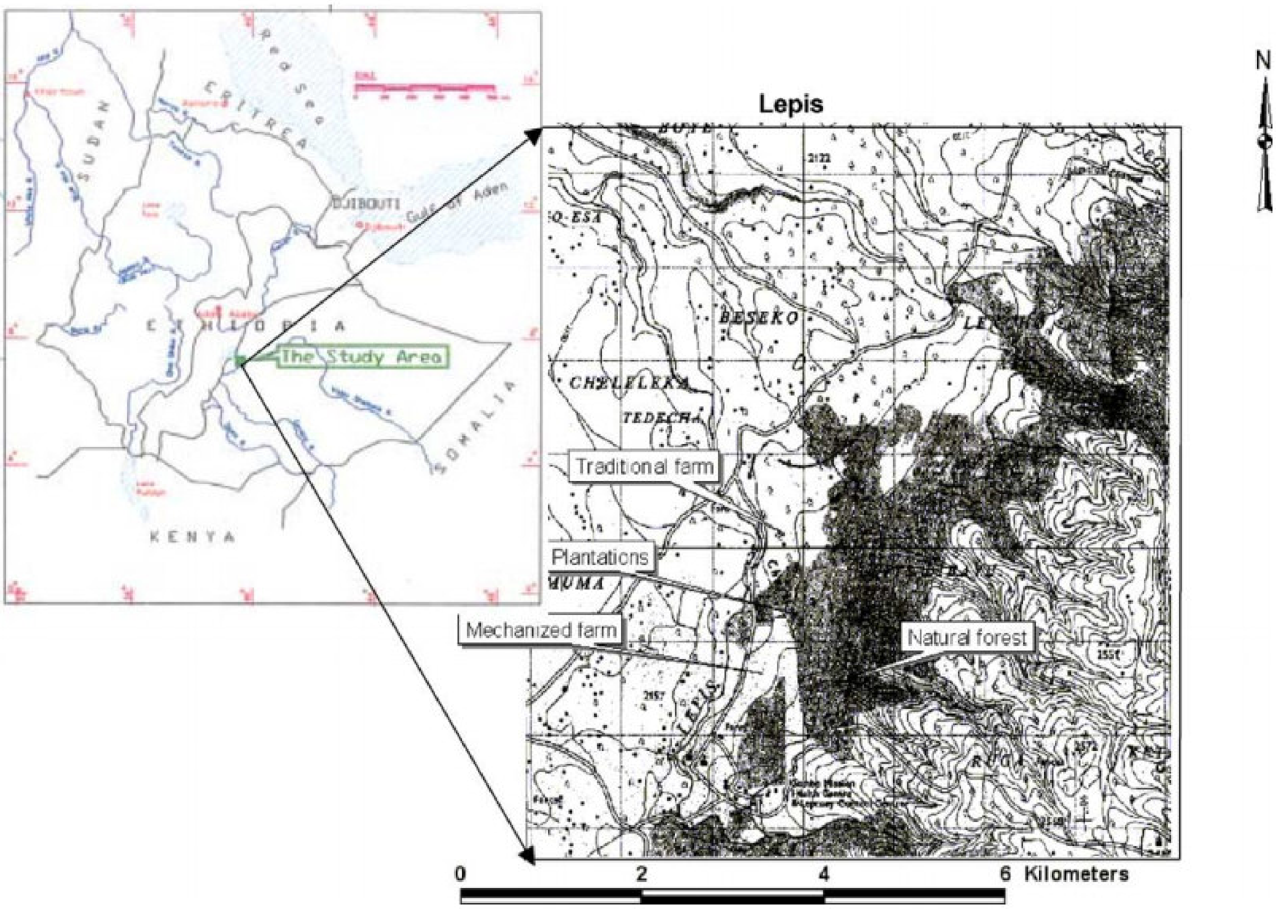

Figure 1: The map of study area showing different land uses from where data collected (adopted from Lemenih *et al*., 2004).

The NF around Lepis is a tropical dry afromontane forest of the eastern escarpment of the central Ethiopian Rift Valley and belongs to the Munesa Shashemane Forest (Lemenih *et al*., 2004). The five land uses sampled are situated near by each other in the bottom at an altitude of approximately 2100 m a.s.l on flat topography. The rainfall has bimodal distribution. The short rainy season extends between March and June and the major rainy season occurs between July and October. The mean annual rainfall is 1333 mm, and the annual range of temperature is about 5.7 to 19.5 ^{0}C. The soils parent materials consist of volcanic lavas, ashes and pumices from quaternary volcanic activities in the Rift Valley. The soils of the area are classified as Humic Haplustands (Soil Survey Staff, 2003) and Mollic Andosol (FAO 1986) as described in Lemenih *et al*. (2004). The agricultural landscape has a scattered remnant trees from the NF which gives the agricultural landscape a parkland agroforestry structure. Self-subsistence agriculture, integrating crop production and animal rearing is the dominant land-use in the area.

The major annual crops produced include different varieties of barley (*Hordeum vulgare*) wheat (*Triticum sp.*), maize (*Zea mays*), sorghum (*Sorghum vulgare*), potato (*Solanum tuberosum*), and perennial crop enset (*Ensete ventricosum*) (Abate, 2004). These crops cultivated during the initial ten to fifteen years after clearance of the NF by only utilizing the natural fertility of the soil (Lemenih *et al*., 2004). Later, an inorganic fertilizer is added in the form of urea and Diammonium phosphate (DAP) at an approximate the rate 50 kg ha^{-1} y^{-1} for each of the two fertilizers. However, some farmers cannot afford to apply the recommended amount. Some farmers do not use any fertilizers at all.

The mechanized farming (MF) site has been plowed since 1968 and cultivated with wheat, barley and maize as major crops in rotation with the use of fertilizer at the rate of maximum 100 kg ha^{-1} y^{-1} of urea and DAP respectively since clearance and conversion of the site. Part of the farmland under MF was abandoned after 16 years of continuous farming and converted to plantations of *E. saligna* and *C. lusitanica* (Lemenih *et al*., 2004). After February 2001, *E. saligna* stand has been thinned or harvested four times. It was clear felled immediately after soil sample was taken at 2001, second coppice at 2005, third coppice at 2008 and singling at 2011. Within these 10 years the total volume of 252 m^3 ha^{-1} was removed as transmission poles, saw logs, construction poles and fuel wood. The stand of *C. lusitanica* at the time of repeated sapling at 2011 was 25 years old. It has been thinned 3 times and the stand stem density at the time of sampling was 400 trees ha^{-1} (data from Gambo district of SFIE).

2.2. Study approach

The most common approach to the study of how soil is affected by different land uses is the spatial analogue method where time is substituted for space. It allows comparisons to be made without waiting for long periods before the effect of land use becomes evident. The spatial analogue method involved sampling from sites presently under different land-use, but within a similar environment and on similar soil types (Lemenih *et al*., 2004). Soil conditions and soil-forming factors, except time variation, are kept as homogeneous as possible, i.e. similar topography, climate, geology and land-use history is preferred (Lemenih *et al*., 2004). However, the method can always be questioned as describing spatial variation instead of actual effects of land-use. In this study, we complemented the spatial analogue method by looking at the actual changes over time for the different land-uses separately. Hence, soil properties in the present soil condition were compared with a previous study by (Lemenih *et al*., 2004) as the base line. In this way, we would be able to determine whether there is a change in soil properties attributed to the land-use that is consistent with the previously detected differences.

2.3. Sampling and laboratory analysis

Following the same procedures in Lemenih *et al*. (2004), soil samples were taken from five different land uses to study the effect of land use change on soil properties over time. The five different land uses that were studied where plantations of *E. saligna* and *C. lusitanica*; mechanized and traditional cropland cultivation and natural forest. A square plot of 20 x 20 m^2 area was established at the same location as the previous study. A set of disturbed soil samples were taken from four corners and the center of the square at 0–10 and 10–20 cm depths uniformly along each depth. Another set of undisturbed soil samples were taken from soil layers of 0-10 and 10-20 cm using sharp edge steel cores (7.2 cm high and 5 cm diameter), and oven-dried at 105oC for the determination of soil bulk density. The experiment had a total of 50 (5 land use types* 2 depths*5 rep) samples for bulk density measurements. Simultaneously, 50 soil samples were collected from the same pits for chemical analysis.

The disturbed soil samples were air-dried, homogenized and made to pass through 2mm sieve for chemical analysis. Soil pH was measured in water and 1 M KCl suspension of 1:2.5 (soil: water ratio) using a glass–calomel combination electrode. Total N was analyzed with a LECO-1000 CHN analyzer and the results were reported on oven-dry basis. Available P (Olsen) was analyzed according to the standard methods (Olsen *et al*., 1954), exchangeable bases (Ca, Mg, K and Na) were analyzed after extraction by using 1 M ammonium acetate at pH 7.0. The experimental outputs of the Ca and Mg in the extracts were analyzed using atomic absorption spectrophotometer; then Na and K were determined by using flame photometry method following Black and Waring (1976).procedures. By using 1 M ammonium acetate the exchangeable base forming cations displaced, and the samples were washed using ethanol. Then it was fixed with ammonia, and replaced by Na^+. The cation exchangeable capacity (CEC) was estimated titrimetrically by distillation of ammonia that was displaced by Na^+ following Chapman (1965). Base saturation (BS %) was computed from the base forming cations (Ca, Mg, Na and K) by CEC of the soil).

2.4. Data analysis

Comparisons of soil properties under *E. saligna*, *C. lustanica*, TF, MF and NF land use systems were made after data was analyzed by using two-way analysis of variance (ANOVA) with the help of SAS 9.0 statistical package.

The Tukey test was used to determine the significant difference between land uses and difference along soil depths at $p<0.05$. Some soil properties from current and previous results for instance total N, available P, available and exchangeable K, exchangeable Ca and exchangeable Na were converted to an amount on area basis by using soil bulk density, soil depth and concentrations of soil properties by using equations 1 and equation 2.

$$Equation1: A * B = C$$

$$Eqation2: c = C * \sqrt{(a/A)^2 + (b/B)^2}$$

$$Equation3: Z = \left(\frac{\overline{X} - \overline{Y} - \square o}{\sqrt{\frac{\sigma 1^2}{m} + \frac{\sigma 2^2}{n}}} \right)$$

Where A stands for mean concentration of soil property, B stands for bulk density, C stands for the value of soil properties in stock bases, and c stands for standard deviation of the soil in stock basis, a is the standard deviation of the soil in concentration basis and b is the standard deviation of the soil bulk density. To detect whether or not the change in physical and chemical properties of the soil under the plantations, the farmlands and the NF were significantly different compared to the previous data, two sample t-tests was used where, X bar is the previous mean and Y bar is the present mean; σ_1^2 and σ_2^2 are the standard deviation of previous and present data respectively, and the m and n are number of samples. The level of statistical significance was computed at $p<0.05$.

3. Result and Discussion

3.1. Soil physicochemical properties by using spatial analogue approach

The soil under *C. lusitanica* plantation gave lower bulk density and even it was close to that of NF. The significantly lower bulk density under NF and *C. lusitanica* at the surface soil depth (0-10 cm) may be attributed to the higher litter accumulation on the surface soil and the reduced surface soil disturbance. With regards to *E. saligna* plantation stand, the observed higher soil bulk density may be the response to lower liter accumulation and less soil aggregate stability under the canopy (Table 1). The study made on the same site at the same time to this study indicated that, most of the farmers lived near the plantations were engaged in collecting branches and leaves during pruning and thinning periods (Poultouchidou, 2012). Due to the periodic tree harvesting of *E. saligna*, the canopy gap gives a chance for free grazing animals and may lead to soil compaction.

Table1. *Mean(SD) of some soil physicochemical properties in the 0–10 and 10–20 cm soil layers under natural forest (NF), mechanized farm (MF), traditional farm (TF), and plantation with C. lusitanica and E. saligna.*

Soil properties	**Depths (cm)**	**NF**	**MF**	**TF**	***C. lusitanica***	***E. saligna***
BD (g cm^{-3})	0-10	0.73 (0.12)^{b}	1.07 (0.04)^{a}	0.98 (9.04)^{a}	0.88 (0.15)^{ab}	1.04 (0.18)^{a}
	10-20	0.77 (0.05)^{d}	0.99 (0.09)^{b}	0.84 (0.04)^{cd}	0.95 (0.07)^{cb}	1.18 (0.06)^{a}
pH	0-10	6.88 (0.27)^{a}	5.88 (0.76)^{b}	5.42 (0.28)^{b}	6.70 (0.29)^{a}	5.70 (0.35)^{b}
	10-20	6.78 (0.33)^{a}	6.00 (0.89)^{a}	5.66 (0.42)^{a}	6.70 (0.37)^{a}	6.18 (0.89)^{a}
N (g Kg^{-1})	0-10	8.02 (0.81)^{a}	5.56 (0.11)^{b}	5.78 (0.15)^{b}	7.30 (0.87)^{a}	5.98 (0.24)^{b}
	10-20	5.26 (0.19)^{b}	5.48 (0.19)^{b}	5.56 (0.36)^{ab}	5.96 (0.24) ^{a}	5.48 (0.15)^{b}
EC (dS m^{-1})	0-10	0.22 (0.12)^{a}	0.1 (0.05)^{ab}	0.15 (0.04)^{ab}	0.13 (0.05)^{ab}	0.06 (0.03)^{b}
	10-20	0.09 (0.08)^{a}	0.05 (0.04)^{a}	0.05 (0.02)^{a}	0.08 (0.02)^{a}	0.05 (0.03)^{a}
CEC (Cmol$_c$ Kg^{-1})	0-10	36.9 (5.44)^{a}	20.9 (1.35)^{b}	24.2 (2.35)^{b}	36.9 (4.40)^{a}	26.6 (2.96)^{b}
	10-20	21.6 (2.87)^{b}	21.4 (2.24)^{b}	22.8 (2.88)^{ab}	27.0 (2.69)^{a}	26.2 (0.89)^{a}
BS (%)	0-10	108 (8.67)^{a}	97.7 (36.5)^{a}	86.0 (16.5)^{a}	97.1 (7.19)^{a}	99.2 (11)^{a}
	10-20	84.2 (19.2)^{a}	95.8 (18.2)^{a}	76.6 (18.7)^{a}	93.9 (20.9)^{a}	90.7 (10.4)^{a}
Av. K (mg kg^{-1})	0-10	647 (422)^{ab}	448 (79.6)^{ab}	270 (77.9)^{b}	717 (264)^{a}	468 (98)^{ab}
	10-20	536 (622)^{a}	377 (141)^{a}	177 (49.9)^{a}	696 (195)^{a}	435 (77.3)^{a}
P (mg Kg^{-1})	0-10	9.53 (4.99)^{ab}	18.4 (8.68)^{a}	6.46 (0.63)^{b}	8.36 (3.74)^{b}	3.66 (1.54)^{b}
	10-20	1.60 (0.83)^{b}	10.9 (8.68)^{a}	2.61 (0.62)^{b}	2.95 (0.73)^{b}	2.30 (1.19)^{b}
K (Cmol$_c$ Kg^{-1})	0-10	1.65 (1.08)^{ab}	1.15 (0.20)^{ab}	0.69 (0.2)^{b}	1.83 (0.68)^{a}	1.20 (0.25)^{ab}
	10-20	1.36 (1.59)^{a}	0.96 (0.36)^{a}	0.45 (0.13)^{a}	1.78 (0.50)^{a}	1.11 (0.20)^{a}
Ca (Cmol$_c$ Kg^{-1})	0-10	32.4 (5.01)^{a}	17.2 (6.92)^{c}	18.0 (5.28)^{c}	30.5 (3.31)^{ab}	22.6 (4.07)^{bc}
	10-20	14.5 (4.44)^{a}	18.1 (5.29)^{a}	15.2 (5.97)^{a}	20.7 (5.11)^{a}	20.3 (2.84)^{a}
Na (Cmol$_c$ Kg^{-1})	0-10	0.25 (0.04)^{a}	0.18 (0.02)^{bc}	0.17 (0.03)^{c}	0.21 (0.04)^{abc}	0.28 (0.05)^{a}
	10-20	0.27 (0.07)^{a}	0.20 (0.05)^{a}	0.20 (0.08)^{a}	0.20 (0.05)^{a}	0.30 (0.04)^{a}

Where BD stands for bulk density, pH for soil pH level, N for total nitrogen, EC for electric conductivity, CEC for cation exchange capacity, BS for base saturation, P for available phosphorus, Av. K for available potassium and K for exchangeable potassium, Ca for exchangeable calcium, and Na for exchangeable sodium. *Different letters in the same row shows significant difference at (p<0.05).*

Table 2. *The amount of soil macronutrient stocks under differnt land uses.*

Nutrients (Mg ha^{-1})	***C. lusitanica***	***E. saligna***	**MF**	**NF**	**TF**
N	1.21	0.13	1.13	0.99	1.04
P	10.4	6.62	30.2	8.36	8.24
K	1.29	1.00	0.84	0.89	0.4
Ca	9.4	9.52	7.27	7.02	6.02
Mg	1.03	0.99	0.64	1.23	0.75

Where N stands for total nitrogen, P for available phosphorus, K for exchangeable potassium, Ca for exchangeable calcium, and Mg for exchangeable magnesium.

Under MF and TF, significantly higher bulk density is observed at the surface soil layer as compared to NF. The finding Fisher (1995) supports current study is in a tropical forest in Zimbabwe and Yao *et al*. (2010) in Mid-West Côte d'Ivoire; where the bulk density of the soil becomes higher after the native vegetation was converted to agricultural land. In current study, continuous cultivation practices may have resulted in the loss of soil organic matter through mineralization and increase soil bulk density. As reported by Lemenih *et al*. (2008), the soil bulk density increased after more than 50 years of cultivation and soil porosity decreased relative to the length of time the soils were subjected to cultivation. (Islam and Weil, 2000, Miralles *et al*., 2009) also made similar observations. The rise in bulk density in continued farmlands is due to crop residue removal during site preparation and crop harvesting, and use of heavy machinery that destroys the soil macro pores, especially under MF at surface soil.

C. lusitanica plantation stand has shown more improvement on the soil pH compared to *E. saligna* (Table 1). The lower level of pH found in the 10-20 cm soil layer for MF, *E. saligna*, and TF may be due to different reasons. The most important is the higher rate of removal of base cations throughbiomass harvest and the corresponding input of H^{+} from the top soil layer. N fertilizer application may also result in nitrification which is an acidifying process and it could mostly be important in the case of MF. The rate of acidification can be increased when there is higher amount of N input through fertilizer (Hazelton and Murphy, 2007).

Soil total N was lower under continuous farm lands compared to NF and *C. lusitanica.* This observation is in line with the results by Lemenih *et al*. (2005), that only 59.2% of the soil total N at 0-10 cm soil depth was remaining after 53 years of continuous cropping following deforestation. Numerous field studies have indicated that crop management practices can either enhance or diminish quantities of soil total N (Knops and Tilman, 2000). The study by Lemma, (2006) attributes that the decline in total soil N is due to lower crop residue inputs and intensive harvest. Despite the urea application at the rate of 100 Kg ha^{-1} y^{-1}, MF land exhibited the lowest value for total N (Lemenih *et al*., 2004) and it was confirmed in this study as well. The higher soil disturbance by the machine plowing that facilitates mineralization and the loss of soil N through leaching or volatilization (Chesworth (Edt.), 2008), but it can also be speculated that this may be the result of long term harvest and complete removal of the aboveground biomass.

The comparison between plantation species for soil total N revealed that significantly higher accumulation was under *C. lusitanica* than under *E. saligna* at both upper and lower soil layers. *E. saligna* diverged more negative from the NF compared to *C. lusitanica* at 0-10 cm soil depth (Table 1). This result may be due to the fast growth rate of *E. saligna* plantation species, frequent export of biomass through harvest and possibly higher volatilization rate which may be facilitated by frequent harvest activity imposed soil disturbance. The poorer soil N status under the fast growing *E. saligna* stand compared to *C. lusitanica* was also reported by (Lemenih *et al*., 2004).

The comparison between continuously cultivated lands, soil available P revealed significantly greater concentration under MF compared to TF (Table 2). This may be attributed to the constant inorganic fertilizer (Diamonium Phosphate) application that helps compensate the nutrient removed through biomass. The application of inorganic fertilizer has a tendency boost the concentration of P. A study in northern Guinea reports that, under continuous cultivation with no fertilizer addition, a significant reduction occurred in available P pool; while the cultivation complemented with inorganic P fertilization, it increased the available P of the site (Agbenin and Goladi, 1998). The lower values of exchangeable K^{+}, exchangeable Ca^{+2} and exchangeable Na^{+1} under these farm lands (Table 2) may be attributed to a cumulative effect of nutrient removal through long term biomass harvest and leaching from the surface soil layer. The reduction in pH of the soil under the farm lands at 0-10 cm soil depth may be an indication of reduction of these base cations.

In general, the soil stock value of N under *C. lusitanica*>MF>TF>NF>*E. saligna;* K^{+} under *C. lusitanica*>*E. saligna*>NF>MF>TF; Ca^{+2} under *E. saligna*>*C. lusitanica*>MF>NF>TF, and Mg^{+2} under *C. lusitanica*>NF>*E. saligna*>TF>MF (Table 2).

3.2. Change in soil physico-chemical properties over time

Comparisons of the data from the study by (Lemenih *et al*., 2004) with the current study data presented in Table

1 shows that the changes in soil property vary depending on the parameters at different soil layers. For instance, pH, base saturation and exchangeable Ca^{+2} increased significantly in both 0-10 cm and 10-20 cm soil depths under NF. On the other hand, available K^{+1} increased significantly at 0-10 cm soil depth however, total N increased significantly at 10-20 cm soil layer under NF (Fig 3, 4, 5, 6 and 7). pH of the soil has shown about 0.68 and 0.75 units increment, base saturation has shown about 29.5% and 28% increment, and exchangeable Ca^{+2} about 196 gm^{-2} and 115 gm^{-2} increment at 0-10 and 10-20 cm soil depths respectively. In line with the higher accumulation of exchangeable Ca^{+2} content in the soil under NF, the pH level was significantly increased over 10 years of land uses. Soil CEC and bulk density which are highly dependent on the soil organic matter as stated by (Yimer *et al*., 2008) did not show significant variation within this two sampling periods. This may be attributed to non-significant increase in soil organic matter under NF as stated in the study made on the same site by Poultouchidou (2012). In contrast, 35.8 gm^{-2} significant increase in Available K^{+1} at 0-10 cm and 252 gm^{-2} total nitrogen at 10-20 cm soil depths at $p<0.05$ was observed. Nutrients that are contained in litter-fall are released after breakdown of the organic matter and be immediately available for plant growth. This is an important process in healthy forest ecosystem (Pöyry, 1992).

Under TF, soil bulk density and base saturation at 0-10 cm soil layer and total N at 0-10 cm and 10-20 cm soil layers increased significantly. CEC at both 0-10 cm and 10-20 cm soil layer, pH at 0-10 cm and available P at 10-20 cm soil layer reduced significantly within ten years of land use (Fig 2, 3, 4, 5, 6, and 7). Soil bulk density showed little rate of change under MF which may indicate that MF land had reached the maximum compaction level already before ten years. As indicated by Powers *et al*. (2005), not all sites responded similarly and the degree of increase in bulk density depends on the initial bulk density. As initial bulk density increased, the relative change due to severe compaction declined. In contrast to MF, soil bulk density showed significant increase under TF after ten years at 0-10 cm soil layer. Under MF, total nitrogen and available K^{+1} at both 0-10 cm and 10-20 cm soil layer increased significantly while, exchangeable Ca^{+2} and Na^{+1} increased at 10-20 cm soil depth only. In contrast, the change in these soil properties were insignificant under TF. In these farmlands where the origin of base cations mainly is the parent material, the change in concentration of some of the base cations were lower compared to other land uses. The level of rate of change of these soil properties under the land uses may be the response of the level of weathering and the amount of nutrients extracted by the plant biomass. The inorganic fertilizer application during every cropping season may be contributed to higher positive change in the soil total N and available K^{+1} under MF. The use of inorganic fertilizers enhances the availability of K^{+1}. Higher K^{+1} was released from the soil K^{+1} reserves in the plots under NP treatment compared to unfertilized soils (Yu *et al*., 2009).

The tree plantations have brought positive effects on some of the soil properties. In fact the positive contribution of plantations to the soil nutrient pool varies with the tree species nutrient acquisition. It may also depend on the amount of litter accumulated under the canopy, harvest management and rate of nutrient release back from the biomass. Hence, total N, base saturation, and exchangeable Ca^{+2} were significantly increased at both 0-10 cm and 10-20 cm soil layers. Available K^{+1} and exchangeable K^{+1} at 10-20 cm soil layer were increased under *C. lusitanica* and *E. saligna*. However, considering some of the soil properties that have shown significant changes under both plantation species, the soil properties under *E. saligna* had higher rate of change than *C. lusitanica* did during the ten years land uses. Under *C. lusitanica,* soil pH and exchangeable Na increased significantly at 0-10 cm soil depth. In contrast to *C. lusitanica*, the level of available K^{+1} under *E. saligna* increased at fast rate in the surface soil layer (Fig 2, 3, 4, 5, 6 and 7).

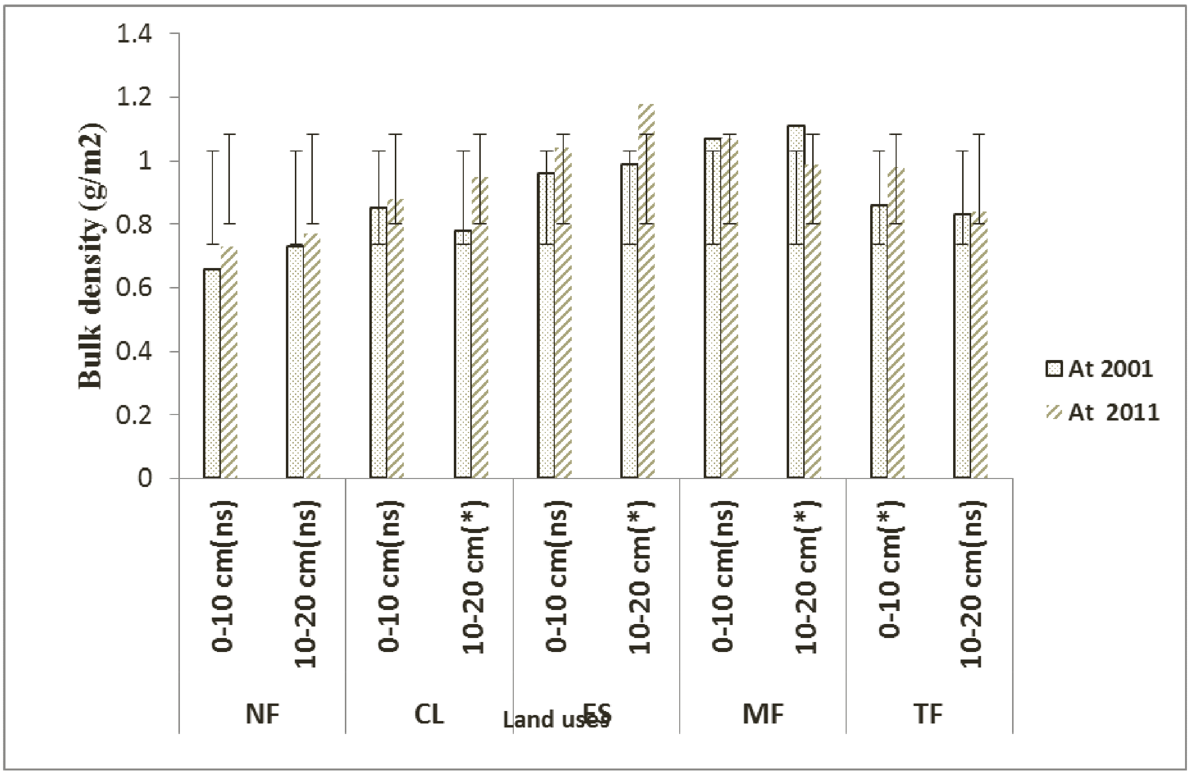

Figure2: comparison of the soil bulk densities at 2001 and 2011 of repeated sampling periods. * - refers to significantly different but, ns – refers not significantly different at p<0.05.

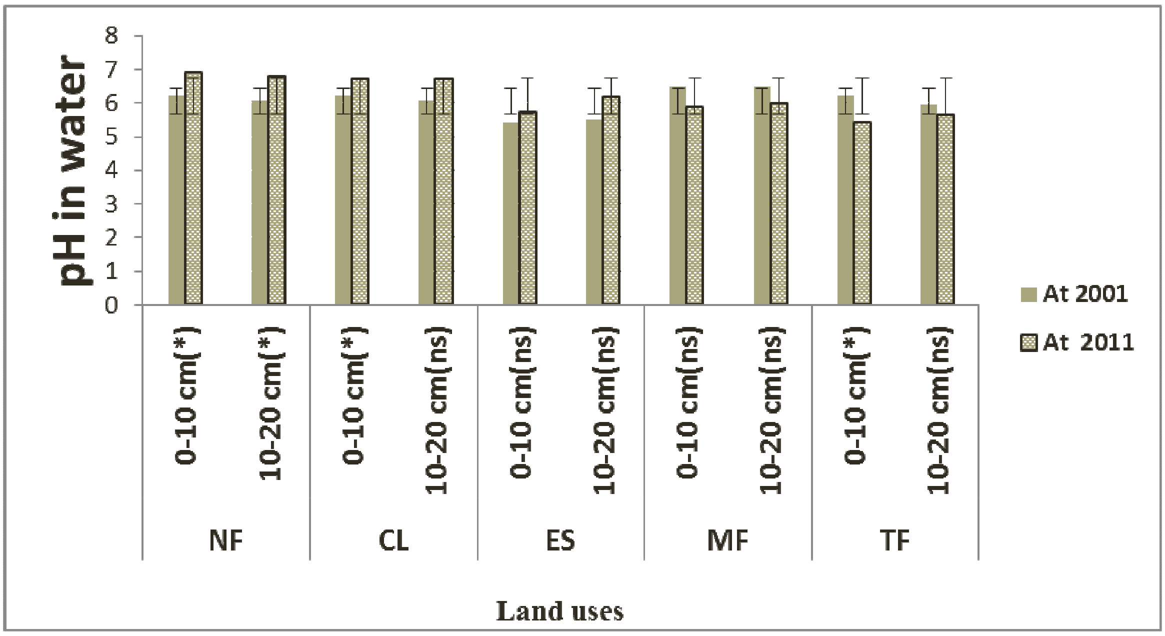

Figure3: Comparison of the soil pH at 2001 and 2011 of repeated sampling periods. * - refers to significantly different but, ns – refers not significantly different at p<0.05.

NB: NF stands for Natural forest, CL for *C. lusitanica*, ES for *E. saligna,* MF for Mechanized farm, and TF for Traditional farm.

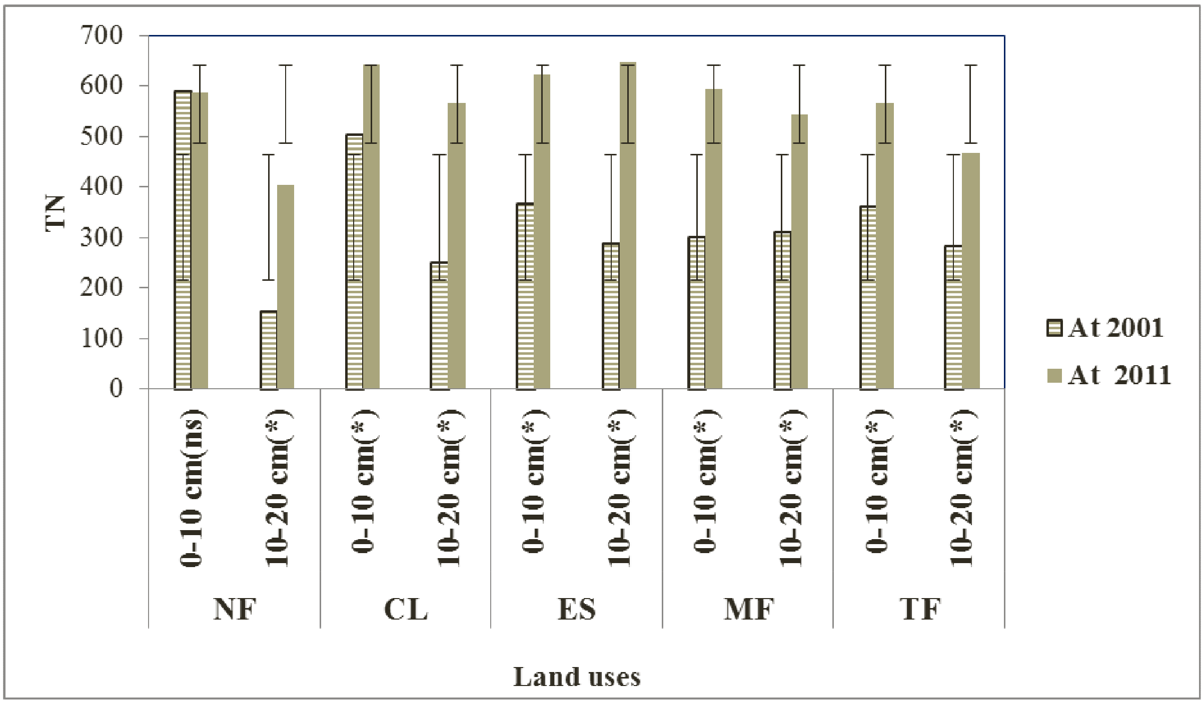

Figure4: Comparison of the soil Total N at 2001 and 2011 of repeated sampling periods. * - refers to significantly different but, ns – refers not significantly different at $p<0.05$.

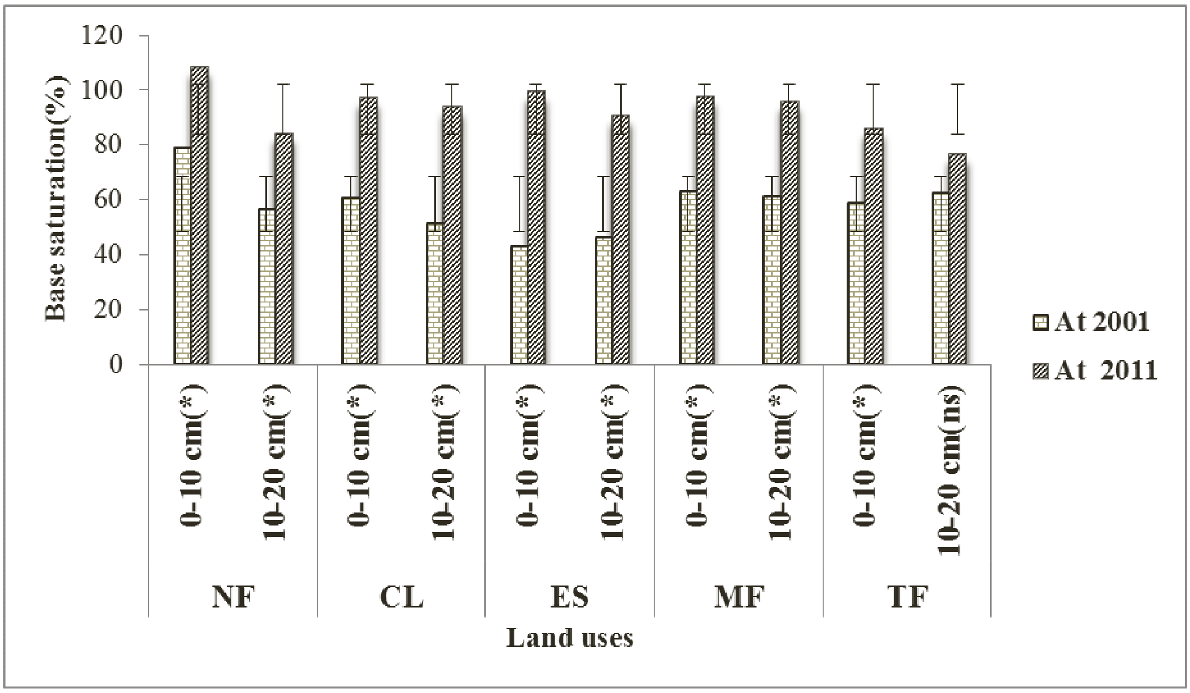

Figure5: Comparison of the soil base saturation at 2001 and 2011 of repeated sampling periods. * - refers to significantly different but, ns – refers not significantly different at $p<0.05$.

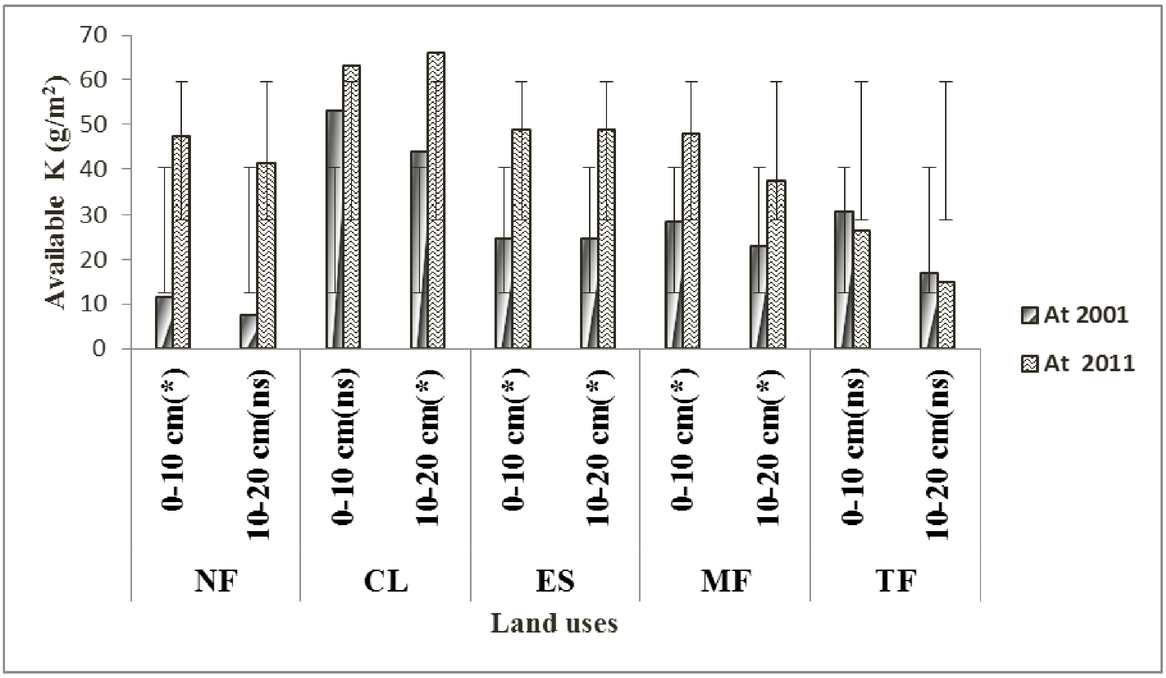

Figure 6: Comparison of the soil Available K at 2001 and 2011 of repeated sampling periods. * - refers to significantly different but, ns – refers not significantly different at $p<0.05$.

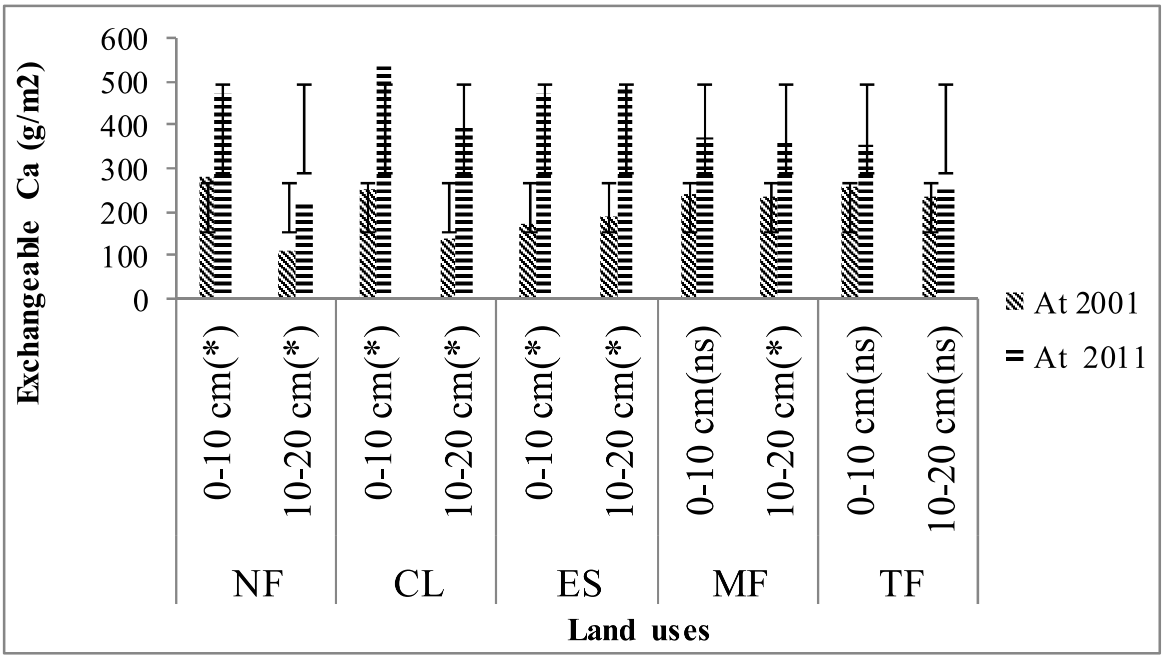

Figure7: Comparison of the soil Exchangeable Ca at 2001 and 2011 of repeated sampling periods. * - refers to significantly different but, ns – refers not significantly different at $p<0.05$.

The factor that may be responsible for the soil properties change is that of the intensity of tree harvesting from the plantation stand in the study site. Plantation stand of *C. lusitanica* in the study site has been thinned but not clear felled, while the *E. saligna* has been coppiced four times within the last ten years. The harvest activates intensify disturbances which facilitates the decomposition of litter in the soil layer and the rate of release of nutrients to soil. The frequent harvest from the plantation stands may lead to the decomposition and mineralization of organic matter under the canopy of *E. saligna*. The finding of Poultouchidou (2012) on the same site, indicated significantly lower organic carbon under *E. saligna* compared to that of *C. lusitanica.* This may be the indication of the higher rate of decomposition and mineralization of the organic matter in the soil. Other studies also revealed that the soil disturbance resulted in an increased contact of the litter with the decomposers which lead to lower organic matter (Lemenih *et al*., 2005, Powers; 2005, Tiarks *et al*. (eds), 2004). In northern Spain, Schmitz *et al*. (1998), reported that logging in native deciduous forests and old pine plantations resulted in mineralization and nutrient loss due to intense exposure of the soils to solar radiation, as well as disturbance due to trunk extraction practices. The soil organic matter is a critical pool in the carbon cycle and contains a pool of nutrients and it plays a key role in nutrient release and availability in soils (Lemma, 2006). Under *C. lusitanica*, the lower divergence of soil properties may be related to the lower disturbance of soil layer. The nutrients may be retained in the organic matter under this land use for long time. The significantly elevated soil bulk density over time under both plantation tree species at 10-20 cm soil depth may be due to the reason that the subsurface layers are subjected to the compacting weight from tree harvesting machineries and grazing animals under the plantation.

4. CONCLUSION

Based on the results, the following conclusion is drawn. According to the spatial analogue approach the soil property under *C. lusitanica* indicated more similar conditions with that of NF compared to *E. saligna*, MF and TF. For instance; lower bulk density, the higher N, the near neutral pH level, higher available and exchangeable K under *C. lusitanica,* which are close to NF. Hence, *C. lusitanica* is better performing with regards to soil physicochemical properties.

The rate of change in some soil properties over time was relatively lower under NF compared to those of other land use types studied. However, based on the intrinsic nature of land use types sampled, the change in soil properties may also be related to the intensity and frequency of harvesting the aboveground biomass and related soil disturbance. The results of repeated sampling after ten years on the continued faming land indicated that the more soil property positive changes were observed under MF compared to TF, i.e. more declining soil property will be expected under TF in future. With regards to plantations, the greater divergence was observed under *E. saligna* over time. The positively higher rate of change in some soil properties under *E. saligna* compared to *C. lusitanica* within these years of land use. This may be attributed to the frequent aboveground biomass removal and the subsequent mineralization of the soil organic matter as result of soil disturbance. Over these ten years land use, plantations of *E. saligna and C. lusitanica* were better in maintaining and restoring soil properties than continuous farmlands. In general, based on the results the long term effect of land use change on the soil properties is influenced by the land management system. Therefore, land management that include return of residues of crop or plantation trees to reduce the loss of nutrients; as well as the right plantation tree species selection can be used as a tool of restoring degraded lands and maintaining sustainability.

Acknowledgments

I am thankful to Swedish Ministry of Foreign Affairs for financing the study. Finally my thanks also extend to Wondo Gent College of Forestry and Natural Resources for providing the field materials and laboratory facilities.

REFERENCES

Abate, A. (2004). Sustainable Biomass and Nutrient Studies of Selected Tree Species of Natural and Plantation Forests: Implications Management of the Munessa-Shashemene Forest, Ethiopia. *PhD Thesis* Universität Bayreuth. 149 pp.

Agbenin, J. O. and Goladi, J. T. (1998). Dynamics of phosphorus fractions in a savanna Alfisol under continuous cultivation. Department of Soil Sci, Institute for Agricultural Research, Ahmadu Rello University, Nigeria. School of Sci, College of Education, Akwanga, Nasarawa State, Nigeria. *Soil use and Management*. 14, 5944 pp.

Binkley, D., and Resh, S.C. (1999). Rapid changes in soils following Eucalyptus afforestation in Hawaii. *Soil Sci. Soc. Am.* 63, pp 222–225.

Binkley, D., and Ryan, M. G. (1998). Net primary production and nutrient cycling in replicated stands of *Eucalyptus saligna* and *Albizia facaltaria*. *Forest Ecol. and Management*. 112, pp 79-85.

Black, S.A., and Waring, S.A. (1976). Nitrate leaching and adsorption in Kresnozen from Redland Bay. *Aust. J. Soil Res.* 14, pp 171–180.

Chapman, H.D. (1965). Cation exchange capacity. In: Black, C.A., *et al.* (Eds.), Methods of Soil Analysis. *Agronomy Am. Soc*. 9, pp 891–901.

Chesworth, W. (Edt.) (2008). Encyclopedia of Soil Sci.: Encyclopedia of Earth Sci. Series University of Guelph Canada. *Springer.* 902pp.

Elias, E. (2002). Farmers'Perceptions of Soil Fertility Change and Management.SOS Sahel & institute for sustainable development. *Doctoral Thesis*. Addis Ababa, Ethiopia. 252p.

FAO (1986). Ethiopian highlands reclamation study (EHRS). Food and Agricultural Organization of the United Nation, Rome, Italy. Final Report. 1 and 2.

Fisher, R.F. (1995). Amelioration of degraded rain forest soils by plantations of native trees. *Soil Sci. Soc. Am.* 59, pp 544-549.

Gindaba, J. (1997). Decomposition and nutrient release from leaves of *Croton macrostchyus* and *Millettia* *ferruginea* for soil improvement in agroforestry systems. *MSc Thesis*. Report No. 1997:24, Swedish University of Agricultural Sciences, Skinnskatteberg.

Harrington, CA. (1999). Forests planted for ecosystem restoration or conservation. *New Forests.* 17, pp 175-190.

Hazelton, P., and Murphy, B. (2007). Interpreting soil test results: What do all the numbers mean? [2nd ed.] CSIRO Publishing, Australia. *NSW Department of Natural Resources*. 152 pp.

Islam, K.R., and Weil, R.R. (2000). Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. *Agri., Ecosys. and Env*. 79, pp 9–16.

Knops, J.M.H., and Tilman, D. (2000). Dynamics of soil nitrogen and carbon accumulation for 61 years after agricultural abandonment. *Ecological sci. of Am. Ecology*. 81, pp 88-98.

Laclau, P. (2003). Biomass and C sequestration of ponderosa pine plantations and native cypress forests in northwest Patagonia. *For. Eco. and Management*. 180, pp 317–333

Lal, R. (1997). Degradation and resilience of soils. Phil. Trans. R. Soc. Lond. *Biol. sci.* 352, pp 997-1010.

Lemenih, M. (2006). Expediting ecological restoration with the help of foster tree plantations in Ethiopia. *Journal of the Drylands.* 1, pp 72-84.

Lemenih, M., Karltun, E., and Olsson, M. (2005). Assessing soil chemical and physical property responses to deforestation and subsequent cultivation in smallholders farming system in Ethiopia. *Agri., Ecos. and Env.* 105, pp 373–386.

Lemenih, M., Lemma, B., and Teketay, D. (2005). Changes in soil C and total N following reforestation of previously cultivated land in the highlands of Ethiopia. *SINET: Ethiop. J. Sci.,* 28, pp 000–000.

Lemenih, M., Olsson, M., and Karltun, E. (2004). Comparison of soil attributes under *Cupressus lusitanica* and *Eucalyptus saligna* established on abandoned farmlands with continuously cropped farmlands and NF in Ethiopia. *Forest Eco. and Manage*. 195, pp 57–67.

Lemenih, M., Tolera, M., and Karltun, E. (2008). Deforestation: Impact on Soil Quality, Biodiversity and Livelihoods in the Highlands of Ethiopia. *Nova Sci. Publishers, Inc.* 1, pp 22-39.

Lemma, B. (2006). Impact of exotic tree plantations on carbon and nutrient dynamics in abandoned farmland soils of southwestern Ethiopia. *Doctor's dissertation* Swedish University of Agricultural Sciences, Uppsala. 42pp.

Lugo, A.E. (1997). The apparent paradox of reestablishing species richness on degraded lands with tree monocultures. *For Ecol. Management.* 99, pp 9-19.

Miralles, I., Ortega, R., Almendros, G., Sánchez-Marañón, M., and Soriano, M. (2009). Soil quality and organic carbon ratios in mountain agro-ecosystems of South-east Spain. *Geoderma* 150, pp 120–128.

Nambiar, E.K.S., and Brown, A., (Eds.) (1997). Stand growth: pattern and controls. Management of soil, water, nutrients in tropical plantation forests. *ACIAR Monograph 43, Canberra*. pp 719-742.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. (1954). Estimation of available P in soils by extraction with sodium bicarbonate. *US Department of Agriculture.* Cir. 939 pp.

Poultouchidou, A. (2012). Effects of forest plantations on soil C sequestration and farmers' livelihoods–A case study in Ethiopia. *Master's Thesis in Biology*. Swedish University of Agricultural Sci. Department of Soil and Env., Upsala.. pp 37.

Powers, R.F., Scott, D.A., Sanchez, F.G., Voldseth, R.A., Page-Dumroese, D., Elioff J.D., and Stone D.M. (2005). The North American long-term soil productivity experiment: Findings from the 1st decade of research. *For. Eco. and Management.* 220, pp 31-50.

Pöyry, J. (1992). Forest Soils: A technical paper for a generic environmental impact statement on timber harvesting and forest management in Minnesota. Jaakko Pöyry Consulting, Inc., Minnesota GEIS, Forest Soils Technical Paper. pp 2-23.

Richter, D.D., Markewitz, D. and Trumbore, S.E., Wells, C.G. (1999). Rapid accumulation and turnover of soil carbon in a re-establishing. *Nature.* 400, pp 56-58.

Schmitz, M.F., Atauri, J.A., de Pablo, C.L., de Agar, P.M., Rescia, A.J., Pineda, F.D. (1998). Changes in land use in Northern Spain: Effects of forestry management on soil conservation. *For. Eco. and Management.* 109, pp 137- 150.

Schroth, G., and Sinclair, F.L. (2003). Trees, crops and soil fertility: Impacts of trees on the fertility of agricultural soils. *CABI International*. 438 pp.

Soil Survey Staff (2003). Keys to soil taxonomy, 9th ed. United States Department of Agri. (USDA), Natural resources conservation service. 332 pp.

Tefera, B., Ayele, G., Atnafe, Y., Jabbar, M.A., and Dubale, P. (2002). Nature and causes of land degradation in the Oromiya Region: A review. Socio-economics and Policy Research Working Paper 36. ILRI (International Livestock Research Institute), Nairobi, Kenya. 82 pp.

Teketay, D. (2001). Deforestation, Wood Famine, and Environmental Degradation in Ethiopia's Highland Ecosystems: Urgent Need for Action. *North east African studies*. 8, pp 53-76.

Tiarks, A., Nambiar, E.K., and Cossalter, C. (1998). Site Management and productivity in tropical forest plantations: Impact on soils and options for management over successive rotations. Indonesia. *CIFOR Occasional Paper No.16*, pp 1-11.

Tiarks, A., Ranjer, J., Nambiar, E.K.S., and Toma, T. (eds) (2004). Site management and productivity in tropical plantation forestry: Effects of Harvesting and Site Management on Nutrient Pools and Stand Growth in A South Africa Eucalypt Plantation. CIFOR. Precedings of workshops in Congo July, 2001 and China February, 2003. pp 185-193.

Tolera, M., Asfawu, Z., Lemenih, M., and Karltun, E. (2008). Woody species diversity in a changing landscape in the south-central highlands of Ethiopia. Agriculture, Ecosystems and Environment 128, pp 52–58.

Yao, M.K., Angui, P.K.T., Konaté S., Tondoh, J.E., Tano, Y., Abbadie, L., and Benest, D. (2010). Effects of land use uypes on soil organic carbon and N dynamics in mid-west Côte d'Ivoire. *European Journal of Scientific Research*. 40, pp 211-222.

Yimer, F., Ledin, S., and Abdelkadir, A. (2008). Concentrations of exchangeable bases and cation exchange capacity in soils of cropland, grazing and forest in the Bale Mountains, Ethiopia. *Forest Ecol. and Management.* 256, pp 1298–1302.

Yu, W-T., Jiang, Z-S., Zhou, H., and Ma, Q. (2009). Effects of nutrient cycling on grain yields and potassium balance. *Nutrient cycle Agroecos*. 84, pp 203–213.