Lowland Bamboo (Oxytenanthera abyssinica) deforestation and subsequent cultivation effects on soil Physico-chemical properties in South-western Ethiopia

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Abstract

In Ethiopia, bamboo thickets and woodlands play an important role in soil-water conservation and climate change mitigation in arid and semi-arid regions. However, bamboo mass flowering, rapid demographic changes and expansion of agricultural investments to bamboo dominated areas have led to deforestation and land degradation. In this study, we determined the effects of deforestation and subsequent cultivation on soil physical and chemical properties along a chronosequence of closely located agricultural lands with different ages (1, 3, 5 and 7 years) since converted from natural lowland bamboo forest. Hence, soil samples (n = 90) have been taken from both natural bamboo forests and adjacent agricultural lands at two soil depths (0-20 cm and 20-40 cm). Our result showed that CEC, K^+, Ca^+, Mg^+ and available P were varied significantly with respect to cultivation periods and soil depth, while soil pH and Na^+ varied with soil depth ($P < 0.001$). Soil C and total N contents (g/kg) in 0-20 cm soil layer declined significantly and exponentially with increasing years under cultivation. Conversion of natural bamboo forest to cropland during the past seven year period significantly increased soil pH with soil depths, while CEC was declined throughout the cultivation period and soil depth. In general, the result revealed that conversion of natural lowland bamboo and subsequent cultivation of soil had negative effects on measured soil physico-chemical properties.

Keywords: *Land use change; soil quality, Lowland bamboo; Cultivation periods; Ethiopia*

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1. Introduction

The Northwestern part of Ethiopia is known as undifferentiated woodland (*White type*) which consists of three major natural vegetation types; Dry Broadleaved deciduous forest *(Combretum-Terminalia* woodland and wooded grassland*)*, Dry evergreen Afromontane forest and Moist evergreen Afromontane forest vegetation (White, 1983; Tadesse, 2007). About 3.9 million hectares of the region (25% of the country) are dominated by dry broadleaved deciduous forest and shrubland vegetation (CRGE, 2011; UNDP, 2017). Benishangul Gumuz Region accounts for 55% of solid-stemmed lowland bamboo cover. These forest ecosystems have both environmental (soil erosion control, soil fertility maintenance and climate change mitigation) and economic (firewood collection, wild food collection, gum-resin production, and marketing) contribution to the region as well as the country. However, rapid population demographic changes and the growth of agricultural investments in the region have led to deforestation and forest degradation. For instance, the region's agricultural investment and cereal crop production have undergone a rapid expansion owing to the growing demand for food crops and fruit production, driven by encroachment, forest fire, lack of land use policy, intensive resettlement programs, socio-economic issues, agricultural expansion to forest areas and current Agriculture Development Led Industrialization (ADLI) economic policy of the country (Kassa et al., 2017; Tadesse., 2007).

Soil is one of the most important components of the biosphere and plays a significant role in nutrient cycling, carbon storage and turnover, regulations of biodiversity, and transforming of pollutant elements and compounds (Juhos et al., 2019; X. Liu et al., 2020; Maschinen et al., 2015; Safaei et al., 2019). Therefore, it is important to assess its quality (Kalu et al., 2015) and direction of change over time (Lemenih et al., 2005; Wang & Gong, 1998) and primary indicators of sustainable agricultural land management (Cardoso et al., 2013; Doran, 2002; Rais & Sharma, 2008). The assessment of soil quality involves measuring soil attributes that influence the capacity of soil to support crop production (Doran, 2002; Seifu & Elias, 2018). These soil attributes could be physical, chemical and biological soil properties and it is the basic in which organic farming is based (Hillele & Rosenweig, 2004).

However, studies indicated that the extent of measured soil quality varies with types of vegetation, management practices, climatic condition of the site, soil type, land use history and time since conversion (Kassa et al., 2017; Lemenih et al., 2005). Changes in those soil properties such as direction of change (positive vs negative), magnitude of change (percentage over a baseline values or rates of change) and duration of change could be used to monitor

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agricultural land management. Land use and agricultural management practices greatly affects the direction and degree of soil quality changes (Aran et al., 2001; Wang & Gong, 1998).

In Ethiopia, agriculture is one of the backbone of the economy and major occupation for nearly 85% of the population. Moreover, long-term sustainable development goals and poverty allevation programs in the country are all designed to be based on the development on-agricultural economy (CRGE, 2011). Conversely, deforestation and land degradation recently become serous concerns for soil quality and agricultural productivity decline in almost all parts of the country. To achieve the CRGE (climate resilent green economy) development goals, land use and agricultural practices should be sustainable in the country. Despite, deforestation and land degradation impacts on soil quality continued, very few studies were conducted to quantify the extent, rate and process of soil fertility depletions under different land uses and management practices (Elias & Scoones, 1999). This study is the first attempt to investigate soil physical and chemical attributes after natural lowland bamboo deforestation and cultivated in a chronosequence for seven years.

Therefore, this study was conducted to assess the effects of lowland bamboo deforestation and subsequent cultivation on soil quality indicators (soil physical and chemical properties) in O. abyssinica dominated and cultivated agricultural land using a chronosequence of agricultural lands recently converted from natural lowland bamboo forest. Changes in the soil physical and chemical properties in the cultivated agricultural lands were compared with similar soil properties under an adjacent natural lowland bamboo forests. The trends in the changes experiential were the used to evaluate the impacts of the agricultural land use on soil attributes and indicators of the sustainability of the cultivated land use.

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2. Materials and Methods

2.1. Study Area

The study is conducted in Southwestern Ethiopia, in Benishangul Gumuz Regional State between $9^0$17'-$12^0$06' N; $34^0$10'-$37^0$04' E, with altitudes ranging from 580 m.a.s.l to about 2,731 m. The area is characterized by plains, undulating lands, and comprises predominantly the outcrops of very old Precambrian rocks. The annual rainfall pattern is unimodal with a rainy season from mid-May to October. The average annual rainfall amount ranges from 500-1800 mm and the minimum and maximum annual temperature vary from 20-35 ^{0}C and the variation is strongly correlated with altitudinal ranges (Demissew et al., 2005). The soil types are deep clayish, Nitisols, Leptisols, Cambisols, Alisols, and Fluvisols (Dewitte et al., 2013). The region covers an area of 50,380 km^2 and has different types of forests, woodlands, and bamboo thickets (Demissew et al., 2005) and known as undifferentiated woodland (Ethiopian type) (White, 1983).

2.3. Soil sampling and analysis

2.3.1. Soil sampling

The soil samples were taken in three replicates from four corners and the center of the squared plot measuring 20 m x 20 m^2 in both bamboo forest and agricultural fields. We collected samples from two soil depths, 0-20 cm, and 20-40 cm. We followed the FAO guideline for soil descriptions (FAO, 2006). For soil chemical analysis, the samples were air-dried, homogenized, and sieved using 2 mm sieve.

2.3.2. Soil laboratory analysis

Soil pH was measured in both water and 1 M KCL suspension of 1:2.5 (soil: liquid ratio) using a glass-calomel combination electrode (Lemenih et al., 2005). Organic C (OC) and total nitrogen were analyzed using (Walkley and Black) and Kjeldahl methods, respectively (Moghiseh et al., 2013). Available P analyzed using the Olson method, while exchangeable bases (Ca, Mg, K, and Na) were analyzed after extracting I M ammonium acetate at pH 7.0 (Barton & Karathanasis, 1997). Ca and Mg in the extracts were analyzed using atomic absorption spectrophotometer (Kassa et al., 2017), while Na and K were measured by flame photometry (Black et al., 1965). The cation exchange capacity (CEC) was measured by the ammonium acetate method.

The soil organic carbon and nitrogen stock were determined based on the formula (Chan, 2008; Smal et al., 2019; Yan Zhang et al., 2020):

$Ct = (H \times \rho \times \%C)*Cf$ -- Eq. 2

Where, Ct = Soil organic carbon stock (g/kg), H = the depth of the soil sample thickness of the sampled soil layer (cm), ρ = the soil bulk density (g cm^{-3}), %C = the percent of organic carbon, Cf = Conversion factor (0.1). The total nitrogen stock was also computed using a similar formula. The losses in soil organic carbon and nitrogen stock -because of deforestation and subsequent cultivation were computed by subtracting the total soil organic carbon and nitrogen stocks under bamboo forest from that of the corresponding depth under cultivated land. The computed loss values were then divided by the number of years since the conversion to obtain the soil organic carbon and nitrogen losses per year. Particle size analysis was performed by the hydrometer method. Textural classes were assigned using the USDA particle size classes, sand (0.05-2.00 mm), silt (0.002–0.05 mm), and clay (<0.002 mm). Electrical conductivity (EC) was measured using the EC meter.

2.4. Data analysis

We used a two-way analysis of variance (ANOVA) to perform each soil property per two depths across the land use age to test whether the changes in the soil physical properties were statistically significant. The mean values were compared using List Significant Difference (LSD). The soil carbon content (g/kg) of the surface 0-20 cm layer was related to cultivation period using exponential decay regression function described as follows:

$C = a \pm be^{-kt}$,

Where C is the soil organic carbon content in (g/kg) at a given time t, a and b are the regression coefficients, k the decay constant. To evaluate the impacts of land-use change on the soils, the soil status under new land use (agricultural cultivation) is compared with the soil under lowland bamboo forest, which can be then expressed as soil degradation index (SDI) (Adejuwon & Ekanade, 1988; Islam & Weil, 2000; Sione et al., 2017). The degradation index (DI) shows the percent changes whether positive or negative in soil properties under a new land use from the values under the natural system (bamboo forest). For the establishment of DI for each soil property, we followed the method used in (Lemenih et al., 2005). We followed the FAOs qualitative land evaluation procedure to evaluate whether, threshold levels had been reached for the observed soil changes (FAO, 1976).

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3. Results

3.1. Soil physical property responses

3.1.1. Soil Textural classes and their distribution

The upper 40 cm soil particle distribution of the sampled sand and clay soil depths showed significant differences at the cultivation period of seven ($P < 0.05$) except for silt fraction in both soil depths showed non-significance differences (Table 1). The soil under the natural lowland bamboo forest showed significantly higher sand and lower clay fractions than the soils on continuously cultivated lands, which may be attributed to the effects of deforestation and the continuous cultivation of the farm fields. The investigated soil particle size distribution difference may have been present before the conversion of the bamboo forest to the agricultural lands. The particle size distribution in the surface and sub-surface soil horizons, particularly the silt fractions of all depths were impartially similar, we have thought that the soil condition before deforestation and cultivation to be similar. Accordingly, we observed changes in soil particle size distribution on the cultivated lands as compared to the soil conditions under the natural bamboo forest and interpreted as the effects of the conversion of bamboo forest to continuously cultivated agricultural lands.

Table 1. Mean particle size distribution of the upper 40 cm soils under agricultural land use chronosequence converted from natural Lowland bamboo forest compared to the soil under adjacent bamboo thickets woodland.

Soil fraction (%)	Soil Depth (cm)	Bamboo forest	Cultivation year				ANOVA
			1	3	5	7	
Sand	0-20	46.03	39.83	42.98	46.02	31.20	*
	20-40	46.45	37.82	40.33	43.89	28.93	*
Silt	0-20	17.34	15.91	16.55	14.35	20.31	ns[a]
	20-40	13.25	12.74	10.51	9.11	15.51	ns[a]
Clay	0-20	36.63	44.26	40.46	42.59	48.48	ns[a]
	20-40	40.29	49.43	49.15	44.02	55.56	*
Silt/Clay ratio	0-20	0.65	0.35	0.48	0.35	0.43	*
	20-40	0.53	0.24	0.24	0.27	0.29	*

* Significant at $P < 0.05$

[a] no significance at $P < 0.05$

The soil types are clayey with the mean clay contents ranging from 36.63 to 48.8% on the upper 0-20 cm and 40.29 to 55.56% in the sub-surface 20-40 cm depths. The clay enrichment in the lower soil depths may be due to the migration of clays. The natural bamboo forest has shown significantly higher silt/clay ratios than all sampled depths under the adjacent cultivated lands. The silt/clay ratio in the upper soil depths ranges from 0.35 to 65 and 0.24 to 0.53 to the lower soil depths, which were rated higher (Table 1), indicating the accumulation of weatherable mineral reserve in the soil layers.

3.2. Soil chemical property responses

3.2.1. Soil carbon and total nitrogen

The soil carbon and nitrogen contents (g/kg) and stocks (t/ha) in the upper 20 cm soil layer decreased continuously and significantly ($P < 0.05$) with the cultivation period and sampling depths of the agricultural lands (Table 2). The magnitude of declines in the soil carbon content (64.5%) was observed after seven years of continuous cultivation compared to the adjacent natural bamboo forest. The soil carbon contents and stocks of the upper soil layer (0-20 cm) showed an exponential decline with increasing cultivation period (Fig. 2) and soil depths and significantly ($P < 0.001$) higher than the last two cultivation periods. Interestingly, the SOC and TN in the subsurface were increased throughout the cultivation periods. The total nitrogen content and concentration in the natural lowland bamboo have a statistically significant mean difference ($P < 0.001$) with all the cultivation periods. The SOC, TN content and stocks have no significant difference in the subsurface soil layer ($p < 0.05$).

Table 2. Mean (±SEM) for soil C and total N (g/kg), C: N ration, and soil C and total N stocks (t/ha) in the 0-20 and 20-40 cm soil layers along agricultural land use chronosequence converted from lowland bamboo compared to soil adjacent to the natural lowland bamboo forest.

Cultivation Year	Soil Depth	SOC (g/kg)	TN (g/kg)	C: N	SOC (t/ha)	TN (t/ha)
Bamboo forest	0-20	36.42 ± 1.83	3.16 ± 0.55	13.20 ± 1.35	830.43 ± 41.78	71.95 ± 12.63
	20-40	12.31 ± 2.27	1.23 ± 0.19	9.95 ± 0.70	263.46 ± 48.58	26.39 ± 4.18
1	0-20	27.86 ± 0.97	1.67 ± 0.10	17.00 ± 0.68	635.11 ± 22.04	38.00 ± 2.37
	20-40	17.43 ± 3.25	1.46 ± 0.25	12.03 ± 1.31	373.07 ± 69.47	31.15 ± 5.34
3	0-20	25.08 ± 1.70	2.03 ± 0.22	13.68 ± 1.78	571.77 ± 38.83	46.36 ± 4.98
	20-40	13.62 ± 3.20	1.00 ± 0.15	13.51 ± 1.71	291.52 ± 68.46	21.40 ± 3.19
5	0-20	24.01 ± 1.70	1.80 ± 0.15	13.56 ± 0.86	547.45 ± 38.83	41.04 ± 3.36
	20-40	13.99 ± 3.18	0.92 ± 0.19	15.04 ± 0.94	299.36 ± 68.11	19.74 ± 4.11
7	0-20	23.49 ± 1.65	1.76 ± 0.04	13.40 ± 0.91	535.55 ± 37.71	40.03 ± 1.01

20-40	14.61 ± 4.09	1.01 ± 0.22	14.36 ± 1.54	312.68 ± 87.55	21.64 ± 4.68

The total amount of nitrogen present in the natural lowland bamboo forest soil was significantly higher than the soil on the cultivated fields ($P < 0.05$), which may be attributed to the effects of high biomass production of the bamboo and conversion and continuous cultivation on the farm fields may contribute for the decline (Fig. 3a). The content of the total nitrogen in the cultivated fields was not significantly different, except the soil depths, which declined significantly to the lower soil layers at ($P < 0.05$) (Fig. 3b). Our study showed that the mean SOC (1.5-3.9) and total nitrogen content (0.25-0.5) in the natural lowland bamboo forest were rated significantly higher than the soil on the farm fields. The mean ratings of the SOC and TN on continuously cultivated agricultural lands were found in medium level (1.5-3.9) and (0.15-0.25), respectively (Table 2).

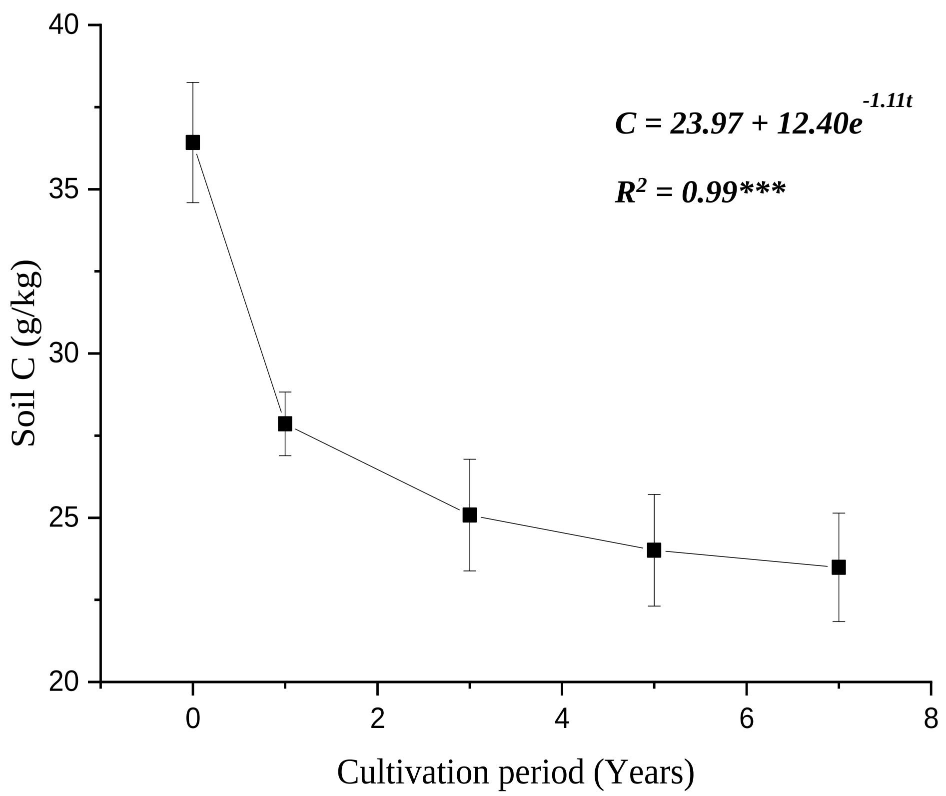

Fig. 2. Effects of deforestation and subsequent cultivation on soil organic C (g/kg) contents in agricultural land use chronosequence converted from natural lowland bamboo forest in the southwest Ethiopia (0-20 cm). Regression equation (*y*), line of best fit, correlation coefficient (*r*) and statistical significance ($P < 0.001$) and confidence interval (the error bars) are shown.

The time zero along the *x*-axis denotes the natural forest and '*t'* in the equation denotes period of cultivation (year).

3.2.2. Carbon-to-nitrogen ratio

The carbon/nitrogen ratios for the two soil layers (0-20 and 20-40 cm) were significantly lower ($P < 0.05$), respectively under the natural bamboo forests compared to continuously cultivated agricultural fields. The two soil layers C/N ratios followed different patterns, increased in the first cultivation period, and declined afterward on the upper 20 cm layer. In the sub-surface soil layer, the C/N ratios increased up to five years of cultivation and decreased at the cultivation period of seven years, but significantly higher than the natural bamboo forest (Table 2). The C/N ratios of the natural bamboo forest declined from the top to the sub-surface and observed a similar pattern in the first and third year cultivation period. In the cultivation period of five and seven years, slightly increased from top to the sub-surface soil layers.

3.2.3. Relative changes in SOC and TN Stocks

Our result showed that the conversion of natural lowland bamboo forest to agricultural lands in a chronosequnce has led to a significant ($P < 0.001$) net C loss of (23.50%, 31.14%, 34.07% and 35.5%) for SOC concentration in an interaction of cultivated years and soil depth and 47.57% across the soil depths (Table 3). The TN concentrations decreased significantly at ($P < 0.001$) with conversion of natural lowland bamboo forest to cultivated agricultural lands in a chronosequences (47.15%, 35.76%, 43.04% and 44.30%), respectively (Table 3). Similarily, SOC and TN stock showed a decreasing trend on the topsoil layers when natural lowland bamboo converted into cultivated agricultural lands. In contrast, the conversion of the natural lowland bamboo into agricultural land has contributed a significant SOC stock in subsurface soil layers with a relative percent changes (41.60%, 10.65%, 13.63% and 18.68%) in a chronosequence of cultivation (Table 3) and 4.75% TN stock gain in the first year.

3.2.4. Soil pH and Cation exchangeable capacity (CEC)

There were no significant interaction effects between the cultivation chronosequences and soil sampling depths on soil pH. The values were significantly higher as the soil sampling depths increased ($P < 0.05$) and the seven year cultivated land had relatively higher soil pH than the bamboo and young cultivated agricultural lands (Table 4). The exchangeable Na and Ca:Mg ratios were not significantly different in both chronological sequences and sampling

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depths. Exchangeable Na and Ca:Mg ratio in the 0-20 cm soil increased by 3.83, 0.17 and 0.03, respectively during the first one year cultivation period following deforestation of bamboo and gradually declined to the rest of the cultivation period except the exchangeable Na and Ca:Mg ration, reaching peak at the fifth years and then declined to next cultivation period in exch.Na and the Ca:Mg ration increased to the last two cultivation periods. CEC, echangeable K, echangeable Ca and echangeable Mg were significantly changes in a chronosequences and soil layers (Table 4). Echangeable K, Echangeable Ca and Echangeable Mg contents of the natural bamboo forest was significantly different from the cultivated lands and varied along the soil layers ($P < 0.05$). CEC was reached peak during the 3rd year cultivation period and declined in the 5th year and then gradualy increased to the rest of the cultivation periods.

The topsoil available P contents of both the natural bamboo forest and cultivated agricultural fields were significantly different in a chronosequence ($P < 0.05$) and declined to the subsurface soil throughout the cultivation periods. The highest available soil P was measured during the first 3 years of cultivated agricultural lands (Table 4)1.83.

Table 3. Mean (±SEM) for the contents of soil C and total N (g/kg), and soil C and total N stocks (t/ha) in the 0-20 and 20-40 cm soil layers along agricultural land use chronosequence converted from lowland bamboo compared to soil adjacent to the natural lowland bamboo forest.

Land-use change	**0-20 cm**		**20-40 cm**	
	SOC content	TN content	SOC content	TN content
Bamboo-Year I	-8.57 ± 2.26	-1.49 ± 0.39	5.12 ± 4.59	0.22 ± 0.29
Bamboo-Year III	-11.34 ± 2.26	-1.12 ± 0.39	1.31 ± 4.59	-0.23 ± 0.29
Bamboo-Year V	-12.41 ± 2.26	-1.36 ± 0.39	1.68 ± 4.59	-0.31 ± 0.29
Bamboo-Year VII	-12.96 ± 2.26	-1.40 ± 0.39	2.30 ± 4.59	-0.22 ± 0.29
Mean	**-11.39 ± 2.26**	**-1.34 ± 0.39**	**2.60 ± 4.59**	**-0.14 ± 0.29**
Land use change	0-20 cm		20-40 cm	
	SOC stock	TN stock	SOC stock	TN stock
Bamboo-Year I	-195.32 ± 51.65	-33.95 ± 8.99	109.62 ± 98.34	4.75 ± 6.15
Bamboo-Year III	-258.65 ± 51.65	-25.59 ± 8.99	20.06 ± 98.34	-4.99 ± 6.15
Bamboo-Year V	-282.97 ± 51.65	-30.90 ± 8.99	35.90 ± 98.34	-6.66 ± 6.15
Bamboo-Year VII	-294.88 ± 51.65	-31.91 ± 8.99	49.22 ± 98.34	-4.76 ± 6.15
Mean	**-257.95 ± 51.65**	**-30.59 ± 8.99**	**53.70 ± 98.34**	**-2.3 ± 6.15**

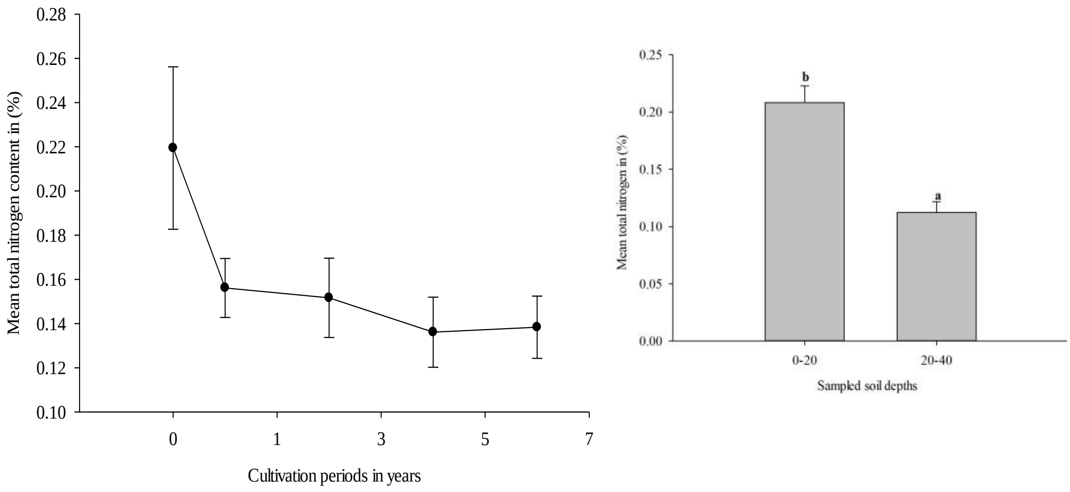

Figure 3. The mean total nitrogen content changes in natural bamboo forests and cultivated lands during the cultivation period (a) and across the sampled soil layers (b).

4. Discussion

4.1. Soil Physico-chemical characteristics

4.1.1. Soil texture distribution

Our study revealed that the sand and silt soil fractions declined rapidly with soil sampling depths, whereas clay soil fraction increased to the subsoils as compared to topsoil. Clay contents increased in subsoils with soil sampling depths as compared to topsoils. In this study, the overall clay content tended to be increased and the sand soil fraction was tended to be smaller in the cultivated lands in a chronosequence as compared the adjacent natural bamboo forest. So, deforestation and cultivation promotes the weathering processes as it shears and pulverizes the soil and changes the moisture and temperature regimes (Reicosky & Forcella, 1998). The soil textural differences also might be due to the variation of pedogenic processes, especially in relation to the rate of weathering.

4.1.2. Soil pH, Soil organic carbon and total N contents

Our study highligheted that soil sampling depths have significant effects on soil pH in both natural bamboo forests and cultivated agricultural lands in a chronological sequences. The soil pH was found to be increased to the higher soil sampling depths that might be due to the availability of high exchangeable base cations and higher acidification near the soil surface.

This finding is consistent with other studies on soil quality following deforestation and conversion to agricultural lands (Davari et al., 2020; Kassa et al., 2017; D. Liu et al., 2018; Moghiseh et al., 2013). The results of low surface soil pH values can be related to low concentrations of base forming cations (Ca^{2+} , K^{+} , Mg^{2+} and Na^{+}) through a continuous nutrient uptake by plants during the continuous cultivation and leaching and surface soil erosion loss. This finding is in accordance with (Adugna & Abegaz, 2015; Negasa, 2020). Even though, the fact that the measured pH values in both natural bamboo forest and cultivated land uses of the subsurface lie within the optimal ranges (6-7.5), we observed that deforestation and subsequent cultivation can lead to rise in soil pH (Table 4). This can be attributed to the use of inorganic soil fertilizers and mixing up of the subsoil which is dominated by carbonates with the topsoil. Elevated level of CO_2 partial pressure lead to low soil pH values in forest soil due to the formation of carbonic acid in the soil solution (Bargrizan et al., 2020). Accordingly, solubility and leaching of calcium carbonates from the surface soil layer to lower depths can be increased (Karchegani et al., 2012; Schindlbacher et al., 2015, 2019).

Soil organic carbon and total N content is found to be decreased significantly on the topsoil in a chronosequence following deforestation and repeated cultivation. We also found that the SOC and TN content increased in the topsoil (0-20 cm) and decreased in the 20-40 cm soil layers. This result suggested that SOC and N dynamics of natural bamboo forest and agricultural lands were dependent on sampling depths under different intensity of land uses which is consistent with our research hypothesis. Our observed increase in the SOC and TN content in the topsoil was consistent with the findings of previous studies by (Kassa et al., 2017; Lemenih et al., 2005; Li et al., 2020). However, the continuous decline in the SOC and TN content in a chronosequence will have a significant effects on the agricultural productivity because the organic matter supplies taken up by the crops. Furthermore, the occurrence of higher topsoil SOC and TN contents in a chronosequence might be due to the litter fall returned to the surface soil as organic matter (Andivia et al., 2016; Innangi et al., 2017; Lei et al., 2019). The first year cultivation period relatively has high subsurface SOC and TN that can be due to root turnover and soil microbials contribution of organic matter decomposition in the subsurface soil. The SOC and TN significantly higher in natural bamboo forest than cultivated lands that might be due to the production of higher biomass in bamboo forests than agricultural lands. (Liang et al., 2018) finding indicated that SOC and TN declined rapidly with sampling depths which corresponds with our observation. Remarkably, in the subsurface soil the SOC and TN were inceasing with the cultivation period. This might be related to the accumulation and decomposition of organic matter through time.

The C/N ratio is influenced by the type of forest vegetation and other site related factors. The range of the C:N ratio in the topsoil layers varied significantly from 13.20-17.00 and declined to the subsoil layers in a range of 9.95-15.04. The C/N ration decreased with increasing soil depths. This might be indicated a decreasing influence of forest and crop roots on a C/N ration with soil depth. This can be elucidated by decreasing soil organic matter content and bamboo and crops root densities with increasing soil depths. This study result is supported by the findings of (Cools et al. 2014; Langenbruch et al. 2012). In the subsoil layers the C/N ratio was increased with increasing cultivation period. The can be related to the accumulated and decomposed organic matter goes to the subsoil layer through time. In general, the C/N ratio in this study < 25 which indicated that high nitrogen content is found in the soil. This result is supported by the study of (Cools et al., 2014) who reported low, medium and high N content with the C/N ratio variation.

4.1.3. Available Phosphorus, exchangeable calcium, exchangeable K and Magnesium

Conversion of natural forest vegetation to long-term agricultural production adversely affects soil available phosphorus (P). The available P was varied significantly with soil layers and cultivation periods in the topsoil layers in a chronosequence. Overall, the P concentration was decreased when natural bamboo forest converted to cultivated agricultural lands. This result is consistent with the study of (Zhang *et al.* 2020a) who reported that higher available P was found in natural forest than crop, pasture and plantation forest. The natural lowland bamboo forest and the three year cultivated lands have significantly higher topsoil available phosphorus than the other cultivated lands. This might be related to the litter fall and decomposition from different leguminous and non-leguminous trees, shrubs, herbs and crop residues. This finding is consistent with the study of (Kassa et al., 2017) who reported higher available in forest and agroforestry.

Our study indicated that the concentrations of exchangeable Ca^+, K^+ and Mg^+ were significantly differ in the two land use types that might be due to the influences of the land uses and application of chemical fertilizers. The concentration of mean exchangeable Na^+ had no significant differences with both sampling soil depths and cultivation periods ($P < 0.05$). Although, there was significant interaction differences in the soil layers and cultivated years, the natural bamboo forest had relatively the highest mean exc. Na^+ (1.11 ppm (+) /100gm soil), while the cultivated lands had lower concentration of Na^+. This result is supported by the findings of (Yimer et al., 2008), who reported that exchangeable Na^+ concentration were higher in grazing and native forest soils than cropland soils.

4.1.4. Cation exchange capacity and Electrical conductivity

Cation exchangeable capacity (CEC) and electrical conductivity (EC) are the most important soil properties for major distinctions among land use-types. The natural bamboo forest and agricultural lands have significantly higher topsoil and subsurface CEC in a chronosequence of cultivation. This might be related to the accumulation of higher organic matter and clay fractions in the surface of both natural bamboo forest and cultivated agricultural lands, from which the organic matter formed by bamboo litter and crops residues completely breakdown and decomposed, in both land use types. Our observation is similar with the study of (Gruba & Mulder, 2015; Sohng et al., 2017). The presence of moderate to higher CEC (12.99-28.20 meq/100g of soil) in the subsurface soils of natural lowland bamboo forest and agricultural lands can be explained by the availability of decomposed organic matter and weathered parent material. The variation of trees, shrubs, and crop root and microbial communities have intrinsic ability to increase the availability of organic matter, releasing base cations and nutrients to the subsurface soil layers. Our result is consistent with the findings of (Kassa et al., 2017), who reported a rapid rise of CEC on the organic matter (in forest and agroforestry) and evergreen forest of India (Grandgirard et al., 2002).

The EC values of both the natural bamboo forest and agricultural lands were ranged from 0.026-0.054 and 0.034-0.057, respectively (Table 4), but the difference within and between soil sampling depths and cultivation year were not significant ($P < 0.05$). We observed relatively higher EC values in cultivated agricultural lands as compared to the natural bamboo forest. Our result is consistent with the findings of (Kizilkaya & Dengiz, 2010), who reported that conversion of forest vegetation into agricultural land increased the value of EC due to the application rate of inorganic fertilizers. This finding is contrasting with (Tellen & Yerima, 2018) who stated that natural forests had higher EC values as compared with grazing and farmlands, conversion of those forest to cultivated lands leading to a decreased EC values in cultivated lands. The contrasting trend of variation in EC of natural bamboo forest and cultivated lands can be attributed to the inconsistent mean annual application of fertilizers in the agricultural lands. In the subsurface soil layers, the EC values were increased along a chronosequence of cultivation upto five years and then slightly declined to seven year cultivation period.

4.2. Soil organic carbon, nitrogen stocks and their relationship with soil depth

Conversion of the forest vegetation into agricultural land uses, affect the soil physico-chemical and biological properties whether positively or negatively with the extents of these effects being controlled by the type of the agricultural practices implemented on the land (Tully et al., 2015; Zajícová & Chuman, 2019). In Ethiopia no work has been done to investigate the effects of the natural bamboo forest conversion to agricultural lands on soil properties.

Table 4. The mean soil chemical properties in the two soil layers along agricultural chronosequence converted from natural lowland bamboo forest compared to the adjacent natural bamboo forestland.

Soil properties	Soil Depth (cm)	Bamboo forest	Cultivation periods (Years)				ANOVA
			1	3	5	7	
pH_H2O (1:2.5)	0-20	5.93 ± 0.05	5.92 ± 0.21	5.82 ± 0.09	5.83 ± 0.09	5.97 ± 0.06	[a]ns
	20-40	6.36 ± 0.07	6.10 ± 0.15	6.25 ± 0.07	6.22 ± 0.1	6.22 ± 0.04	[a]ns
pH_KCL	0-20	4.89 + 0.13	5.18 + 0.23	4.95 + 0.10	5.00 + 0.14	5.20 + 0.11	[a]ns
	20-40	5.43 + 0.08	5.57 + 0.20	5.40 + 0.05	5.39 + 0.13	5.47 + 0.08	[a]ns
CEC	0-20	48.45 ± 4.72	39.25 ± 4.75	34.22 ± 3.75	23.26 ± 4.70	20.08 ± 6.11	*
(meq/100gm Soil)	20-40	28.20 ± 3.57	21.76 ± 2.46	20.42 ± 5.27	17.02 ± 4.50	12.99 ± 2.58	*
ECe	0-20	0.51	0.48	0.30	0.54	0.50	[a]ns
	20-40	0.25	0.32	0.40	0.47	0.42	[a]ns
EC (ms/cm)	0-20	0.054 ± 0.01	0.051 ± 0.009	0.032 ± 0.003	0.057 ± 0.018	0.053 ± 0.006	[a]ns
	20-40	0.026 ± 0.003	0.034 ± 0.003	0.042 ± 0.014	0.049 ± 0.004	0.044 ± 0.005	[a]ns
Echangeable Sodium Percentage (ESP)	0-20	3.25 ± 0.72	1.69 ± 0.39	2.04 ± 0.42	2.11 ± 0.44	2.47 ± 0.21	*
	20-40	3.51 ± 0.66	2.59 ± 0.62	2.67 ±0.38	5.33 ± 1.02	3.81 ± 0.60	*
Exchangeable Na (ppm)	0-20	0.79 ± 0.18	0.96 ± 0.15	0.72 ± 0.18	1.11 ± 0.15	0.76 ± 0.14	[a]ns
	20-40	1.00 ± 19.00	0.89 ± 0.11	1.10 ± 0.16	1.14 ± 0.14	0.97 ± 0.13	[a]ns
Exchangeable K (ppm)	0-20	0.13 ± 0.02	0.11 ± 0.02	0.33 ± 0.08	0.12 ± 0.02	0.16 ± 0.05	*
	20-40	0.10 ± 0.01	0.30 ± 0.18	0.18 ± 0.03	0.23 ± 0.03	0.28 ± 0.05	*
Exchangeable_Ca (ppm)	0-20	12.90 ± 0.99	10.98 ± 1.63	16.92 ± 1.04	10.37 ± 0.59	14.29 ± 1.23	*
	20-40	13.47 ± 2.82	25.67 ± 2.26	12.32 ± 1.29	23.17 ± 3.48	22.46 ± 3.15	*
Exchangeable Mg (ppm)	0-20	4.54 ± 0.36	3.89 ± 0.59	5.88 ± 0.39	3.61 ± 0.21	4.89 ± 0.40	*
	20-40	4.44 ± 0.97	8.60 ± 0.66	4.25 ± 0.46	7.79 ± 1.11	7.63 ± 1.04	*
Available Phosphorus (P-available)	0-20	47.37 ± 8.24	23.68 ± 2.03	50.48 ± 6.27	29.20 ± 1.43	37.44 ± 2.06	*
	20-40	18.97 ± 2.55	21.35 ± 2.07	18.62 ± 3.38	24.22 ± 3.61	22.96 ± 2.55	[a]ns
Ca:Mg ratios	0-20	2.85 ± 0.05	2.88 ± 0.15	2.89 ± 0.04	2.88 ± 0.07	2.91 ± 0.05	[a]ns

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20-40	3.07 ± 0.08	2.96 ± 0.05	2.91 ± 0.04	2.94 ± 0.03	2.93 ± 0.07	[a]ns

[a] no significance at P < 0.05

* Significant at P < 0.05

SOC and TN were the most discriminating variables across all sampling soil depths and cultivated agricultural lands. Our study revealed that SOC and TN consistently decreased with soil depth and agricultural land in a chronosequence. This pattern taking place in most ecosystems and ascribed to the higher inputs of C and nutrients at the soil surface compared to the subsurface soil layers (Jobbágy *et al.* 2001; Omonode & Vyn 2006; Chai *et al.* 2015; Goebes *et al.* 2019; Murphy *et al.* 2019). Both SOC and TN were significantly higher in natural lowland bamboo forest as compared with agricultural lands in a chronosequences (P < 0.001). This clearly shows that without the accumulation of litter on agricultural lands, SOC and TN could become lower. Whereas in the subsurface soil layers no significance differences were observed when we compared natural bamboo forest and agricultural lands cultivated in a chronosequences. As the stocks declined with soil depths, the organic matter becomes progressively enriched with N, leading to lower C:N ratio at depth (Tipping et al., 2016). Given its fast growth, large biomass and high litter production, bamboo could play an important role in redressing most of the deforestation related problems (Embaye et al., 2003) and affecting the nutrient turnover and forest regeneration (Takahashi *et al* 2007; Austin and Marchesini 2012). This result is in line with the previous work of (Mohammed & Bekele, 2017; Yuen et al., 2017; T. Zhang et al., 2013) who evidenced high soil carbon stock in bamboo forest as compared to native forest, evergreen forest and paddy fields, respectively. The result is in contrary of (Kenye *et al.* 2019) that bamboo has low SOC stock as compared to homegarden, grassland, natural forest and shifting cultivation. This can be explained by the legacy effects of the land use history, climate and types of bamboo species used in the studies are different.

Additionally, we found low SOC and TN in agricultural lands that might be due to the crops nutrient uptake, leaching and surface erosion losses. Inappropriare land management practices, animal grazing and crop residue removal might have negative effects on SOC and TN to be low in the croplands surface and subsurface soils. The finding is in line with the study of (Don et al., 2011; D. Liu et al., 2018). And also a meta-analysis conducted by (Wei et al., 2014) indicated that 34.7% and 45% of Soil C stock was lost due to conversion of forest to agricultural lands in early stage (≤ 10 years) and middle stage (11-15 years), respectively.

5. Conclusion

The conversion of the natural lowland bamboo forest into agricultural lands has significant changes on the soil physical and chemical properties. Soils collected from the natural lowland bamboo forest and cultivated in a chronosequence, showed a significant differerences in soil sand, silt/clay ratio, SOC, TN concentration and stocks, CEC, ESP, available P, exchangeable K, Ca, and Mg in both soil sampling depths and cultivation periods. Our result suggests that conversion of natural lowland bamboo forest into agricultural lands has direct implications on soil physical and chemical properties. Sebsequent cultivation of agricultural lands will not be sustainable as the result indicated significant soil degradation. Therefore, soil improvement practices should be in place to esnsure sustainability of soil quality and agricultural productivity.

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