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Impact of deforestation and subsequent cultivation on soil fertility in Komto, Western Ethiopia

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The study examined the impact of deforestation and subsequent cultivation on soil fertility and acidity conditions under varying soil depths. Soil profiles were opened in two adjacent land units, namely forestland and arable land and samples were collected from genetic horizons. Deterioration of soil fertility was observed after deforestation and traditional cultivation. The main aim of deforestation was agricultural expansion. Soil pH consistently decreased with depth in both land units and it was relatively lowest in arable land perhaps due to depletion of organic matter (OM) and decrease in buffering capacity of the soil. The OM and total nitrogen (N) ranged from 0.78 and 0.06% in the 75 to160 cm layer of arable land to 15 and 0.61% in the 0 to10 cm layer of forestland, respectively. Total N was strongly and positively correlated with soil OM (r = 0.99). Exchangeable Al was poorly and negatively correlated with available phosphorous (r = -0.41). Conversion of forestland to arable land reduced the mean available phosphorus (P) from 4.04 ppm to 1.95 ppm most probably due to decline in OM, soil acidification and erosion. Deforestation and subsequent continuous cultivation over the past 25 years apparently amplified the mean exchangeable acids from 0.83 cmol (+) kg^{-1} to 5.96 cmol (+) kg^{-1}. Soil acidification and related problems were the major challenges of continuous cultivation in the study area. The study indicated that land use change and management practices have had a considerable negative effect on soil physical and chemical properties.

Key words: Deforestation, continuous cultivation, land use change, soil properties, soil fertility, soil acidity, Western Ethiopia.

INTRODUCTION

One of the most important driving forces of land use change induced soil degradation is human activities such as deforestation and poor agricultural practices. Owing to deforestation, the area of native forest in Ethiopia was declined from 40% land cover during the 1950 according to Pohjonen and Pukkala (1990) to about 2.2% in 2002

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(Berry, 2003).

Increase in population and a continuous decline in the amount of agricultural land have led to relentless and an indiscriminate exploitation of natural forests and fragile lands for agriculture (Mahtab and Karim, 1992). Intensive farming and mismanagement of the deforested areas brought environmental problems and soil impacts such as soil erosion, acidification, soil compaction and pollution (Salehi et al., 2008). These problems have many interlink effects that can appear through the reduction of chemical and physical qualities of the soil resources (Seeger and Ries, 2008). Studies by Mulugeta et al. (2005) and Nega and Heluf (2009) indicated increment of bulk density, organic matter deterioration and reduction in cation exchange capacity (CEC) following deforestation and continuous cultivation in Ethiopia. Another study in Ethiopia showed that soil organic carbon (SOC) and total N of the top 0 to 10 cm soil layer declined significantly and exponentially with increasing years under cultivation following deforestation (Lemenih et al., 2005).

In addition to natural factors such as excessive leaching of basic cations and nature of the parent materials, agricultural practices and processes such as intensive cultivation of leguminous crops and continuous use of ammonium containing fertilizers in N limited cultivated soil, soil erosion and tillage triggered OM oxidation were the main causes of soil acidification in the study area. Because of limitation of N in the arable soils, farmers usually used to apply ammonium nitrate and commonly grow legumes. Agriculturally, acidic soils have limiting characteristics like weak buffering capacity; low P bioavailability due to high P fixation capacity; toxicities of Al, occasionally H; deficiencies of Ca, Mg, K; and low CEC (Clark et al., 1988).

Soils unconditionally respond to human as well as natural disturbances. The reaction of soils to human influence can be measured from changes in soil properties following the interference. Cognizant of this issue, the study was conducted in soils of adjacent land units; namely forestland and arable land (historic forestland) mainly to examine the impact of major land use shift from forestland to arable land on soil fertility and acidification. Although soil deterioration following forest clearing and continuous cultivation is well known, the degree of changes in soil physical and chemical properties for the study area was not depicted. The study is in line with the current Ethiopia's Agricultural Transformation Plan aimed to strengthen the Ethiopian Soil Information System (Ethio-SIS) by creating soil information at large scale map.

The results of the study can help the farming community to recognize the negative effects of deforestation and adopt recommendations of sustainable land use and management practices. It also assists policy makers and land administrators to pose strong policy ground on protection of natural forests and devise options to practice precision agriculture.

MATERIALS AND METHODS

Description of study area

The study site is situated between 9.084768 and 9.111881N and 36.609009 and 36.630832E in Komto village of Wayu Tuka district, western Ethiopia (Figure 1).

The area is characterized by a unimodal rainfall pattern receiving mean annual rainfall of 2140 mm. The mean annual temperature is 18.7°C. The entire village was once covered with Afromontane moist ever green forest known as Komto forest. Population growth over the past 25 years had led to destruction of portion of the native forest and expansion of arable land. Western Ethiopia in general and the study area in particular are dominated by highly weathered soils like Alfisols, Ultisols, and Nitisols (Mesfin, 1988).

The dominant agriculture in the district is mixed farming system where livestock and subsistence crop production supports the livelihoods of the community. Portion of the forestland converted to arable land was under cultivation for the last 25 years. The most widely cultivated crops include cereals such as Teff (*Eragrostistef*), millet (*Panicummiliaceum*), wheat (*Triticumaestivum*), maize (*Zea mays*), barley (*Hordeumvulgare*) and legumes such as horse bean (V*iciafaba*), ground nut (*Arachishypogaea*) and oats (*Avena sativa*). Crop residues were partly subjected to uncontrolled grazing and partly collected for fuel wood usually leaving bare soil surface.

Soil sampling, preparation and analysis

Small scaled study by Mesfin (1988) indicated that arable land was dominated with Nitisol while forestland was dominated with Alfisols. Due to similarity of soil types across specific land units in the site, one representative pedon with 1.5 m x 2 m x 2 m was opened in each land unit, namely forestland and arable land. Soil samples were collected from genetic horizons−layers designated based on differences in color and other morphological properties. Horizons can be designated either simply by assigning evenly distributed random depths or depths based on genetic/ nature of the soil layers. Horizon classification for this study was, thus, based on depths equivalent to genetic layers that vary with the type of soil. Following sampling, soil samples were labeled, air dried, cleaned from contaminants and plant debris, ground by mortar and pestle and finally sieved with a 2 mm sieve. Based on standard laboratory procedures, soil particle size distribution was determined by the Bouyoucous hydrometer method while particle density was determined using pcynometer method. Dry bulk density was determined by core method. Soil pH was measured potentiometrically in 1:1.25 soil water suspensions. Exchangeable acidity was determined by titration with NaOH. Organic C was determined by Walkley–Black oxidation method. Total N was determined by Kjeldhal method and available P was determined following Bray II method. The CEC was determined by using ammonium acetate method. Among exchangeable bases, Ca^{2+} and Mg^{2+} in the original ammonium acetate leachate were measured by atomic absorption spectrophotometer; whereas exchangeable K^+ and Na^+ were determined by using flame photometer.

Statistical analysis

Measured and weighted average values for variables were

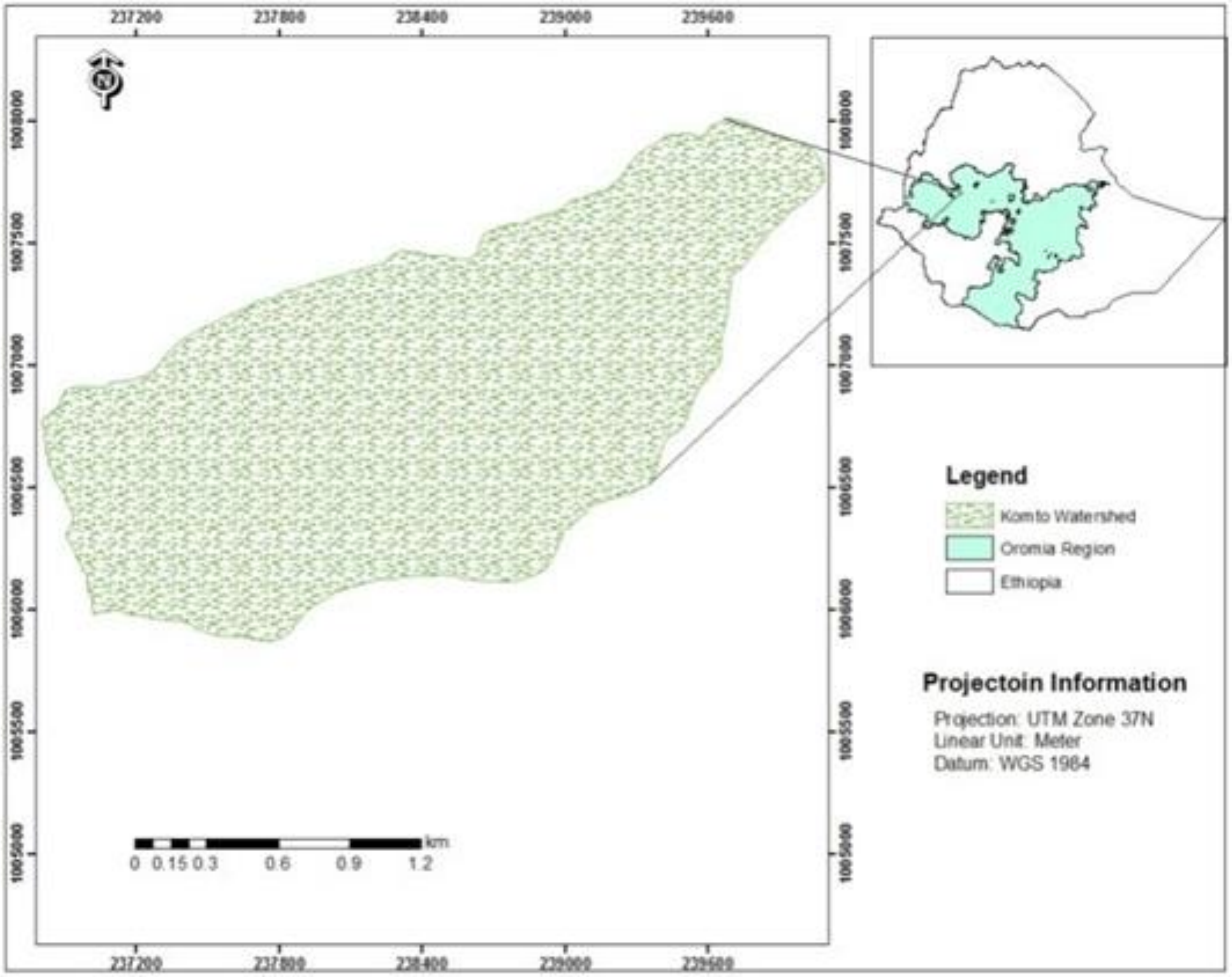

Figure 1. Location map of the study site.

compared with critical value and interpreted. Pearson correlation coefficient was used to evaluate the relationship between variables (LSD) was employed to compare means of parameters of the land uses at 0.05 and 0.1 significance levels.

RESULTS AND DISCUSSION

Response of soil physical properties to deforestation and subsequent cultivation

Particle size distribution

Variations in particle size distribution within a pedon with soil depth and between pedons due to land use change was observed in the study site (Table 1). Whilst sand and silt fractions showed consistent trend with depth in soils

at $p < 0.05$ and 0.01. Descriptive statistics was used to illustrate mean of the measured variables. The least significant difference

of arable land, clay and silt fractions did in soils of forestland. Clay content was relatively higher at subsoil than the topsoil which might be the result of pedoturbation following intensive weathering accelerated by continuous tillage. The mean clay content was higher for arable land than forestland whereas the mean sand and silt contents were lower for arable land.

This was attributed to the fact that forest destruction and shift to arable land facilitates soil particle breakdown during plowing. Chikezie (2009) revealed that higher mean clay fraction recorded in the arable land attributed to the impacts of deforestation and farming practices. Study by Amir et al. (2010) also suggested that increase in clay content after land use shift from forestland to arable land is a result of intensified chemical soil

Table 1. Comparison of particle size distribution, bulk density, particle density and total porosity in soils of forestland and arable land.

Land unit	Horizon	Depth (cm)	Particle size distribution (%)			STC	Densities (g cm^{-3})		TP (%)
			Sand	Silt	Clay		Bulk	Particle	
Forestland	O_e	0-10	42.00	30.00	28.00	CL	0.99	2.10	52.86
	A_h	10-60	47.00	22.00	31.00	SCL	1.12	2.20	49.09
	EB	60-115	38.00	20.00	42.00	C	1.25	2.43	48.56
	B	115-200	36.00	14.00	50.00	C	1.29	2.56	49.61
	-	Mean	41.75	21.50	37.75	-	1.16	2.32	50.03
Arable land	A_p	0-30	37.00	30.00	33.00	CL	1.28	2.49	46.44
	B_t	30-75	38.00	10.00	52.00	C	1.26	2.54	50.39
	BC	75-160	46.00	6.00	48.00	SC	1.40	2.61	46.36
	-	Mean	40.33	15.33	44.33	-	1.31	2.55	47.73

STC= soil textural class, CL=clay loam, SC=sandy clay, SL=sandy loam, SCL= sandy clay loam, L=loam, C= clay, TP = total porosity.

Table 2. Comparison of soil pH, organic matter, total nitrogen, available phosphorus and C:N ratio in soils of forestland and arable land.

Land unit	Depth (cm)	pH (H_2O)	OM (%)	Total N (%)	Av. P (ppm) Olsen	C:N ratio
Forestland	0-10	6.36	15.40	0.61	9.75	14.64
	10-60	5.92	10.05	0.42	4.09	13.88
	60-115	5.62	4.72	0.27	1.42	10.15
	115-200	5.36	0.97	0.08	0.90	7.00
Arable land	0-30	5.02	4.17	0.22	3.12	11.00
	30-75	5.00	2.05	0.15	1.06	7.93
	75-160	4.38	0.78	0.06	1.67	7.50
Forestland mean values		5.82^a	7.79^a	0.35^a	4.04^a	11.42^a
Arable land mean values		4.80^b	2.33^b	0.16^b	1.95^a	8.02^b

Means within column followed by different letters are significantly different at ($p < 0.1$).

degradation. Mean silt content of forestland was higher than arable land. Significant alteration of particle size distribution due to management practices like intensive tillage over a long period of time could result in soil textural change.

Soil densities and total porosity

Bulk density regularly increased with depth in soils of forestland (Table 1). This might be attributed to consistent decrease in OM content (Table 2) and subsequent increase in dry weight per unit volume of the soil with depth. Sandy soils usually have higher bulk density than clay soils provided that other factors including soil OM content are not significantly different.

Comparatively, the highest bulk density (1.40 gcm^{-3}) was recorded in arable soil at a layer containing significant proportion of sand fraction (46%) but very low OM (0.78%) whereas the lowest bulk density (0.99 g cm^{-3}) was recorded in forest soil at the OM rich topsoil (0 to 10 cm). The mean bulk density was increased during course of deforestation and subsequent cultivation from 1.16 g cm^{-3} for soils of forest ecosystem to 1.31 g cm^{-3} for soils of arable land. This could be mainly caused by soil compaction during tillage practices and reduction of soil OM, similar to the reports of Amir et al. (2010). Based on rating the effect of bulk density on soil condition given by

Table 3. Comparison of exchangeable cations, cation exchange capacity, total exchangeable bases and total exchangeable acids in soils of forestland and arable land.

Land unit	Depth (cm)	Ex. Ca	Ex. Mg	Ex. K	Ex. Na	Ex. Al	Ex. H	CEC	EB	EA
		------------ (cmol(+) kg $^{-1}$) --------------								
Forestland	0-10	19.88	3.67	2.71	1.10	T	0.78	54.83	27.36	0.78
	10-60	9.94	2.04	0.92	0.65	T	0.71	40.74	13.55	0.71
	60-115	8.19	2.53	0.59	0.61	T	0.86	42.81	11.92	0.86
	115-200	4.28	2.15	0.43	0.51	0.32	0.65	28.16	7.37	0.97
Arable land	0-30	3.68	1.36	0.53	0.47	2.60	2.17	25.59	6.04	4.77
	30-75	2.18	1.02	0.32	0.21	4.87	1.41	22.85	3.73	6.28
	75-160	1.16	0.99	0.23	0.26	5.87	0.96	15.03	2.64	6.83
Forestland mean values		10.57^{a}	2.60^{a}	1.16^{a}	0.72^{a}	0.08^{a}	0.75^{a}	41.64^{a}	15.05^{a}	0.83^{a}
Arable land mean values		2.34^{b}	1.12^{b}	0.36^{a}	0.31^{b}	4.45^{b}	1.51^{b}	21.16^{b}	4.14^{b}	5.96^{b}

Means within column followed by different letters are significantly different at ($p < 0.05$); CEC: cation exchange capacity; EB: exchangeable bases; EA: exchangeable acids; T: trace.

(Hunt and Gilkes, 1992), soils containing bulk density >1.8 g cm^{-3} for sandy soils, >1.6 g cm^{-3} for loam soils, and >1.4 g cm^{-3} for clay soils were considered very compacted and restrict root penetration. Accordingly, the 75 to 160 cm layer of arable land was very compacted and affects soil property and root penetration.

The value of particle density consistently increased with depth in all land units. Forest soils have lower particle density than arable soils since the former have better OM. Heavy soils or soils containing high clay fraction including the 30 to 160 cm layer of arable soils and the 60 to 200 cm layer of forest soils tends to have larger particle density (Table 1). Total porosity was highest (52.86%) for the top organic layer of native forest as compared to arable land. The study result suggested that deforestation and consecutive cultivation had posed more effect on the total porosity of the topsoil than subsoil. Handayani (2004) revealed that porosity decreased by 10.50% following deforestation and continuous cultivation.

Similarly, previous authors reported that macro-pore volume decreased as a result of soil compaction due to tillage and trampling by humans coupled with depletion of SOC content in the upper soil horizon (Yimer et al., 2008). A reduction of the volume of soil pores has a direct negative effect on infiltration capacity and moisture content encouraging soil erosion.

Response of soil chemical properties to deforestation and subsequent cultivation

Soil pH, organic matter, total nitrogen and C:N ratio

Soil pH consistently decreased with depth in soils of both land units indicating subsurface soils are more acidic than surface soil (Table 3). This might be due to leaching of exchangeable aluminum (Ex. Al) from the surface to subsurface horizon facilitated by tillage practices and subsequent hydrolysis reaction that releases hydrogen (H) ions into the soil solution. According to Donald (2012) soil pH classification, arable soils of the study area were more acidic than forest soils. Destruction of native forest and subsequent cultivation had decreased OM content and finally reduced the buffering capacity of soils. This factor coupled with continuous use of ammonium containing fertilizers, soil erosion, OM oxidation facilitated by tillage, complete removal of crop residues and elevated Ex. Al might have made soils of arable land to be more acidic.

Study by Amir et al. (2010) indicated that oxidation of nitrogen could result in an intensified decomposition of soil OM under cultivated land and subsequent reduction in the soil pH. In contrast, forest soils contain high OM and are less subjected to pH changes, for such soils have high buffering capacity. Besides, chelating of H ions with organo-complexes of the forest soils might have reduced the likely release of free H into the soil solution. Had the farmers practiced conservation tillage, the difference in soil reaction between arable land and its counterpart would have been narrow. Due to consistent decrease in soil OM and total N, the C:N ratio regularly decreased with depth for both land units. Soil OM content was smaller for soils of arable land than forestland (Table 2).

The relatively low OM content in soils of arable land as compared to native forest ecosystem could be attributed to intensive cultivation which aggravated oxidation of OM (Alemayehu et al., 2011) and prolonged cultivation coupled with frequent burning of crop residues that accelerated the rapid turnover rates of OM (Yacob, 2015). Farmers usually collect and store crop residues for livestock feed, fuel wood, and sell to the market to generate income. A portion of residues remaining in the field was purposely burned thinking it enhances soil fertility. Poverty and lack of knowledge were, therefore, the major driving factors for complete removal of crop residue prohibiting it from enriching the soil OM.

Additionally, increased soil erosion due to complete removal of crop residues in the arable land could have resulted in low soil OM. This indicates a reduction in the nutrient supply, water holding capacity, structural stability and cation exchange capacity of the soils (Amir et al., 2010). Conversely, the virgin soils of forestland produced high mean value of OM which could be due to the continuous accumulation of decomposed plant and animal residues in the absence of disturbance of soil environment over a long time period.

As 95% of total N is found in organic form, it followed similar pattern as the OM change with land unit and soil depth. In this view, OM could have contributed to higher level of total N in soils of forestland. Although rating of soil parameters slightly differ among authors, Bruce and Rayment (1982) adopted that total N (%) < 0.05 is very low, 0.05 to 0.15 low, 0.15 to 0.25 medium, 0.25 to 0.5 high, and >0.5 is very high. In relation to this rating, the total N in soils of forestland ranged from low (0.08%) for the 115 to 200 cm layer to very high (0.61%) for the top 0 to10 cm layer whereas that of arable land ranged from low (0.06%) for 75 to160 cm genetic depth to medium for the top plow layer (0 to 30 cm).

Continuous cultivation and lower activity of N fixing bacteria due to strong acidity (pH < 5.5) might have resulted in the reduction of total N in soils of arable land as compared to forestland. A report of Wakene and Heluf (2004) revealed that intensive and continuous cultivation forced oxidation of SOC and thus resulted in reduction of total N. The present study result indicate that total N was strongly correlated with soil OM ($r^2 = 0.99$ for forestland and $r^2 = 0.98$ for arable land) and it was consistent with the conclusion of Jobbagy and Jackson (2000). The C:N ratio, a measure of balance between SOC and total N, is an important indicator for well-functioning of soil micro-organisms and adequate supply of N to plants. The mean C:N ratio was higher for forestland than arable land. The reason could be obviously the significantly higher OM content in soils of forestland (Teshome et al., 2013).

Based on Gavlak et al. (1994) rating, soil C:N ratio of < 10 is medium, 10−14 is good, and >14 is poor. Accordingly, the mean C:N ratio for forest soils (11.42) was classified as good. This was because the proportion of SOC and total N was at par for normal functioning of soil micro-organisms. In contrast, arable soils had mean C:N ratio of <10, which means too low OC.

Available phosphorus

Though not consistent in soils of arable land, available P was decreased with depth in both land units. Reduction in available P value with depth could be attributed to P fixation caused by increased Ex. Al with depth. Numerically, the mean available P value for forest soils was higher than arable soils. Since there exists positive correlation between available P and SOC ($r^2 = 0.78$ for arable soils and $r^2 = 0.95$ for forest soils). Decline in OM content, soil acidification and erosion could be the main causes for the depletion of available P from arable land. Due to current management practices, deforestation and continuous cultivation and crop residue removal, the existence of available P in the soil is endangered for the near future (Alfred and Tom, 2008).

Exchangeable cations, percent base saturation and acid saturation

Exchangeable calcium (Ex. Ca) and potassium (Ex. K) regularly decreased with depth in soils of both land units (Table 3). The concentration of basic cations on exchange site of arable and forest soils in the study area decreased in order of Ca >Mg >K >Na. According to Eckert (1987) rating of Ca/Mg ratio, arable soils have extremely low Ca relative to Mg and leads to Ca deficiency in plants. The data presented in Table 3 indicate that exchangeable bases were better in soils of forestland than arable land. Though leaching of exchangeable bases is common in soils of humid tropics including the study site, absence of better OM for ionic retention might have contributed for the significant depletion of exchangeable bases from the arable soils.

Except exchangeable K, exchangeable cations of different land units are significantly different at $p < 0.05$. The OM rich 0 to 10 cm layer of forest soils contained comparatively the highest exchangeable bases (27.36 cmol(+) kg^{-1}). This manifests that the colloidal site of soil OM might have retained better quantity of exchangeable bases. In contrast, continuous tillage practices considerably disturb natural soil structure; facilitate soil OM decomposition and leads to depletion of exchangeable bases from the arable land. Study by Achalu et al. (2012) found that exchangeable bases decreased when natural forest was changed to cultivated land. The mean exchangeable base for forest soils was about 3.6 times higher than arable soils. This shows that 25 years after conversion of forestland to arable land, the mean exchangeable bases was averagely reduced by 72.5%. Percent base saturation was reduced following deforestation and intensive cultivation (Figure 2). As per the rating of Metson (1961), percent base saturation of the study area ranged from very low (0 to 20%) for arable soils to moderate (40 to 60%) for forest soils.

Ex. Al increased with depth for both land units which could be caused by eluviations of Al oxides from surface to subsurface horizons. In line with the finding of Taye (2008), the present study revealed that large proportion of exchangeable acids in arable soils of western Ethiopia

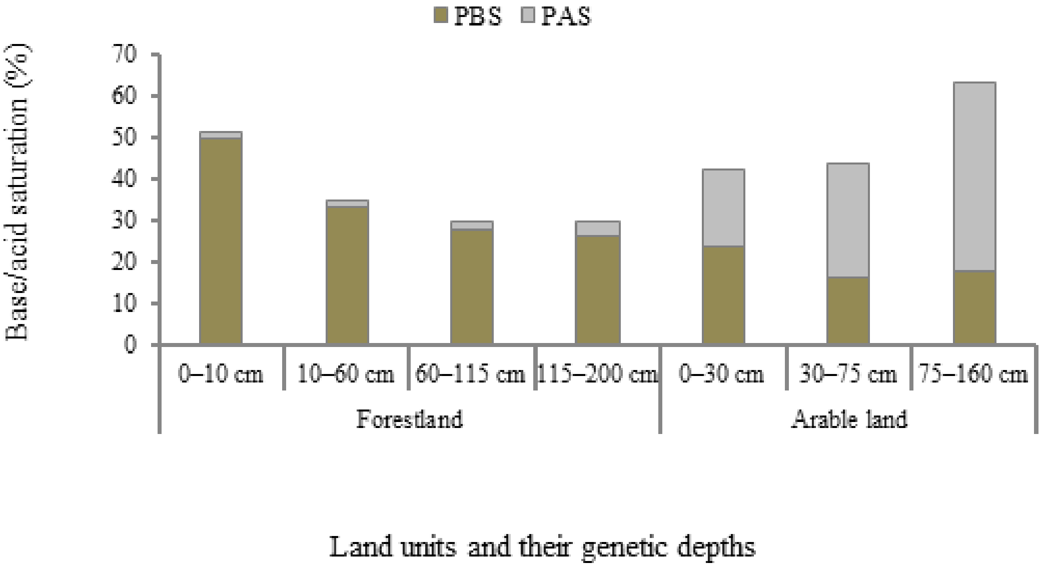

Figure 2. Percent base saturation (PBS) and percent acid saturation (PAS) in soils of forestland and arable land. The graph shows decrease in PBS and subsequent increase in PAS following deforestation and continuous cultivation.

was occupied by Ex. Al. In contrast, the relatively low level of Ex. Al in forest soils could be due to complexation of Ex. Al with OM. These organo-complexes reduce the flux of exchangeable acids between soil colloidal site and the soil solution and hence, resist major pH changes. The exchangeable acids (Ex. Al and Ex. H) in soils of arable land were by far higher than the forestland. Conversion of native vegetation to arable land over the past 25 years had amplified the mean exchangeable acids from 0.83 cmol(+) kg^{-1} to 5.96 cmol(+) kg^{-1}. During this course, the mean exchangeable acids remarkably increased by nearly 7 folds. Percent acid saturation was considerably higher for soils of the arable land mainly due to appreciable amount of exchangeable acids present in the soil (Figure 2). Unless proper management measures are taken, this leads to soil deterioration (Faykah, 2014).

Cation exchange capacity

From the investigated soils, the highest CEC (54.83 cmol(+) kg^{-1}) was recorded for 0 to10 cm layer of forest soils and the lowest CEC (15.03 cmol(+) kg^{-1}) was recorded for 75 to 160 cm layer of arable soils (Table 3). The mean values of CEC were 41.64 cmol(+) kg^{-1} and 21.16 cmol(+) kg^{-1}for soils of forestland and arable land, respectively. The higher CEC value in soils of forestland might be attributed to the relatively higher OM colloid in the soil. This concurs with the finding of Sanchez et al. (2002) that changing land use from native forest to cultivated land reduced CEC. The study result showed that large proportion of CEC in the topsoil of arable land was dominated by exchangeable bases whereas the subsoil was dominated by exchangeable acids.

Conversely, soils of forestland were generally dominated by exchangeable bases. The mean proportion of exchangeable cations decrease in order: Al > Ca > H > Mg > K > Na in soils of arable land and Ca > Mg > K > H > Na > Al in soils of forestland. This clearly indicates that land use change and management practices had a considerable influence in modifying soil properties. The proportion of CEC of different cations or simply cation saturation percentage varies for different land uses. Soils of forestland were saturated with Ex. Ca while soils of arable land were saturated with Ex. Al. Comparing with desirable proportions of Ex. Al in the soil for plants adopted by Abbott (1989) as Al < 5%, the study result showed that Ex. Al was above the critical for arable land (10.16 to 39.06%) and in the optimum range for forestland (0 to 1.14%). Continuous cultivation significantly increased Ex. Al concentration in the soil and aggravated soil acidification.

Soil pH has strong and positive correlation with CEC (r = 0.97) (Table 4). Soil pH is negatively correlated with exchangeable acidity indicating increase in exchangeable acidity reduces soil pH. Exchangeable Al is strongly and positively correlated with exchangeable acidity (r = 0.98) at $p < 0.01$ but poorly and negatively correlated with available phosphorus. This implies that increase in Al toxicity in the soil reduces P availability through strong

Table 4. Correlation matrix among measured soil chemical properties.

Variable	pH	Ex. Al	EB	EA	CEC	OM	TN	Av. P
pH	1.00	-0.87*	0.92**	-0.87*	0.97**	0.87*	0.89**	0.72
Ex. Al	-	1.00	-0.69	0.98**	-0.83*	-0.59	-0.62	-0.41
EB	-	-	1.00	-0.71	0.95**	0.94**	0.94**	0.90**
EA	-	-	-	1.00	-0.83*	-0.58	-0.60	-0.40
CEC	-	-	-	-	1.00	0.88**	0.91**	0.75
OM	-	-	-	-	-	1.00	0.99**	0.94**
TN	-	-	-	-	-	-	1.00	0.91**
Av. P	-	-	-	-	-	-	-	1.00

*Significant at $P < 0.05$, ** $p < 0.01$.

Table 5. Percent change of selected soil properties after major land use transformation from forestland to arable land with 20-30 years periods of cultivation in the top plow depth as compared to other studies.

Soil properties	Percent of soil change under the present study	Percent of soil change during the previous studies	
% Clay	15.15% increase	2.67% increase	Amir et al. (2010)
Porosity	12.15% decrease	9.44% decrease	Amir et al. (2010)
Bulk density	22.66% increase	27.40% increase	Amir et al. (2010)
Topsoil pH	20.75% decrease	10.77% decrease	Alfred et al. (2008)
Total N	63.93% decrease	26.00% decrease	Handayani (2004)
OM	72.92% decrease	75.00% decrease	Fisseha et al. (2011)
Av. P	68.00% decline	48.14% decline	Lechisa et al. (2014)
CEC	53.32% decrease	16.16% decrease	Teshome et al. (2013)

fixation. The general interrelationship between different soil fertility parameters can be depicted as in Table 4.

Quantum of soil changes with the periods of cultivation

Soil deterioration following deforestation and subsequent cultivation is a known fact. However, the degree of soil deterioration might varies depending on climatic condition, cropping intensities, periods, cropping pattern, crop rotation, crop types and crop management practices. In humid tropics, soil deterioration following deforestation is aggravated by water erosion.

Percent of change in clay content is higher in the present study than previous research conducted by Amir et al. (2010) (Table 5). This might be due to the severity of soil disturbance by tillage practices in the present study site. Decline in CEC following deforestation and periods of cultivation was higher in the present study site than reported by Teshome et al. (2013). This could be due to intensive leaching of basic cations facilitated by continuous tillage practices. Although all soil properties were affected by forest clearing and shift to cultivation, the most seriously deteriorated soil properties in the present study site include OM, total N, available P, and CEC. Therefore, as recommended by Biyogue (2016), regulating human activities across the reserve forests as well as stepping up protection of existing reserves in the area is needed to avoid further deterioration of the physical properties of the soils under these forests.

Conclusions

Intensive cultivation following deforestation has a profound negative effect on soil physical and chemical properties. Though the distribution of soil particles (sand, silt, and clay fractions) greatly affected by land use change, clay and clay loam were still the dominant soil textural classes in both land units. Decrease in OM and soil compaction in the arable land led to increased bulk density. This can reduce air and water movement in the soil facilitating water erosion.

Deforestation and subsequent intensive cultivation leads to soil acidification. This factor combined with exhaustive removal of crop residues and consequent loss of OM from soils of the arable land lead to depletion of available P and total N. The CEC of arable land was saturated with exchangeable acids while that of forestland was dominated by exchangeable bases. Presence of better OM in the forestland had increased buffering capacity of the soil, maintained soil pH and reduced the impact of acidification on other soil properties.

Therefore, to confront soil acidification and fertility decline in soils of arable land, two optional agronomic strategies can be adopted. Firstly, cultivators should give due emphasis on conservation tillage that can improve the overall quality of the soil. If farmers' traditional cultivation system inhibits use of conservation tillage, researchers need to provide a lasting solution for continuous cultivation induced soil acidification. In this case, researchers should focus on permanent solutions like breeding and development of acid tolerant crop genotypes to address resource poor farmers who cannot afford the cost of chemicals amendments like lime. Secondly, for soil sustainability and productive crop cultivation, dependence on green manuring, farm yard manuring, composting and biofertlizers should be the first priority management practices to be relied on. Protection of forest reserves and practicing conservation tillage enhances soil fertility, enriches biodiversity, and sustains productivity.

Conflict of interests

The authors have not declared any conflict of interests.

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