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RESEARCH PAPER

Impacts of deforestation on selected soil fertility status: the case of Cheliya District, West Shoa Zone, Oromia national regional state, Ethiopia

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Abstract

The objective was to assess impacts of deforestation on selected soil fertility status in Chellia District, West Shoa zone of Oromia Regional National State, Ethiopia. The experiment was undertaken in selected deforested areas for soil fertility status by descriptive cross-sectional method which describes and obtains relevant and various forms of data concerning the existing current status of the study area. The data for the study were collected through field observation and laboratory test. Two representative composite soil samples were collected in zigzag manner from the upper (0-20 cm) depth of the top soil from the forest and deforested lands. The study was mainly focused on analyzing the soil physicochemical and fertility status between forest and deforested lands. The cumulative values of deforestation were decreasing the marginal status of soil nutrients, showing that the overall soil condition in the deforested land was deteriorating and getting below the condition of the soils under the forest lands. The comparisons between the forest and deforested lands revealed a highly significant difference on major soil fertility parameters. Therefore, there is a need to develop sustainable forest management and practicing afforestation and reforestation programs to overcome the deterioration of soil fertility of the present study area.

Keywords: Deforestation, soil fertility, soil physicochemical properties

Introduction

In Ethiopia where agriculture is the mainstay of the national economy, agricultural production has been highly dependent on natural resources for increasing productivity. As a result, agricultural lands have expanded at the expense of natural forests to meet the additional food demand for the increasing population. Besides the expansion of cultivated and grazing lands, forests have been heavily exploited for fuel wood and construction material in order to meet the needs of the rapidly expanding population (Kidanu, 2004, Abaynesh *et al*., 2015b, Achalu and Teshome, 2019).

Ethiopia is one of the most severely deforested countries in sub-Saharan African countries, particularly in forest degradation which resulted in soil erosion and degradation of agricultural lands. (Temesgen *et al.,* 2014). The decline in overall stability and productivity of the country's natural resource is the result of complex and interrelated series of processes that were triggered by the loss of forest cover in critical watershed (Tumcha, 2004, Abaynesh *et al*., 2015b). The recent data on forest resources of Ethiopia indicates that the country is among countries with forest cover of greater than 10-30% (FAO, 2015). The increasing population of Ethiopia has resulted in an excessive forest clearing for agricultural, overgrazing and exploitation of the existing forests and use of woodlands for firewood consumption and building materials. As a result, Ethiopia will face a difficult future, because the agricultural sector which forms the back bone of economy is dependent on forest resource (Abaynesh *et al.*, 2015b). Deforestation of these natural forests leads to various environmental impacts such as land degradation with associated low soil fertility, heavy soil erosion, low productivity and other ecological imbalances with frequent drought, desertification and aggravated soil degradation, thereby resulting in soil fertility decline (Abaynesh *et al.*, 2015a)

Improving soil fertility becomes an important issue in development agendas because of its linkage to food insecurity and economic well being of the population. Radical losses in soil fertility have been recorded in the first 20–25 years after deforestation in the southern region of Ethiopia (Tesfaye *et al.*, 2016). Land use changes have several undesirable consequences like decline in soil fertility (Tesfaye *et al.*, 2016; Henok *et al.*, 2017). Achalu *et al.*, (2012); Bhan and Behera (2014) suggested alternative land uses did not bring changes to the livelihood of the local community and did not reduce the pressure on the natural forest. Further, they did not include and verify locally adopted alternative land use types. Because of this, the earlier work did not come up with outcomes that could sustain the forest cover. For instance, majority of land use changes or deforestation related impact studies did not include agro-forestry on their experimental research works; they mainly focused on comparison of forest with cropland, grazing, enclosures (enclosed space) conservation agriculture and fallow land. It was in the light of the above background; the study was initiated to focus on assessing the impact of deforestation on selected soil fertility status of the study area. Therefore, the objective was to assess impacts of deforestation on selected soil fertility status by determining and analyzing selected soil physical and chemical properties of Cheliya District, West Shoa Zone, Oromia Regional National State, Ethiopia.

Materials and Methods

Description of the Study Area

The study was conducted in Cheliya district (Gedo area), West Shoa Administrative Zone, Oromia Regional National State, Western Ethiopia. It is located at about 184 km from Addis Ababa and 65 km from Ambo town in Western part on the way to Nekemte town. Geographically it is located in between 8°48'0'' N to 9°10'30'' N Latitude and 37°10'0'' E to 37°3'50'' E longitude (Figure 1) with altitudinal range of 1900 - 3140 meter above sea level.

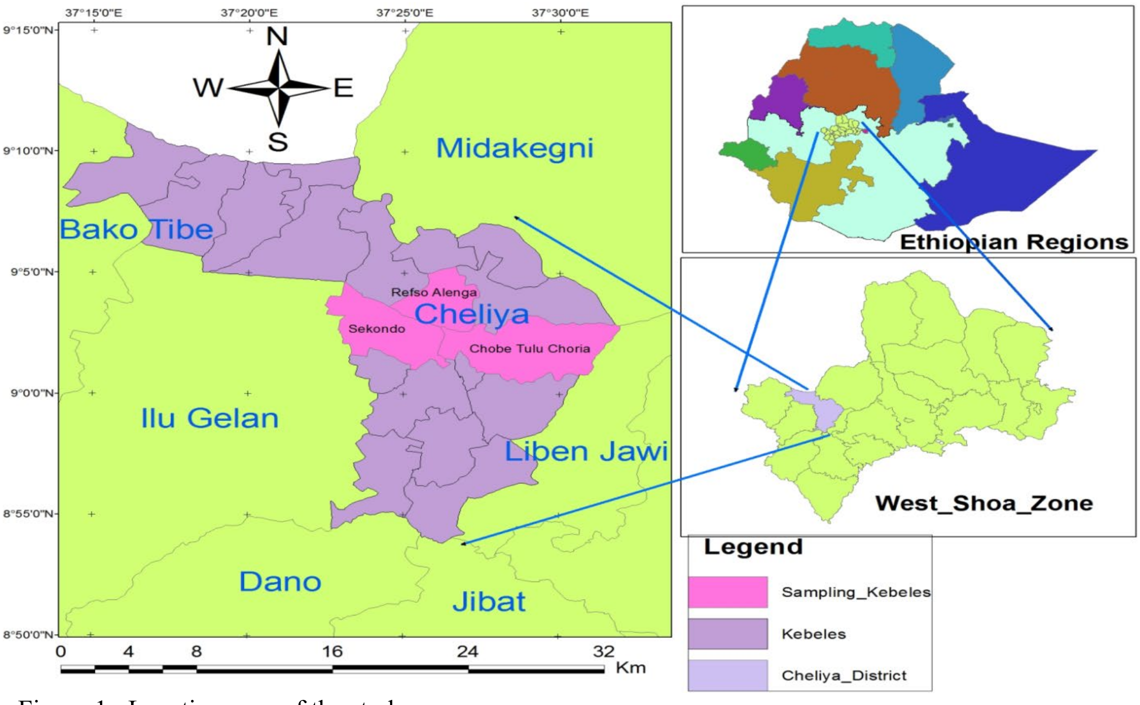

Figure 1. Location map of the study area

The physiographic features of the study area have various land forms such as plateaus, hills, plains and valleys. *Tullu Mara, Tullu Gedo, Tullu Dalat* and *Tullu Lencha* are local named important mountains of the district (CDAO, 2015). The district is located in Central Oromia, Ethiopia. Based on its agro-ecology, the district is divided in to two zones; the midland which lies below 2,500 m above sea level and highland which is above 2,500 m above sea level (CDAO, 2015). The majority (80%) of the district's areas are covered by high land agro-ecology while the remaining 20% is under mid- high land. The mean annual temperature ranges from 8to 28°C (CDAO, 2015). The area has a unimodal rain fall, where the shortest rainy season is the period from March to the end of September. The annual precipitation ranges from 800 to 1200 mm (CDAO, 2015). The main economy of the district is agriculture. Since the majority of its agro ecology is *Bada-Dare*, mixed farming (crops, livestock, and livestock product productions) are highly practiced in the study area. The area is moderately productive and subsistence in food crops. Crop production is mainly based on rain fed.

The local geology and its interaction with climate largely determine the nature and type of soils that occurs at ground surface. The geological characteristics of principal importance in this respect include the mineralogical composition of the bed rock which determines its chemical stability under different climatic regimes. The two major soil types which dominate the study area are red and black soil. In Ethiopia, temperature and rainfall highly determine the type and density of vegetation. Many of natural vegetation have been destroyed by prolonged cultivation and human settlements. As a result, much of the natural vegetation areas except, some protected areas have changed to farm and pasture lands. Most of the study areas covered with the indigenous trees such as *Junipers procera, Cordia africana, Olea africana, Prunus africana, Fichus vasta, Ficussur, Hygeia abyssinica,* and *Podocarpusfalactus* at the past four or five decades. However, now a day, these species of the trees are not observed in the study area, except in small protected areas. The study area has few natural forests in the high lands. In fact, man-made forests (Eucalyptus species, *Cuppers uslustanica, Gravillea Robusta, Juniper sprocera, Jacaranda mimosa folia*, and *Pinus patula*) are found scattered in highland and midland regions. As it is true for most area of the study areas deforestation has been one of the problems.

Methods

Biological and physical environment existing within the study area was identified through field survey: survey of soil, water, vegetation, conservation practices, and strategies, climate (rainfall, altitude and winds) specific topographic features. The research was designed and implemented in Cheliya district by using field observation and selected soil sample laboratory test analysis to assess impacts of deforestation on selected soil fertility status. The research method selected for this study was cross sectional method, which helps investigator to describe and obtain relevant and various forms of data concerning the existing status of soil physico-chemical properties of forest and deforested lands of the present study area.

Site Selection, Soil Sampling and Preparation

In order to have general information about the study area, a preliminary survey and field observation was carried out and selecting natural forest and deforested lands based on dominancy of the natural forest and soil surveys (physically) and two land uses (natural forest and deforested land) was delineated. Two representative composite soil samples were collected in zigzag manner from (0-20 cm) depth of the top soil from each selected sampling villages (*Sekondo, Chobi Tulu Cori and Refiso Alenga*) of the forest and deforested lands. From each land use types composite sample (after being well mixed in a bucket) of about 2 kg of the mixed composite sample were properly bagged, labeled and transported to the laboratory for analysis. The soil samples collected from representative fields' with three replications were then air-dried at room temperature for 15 days, homogenized, lightly grounded and passed through a 2 mm sieve for the analysis of selected soil physical and chemical properties. Soil sample preparation and laboratory was done in the following centers of the soil laboratories (Ambo University, Chemistry and Plant Science department). The following variables was determined: soil moisture content, soil texture, bulk density (BD), pH, organic matter, available and total P, exchangeable basic cations (Ca, Mg, K and Na), cations exchange capacity (CEC), total exchangeable acidity (Al and H^+), percent acid saturation (Al and H^+), electrical conductivity and total nitrogen.

Determination of Soil Physical and Chemical Properties

Soil textural analysis was determined by hydrometer or Bouyoucus method. Moisture Content was determined by initially weighing the field samples, drying the field samples at 105°C for 24 hours by oven-drying method. Bulk Density (BD) was determined by undisturbed soil samples collected using a core sampler method.

The pH of the soil was measured using pH (H_2O) 1:2.5 soil water ratios using digital pH meter and from a supernatant suspension of pH (KCl) 1:2.5, soil to KCl liquid ratio. Electrical conductivity (EC) was measured using a conductivity bridge by extracting the soil sample with water (1:1 or 1:5 soil: water ratio). Soil organic matter was determined by using titrimetric methods and then its contents can be estimated from the organic carbon content by multiplying by 1.724 following the assumptions that OM is composed of 58% carbon. Total P was determined using perchloric acid digestion. Available soil P was analyzed by using digestion method as described by (Bray and Kurtz. (1945). Exchangeable basic cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) was determined as described by (Black, 1965). Exchangeable Ca and Mg in the extracts was analyzed using atomic absorption spectrophotometer, while Na and K were analyzed by flame photometer (Rowell, 1994). The percent base saturation of the soil samples was calculated from sum of the basic exchangeable cations (Ca^{2+}, Mg^{2+} and Na^+) as percentage of CEC. Total exchangeable acidity was determined by saturating the soil samples with potassium chloride (1M KCl) solution and titrated with hydrogen chloride 0.02M HCl as described by (Rowell, 1994). From the same extract, exchangeable Al^{3+} in the soil samples was titrated with a standard solution of 0.02M HCl. Then the exchangeable H^+ was obtained by subtracting exchangeable Al^{3+} from total exchangeable acidity, which is Al^{3+} and H^+ ions (Rowell, 1994). Cation exchange capacity (CEC) was determined by measuring the total amount of a given cation needed to replace all the cations from a soil exchange site. The percent acid saturation of the soil samples was calculated from sum of the acidic exchangeable cations (Al, H^+) as percentage of CEC. Total N was determined by the Kjeldahl procedure as described by Jackson, (1958).

Data Analysis

Pearson's simple correlation coefficient was executed using Statistical Package for Social Science (SPSS) version 20 was used to test differences in soil physical and chemical properties across the forest and deforested lands. The organized quantitative primary data were expressed in tabular form to summarize results from laboratory test.

Results

Response to Selected Soil Physical and Properties

The textural class of the top (0-20 cm) soils from forest and deforested lands were clay, indicating the similarity in parent material (Table 1). The average clay, silt and sand content of the forest and deforested lands were 57.86 and 58.33, 16.74 and 29.25, 13.82 and 25.40%, respectively. For soils of forest the average clay content was higher than silt and sand contents. The percent average silt content was also higher than the percent sand content in two land use types. Soil moisture content was significantly (P<0.05) influenced by deforestation. Results revealed that soil moisture content varied from 29.61 to 9.83% for the forest and deforested land use, respectively (Table 1). Negative and significant relationship of moisture content deforested land with percent silt content of forest land (r = -0.99) were observed from the output of the correlation matrix.

Bulk density of soils was influenced by deforestation (P<0.05). The mean values of bulk density obtained from the two land use types was 1.143 to 1.693 gm/cm^3 for forest and deforested lands, respectively (Table 1). The bulk density of deforested land was higher as compared to forest lands (P<0.05). Negative and significant relationship of bulk density of deforested with silt textural class of forest land (r = -0.99) were observed from the output of the correlation matrix. Islam and Weil (2000) reported lowest bulk density in the soil taken from natural forest compared to other land uses like deforested land.

Table 1. Mean value of selected soil physical properties of experimental soils

	Soil physical parameters					
Land uses	MC (%)	BD (g/cm^3)	Clay (%)	Silt (%)	Sand (%)	Textural class
FL	29.61	1.143	57.86	16.74	13.82	Clayey
DFL	9.83	1.693	58.33	29.25	25.40	Clayey
LSD(FL)	3.27	0.10	0.00	2.29	2.63	
LSD(DFL)	0.19	0.02	0.74	4.78	1.18	
CV(FL)	11.04	8.76	0.00	13.70	19.01	
CV(DFL)	1.50	0.90	1.26	16.33	4.64	

BD=bulk density, CV= Coefficient of variation, FL=Forest land; DFL=Deforested land, LSD= Least significant difference, MC= moisture content;

Response to Selected Soil Chemical Properties

The soil pH measured in water was higher by about 0.84-1.13 units than the respective pH values measured in KCl solution in forest and deforested land (Table 2). The low soil pH with KCl solution determination indicates the presence of substantial quantity of exchangeable hydrogen ion. Anon (1993) high soil acidity with KCl solution determination showed the presence of high potential acidity and weather ability of minerals. The soils pH measured in water was significantly (*P*<0.001) affected by deforestation Negative and significant relationship of soil pH of forest land with percent average silt content of deforested land (r= -1.00) were observed from the output of the correlation matrix. The relatively higher 6.87 (H_2O) and 5.75 (KCl) and the lower 6.18 (H_2O) and 5.35 (KCl) soil pH values were recorded under the forest and the deforested lands measured in water and KCl solution, respectively (Table 2). Considering the main effects of land use types, the higher 0.28 dS/m and the lower 0.26 dS/m EC of the soils were obtained from deforested and forest lands respectively (Table 2). The highest EC value under the deforested land might be due to its highest exchangeable Na^+ content whereas, the lowest EC value under forest land might be associated with the gain of base forming cations (Ca^{2+} and Mg^{2+}). Thus, more or less EC values of both land uses were similar, which indicates the similarity (clay) in parent material (Table 1). The soil organic matter content of the soil was influenced by deforestation. Higher percent of organic matter content for forest as compared to deforested lands. The mean value of percent soil organic matter was 2.58 and 2.36% for soil taken from forest and deforested lands, respectively (Table 2). The percent organic matter from forest land was higher as compared to that of deforested lands (*P*<0.05). Total nitrogen was significantly (*P*<0.05) influenced by deforestation. The mean values of percent total nitrogen were 0.24 and 0.18% for soil of forest and deforested lands, respectively (Table 2). The percent total nitrogen content of soils obtained from forest lands was higher than that of from deforested lands. This might be conversion of forest land to different land uses causes a decline of total N. Similarly, Heluf and Wakene (2006) reported decline in organic carbon and total nitrogen is due to deforestation and land use changes.

The carbon to nitrogen ratio was considerably influenced (*P*<0.05) by deforestation. Considering the interaction effect of deforestation, the lowest (6.23) and the highest (7.61) C: N ratio values were recorded in forest and deforested land, respectively (Table 2). Negative relationship of C: N ratio with percent clay content and PAS of deforested land soil (r=-0.99) were, respectively observed from the output of the correlation matrix. The C: N ratios were narrow in both forest and deforested lands. There was significant (*P*<0.05) difference of available phosphorus and total phosphorous between forest and deforested lands. The mean values of available phosphorus were, 24.07 and 19.96 mg/kg in the forest and deforested lands, respectively (Table 2). Negative and significant relationship of available phosphorus of deforested land soil with percent silt content and

OM of forest land (r=-0.99), were observed from the output of the correlation matrix.

The distribution of total P content followed a similar pattern to available P distributions and the mean values of total phosphorus were, 606.85 and 448.15 mg/kg in the forest and deforested lands, respectively (Table 2). The negative and significant relationship of total phosphorus soil of forest land with EC of deforested land and OM of forest land (r=-0.99) were, respectively observed from the output of the correlation matrix. As per the ratings of Landon (1991), medium total P content was observed in both forest and deforested land use types. Relative to forest land, soils of the deforested land recorded lower TP in the soil. This might be implying that conversion of forest land to deforested land results in the decline of the distribution of soil total P.

Table 2. Mean value of selected soil chemical properties of experimental soils

	Soil chemical parameters								
Land uses	pH (H_2O)	pH (KCl)	EC (dS/m)	OM	TN %	C:N Ratio	Av. P (mg/kg)	Tot. P (mg/kg)	Ex. Ac (meq/100g)
FL	6.88	5.75	0.26	2.58	0.24	6.23	24.07	606.85	0.91
DFL	6.19	5.35	0.28	2.36	0.18	7.61	19.96	448.15	1.76
LSD(FL)	0.08	0.13	0.03	0.20	0.00	0.57	5.07	134.14	0.06
LSD(DFL)	0.03	0.20	0.04	0.20	0.02	0.94	5.64	144.59	0.09
CV(FL)	1.09	2.21	9.87	7.62	1.67	9.17	21.05	22.10	6.59
CV(DFL)	0.41	3.71	12.74	9.50	11.11	12.34	28.27	32.26	5.11

FL=Forest land; DFL=Deforested land; CV= Coefficient of variation, LSD = Least significant difference OM=organic matter; EC=Electrical conductivity; TN=total nitrogen; C:N = Carbon to nitrogen ratio; Av. P=Available Phosphorus; TP=Total Phosphorus;
Ex. Ac.=Exchangeable acidity

The content of exchangeable calcium (Ex. Ca^{2+}) was significantly (*P*<0.01) affected by deforestation. The mean values of exchangeable calcium (Ca^{2+}) under the forest and the deforested lands were 11.23 and 7.20 cmol/kg, respectively (Table 3). Negative and significant relationship of exchangeable calcium of deforested land soil (Ex. Ca^{2+}) with exchangeable acidity of forest land (r=-0.99) were observed from the output of the correlation matrix. Exchangeable Mg^{2+} content was significantly (*P*<0.01) affected by deforestation. The main effects of land use types, the mean exchangeable Mg^{2+} ion was 5.32 cmol/kg in the forest lands and 4.67 cmol/kg in the deforested lands (Table 3). Negative and significant relationship of exchangeable magnesium of forest land soil (Ex. Mg^{2+}) with percent acid saturation of forest land (PAS) and Total nitrogen (TN) of deforested land (r=-0.99) were observed from the output of the correlation matrix.

Exchangeable K^+ content was also significantly affected by deforestation (*P*<0.01). It was higher 22.49 cmol/kg in the forest land than 18.57 cmol/kg in the deforested land use types. Negative and significant relationship of exchangeable K^+ of deforested land soil with percent acid saturation (PAS) of forest land and total nitrogen of deforested land (r=-0.99, *P*<0.01) were observed from the output of the correlation matrix. The lower exchangeable K^+ contents in different land uses like deforested lands than forest lands resulted from continuous losses of harvested biomass (Gebeyaw, 2007). Exchangeable Na^+ of soil was significantly affected by deforestation (*P*<0.01 and *P*<0.05). The concentration of Na^+ content in the soils of two land use types were 0.11 and 0.13 cmol/kg for forest and deforested land soils (Table 3). Negative and significant relationship of Exchangeable Na of deforested land soil with percent silt content of deforested land and bulk density of forest land (r=-0.99 and r=-0.99) and with percent acid saturation of forest land soil (PAS) and TN of soil (r=-1.00, *P*<0.01) were, respectively observed from the output of the correlation matrix.

The mean values of CEC in forest and deforested land uses were not significantly different from each other *(P*>0.05). The Mean value of CEC in soil of the two land types were 30.42 and 21.65 meq/100 g for forest and deforested lands, respectively (Table 3). The CEC value in soil of forest land was highest as compared to in soil of deforested land. This high value of CEC in soils of forest land might be due to the high clay content and colloidal organic matter which have the ability to absorb and hold positively charged ions. The Percent base saturation (PBS) was significantly influenced by deforestation ($P<0.05$). Considering the main effects of land use, the highest (141.1%) and the lowest (128.7%) values of PBS were recorded under the deforested and the forest lands, respectively (Table 3). There was negative and significant relationship of Percentage base saturation of forest land soil with exchangeable acidity and Ca^{2+} of forest land ($r=-0.99$, $P<0.05$) were, respectively observed from the output of the correlation matrix. In general, processes that affect the extent of exchangeable bases also affect percent base saturation. However as per the ratings recommended by Murphy (2007), the value of PBS of the top soil (0-20 cm) depth of all land use types can be classified as low status of percent base saturation (PBS). This low value of PBS in soils of forest land might be due to the high value of CEC and clay content, and where high value of PBS in soil of deforested land might be due to the low value of CEC and clay content.

Table 3. Mean value of Exchangeable Bases, CEC and PBS properties of studied soils

	Soil Chemical Parameters					
Land uses	Ex. Ca (cmol/kg)	Ex. K (cmol/kg)	Ex. Mg (cmol/kg)	Ex. Na (cmol/kg)	CEC (cmol/kg)	PBS (%)
FL	11.23	5.32	22.49	0.11	30.42	129.33
DFL	7.20	4.66	18.6	0.13	21.65	141.47
LSD(FL)	0.01	0.03	0.02	0.01	2.60	11.56
LSD(DFL)	0.10	0.05	0.05	0.01	0.70	5.16
CV(FL)	0.09	0.11	0.38	9.09	8.53	8.95
CV(DFL)	1.39	0.27	1.10	7.69	3.25	3.65

FL=Forest land; DFL=Deforested land; CV= Coefficient of variation, LSD= Least significant PAS=Percent acid saturation; Ex. Ca=exchangeable Calcium, Ex. Mg=Exchangeable Magnesium, Ex. K=exchangeable potassium, Ex. Na= exchangeable sodium; CEC=cation exchange capacity; PBS=Percent acid saturation

The exchangeable acidity was significantly ($P<0.05$) affected by deforestation. The highest 1.76 meq/100g and the lowest 0.91 meq/100g exchangeable acidity were recorded under the deforested and the forest lands, respectively (Table 2). These results show that deforestation, intensive cultivation, land degradation, soil erosion and application of inorganic fertilizers leads to the higher exchangeable acidity content under the deforested field. Negative and significant relationship of exchangeable acidity with percent silt content and bulk density of soil ($r=-1.00$ and $r=-0.99$, $P<0.05$), were observed from the output of the correlation matrix. The lowest (2.99%) and highest (8.12%) percent acid saturation (PAS) were recorded in the soils of forest and deforested lands, respectively (Table 2).

Discussion

The lowest interaction mean values of sand, silt and clay were observed in both of the forest land and deforested land. In this study, there were relatively less differences in particle size distribution of the soils under forest and deforested land use types because these are relatively little affected by changes in land management. The results were in agreement with those reported by Sanchez, (2002) and support the assumption that the soil conditions prior to the shifts in and management were more or less similar.

The moisture content was higher for soil taken from forest land than from deforested lands. The soil of forest land with higher moisture content might be due to accumulation of absorbent humus on the soil surface and leaching capacity of surface run-off by leaves and roots of trees as well as the residual effects of underground grass biomass that facilitate infiltration may account for the relatively high moisture content. The deforested land shows the lower moisture content which is influenced by low organic matter content may be due to the removal of biomass and exposed to erosion. The lower BD observed in soils of forest land might be due to undisturbed soil and high organic content. The removal of biomass like leaves, branches and wood biomass from forest land and the removal of trees by deforestation might have resulted in the soil compaction and may resulted in higher bulk density. Organic matter decreases bulk density in that, organic matter is much lighter in weight than a corresponding volume of mineral matter and gives increased aggregate stability to soil. Soil with higher organic matter content has less degree of compaction. Thus, soil compaction determines soil BD according to Arshad *et al*., (2006). Soil bulk density was positively and significantly correlated with the silt contents of forest and deforested lands ($P<0.05$).

Higher soil pH value in forest land than deforested lands. The lower soil pH recorded in soil of deforested land might be due to depletion of basic cations drainage to streams in runoff generated from accelerated erosions and highest microbial oxidation that produces organic acids, which provide H ions to the soil solution. Similarly, Gebeyaw (2007) reported that the highest pH recorded in forest land than deforested land due to cation drainage to streams in run-off generated from accelerated erosion. Based on rating system of Soil Science Society of America (SSSA, 2010) the pH value of soil observed in the study area of forest land was moderately acidic, whereas that of the deforested land was slightly acidic. Eshetu (2010) also revealed that, total organic matter (OM), in forest land was greater than both the grassland and agricultural land, whereas grazing land was greater than agricultural land. Michel *et al*., (2010) indicated the decrease of soil OM content was due to shifting of natural forest to grassland, fallow and agricultural lands. The higher percent OM content in forest land attribute to plant litter fall which abundantly returned to soil surface enhancing the fraction of percent soil OM in soils of forest land and the lower in deforested land might be due to high clay fraction. The decline in soil OM contents in the deforested land following deforestation and conversion to farm fields might have been aggravated by the insufficient inputs of organic substrate from the farming system due to residue removal. As per the rating of nutrients suggested by Tan (1996), the soil OM content of the study area can be categorized as medium (2.1% to 4.2%) in both forest and deforested land uses. This might be due to high clay fraction of soil textures. The depletion of soil OM was higher in deforested land than forest land due to the fact that, deforestation increases soil aeration which enhances decompositions of soil OM and causing for reduction in values of OC content which in turn an increased in soil bulk density.

The study revealed that, there was negative relationship of percent total N of forest land soil with Percent acid saturation of forest land and percent average silt content of deforested land ($r=-0.99$, $P<0.05$) were, respectively observed from the output of the correlation matrix. Soil of forest land showed a medium (0.2 - 0.3) and deforested land were low (0.1 - 0.2) percent total N, respectively based on the classification rated by Barber (1984). The higher percent total N content from forest land might be due to the fact that the forest ecosystem was dominated by nitrogen fixing trees which might have resulted in biological nitrogen fixation. The low percent total N in deforested land in contrast, could be attributed to the reduction in SOM content and removal of the nitrogen fixing trees. Similarly, Wolde and Edzo (2005) also observed higher total N content in closed areas as compared to deforested lands.

Numerically, distribution of C: N followed similar patterns to OC and total N distributions within the forest and deforested land uses. The narrow C: N ratio in both soil of forest and deforested lands concurs with the study of Abbasi *et al*., (2007) who concluded higher microbial activity and more CO_2 evolution and its loss to the atmosphere in the top (0-20 cm) soil layer resulted to the narrow C: N ratio. Relative to deforested land, soils of the forest land recorded narrow C: N ratio. Generally, the C: N ratios were narrow (below 7) in all land uses.

The available P and total P content of soils in the forest land was significantly higher as compared to the soil of deforested land. This might be because of the forest vegetation with their larger biomass (higher quantity of litter fall) absorb larger amount of available P where, the lower available P in deforested land may be due to lower SOM status, soil erosion and leaching. Likewise, Achalu *et al*., (2012) reported SOM as the main source of available P in most soils of Ethiopia and declined by the impacts of P fixation, abundant deforestation and erosion. Generally, variations in available P contents in soils are related with the intensity of soil weathering or disturbance (the degree of phosphorus fixation with calcium) (Paulos, 1996). The available P of the soils of the study area was qualifying for a medium range. The medium contents of available P observed in the soil of the study area are in agreement with the results reported by many authors (Eylachew, 2001) that the availability of phosphorus under most soils of Ethiopia decline by the impacts of deforestation, land degradation and erosion.

Compared to forest land, the relatively lower concentration of exchangeable Ca^{2+} content recorded in soils of deforested land might be due to leaching and the higher exchangeable Ca^{2+} in forest land was attributed to higher organic soil colloids. The organic matter content of forest land was higher than that of deforested lands (Table 2) and hence forest soil has more a strong affinity to adsorb Ca^{2+} than others soil land use types. Likewise, Achalu *et al*., (2012) revealed that, deforestation contributed to depletion of basic cations. The lower exchangeable Mg content (Ex. Mg^{2+}) in soil of deforested land might be attributed to losses in the harvested parts of plants and leaching from surface soil. Also, Gebeyaw (2007), deforestation, limited recycling of biomass in the soil, land degradation and soil erosion have contributed to depletion of basic cations and CEC from other land uses compared to forest land soil. The lower exchangeable K^+ contents in the deforested than in the forest land might be due to its continuous losses in the harvested parts of the trees from the deforested lands. In general, deforestation, limited recycling of plant residue in the soil, continuous cropping, land degradation and soil erosion have contributed to depletion of basic cations and CEC on the deforested land as compared to the forest land.

The Na^+ content of soil from deforested land was significantly the highest as compared to that of forest land soil where, Na^+ content of forest land was the lowest. The highest Na^+ under the deforested land might be due to its highest EC value. Deforestation and soil erosion have contributed to depletion of basic cations except sodium ion. In general, variations in exchangeable bases among the forest and deforested land use types were insignificant (Table 3). This may be due to same clayey textural classes of the soils. The observed low-level of CEC in deforested land might be attributed to the decline in soil OM content through deforestation followed by soil erosion and land degradation. Also, Gebeyaw (2007) reported that the high CEC obtained from forest land soil was directly related to the high content of clay and organic matter of the forest land. It is a general truth that both clay and colloidal OM have the ability to absorb and hold positively charged ions. Thus, soils containing high clay and OM contents have high cation exchange capacity. Cation exchange capacity was significantly and positively correlated with clay and OM content. Landon (1991), the soils having CEC of 15-25 and greater than twenty-five (>25 meq/100g) is classified as medium and high, respectively. Based on the above ratings, the soils of the forest and the deforested lands qualify for high and medium status of CEC, respectively (Table 3). Achalu *et al*., (2012) revealed that, deforestation contributed to depletion of CEC. Therefore, the result of this study indicated that the CEC of the forest land soil were higher than the deforested land use types.

The inverse relationship of exchangeable acidity and Percent acid saturation (PAS) with Percent base saturation (PBS) may be attributed to deforestation and intensive cultivation which leads to the higher exchangeable acidity content in soils of deforested land than the forest land uses. Because the more acid the soil, the greater Al will be dissolved into the soil. Once the soil pH is lowered much below 5.5, aluminosilicate clays and Al- hydroxide minerals begin to dissolve and release Al-hydroxycations from soil colloids and fractions of exchange sites occupied by Al^{3+} and H^+ ions. The soil chemical reaction processes that affect the extent of acidic cations (Al^{3+} and H^+) also affect the percent acid saturation (PAS). At low soil pH, oxides of Al get in to solution and through step wise hydrolysis and releases H^+ ions resulting in to further soil acidification. In this study, higher exchangeable acidity and percent acid saturation were recorded in the soils of deforested land than forest lands. This is in agreement with the findings of Achalu *et al*., (2013) that showed an increase in soil acidity due to land use changes following deforestation. Basically, the severity of acidity of the soil in deforested land comes from intensive cultivation, which results in leaching of basic cations from soil solutions. In line with this, the process of evaporation in the form of carbonates and bicarbonates in the soil solution of such type of land use is faster than the forested land use system.

Conclusions

Deforestation is one of the most serious environmental problems and major drivers of land degradation that poses key problems to soil fertility in recent times. It has become an issue of global concern because of the relevance of tropical forests in biodiversity conservation, and in limiting the green house effects. Deforestation disturbs soil structure and may result in variations and even deterioration in the soil properties of the present study area over many years. The study areas have been using natural forest in unsustainable way which accompanied by high level of deforestation and aggravated loss of soil fertility. The significant changes in the soil quality attributes following the removal of forest there by declining soil fertility of the deforested land. In this study, there was significantly declined of selected soil physicochemical properties such as (bulk density, moisture content, soil texture, pH, organic matter, total nitrogen, cation exchange capacity, available phosphorus, total phosphorus and exchangeable bases). This nutrient deterioration might indicate risk to the soil fertility. The soil fertility of the deforested land was significantly lower compared to the forest land.

Major declines were observed for organic matter which is the principal source of plant nutrients and helps to sustain soil fertility by mineralization and nutrient retention. The total soil organic matter and nitrogen stocks were higher under forest land than deforested land. The decreased values of the soil organic matter on the deforested land would indicate higher N and organic carbon losses compared to the forest land. The higher OM values in the forest lands indicate low activities of N-losing processes, which is due to the relatively closed nutrient cycling and minimal disturbance in the natural forest land. This decline in organic matter and other soil quality attributes also affects the status of soil basic nutrients. So, the process of prolonged use of forest without re-plantation and conservation has exacerbated deforestation and deterioration of soil fertility status. In general, forest ecosystems were found to retain soil nutrients very efficiently. Therefore, there is a need to maintain and develop sustainable forest management (conservation) by practicing afforestation and reforestation programs to overcome the deterioration of soil fertility of the present study area.

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