# Land Use Changes and Their Effects on Soil Physical and Chemical Properties in Abol woreda Gambella Regional State

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**Abstract**

In Abol woreda continuous cultivation, intensive grazing and investment are the major practiced in the woreda soil without out intensive care was decline in soil chemical, biological and physical properties. The current research, therefore, is intended to determine Land use Changes and consequence on Soil Physicio-Chemical Properties in Abol woreda Gambella Regional State. General visual field observation and survey were carried out and the research site was portioned in to three major land uses (cropped grazing and forest land use types). Accordingly, a total of three major land uses (cultivated grazing and forest land use types) were identified in field based on soil texture and land use systems.  Finally three major land use system were identified, and from each major site, composite soil samples were taken from thirteen soil sub-samples (spots) within one depths of 0-20cm using soil auger. The physico-chemical of soils was analyzed in the standardized soil laboratory procedure through the analysis of soil samples augured from three major land use systems. The results obtained from this study explore that the kebele soil did not showed the textural class difference in three land use system all showed clay loam, texture. The value of soil bulk density was increase in cropped land followed by grazing land and low in forest or reserved area land use system it ranges from 1.37, 1.24 and 1.13 g/cm$^3$ respectively. The percent of total porosity soils under the cultivated land was recorded average of 48.3, grazing land use also 53.2% and land use forest 57.3%. All of the soil chemical properties of the present research site were numerical influenced by land use system and soil textural class. For example, the highest value was recorded in basic cations Ca (10.02 cmol/kg), Exch-base of Mg (5.46cmol $^{(+)}$/kg),Exch-base K (5.45cmol $^{(+)}$/kg)and CEC (28.17 cmol$^{(+)}$/kg) were observed under the forestland as compared to the lowest values (5.64, 2.05and 1.97cmol/kg), respectively,  in the cultivated land. The present study showed that soil fertility status decrease as land use type goes to from forest to pasture and farming lands. Hence, it is possible to infer that continuous and intensive cultivation degrade plant essential nutrients highly which urge to take action for modifying its fertility status of the agricultural soils of in the Abol district.
**Keywords :**-land use effect, change, physical, chemical, properties

## 1.  INTRODUCTION

The rapid increase of world population demands more production of food, fodder, fiber and fuel required from the existing land. To achieve this issue integrated land management system being practiced in order to maintain the land from intensive cultivation and free grazing lands that are causes overgrazed and degraded in Ethiopia.

In Ethiopia, population growth and environmental factors lead to the conversion of natural forestland and grassland into cultivated farmland (Tesfahunegn, 2016) Land use changes are regarded as important components and a primary cause of global environmental changes (Turner *et al.,* 1995; Li, 1996).

This as a result has received the major focus of global change research as its impacts on global biogeochemical cycles, climatic and hydrologic processes are profound.

These changes are driven by the interaction in space and time between biophysical and human dimensions (Turner, 1995). In most of the developing countries, its research has evolved out of efforts to identify, predict and manage ecologically damaging land use changes such as deforestation as its implications for human livelihood systems are immense.

Hence, adequate knowledge on soils of such area especially in abol woreda is mandatory in order to conserve and use the resources based on their potentials and limitations and there by maximize crop production and conserve the soils for future use. The present study involved Land use Changes and consequence on Soil chemical, physical and biological Properties at Abol area of the Gambella region. Current research topic will give good experience for the future research activities on soil related research and effects of agricultural farming on soil fertility status   of the area. Therefore, this study was conducted with the general objectives of:

➢   To determine the Land use types and their Effects on Soil Physio- Chemical Properties in Abol woreda Gambella Regional State**.**
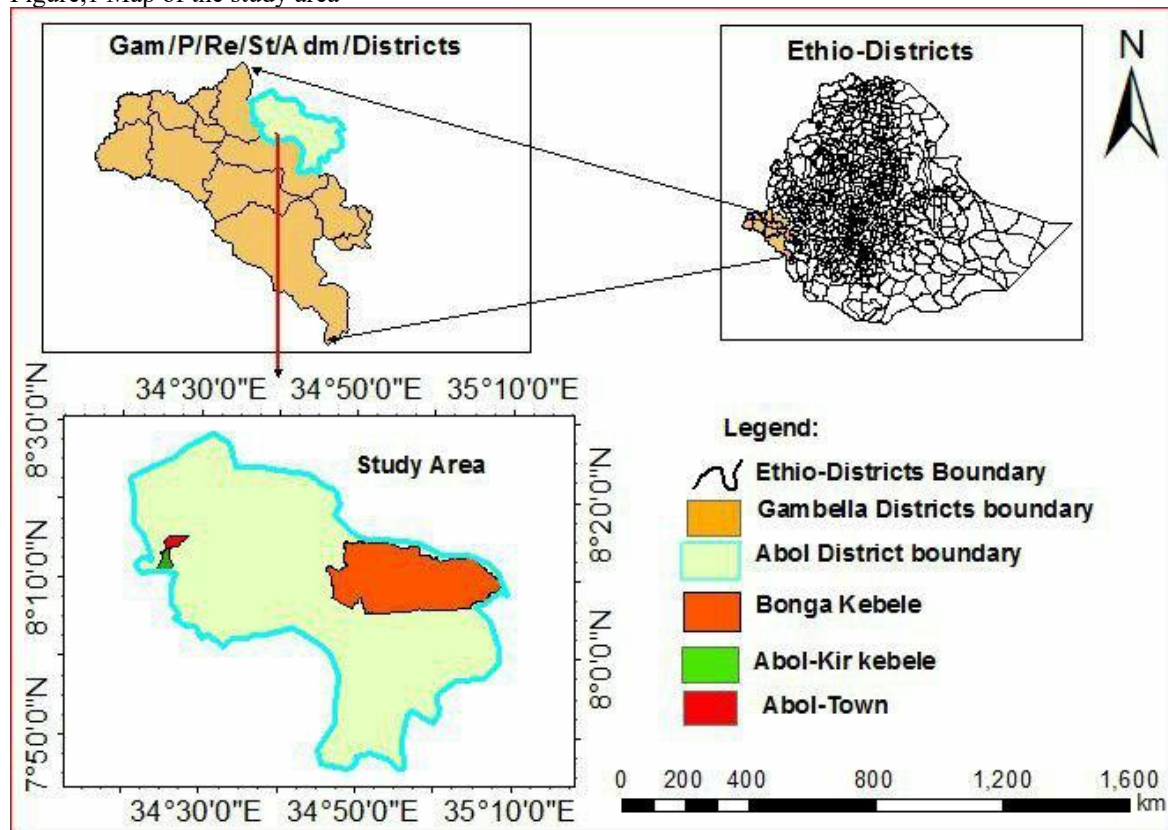
**Specific objective**
➢  To investigate the effects of  agricultural cultivation on selected physio-chemical properties of  the soil in Abol area
➢  To evaluate impacts of land use change on  the chemical and physical properties of the soil

## 2.    MATERIALSAND METHODS

### 2.1. Description of the Study Area

The study was conducted at Abol woreda , in western Ethiopia Gambella National Regional State,. It is located at about 820 km western of Addis Ababa. The average altitude of the research site is about 520 meters above sea level.

Figure,1 Map of the study area



### 2.1.2. Soil Sampling and Preparation

Representative composite Soil samples were augured in the three major land uses system which is (agricultural, pasture and forest land use types). Land use system was chosen based on the current land management activities practiced in specific study area.  Firstly, a general visual field observation was carried out to have a general view of the physical difference in the researched area. Based on the past land management history, the cropland selected for this study has been under cultivation for more long time  whereas the adjacent  grazing and forest land use types were used previously as forest and grazing use system.

From the forest lands and grazing lands, natural forest and communal grazing land were used and while from agricultural lands, cereal crop land under rain fed condition were selected. Representative soil sampling sites were chosen randomly from each land use types according to slop position. A total of three major land use type were considered and replicate four times and a total of , twelve, composite soil samples were augured from thirteen soil sub-samples within one depths of 0-20 cm using an auger. During soil sampling, furrow, dead plants old manures, was carefully excluded to avoid variation among the spot area. The representative composite soil samples taken from each site with four replications were air dried ground and sieved to passed through a 0.5 for total nitrogen and organic carbon and 2 mm sieve for the analysis of other selected soil physicochemical properties.

### 2.1.3. Soil Physicochemical Analysis

The soil samples collected from each land use system were air dried, crushed and passed through 2-mm sieve size for the determination of soil physical and chemical properties of soil except for total N and OC which were pass 0.5-mm sieve size. Total porosity and soil bulk density were obtained from undisturbed core sampler Particle-size analysis was done using the Bouyoucos hydrometer method. Total porosity was estimated from the bulk and the particle densities as:

Total pore space (%) = (1-BD/PD) x 100

Where Bd = bulk density, and Pd = particle density

Laboratory analysis were carried for the chemical properties of the soil including soil pH, total nitrogen (TN), soil organic carbon, (SOC) Available Phosphorus, Exchangeable bases (Ca, Mg, Na and K), and electrical

conductivity (EC) on samples collected from the field. The pH of soil was measured potentiometrically using a pH meter in the suspension of 1:2.5 soils to liquid ratio of distilled water and 1M KCl solution with combined glass electrode pH meter (Thomas, 1996). Organic carbon(OC) content was determined following the wet digestion method as described by Walkley and Black (1934) and percent of organic matter (OM) was calculated by multiplying OC by 1.724. Total nitrogen (N) content in the soil samples was determined titirimetrically following the Kjeldahal Procedures as described by Jackson (1958). Available P was determined by using Olsen method (Olsen *et al*., 1954) as outlined by Sahlemedhin and Taye (2000). The absorbance of the P extracted by Olsen method was measured using spectrophotometer after color development. Exchangeable bases (Ca, Mg, Na and K) were extracted with 1N $NH_4OAc$ at pH 7 (Van Reeuwijk, 1992). Exchangeable $Ca^{2+}$ and $Mg^{2+}$ were determined from the extract with EDTA; whereas $K^+$ and $Na^+$ were determined from the same extracts with flame photometer.

Extractable micronutrients (Fe, Mn, Zn, and Cu) were extracted with diethylene tri-aminepentaacetic acid (DTPA) and all were quantified by atomic absorption spectrophotometer at their respective wavelengths (Lindsay and Norvell, 1978).

## 2.1.4. Statistical Methods
Descriptive statistics was carried out to expose the effects and relationships between among the three land use system. Land use types were analyzed or compared with each other by considering critical values for the physico-chemical properties of Ethiopia soils.

## 3. RESULT DISCUSSION AND EXPLANATION
### 3.1. Site Description of the study area
The study was conducted at Abol district in Gambella Regional state the area is characterized by level slope and the area divided into three major land use system accordingly soil physical soil property (texture) (Table 1).Based on, the clay loam texture was dominated by level slop position (0.5 - 2%) with moderately suitable soils, which occupied more than 65% of agricultural land use system were taken place in this area.

### 3.2. Soil Physical Properties
The physical properties of the study area soil showed that similarity in textural class except numerical variation among the adjacent land use systems they showed only numerical variation within land use type on the three land use type showed clay loam in texture. The highest sand fractions (37%) was observed on the agricultural land use system whereas the highest clay percentage (38%) was obtained in the forest land use system and the least value of clay soil textural percentage were recorded on cultivated fields which might probable due to high removal of clay by water (leaching) of clay particles down the profile in specifically agricultural fields.

**Table 1.Soil Particle size distribution Abol across different land unit and land use**

| Land use type | sand% | silt% | clay% | textural class |
|---|---|---|---|---|
| | Soil texture | | | |
| Forest land | 27 | 35 | 38 | CL |
| Grazing land | 34 | 37 | 29 | CL |
| Cultivated land | 37 | 36 | 27 | CL |

FL= forest land GL= grazing land CL= cultivated land,Cl= clay loam

The texture of the soil determined in the field (feel method) was similar in most cases to the determinations carried out in the laboratory (Table 1). The textural class of the all land use system were obtained similar which is Clay loam, This result explore that the different land use types did not have effect on the soil texture of the study area, since texture is an permanent and intrinsic  soil property that not influenced in short period of time with management practice.

Despite the fact that texture is permanent soil property, human management practices cannot alter to changes in particle size (Table 1).

Low clay and silt; and higher sand content in the soil of agricultural lands and grasslands are attributed to the selective removal of clay particles by processes of erosion, leaving behind the sand fraction in situ.

The cultivated land and grasslands (overgrazed) are more vulnerable to erosion as they have little or no protective vegetation cover. Thus, when erosion occurs, the finer and lighter materials are selectively removed.

The absence of protective vegetation covers in the surface soil of cultivated land and grasslands soil leads to directly contributes to the removal of soil finer particles size as it reduces the organic matter that flocculate soil aggregates and increase  soil loss in erosion (Abbasi et al*.,* 2007).

### 3.3 Soil bulk density and total porosity
In general, the bulk densities of soils were  low in all research sites  the soils belong to fine textured soils known to have lower bulk densities (Table 2). Soils tend to be organized in porous grains or granules, especially if

adequate organic matter content is present (Brady, 1990) which is the case. In line with this Larson *et, al.* (1980) also reported a bulk density rise from 0.95 in plow layer to 1.00 g/cm in lower subsoil's from Oxisols clays in Brazil. It was lowest in soils under forest land and surface soils while highest in cultivated lands use types.

**Table 2.soil Bulk density and porosity as influenced by different land use type**

| Land use type | BD (g/cm$^3$) | TP% |
|---|---|---|
| Forest land | 1.13 | 57.3 |
| Grazing land | 1.24 | 53.2 |
| Cultivated land | 1.37 | 48.3 |

BD= bulk density, TP= total porosity GL= grazing land CL= cultivated land FL= forest land

The present study observed variation in bulk density value lowest in forest land (1.13 g/cm$^3$) flowed by grazing land (1.24 g/cm$^3$) and highest in cultivated land (1.37 g/cm$^3$) (Table 2).this might be due to the effects of high animal trampling  by grazing animals in grazing and cultivated lands and high OM content in forest land.

The other reason that can explain the change in bulk density is attached to the intense tillage practices. Cultural tillage practices could also temporarily loosen the tilled soil layer, in the long term it increases soil bulk density due to compaction. Absence of soil surface cover soil were expose to direct impact of rain drops under fields with long period of continuous cultivation might have also contributed to the increment of bulk density as raindrop impacts cause soil compaction through disintegration of the soil structure. This creates unfavorable plant growth environment through limiting root growth and air circulation which in turn has implications for agricultural productivity.

As total porosity values were derived from manipulating values of bulk and particle densities, this characteristic showed almost similar pattern of differences as that of the bulk density values. Total porosity of the study area soils registered between 48.3- 57.30% (Table 2). The lowest (48.3%) and highest (57.30%) total porosity were observed in the forest and cultivated land use type, respectively. According to London (1991), sands with a total pore space of less than 40% are liable to restrict root growth due to excessive strength whilst in clay soils, limiting total porosities are higher and less than 50% can be taken as corresponding value. Hence, the value of total porosity lies almost in the usual range (30% and 70%). The results obtained from the current study area are in agreement with the findings reported by other researchers (Singh et al., 1995; Maddonni et al., 1999).

### 3.4. Responses of Soil Chemical Properties to Land Use Changes
### 3.4.1. Soil pH and electrical conductivity

In all of the land use system described, soil pH values measured in a suspension of 1:2.5 soil to water ratio (pH in H$_2$O) were greater than the pH values measured in the same ratio of soil to KCl solution (pH in KCl).Land use systems changes from pasture land use system to crop land use system showed that in relatively slightly decline of soil pH of the current research area. For example, the highest value (8.56) and the lowest value (7.64) soil pH were obtained under the forest land use system and cultivated lands, respectively (Table, 3).

The least value obtained from soil pH under the agricultural land use type system might be due to low exchangeable bases and absence of application house refuse in the farm land and crop mining.

The highest values of soil pH under natural forest and grazing land use system probable due to higher values this may be due to better content of exchangeable bases and low low human disturbance in the specific area. This is evident from the positively relation between soil pH and the exchangeable bases in both land use system. Generally the effect of land use system was showed slightly variations in soil pH in the study area. Considering the soil pH (H$_2$O), the soils in the present study area forest land rated as strongly alkaline and grazing and cultivated land use rated as moderately alkaline, (Table 3) according to  classification set by Tekalign (1991).

Soil EC of the research site again exhibited the same trend with pH. It was showed small variation among land use. The lowest figures in electrical conductivity were agricultural land use system and followed by pasture land and higher value obtained in forest in land use types.

The lowest value of EC was registered under agricultural fields and can be related to the loss of Ca and Mg by crop mining and containing soluble salts after deforestation and cultivation. In addition the decline in electrical conductivity in agricultural fields is the implication of decreasing basic cations which forms the soluble salt that ultimately enhances electrical conductivity.

### 3.4.2. Organic matter

The amount of soil organic matter (OM) was relatively higher in the forest land use followed by grazing land use and lowest in cultivated land use. Considering the forest soils, the highest (5.32%) OM content was measured and (4.27%) and lowest (2.56%).

Most cultivated soils of Ethiopia are poor in organic matter contents due to low amount of organic materials applied to the soil and complete removal of the biomass from the field (Yihenew, 2002), and due to severe deforestation, steep relief condition, intensive cultivation and excessive erosion hazards (Eylachew, 1999).

Organic matter content was registered higher value on the natural forest land use system and medium under

pasture land use types which might be due to the contribution of vegetation cover and less disturbance by anthropogenic and animal. Tate (1987) also reported similar findings that agricultural management of crooped land soil induces a drastic change in the equilibrium of soil OM attained under undisturbed conditions, and thereby affects its quantity and quality especially in the near surface soil.

**Table 3. The three land use system influenced by some chemical properties of soil**

| LU type | pH ($H_2O$) | pH (KCl) | ECe(dS m$^{-1}$) | OM (%) | C: N ratio | Total N % | Av P(mg kg-1) |
|---------|-------------|----------|------------------|--------|------------|-----------|----------------|
| FL | 8.56 7.42 | 0.43 | 5.32 | 10 | 0.46 | 30 | |
| GL | 7.94 | 6.87 | 0.34 | 4.27 | 11 | 0.28 | 23 |
| CL | 7.64 | 6.66 | 0.25 | 2.56 | 11 | 0.22 | 21 |

FL= forest land GL= grazing land CL= cultivated land EC= Electrical conductivity OM= organic matter C: N= carbon to nitrogen ration TN= Total Nitrogen Av P= available phosphorus

**3.4.3. Total nitrogen**

The nitrogen content of the study area soil showed that numerical decline among the major land use system with similar arrangement of SOM (Table 3). In addition, the findings showed that the soil in the forest, pasture and agricultural land use system, had 0.46%, 0.28% and 0.22% of total nitrogen (N) content of respectively. Generally total nitrogen content on agricultural field depleted by 52% as compared to forest land and 21.24% from adjacent grazing land use system.

Relatively better vegetation cover in grazing and forest land resulted higher OM content which might contribute to have higher total nitrogen content in the respective land use system. This findings supported by many authors (Jaiyeoba, 2003; Heluf and Wakene (2006); Abbasi *et al.*, 2007).

**3.4.4. Available phosphorus**

The available P content in current study area had registered higher value in all land use types forest soil registered 30 mg/kg followed by grazing land 23 mg/kg and lowest value under cultivated land use system 21 mg/kg (Table 3).

This finding showed that available P content of soils numerical change when we go from forest to cultivated land use system.

Available P content of the agricultural field showed decreased by 30% from forest and 8.69% from grazing land use system this variation or decline could be due to crop mining and crop residue removal from the field for many reasons.

The highest value of available phosphorus in the protected forest soil could be arise  due to high content of soil organic matter resulting in the release of organic phosphorus. Probably for this reason, available P is highly associated with SOM content.

Based on the rating set by Carrowet *al.* (2004), P-Olsen between 12 to 18 mg kg$^{-1}$ is categorized as sufficient range in all land use. This finding is in line with (Hartz, 2007).  It was suggested that soil P is more dominant in warm climate than in cool climate. Therefore, phosphorus content in the current research site could be due to hot climatic condition in the study area might have been favored of the study area along with the convenient  pH range.  This result is in line with the research results reported by two authors (Yacob, 2012; Teshome, 2013) that available P content of soils in the Gambella region had high range.

**3.4.5. Exchangeable bases**

The average soil exchangeable calcium of the current study area of Abol districts are 10.02 and 5.46cmol(+)/kg (Table 5) in the forest land use  respectively and 7.07, 2.96cmol(+)/kg whereas cultivated land use registered lowest contents compared to adjacent land use types which is 5.64, 2.05cmol(+)/kg calcium and magnesium respectively.. According to (FAO, 2006a) exchangeable calcium and magnesium is falls or rated as high rate value.

Exchangeable bases showed the highest concentration of bases registered in the forest and grazing land use system this value highest could be probably due to the contribution of addition of more farmyard manure (FYM) and the presence of high organic matter content (Appendix 2). This finding consistent with this finding, reported by many researchers that exchangeable bases were highly influenced by soil organic matter content, soil texture and management practice (Taye *et, al.*, 2003; Heluf and Wakene, 2006).

The minimum  value of exchangeable base was  registered  under agricultural land use system and higher at adjacent forest land use system this might be the result of mismanagement of land might have less organic matter content and less exchangeable bases due to complete removal of crop biomass from agricultural reported by Singh *et al.* (1995) and He *et al.* (1999). This finding is consistent with the findings of (Taye *et. al.*, 2003; Heluf and Wakene, 2006). Exchangeable bases were highly influenced by OM content of the soil maintained due to virgin land management or added to the soil of cultivated land.

**Table 4. Exchangeable bases on soil under three land use types**

| LU type | Exchangeable cations (cmol (+)/kg) | | | | |
|---|---|---|---|---|---|
| | Ca | Mg | K | Na | TEB |
| FL | 10.02 | 5.46 | 3.45 | 2.02 | 17.34 |
| GL | 7.07 | 2.96 | 2.58 | 1.96 | 13.22 |
| CL | 5.64 | 2.05 | 1.97 | 1.07 | 9.87 |

TEB= total exchangeable base, GL= grazing land, FL= forest land and CL= cultivated land,

Based on the ratings set by FAO (2006), calcium (Ca) and magnesium (Mg) of exchangeable bases contents under forest land use system was categorized as high rate level and (K and Na) were rated as very high in forest land use system whereas grazing land use type falls under medium condition in the exchangeable bases (Ca and Mg,) and high rete value for (K and Na) and agricultural land use types was rated as medium for all exchangeable base.

Generally exchangeable bases were slightly influenced by land use type (Table 5). Considering the land use system lower exchangeable bases were registered under forest land and lower in the agricultural fields this indicates that frequent farming and mismanagement grazing contribute to crop mining and animal grazed deplete exchangeable base in the study area.

The Cation exchange capacity of the current research site was influenced by land use types and soil texture. The highest value was registered (51.08Cmol/kg$^{-1}$ soil) under forest land use type's soil while the lowest (46.74Cmol/kg$^{-1}$) was obtained under agricultural land use types (Table 5).

The soil Cation exchange capacity values in the agricultural land use showed decline trend   mainly due to the reduction in organic matter contents compared to adjacent land use system.

**3.4.6. Present base saturation and cation exchange capacity**

**Table 5.  Percent base saturation and Cation exchange capacity and of the soils under the three land use types**

| LU type | CEC (cmol$_c$ kg$^{-1}$) | PBS (%) | ESP (%) |
|---|---|---|---|
| FL | 51.08 | 33.94 | 3.95 |
| GL | 48.12 | 27.47 | 4.07 |
| CL | 46.74 | 21.11 | 2.28 |

GL= Grazing land CL= Cultivated land FL= Forest land PBS = Percent base saturation

CEC =Cation exchange capacity

Basically, Cation exchange capacity is the capacity of the soil to hold and exchange cations. It provides a buffering effect to changes in pH, available nutrients, calcium levels and soil structural changes.  Organic matter particularly plays important role in exchange process because it provides more negatively charged surfaces than clay particles do. On the contrary percent base saturation was influenced by land use types.

The exchangeable bases of the soil that affect extent of bases also affect PBS (Table 5). It has declined from 33.94 in the forest soils to 21.11 and 27.47 in cropped and grazing soils respectively. It may not be surprising to note that deforestation and conversion to agricultural land use result in numerical changes in percent base saturation. This is usual as far as there exists loss of exchangeable bases and since percent base saturation by itself is a straight function of exchangeable bases.

Therefore, the reduction in PBS values from 33.94 in forest soil to 21.11 in agricultural soil also can be attributed to the observed general reduction of bases with increasing depletion of organic matter content.

**3.4.7. Available micronutrients**

In terms of soil chemical fertility, one cannot talk about the complete fertility of soils in the absence of micronutrients. Though they are required in equally important, they are as essential as the macronutrients. Therefore, their adequate presence and availability like their counterpart primary nutrients in the soil is highly necessary for the productivity of soils. Unfortunately, there is no enough information on micronutrients of Ethiopian soils in general and particularly in the current study site.

Highest numerical variation were registered on micronutrients of Zn, Cu, Fe and Mn on the three land use system where the highest value registered (17.05, 14.52 and 10.22 mg kg$^{-1}$) under the forest, grazing and cropped land use system respectively for extractable iron, 15, 12.3 and 10.8, 2.84, 1.44, 1.22 and 3.53, 2.23 and 2.16 for (Mn, Zn, and Cu) in the three land use types

**Table 6. Extractable micronutrient of the soils in two land use types Land unit extractable micronutrient (mg kg$^{-1}$)**

| Land use types | Fe | Mn | Zn | Cu |
|---|---|---|---|---|
| Forest land | 17.05 | 15 | 2.84 | 3.53 |
| Grazing land | 14.52 | 12.3 | 1.44 | 2.23 |
| Cultivated land | 10.22 | 10.8 | 1.22 | 2.16 |

The high variability of micronutrients among land use types could be probable due to differences cultural soil management practices in the area, land use, OM application Fisseha (1996) reported similar phenomena as a result of exploring micronutrient status of three Ethiopian Vertisols landscapes. Heluf and Wakene (2006) also reported that micronutrients were highly influenced by different land use systems and significant variation was observed among the different land use systems.

## 4. CONCLUSIONS

Sustainable agriculture system requires high investment effort in order to sustain the soil resource wisely because soil is a non-renewable and it is highly important precious resource, determining the agricultural potential of a given area. Hence, study and understanding of soil physical, chemical and biological properties and behavior is crucial for the development of soil management plan for efficient utilization of land resource.

Findings on this research suggest that most of soil chemical properties showed slightly reduced in cropped land use types as compared to adjacent forest land use types due to crop mining and intensive grazing without management. The textural class of the study area soils of all land use systems did not showed textural difference among land use types all showed similarity which is clay loam all the three land use system this indicating the similarity in parent material from which the soil is formed moreover soil texture is an inherent soil property that cannot be influenced in short period of time.

The results of this study are evidences of significant changes in the quality attributes of the soils in the study area following the removal or destruction of vegetative cover and frequent tillage that lead to soil erosion and thereby declining soil fertility.

## 5. RECOMMENDATION

The information obtained from this study will help in developing sustainable and ecologically sound soil conservation or management strategies in Abol area. Moreover, different governmental and non-governmental organizations, people living in the area and others stake holders  who intend to invest on land should collaborate each other to maintain and conserve  this precious to benefit the current and future generation without depleted.

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