

# Assessing the Physicochemical Properties of Soil under Different Land Use Types

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## Abstract

The economies for most developing countries primarily depend on agriculture. Studying the physicochemical properties of soil is important for sustainable management of the agricultural resources and economic growth. Soil acidity is one of the main reasons for nutrient depletion as well as causes of fertility decline that affects crop production. The main objective of this investigation is to assess the acidity status and physicochemical properties of soil in different land use types in Alket Wonzi Watershed, Farta district, Northwest Ethiopia. Soil samples were taken at 0-25 cm depth, on four land use types viz., natural forest, cultivated land, plantation forest and grazing land. The result soils in the natural forest had significantly ( $p < 0.05$ ) higher soil pH and lower exchangeable acidity ( $p < 0.01$ ). Similarly, significantly higher ( $p < 0.01$ ) exchangeable bases ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^{+}$ ), total nitrogen, organic matter, available potassium, cation exchange capacity and clay content was also registered from soil of the natural forest compared to the other land use types. The study further revealed that there was significant ( $p < 0.05$ ) difference in available phosphorus among the different land use types. However, there was no significant difference in silt fraction, sand, bulk density and exchangeable sodium under soils of different land uses. The results obtained from the study indicated that soils of grazing, cultivated land and plantation forest are strongly acidic ( $\text{pH} < 5.5$ ). Therefore, appropriate reclamation method should be lunched to improve agricultural productivity and sustainability of the study area.

**Keywords:** Land use types; Physicochemical properties; Soil degradation; Nutrient depletion

## Introduction

In most developing countries, the economy is primarily based on agricultural production [1]. Thus, sustainable management of the agricultural resources such as soil provides the long-term benefits required for environmental health [2] as well as for economic growth. For this reason, recent interest in evaluating the quality of soil resources has been inspired in Ethiopia [3]. In the past few decades, the global grain production growth rate has been decreased from 3% in the 1970s to 1.3% in the early 1990s, which is one of the key indicators of declining soil fertility [4]. Thus, soil fertility recovery is a major concern in tropical Africa, due to rapid population growth [5]. In Ethiopia, soil degradation and nutrient depletion have gradually increased [6] in which the annual nutrient deficit of N, P and K is  $-41$ ,  $-6$  and  $-26 \text{ kg ha}^{-1} \text{ yr}^{-1}$ , respectively with 2 to 3% of productivity decline per year [7]. One of the major constraints to retaining soil fertility in Ethiopia is the failure to return crop residues and animal manure to the soil [8]. These in turn reduce Ethiopia's agricultural gross domestic product (GDP) by 7% [1].

A variety of factors cause water logging and salinity problems which have direct relationship with acidity and physicochemical properties of soil. Among these, unsuitable cropping pattern, torrential rains and floods, lack of sufficient drainage, uncontrolled drainage, lack of adequate knowledge, wrong management decisions, very poor construction and rehabilitation rates of drainage systems, increase of irrigation systems without paying any attention to their adverse impacts on soil and quality of water resources [9].

One effective way to reduce water logging and salinity problems is drainage. Horizontal drainage systems due to the higher spacing between drains (reducing number of drainage and thus reducing the cost) are better than vertical drainage systems. But, vertical drainage systems due to the lower changes in well spacing in different anisotropic soils are suitable for conditions that soil hydraulic conductivity is likely to change [10]. Therefore, in conditions that soil hydraulic conductivity

is unstable and it may be essential change over time, use of vertical drainage will reduce risk of failure, efficiency decreasing, and drains spacing changing in drainage system that can prevent enhancement of soil acidity [11].

In addition, lack of agricultural inputs, traditional farming methods, overgrazing and continuous cultivation practice, coupled with environmental factors aggravates the degradation of soil physicochemical properties [12] that results in the reduction of pH in the soil system ultimately brings soil acidity [13]. Thus, soil acidification is a process by which soil pH decreases over time due to high rainfall and traditional farming system [3]. Thus, soil acidity is expanding both in scope and magnitude in Ethiopia and severely limits crop productivity and sustainability. Amhara region, South Gondar including Farta district in particular Alket Wonzi watershed is among high land area, which is susceptible to soil acidity caused by due to the conversion of forested land to cultivated lands, leaving the soil exposed for erosion and nutrient depletion. Therefore, the main objective of this investigation is to assess the acidity status and physicochemical properties of the soil in Alket Wonzi watershed, Farta district, Northwest Ethiopia.

## Materials and Methods

### Description of the study area

The study was conducted at Alket Wonzi watershed in Farta

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district, South Gondar Zone of Amhara National Regional State, Northwest Ethiopia. It is situated 684 km North West of Addis Ababa, 97 km Northeast of Bahir Dar and at about 21 km distance from Debre Tabor town Figure 1. It is located between 11°43.8' N - 11°45' E latitude and 38°08' N - 38°10' E longitudes and at an altitude of 2913 meters above sea level.

Geologically the study area is covered with thick trap series volcanic rocks [14]. The majority of the soils in the study area are chromic Luvisols that are silt loam in texture [15]. It is a representative of the “*dega*” agro-climatic zone with a unimodal rainfall pattern of an average annual rainfall of 1599 mm and maximum rain is received between June and August. The annual mean minimum and mean maximum temperatures at the study area are 8 and 24.7°C respectively Figure 2.

### Cropping practice and land use types

The farmers in the study area are practicing “mixed” farming system. The major crops types grown in the area include cereals such as barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), ‘teff’ (*Eragrostis tef*), maize (*Zea mays*), pulses such as field pea (*Pisum sativum*), tuber crops such as potato (*Solanum tuberosum*), oil seeds and the dominant vegetations are *Juniperus procera*, *Eucalyptus globules*, *Euphorbia abyssinica*, *Podocarpus falcatus*, *Acacia* and other exotic tree species. However, one can see small patch of natural forest due to land use change for food crops production, leaving the soil exposed for erosion and nutrient degradation.

### Soil Sample sites and laboratory analysis

**Soil sample sites:** Four major land use types namely natural forest, grazing land, plantation forest and cultivated land were used for this study. Composite soil sample from 0-25 cm were collected from representative sites of each land use types with three replications and then air dried ground and passed through a 2 mm sieve to determine soil physiochemical properties. Additionally three replicate of undisturbed soil samples of known volume were taken with a sharp-edged steel cylinder forced manually into the soil for bulk density determination at three sites from each of the land use types.

**Laboratory analysis of soil samples:** Soil textural analysis was determined by Bouyoucus hydrometer method. Bulk density was

determined using undisturbed core sampler method using volumetric cylinder and calculated by dividing the oven dry mass at 105°C [17]. The pH of the soil was measured potentiometrically with a supernatant suspension of 1:2.5 soils to water ratio using a glass-calomel electrode (MP 220 AFAB Lab, LLC) [18]. Soil organic matter was determined by using titrimetric methods and then its contents were estimated from the organic carbon content by multiplying with 1.724 [19]. Total nitrogen (TN) content was determined using the Kjeldahl digestion, distillation and titration method. The soil available phosphorous content was analysed by 0.5M sodium bicarbonate extraction solution /pH 8.5/method of Olsen as described by Reeuwijk [18].

Exchangeable basic cations ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^{+}$  and  $\text{Na}^{+}$ ) were determined by saturating the soil samples with 1N  $\text{NH}_4\text{OAc}$  solution at pH 7. Then,  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  were determined from extract by using atomic absorption spectrometry (AAS) (Buck Scientific Model 210), while exchangeable  $\text{K}^{+}$  and  $\text{Na}^{+}$  were measured by flame photometer from the same extract. Cation exchange capacity (CEC) was estimated titrimetrically by distillation of ammonium that was [20]. Effective cation exchange capacity (ECEC) was calculated by the summation of exchangeable bases and acidity. The percent base saturation (PBS) of the soil samples were calculated from the sum of the basic exchangeable cations ( $\text{Ca}^{2+}$ ,  $\text{K}^{+}$ ,  $\text{Mg}^{2+}$  and  $\text{Na}^{+}$ ) as percentage of CEC [21]. Total exchangeable acidity was determined by saturating the soil samples with 1M KCl solution and titrated with 0.02M HCl. From the same extract, exchangeable  $\text{Al}^{3+}$  in the soil samples was titrated with a standard solution of 0.02M HCl. Then the exchangeable  $\text{H}^{+}$  was obtained by subtracting exchangeable  $\text{Al}^{3+}$  from total exchangeable acidity, which is Al and H ions [22].

### Data analysis

Statistical difference in soil characteristics among land use types was analyzed by a one- way analysis of variance (ANOVA) at  $p < 0.01$  and 0.05 significant levels. Least significant difference (LSD) test and Correlation analysis were employed to assess mean difference and the association between soil variables.

## Result and Discussion

### Soil physical properties

There was significant difference ( $p < 0.01$ ) in clay contents among

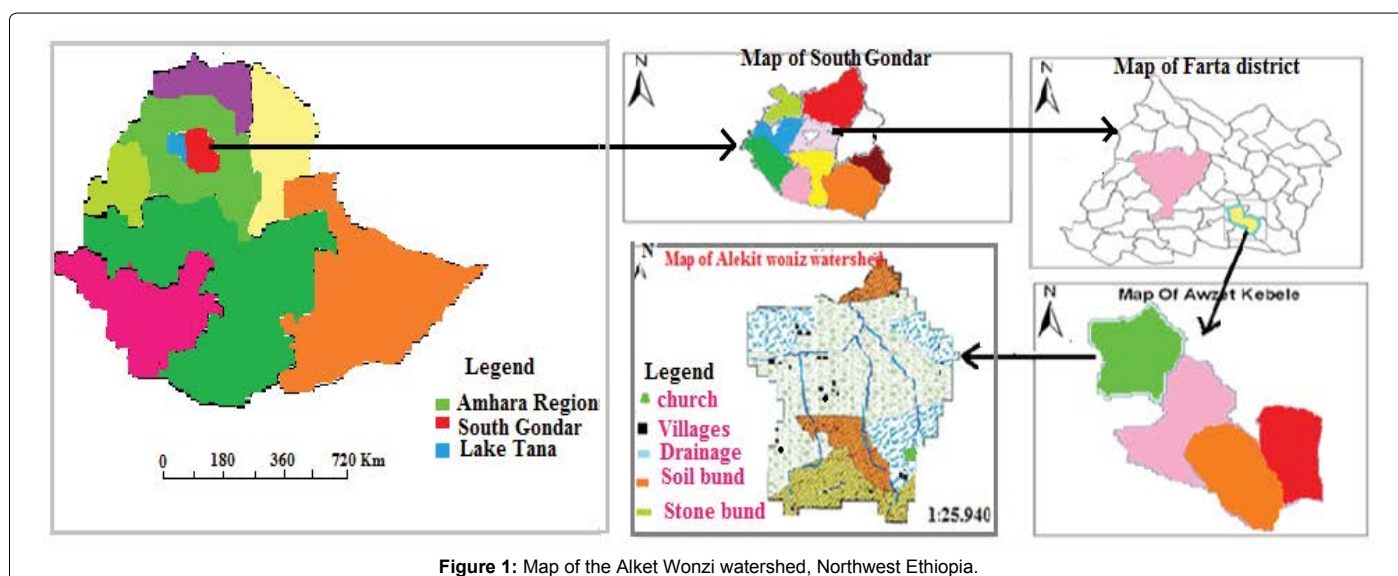


Figure 1: Map of the Alket Wonzi watershed, Northwest Ethiopia.

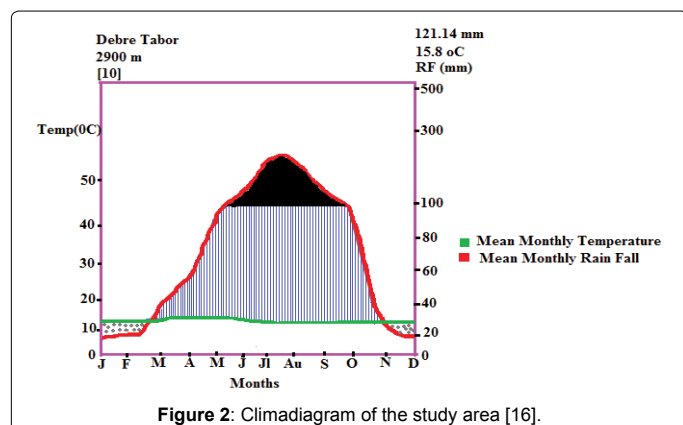


Figure 2: Climadiagram of the study area [16].

land use types. The highest average clay content was recorded under natural forest (46.4%) and the lowest in the cultivated land (31.75%). Regarding with the association, clay was ( $r=0.64$ ;  $p<0.05$ ) correlated with TN and ( $r=-0.64$ ;  $p<0.05$ ) with exchangeable acidity. Although, the silt and sand fraction did not show significant difference among land uses, the highest average silt and sand fraction were observed on cultivated land (34% and 34.25%) compared to the other land use types Table 1. Thus, the sand content recorded under cropped land could be due to the intensive cultivation and crop residue harvest.

Even though, the average bulk density (BD) values of the soils under different land use types are found in the acceptable range for plant growth, relatively the highest ( $1.2 \text{ gm/cm}^3$ ) average value of BD was obtained under the grazing land Table 1. The possible reason for the difference is attributed to the trampling effect of livestock during free grazing activities. This result is in harmony with the research findings reported by Wakene and Heluf [3] who reported that the highest BD in the abandoned land is due to the soil compaction and organic matter (OM) degradation.

Mean values within rows followed by the same letters are not significant difference ( $p<0.05$ ); \*significant at ( $p<0.05$ ); NF, natural forest; CUL, cultivated land; PF, plantation forest; GL, grazing land; CL, clay loam; NS, not significant; LSD, least significance difference.

### Soil chemical properties

The analysis of variance revealed that the soil pH was significantly affected by land use types ( $p<0.05$ ). Numerically soil pH ranges from 5.0 in the cultivated land to 6.2 in the natural forest Table 2. The present study also showed that there was significance difference in exchangeable acidity and acid saturation among land use types ( $p<0.01$ ). The main reasons for the lowest value of soil pH in the cultivated land are due to poorly managed cultivation; inappropriate use of ammonium based fertilizers and accelerated erosions that implied the deterioration of soil quality [23]. Similarly, the decrease in soil pH of the plantation forest could be due to prolonged uptakes of basic cations by tree roots [24]. There were significant ( $p<0.01$ ) difference on the concentration of exchangeable Ca, Mg and K among different land use types. However, there was no significant variation in exchangeable Na between land use types. Thus, the contents of exchangeable bases were ranged high to low as recommended by FAO [25]. The highest content of  $\text{Ca}^{2+}$  ( $19.0 \text{ cmol}^+/\text{Kg}$ ) was observed in the natural forest and the lowest was in the plantation forest ( $8.1 \text{ cmol}^+/\text{Kg}$ ) Table 2. This variation in exchangeable bases ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and  $\text{K}^+$ ) may be attributed to leaching losses, low content in the parent rock and the proportion of clay minerals as well as the conversion of forest land into the other land use types. This

study is in agreement with the findings of Wakene and Heluf [3] who reported that continuous cultivation and use of acid forming inorganic fertilizers deplete exchangeable Ca and Mg.

According to Landon [26], the rate of CEC in the soils of natural forest was described as very high compared to the other land use types. Correspondingly, the result revealed that ECEC and PBS were significantly ( $p<0.01$ ) varied between land use types. The highest values of ECEC and PBS ( $31.9 \text{ cmol}^+/\text{kg}$ ; 61.1%) were recorded in the natural forest whilst the lowest ( $14.4 \text{ cmol}^+/\text{kg}$ ; 33.1%) registered in the cultivated field, respectively Table 2.

The highest amount of CEC and percent base saturation (PBS) in the natural forest could be because of the amount and nature of the clay particles and organic matter content. The amount and type of clay mineral are responsible factors for CEC in that both clay and colloidal OM are negatively charged and therefore can act as anions; as a result, these two materials have the ability to absorb and hold positively charged ions (cations) [6]. Soil organic matter (SOM) and total nitrogen (TN) content showed significant variation ( $p<0.01$ ) under soils of different land use types with higher contents (7.5%; 0.29%) and lower (3.1%; 0.15%) registered in natural forest and cultivated land, respectively Table 2. Thus, the content of SOM and TN ranged from medium in the natural forest and low in the cultivated land as recommended by Landon [26]. This range is however, consistent with the findings of Eyayu *et al.* [27] who reported that in the cultivated land TN and SOM depleted by 42.1 and 43.2% respectively from the natural forest. Similar studies also reported that a decline in soil organic matter stocks was registered in cultivated soils than to soils of natural vegetation in southern Ethiopia [4] and in the Bezawit Sub-Watershed of North West Ethiopia [28]. Furthermore, the correlation coefficient depicted that SOM was correlated ( $r=0.99$ ;  $p<0.01$ ) with TN but ( $r=-0.53$ ) to exchangeable acidity.

The present study showed that accessible phosphorus was significantly ( $P<0.05$ ) varied between land use types. According to Landon [26], the level of accessible phosphorus on the soils of natural forest and grazing land can be illustrated as a medium whereas the other two land uses were less than  $5 \text{ mg/kg}$  and hence described as low. Another study showed that most of the soils of the highlands of Ethiopia are deficient in their inherent available phosphorus due to acidic nature of the soil [29]. Furthermore, the correlation Coefficient showed that available phosphorus was correlated ( $r=0.89$ ;  $p<0.01$ ) with pH ( $\text{H}_2\text{O}$ ) but ( $r=-0.42$ ) to acid saturation. In similar way, obtainable potassium was significantly varied ( $p<0.01$ ) among land use types. The occurrence of high rates of accessible K in the natural forest ( $120 \text{ mg/kg}$ ) could be attributed to the highest value of CEC of the sampled soils which indicate their greater storage capacity and supplying power of potassium Table 2.

### Conclusion

The study assessed soil acidity status under different land use types. Based on the result of the study, variations in soil physicochemical properties were observed under soils of selected land use types in the study area. This variation in soil physicochemical properties could be related to frequent tillage practice, crop residue harvest, application of acid forming fertilizers and conversion of forested land to the other land use types that causes poor nutrient availability in the soil and hence limits crop productivity.

Furthermore, the results revealed that soils in all of the land use types of the study area were generally acidic ( $\text{pH}<7$ ). Therefore, this soil acidity problem would be prevented if intensive cultivation and

Soil physical properties	land use types	Land use types				LSD (p<0.05)
		NF	CUL	PF	GL	
Clay (%)		46.4 ± 1.8 <sup>a*</sup>	31.75 ± 0.67 <sup>b</sup>	37.75 ± 2.9 <sup>b</sup>	45.08 ± 2.3 <sup>a*</sup>	12.7
Silt (%)		27.3 ± 2.4	34.00 ± 2.3	34.00 ± 3.1	28.00 ± 3.5	NS
Sand (%)		26.3 ± 2.9	34.25 ± 2.4	28.25 ± 1.8	26.92 ± 3.1	NS
BD (gm/cm <sup>3</sup> )		1.0 ± 0.06	1.1 ± 0.1	1.1 ± 0.1	1.2 ± 0.1	NS
Soil textural class		CL	CL	CL	CL	-

Table 1: Average value of soil physical properties with land use types (Mean ± SE).

Soil chemical properties	Land use types				LSD (p<0.05)
	NF	CUL	PF	GL	
pH (H <sub>2</sub> O)	6.2 ± 0.33 <sup>a*</sup>	5.0 ± 0.05 <sup>b</sup>	5.2 ± 0.08 <sup>b</sup>	5.2 ± 0.16 <sup>b</sup>	1.15
pH (KCl)	4.8 ± 0.08 <sup>a*</sup>	4.1 ± 0.16 <sup>b</sup>	4.0 ± 0.15 <sup>b</sup>	4.1 ± 0.12 <sup>b</sup>	0.78
Ex. Ac (cmol <sup>+</sup> /kg)	0.23 ± 0.09 <sup>b</sup>	2.5 ± 0.43 <sup>a*</sup>	0.27 ± 0.12 <sup>b</sup>	0.57 ± 0.12 <sup>b</sup>	1.9
CEC (cmol <sup>+</sup> /kg)	51.9 ± 0.1 <sup>a*</sup>	36.3 ± 1.3 <sup>b</sup>	36.6 ± 1.6 <sup>b</sup>	37.3 ± 2.0 <sup>b</sup>	14.6
Ca <sup>2+</sup> (cmol <sup>+</sup> /kg)	19.0 ± 1.0 <sup>a*</sup>	9.8 ± 0.9 <sup>b</sup>	8.1 ± 1.0 <sup>b</sup>	11.1 ± 1.0 <sup>b</sup>	8.0
Mg <sup>2+</sup> (cmol <sup>+</sup> /kg)	11.4 ± 1.6 <sup>a*</sup>	1.7 ± 0.6 <sup>c</sup>	6.7 ± 0.9 <sup>b*</sup>	6.3 ± 0.4 <sup>b*</sup>	9.7
K <sup>+</sup> (cmol <sup>+</sup> /kg)	1.1 ± 0.02 <sup>a*</sup>	0.34 ± 0.04 <sup>b</sup>	0.29 ± 0.01 <sup>b</sup>	0.3 ± 0.1 <sup>b</sup>	0.76
Na <sup>+</sup> (cmol <sup>+</sup> /kg)	0.15 ± 0.01	0.12 ± 0.02	0.13 ± 0.01	0.11 ± 0.02	NS
ECEC (cmol <sup>+</sup> /kg)	31.9 ± 0.6 <sup>a*</sup>	14.4 ± 0.9 <sup>c</sup>	15.5 ± 0.8 <sup>b*</sup>	18.4 ± 1.5 <sup>b*</sup>	13.5
Av P (mg/kg)	8.6 ± 1.7 <sup>a*</sup>	3.75 ± 0.6 <sup>b</sup>	3.21 ± 0.51 <sup>b</sup>	5.2 ± 0.34 <sup>b</sup>	1.3
Av K (mg/kg)	120 ± 17.6 <sup>a*</sup>	10 ± 0.00 <sup>b</sup>	28.3 ± 4.4 <sup>b</sup>	11.7 ± 1.7 <sup>b</sup>	91.7
SOM (%)	7.5 ± 0.68 <sup>a*</sup>	3.1 ± 0.21 <sup>b</sup>	4.6 ± 0.59 <sup>b</sup>	3.7 ± 0.31 <sup>b</sup>	4.44
TN (%)	0.29 ± 0.02 <sup>a*</sup>	0.15 ± 0.01 <sup>b</sup>	0.21 ± 0.02 <sup>b</sup>	0.18 ± 0.05 <sup>b</sup>	0.13
C:N	15.23 ± 0.48 <sup>a*</sup>	11.6 ± 0.23 <sup>b</sup>	12.63 ± 0.68 <sup>b</sup>	12.13 ± 0.69 <sup>b</sup>	3.6
AS (%)	0.73 ± 0.3 <sup>b</sup>	17.6 ± 4 <sup>a*</sup>	1.8 ± 0.9 <sup>b</sup>	3.1 ± 0.6 <sup>b</sup>	2.9
PBS (%)	61.1 ± 1.4 <sup>a*</sup>	33.1 ± 4.5 <sup>c</sup>	41.8 ± 4.1 <sup>bc</sup>	47.7 ± 2.7 <sup>b*</sup>	4.8

Mean values within rows followed by the same letters are not significant difference (p<0.05); \*Significant at (p<0.05).

Table 2: Average values of soil chemical properties with land use types (Mean ± SE).

grazing are reduced, use of integrated inorganic and organic fertilizers, application of liming and soil conservation practice increased. Further studies need to be conducted, on the deterioration rate of soil chemical properties, soil microbial activity, plant nutrition and sustainable land management to investigate possible solution regarding with soil acidity and to identify easily acceptable technologies for the maintain soil environment.

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