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M. Sc. THESIS ON:

ASSESSMENT OF MACRO AND MICRONUTRIENTS STATUS OF SOIL IN DIFFERENT LAND USE TYPES IN KAKE *KEBELE* DALLE WABERA DISTRICT KELLEM WOLLEGA ZONE SOUTH WEST ETHIOPIA

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THESIS ON: ASSESSMENT OF MACRO AND MICRONUTRIENTS STATUS OF SOIL IN DIFFERENT LAND USE TYPES IN DALLE WABERA DISTRICT KELLEM WOLLEGA ZONE SOUTH WEST ETHIOPIA

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TABLE OF CONTENTS

Contents

Page

LIST OF TABLES

LIST OF FIGURE

LIST OF FIGURES IN THE APPENDICES

LIST OF TABLES IN THE APPENDIX

LIST OF ACRONYMS AND ABBREVIATIONS

AAS	Atomic absorption spectroscopy
ANOVA	Analysis of Variance
Av.P	Available Phosphorus
BD	Bulk Density
C:N	Carbon to nitrogen ratio
DTPA	Diethylenetriamine pentaacetate
EC	Electrical Conductivity
GDP	Gross Domestic Product
GPS	Global positioning system
LSD	List Significance Difference
OC	Organic Carbon
OM	Organic matter
PD	Particle Density
SAS	Statistical Analysis System
SEM	Standard Error of the Mean
SOM	Soil Organic Matter
TN	Total nitrogen
TP	Total Porosity

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ABSTRACT

The nutrient supplying power of a soil depends on dissociation of the nutrients from the exchange site, which is in turn dependent on the degree of saturation of the nutrients on the exchange site, type of clay and complementary ion effect. The study was conducted in Kake *kebele*, Dalle Wabera District, Kellem Wollega Zone, South West Ethiopia. The aim of the study was to assess macro and micro nutrient status of soil in different land uses (Cultivated, Fallow and Forest lands) on the magnitudes and directions of major soil fertility parameters and among land use types and soil depths. Site selection, Sample collection, Sample preparation and Laboratory analysis are the major methods of sampling technics. The results showed that the highest (5.56) and the lowest (5.27) soil pH-H_2O values were recorded under the forest and the fallow lands, respectively. Electrical conductivity (EC) of soils was not significantly affected by land use types and by the soil depth. Considering the main effects of land use types, the highest (1.02 dS/m) EC was recorded under the cultivated and fallow lands whereas the lowest (0.96 dS/m) EC value was obtained under forest land. The mean values of exchangeable calcium (Ca^{2+}) under cultivated land, the fallow and the forest lands were 2.20, 4.20 and 3.22 cmol$_{(+)}$ /kg, respectively. The contents of available micronutrients (Fe, Mn, Zn and Cu) under the different land use types were significantly different ($P \leq 0.01$) and Cu showed reduction from the cultivated land to forest land (2.91, 2.77 and 2.68 mg/kg) respectively. The results observed in this study revealed that the average mean values of available Fe and Mn were in the adequate range for the production of most crop plants. Available Fe under land uses and soil depths was positive and significantly correlated with organic carbon (r = 0.373). The manner in which soils are managed has a major impact on agricultural productivity and its sustainability. The contents of exchangeable bases will be reduced because of leaching by erosion, removal of plant residue and burned for energy consumption and will be used as food for animals. Therefore, to increase the pH and exchangeable bases lime should be added and to increase the availa ble phosphorus, DAP should be added to the soil of the study area.

Keywords: *Macronutrients and Micronutrients, forest land, fallow land and cultivated land.*

1. INTRODUCTION

1.1. Background of the Study

Soil is a complex mixture of minerals, water, air, organic matter, and countless organisms that are the decaying remains of once-living things. It forms on the surface of land and it is called "skin of the earth" [1]. The soil is a natural formation resulting from the transformation of surface rock by the combination of the climate, plant and animal's life and ageing. Soil fertility in Ethiopia is currently under great challenges due to deforestation, overgrazing and improper agricultural practice [2]. The loss of soil nutrients in Ethiopia is related to cultural practices like cultivation. The removal of vegetative cover (such as straw or stubble) or burning plant residues as practiced under the traditional system of crop production or the annual burning of vegetation on grazing lands are major contributors to the loss of nutrients [3], while the use of chemical fertilizer is also minimal. Soil fertility is a quality of a soil to supply nutrients in proper amounts without causing toxicity, whereas soil productivity is the capacity of a soil to produce a specific crop or sequences of crops at a specific management system. Periodic assessment of important soil physical, chemical and biological properties and their responses to changes in land management is necessary to apply appropriate agricultural technologies and effective design of soil fertility management techniques; and to improve and maintain fertility and productivity of soil [4].

Optimum productivity of any cropping system depends on an adequate supply of plant nutrients. When the soil does not supply sufficient nutrients for normal plant development and optimum productivity, application of supplemental nutrients is required. The proper application rates of plant nutrients are determined by knowledge about the nutrient requirement of the crop and the nutrient supplying power of the soil. The nutrient supplying power of a soil depends on dissociation of the nutrients from the exchange site, which is in turn dependent on the degree of saturation of the nutrients on the exchange site, type of clay and complementary ion effect. Continued removals of nutrients, with little or no replacement have aggravated the potential for future nutrient related plant stress and yield loss. Therefore, evaluating the fertility status of a soil is important to know the productivity of a soil as soil fertility is one of the parameters of soil productivity [4].

Soil acidification, which covers 41% of the country, organic matter depletion due to competing uses of crop residues and manure for livestock feed, thatching, temporary construction, fuel and others [5]. The use of the livestock dung for fuel, according to [6] reduced Ethiopia's agricultural GDP by approximately 7%. Depletion in soil organic matter in turn resulted in the reduction of soil macro and micro nutrients and physical properties which finally resulted in the poor crop harvest and food self-sufficiency. According to [5] 24% of Ethiopia's soil faced moderate to very severe fertility constraints affecting the key farming regions. The causes of nutrient depletion include farming without replenishing nutrients over time (lose through continuous crop harvest), leaching due to runoff and poor land use management, removal of crop residue, low level of fertilizer use and unbalanced application of nutrients [5].

To overcome the problems in soil fertility, only N and P fertilizers were applied even below the required rate due to high price and low availability of credit and limited reach of distribution network [5]. The land uses which have a long history of settlement and agriculture are the most severely affected in this regard. Currently, the major soil fertility issues are only understood at the highest level. However, more area specific, problem solving researches have to be carried out at a community (village) level and sustainable land use management options have to be set and recommended. Hence, prior to the recommendation of management options soil nutrient supply has to be assessed for different land use type. There are 17 essential nutrients which are required for plant growth. Study of macro and micronutrients is important to soil chemists for soil management. Soil fertility is determined by the presence or absence of nutrients, i.e. Macro and micronutrients. Soil fertility is the inherent ability of soils to supply nutrient elements to plants [7].

However, micronutrients like Fe, Mn, Zn and Cu are only easily accessible in acidic situation. Sometimes these nutrients also cross the toxic limit and high concentrations leads to toxic effects on plants. Sometimes the micronutrient status also changes due to cropping pattern and fertilizer practices. Organic matter is store house of the nutrients in a soil. Besides these organic matters is responsible for most desirable surface soil structure, promotes a greater proportion of larger sizes, and improves water holding capacity and also the aeration status of the soil. Therefore, determining the status of macro and micronutrients is very essential to know about the fertility status of the soil of the study area. The five macronutrients analyzed include potassium, Nitrogen, Phosphorus, Calcium and Magnesium four micronutrients Zinc, Iron, Copper and Manganese.

The elements nitrogen (N), phosphorus (P), and potassium (K) are the nutrients that most often limit crop growth, and they are called macronutrients [8]. ”Since N, P, and K are the nutrients most widely deficient in soils, they are also called the “major,” “primary,” or the “fertilizer” nutrients. Ca, Mg, and S are called the “secondary” nutrients of the macronutrients because they are not as widely deficient as N, P, and K. Other elements that are needed by plants in much lower amounts than the macronutrients are called micronutrients or trace elements. They are as essential to plant growth as the macronutrients because they perform very essential and specific roles, particularly in molecules involved with the energy transfer process, hormones, and enzymes. The mineral nutrients like macro and micro has a unique importance in plants such as cell elongation, metabolism, O_2 evolution, N_2 fixation, respiration to constitute chlorophyll contain [7]

The aim of this study is to assess the status of macro and micronutrients in soils of the Dalle Wabera District Kake Area. According to Mulugeta Tufa *et al* [8] research was done on assessment of macro and micronutrient status of soil in different land use types to asses macro and micro nutrient parameters. But to the best of our knowledge, this type of research has not done around this study area. Therefore, the objective of this study is to assess macro and micronutrient status of the soil in different land use types in kake *kebele* Dalle Wabera District Kellem Wollega Zone Southwest Ethiopia .

1.2. Statement of the Problem

Different research workers or investigators have worked on evaluation of soil macro and micro nutrient status in different land use types to asses macro and micro nutrient parameters; such as OC, Av.P, TN, etc. [8]. This study concentrates on the assessment of macro and micro nutrient status of soil in different land use types. Different researchers have worked on evaluation of soil parameters in different areas. The area where this research was conducted was not considered for macro and micronutrient status of the soil. However the researcher couldn’t include all the areas found in all Ethiopian highland areas. Therefore, in Oromia regional, state since most areas are found in the highland areas of Ethiopia the assessment was conducted to know and investigate such parameters to assess soils found in this area and if possible to amend soil quality for future direction in Kuchaes’ areas of Kellem Wollega zone Kake *Kebele*.

- Generally, this finding may answer the following research questions:

1. What is the status of macro and micronutrients in the study area?

2. Which of these nutrients is deficient in the study area?

3. What are the factors affecting macro and micronutrients in the productivity of the soil in the study area?

1.3. Objectives of the Study

1.3.1. General Objective

The main objective of this study is to assess the status of macro and micronutrients in soils of the Dalle Wabera District Kake Area.

1.3.2. Specific Objectives of the Study

- To determine the status of the some selected macro (NPK, Ca and Mg) and micronutrient (Fe, Zn, Mn and Cu) of soil under natural forest, fallow and cultivated lands in the study area.
- To compare and contrast macro and micro nutrient status of different land uses.
- To estimate the nutrient contents and their forms in nutrient supply of the soils to the crops which largely helps in the scientific nutrient management?

1.4. Significance of the Study

The result of this study could be used to identify the land use type that is more affected by macro and micro nutrients among the three land use types; also it may help the community who live in the study area to use necessary treatments for the affected soil by macro and micro nutrients. Macro and micro nutrients and their availability are paramount for proper crop development. The finding of the research will serve as an input for the policy makers and concerned bodies working in assessment of macro and micronutrients status of soil in different types of lands as well as soil fertility treatment. This piece of work may serve as reference material for other researchers who are interested to work in the study area.

2. RELATED LITERATURE REVIEW

2.1. Macro-nutrients and micro-nutrients

The elements nitrogen (N), phosphorus (P), and potassium (K) are the nutrients that most often limit crop growth, and they are called “macronutrients.” Since N, P, and K are the nutrients most widely deficient in soils, they are also called the “major,” “primary,” or the “fertilizer” nutrients. Ca, Mg, and S are called the “secondary” nutrients of the macronutrients because they are not as widely deficient as N, P, and K. The term micronutrients refer to a number of elements that are required by plants in very small quantities. This term usually applies to elements that are contained in plant tissues in amounts less than 100 mg /Kg [9].

The four essential micronutrients that exist as cations in soils unlike to boron and molybdenum are zinc (Zn), copper (Cu), iron (Fe), and manganese (Mn). Adsorption of micronutrients, either by SOM or by clay-size inorganic soil components is an important mechanism of removing micronutrients from the soil solution. Factors affecting the availability of micronutrients are parent material, soil reaction, soil texture, and SOM [10]. The presence of SOM may promote the availability of certain elements by supplying soluble complex forming agents that interfere with their fixation. According to Gebeyaw Tilahun [11] stated that the main source of micronutrient elements in most soils is the parent material, from which the soil is formed. Iron, Zn, Mn, and Cu are somewhat more abundant in basalt. According to Hillel *et al* [10] indicated that the solubility, availability and plant uptake of micronutrient cations (Cu, Fe, Mn, and Zn) are more under acidic conditions (pH of 5.0 to 6.5).

The soil plays a vital role in determining the sustainable productivity of an agro-ecosystem. Sustainable productivity of soils depends upon its ability to supply essential nutrients to the growing plants. Field trials have shown that the deficiency of micronutrients in soils has become a major constraint to the productivity and sustainability of soil [12]. Large hectares of arable land in Nigeria have been reported to be deficient in both macro and micronutrients and these deficiencies were brought about by factors such as continuous use of inorganic fertilizers, particularly nitrogen, phosphorus, and potassium by farmers, limited use of organic manures as well as non-recycling of crop residues [13].

However, the total amount is rarely indicative of the availability of plant, because availability depends on soil pH, organic matter, content, absorptive surfaces and other physical, chemical and biological conditions in the rhizosphere. Micro- nutrient availability to plants can be determined in direct uptake experiments or estimated with techniques that correlate the quantities of micro-nutrients extracted chemically from the soils [14]. Micronutrient cycling is quite different among various terrestrial ecosystems [15]. In trying to meet up with the food demand for teeming human population as well as the need for raw materials for industrial purposes in Nigeria, agricultural lands is subjected to different land uses and anthropogenic activities such as deforestation, overgrazing and improper agricultural practice [16]. Others are plantation farm and continuous cultivation of arable lands. These activities change soil physicochemical properties including soil micronutrients over time [17] as a result of top soil removal by erosion [18], soil acidification and organic matter depletion [5].

2.2. Soil Physical Properties

Soil fertility and productivity is more than just plant nutrients and can be defined as “the physical, biological and chemical characteristics of a soil, for example its organic matter, content, acidity, texture, depth, and water retention capacity all influence fertility” [19]. The physical properties of soils determine their adaptability to cultivation and the level of biological activity that can be supported by the soil. Soil physical properties also largely determine the soil's water and air supplying capacity to plants. Many soil physical properties change with changes in the land use system and its management, such as intensity of cultivation, the instrument used and the nature of the land under cultivation, rendering the soil less permeable and more susceptible to runoff and erosion losses [20].

2.2.1. Soil texture

Soil texture determines a number of physical properties of soil and describes the relative proportions of sand, silt, and clay. It affects the infiltration and retention of water, soil aeration, absorption of nutrients, microbial activities, tillage and irrigation practices [21-22]. It is also an indicator of some other related soil features such as type of parent material, homogeneity and heterogeneity within the profile, migration of clay and intensity of weathering of soil material or age of soil [23-24]. Soil texture is one of the inherent soil physical properties less affected by management. The rate of increase in stickiness or ability to mold as the moisture content increases depend on the content of silt and clay, the degree to which the clay particles are bound together into stable granules and the OM content of the soil [25]. Over a very long period of time, pathogenic processes such as erosion, deposition, elevation and weathering can change the textures of various soil horizons [10, 21].

2.2.2. Bulk and particle densities

Measurement of soil bulk density (the mass of a unit volume of dry soil) is required for the determination of compactness, as a measure of soil structure, for calculating soil pore space and as an indicator of aeration status and water content [26]. Bulk density also provides information on the environment available to soil microorganisms. White *et al* [25] stated that values of bulk density range from < 1 g/cm^3 for soils high in OM, 1.0 to1.46g/cm^{3}for well- aggregated loamy soils and 1.2 to 1.8 g/cm^{3}for sands and compacted horizons in clay soils. Bulk density normally decreases as mineral soils become finer in texture. Soils having low and high bulk density exhibits favorable and poor physical conditions, respectively. Bulk densities of soil horizons are inversely related to the amount of pore space and soil OM [10, 22].

Any factor that influences soil pore space will also affect the bulk density. For instance, intensive cultivation increases bulk density resulting in reduction of total porosity. The study results of [27-28] revealed that the bulk density of cultivated soils was higher than the bulk density of forest soils. Soil bulk density increased in the 0-10 and 10-20 cm layers relative to the length of time the soils were subjected to cultivation [28]. Similarly, Ahmed Hussein *et al* [29] reported that soil bulk density under both cultivated and grazing lands increased with increasing soil depth. On the other hand, Wakene Negassa *et al* [30] reported that bulk density was higher at the surface than the subsurface horizons in the abandoned and lands left fallow for twelve years.

The changes in the physical soil attribute on the farm fields can be attributed to the impacts of frequent tillage and the decline in OM content of the soils. Particle density is the mass or weight of a unit volume of soil solids. It affects soil porosity, aeration and rate of sedimentation of particles. The mean particle density of most mineral soils is about 2.60 to 2.75 g/cm^3, but the presence of iron oxide and heavy minerals increases the average value of particle density and the presence of OM lowers it [31]. According to Ahmed Hussein *et al* [29], the surface soil layer had lower particle density value than the subsoil horizons and the higher particle density (2.93 g/cm^3)

was obtained at the subsoil horizons in different land use systems at different elevations. This is attributed to the lower OM content in the subsoil than in the surface horizons.

2.2.3. Total porosity

The total porosity of soils usually lies between 30% and 70%. In soils with the same particle density, the lower the bulk density, the higher is the percent total porosity. As soil particles vary in size and shape, pore spaces also vary in size, shape and direction [21]. Coarse textured soils tend to be less porous than fine texture soils, although the mean size of individual pores is larger in the former than in the latter. There is a close relationship between relative compaction and the larger (macrospores) of soil [33].

According to the same authors, tillage reduces the macro pore spaces and produces a discontinuity in pore space between the cultivated surface and the subsurface soils. Generally, intensive cultivation causes soil compaction and degradation of soil properties including porosity. Macrospores can occur as the spaces between individual sand grains in coarse textural soils. Thus, although a sand soil has relatively low total porosity, the movement of air and water through such soil is surprisingly rapid because of the dominance of macrospores. Fertile soils with ideal conditions for most agricultural crops have sufficient pore space, more or less equally divided between large (macro) and small (micro) pores. The decreasing OM and increasing in clay that occur with depth in many soil profiles are associated with a shift from macro-pores to micro-pores [10]. Microspores are water field; and they are too small to permit much air movement. Water movement in microspores is slow, and much of the water retained in these pores is not available to plants. Fine textured soils, especially those without a stable granular structure may have a dominance of micro pores, thus allowing relatively slow gas and water movement, despite the relative large volume of total pore space [33].Considering the surface soils, [30] stated that the lowest total porosity (36.2%) was observed in the abandoned research field, followed by (41.6%) under the land left fallow for twelve years and the highest (56.7%) was recorded in the farmer's field. Along with the increase in soil bulk density, soil total porosity showed marked declines in both soil layers (0-10 and 10-20 cm) with increasing period under cultivation [28]. The lowest total porosity was the reflections of the low OM content.

2.3 Soil chemical properties

Soil chemical properties are those soil properties which are responsible in the chemical reactions and processes of soil and are the result of soil mineral component weathering, decomposition of OM in the soil and the activity of plants and animals pertaining to plant and animal growth and human development [34-35]. The chemical reactions that arise in the soil highly affects the processes leading to soil improvement and soil fertility build up.

2.3.1. Exchangeable cations

Potassium (K) is the third most important plant growth-limiting nutrient just next to N and P. Its behavior in the soil is influenced primarily by soil cation exchange properties and mineral weathe ring rather than by microbiological processes. It is not toxic and does not cause eutrophication in aquatic system [10]. Johns *et al* [36] reported that rate of K fertilizers that displaces both exchangeable Ca and Mg into the soil solution from where they could be lost by leaching. The variation in the distribution of K depends on the mineral present, particle size distrib ution, degree of weathering, soil management practices, climatic conditions, degree of soil development, the intensity of cultivation and the parent material from which the soil is formed. For instance, soils formed from sedimentary materials are generally low in K content, while soils formed from crystalline rocks contain relatively high K [37]. Soils in the area of moisture scarcity (such as in arid and semi-arid regions) have less potential to be affected by leaching of cations than do soils of humid and sub humid regions.

Soils under continuous cultivation, application of acid forming inorganic fertilizers, high ex changeable and extractable Al and low pH are characterized by low contents of calcium (Ca) and magnesium (Mg) nutrients resulting in Ca and Mg deficiencies due to excessive leaching [37]. However, virgin /grazing lands and areas under long years of fallow practice [38] and Vertis oils [39-40] retain more basic cations, which retain large amounts of Ca and Mg. Tisdale *et al* [41] exchangeable cations generally are available to both higher plants and microorganisms. By cation exchange, H^+ ion from the root hair and microorganisms replace nutrient cations from the exchange complex.

2.3.2. Available Phosphorus

Phosphorus (P) is known as the master key to agriculture because lack of available P in the soils limits the growth of both cultivated and uncultivated plants [4]. Following N, P has a more widespread influence on both natural and agricultural ecosystems than any other essential elements. In most natural ecosystems, such as forests and grasslands, uptake by plants is constrained by both the low total quantity of the element in the soil and by very low solubility of the scarce quantity that is present [10]. It is the most commonly plant's growth-limiting nutrient in the tropical soils next to water and N [40]. Erosion tends to transport predominantly the clay and OM fractions of the soil, which are relatively rich in P fractions. Thus, compared to the original soil, eroded sediments are often enriched in P by a ratio of two or more [10]. Foth, H.D *et al* [4] natural soil will contain from 50 to over 1,000 mg of total P per kilogram of soil. Of this quantity, about 30 to 50% may be in an inorganic form in mineral soils [4]. The main sources of plant available P are the weathering of soil minerals, the decomposition and mineralization of soil OM and commercial fertilizers.

2.3. 3. Soil Organic Matter

Soil organic matter is a large reservoir of carbon that can act as a sink or a source of atmospheric CO_2 [42- 43]. Its sound effects are far out of proportion to the small quantities present, hence, considered the single most important indicator of soil quality [44]. Meanwhile, many factors that change soil organic matter levels and forms are controlled by management, and also processes governing its dynamics are complex. These found it to be the most sensitive soil characteristics to land use change [45]. These differ across eco-regions and strongly interact with land use, farming systems and soil/crop management systems [43, 46, and 47]. The changes in land use impact soil OM pools and fluxes The impact due to land use change on OM content depends on a number of factors such as the old and new land use types, the soil type, management and climate [48- 49].

These changes typically result in differing rates of soil erosion, aggregate formation, biological activity, and drainage all of which have a profound impact on OM accumulation and CO_2 evolution. However, forest and pasture lands make up the potential to build up large amounts of OM, whereas conversion of natural ecosystem to croplands which results in high rates of its turnover led to declined level of OM [46, 49].

Extensive deforestation and conversion of natural forests into agricultural lands in Ethiopian ecosystems led to a significant decline in forest-derived OM levels of these tropical soils. Woldeamlak Bewket, *et al* [27] reported the conversion of forest land into cultivation and grazing led to a drop down of OM with 87% and 85%, respectively at Chemoga watershed, the sub humid tropical agro ecosystem. In favor of this, Tesfu Kebede *et al* [50] reported intensive cultivation of Nitosol at Holetta profoundly decreased soil OM content as compared to the uncultivated counterpart of the same soil. Similarly, Solomon *et al* [51] reported a drop down of OM by 55% (32.0 Mg ha^{-1}) at Wushwush and by 63% (40.2 Mg ha^{-1}) at Munessa following conversion of natural forest to cultivated fields after 25 and 30 years of continuous cultivation, respectively.

In general, one can confirm that losses of forest-derived OM were not fully compensated by OM input from the cereal crops due to its low OM inputs and removal of residues from cultivated fields. This indicates that land use practices that have detrimental effects on OM level and composition have far-reaching implications because of the multiple roles that OM plays in soil quality and link with soil fertility [51].

The total amount of OC in the soil can be considered as a measure of stored OM. In a sense, stored OM is a mean OM store or standing stock of OM because it reflects the net product or balance between ongoing accumulation and decomposition processes and it is thus greatly influenced by crop management and productivity. Over the past few years, various attempts have been made to obtain both global and regional inventories of soil OM storage based on soil map units. Generally, sample generic soil horizons based on the effects of land use types and/or management practices, provides a useful estimate of total soil carbon storage [52].

2.3.4. Total nitrogen and C: N ratio

Nitrogen (N) is the fourth plant nutrient taken up by plants in greatest quantity next to carbon, oxygen and hydrogen, but it is one of the most deficient elements in the tropics for crop production [40]. The total N content of a soil is directly associated with its OC content and its amount of cultivated soils is between 0.03% and 0.04% by weight [53]. The N content is lower in continuously and intensively cultivated and highly weathered soils of the humid and sub humid tropics due to leaching and in highly saline and sodic soils of semi- arid and arid regions due to low SOM content [54]. Wakene Negassa, et *al* [30] reported that there was a 30 and 76%

depletion of total N from agricultural fields cultivated for 40 years and abandoned land, respectively, compared to the virgin land in Bako area, Ethiopia.

Average total N increased from cultivated to grazing and forest land soils, which again declined with increasing depth from surface to subsurface soils [55]. The considerable reduction of total N in the continuously cultivated fields could be attributed to the rapid turnover (mineralization) of the organic substrates derived from crop residue (root biomass) whenever added following intensive cultivation [56]. Moreover, the decline in soil OC and total N, although commonly expected following deforestation and conversion to farm fields, might have been exacerbated by the insufficient inputs of organic substrates from the farming system [28]. The same author also stated that the levels of soil OC and total N in the surface soil (0-10 cm) were significantly lower, and declined increasingly by cultivation time in the farm fields, compared to the soil under the natural forest. In view of high nitrogen requirements of plants and low levels of available N in virtually all types of soils, it is considered most important and dynamic nutrient element in managing ecosystems. Soil total N (TN) composed of inorganic (NH_4^+, NO_3^- and NO_2^-) and organic forms (OM) are subject to change due to various factors. Management (cropping, fertilization, erosion and leaching) and climate (temperature and moisture) determine its level and dynamics [57]. At the same time, the C: N ratio increases to some extent. In tropical environments where forest ecosystems are usually converted to agricultural systems, total nitrogen content of soils tends to turn down quickly. Intensive cultivation of the soil, which led to high rates of OM turnover accelerates its decomposition and makes the soil more susceptible to erosion and decreases its water holding capacity at saturation [30, 51].

2.3.5. Soil reaction (pH) and electrical conductivity

Soil reaction (usually expressed as pH value) is the degree of soil acidity or alkalinity, which is caused by particular chemical, mineralogical and/or biological environment. Soil reaction affects nutrient availability and toxicity, microbial activity, and root growth. Thus, it is one of the most important chemical characteristics of the soil solution because both higher plants and microorganisms respond so markedly to their chemical environment [4].

Descriptive terms commonly associated with certain ranges in pH are extremely acidic (pH < 4.5), very strongly acidic (pH 4.5-5.0), strongly acidic (pH 5.1-5.5), moderately acidic (pH 5.6-

6.0), slightly acid (pH 6.1-6.5), neutral (pH 6.6-7.3), slightly alkaline (pH 7.4-7.8), moderately alkaline (pH 7.9-8.4), strongly alkaline (pH 8.5-9.0), and very strongly alkaline (pH > 9.1) [4]. The degree and nature of soil reaction influenced by diverse anthropogenic and natural activities including leaching of exchangeable bases, acid rains, organic materials decomposition ,use of Commercial fertilizers and other farming practices [10]. It's also influenced by the response of different nitrogenous fertilizer absorption and releases of nutrients at the soil water interface [58]. Most soil and plant organisms prefer a pH range between 6.0 and 7.5 [59]. According to [60], about 61% of the vertsoils have pH values between 5.5 and 6.7, 21% have pH values of 6.7-7.3, and 9% have pH values of more than 8. Organic matter decomposition can produce carbonic acid, carboxylic acid and inorganic acids [10] that cause acidic pH in the high organic matter content region.

3. MATERIALS AND METHODS

3.1. Instruments, Apparatus and Chemicals

3.1.1. Instruments and Apparatus

The apparatus that are used for the analysis of the soil physicochemical properties were, measurin g cylinder, thermometer, electronic balance, oven, 500 mL plastic bottle and sieve (2 and 0.5 mm) , auger, core sampler, moisture boxes, water bath, digital conductivity meter, glass beaker (100 m L) and glass rod. Conical flask 500 mL and 20 mL capacity, burette, stopwatch,50 mL reagent bot tles,and funnel.

Instruments: Atomic absorption spectrophotometer (AAS, 210 VGP), flame photometer (CL378),microwave digester tube in heating block, Bouyoucos hydrometer (ASTM No.152H), pH meter, UV- spectrophotometer (V-630)

3.1.2 Reagents/ Chemicals

The reagents used to perform the laboratory analysis were: Sodium hexa meta phosphate $[NaPO_3]_6$,Sodium carbonate (Na_2CO_3), Potassium chloride (KCl), distilled water (H_2O), 1N potassium dich romate ($K_2Cr_2O_7$), concentrated sulphuric acid (Conc. H_2SO_4), phosphoric acid ($H3PO_4$), DTPA ($C_{14}H_{23}N_3O_{10}$), sodium fluoride (NaF), 0.5N ferrous ammonium sulfate $Fe(NH_4)_2(SO_4)_2$, Sodium bicarbonate (0.5M $NaHCO_3$), ammonium paramolybdate ($(NH_4)_6Mo_7O_{24}$), 0.02 M hydrochloric acid solution (HCl), selenium (Se) powder, 96% ethanol (CH_3CH_2OH), 30% Hydrogen per oxide (H_2O_2), Sodium hydroxide (NaOH) solution and deionized water.

3.2. Description of the Study Area

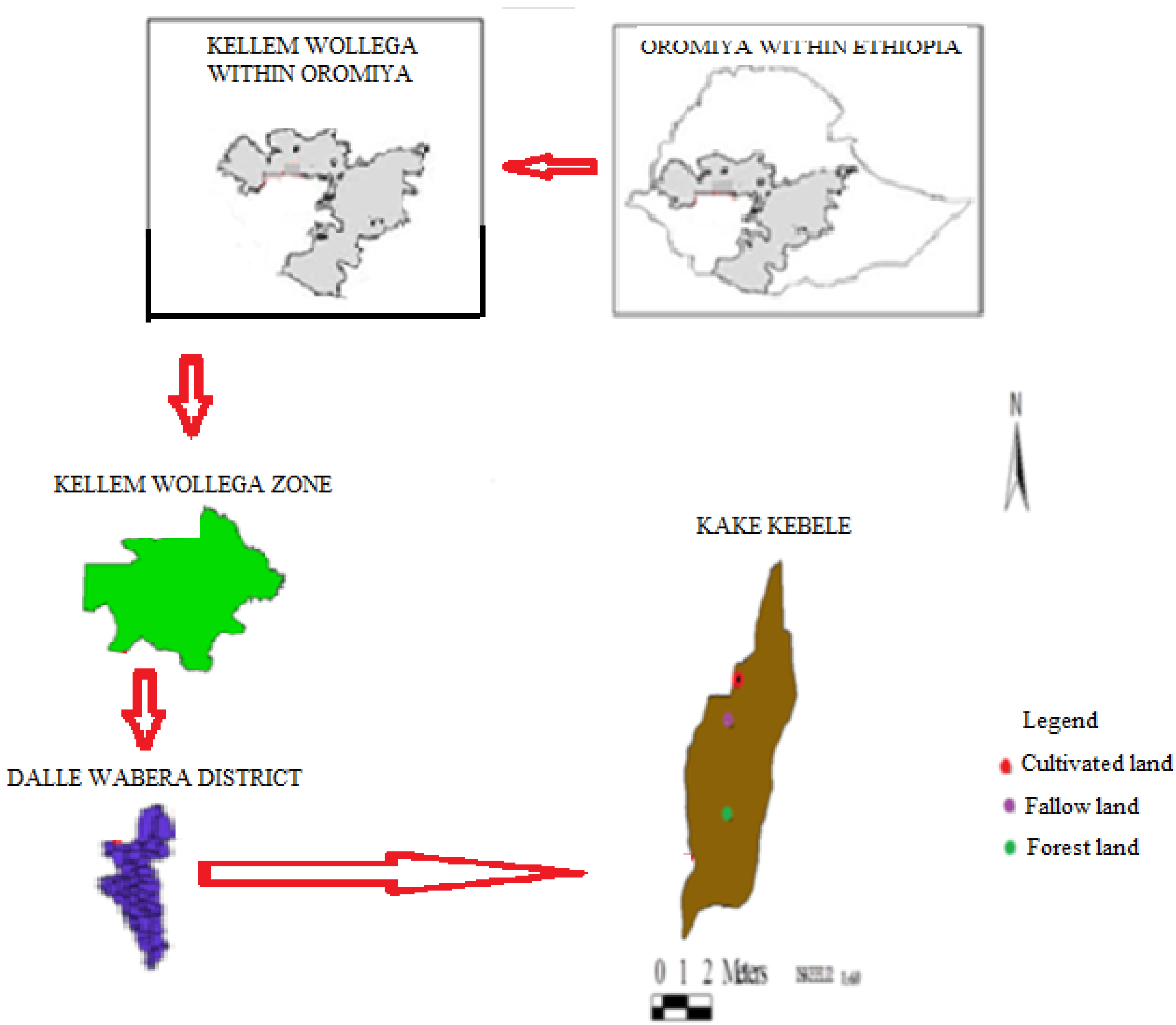

Figure 1: Location Map of the Study Area

3.2.1 Climate, vegetation and farming system of the study area

The area has no drainage system because of absence of the river. Areas are characterized by mono-modal rainfall pattern with inconsistent distribution. The main rainy season (Kiremt) season occurs from June to September with a dry season from December to April having a humid and sub humid climatic condition. The natural vegetation of the area consists of trees, and grasses. Trees occurring on slopes are Juniper (tid in Amharic and gattiraa in Afan Oromo), Eucalyptus (Bahr zaf in Amharic and Bargamoo in Afan Oromo)), Wadesa (wanza in Amharic*)* and shrubs are found on steep slopes. The land is cultivated by cultural farming system as usual in Ethiopia using a pair of oxen and traditional implements. The farming system is a typical mixed crop-livestock system that is carried out in the area. The main crops grown in the study area include maize, beans, pea, coffee and wheat. Cattle's, goat, sheep, horse and donkey are among the common types of livestock in the study area.

3.3 Site Selection of Soil Sampling

At the beginning, a general visual field survey was carried out to have a general view of the variations in the study area. Global Positioning System (GPS) was used to identify the geographical locations of the sampling sites**.** Representative land use types were selected. The land use types selected for the study purpose were cultivated land, fallow land and forest land. Soil sampling sites were selected based on vegetation and cultivation history. The study area was selected as a representative nutrient status of high productivity potential in the Kake *kebele* to use as an experimental site for the Sustainable Rural Agricultural Development Project Funded by Concern. Following the general site selection, three representative fields were selected from each land use type (cultivated, forest and fallow) lands which were replicated three times. Two main factors such as depth and the land use types are usually considered when developing soil-sampling protocols to monitor change in major soil fertility parameters.

3.4 Soil Sample Collection

To analyze the soil quality of the study area 18 samples were collected from three different land use types in the Kake areas. A field was treated as a single sampling unit when it was appreciably uniform in all respects. Variations in macro and micronutrients, texture, color, crops grown and management levels followed to account. When Samples were collected fertilized plots, channels, wet areas, tracts and trees, wells, compost pits were avoided during sampling. The soil samples were collected in zig-zig pattern from the study area. Soil samples were collected from 0- 20 cm and 20- 40 cm. Soil samples were collected from a field at Dalle Wabera District.

3.5. Soil sample preparation and laboratory analysis

The soil samples which were collected from the study area was air dried, crushed and all composite soil samples were passed through a 2 mm sieve for chemical analysis, but samples for OC and TN were sieved through a 0.5 mm sieve. All the samples were stored in the polythene bags for further analysis. Selected soil physical and chemical properties were analyzed at Jimma University College of Agriculture and Veterinary Medicine soil laboratory. The AAS analysis was carried out in Arbaminch University. Soil parameters that were analyzed include particle size distribution, soil pH, organic carbon, total nitrogen, exchangeable acidity, available P, excha ngeable basic cations (Ca, Mg and K) and micronutrients (Fe, Mn, Zn and Cu) by the following standard procedures [61].

Soil particle size distribution was analyzed using the Bouyoucos hydrometer method [62]. The detailed method procedure was the following bulk density of the soil was determined by following the procedure using undisturbed soil samples which were collected by using a core sampler. Then the wet mass was measured using a balance and the samples were dried for 24 hrs in the oven at 105 ^{0}C, and the mass of the dried sample was recorded. Finally, the mass of the core sampler was measured alone and calculated the volume of core sampler and lastly the bulk density and total porosity were calculated by using the mass of wet sample and dried sample of the data.

$$\text{Total porosity (\%)} = \left(1 - \frac{BD}{PD}\right) x\ 100$$

Where,

BD = bulk density in (g/cm^3) and

PD = particle density in (g/cm^3)

Soil pH was determined in H_2O using a 1:2.5 soil to water ratio using a digital pH-meter [28]. Organic carbon of the soils was determined following the wet digestion method as described by [57] while a percentage organic matter of the soils was determined by multiplying the percent organic carbon value by 1.724.

% Organic matter = 1.724 x % carbon

Total N of the soil was determined by the Micro-Kjeldahl digestion, distillation and titration method. Available P was determined using the Bray II method by shaking the soil samples with an extracting solution of 0.03M ammonium fluoride in 0.01M hydrochloric acid as described by [63]. Exchangeable bases were extracted with 1N ammonium acetate at pH 7.

Exchangeable Ca and Mg were measured by atomic absorption spectrophotometer (AAS), while exchangeable K was measured by flame photometer [26]. Available micronutrients (Fe, Mn, Zn, and Cu) were extracted with DTPA as described by [59]. The amounts of these nutrients in the extracts were determined by atomic absorption spectrophotometer (AAS).

3.6. Statistical Analysis

The soil physical and chemical properties were subjected to analysis of variance using the general linear model procedure of the statistical analysis system (SAS 9.0 model). The least significance difference (LSD) test was used to separate significantly differing treatment means after main effects will be found significant at ($P < 0.05$). Moreover, simple correlation analysis was carried out with the help of Gomez and Gomez [64] to reveal the magnitudes and directions of relationships between selected soil fertility parameters and within and among land use types and soil depths.

4. RESULTS AND DISCUSSION

4.1. Land Use Types and Soil Depth Effects on Soil Physical Properties

4.1.1. Soil texture

The sand Silt and clay fractions were significantly ($P \leq 0.01$) affected by land use under main e ffect; but not significantly affected by soil depth and significantly ($P \leq 0.05$) affected under the interaction effect by of land use and soil depth. Similarly, the silt fraction was highly significan t ($P \leq 0.01$) affected by land use under the surface layer in the interaction of the two factors.

Table 1: Interaction effects of land use and soil depth of particle size (sand, silt and clay) distribution of the soils in the Kake Kebele.

LUT	% Sand		% Silt		% Clay	
	Soil depth (cm)					
	0-20	20-40	0-20	20-40	0-20	20-40
CL	21.66[b]	23.00[b]	36.00[a]	33.00[a]	41.66[b]	44.00[b]
FaL	39.00[a]	33.66[a]	15.00[c]	16.33[b]	46.00[a]	44.00[b]
FoL	21.00[b]	18.66[c]	31.00[b]	32.66[a]	48.00[a]	48.66[a]
LSD (0.05)	1.76	3.76	1.99	1.88	2.40	2.90
SEM (±)	0.33	0.57	0.57	0.57	0.33	0.57

Interaction means within a specific soil parameter followed by the same letter (s) are not significantly different from each other at $p \leq 0.05$; LSD = Least significant different; SEM = Standard Error mean CL=Cultivated Land; FaL =Fallow Land FoL=Forest Land; LUT = Land use types

4.1.2. Bulk, particle densities and Total porosity

Numerically the highest mean (1.23 g/cm^3) value of bulk density was recorded on the cultivated land and the lowest mean (1.15 g/cm^3) value under the forest land (Table 2). The reason of increasing bulk density may be due to continuous cultivation of the land. It was reported that soils under cultivated land having a significantly higher bulk density than soils under forest and fallow lands [65]. The ranges of bulk density values observed in this study are within the ranges expected in most mineral soils as indicated by [31].

Table 2 : Main effects of land use and soil depth on selected physical properties of the soils in the Kake Kebele

LUT	Sand (%)	Silt (%)	Clay (%)	STC	BD (g/cm^3)	PD (g/cm^3)	TP (%)
CL	22.33^b	34.50^a	42.83^c	C	1.23^a	2.61^a	52.87^c
FaL	39.33^a	15.66^c	45.00^b	C	1.20^b	2.63^a	54.37^b
FoL	19.83^c	31.83^b	48.33^a	C	1.15^c	2.61^a	56.01^a
LSD (0.05)	1.85	1.22	1.67	C	0.02	NS	0.97
SEM(±)	1.21	0.96	1.33	C	0.018	0.018	0.77
Soil depth (cm)							
0-20	27.22^a	27.33^a	45.22^a	C	1.17^b	2.61^b	54.86^a
20-40	27.11^a	27.33^a	45.55^a	C	1.21^a	2.63^a	53.85^b
LSD (0.05)	NS	NS	NS		0.019	0.019	0.78
SEM(±)	1.21	0.96	1.33		0.018	0.018	0.77

Main effect mean within a column followed by the same letter are not significantly different from each other at $p \leq 0.05$; STC = Soil textural classification; TP = total Porosity BD = Bulk Density; PD = Particle Density

The average bulk density across the land use type varies due to variation in soil depth (Table 2). However, bulk density increased from 0-20 to 20-40 cm layer under the fallow land and decreased under the forest and the cultivated lands (Table 2). Soil bulk density was positive (= 0.73) correlated with the sand and negatively (r = -0.61**) with silt (Appendix Table 1). Relatively the same (2.61g/cm) mean value of particle density was obtained in forest and cultivated land use and (2.63 g/cm) in the fallow land (Table 2). The particle density under the different land uses increasing with increasing soil depth. These higher particle density values in all the surface and subsurface soil layers might be due to the presence of heavy minerals of Fe and Mn in the surface and subsurface soil as indicated by the higher Fe and Mn contents on the surface and subsurface layers (Tables 7 and 8) which is in agreement with past reports by [30,31]. Considering the surface and the subsoil depths, relatively the highest particle density values were recorded under the fallow land (2.63g/cm) and the lowest values were recorded under forest and cultivated lands, respectively.

According to total porosity the average (surface and subsurface) total porosity percentages of cultivated, fallow and forest lands are 52.87 %, 54.37% and 56.01%, respectively (Table 2). Percentage total porosity decreased from the surface soil 54.86% to the subsurface soils 53.85%. Although this numerical variation was observed, total porosity was significantly ($P \leq 0.01$)

affected by land use, soil depth and the interaction of land use types. The lowest total porosity in fallow land may be due to high bulk density (Table 2).

4.2. Land Use Types and Soil Depth Effects on Soil Chemical Properties

4.2.1. Soil reaction (pH) and Electrical conductivity

The soils pH-H_2O value was significantly affected by land use and soil depth ($P \leq 0.05$). On the other hand, both pH-H_2O and pH-KCl values were affected by the interaction of land use by soil depth. Land use changes, for example from forest to fallow land, resulted in reduction of soil pH in the study area. For instance, the highest (5.56) and the lowest (5.27) soil pH-H_2O values were recorded under the forest and the fallow lands, respectively (Table 3). The lowest value of pH under the fallow land may be due to two major reasons. The first is drainage to streams in runoff generated from accelerated erosions and the depletion of basic cations in crop harvest. Secondly, it may be due to its highest microbial oxidation that produces organic acids, which provide H ions in the soil solution and thereby lowers soil pH. Generally, the pH values observed in the study area are within the ranges of very strongly acidic soil and strongly acidic soil reactions as indicated by [4]. Considering the two soil depths, the higher mean values of pH-H_2O (5.43) and pH-KCl (4.65) were observed within the surface soils and subsurface soils respectively. In general, pH (H_2O) values decreased with increasing soil depth (Table 3). The reason can be the reduction of Ca and Mg ions along soil depth which lowers soil pH from top down to the soil layers.

Electrical conductivity (EC) of soils was not significant ($P \leq 0.05$) affected by land use or by soil depth (Tables 3, 4).Considering the main effects of land use types, the highest (1.02 dS/m) EC was recorded under the cultivated and fallow lands and the lowest (0.96 dS/m) EC value was obtained under forest land (Table 3). The highest EC value under the cultivated and fallow land might be due to its highest exchangeable Ca content, whereas the lowest EC value under the forest land can be associated with the loss of base forming cations ($K^{1+}$and Mg^{2+}). As indicated in Appendix. Table 1, EC is negative and significantly correlated with pH (r = -0.439), OC (r = -0.361), TN (r = -0.232) and EC is positively and significantly ($P \leq 0.05$) correlated with exchangeable bases. Relatively, higher EC values were recorded in the surface than in the subsurface soils (Table 3). The mean EC contents of the interaction of land use types of subsoil layer treatment combinations were significantly different ($P \leq 0.05$) from each other (Table 4).

Considering the interaction effect of land use of soil depth, the highest interaction mean value of EC (1.04 dS/m) was obtained in the subsurface soil (20-40 cm) layer of the cultivated land, generally electrical conductivity increase with increasing soil depth.

4.2.2. Soil organic Carbon

Organic matter content was affected by land use, soil depth and the interaction of land use of soil depth (Tables 3, 4). Soil OC content was highest (1.40%) under the cultivated land and lowest (1.29%) on the fallow land (Table 3). The decline in soil OC and total N contents in the fallow land, leaching problem that can be attributed to the relatively high clay content (Tables 1 and 2) and the resultant light texture of soils also might be the cause of OC reduction. Considering the two soil depths, higher average OC (1.37%) was observed in the surface (0-20 cm) than the subsurface soil (20-40 cm) layers (Table 3). The mean OC contents of the all treatments combinations were significantly different ($P \leq 0.05$) from each other due to the interaction effects (Table 4). Soil OC contents in the 20-40 cm soil depths were highest (1.41%) on the cultivated lands and lowest (1.26%) under the fallow lands in the study area (Table 4).This may be due to complete removal of soil by erosion of the fallow land might have resulted in declining soil OM [66]. Similarly, except on the fallow land, soil OC content increased with increasing soil depth. OC content under the land use was higher in the subsoil layer of cultivated land than at the surface layer. This might be due to soil OM incorporation from the surface layer to subsoil layer as a result of the mixing effect of tillage activities and downward movement due to its higher clay content in subsoil surface than surface soil. Furthermore, the substantial amount of organic materials added from root biomass after the crop is harvested as stated by [67]. Dereje Tilahun *et al* [68] Coupled with rapid decrease of soil microorganism activity with increasing soil depth may explain the higher soil OM stocks in the subsoil of the land. The capacity of the soil to accumulate, stabilize or protect and gradually mineralizing the OM and release plant nutrients that are accumulated in the soils during the period the land was under the forest as well as from the slash is influenced by the clay texture property of the soils.

Table 3: Main effects of land use and soil depth on some chemical properties of the soils in the Kake *Kebele*

LUT	pH (H_2O)	pH (KCl)	EC (dS/m)	OC (%)	TN (%)	C/N ratio	Av.P (mg/kg)
CL	5.42[b]	4.65[a]	1.02[a]	1.40[a]	0.10[ab]	13.64[a]	2.25[b]
FaL	5.27[c]	4.64[a]	1.02[a]	1.29[a]	0.09[b]	13.95[a]	2.42[a]
FoL	5.56[a]	4.57[b]	0.96[a]	1.38[a]	0.12[a]	11.55[a]	2.44[a]
LSD(P=0.05)	0.02	0.05	NS	NS	0.01	NS	0.07
SEM (±)	0.019	0.04	0.05	0.11	0.01	2.37	0.06
Soil depth (cm)							
0-20	5.43[a]	4.58[b]	1.00[a]	1.37[a]	0.11[a]	12.92[a]	2.37[a]
20-40	5.41[a]	4.65[a]	1.01[a]	1.35[a]	0.10[a]	13.17[a]	2.36[a]
LSD (0.05)	NS	0.03	NS	NS	NS	NS	NS
SEM (±)	0.019	0.037	0.05	0.11	0.01	2.37	0.06

Main effect means within a column followed by the same letter are not significantly different from each other at $P \leq 0.05$; TN = total nitrogen; Av.P=Available phosphorus; OC=Organic Carbon; EC= Electrical Conductivity; C/N= Carbon to Nitrogen ratio

4.2.3. Total nitrogen

TN content of soils was significantly affected by land use, soil depth and the interaction of land use of soil depth (Tables 3, 4). The average values of total N were highest (0.12%) on the forest land and lowest (0.09%) under the fallow land (Table 3). The mean N content decreased consider ably from 0.11% in the surface (0-20 cm) to 0.10% in the subsurface (20-40 cm) soil layers (Tabl e 3). Considering the interaction of land use of soil depth, the highest (0.12%) value of total N was recorded at the surface (0-20 cm) layer of the forest land and the lowest (0.10, 10) values of TN were recorded under cultivated and fallow lands respectively (Table 4). Following the rating of total N of < 0.05% as very low, 0.05 - 0.12% lower, 0.12 - 0.25% moderate and > 0.25% as high TN status as indicated by [69]. Generally the surface soils and the subsurface soils of the cultivated, the fallow lands and the forest lands qualify low status for TN%. At the OC and total N contents showed positive correlated (r = 0.350) as shown in (Appendix Table 1).

Table 4: Interaction effects of land use and soil depth (cm) on EC, soil OC, total N, C/N ratio and Available P of the soils in the Kake Kebele

LUT	EC(ds/m)		OC (%)		TN (%)		C/N		Av.P (ppm)	
	Soil Depth (cm)									
	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
CL	1.00[a]	1.04[a]	1.40[a]	1.41[a]	0.10[a]	0.10[ab]	13.99[a]	13.28[a]	2.26[b]	2.24[b]
FaL	1.01[a]	1.03[a]	1.32[a]	1.26[a]	0.10[a]	0.08[b]	13.63[a]	14.27[a]	2.42[a]	2.42[a]
FoL	0.96[a]	0.97[a]	1.38[a]	1.39[a]	0.12[a]	0.11[a]	11.15[a]	11.95[a]	2.44[a]	2.44[a]
LSD(0.05)	NS	NS	NS	NS	NS	0.02	NS	NS	0.10	0.12
SEM(±)	0.00		0.00		0.01		1.90		0.02	

Interaction means within a specific soil parameter followed by the same letter (s) are not Significantly different from each other at P ≤ 0.05

4.2.4. Carbon to nitrogen ratio

The carbon to nitrogen (C/N) ratios of the soils at Kake *Kebele* was not significantly affected by soil depth and the interaction of land use by soil depth (P ≤ 0.05) (Tables 3 and 4). On the other hand, although slight numerical variation was observed among land uses, C/N ratio was not significantly (P > 0.05) affected by land use types. Considering the main effects of soil depth, higher mean C/N ratio values of 13.95, 13.64 were found within the subsurface soil layer of fallow and surface layer of cultivated lands respectively (Table 3). On the other hand the interaction effects on land use types of C/N ratio; the highest (14.27) value was recorded under subsurface soil of fallow land and the lower (11.15) value was observed under the surface layer of forest land in soil depth (Table 4). This indicates that the rate at which total N decreased with soil depth was much higher than the reduction in carbon.

4.2.5. Available phosphorus

The available phosphorus (P) was significantly (P ≤ 0.05) affected by land use types in main effects and the interaction of land use with soil depth (Tables 3, 4) content of available P in the forest land appeared to be significantly higher than the rest two land use types. Accordingly, the highest (2.44 mg/kg) and the lowest (2.25 mg/kg) available P contents were observed under the forest and the cultivated lands, respectively (Table 3). The data also revealed that available P was higher (2.37 mg/kg) in the subsoil (0-20 cm) than in the subsurface layer. Generally, variations in available P contents in soils are related to the intensity of soil weathering or soil disturbance, the cultivated land showed variation in available P content from the forest and fallow lands which obviously could be due to crop mining, crop residue removal and erosion [70]. The degree of Av.P fixation with Fe and Ca continuous application of mineral P fertilizer sources as indicated by [71]. According to Paulos Dubale [72] available soil P level < 5 mg/kg Very low, 5 -9 mg/kg, and 10-17 mg/kg Low, Medium, 18-25 mg/kg, High and > 25 mg/kg very high. Thus, the available P of the soils of the study area with the exception of the surface soil and subsurface soil layer of the all land use types, were less than 5 mg/kg qualifying for the very low range. In general, all treatment combinations were significantly different ($P \leq 0.05$) from each other due to the interaction effects.

4.2.6. Basic exchangeable cations

The content of exchangeable calcium (Ca) was significantly ($P \leq 0.01$) affected by land use types and the interaction of land use by soil depth (Tables 5, 6 and Appendix Table 1). The mean values of exchangeable calcium (Ca) under cultivated land the, the fallow and the forest lands were 2.20, 4.20 and 3.22 cmol($_+$)/kg or (440 ppm, 840 ppm and 644 ppm) respectively (Table 5). Considering the two soil depths, it was higher (3.22 ($_+$) /kg) at the surface layer than in the subsurface soil (20-40cm) depth. Considering the interaction of land use of soil depth, the highest (4.22Coml (+) /kg) exchangeable Ca was recorded at the surface (0-20cm) layer of the fallow land, and the lowest (0.47 cmol($_+$)/kg) was obtained at the surface layer of the cultivated land (Table 6).

Exchangeable magnesium content was significantly ($P \leq 0.01$) affected only by land use types (Table 5). Considering the main effects of land use, the mean exchangeable magnesium (Mg) value was highest (1.25 cmol ($_+$)/kg) under the fallow land and lowest (1.12 cmol($_+$)/kg) on the forest land (Table 5). The contents of both exchangeable Ca and Mg small variation with soil depth under all land use types (Table 6). These indicate that there was higher downward leaching of basic cations in the crop field than in the other land use practices.

Exchangeable K content was significantly ($P \leq 0.05$) affected by land use types and not significantly ($P \leq 0.05$) affected in the interaction of land use by soil depth (Tables 5, 6). It was highest (0.52, 0.51 cmol ($_+$)/kg) or 202.2 ppm, 198.9 ppm) in the cultivated land and fallow land respectively. The lowest (0.47cmol (+)/kg) value was observed in the forest land. Considering the interaction effects of land use of soil depth, similar to the main effects of exchangeable K in all land use types (Table 6). Generally, the lower exchangeable K contents in the forest land than in the cultivated and fallow lands might be due to high erosion. Previous findings have also considered these factors and the application of acid forming fertilizers as major factors affecting the distribution of K^+ in soil systems mainly enhancing its depletion especially in tropical soils [30, 73].

Table 5: Main effects of land use and soil depth on selected exchangeable cations (cmol(+)/kg)

LUT	K	Ca	Mg
	Cmol (+)/kg		
CL	0.52[a]	2.20[c]	1.23[b]
FaL	0.51[ab]	4.20[a]	1.25[a]
FoL	0.47[b]	3.22[b]	1.12[c]
LSD (0.05)	0.04	0.02	0.01
SEM (±)	0.03	0.012	0.011
Soil depth			
0-20 (cm)	0.50[a]	3.22[a]	1.20[a]
20-40 (cm)	0.51[a]	3.20[b]	1.21[a]
LSD (0.05)	NS	0.01	NS
SEM (±)	0.03	0.012	0.011

Main means within a specific soil parameter followed by the same letter (s) are not significantly different from each other at $P \leq 0.05$

Table 6: Interaction effects of land use and soil depth on exchangeable cations (Ca, K and Mg) of the soils in the Kake Kebele

LUT	K		Ca		Mg	
	Cmol (+)/kg					
	Soil Depth (cm)					
	0-20	20-40	0-20	20-40	0-20	20-40
CL	0.52[a]	0.52[a]	0.47[c]	2.19[c]	1.22[b]	1.24[a]
FaL	0.51[a]	0.51[a]	4.22[a]	4.19[a]	1.26[a]	1.25[a]
FoL	0.47[a]	0.47[a]	3.24[b]	3.21[b]	1.12[c]	1.12[b]
LSD (0.05)	NS	NS	0.02	0.02	0.02	0.02
SEM (±)	0.00		0.01		0.01	

Interaction means within a column followed by the same letter are not significantly different from each other at $P \leq 0.05$

4.2.7. Micronutrients (Fe, Mn, Zn and Cu)

The contents of available micronutrients (Fe, Mn, Zn and Cu) under the different land use types were significantly different ($P \leq 0.01$) due to the interaction effects and Cu showed reduction from the cultivated land to fallow land and forest land (2.91, 2.77 and 2.68 mg/kg) respectively. But for Fe, Mn and Zn there are numerical variation in all land use types. These variations of soil nutrients between land use types indicate the risk to the sustainable crop production in the study area. With regards to the interaction effects of land use of soil depth, except Cu the three nutrients were decreased from the surface layer to the subsurface layer of the soil under forest land (Table 8). On the other hand, the highest mean values of available Mn (mg/kg), Mn (5.20, 5.99 and 4.83mg/kg) and the lowest values of available Zn (0.37, 0.67and 0.46 mg/kg) were recorded under cultivated, fallow and forest lands respectively.

Sims *et al* [74] indicated that the critical or threshold levels of available Fe and Mn for crop production are 2.5-4.5 mg/kg and 1-50 mg/kg, respectively. Therefore, the results observed in this study revealed that the average mean values of available Fe, and Mn were in the adequate range for the production of most crop plants. Generally, available Fe under land uses and soil depths was positive and significantly correlated with organic carbon (r = 0.373) (Appendix Table 1) similar to the report by [30, 69]. Generally, except Zn the three micronutrients (Fe, Mn and Cu) were above the critical level for all plants in the study area.

Table 7: Main effects of land use and soil depth on available micronutrients (mg/kg)

LUT	Fe	Mn	Zn	Cu
	mg/kg			
CL	4.25^{a}	5.20^{b}	0.37^{c}	2.91^{a}
FaL	3.39^{c}	5.99^{a}	0.67^{a}	2.77^{b}
FoL	3.84^{b}	4.83^{c}	0.46^{b}	2.68^{c}
LSD (0.05)	0.08	0.12	0.02	0.05
SEM (±)	0.06	0.09	0.02	0.04
Soil depth				
0-20 (cm)	3.84^{a}	5.35^{a}	0.51^{a}	2.77^{a}
20-40 (cm)	3.82^{a}	5.34^{a}	0.49^{a}	2.80^{a}
LSD (0.05)	NS	NS	NS	NS
SEM (±)	0.066	0.098	0.018	0.04

Main effect means within a column followed by the same letter are not significantly different from each other at $P \leq 0.05$

Table 8: Interaction effects of land use and soil depth on available micronutrients of the soils in the Kake Kebele

LUT	Fe		Mn		Zn		Cu	
	($mg\ kg^{-1}$)							
	Soil depth (cm)							
	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
CL	4.25[a]	4.26[a]	5.22[b]	5.18[b]	0.38[c]	0.36[c]	2.89[a]	2.93[a]
FaL	3.41[c]	3.37[c]	5.97[a]	6.01[a]	0.67[a]	0.67[a]	2.78[b]	2.77[b]
FoL	3.85[b]	3.82[b]	4.83[c]	4.82[c]	0.48[b]	0.45[b]	2.65[c]	2.70[b]
LSD(0.05)	0.14	0.12	0.13	0.24	0.03	0.03	0.05	0.09
SEM(±)	0.03		0.10		0.01		0.03	

Interaction means within a column followed by the same letter are not significantly different from each other at $P \leq 0.05$

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The macro and micronutrient status of soil from the Kake *Kebele* have been determined. Based on the ANOVA result**,** 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. The nature of the Soil in the study area is acidic; because of land use changes from forest to fallow land, resulted in reduction of soil pH in the study area. For instance, the highest (5.56) and the lowest (5.27) soil pH-H_2O values were recorded under the forest and the fallow lands, respectively. The average values of selected soil physical properties under the cultivated, fallow and forest lands showed changes in total porosity (52.87 %, 54.37% and 56.01%), clay (42.83, 45.00 and 48.33%), respectively. Similarly, there was also changes in soil OC (1.40, 1.29 and 1.38%), TN (0.10, 0.09 and 0.12%), in the cultivated, fallow and forest lands, respectively. On the other hand, Av.P and exchangeable bases (Ca^{2+} and Mg^{2+}) are low in the study area. The content of available micronutrients (Fe, Mn, Zn and Cu) under the different land use types was significantly different ($P \leq 0.01$) but not significantly affected under soil depths and Cu showed a reduction from cultivated land to fallow land and then to forest land (2.91, 2.77 and 2.68 mg/kg) respectively. But for Fe, Mn and Zn there are numerical variation in all land use types. Therefore, the variations in pH, total porosity, clay contents, OC, TN, Av.P, exchangeable bases and micronutrients are responsible for the reduction of soil fertility in the study area. The macro and micronutrients' assessment showed that the fertility of the study site shows a reduction of nutrients and leading to lose of soil fertility.

5.2. Recommendation

Strategies to feed the expanding population in the study areas will have to seek a sustainable solution that best addresses integrated soil management. Appropriate policy formulation and implementation are needed, which enables farmers to reduce the impact of soil fertility depletion as this is expected to result in low productivity which hinders achievement of food security. Understanding of these factors would contribute to the design of appropriate strategies to achieve better utilization of soil in the soil fertility management system in the study areas and other similar areas of the district, zone and the region. The findings of more research work on nutrient management with indigenous practices such as traditional agro forestry, composting, crop rotation, biomass transfer, etc. and improved practices such as chemical and organic fertilizers, improved fallows, improved crop variety and livestock, etc., techniques complemented with strong land use policy and alternative rural energy sources should be integrated into a strategy for sustainable agricultural development in the study area.

Therefore, this study would like to recommend the following points to the concerned body in the study area.

1. The soil pH of the study area ranges from strongly acidic to moderately acidic, therefore, the soil under the cultivated land needs treatment with DAP fertilizer to increase available phosphorus and using lime to increase exchangeable bases.
2. Finally, to increase the fertility of the soil of the study area there should be concern by the Agricultural Development Office, Farmers, policy makers and further study should be conducted to give attention for this serious decrement of soil fertility

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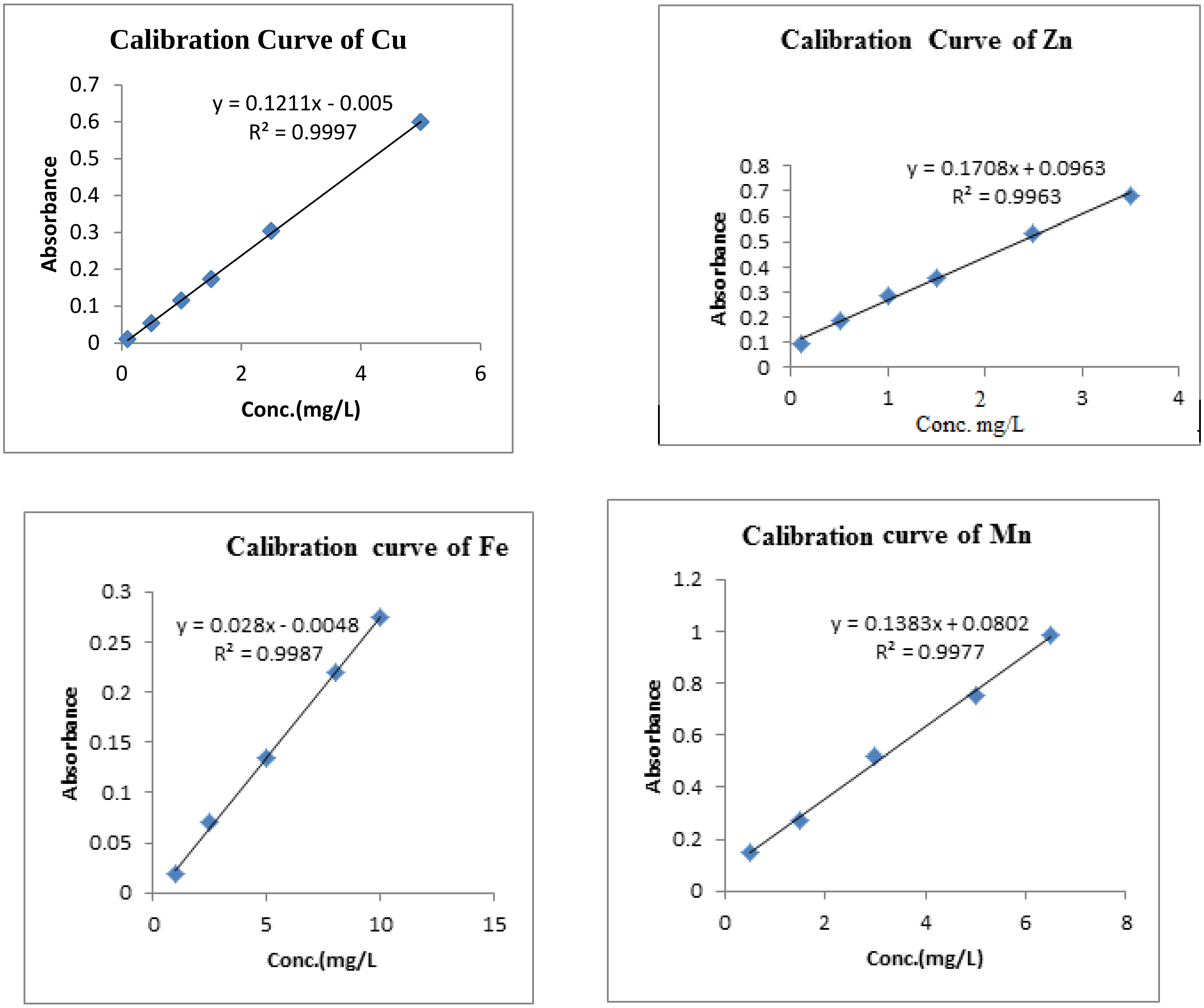
APPENDICES

Appendix Table 1. Pearson's correlation matrix for various soil physico-chemical parameters.

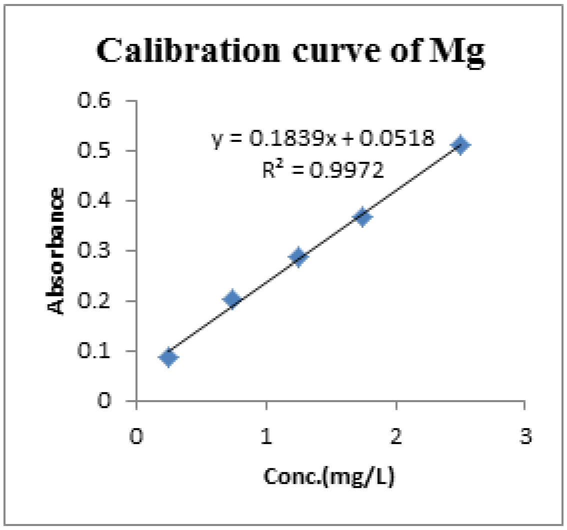
	Sand	Silt	Clay	BD	PD	TP	pH	pKCl	EC	OC	TN	CN	Av.P	K	Ca	Mg	Fe	Mn	Zn	Cu
Sand	1																			
Silt	-.95**	1																		
Clay	-.24	-.04	1																	
BD	.73**	-.61**	-.45	1																
PD	-.25	.30	-.15	.17	1															
TP	-.80**	.69**	.42	-.97**	.05	1														
$pH(H_2O)$	-.91**	.78**	.53*	-.85**	.04	.87**	1													
pH(KCl)	.31	-.22	-.34	.71**	.41	-62**	-.47*	1												
EC	.34	-.20	-.49*	.48*	-.19	-.53*	-.43	.46	1											
OC	-.51*	.44	.29	-.34	.26	.40	.39	-.04	-.36	1										
TN	-.56*	.46	.38	-.60**	-.17	.57*	.65**	-.27	-.23	.35	1									
CN	.25	-.21	-.18	.37	.28	-.31	-.40	.18	-.00	.26	-.80**	1								
Av.P	.27	-.46	.63**	-.15	-.32	.08	.03	-.26	-.41	-.29	.21	-.38	1							
K	.27	-.14	-.46	.36	.34	-.29	-.49*	.43	.21	-.14	-.31	.17	-.11	1						
Ca	.78**	-.90**	.33	.35	-.42	-.45	-.50*	-.02	.01	-.41	-.27	.04	.71**	-.13	1					
Mg	.71**	-.53*	-.64**	.81**	.03	-.82**	-.87**	.56*	.52*	-.24	-.66**	.50*	-.38	.51*	.17	1				
Fe	-.78**	.90**	-.32	-.38	.38	.47*	.51*	-.00	.00	.37	.31	-.12	-.64**	.17	-.98**	-.19	1			
Mn	.94**	-.86**	-.33	.76**	-.19	-.82**	-.93**	.34	.34	-.36	-.66**	.45	.07	.33	.64**	.83**	-.67**	1		
Zn	.88**	-.95**	.14	.48*	-.38	-.57*	-.66**	.03	.10	-.45	-.41	.17	.57*	-.03	.96**	.37	-.96**	.79**	1	
Cu	.02	.19	-.73**	.47*	.34	-.39	-.33	.61**	.44	.10	-.39	.43	-.85**	.36	-.54*	.65**	.48*	.20	-.38	1

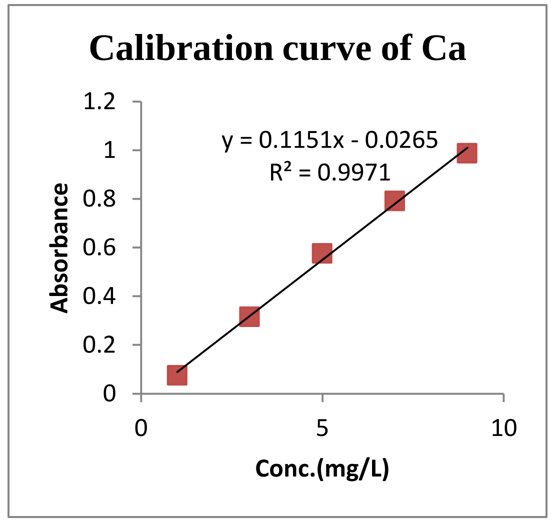
A. Cultivated Land B. Fallow Land C. Forest Land

Appendix figure 1: Soil samples from the study area



Appendix figure 2. Calibration Curves of Cu, Zn, Fe and Mn





Appendix figure 3 .Calibration curve of exchangeable bases (Mg, Ca)