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Effects of Soil Conservation Practices on Selected Soil Nutrients in Borodo Watershed, Ethiopia

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This is to certify that the thesis prepared by Mamaru Assefa, entitled: *Effects of Soil Conservation Practices on Selected Soil Nutrients in Borodo Watershed, Ethiopia* and submitted in partial fulfillment of the requirements for the degree of Degree of Master of Science (Environmental Science) Complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
Av. P	Available Phosphorus
BD	Bulk Density
CEC	Cation Exchange Capacity
DAP	Diammonium phosphate
DEM	Digital Elevation Model
DMRT	Duncan’s multiple range tests
DTPA	Diethylene Triamine Pentaacetic Acid
DZARC	Debrezeit Agricultural Research Center
EPRDF	Ethiopian People’s Revolutionary Democratic Front
GPS	Global Positioning System
HARC	Holleta Agricultural Research Center
HHs	Households
ISFM	Integrated Soil Fertility Management
LSD	Least Significance Difference
LULC	Land Use Land Cover
m.a.s.l	meter above sea level
MS	Mean Square
NGO	Non Governmental Organization
OC	Organic Carbon
OM	Organic Matter
PBS	Percentage Base Saturation
PD	Particle Density
PH	Power of Hydrogen
PRA	Participatory Rural Appraisal
PSD	Particle Size Distribution
SAS	Statistical Analysis System
SFM	Soil Fertility Management
SWC	Soil and water conservation
TP	Total porosity
USDA	United States Department of Agriculture

ABSTRACT

Effects of Soil Conservation Practices on Selected Soil Nutrients in Borodo Watershed, Ethiopia

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Soil degradation is evident in the mountainous areas of Ethiopia and is often represented as results of human pressure. It can be reduced through different Soil and Water Conservation (SWC) measures. The study was conducted at the Borodo watershed, which is situated in Dendi district, west shewa zone of oromya region in Central highlands of Ethiopia. The aim of the study was to assess the effect of soil conservation practices on selected soil nutrients in different land use systems in Borodo watershed. The results of the soil analysis showed that most of soil physicochemical properties had significant variations with respect to Soil Conservation practices, land use types and slope gradients. The highest average mean values of exchangeable Ca (40.05meq/100g), Mg (19.17meq/100g) and CEC (53.14 Cmol /kg) were observed under the forest land as compared to the lowest values (14.54, 5.11 and 32.92 Cmol/kg) in the unconserved lower eucalyptus and Upper grazing lands respectively. The cumulative values of land use changes without proper management were negative (decreasing the marginal status of soil nutrients). The results of the study indicates that soil bunds could benefit farmers through improving the nutrient status of the soil better if integrated with biological structures (stabilizing bunds with vetiver and other improved forage seeds). For optimizing and maintaining the favorable soil physicochemical properties sustainably farmers need to know the appropriate soil conservation structures, their application and benefits.

KeyWords: Borodo, Conservation, Macronutrients, Micronutrients, Physical properties and Watershed.

1. INTRODUCTION

1.1 Background and Justification

Soil fertility maintenance is a major concern in tropical Africa, particularly with the rapid population increase, which has occurred in the past few decades. In traditional farming systems, farmers use bush fallow, plant residues, household refuse, animal manures and other organic nutrient sources to maintain soil fertility and soil organic matter. Although this reliance on biological nutrient sources for soil fertility regeneration is adequate with low cropping intensity, it becomes unsustainable with more intensive cropping unless fertilizers are applied Mulongey and Merck (1993).

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 Mesfin Abebe (1998). 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 Foth and Ellis (1997).Optimum productivity of any cropping system depends on adequate supply of plant nutrients. 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.

In the Ethiopian highlands, population pressure which accounts for 85% of the country’s total population as well as 67% of its livestock population has pushed cultivation and livestock grazing to steep slopes and fragile lands causing serious overgrazing and soil erosion. The mild sub humid highlands of the Borodo watershed areas in Dendi District are not exceptions of these problems. However, little has been done to maintain the fertility of the soils in the watershed locally available data of soil fertility status are insufficient.

In Borodo watershed most of the lands were covered by the indigenous trees and shrubs and erosion was not a serious problem before 1974 Haileselasie regime. After

1974 land become public property under the custody of the Government, natural forests converted to cropping and erosion become a serious natural resource problem and government sponsored Soil and water conservation project initiated. Land remained under public domain under after 1991. Landholding declined due to population pressure and erosion problem worsened and threatened livelihood of the local community. In response of such problems there was Construction of physical SWC Structures.

The major agricultural constraints at Borodo watershed are shortage of land for crop cultivation and livestock grazing, decline of soil fertility, rainfall variability and pests and diseases. Nowadays, due to increasing population pressure and shortage of land, deforestation and cultivation activities are being carried out on steep slopes, which accelerate soil erosion. . Therefore, this study was initiated to assess the effect of soil conservation practices on selected soil nutrients in different land use systems in Borodo watershed.

1.2 Statement of the Problem

Watershed resource degradation in the highlands is becoming a growing concern in many countries Laura et al. (2005). The Ethiopian highlands with inherently fertile soil, sufficient rain fall and with highest agricultural potential are threatened by accelerating resource degradation from time to time Bekele Shiferaw and Holden (1997).

In *Borodo* Watershed the coverage of trees and shrubs has declined due to various anthropogenic factors. Farmers cut trees from the upstream, midstream and downstream sides of the watershed to expand agricultural fields and gain some benefits from the sale of wood and wood products. As a result of reckless cutting of the forest trees, the watershed is suffering from soil erosion, depletion of soil nutrients and formation of gullies and other related problems. The communities in the watershed are also challenged with shortage of wood for various uses and services.

Due to this fact, efforts have been made in the Ethiopian highlands by different governmental and nongovernmental organizations to offset the problem of land degradation, loss of biodiversity and environmental deterioration. However as Kindu et al. (2008) noted, the desired results have not been achieved, as most efforts lacked proper methodologies, follow-up, farmers participation, understanding of the existing socioeconomic, biophysical and institutional circumstances at farm, landscape and watershed levels. Although, there are several efforts made in SWC investment in Borodo watershed, evidence is limited regarding the effect of these conservation practices and other land uses on soil properties in the study area. Moreover, the major factors in land use systems affecting soil nutrient conditions and soil fertility management (SFM) practices in the watershed were not identified.

This study, therefore, aims to contribute an empirical analysis of effects of soil conservation practices on selected soil nutrients in different land uses in Borodo watershed.

1.3 Objectives of the Study

1.3.1 General Objective

The general objective of the study was to assess the effect of soil conservation practices on selected soil nutrients in the different land use systems in Borodo watershed.

1.3.2 Specific Objectives

- To assess the impact of soil conservation practices on selected soil nutrients
- To assess the selected soil nutrients under the different land use systems.
- To identify the major causes and effects of land degradation using farmers perceptions

1.4 Research Questions

The research questions of the study include:

- What are the effects of soil conservation practices on the selected soil nutrients in Borodo watershed?
- What are the effects of soil conservation practices on selected soil nutrients in different land use systems in this watershed?
- How farmers perceive about the causes and effects of land degradation in this watershed?

2. LITERATURE REVIEW

2.1 Soil Physical Properties

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 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 Sanchez (1976).

2.1.1 Soil Texture

Soil texture determines a number of physical and chemical properties of soils. It affects the infiltration and retention of water, soil aeration, absorption of nutrients, microbial activities, tillage and irrigation practices Foth (1990) and Gupta (2004). 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 Miller and Donahue (1995) ,Lilienfein *et al*., (2000).

2.1.2 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 indicator of aeration status and water content Barauah and Barthakulh (1997). Bulk density also provides information on the environment available to soil microorganisms. White (1997) stated that values of bulk density ranges from < 1 g/cm3 for soils high in OM, 1.0 to 1.4 g/cm3 for well- aggregated loamy soils and 1.2 to 1.8 g/cm3 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 exhibit favorable and poor physical conditions, respectively. Bulk densities of soil horizons are inversely related to the amount of pore space and soil OM Brady and Weil(2002); Gupta (2004). 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 Woldeamlak Bewket and Stroosnijder (2003) and Mulugeta Lemenih (2004) 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 Mulugeta Lemenih (2004). Similarly, Ahmed Hussein (2002) reported that soil bulk density under both cultivated and grazing lands increased with increasing soil depth. On the other hand, Wakene Negassa (2001) 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 attributes 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/cm3, but the presence of iron oxide and heavy minerals increases the average value of particle density and the presence of OM lowers it Hillel (1980). According to Ahmed Hussein (2002), the surface soil layer had lower particle density value than the subsoil horizons and the higher particle density (2.93 g/cm3) was obtained at the subsoil horizons in different land use systems at different elevation. This is attributed to the lower OM content in the subsoil than in the surface horizons.

2.1.3 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 Foth (1990). 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 close relationship between relative compaction and the larger (macro pores) of soils Ike and Aremu (1992). 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. Macro pores 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 macro pores. 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 Brady and Weil (2002). 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 Mulugeta Lemenih (2004). The lowest total porosity was the reflections of the low OM content.

*Total porosity (%) = (1-BD/PD)*100*

2.2 Soil Chemical Properties

Soil chemical properties are the most important among the factors that determine the nutrient supplying power of the soil to the plants and microbes. The chemical reactions that occur in the soil affect processes leading to soil development and soil fertility build up. Minerals inherited from the soil parent materials overtime release chemical elements that undergo various changes and transformations within the soil.

2.2.1 Soil Reaction (pH)

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.

The degree and nature of soil reaction influenced by different anthropogenic and natural activities including leaching of exchangeable bases, acid rains, decomposition of organic materials, application of commercial fertilizers and other farming practices Rowell (1994), Miller and Donahue (1995); Tisdale et al., (1995), Brady and Weil (2002). In strongly acidic soils, Al^{3+} becomes soluble and increase soil acidity while in alkaline soils; exchangeable basic cations tend to occupy the exchange sites of the soils by replacing exchangeable H and Al ions Miller and Donahue (1995), Eylachew Zewdie (1999), Brady and Weil (2002).

2.2.2 Soil Organic Matter (SOM)

Soil OM arises from the debris of green plants, animal residues and excreta that are deposited on the surface and mixed to a variable extent with the mineral component White (1997).

In most tropical environments, the conversion of forest vegetation to agricultural land results in a decline of the soil OM content to a newer, lower equilibrium Woldeamlak Bewket and Stroosnijder (2003). Most cultivated soils of Ethiopia are poor in OM contents due to low amount of organic materials applied to the soil and complete removal of the biomass from the field Yihenew Gebreselassie (2002), and due to severe deforestation, steep relief condition, intensive cultivation and excessive erosion hazards Eylachew Zewdie (1999). Biological degradation is frequently equated with the depletion of vegetation cover and OM in the soil, but also denotes the reduction of beneficial soil organisms that is important indicator of soil fertility Oldman (1993).

Uncultivated soils have higher in soil OM (both on surface and in soil) than those soils cultivated years Miller and Gardiner (2001). In the forest, there is a continuous growth of plants and additions to the three pools of OM: standing crop, forest floor and soil. In the grassland ecosystems, much more of the OM is in the soil and much less occurs in the standing plants and grassland floor. Although approximately 50% of the total OM in the forest ecosystems may be in the soil, over 95% may be in the soil where grasses are the dominant vegetation Foth (1990). This means land management practices, which reduce soil fertility, will seriously decrease its chemical activity and also its ability to hold plant nutrients Assefa Kuru (1978). Soluble and exchangeable aluminum in acid soils are substantially reduced by organic amendments (Hoyt and Turner (1975); Hue and Amien (1989).

Gregorich et al. (1995) reported that the concentration of organic carbon (OC) in the forest soil decreased with depth by more than 10-fold in the surface 30 cm, from 139 g/kg soil in the 0-15 cm layer to 12 g/kg soil in the 15-30 cm layer. In contrast, the OC concentration under corn was similar for soil layers within the plow layer, ranging between 19 and 21 gram carbon per kg of soil. However, the mass of OC in the surface 10 cm of the forest soil was about three times greater than the soil under corn, but below 10 cm, the quantity of OC in the forest was similar to that of the soils cultivated for corn Gregorich *et al*. (1995). Thus, the surface layer is most relevant to assess the impact of management practices on soil OM, because surface soils are easily modified directly by cultivation.

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 provide a useful estimate of total soil carbon storage Carter *et al*. (1997).

2.2.3 Total Nitrogen

Nitrogen (N) is the forth 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 Sanchez (1976); Mengel and Kirkby (1987); Mesfin Abebe (1998). The total N content of a soil is directly associated with its OC content and its amount on cultivated soils is between 0.03% and 0.04% by weight (Mengel and Kirkby (1987); Tisdale *et al*. (1995).

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 OM content Tisdale *et al*.(1995). Wakene Negassa (2001) 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 Nega Emiru (2006). 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 McDonagh et al.(2001). 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 Mulugeta Lemenih (2004). 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 with cultivation time in the farm fields, compared to the soil under the natural forest.

2.2.4 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 Foth and Ellis (1997).Following N, P has more wide spread influence on both natural and agricultural ecosystems than any other essential elements. In most natural ecosystems, such as forests and grasslands, P 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 Brady and Weil (2002). It is the most commonly plant growth-limiting nutrient in the tropical soils next to water and N Mesfin Abebe (1996). 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 Brady and Weil (2002). According to Foth and Ellis (1997), 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 inorganic form in mineral soils Foth and Ellis (1997).

The main sources of plant available P are the weathering of soil minerals, the decomposition and mineralization of soil OM and commercial fertilizers. Most of the soils in Ethiopia particularly Nitisols and other acid soils are known to have low P contents, not only due to the inherently low available P content, but also due to the high P fixation capacity of the soils Murphy (1968); Eylachew Zewdie (1987). Oxisols, Ultisols, Vertisols and Alfisols are generally low in total P while Andosols are generally high in P content Mesfin Abebe (1996).

2.2.5 Cation Exchange Capacity

The Cation exchange capacity (CEC) of soils is defined as the capacity of soils to adsorb and exchange cations Brady and Weil (2002). Cation exchange capacity is an important parameter of soil because it gives an indication of the type of clay minerals present in the soil, its capacity to retain nutrients against leaching and assessing their fertility and environmental behavior. Generally, the chemical activity of the soil depends on its CEC.

The CEC of a soil is strongly affected by the amount and type of clay, and amount of OM present in the soil Curtis and Courson (1981). Both clay and colloidal OM are negatively charged and therefore can act as anions Kimmins (1997)**.** As a result, these two materials, either individually or combined as a clay-humus complex, have the ability to adsorb and hold positively charged ions (cations). Soils with large amounts of clay and OM have higher CEC than sandy soils low in OM. In surface horizons of mineral soils, higher OM and clay contents significantly contribute to the CEC, while in the subsoil particularly where Bt horizon exist, more CEC is contributed by the clay fractions than by OM due to the decline of OM with profile depth Foth (1990) Brady and Weil (2002).

Soil solutions contain dissolved chemicals, and many of these chemicals carry positive charges (cations) or negative charges (anions) Fisher and Binkley (2000). Cation exchange is considered to be of greater importance to soil fertility than anion exchange, because the majority of essential minerals are absorbed by plants as cations Poritchett and Fisher (1987). The nutrients required for plant growth are present in the soil in a variety of forms Kimmins (1997). They may be dissolved in the soil solution, from where they can be utilized directly. They may be absorbed onto exchange sites, from where they inter soil solution or be directly exploited by tree roots or microorganisms that come in contact with the exchange site. Alternatively, they may be firmly fixed in clay lattices, immobilized in decomposition resistant OM, or present in insoluble inorganic compounds. Cations removed from the exchange sites often are replenished rapidly from other sources, such as OM decomposition, mineral weathering, or release of ions fixed within the layers of clay minerals.

Generally, processes that affect texture (such as clay) and OM due to land use changes also affect CEC of soils. Woldeamlak Bewket and Stroosnijder (2003) reported that CEC value was highest in soils under forest land and lowest under cultivated land. Besides, due to intensity of human action, there was a drastic loss of CEC in the surface than in the subsurface layers in soils of Senbat watershed, western Ethiopia Nega Emiru (2006). Therefore, it is necessary to study and evaluate soil chemical properties to avoid soil nutrient depletion and degradation, and to sustain production.

2.2.6 Exchangeable Acidity

Exchangeable hydrogen (H) together with exchangeable aluminum (Al) is known as soil exchangeable acidity. Soil acidity occurs when acidic H^+ ion occurs in the soil solution to a greater extent and when an acid soluble Al^{3+} reacts with water (hydrolysis) and results in the release of H^+ and hydroxyl Al ions into the soil solution Rowell (1994); Brady and Weil (2002).

As soils become strongly acidic, they may develop sufficient Al in the root zone and the amount of exchangeable basic cations decrease, solubility and availability of some toxic plant nutrient increase and the activities of many soil microorganisms are reduced, resulting in accumulation of low OM, reduced mineralization and lower availability of some macronutrients like N, S and P and limitation of growth of most crop plants Rowell (1994) and ultimately decline in crop yields and productivity (Miller and Donahue (1995); Tisdale *et al*. (1995); Foth and Ellis (1997); Brady and Weil (2002).

Foth and Ellis (1997) stated that during soil acidification, protonation increases the mobilization of Al and Al forms serve as a sink for the accumulation of H^+. The concentration of the H^+ in soils to cause acidity is pronounced at pH values below 4 while excess concentration of Al^{3+} is observed at pH below 5.5 Nair and Chamuah (1993). In strongly acidic conditions of humid regions where rainfall is sufficient to leach exchangeable basic cations, exchangeable Al occupies more than approximately 60% of the effective cation exchange capacity, resulting in a toxic level of aluminum in the soil solution Buol *et al*.(1989). Generally, the presence of more than 1 parts per million of Al^{3+} in the soil solution can significantly bring toxicity to plants. Hence, the management of exchangeable Al is a primary concern in acid soils.

2.2.7 Exchangeable Potassium and Sodium

Soil parent materials contain potassium (K) mainly in feldspars and micas. As these minerals weather, and the K ions released become either exchangeable or exist as adsorbed or as soluble in the solution Foth and Ellis (1997). Potassium is the third most important essential element next to N and P that limit plant productivity. Its behavior in the soil is influenced primarily by soil cation exchange properties and mineral weathering rather than by microbiological processes. Unlike N and P, K causes no off-site environmental problems when it leaves the soil system. It is not toxic and does not cause eutrophication in aquatic systems Brady and Weil (2002).

Wakene Negassa (2001) reported that the variation in the distribution of K depends on the mineral present, particles size distribution, 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. The greater the proportion of clay mineral high in K, the greater will be the potential K availability in soils (Tisdale *et al.* (1995). Soil K is mostly a mineral form and the daily K needs of plants are little affected by organic associated K, except for exchangeable K adsorbed on OM. Mesfin Abebe (1996) described low presence of exchangeable K under acidic soils while Alemayehu Tadesse (1990) observed low K under intensive cultivation. Normally, losses of K by leaching appear to be more serious on soils with low activity clays than soils with high- activity clays and K from fertilizer application move deeply Foth and Ellis (1997).

Exchangeable sodium (Na) alters soil physical and chemical properties mainly by inducing swelling and dispersion of clay and organic particles resulting in restricting water permeability and air movement and crust formation and nutritional disorders (decrease solubility and availability of calcium (Ca) and magnesium (Mg) ions) Szabolcs (1969) and Sposito (1989). Moreover, it also adversely affects the population, composition and activity of beneficial soil microorganisms directly through its toxicity effects and indirectly by adversely affecting soil physical and as well as chemical properties. In general, high exchangeable Na in soils causes soil sodicity which affects soil fertility and productivity.

2.2.8 Exchangeable Calcium and Magnesium

Soils in areas 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 humid regions Jordan (1993). Soils under continuous cultivation, application of acid forming inorganic fertilizers, high exchangeable and extractable Al and low pH are characterized by low contents of Ca and Mg mineral nutrients resulting in Ca and Mg deficiency due to excessive leaching Dudal and Decaers (1993).

Exchangeable Mg commonly saturates only 5 to 20% of the effective CEC, as compared to the 60 to 90% typical for Ca in neutral to somewhat acid soils Brady and Weil (2002). Research works conducted on Ethiopian soils indicated that exchangeable Ca and Mg cations dominate the exchange sites of most soils and contributed higher to the total percent base saturation particularly in Vertisols Mesfin Abebe (1998); Eyelachew Zewdie (2001). Different crops have different optimum ranges of nutrient requirements. The response to calcium fertilizer is expected from most crops when the exchangeable Ca is less than 0.2 cmol (+)/kg of soils, while 0.5 cmol (+)/kg soil is reported to be the deficiency threshold level for Mg in the tropics Landon (1991).

2.2.9 Micronutrients (Fe, Mn, Zn and Cu)

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 Foth and Ellis (1997). According to the same authors, 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 soil OM or by clay-size inorganic soil components is an important mechanism of removing micronutrients from the soil solution Foth and Ellis (1997). Thus, each may be added to the soil’s pool of soluble micronutrients by weathering of minerals, by mineralization of OM, or by addition as a soluble salts Foth and Ellis (1997). Factors affecting the availability of micronutrients are parent material, soil reaction, soil texture, and soil OM Brady and Weil (2002). Tisdale *et al.* (1995) stated that micronutrients have positive relation with the fine mineral fractions like clay and silt while negative relations with coarser sand particles. This is because their high retention of moisture induces the diffusion of these elements Tisdale *et al.* (1995). Soil OM content also significantly affects the availability of micronutrients. According to Hodgson (1963), the presence of OM may promote the availability of certain elements by supplying soluble complexing agents that interfere with their fixation.

Krauskopf (1972) 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. Brady and Weil (2002) 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).

3. MATERIALS AND METHODS

3.1 Description of the Study Area

The study was conducted in Borodo watershed. The watershed is administratively situated in *Dendi* district, west *shewa zone of oromya* region in central Ethiopia. (Figure.1) .Geographically, the watershed is located between $9^{0}02'$ N and $38^{0}07'$E with an altitude ranging between 1800 and 2700 m.a.s.l. HARC (2010). Its *slope* varies from 2-3%, 10-12% and 20-21% in the *Deposition zone*, *Transition* and *Upstream* parts respectively and the scarp of the watershed was covered by forest and its slope reached to 67-118 %. (Figure.2)

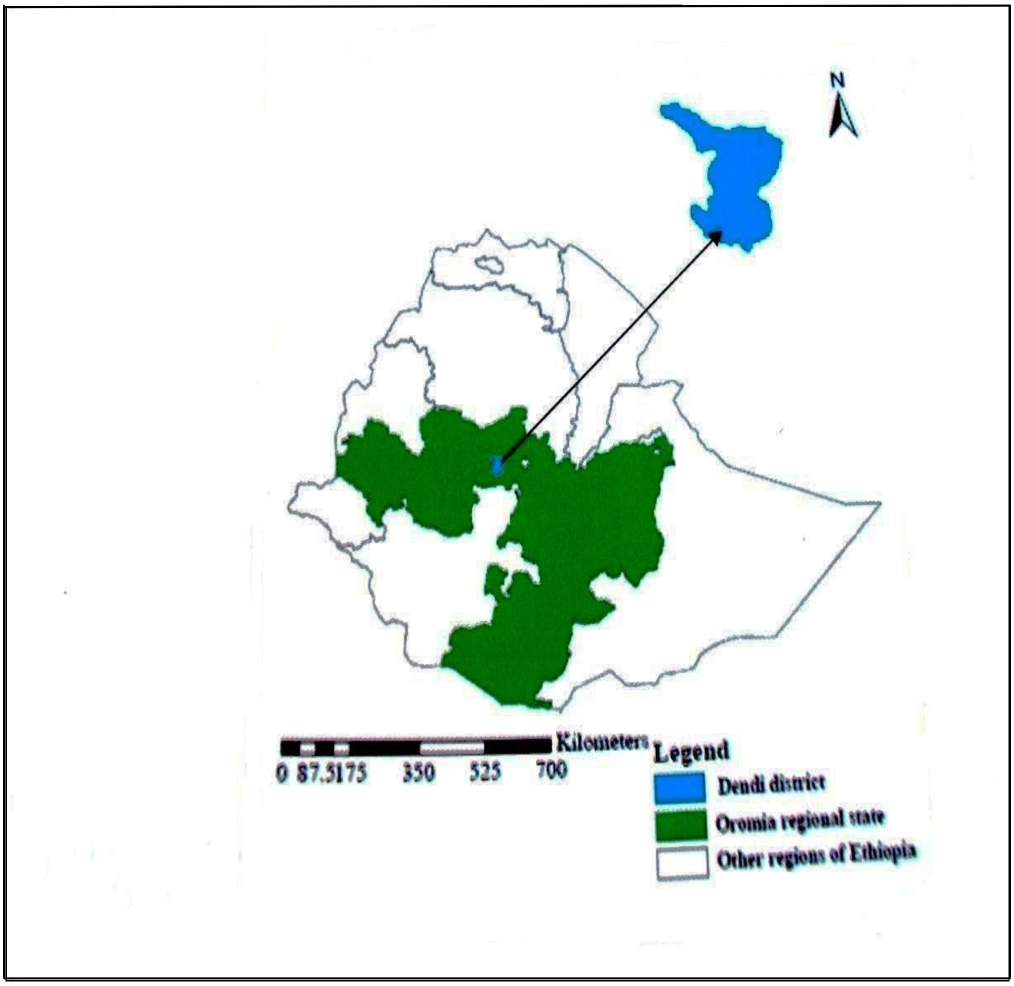


Figure.1 Location of the Study Area,Borodo Watershed in Dendi District

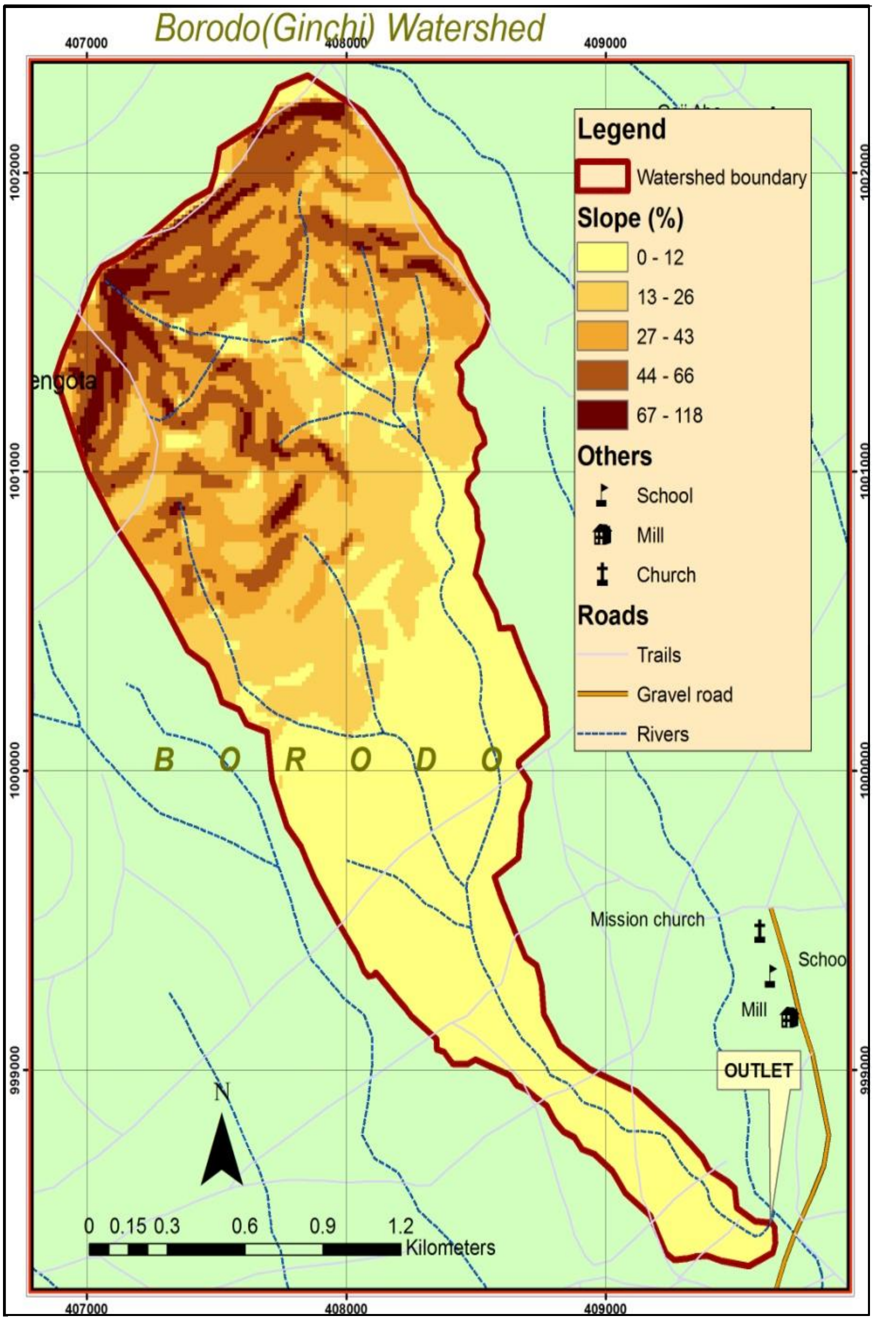


Figure.2 Digital Elevation Model (DEM) of Borodo Watershed, Dendi District West Shewa Zone Oromia Region, Central Ethiopia (HARC, 2010)

The watershed covers 320ha area and elevation ranges from 2160m in the south to 2800m in the north with a mean slope of 8.2%.Vertisols, VerticCambisols and Nitosols in the order are the three dominant soil types in the watershed. Vertisols occupy the lower parts in the landscape while Nitosols dominant the upper part of the watershed. VerticCambisols occur in mid-slope**.** Selamyihun Kidanu (2004).

3.2 Natural Resources

Borodo watershed is enriched with different environmental resources such as soil resources, water resources and forest resources. The management and use of natural resources determine both current and future livelihood.

3.2.1 Soil Resources

Farmers recognize three soil types, namely, *Koticha*, *Abolsi* and *Dimile* based on color, fertility level and workability. Soil color and relative fertility are the most important criteria for differentiating among the various soil groups.

Vertisols locally referred as *Koticha* are black in color and relatively fertile soils. These soil types is most often found on valley bottoms and hence by virtue of its slope are characterized by inadequate drainage. As farmers said that, this soil is the most fertile soil found in their area and tef is the most preferred crop grown. Tef is the most preferred and well adapted crop on *Koticha* soils. Lentil, chick pea, rough pea and durum wheat are also grown on vertisols late in the season or residual moisture.
Vertic Cambisols locally referred as *Abolsi* is the second most important soil type often found on relatively gentle slopes and undulating topography in the watershed. It is dark red and gray in color, relatively fertile and well drained .Bread wheat, faba bean and field peas are usually grown on this soil type.

Nitosols locally referred as *Dimile* soils are red to reddish brown in color often found at the Upper part of the watershed. Dimile soils are well drained but are often considered less fertile. Wheat, faba bean and field pea are the preferred crops on this soil types HARC (2010).

Participatory diagnosis of the natural resources revealed that crop production expanded to protected natural forests and marginal lands. As population grew and the demand for land increased, traditional soil fertility management practices such as fallowing, crop rotations and the use of manure which had been used widely gave way to continuous cropping. Consequently, workability of the soil has declined which increased cost of production and lowered agricultural productivity on household food security. Aware of the worsening land degradation and in an attempt to improve soil fertility and productivity, farmers have started using chemical fertilizers.

Nevertheless, chemical fertilizer use in the study area is still low. Even those households using inorganic fertilizer apply at sub-optimal level mainly due to high fertilizer prices and restricted access to credit.

As noted earlier, *Koticha* soils by their very nature suffer from water logging due to inadequate drainage. Farmer soil management strategies on koticha soils include: *Planting crops such as teff which are tolerant to water logging on relatively flat lands and Planting crops such as lentil, chick pea and rough pea on residual moisture late on gentle slopes late in the season.*

Given that most of the *Koticha* soils in the study area are on relatively gentle slopes the traditional management practices are considered good enough for *Kotich*a soils in the study area. Consequently, water logging, though important yield limiting factor, is not considered a serious soil management problem by the local community in the watershed.

3.2.2 Water Resources

Rainfall, rivers, torrents and perennial springs and tap- water are the main sources of water for agriculture and domestic use. All of the rivers in watershed are seasonal and hence agriculture is dependent on rainfall. Efforts made to build big water harvesting ponds for irrigation purposes were not successful for the pond did not hold water due to high percolation. As a results farm households' aspiration to engage in the production of high value crops using irrigation was thwarted.

Farmers in the middle and lower part of the watershed have tap-water from the ground for domestic use while residents in the upper parts of the watershed get drinking water from two well developed springs.

3.2.3 Forest Resources and Tree Management

Natural forest resources in the district have declined considerably. The Chilemo forest reserve which used to cover 26 thousand ha about 30 years ago has now shrunk to less than 6 thousand ha. Of this forest area only a small proportion is part of the Borodo Watershed. Over the years households need for forest products have changed considerably. Previously trees were mainly cut for making traditional plough equipments, bee hives and house construction. Recently, however, indigenous trees which had made a significant proportion of the Chilimo forest have been cut for domestic fuel and commercial purpose. Consequently, the indigenous trees such as zigba (*Podocarpus falcatus*), Yabesha tid (*Juniperus procera*), weira (*Olea africana*) tikur enchet (*Prunus africana*) agam (*Carissa edulis*) shenet and shola (*Ficus sur*), girar (*Acacia abyssinica*), Cheleleka (*Apodytes dimidiata*) are almost wiped out from the tree population.

In an attempt to protect the dwindling forest coverage and make the most out of it, households bordering the Chilimo forest have been organized into forest management and utilization cooperatives. The cooperatives have now developed byelaws governing the utilization and development of the forest under their influence. This development, on one hand, by improving sense of ownership encouraged sustainable utilization of the forests. On the other hand, this arrangement which has denied households residing in the middle, lower parts of the watershed and the ownership access to the forest has become a source of conflict. Farmers who do not access to the forest are now planting Eucalyptus trees on farm lands, homesteads and river banks to satisfy their firewood and construction demand. Eucalyptus has now expanded to all parts of the watershed as demand for energy and construction increased. For instance one farmer has about 14 ha of eucalyptus woodlot in the watershed. There is also one communally owned Eucalyptus woodlot established during the Derg regime. This wood lot, however, is poorly managed and as a result the trees couldn’t grow up to commercial size.

Owing to the dwindling natural forest, government and NGOs are promoting aforestation programs and woodlot in the watershed. To this end one community nursery has been established in the kebele near the watershed which provides tree seedlings. Eucalyptus seedlings are most preferred in the watershed for its fast growing ability and high market demand. Among others, the swelling and cracking nature of the *Koticha* soil has contributed to poor survival rate of seedlings. Future attempts in the forestry sector, therefore, need to provide farmers with high value fruit trees and multipurpose tree species that could do well under the *Koticha* soils.

3.3 Major Crops and Cropping Systems

3.3.1 Major Crops

The major crops in the watershed include tef, chick pea, rough/grass pea, wheat, maize and faba bean in the given order while noug, lentil, potato, oats, sorghum, black and white cumin, fenugreek and linseed are minor crops. Household preference to grow these crops depends on their relative contributions to the household food basket, feed and marketing values. Choice of crop also depends on suitability to edaphic and climatic conditions to the area. Crops such as wheat, potato and linseed are mainly grown in the relatively high altitude areas of the watershed whereas tef, chickpea, rough pea and spices like Fenugreek thrive in the lower and middle parts of the watershed.

3.3.2 Cropping Systems

Crops and cropping activities in Borado watershed are essentially determined by the onset of rainfall and its distribution. Although, the area receives a bimodal rainfall, *belg* extending from February to May and *meher* from June to September, much of the cropping is done in the main rainy season (June-September) when there is assured rainfall. Cultivation of crops during the *belg* season is insignificant and only few farmers are noted growing oats for cattle feed. All crops are entirely rain dependent and there is no irrigation service in the area due to lack of water sources.

3.4 Methods of Data Collection

This research uses primary and secondary data to answer the research questions and to achieve objectives. Secondary data sources like published and unpublished studies, journals and office reports were some of the secondary sources used to obtain socioeconomic and biophysical conditions of the study area.

Different participatory rural appraisal (PRA) tools /techniques were employed to interview farmers, development agents and experts. Qualitative information was generated from focus group discussions.

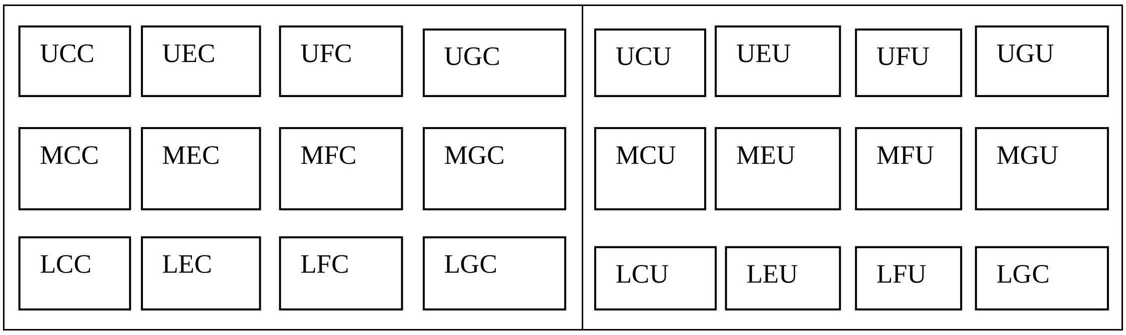
3.4.1 Participatory Rural Appraisal (PRA) Techniques

The PRA tools used for the study include observation/transect walk, focus group discussion. Reconnaissance surveys (field visit of the study area) were made to get first impression on the soil conservation structures constructed in the study watershed. Key informants who are knowledgeable about the area were used to identify the causes and effects of land degradation in the watershed. Checklist was used to ask and probe key informants regarding the causes and effects of land degradation. The focus groups one from each watershed zone was conducted using check list (Appendix II). The number of members in the group was eight to ten.

3.5 Soil Sampling

Representative sites in the Watershed where conservation practices are exercised were identified. Similarly farmers managing their land without conservation practice were identified. These watershed zones as much as possible needs to have representative land use systems including *crop lands, permanent grazing lands, forestlands and land covered by Eucalyptus trees*. Replicate soil samples were taken by drawing a quadrant from the four land use types. (Figure.3)

Figure.3 Soil Sampling Design of my Study Area.



UCC	UEC	UFC	UGC	UCU	UEU	UFU	UGU
MCC	MEC	MFC	MGC	MCU	MEU	MFU	MGU
LCC	LEC	LFC	LGC	LCU	LEU	LFU	LGC

Where; UCC- Upstream Cultivated Conserved, MCC- Middle Cultivated Conserved, LCC- Lower Cultivated Conserved, UEC- Upstream Eucalyptus Conserved and UCU- Upstream Cultivated Unconserved, UEU- Upstream Eucalyptus Unconserved,UFU- Upstream Forest Unconserved, UGU- Upstream Grazing Unconserved.

During collection of samples; dead plants, furrow, old manures, wet spots, areas near trees and compost pits were excluded this was done to minimize differences, which may arise because of the dilution of soil OM due to mixing through cultivation and other factors.

Soil sampling was done around December, at early dry season after the crop harvest. Composite soil samples were taken using standard procedures at 20cm depth using soil sampling auger. From each Watershed zone a total of 24 composite samples were collected in 3 triplicates. In total for the three locations (*upstream, middle and downstream*) would have 72 soil samples (3slopes*4landuse systems*3replications*2(*conserved/ unconserved areas in the watershed)* was collected. The soil samples collected from representative watershed zones with three replications were then air-dried, mixed well and passed through a 2 mm sieve for the analysis of selected soil physical and chemical properties. Soil core samples from 0-20cm depth were taken with a sharp-edged steel cylinder forced manually into the soil for bulk density determination. Global Positioning System (GPS) and clinometers were used to identify the geographical locations and slopes of the sampling sites, respectively.

3.6 Soil Laboratory Analysis

The soil physical and chemical analysis was carried out at Holleta Agricultural Research Center (HARC) and Debrezeit Agricultural Research Center (DZARC) Agricultural and Nutritional Research Laboratories. Standard laboratory procedures were followed in the analysis of the selected physicochemical properties considered in the study.

3.6.1 Analysis of Soil Physical Properties

Soil particle size distribution was determined by the Boycouos hydrometric method Bouyoucos (1962); Van Reeuwijk (1992). The USDA Particle size classes viz. sand (2.0-0.05mm), silt (0.05-0.002mm) and clay (<0.002mm), were used when classifying the textural classes. Moisture content was determined by initially weighing the field samples, drying the field samples at 105^{o}C for 24 hours, and weighing them again. The percentage of water held in the soil was calculated gravimetrically as the weight difference of field and oven dried soils divided by field soil alone multiplied by 100 Anderson et al. (1982). Soil bulk density was determined by the undisturbed core sampling method after drying the soil samples in an oven at 105^{o}C for 24hr to constant weights, while particle density was measured by the pycnometer method Black (1965). Percentage pore space was computed from the values of bulk density (BD) and particle density (PD) Brady and Weil (2002) as:

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

3.6.2 Analysis of Soil Chemical Properties

The pH of the soils was measured in water suspension in a 1:2.5 (soil: water ratio) Van Reeuwijk (1992). The Walkley and Black (1934) wet digestion method was used to determine soil carbon content and percent soil OM was obtained by multiplying percent soil OC by a factor of 1.724 following the assumptions that OM is composed of 58% carbon. Total N was analyzed using the Kjeldahl digestion, distillation and titration method as described by Black (1965). Available soil P was analyzed according to the standard procedure of Bray K.H. and Kurtz L.T (1945) extraction method. Available sulfur was determined by 0.5M NH_4OAC-0.25 (CH_3COOH) Acetic Acid Extraction method Singh et.al (1995).

Cation exchange capacity (CEC) and exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were determined after extracting the soil samples by ammonium acetate (1N NH_4OAc) at pH 7.0. Exchangeable Ca^{2+} and Mg^{2+} in the extracts were analyzed using atomic absorption spectrophotometer, while Na^+ and K^+ were read by flame photometer Chapman (1965); Rowell (1994). Cation exchange capacity was thereafter estimated titrimetrically by distillation of ammonium that was displaced by sodium from NaCl solution Chapman (1965). Percentage base saturation (PBS) was calculated by dividing the sum of the charge equivalents of the base-forming cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) by the CEC of the soil and multiplying by 100. Exchangeable acidity was determined by saturating the soil samples with potassium chloride solution and titrated with sodium hydroxide as described by Mclean (1965).Available micronutrients (Fe, Cu, Zn and Mn) were extracted by DTPA (Diethylenetriamine acetic acid) as described by Sahlemedhin Sertsu and Taye Bekele (2000) and all these micronutrients were measured by atomic absorption spectrophotometer.

3.7 Data Analysis

Data analysis was done by Statistical analysis system (SAS) software SAS (2002). Analysis of variance (ANOVA) was performed to see the effect of different treatments. Mean separation was performed using Duncan's multiple range test (DMRT). Moreover, simple correlation analysis was done with the method of Gomez (1984) to reveal the magnitudes and directions of relationships between selected soil fertility parameters.

4. RESULTS AND DISCUSSION

4.1 Impact of Soil Conservation Practices on Soil Physical Properties

The results of soil analyses on bulk density (BD), particle density (PD), Moisture retained in the soil, total porosity (TP) of different land use systems at both conserved and unconserved sites within three slope positions are presented in (Table 1 and 2). The highest BD was found at both Conserved Lower cultivated land (1.06g/cm^3) and Unconserved middle Cultivated Land (1.01g/cm^3) followed by the soil under Grazing Lands. In contrast, the lowest BD values of middle conserved forest land (0.67g/cm^3) and unconserved middle forest land (0.68g/cm^3) respectively. The high bulk density under cultivated lands was due to frequent tillage for growing for small sized annual crops, particularly teff (*Eragrostis tef*) may be a major contributing factor. The highest bulk density in the cereal land use may also be a reflection of low organic carbon under cereal lands. Tillage could be the main factors that could reduce organic carbon by destroying soil aggregate, thereby exposing organic carbon for decomposing agent Solomon *et al.* (2002).

The results were in agreement with that of Islam and Weil (2000). Similar study by (Lemenih et al., 2005) also reported that significant higher bulk density under farmlands as compared to other land uses in the highlands of Ethiopia. The grassland had lower bulk density than the cultivated land which could be due to restricted grazing at the grassland to harvest fodder and free grazing on crop lands after harvest and continuous ploughing at the same depth of cultivated lands. Evrendilek et al. (2004) also reported that conversion of grassland into cultivated land during a 12-year period increased Bulk density by 10.5% but decreased Total Porosity by 9.1%.

Moreover, in uncultivated land, there was relatively higher organic matter (OM) making the soil loose, porous and well-aggregated that might have reduced the BD. The BD was negatively correlated with OM (r = -0.47**) and low in conserved lands for all land use systems. (Table.10) Similar results were reported by Celik (2005). The reason for the lowest soil bulk density on the forest land could be due to the highest clay and OM content and less disturbance of the land under forest unlike other land uses.

Considering the main effects of land use, slope positions and conservation soil moisture (%) was significantly different at (p≥0.05) (Table 2). The highest (17.14%) and lowest (7.24%) moisture contents were found in the conserved upper forest and unconserved upper cultivated lands, respectively.

Table.1 Soil Bulk Density (g/cm^{3}) Under Different Slope Positions and Land use Systems in Both Conserved and Unconserved Sites of Borodo Watershed, Central Ethiopia.

Slope position	Land use type							
	Conserved Land				Unconserved Land			
	E	F	G	C	E	F	G	C
Lower	0.75^{d}	0.71^{de}	0.84^{c}	1.06^{a}	0.69^{f}	0.76^{e}	0.79^{e}	1.01^{ab}
Middle	0.86^{c}	0.67^{e}	0.74^{d}	1.03^{a}	0.82^{e}	0.68^{f}	0.98^{ab}	1.03^{a}
Upper	0.82^{c}	0.72^{de}	0.95^{b}	1.01^{ab}	0.91^{cd}	0.76^{a}	0.89^{d}	0.97^{bc}

*Means with same superscript in the same column and row for same conservation practice are not significantly different (P≥0.05). E= Eucalyptus plantation Land, F= Forest, G= Grazing, C= Cultivated land.

The reason for the highest present of moisture on the forest land could be due to the highest OM and conservation measures makes the forest lands undisturbed. The results were in agreement with that of Woldeamlak Bewket and Stroosnijder (2003) reported that soil organic matter helps to retain essential nutrients, improves infiltration and water holding capacity and reduces erosion.

The moisture content at conserved site negatively correlated with BD and PD (r = -0.87**and -0.17**). On the other hand, it was positively correlated with OM and total N (r = 0.48** and 0.49**). (Table.10). Moisture in a soil was the highest in natural forestland followed by Eucalyptus plantation in both conserved and unconserved sites. Higher clay and OC provided large surface area required for absorption and retention of water molecules Mulongey & Merck (1993). Natural forest soils have more available water holding capacity compared to the cultivated lands (Ayoubi et al., 2011). It is apparent, however, that soils with clayey texture have high moisture retention than loam textured soils Brady & Weil (2002).

Table.2 Percent Soil Moisture, Particle Density (PD) and Total Porosity (TP) Under the Different Slope Positions and Land use Systems Both in Conserved and Unconserved Sites in Borodo Watershed, Central Ethiopia.

Slope position	Land use type							
	Conserved Land				Unconserved Land			
	E	F	G	C	E	F	G	C
	Moisture (%)							
Lower	12.75^{bc}	16.97^{a}	10.71^{c}	8.35^{d}	15.59^{ab}	13.49^{ab}	11.42^{ab}	7.60^{bc}
Middle	9.60^{cd}	16.14^{ab}	13.59^{b}	7.90^{d}	12.48^{ab}	17.66^{a}	7.67^{b}	7.47^{c}
Upper	13.31^{b}	17.14^{a}	10.42^{c}	6.47^{e}	13.04^{ab}	13.59^{ab}	10.93^{ab}	7.24^{c}
	Particle density (g/cm^3)							
Lower	2.14^{ab}	2.27^{a}	2.11^{ab}	2.17^{ab}	2.08^{ab}	2.08^{ab}	2.08^{ab}	2.08^{ab}
Middle	2.14^{ab}	2.27^{a}	2.21^{ab}	2.24^{ab}	2.00^{ab}	2.08^{ab}	2.20^{a}	2.20^{a}
Upper	2.20^{ab}	2.04^{b}	2.14^{ab}	2.27^{a}	2.00^{ab}	1.86^{ab}	2.03^{ab}	2.08^{ab}
	Total porosity (%)							
Lower	65.33^{ab}	69.00^{a}	60.66^{ab}	51.66^{c}	67.00^{a}	63.33^{a}	62.66^{ab}	51.33^{b}
Middle	60.00^{ab}	70.66^{a}	66.33^{ab}	54.00^{c}	59.00^{b}	67.33^{a}	55.66^{b}	53.00^{b}
Upper	62.66^{ab}	64.33^{ab}	55.66^{bc}	55.33^{c}	54.66^{b}	59.33^{ab}	56.00^{b}	53.66^{b}

*Means with same superscript in the same column and row for same conservation practice are not significantly different ($P \geq 0.05$). E= Eucalyptus plantation Land, F= Forest, G= Grazing, C= Cultivated land.

The highest PD of (2.27 g/cm^3) was recorded on the upstream cultivated conserved land and lowest (1.86g/cm^3 and 2.0 g/cm^3) were recorded on the upper stream forest and middle and upper eucalyptus lands respectively. In unprotected cultivated lands, the finer soil particles will be selectively removed by erosion, thereby increasing the proportion of the coarser particles in the soil which leaves more sand particles (Ayoubi et al., 2011) that increases particle density. In similar soil types, keeping other things constant, soils with higher proportion of sand particles have higher particle density than otherwise Brady & Weil (2002).

The sand and clay fractions were significantly ($P \geq 0.05$) affected by Slope positions, land use types and conserved /unconserved sites. Similarly, the silt fraction was highly significantly affected by land use and significantly ($P \geq 0.05$) by the interaction of the three factors (Table 3).The highest average sand content (25%) was observed under the unconserved lower grazing land lowest (12.5%) was recorded under conserved middle forest Land. Opposite to sand the highest clay fraction (70.83%) was found in the lower conserved forest Land. Unlike conserved lands, the sand fraction in unconserved land is not significantly different at ($P \geq 0.05$) in both streams and land use types. This indicates that it is the inherent soil property and the position on the landscape (slope gradient) which cause the variation in texture. With steep landscapes, transportation and translocation of fine particles are expected.

This result also confirms the presence of higher clay fraction in the lower slope gradient due to deposition from the upper slope. Regina et.al (2004) also reported that on the steep cultivated hill slope the most noticeable changes were a decrease in clay and a corresponding increase in sand and silt fractions as the slope gradient increases.

This may be due to the fact that the high mean annual precipitation over the study area may be selectively transported and/or leached fine fractions leaving behind the coarser fraction Chesworth.W (2008).

Sand was positively and significantly ($r = 0.26$) correlated with the exchangeable acidity and negatively ($r = -0.11$) with the CEC of the soils while clay was positively and significantly ($r = 0.15$) correlated with the CEC and negatively ($r = -0.12$) with the exchangeable acidity of the soils. (Table. 10)

Table.3 Particle size (Sand, Silt and Clay) Distributions of the Soils Under the Different Slope Positions and Land use Systems Both in Conserved and Unconserved sites in Borodo Watershed, Central Ethiopia.

Slope position	Land use type							
	Conserved Land				Unconserved Land			
	E	F	G	C	E	F	G	C
	Clay (%)							
Lower	57.50^{bc}	70.83^{a}	55.83^{c}	65.00^{ab}	60.00^{a}	45.00^{bc}	44.16^{bc}	61.66^{a}
Middle	59.16^{bc}	64.16^{ab}	60.83^{b}	67.50^{ab}	55.00^{ab}	54.16^{b}	55.00^{ab}	49.16^{bc}
Upper	50.41^{cd}	40.00^{d}	35.83^{d}	52.50^{c}	36.66^{c}	45.83^{bc}	59.16^{a}	40.83^{bc}
	Silt (%)							
Lower	27.50^{b}	16.66^{bc}	30.83^{ab}	21.66^{b}	23.50^{bc}	30.83^{bc}	30.83^{bc}	21.66^{c}
Middle	27.50^{b}	22.50^{b}	25.83^{b}	19.16^{bc}	21.66^{c}	30.00^{bc}	29.16^{bc}	25.83^{bc}
Upper	34.58^{ab}	39.16^{ab}	40.83^{a}	30.00^{b}	39.16^{ab}	32.50^{bc}	32.66^{b}	40.83^{a}
	Sand (%)							
Lower	15.00^{b}	12.50^{b}	13.33^{b}	15.83^{b}	16.66^{a}	24.16^{a}	25.00^{a}	16.66^{a}
Middle	13.33^{b}	12.50^{b}	13.33^{b}	13.33^{b}	23.33^{a}	15.83^{a}	15.83^{a}	25.00^{a}
Upper	15.00^{b}	20.83^{ab}	23.33^{a}	17.50^{ab}	24.16^{a}	21.66^{a}	15.00^{a}	20.00^{a}

*Means with same superscript in the same column and row for same conservation practice are not significantly different (P≥0.05).). E= Eucalyptus plantation Land, F= Forest, G= Grazing, C= Cultivated land.

4.2 Impact of Soil Conservation Practices on Soil Chemical Properties.

The soils pH-H_2O value was significantly affected by slope positions, landuse types and conserved and unconserved lands (P ≥0.05). (Table.4) The highest soil pH values of 6.75 and 6.36 were found under lower cultivated unconserved and lower conserved forest land; whereas, the lowest pH values of 5.53 were registered under middle conserved grazing and cultivated lands. (Table.4).The soil pH range of 5.5-6.5 indicated moderately to slightly acidic soil condition under all the land use systems. Soils under grazing land were more acidic, owing to leaching of basic cations by erosion since the land is over grazed and highest in forest land due to the presence of high OM that is the primary source of basic salts.

On the other hand low pH under cereal lands may be caused due to complete removal of crop biomass also long-term application of chemical fertilizer mainly DAP and Urea which may rise the carbonate level of the soil. Similarly it may be due to its highest microbial oxidation in cultivated lands that produces organic acids, which provide H ions to the soil solution and thereby lowers soil pH. (CEC, OC, TN) and pH have had strong positive relations with each other at CEC (r= 0.35**), OC (r= 0.18) and TN(r= 0.12). (Table.10)

The organic carbon (OC) content varied widely under different slope positions, land use types and conserved and unconserved lands. It ranged between 0.93% in cultivated middle unconserved land to 4.20 % in the conserved upstream natural forest land (Table 5). Based on the ratings of Landon (1991), it was very low in cultivated land and medium under natural forest land.

It could be attributed to improved aeration that promoted mineralization of OC or owing to the little or no return of plant residues and manures into the soils. The conversion of forest ecosystem to other forms of land cover may decrease the stock of OC due to changes in soil moisture and temperature regimes, and succession of plant species with differences in quantity and quality of biomass returned to the soil Offiong et al. (2009).

Evrendilek et al. (2004) showed that deforestation and subsequent cultivation decreased organic matter by 48.8%. Moreover, the conversion of forest into cropland is known to deteriorate soil physical properties and making the land more susceptible to erosion since macro-aggregates are disturbed Çelik (2005). OC is a powerful indicator for assessing soil potential productivity Shukla et al. (2006).

Total N contents of the soil were slightly affected by the different land use, slope positions and conserved and unconserved lands. Total N varied from 0.42 under upper forest conserved land to 0.06 under middle unconserved cultivated lands. The presence of dense vegetation affords the soil adequate cover thereby reducing the loss in macro and micro nutrients that are essential for plant growth and energy fluxes Iwara et al. (2011).

According to Havlin et al. (1999) the N content of natural forestland (0.42) and (0.06) cultivated land could be rated as high and low, respectively. Ayoubi et al. (2011) reported that natural forest soils had more TN as compared to the cultivated lands. Heluf Gebrekidan and Wakene Negassa (2006) recorded the highest total N on surface soil layers of virgin lands compared to research and farmers' fields. Total nitrogen had positive and significant correlation with organic carbon content of the soil (r = 0.62**) at both conserved and unconserved sites. (Table.10). Fisseha Itanna (2002) reported highly significant correlation ($p<0.01$) between nitrogen and organic matter contents of Vertisols at Shoa Robit (r = 0.90), Debre Zeit (r = 0.96) and Sheno (r = 0.99) sites of Ethiopia.

Table.4 Soil Reaction (PH), Organic Carbon, Total Nitrogen and Available Phosphorus Under Different Slope Positions and Land Use Systems in Both Conserved and Unconserved sites of Borodo Watershed Central Ethiopia.

Slope position	Land use type							
	Conserved Land				Unconserved Land			
	E	F	G	C	E	F	G	C
	(1:2.5 Soil-H_2O)							
Lower	5.60^{b}	6.36^{ab}	6.55^{a}	6.35^{ab}	5.91^{ab}	5.96^{ab}	6.38^{ab}	6.75^{a}
Middle	5.79^{b}	5.56^{b}	5.53^{b}	5.77^{b}	6.05^{ab}	5.53^{b}	5.66^{b}	6.13^{ab}
Upper	5.81^{b}	5.92^{b}	5.98^{b}	5.95^{b}	5.84^{ab}	5.84^{ab}	5.57^{b}	6.31^{ab}
	Organic Carbon (%)							
Lower	2.21^{bc}	2.82^{b}	2.74^{b}	1.43^{bc}	2.17^{ab}	2.39^{ab}	2.67^{ab}	1.15^{b}
Middle	2.40^{bc}	1.89^{bc}	2.58^{b}	0.93^{bc}	3.50^{a}	2.88^{ab}	2.54^{ab}	1.17^{b}
Upper	2.22^{bc}	4.20^{a}	1.54^{bc}	1.96^{bc}	2.10^{ab}	2.66^{ab}	2.92^{ab}	1.84^{b}
	Total nitrogen (%)							
Lower	0.29^{b}	0.19^{bc}	0.18^{bc}	0.07^{c}	0.20^{c}	0.16^{cd}	0.18^{c}	0.08^{cd}
Middle	0.19^{bc}	0.16^{bc}	0.17^{bc}	0.08^{c}	0.31^{b}	0.19^{c}	0.18^{cd}	0.06^{d}
Upper	0.26^{bc}	0.42^{a}	0.12^{c}	0.12^{c}	0.28^{bc}	0.47^{a}	0.25^{c}	0.16^{cd}
	Available Phosphorus (ppm)							
Lower	4.67^{c}	3.22^{c}	2.75^{c}	6.05^{b}	8.08^{b}	6.13^{bc}	3.67^{c}	3.40^{c}
Middle	2.61^{c}	3.57^{c}	5.02^{bc}	3.27^{c}	5.51^{bc}	4.92^{bc}	4.66^{bc}	5.38^{bc}
Upper	5.52^{bc}	16.73^{a}	0.92^{cd}	4.45^{c}	4.14^{c}	19.07^{a}	2.89^{c}	2.75^{c}

*Means with same superscript in the same column and row for same conservation practice are not significantly different ($P \geq 0.05$). E= Eucalyptus plantation Land, F= Forest, G= Grazing, C= Cultivated land.

The Available phosphorus (AP) content of all land use systems ranged from 19.07 in the upstream forest lands and 0.97 occur in upper grazing land revealing that soils in the forest lands rating medium and very low in grazing lands. Thomas (2000). Among the land use systems, the natural forestland contained relatively higher concentration of Available Phosphorous as a result of high organic matter which released phosphorus during its mineralization. Organic compounds in soils increase P availability by the formation of organophosphate complexes that are more easily assimilated by plants, anion replacement of H_2PO_4 from adsorption sites, the coating of Fe/Al oxides by humus to form a protective cover and reduced phosphorus fixation. Moreover, decomposing of OM releases acids that increase the solubility of calcium phosphates Ahn (1993) and Havlin et al. (1999). Available P was positively correlated with OC (r = 0.33 **) for both conserved and unconserved lands. (Table.10). The results were in agreement with the reports of Yihenew Gebreselassie (2002) who indicated that OC positively correlated with AP.

The content of exchangeable calcium (Ca) was significantly ($P \geq 0.05$) affected by slope positions, land use types and conservation and their interaction. The highest Exchangeable calcium (40.05meq/100g) and the lowest (14.54meq/100g) was observed under conserved upper forest and lower eucalyptus lands respectively. (Tables .5)

Exchangeable magnesium content was significantly ($P \geq 0.05$) affected by slope positions, land uses types and conserved and unconserved sites (Table 5). Considering the main effects of land use, slope positions and conserved and unconserved sites the highest (19.17meq/100g) and the lowest (5.11meq/100g) exchangeable magnesium value was recorded under upper conserved forest and lower unconserved eucalyptus lands, respectively (Table 5).

This result agrees with similar studies by Muluneh Mengist (2011) who found a decreasing trend of Ca^{2+} and Mg^{2+} with increasing age of eucalypts globules plantation in the high lands of Ethiopia. Fast growing nature of eucalyptus species and its voracious nutrient uptake may cause the changes.

Exchangeable Ca was positively and significantly correlated with exchangeable Mg (r = 0.49**), CEC (r = 0.07), exchangeable K (r =0.30**), clay (r = 0.27*) and total N (r = 0.18). (Table.10)

Exchangeable K content was significantly ($P \geq 0.05$) affected by land use and the interaction of slope positions, land use types and conserved and unconserved sites. (Table.5). It was highest (1.23meq/100g) unconserved upper forest land and lowest (0.29meq/100g) in the upper grazing lands. The highest content in the forest land was related with its high pH value and was in agreement with study results reported by Mesfin Abebe (1996) that high K was recorded under high pH tropical soils.

The ranges of mean exchangeable K values observed in this study show that K^+ was above the critical levels (0.38 meq/100g) for the production of most crop plants as indicated by Barber (1984).

Generally, the lower exchangeable K contents in the cultivated and the grazing lands than in the forest land might be due to its continuous losses in the harvested and grazed parts of the plants from the cultivated and grazing lands, respectively. 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 Baker *et al*. (1997); Wakene Negassa (2001).

The content of exchangeable Na was significantly affected by the interaction of slope positions, land use types and conserved and unconserved lands at ($P \geq 0.05$). Considering the main effects of land use, slope positions and conserved and unconserved lands exchangeable Na content was highest (3.39 meq/100g) under conserved lower grazing land and lowest (0.34meq/100g) in the upper unconserved cultivated land (Table 5).

The highest concentration of the exchangeable Na^+ in pasturelands may be due to the effects of livestock urine, which is added daily to this land use type through free grazing. This result was in agreement with Landon (1991).

Table.5 Exchangeable Calcium (Ca), Magnesium (Mg), Potassium (K) and Sodium (Na) Under Different Slope Positions and Land use Systems in Both Conserved and Unconserved sites of Borodo Watershed, Central Ethiopia.

Slope position	Land use type							
	Conserved Land				Unconserved Land			
	E	F	G	C	E	F	G	C
	Calcium (meq/100g) soil							
Lower	14.54^{e}	23.25^{d}	15.70^{e}	19.69^{d}	26.20^{ab}	24.17^{b}	22.36^{bc}	19.03^{c}
Middle	27.60^{c}	25.31^{cd}	25.98^{cd}	33.13^{bc}	16.47^{c}	16.39^{c}	17.41^{c}	24.17^{b}
Upper	31.78^{bc}	40.05^{a}	31.86^{bc}	34.31^{b}	28.42^{a}	31.65^{a}	19.51^{c}	27.25^{ab}
	Magnesium (meq/100g) soil							
Lower	8.94^{d}	11.76^{c}	7.71^{d}	8.88^{d}	5.11^{f}	13.22^{b}	12.95^{b}	8.87^{d}
Middle	16.37^{b}	18.80^{a}	16.33^{b}	14.69^{bc}	12.20^{bc}	17.70^{a}	10.10^{cd}	16.83^{a}
Upper	15.11^{b}	19.17^{a}	19.06^{a}	15.49^{b}	10.16^{cd}	11.26^{c}	7.38^{e}	10.15^{cd}
	Potassium (meq/100g) soil							
Lower	0.77^{b}	0.66^{bc}	0.52^{c}	1.15^{a}	0.99^{ab}	0.76^{b}	0.65^{bc}	0.76^{b}
Middle	0.64^{bc}	0.38^{c}	0.76^{b}	0.79^{b}	1.09^{ab}	0.35^{c}	0.50^{bc}	0.86^{ab}
Upper	0.68^{bc}	1.07^{a}	0.64^{bc}	0.77^{b}	1.23^{a}	1.23^{a}	0.29^{c}	1.18^{a}
	Sodium (meq/100g) soil							
Lower	1.54^{b}	1.14^{bc}	3.39^{a}	3.28^{a}	1.28^{c}	1.86^{bc}	1.89^{bc}	3.38^{a}
Middle	1.51^{bc}	0.92^{c}	0.96^{bc}	0.88^{c}	1.35^{c}	0.79^{d}	1.06^{c}	2.26^{b}
Upper	1.45^{bc}	1.52^{bc}	0.80^{c}	0.49^{c}	0.99^{c}	0.97^{c}	0.87^{cd}	0.34^{d}

*Means with same superscript in the same column and row for same conservation practice are not significantly different ($P \geq 0.05$). E= Eucalyptus plantation Land, F= Forest, G= Grazing, C= Cultivated land.

The exchangeable acidity was significantly ($P \geq 0.05$) affected by slope positions, land use types and conserved and unconserved sites. (Table. 6) The highest (0.65 cmol /kg) and the lowest (0.11 cmol /kg) exchangeable acidity were recorded under the middle conserved eucalyptus land and the upper unconserved forest and grazing lands, respectively (Table 6).

This result agrees with similar studies by Muluneh Mengist (2011) who found a decreasing trend of Ca^{2+} and Mg^{2+} with increasing age of eucalypts globules plantation in the high lands of Ethiopia.

Exchangeable acidity was negatively and significantly correlated with pH (r = -0.15) and exchangeable basic cations such as Ca (r = -0.32**), Mg (r = -0.07), K (r = -0.16) and Na (r= -0.25*). (Table.10). Nair and Chamuah (1993) reported that the concentration of the H^+ to cause acidity is pronounced at pH value below 4 while excess concentration of Al^{3+} is observed at pH below 5.5. However, the results of this study indicate that the pH of the study area was above 5.5 and basic cations had occupied the site. Therefore, the concentration of exchangeable Al^{+3} was trace and Al toxicity is not expected in the area.

Table.6 Exchangeable Acidity (Cmol/kg) Under Different Slope Positions and Land use Systems in Both Conserved and Unconserved sites of Borodo Watershed, Central Ethiopia.

Slope position	Land use type							
	Conserved Land				Unconserved Land			
	E	F	G	C	E	F	G	C
Lower	0.35^{b}	0.21^{bc}	0.24^{b}	$0.18b^{c}$	0.30^{ab}	0.32^{ab}	0.31^{ab}	0.28^{ab}
Middle	0.65^{a}	0.13^{bc}	0.15^{bc}	0.23^{bc}	0.33^{ab}	0.37^{a}	0.30^{ab}	0.24^{b}
Upper	0.14^{bc}	0.15^{bc}	0.10^{c}	0.18^{bc}	0.23^{b}	0.11^{c}	0.16^{bc}	0.14^{bc}

*Means with same superscript in the same column and row for same conservation practice are not significantly different ($P \geq 0.05$). E= Eucalyptus plantation Land, F= Forest, G= Grazing and C= Cultivated land.

The CEC values of the soils in the study area were significantly ($P \geq 0.05$) affected by slope positions, land use types and conserved unconserved lands. (Table .7) Considering the main effects of slope positions, land uses and conserved and unconserved lands the highest (53.14 cmol /kg) and the lowest (32.92 cmol / kg) values of CEC were observed under the lower conserved forest and the upper grazing unconserved lands, respectively (Table 7). It is a general truth that both clay and colloidal OM have the ability to absorb and hold positively charged ions.

Table.7 Cation Exchangeable Capacity (Cmol/kg) Under Different Slope Positions and Land use Systems in Both Conserved and Unconserved sites of Borodo Watershed, Central Ethiopia.

Slope position	Land use type							
	Conserved Land				Unconserved Land			
	E	F	G	C	E	F	G	C
Lower	39.74^{d}	53.14^{a}	43.56^{cd}	48.03^{bc}	45.14^{ab}	42.68^{b}	$41.31b^{c}$	47.72^{ab}
Middle	40.08^{d}	40.58^{cd}	40.24^{d}	38.86^{d}	43.04^{b}	48.42^{a}	36.58^{c}	42.43^{b}
Upper	42.08^{cd}	49.14^{b}	43.73^{c}	41.40^{cd}	37.95^{c}	46.34^{ab}	32.92^{d}	37.53^{c}

*Means with same superscript in the same column and row for same conservation practice are not significantly different (P≥0.05). E= Eucalyptus plantation Land, F= Forest, G= Grazing and C= Cultivated land.

Thus, forest soils containing high clay and organic matter contents have high cation exchange capacity. The Cation exchange values of soils under conserved plots were relatively better than in the non-conserved plots. This could probably be due to higher organic matter content in the conserved plots than in the non-conserved ones. Cation exchange capacity was significantly and positively correlated with clay and organic matter (OM).

According to Landon (1991), the top soils having CEC of > 25, 15-25 cmol /kg, 5-15 cmol(+)/kg and < 5 cmol(+)/kg are classified as high, medium, low and very low, respectively. Based on the above ratings, all land uses in all of the three slope positions qualify for high status of CEC, respectively (Table 7).

Therefore, deforestation, overgrazing and changing of land from forest to crop land without proper management aggravates soil fertility reduction. Therefore, the result of this study indicated that the CEC of the forest land was significantly higher than the adjacent three land use types.

The contents of available micronutrients (Fe, Mn, Zn and Cu) were significantly (P ≥ 0.05) affected by slope positions, land use systems and conserved and unconserved lands (Table 8). Considering the main effects of land use, slope positions and conserved and unconserved lands the highest (17.23ppm) and lowest (9.53ppm) contents of Fe were recorded under unconserved middle eucalyptus and in the middle unconserved cultivated lands. Similarly the highest (9.18ppm) and lowest (1.20ppm) Zn content were recorded under upper forest and lowest in the upper unconserved cultivated land. The highest and lowest (3.63ppm, 0.14ppm) and (7.85ppm, 1.38ppm) Mn and Cu values were recorded under middle conserved cultivated and forest lands and lower unconserved grazing and middle forest unconserved lands, respectively.

The results of the study also indicated that the contents of all these micronutrients were higher in the forest land these may be due to the presence of high amount of OM in forest lands.

These results were also supported by Wakene Negassa (2001) who stated that micronutrients content increased with the increase in OM and total N. In this study, available Fe, Cu and Zn had significant ($P > 0.05$) and strong positive correlation ($r = 0.32^{**}$, 0.12 and 0.24) with OC in their orders (Table 8 and 10).

Table.8 Available Soil Micro Nutrients (Fe, Mn, Zn and Cu) Under Different Slope Positions and Land use Systems in Both Conserved and Unconserved sites of Borodo Watershed, Central Ethiopia.

Slope position	Land use type							
	Conserved Land				Unconserved Land			
	E	F	G	C	E	F	G	C
	Iron (ppm)							
Lower	10.23^{c}	14.13^{ab}	11.60^{bc}	10.22^{c}	10.59^{cd}	12.63^{bc}	14.06^{bc}	8.62^{d}
Middle	12.33^{b}	15.06^{a}	10.86^{bc}	12.06^{bc}	17.23^{a}	14.80^{b}	8.98^{d}	9.53^{d}
Upper	12.36^{b}	12.66^{b}	11.83^{bc}	14.60^{ab}	10.76^{cd}	11.30^{cd}	12.50^{c}	10.56^{cd}
	Zinc (ppm)							
Lower	1.44^{c}	1.79^{c}	1.91^{c}	1.51^{c}	1.33^{d}	1.54^{d}	2.18^{d}	1.83^{d}
Middle	2.15^{c}	1.83^{c}	1.78^{c}	1.60^{c}	5.16^{b}	2.36^{cd}	2.46^{cd}	2.08^{d}
Upper	1.53^{c}	6.15^{a}	3.99^{b}	1.20^{c}	3.68^{c}	9.18^{a}	1.89^{d}	7.94^{a}
	Manganese (ppm)							
Lower	0.78^{d}	1.70^{c}	2.36^{bc}	1.26^{cd}	4.33^{a}	3.60^{ab}	0.66^{d}	3.46^{b}
Middle	2.37^{b}	0.14^{d}	1.03^{cd}	3.63^{a}	1.72^{cd}	1.07^{d}	0.74^{d}	0.58^{d}
Upper	0.63^{d}	1.32^{cd}	0.30^{d}	1.40^{cd}	0.71^{d}	1.43^{cd}	2.10^{c}	1.32^{cd}
	Copper (ppm)							
Lower	2.20^{b}	2.20^{b}	3.91^{b}	3.32b	3.65^{c}	5.00^{b}	7.85^{a}	3.48^{c}
Middle	2.16^{b}	2.12^{b}	2.72^{b}	2.36^{b}	3.04^{c}	1.38^{d}	3.97^{bc}	3.28^{c}
Upper	2.88^{b}	6.00^{a}	2.14^{b}	5.54^{ab}	1.97^{d}	2.21^{d}	2.11^{d}	1.80^{d}

*Means with same superscript in the same column and row for same conservation practice are not significantly different ($P \geq 0.05$). E= Eucalyptus plantation Land, F= Forest, G= Grazing and C= Cultivated land.

Lindsay and Norvell (1978) indicated that the critical levels of available Fe and Mn for crop production are > 40 (ppm) and 48 (ppm), respectively. Therefore, according to the suggestions made by them, the soil of the study area was below the toxicity level of Fe and Mn nutrients for producing crops.

The lowest available micronutrients under the cultivated land compared to the other land use types might be due to crop harvest, OM degradation, and sheet and rill erosions that were aggravated by continuous cultivation with very low input of farming system.

Generally, the SOC, N, Av-K and Av-P concentrations in land uses with structures were found to be significantly higher than in the adjacent non-conserved land use types. This indicates the positive impacts of SWC structures in improving the nutrient status of land uses treated by structures. According to Troeh et.al (1980) the aim of soil and water conservation is both addressing proper use of soil and maintaining its productive capacity by minimizing soil degradation rate. Diaz et.al (2005) also indicated that organic carbon (OC), total nitrogen (N) and bulk density were significantly affected by soil conservation measures**.**

Based on this study soil bunds stabilized with vetiver and other improved forage grasses were more effective in reducing soil fertility loss and runoff losses in Borodo watershed.

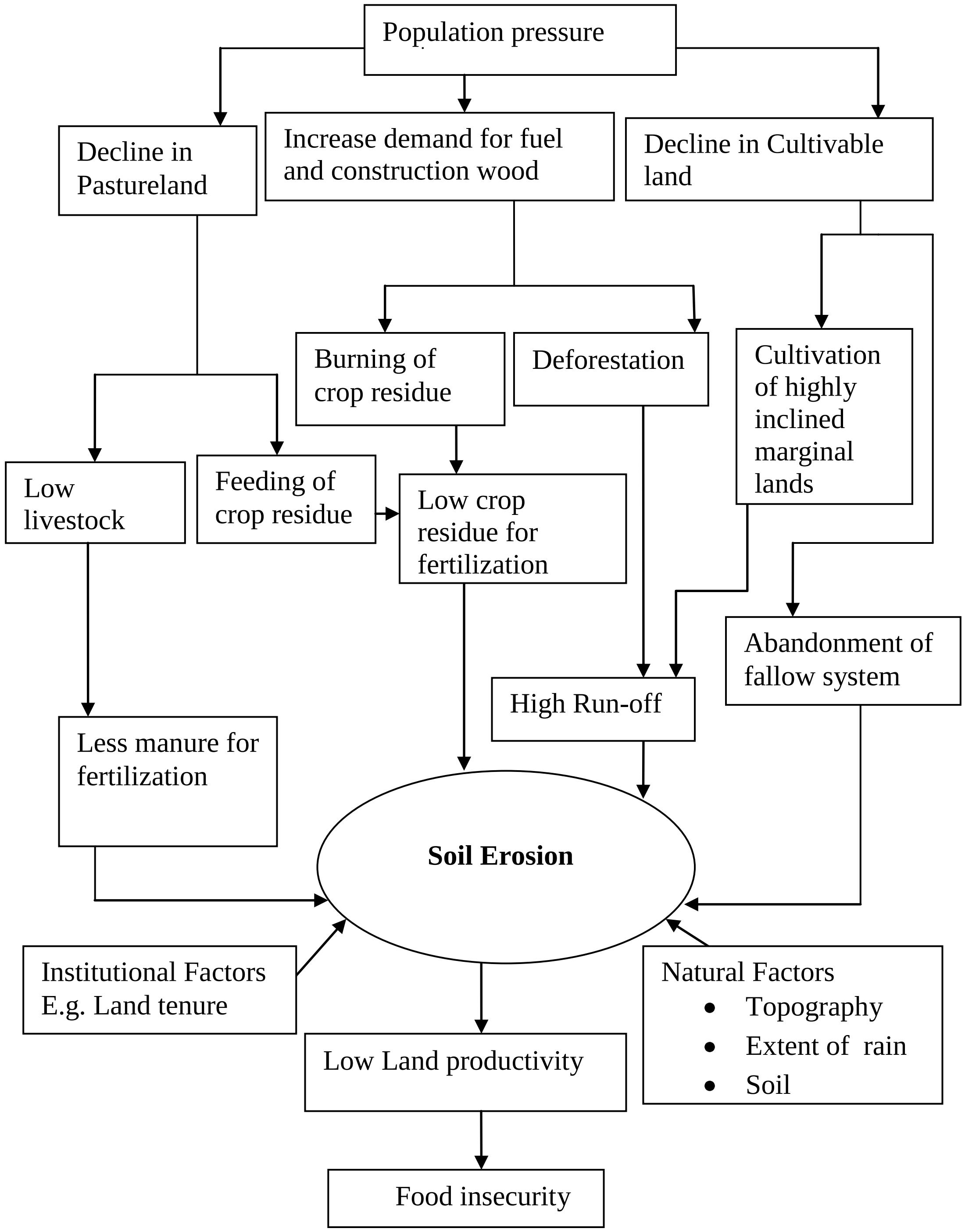
4.3 Causes and Effects of Land Degradation in Borodo Watershed.

The effect of increased human population and its subsequent effect on natural resources degradation and soil fertility, which ultimately end with lower agricultural productivity and food insecurity. Figure 4 described the focused group discussion of causes and effects on natural resource management with key informants in Borodo watershed. Rapid population growth and long history of sedentary agriculture has changed the land use/land cover system and has been a major cause of environmental degradation on most parts of the world including Ethiopia Feoli et al. (2002). The problem of land degradation and low agricultural productivity in the study area, resulting in food insecurity and poverty is also assessed and indicated in figure 4. Finding solutions to these problems require identifying the farming system, the environment, the community and the overall interactions.

Land shortage is the most common socio-economic problem in Borodo watershed. It is the most important source of livelihood for smallholder farmers in Ethiopia in general and the study watershed in particular. Land holdings vary considerably among the community, ranging from nil to as high as 1.4ha. Analysis of landholdings by the community revealed that about 15% households do not own any land. Land ownership per household has declined considerably over years due to population pressure.

Although land is a public property and land holders could not sell their land, a thriving land market has emerged in the study area. Consequently, quite a good number of households acquire additional land from fellow farmers who could not cultivate their holding as a result of resource constraints such seed and fertilizer. This and the other cause and effect of major socio-economic and biophysical problems of Borodo watershed is presented in (Table.9).

Figure.4 Schematic Presentation of Cause and Effect of Land Degradation in Borodo Watershed.



4.4 Major Problems in the Watershed

Table.9 Cause-Effect Relationships of Major Socio-Economic and Biophysical Problems in Borodo Watershed, Dendi Woreda

No.	Constraint	Cause	Effect	Response to the problems
1	Land shortage	•Increasing population •Land degradation	•Increasing landlessness •Informal land market developed. •Increased involvement of HHs in off-farm activity •Increased conflict	•Deforestation (encroachment of cultivated lands to Chilemo forest) • Plowing marginal lands • Land intensification (e.g. inorganic fertilizer use)
2	Soil erosion	• Soils are fragile and susceptible to erosion • Increased run off due to deforestation of uplands	• Low soil fertility • Cultivated lands transected by Gullies • Reduced arable land • High cost of production • Increased soil acidity particularly on *dimile* soils	• Uncoordinated effort to construct physical SWC structures • Few HHs use inorganic fertilizer and Manure • Acquire additional land through various arrangements • Migrate seasonally in search of work

3	Weed on crops	• Continuous and mono cropping • Use of recycled seeds repeatedly	• Low crop yield • Low quality seed • High cost of production due to high labor input • Divert scarce cash resources to purchase herbicide	• Resort to herbicide use • Utilize traditional labor pooling arrangements locally know as *debo* and *wonfel*
4	Shortage of water • Household consumption • Cattle • Irrigation	• Increased demand due to human and livestock population pressure • Early drying of springs • Low recharge of ground water	• Female travel long distance to fetch water • Reduced water use for domestic purpose	• Use water stringently
5	Shortage of animal feed	• Limited grazing land • Use of low yielding natural pasture	• Reduced livestock productivity • Increased livestock death	• Collect and conserve crop residues • Maintain few livestock

6	Deforestation	• Excessive and illegal tree cutting • Limited tree planting • Inefficient utilization of communally owned natural forests	• Excessive run off • Shortage of wood and timber for domestic use • Reduced income • Micro-climate change	• Establish private and communal eucalyptus woodlots • Stringent use of available trees • Increased use of livestock dung for domestic fuel
7	High input and commodity prices • Fertilizer • Clothing • Grocery items	• High inflation • Lengthy marketing chain • Low income	• Reduced input use (e.g. suboptimal use of commercial fertilizers) • Low school enrolment • Worsening living standards (poverty)	• Depend on own farm products • Started using compost • Reduce consumption of purchased inputs and commodities

8	Low crop yield	• Limited use of improved crop varieties • Use of traditional cropping practices • Use of recycled own seeds	• Insufficient production • Inadequate nutrition • Low income • Low living standard	• Start using improved varieties • Seeking extension support to have access to improved technologies • Involve in Off farm activities.

Table.10 Pearson’s Correlation matrix for various Soil physicochemical parameters

	BD	MO	PD	TP	EA	PH	CEC	N	S	P	OC	K	Clay	Silt	Sand	Mg	Ca	Na	Cu	Zn	Mn	Fe
BD	1																					
MO	-0.87**	1																				
PD	0.17	-0.17	1																			
TP	-0.90**	0.77**	0.25*	1																		
EA	-0.08	-0.05	-0.01	0.09	1																	
PH	0.24*	-0.19	-0.08	-0.28*	-0.15	1																
CEC	-0.25*	0.38**	-0.08	0.21	-0.03	0.35**	1															
N	-0.49**	0.49**	-0.52**	0.25*	-0.06	0.12	0.09	1														
S	- 0.25*	0.38**	-0.26*	0.13	-0.03	-0.18	0.08	0.55**	1													
P	-0.30*	0.35**	-0.44**	0.11	-0.19	-0.01	0.35**	0.68**	0.41**	1												
OC	-0.47**	0.48**	-0.39**	0.30**	-0.05	0.18	0.07	0.62**	0.38**	0.33**	1											
K	0.15	-0.05	-0.29*	-0.29*	-0.16	0.35**	0.19	0.28*	0.36**	0.44**	-0.06	1										
Clay	-0.05	0.04	0.27*	0.16	- 0.12	0.05	0.15	-0.22	-0.16	-0.16	0.14	0.25*	1									
Silt	0.02	-0.07	-0.14	-0.08	-0.14	-0.23*	-0.27*	0.23*	0.10	0.06	0.19	-0.02	-0.82**	1								
Sand	0.14	-0.01	-0.33**	-0.28*	0.26	0.21	-0.11	0.05	0.13	0.15	0.10	0.42**	-0.57**	0.07	1							
Mg	-0.12	0.18	0.20	0.20	-0.07	-0.21	0.14	-0.05	0.06	0.05	0.04	-0.15	-0.19	0.11	0.09	1						
Ca	0.03	0.03	-0.03	-0.05	-0.32**	-0.08	0.07	0.18	0.04	0.39**	0.01	0.30**	0.27*	0.25*	0.12	0.49**	1					
Na	0.22	-0.20	-0.20	-0.21	-0.25*	0.44**	0.31**	-0.22	-0.16	-0.01	0.15	0.05	0.17	-0.22	0.01	-0.30**	-0.37**	1				
Cu	0.02	-0.07	-0.05	-0.02	-0.03	0.38**	0.11	0.01	-0.08	0.19	0.12	0.11	-0.15	-0.06	0.30**	0.03	0.14	0.25*	1			
Zn	-0.04	0.04	-0.44**	-0.15	-0.25*	0.01	0.05	0.49**	0.34**	0.46**	0.24*	0.46**	-0.50**	0.43**	0.29*	0.05	0.29*	-0.27*	-0.11	1		
Mn	0.03	-0.03	-0.14	-0.08	0.25*	0.16	0.12	-0.11	-0.42**	0.03	0.04	0.05	0.33**	-0.32**	-0.06	-0.39**	-0.01	0.20	0.07	-0.17	1	
Fe	-0.42**	0.36**	0.01	0.40**	0.03	-0.08	0.07	0.17	0.08	-0.04	0.32**	-0.16	-0.05	-0.08	-0.01	0.36**	0.03	-0.30**	0.03	0.01	-0.14	1

**Significant at P = 0.01 level; * significant at P = 0.05 level; EA = Exchangeable Acidity; TN =Total nitrogen (N), BD= Bulk Density, PD= Particle density, Mo=Moisture, CEC=Cation exchangeable capacity, OC= Organic carbon, N= Nitrogen, S= Sulfur, P= Phosphorus, K= Potassium, Ca= Calcium, Mg= Magnesium, Na= Sodium, Cu= copper, Zn= Zinc, Mn= Manganese, Fe= Iron

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study revealed that, the use of soil and water conservation structures in Borodo watershed had been found beneficial in protecting the cultivated land and other land use types from erosion and the corresponding nutrient depletion.

Reckless deforestation and conversion to crop production and continuous and intensive cultivation of soils with very low inputs have been practiced in the highlands of the study area over thousands of years as elsewhere in the country. Population pressure has also led to cultivation of marginal lands and steep slopes.

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 direct causes of land degradation, including decline in the use of fallow, limited recycling of dung and crop residues to the soil, limited application of external sources of plant nutrients, deforestation and overgrazing are apparent and generally agreed. Underlying these direct causes include population pressure, poverty, high cost and limited access to agricultural inputs and credit, fragmented land holdings and insecure land tenure, and farmers' lack of information about alternative appropriate technologies. The process of prolonged use of lands for crop production with no or only little inputs has exacerbated soil quality decline leading to soil degradation, which may ultimately lead to complete loss of land values.

The attributes of the soils under the cultivated lands showed overall change towards the direction of loss of their fertility compared to the soils attributes of the adjacent forest and grazing land soils. Major declines were observed for soil organic matter, which is the principal source of plant nutrients (such as Ca^{2+}, $Mg^{2+,}$ N, S and P) and helps to sustain soil fertility by mineralization and nutrient retention in low input tropical farming systems. The decreased values of the soil organic matter on the cultivated fields would indicate higher N and organic carbon losses from the agro ecosystem compared to the forest system. The higher OM values in the grazing and forest lands indicate low activities of N-losing and P- losing processes, which is due to the relatively closed nutrient cycling and minimal disturbance in the natural forest system.

The process of declining soil organic matter following land use changes and lack of Soil conservation structures has apparently caused significant impacts not only on the continuous decline in plant nutrient pools such as the pool of total N, P and OC but also on the soil physical properties such as pore space and Particle density and moisture holding capacity of the soils.

The results of the soil analysis showed that most of soil physicochemical properties had significant variations with respect to management practices, land use types and slope gradients. Bulk density in soil under conserved farm plots was lower than in the non-conserved farm plots. Bulk density and texture fractions of sand and clay also varied with landuse types and slope gradients the average values of selected soil physical properties under the Eucalyptus plantation lands, forest, grazing, and cultivated lands showed changes in total porosity from (60.23, 63.33, 58.10 and 52.66%) for unconserved land to (62.00,66.80,60.88,60.22%) conserved landuse types, respectively.

The contents of available micronutrients (Fe, Mn, Zn and Cu) were significantly ($P > 0.05$) affected by slope positions, land uses and conserved and unconserved lands. The results of the study indicated that the contents of all these micronutrients were higher in the conserved forest land these may be due to the presence of high amount of OM in forest lands.

5.2 Recommendations

The risk of sustainable crop production is indicated by these variations of soil physicochemical properties between land use types and conserved unconserved lands and watershed zones in the study watershed. Therefore, strategies to feed the expanding population in the study areas will have to seek a sustainable solution that better addresses integrated soil management. In addition, improvement in the management of the soil resources for sustainable agricultural use would be one of the most useful strategies that could help to protect biological diversity from agricultural land expansion. Findings of more research work on nutrient management that integrates the present soil conservation structures (Soil bunds and soil bunds stabilized by vetiver grass and other improved forage grasses) 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 watershed.

Generally, the SWC structures had shown positive impacts on the soil conditions, measured by the various soil physical and chemical properties. Considering the advantages of SWC structures towards improving the soil quality and thereby sustainable agricultural productivity, there should be a continuous awareness creation mechanism and a follow up process on the proper maintenance and management of the structures along with integrating agronomic measures using appropriate plant species and also governmental and non-governmental rural development programs and strategies should be flexible in responding to the various agro-ecological zones, local resource endowment and farmers capacity to invest in affordable integrated soil fertility management (ISFM) techniques.

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APPENDICES

Appendix I: Long Year climatic data form Ginchi (near Borodo watershed) Station

Element: Monthly rainfall (mm)

Region: Oromya

Station: Ginchi

Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1995	0.0	42	81	158	70.0	135	166	183	159	3.3	0.0	6.7
1996	59	5.5	149	123	176.1	195	225	168	124	11	1.5	0.0
1997	34	0.0	4.7	85	60.1	156	265	230	166	76	53.3	0.7
1998	35	39	114.8	85	120.4	209	227	330	176	91	0.0	0.0
1999	18	1.3	38.5	240	77.8	83	239	193	96	157	3.5	0.0
2000	0	0.0	10.70	77	50.6	153	200	224	168	45.4	58.2	3.0
2001	18	16	152.4	23	114.1	228	192	149	83	28.6	2.6	1.5
2002	98	22	88.1	23	7.8	142	158.8	158	48	3.8	1.8	59.0
2003	7.5	48	62.4	13	4.7	125	253	280	96	4.9	4.6	4.5
2004	53	5.6	42.5	101	46.4	119	211	248	169	10.6	7.9	0.0
2005	64	2.4	97.8	59	134.8	144	219	217	132	14.1	6.3	0.0
2006	0.0	0	102.7	85	75.4	131	330	235	177	28.4	7.3	4.8
2007	16	33	40.2	53	105.8	232	207	199	91	25.7	0	0.0
2008	16	33	40.2	53	105.8	232	207	199	91	25.7	0	0
2009	14	6.6	14.2	21	56.7	105	249	257	80	55	0	9.9
Mean	19	36	69.3	89	88.4	152	228	223	133	34.7	11.8	7.2

Element: Monthly Maximum temperature (^{0}C)

Region: Oromya

Station: Ginchi

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1995	26.2	27.1	27	24.9	25.6	25	21.2	21.7	22.8	24.6	25.9	25.1
1996	24.7	27.5	26	25.3	24.7	22.7	21.6	21.7	22.8	24.8		
1997	24.9	27	27.9	25.4	27.3	24.1	21.4	21.9	23.5	23.7	24	25.2
1998	25.7	27	26.1		26.6	24.7	21.8	21.6	22.6	23.5	24	24.2
1999	24.9		26.9	27.5	26.2	31.7	20.6		22.3	22.3	23.4	23.6
2000	25.7	26.7	27.4	26	26	24.1	21.7	20.7	21.8	22.8	23.8	24.1
2001	24.9	26.6	24.9	26.7	25.3	23	21.4	21.6	23.1	24.3	24.8	24.9
2002	24.6	26.8	25.7	27.5	27.7	24.8	23	21.9	23	25.5	25.7	25
2003	25.7	27.6	27	26.1	28.4	24.3	21	21.2	21.9	24.1	24.8	24.5
2004	25.9	8.2	27.1	25.7	27.1	23.6	21.5	22	22	22.8	24.9	25.2
2005	25.3	28.1	27.2	27	25.7	25.1	22.6	22.3	22	23.7	24.4	24.8
2006	26.1	27.5	26.4	26	26.6	24.2	21.8	20.9	21.8	24	24.1	24.3
2007	26	26.1	26.9	25.8	26.2	23.7	21	21.1	21.9	23.3	23.7	23.6
2008	25.4	25.7	27.3	26.9	25.4	23.1	21.6	21.3	21.7	23.5	22.3	23.9
2009	23.9	25.9	27.1	26.3	27.2	25.7	21.0	20.8	22.3	23.0	24.1	22.7
Mean	25.25	25.6	26.638	25.94	26.06	24.199	21.519	21.288	22.23	23.559	24.248	24.406

Element: Monthly Minimum temperature (^{0}C)

Region: Oromya

Station: Ginchi

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1995	6.53	9.54	9.71	11.1	9.85	8.42	9.84	9.53	8.49	5.59	5.02	6.55
1996	7.5	6.64	9.05	7.99	8.73	8.92	8.55	8.15	7.48	4.23	5.4	3.95
1997	6.19	3.64	7.6	7.28	6.23	7.23	7.55	7.52	6.48	6.19	5.68	3.55
1998	5.58	7.83	6.6		9.04	7.27	8.88	8.94	7.33	6.82	2.37	1.69
1999	5.47		7.4	8.02	7.94	4.13	5.18		2.43	2.76	3.77	6.04
2000	6.45	7.45	10.49	11.02	10.48	9.67	10.69	10.63	10	8.69	6.57	5.47
2001	7.02	7.42	10.31	9.53	10.19	9.83	10.69	11.15	8.65	7.57	5.08	5.84
2002	7.4	7.11	9.71	8.95	10.82	9.55	10.4	9.79	8.93	6.19	5.02	8.29
2003	6.72	8.04	9.11	9.8	9.29	9.63	11.29	11.52	10.52	6.87	6.45	5.84
2004	9.5	8.22	9.41	10.44	10.18	10.87	11.06	11.55	10.68	7.96	6.63	8.1
2005	8.73	8.7	10.74	11.8	11.81	10.53	11.11	11.45	11.12	7.89	6.45	4.77
2006	8.65	10.74	11.38	11.65	10.69	10.94	11.53	11.58	10.64	10.1	7.27	8.06
2007	9.8	10.3	9.9	11.1	10.9	11	11.4	11.2	11	6.4	5.7	4.42
2008	7.6	8.0	9.7	10.2	10.5	9.8	10.4	10.5	9.2	7.8	6.1	5.2
2009	7.6	8.0	9.7	10.2	10.6	9.8	10.4	10.5	9.2	7.8	6.7	
Mean	7.59	8.80	9.61	10.16	9.99	9.45	10.08	10.30	9.30	6.99	5.81	5.97

Appendix II: 14. Checklists used for group discussion

1. What are the major socio-economic and biophysical problems in Borodo watershed?
2. Which are the major causes for the existing socio-economic and biophysical problems?
3. What are the effects perceived by the farmers about the major problems of this watershed?
4. What was the farmer’s response/current practice to curve the existing problems?
5. What was the major cause of land degradation in this Watershed?
6. What are the effects caused by land degradation in this watershed?
7. What are the most and frequently used soil and water conservation practices by local farmers in this watershed?
8. What are the major crops and cropping systems of this watershed?
9. What are the major soil types and other natural resources in this watershed?

DECLARATION

This is to certify that the thesis entitled "***Effects of Soil Conservation Practices on Selected Soil Nutrients in Borodo Watershed, Ethiopia*"** is my original work and has not been presented for a degree in any other university, and that all sources of material used for the thesis have been duly acknowledged. This is the actual work done by Mamaru Assefa under my guidance and supervision for the partial fulfillment of the award of the Degree of Master of Science in Environmental Science from Addis Ababa University, Addis Ababa.

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