EFFECTS OF FRUIT BASED LAND USE SYSTEMS ON SOIL PHYSICOCHEMICAL PROPERTIES: THE CASE OF SMALLHOLDERS FARMING SYSTEMS IN GAMO GOFA, SOUTHERN ETHIOPIA

M. Sc. THESIS

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APRIL 2007

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A THESIS SUBMITTED TO
SCHOOL OF GRADUATE STUDIES
HAWASSA UNIVERSITY (HU)

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGRE OF MASTER OF SCIENCE IN AGRICULTURE (SPECIALIZATION: SOIL SCIENCE)

TUMA AYELE YADDA

APRIL 2007
AWASSA

APPROVAL SHEET 1

This is to certify that the thesis entitled: Effect of Fruit Based Land use systems on soil Physicochemical Properties:The Case of Smallholders Farming Systems in Gamo Gofa, Southern Ethiopia; submitted in partial fulfillment of the requirements for the degree of Master of Science in Agriculture with specialization in Soil Science of the Graduate program of the Department of Plant Sciences, Awassa College of Agriculture, and is a record of original research carried out by Tuma Ayele Yadda ID. No. AWR/0026/98, under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged. Therefore I recommend that it be accepted as fulfilling the thesis requirements.

___________________	______________	_________
Name of major advisor	Signature	Date

or

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Name of co- advisor	Signature	Date

APPROVAL SHEET –2

We, the undersigned, members of the board of Examiners of the final open defense by Tuma Ayele Yadda have read and evaluated his thesis entitled "Effect of Fruit Based Land use systems on soil Physicochemical Properties: The Case of Smallholders Farming ystems in Gamo Gofa, Southern Ethiopia, and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Agriculture with Specialization in Soil Science

Chairman	Signature	Date
Advisor	Signature	Date
Internal Examiner	Signature	Date
External Examiner	Signature	Date

ACKNOWLEDGMENTS

The favor of God is really beyond my capacity of writing and saying in words, in all dimensions of my life and would like to take this opportunity to sincerely praise my God. The lord of universe ***"What shall I render unto the Lord for all his benefits toward me?"*** My thanks to my Lord and my God who guides and assists me in all the ups and downs I encountered in my life is inexpressible.

I extend my deepest gratitude to my advisor, Dr Sheleme Beyene, for his invaluable and endless support, his intellectual guidance and critical suggestions, which were instrumental in planning and implementation of the research work and production of this thesis in its present form. I would also like to express my internal appreciation to my co-adviser and instructor, Dr Abayneh Esayas for his unreserved and continuous encouragements, comments and material supports starting from the beginning of the work until its completion.

My deep thank is also for all my instructors for their encouragements and sympathy during the whole life at the Hawassa University. My acknowledgement also goes to my classmates and all the staff members of Gamo Gofa Zone Administrative office, especially the chief administrator, Ato Darot Gumaa and his secratary, W/ro Fasika Belete for their incomparable contributions in all the necessary things.

1 deeply acknowledge my whole family for their supporting and taking care in a good moral and behavior from my side

Finally, 1 would like to acknowledge the NORAD and NORAD Coordinator Dr. Admasu Tsegaye for the sponsoring this thesis work.

DEDICATION

This work is dedicated to my beloved wife W/ro Adanech Amanuel and my sons Zerubabel Tuma and Nathan Tuma.

ACRONYMS AND ABBREVIATIONS

ADLI	Agricultural Development Led Industrialization
AP (Olsen)	Available phosphorus extracted with Olsen method
ARD	Agriculture and Rural Development
Bd	Bulk density
C/N	Carbon to Nitrogen ratio
CEC	Cation Exchange Capacity
cm	centimeters
cmol	centi mole
CSA	Central Statistical Authority
DTPA	Diethylene triamine pentaacetic acid
EC	Electrical Conductivity
ECe	Electric conductivity of the saturated extract
EDTA	Ethylene diamine tetraacetic acid
EMA	Ethiopia Mapping Authority
ESP	Exchangeable Sodium Percentage
ESRDF	Ethiopia Social Rehabilitation Development Fund
FAO	Food and Agricultural Organization
FAO/UNESCO	Food and Agriculture Organization/United Nations Educational, Scientific and Cultural Organization.
GDP	Gross Domestic Product
HPCZ	High Potential Cereal Zone

HPPZ	High Potential Perennial Zone
IFOMA	International Federation of Organic Agriculture Movements
ILACO	International Livestock Agricultural Compendium
LPCZ	Low Potential Cereal Zone
m	meters
M	Molarity
Max.	Maximum
Mg/M^3	Mega gram per cubic meter
Min	Minimum
MOA	Ministry of Agriculture
N	Normality
NFIU	National Fertilizer Inputs Unit
OC	Organic Carbon
OFRF	Organic Farming Research Foundation
PBS	Percent Base Saturation.
Pd	Particle density
PET	Potential evapotranspiration
SNNPR	Southern Nations, Nationalities and Peoples Region.
TN	Total nitrogen
TP	Total Phosphoruse
ΔpH	Delta pH
θ	volumetric soil water content at sampling

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"Effect of Fruit Based Land use systems on soil Physicochemical Properties:
The Case of Smallholders Farming Systems in Gamo Gofa, Southern Ethiopia."

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ABSTRACT

An attempt has been made for systematic examination, description, characterization and assessment of Fruit Based Land Use Systems and their effect on physicochemical properties of the soils in Gamo Gofa Zone, Southern Ethiopia. The study area lies between 6^o 05' 53" to 6^o 06' 58" N and 37^o35' 09" to 37^o 36' 50" E at an elevation varying from 1100 to 1350 masl in Abaya Chamo Basin (ACB).In the ACB, the study catchment comprise of four peasant associations (3243.60 ha) in Arba Minch Zuria Woreda, which is one of the 15 woredas in Gamo Gofa Zone. The physiography is characterized by flat plain under forest and under cultivation. A survey was carried out in the study area, using semi-structured techniques. The different land use systems were subsistence farming (maize field), virgin land (natural forest), cash crop (monoculture banana field), and mixed fruit crop (mixed banana and mango) lands. Keeping in view the heterogeneity of the LUTs, four soil profiles were exposed and characterized for morphometric and physicochemical characteristics. One soil profile was opened in each LUT for field descriptions and laboratory studies in 2007. The soils were classified into Fluvisols and Cambisols as per FAO/UNSECO soil map of the world. The soil physical properties such as structure, bulk density, and total porosity were showed notable variations due to different land use system, particularly in A- horizon. The depletion of OC and TN from the A-horizon of maize field compared to virgin land was 61 and 59% respectively. Similarly, the depletion in OC and TN were 48.5 and 55.5% in banana field and 34 and 52% for mixed fruit cropland, respectively, during the past three decades. Likewise, the depletion of CEC from the banana and the maize fields were 32 and 13%, respectively, as compared to the CEC of A-horizon in the virgin land. The available micronutrients especially Fe and Cu were influenced due to difference in land use systems. These soil properties were positively and highly significantly correlated with total nitrogen and organic carbon content. Clay, organic carbon, total nitrogen and available phosphorous contents decreased with increasing depth. Total nitrogen and available phosphorous contents correlated positively and highly significantly with organic carbon and electrical conductivity. Generally, OC, TN, PBS, exchangeable K, Ca and Mg, available P, Mn and Fe contents decreased due to cultivation, where as build up of OC and TN were obtained in virgin land during the past four decades. Compared to cultivated land use systems. Therefore, management practices that improve soil quality should be integrated when the land is used for crop production. Further, studies on selection of appropriate leguminous specious that bring N to the system, nutrient flows and soil- plant analysis are recommended to draw sound conclusion.

1. INTRODUCTION

Agriculture in Ethiopia employs 85% of its population, accounts for about 45% of the gross domestic product (GDP) and over 90% of the national export earnings (MoA, 1995). In 2003/04 the agricultural sector contributed 43% to GDP (ESRDF, 2005). Within agriculture, some 60% of output comes from crop production, while the contribution of livestock and forest are 30% and 7%, respectively. In addition, Ethiopia has adapted a long-term development strategy of Agricultural Development-Led Industrialization (ADLI), more specifically, the smallholders' agriculture is the primary stimulus to generate employment and income, reduce poverty, promote industrialization and ensure a dynamic and self-sustaining growth (ESRDF, 2005).

Land, water and forests are the primary resources of agricultural production; and are essential to maintain human life and well being (FAO, 1994). The direct impact of the natural environment on productivity is correspondingly greater in tropics than in temperate developed regions (Norman *et al*., 1995). Land is basic agricultural resource, which, in Ethiopia is used by the farmers in traditional way without a logical organization of different types of land according to their actual physical configuration (MoA, 1995). This leads to risking degradation of the soil and disruption of agricultural production. Thus, the main cause of soil degradation in Ethiopia is the inappropriate use of land by man that is accentuated by population pressure and is characterized by high deforestation rate, poor management, over cultivation and overgrazing.

According to Turner *et al.* (1993), land use is obviously determined by environmental factors such as soil characteristics, climate, topography, and vegetation; it also reflects land's importance as a fundamental factor of production. Thus, understandings in land use and projecting future land use trajectories require understanding the interactions of the basic human forces that motivate production and communication. Moreover, information on soil management, use of fertilizers, and duration of fallow period, rotation systems and yield are important parameters for arable land use description (FAO, 1990; FAO, 1994).

Soil is part of the land, and the most important production factor for crops and at the same time, most influenced by the farmers. Soils are very diverse and complex system and full of life (IFOAM, 2002) that consist of mineral particles, organic matter and pores. The mineral particles contain nutrients, which are slowly released in the process of weathering; organic matter or humus vary in quantities, resulting from the decomposition of biomass; and minute pores filled with air or water (IFOAM, 2002). It is important for us to understand soils, the spatial arrangement of particles and pores, their physical and chemical characteristics, types, spatial distribution and how they are indispensable for our existence. Each soil type has quite different properties, qualities, characteristics and potentials (Gerrard, 2000; MoA, 1995).

Traditional fruit-based multi-tier cropping systems exist in Gamo Gofa, specifically around Arba Minch area, which is within the High Potential Perennial Zone (MoA, 1995). The cropping pattern of the area is substantially changed through time particularly with the modern irrigation systems intervention and subsequent infrastructure development such as asphalt road facility and land tenuring system during the last 10-15 years. As a result, a mixture of perennial fruit crops (dominantly bananas and mangoes) together with monoculture banana farming, and annual characterized subsistence farming systems are the current dominant land use types. The reasons for such land use /land cover changes were population pressures in need for fertile land and the near Arba Minch urbanization. Also in the past, extension recommendation and land tenuring ways enhanced production of annual crops (e.g., maize, cotton, etc) rather than perennial (e.g., pure stand banana plantations). In the last 10-15 years, however, the perspective of farmers was changed into diversification and /or pure stand banana plantation. These systems were implemented gradually and according to the farmer's time. Recently, the area was modified with irrigated farming system and the extension recommendation changed into crop specialization; specifically pure stand banana plantation rather than simple diversification because of higher economic importance. However, a large part of agriculture is still practiced with multiple (mixed) cropping and subsistence farming systems together with pure stand banana plantations without the use of agrochemicals.

Present land use studies are generally required to determine the production, which will be foregone when, and where irrigation project is implemented, monitor and improve the resource base for sustainable production, match the capability of land to appropriate agricultural use, secure food-plant nutrient management, and optimize management processes, and also for quantitative understanding of crop/environment relations (Norman *et al.,* 1995; FAO, 1985). In order to attain sustained production and increased yield, it is necessary to follow scientific approaches. Such approaches call for thorough understanding of the soil environment and the factors that influence agricultural yields. A proper understanding of the soil properties, both physical and chemical, is necessary to optimize management processes.

Despite the great economic importance of the traditional fruit-based land use systems in the area, limited studies have been carried out. The previous study of soils in the area by Murphy (1968) was on the fertility status and other data on some surface soils. The author indicated that the soils were neutral in reaction, contains between 1.3% and 2.3% OM, 0.05% to 0.11% total nitrogen, and were high in available phosphorus. The soils were high in calcium and well supplied with magnesium and varied in texture from sandy loam to silty clay (Murphy, 1968).

At present, about 80% of the study area is under cultivation, as people mainly depend on agriculture to meet their basic needs. It was found to be of paramount importance to study soil physicochemical properties in relation to fruit based land use systems with an emphasis on a comparison between natural virgin lands as well as subsistence farming system. Because, understanding soil physicochemical properties help to identify practical options that fit different farming systems (Bierman and Rosen, 2005; FAO, 1994). Therefore, the objectives of this study were research was initiated to:

- Understand the fruit based land use system(s) and its role on soil properties,
- Characterize the soil of the experimental area, and
- Make suggestion for sustainability fruit based land use system.

2. LITERATURE REVIEW

2.1. Land Use Systems

Land use is obviously constrained by environmental factors such as soil characteristics, climate, topography, and vegetation. It also reflects the importance of land as a key and finite resource for most human activities including agriculture, industry, forestry, energy production, settlement, recreation, and water catchments and storage (Turner *et al*., 1993). Land is a fundamental factor of production, and through much of the course of human history, it has been tightly coupled with economic growth (Richards, 1990). As a result, control over land and its use are often objects of intense human interaction. Human activities that make use of, and hence change or maintain, attributes of land cover are considered the proximate sources of change. They range from the initial conversion of natural forest into cropland to on-going management (Turner *et al*., 1993). According to the same, common land uses include agriculture, grazing, forestry, mineral extraction, and recreation.

The department of Land Use Study and Rural Technology Promotion (MoA, 1995; FAO 1985) indicated that the general land utilization pattern in Ethiopia with respect to area (percentage) include grazing land (51.0%), cultivated with perennial and annual crops (14.8%), forest land (3.6%), bush-and-shrub land (8.1%), currently unproductive land (3.8%) and unutilizable land (18.7%). Similarly, socio-economic data of Gamo Gofa Zone (1999-2003) indicated that the land use pattern of Arba Minch Zuria Woreda with respect to area coverage include cultivated land with perennial and annual crops, grazing land, forest land, currently unproductive land, and unutilizable land.

According to MoA (1995), there are three main production zones in the country depending altitude, temperature and rain fall: (1) High Potential Cereal Zone (HPCZ) covering most of Shewa, Gojam, parts of Wollo and the Hararge highlands; (2) Low Potential Cereal Zone (LPCZ) covering the northern highlands, Wollo, north Shewa and parts of Hararge, and (3) High Potential Perennial Zone (HPPZ) covering all the west and south western part of the country (MoA, 1995).

The land use systems are classified based on present land use types, which are used as guidelines for soil descriptions (FAO, 1990 & 2006). The recommended land use types were crop agriculture (cropping), Mixed farming, forestry, and settlement and industry, each of them having subdivisions (FAO, 1990 & 2006).

Generally, land use refers to the purposes for which human being exploited the land cover. Changes in land use frequent cause conversion and modification of land-cover. Land-cover conversion refers to the complete replacement of one cover type by another, the consequence of which is dependent upon its characteristics geographic location, spatial and temporal distribution, and its species composition and abundance. Research work indicated that the human-induced conversions of land cover have significance for the functioning of the Earth system (Turner *et al*., 1993). Measuring the impact of management practices under agro ecosystem is also a particular challenge, because the measurement includes two sets of data, with and without the farmer's intervention. However, if necessary data are collected from two points, one with and one without the intervention, the effects of management practices on crop diversity could be identified (Jarvis *et al*., 2000; Jarvis and Hodgkin, 2000). The land use systems and their changes greatly influence the physicochemical properties of the soil.

2.1.1. Forestland

Natural ecosystems are self-sustaining through food manufacture by plants, energy flow by the food chain, and nutrient recycling through microbial activities in natural cycles (Acquaah, 2002). In Ethiopia, massive deforestation of natural forests and extensive use of agricultural lands have resulted in soil degradation and loss of environmental quality (EFAP, 1994). The major causes for the disappearance of forests are rapid population growth leading to extensive forest clearing for cultivation and grazing, exploitation of forest for fuel wood and construction material (EFAP, 1993, 1994). The destruction of forests has widespread implications for all mankind and has wider implications of global importance (Yeshanew *et al*., 2004). This is particularly of paramount importance to rural populations living in and near the forest areas. Studying forest ecosystem is of critical importance because of the potential ecological significance of atmospheric depositions in forest ecosystems nutrient cycling and the need for such information to make reliable forest management decisions (Yeshanew *et al*., 2004). Soil properties depend on a number of factors, such as parent material, organism, relief, climate and time, the combine effect of which over a period of time gives rise to distinct soil type (Amusan *et al*., 2001). Knowledge of soil with respect to its properties is of utmost importance in determining the agricultural, engineering or any other use to which it may be put Assessment of changes in selected soil properties under different Land use system.

Trees can potentially improve soils through numerous processes including maintenance or increase of soil organic matter, biological nitrogen fixation, uptake of nutrients and water below the reach of crop roots, increased water infiltration and storage, reduced loss of nutrient by erosion and leaching, improved soil physical properties, reduced soil acidity and improved soil biological activity. The levels of productivity that can be achieved reflect the potential and degree of management of the resource base (Kang, 1993). High productivity can be obtained only from systems where management intensities, which are necessary for sustainability, are attained without extensive depletion of the resources. Trees are able to mobilize nutrients from the subsoil and then return these nutrients to the topsoil making them available for annual crops (Buresh and Tian, 1998) up on senescence and decomposition of plant parts. A big problem in most developing countries is high population growth. This increases the demand on natural resources, especially on soil and water resources. In many countries, population growth increases the pressure on land (Doran and Parkim, 1994).

2.1.2. Cropland

Field crops constitute cultivated communities of plants. There are two basic types of cultivated communities: monocultures and mixed cropping (polycultures), which differ in genetic content and structure i.e., in terms of density, spacing pattern, plant size, and stage of development (Acquaah, 2002). Agroecosystems are dynamic, being subjected to change from intervention of human managers (farmers) and changes in weather factors. They intensify and change because managers perceive opportunities, or simply change their perception of the current status of the crop ecosystem (Acquaah, 2002).

Farmers shape the distribution and degree of genetic diversity in their crops both directly through selection, and indirectly, through management of biotic and abiotic agro ecosystem components (Jarvis and Hodgkin, 2000). Farmers make decisions in the process of planting, managing, harvesting, and processing their crops that affect the genetic diversity of crop population. Over time, they will modify the genetic structure of a population by selecting plants with preferred agro morphological characteristics; influence the survival of certain genotypes by choosing a particular management practice of planting a crop population in a site with a particular micro environment; and make decisions on the size of the population of each crop variety to plant each year. These factors can affect the genetic diversity of cultivars/species and are linked to a complex set of environmental and socio economic influences on the farmers (Jarvis and Hodgkin, 2000).

Agricultural activities like cultivation have great impact on the soil morphological, physical, and chemical properties. According to Briggs and Courtney (1989), agricultural practices like cultivations, crop growth and harvesting lead to marked changes in the structure of the soil. Moreover, ploughing tends to open up pore spaces and increase the volume of macrospores in the soil and reduces aggregate size. In addition, cultivations have negative impact on soil organic matter due to the removal of crop residues and tillage effects, which result in lower structural stability and a higher soil bulk density. Long-term tillage practices reduced soil carbon 30-50% (Mitchell et al., 2000). Many research results revealed that the nutrient lost by cultivation is remarkably very high. For example, Keeney and Bremen (1964) compared the quantities of nutrient in cultivated and virgin land and concluded that cultivation led to a marked release of nutrients, especially in all forms of nitrogen compared with virgin land. Moreover, Ihor *et al*. (1995) found that the organic matter of a soil is highly dependent on the cultivation history. Similarly, Biswas and Mukherjee (1987) indicated that there was a great difference in both organic matter and total nitrogen content in native vegetation, forest and cultivation. Their result also showed that the amount of organic matter and total nitrogen were lowest in cultivated and highest in forest areas.

The diversion of net primary production to meet human needs usually requires alterations of nature (Turner *et al*., 1993). The environmental consequences of changes in the state of cover affect the original driving forces through the environmental impacts feedback loop. Transformation of a one system (dominated by one or more species) into another system of different species of plantation the result of changes in land use and management can affect soil structure, soil organic carbon and other nutrients reserve (such as N, P, S). (Yeshanew *et al.*, 2004)

According to FAO (1995), evaluation of field crop ecosystems is based on changes in cropping systems, which have evolved over historical time and/or carried out by deliberate modification on environment, most obviously through irrigation. Such modification generally gives: (1) greater diversity of land use and crop management; (2) some intensively use cropping land; (3) some under-used or unused land; and (4) reestablishment of deep-rooted perennial plants that draw nutrients from depth and maintain soil surface cover, will improve soil productivity provided that nutrients are not removed from the system. Most commonly, a short fallow of annual crops leaves the soil bare and liable to erosion in the dry season, causes structural degradation through trampling and plant up rooting, and conserves insufficient soil water for the next crop (FAO, 1995; Amusan *et al*., 2001). Amusan *et al*. (2001) noted that the practice of mixed cropping and cultivation of cover crops over the soil and protection against raindrop and erosion impact should be encouraged to reduce water erosion and increase both organic matter and available phosphorus content of the soil.

Monoculture cropping system is characterized by planting only one cultivar on a large acreage. The land used for this system is often flat and readily amenable to mechanization, which is used at all stages of crop production. Plants in this system feed at the same level and draw the same nutrients from the soil (Acquaah, 2002). Biomass accumulation in monoculture is exponential in pattern and could be modified by plant density; the lag-phase shortens as density increases. Monocropped plantations have been placed in areas of decimated primary rainforest (Astorga, 1996), the biomass of which determines characteristics of tropical soils. Once the protective forest is eliminated, the productivity and soil fertility per unit of area decline, diminishing sharply after the first 2 years.

Soils which are deep well drained loams and light clay loams give constantly high yields and prepared by banana companies because; (1) they have high organic content and, (2) they require practically no alteration, disturbance, or further attention (Astorga, 1996). The banana plant is an ecologically demanding species that requires abundant humidity, high temperatures, and soil with diverse nutrients. If bananas are cultivated without rotation, it is common to find noticeable mineral deficiencies, especially of calcium, iron, magnesium, nitrogen, phosphorus, potassium, and zinc (Astorga, 1996).

Moreover, when yields are heavy, uptake and removal of nutrients in harvest fruit is high. Only exceptional soils will sustain high yields without fertilization (Normal *et al*., 1995). Thus, the loss of N, P, K, Ca, Mn and Cu from the pseudostem after bunch harvest was equivalent to 40% of the needs of a young follower over a 10-week period. N and K are the most commonly required fertilizer nutrients by banana. But, relative to N and K, the P requirement of banana is low and with continued banana cropping K deficiency has become more common even on fertile soils (Norman *et al*., 1995). The yield of banana increased when supplied with OM (Normal *et al*., 1995), since SOM can modify soil properties such as soil pH, structure, bulk density, etc.,

However, bananas are ubiquitous crops in the better-watered areas of the tropics. The reasons for their popularity summarized by Normal *et al.* (1995) are: (1) land clearance and cultivation inputs are low; (2) fruit is produced within 1 year of planting and is harvestable for most months of the year; (3) the crop has many end-uses (fresh and cooked); (4) food energy is high; and (5) it returns substantial quantities of OM to the soil and protects soil against serious erosion

One of important agro ecosystem management strategies is the use of inter-and interaspecfic crop diversity to combat potential environmental stresses (Jarvis and Hodgkin, 2000). If a crop population has a diverse genetic make-up, its risk of its being entirely lost due to any particular stress, such as drought, floods, pests, and other environmental variables, is reduced. Crop production, especially in developing countries, involves different kinds of crop combinations, simultaneously cultivated on the same site. For instance, bananas are characteristic component of mixed–garden communities in house compounds of smallholdings in tropics (Norman *et al*., 1995). Growing different kinds of crops on the same piece of land is called mixed cropping, or simply mixtures. Some of these mixtures involve unlike genotypes of the same or different species. Polycultures (mixed cropping) are associated with small-scale, subsistence agriculture and are most common in the tropics (Acquaah, 2002). There is diversity in crop cultivars planted and the operations are not mechanized, depending on draft and human labor as sources of farm energy. Subsistence agriculture is generally low-input, with minimal or no use of agrochemicals. Natural methods are followed to improve soil fertility. The practice of mixed cropping should be encouraged to reduce water erosion and increase both organic matter and available phosphorus content of the soil (Amusan *et al*., 2001).

Land use systems based on mixed tree crops have clear advantages over annual cropping systems for the maintenance of soil fertility in the humid tropics. The advantages include permanent soil protection; a more favorite environment for soil biological processes, which affect litter decomposition and soil structural improvement, and more efficient nutrient cycling. (Noordwijk *et al*., 1996). Therefore, the integration of deep-rooting trees into system increases the nutrient availability in the topsoil, if the quantity of nutrients taken up from below the crop-rooting zone is greater than the quantity stored in the tree biomass and undecomposed tree litter. This is most likely to occur in soils with high subsoil fertility or if the crops compete efficiently with the deep-rooting trees for nutrients in the topsoil. However, soil degradation under such systems has repeatedly been observed and the integration of deep-rooting trees may not always be advantages as the crop themselves may be sufficiently deep-rooted, depending on crop species, climate and soil conditions (Noordwijk *et al.*, 1996). Vigorous ground cover is strongly recommended to avoid soil loss in water run-off. Cropping methods include early sowing, cover crops, mixed cropping, higher seed density, inter-row cropping and planted fallows. Because, splash erosion can be controlled by mulching, or by leaving the residues of harvested crops on the soil surface. Rill and gully erosion can be controlled by terracing, or by placing other barriers parallel to the slope such as contour strips planted with different species of grass (Doran and Parkin, 1994).

2.2. Influence of Land Use Changes on Soil Properties

As described by FAO (1995), a land quality is a complex attribute of land, which acts in a manner distinct from the actions of other land qualities in its influence on the suitability of land for a specified kind of use. Land that is recently cleared from forest has a positive quality in respect of arable cropping as “development costs”, adding to the value of potential agricultural land, but has a negative quality in respect of sustainable use of the natural vegetative cover. Land quality describes the combined state of soil, water and vegetation cover for each unit of land and its capacity to support biological systems for specific human uses.

Soil is part of land and soil quality is a subset of land quality. The nature of the soil exerts major influence in determining the feasibility of land uses. Therefore, study of the overall characteristics of soil variability in a local scale is used to estimate changes in soil properties due to agriculture. Understanding the spatial distribution pattern of soil properties is also important to determine soil constraints to plant nutrition and appropriate management options of soil resources that fit different farming systems in recently cultivated areas (Bierman and Rosen, 2005). An understanding of such agro ecosystem is a key to determine effective land use systems (FAO, 1994). Thus, soil fertility today is a social issue as well as a crop production concern. Therefore, assessment for soil management practices and evaluating factors influencing soil nutrient availability in agricultural land uses that make it possible for sustainable farming system to work are important for developing and maintaining the system (Bierman and Rosen, 2005).

Conversion of natural forests into cultivation can affect soil fertility and carbon sequestration thus CO_2 induced climate change phenomena (Yeshanew *et al*, 2004). This further influences soil physical and chemical properties. Amusan *et al*. (2001) noted that many soil physical properties deteriorate with cultivation rendering the soil less permeable and more susceptible to runoff and erosion losses. The ability of soil to retain water and supply it to plant is one of the main limiting factors in tropical agriculture. The changes in soil that decrease its productivity may result from three processes: cropping, erosion and leaching (Amusan et al., 2001). This may adversely affect the physical conditions and the chemical composition of the soil such as a decline in soil organic carbon, and nutrients, and deterioration of soil structure. Clearing and cultivation of forested lands resulted in deterioration of soil properties compared to soils under well-stocked natural forest (Islam and Weil, 2000). According to the same, cultivated soils had higher bulk density and lower aggregate stability whereas total organic C and N, soluble and utilizable C, total and active microbial biomasses were reduced due to cultivation. Moreover an agroecosystem is the community of selected plants and/or animals, growing at a location and interacting with biotic and abiotic environmental factors under the management and supervision of humans (Acquaah, 2002). As the result, there is limited nutrient cycling as the crop is harvested for use elsewhere, and consumers do not recycle the nutrients from where extracted. Agroecosystem, hence, depend on humans for addition nutrients and other cultural inputs. Further, participants in agroecosystems are not selected by nature and hence are not necessarily compatible. Through the use of technology, agroecosystems can be designed to overcome natural barriers to growth and development. For example, through irrigation, crops can be produced in arid regions.

An understanding of traditional farming systems can enable one to design appropriate technology options, and soil characterization helps in interpreting experimental results and serve as a guide to scientific soil management (Tekalign *et al*., 1993). Also understanding the effects of land use change on soil properties is important for soil quality improvement and sustainable land use (Gong *et al*., 2005). Changes in land use and management can affect soil structure, soil organic carbon and other nutrients reserve (Yeshanew *et al*., 2004). Gong *et al*. (2005) indicated that land use changes, for instance, from natural vegetation to agricultural land, or from grassland to arable land, could strongly influence soil carbon and nutrient concentrations. This is because (1) human activities, such as tillage, harvest and vegetation plantation, could affect soil nutrient decomposition or loss; (2) human disturbance may affect soil moisture by changing micro-climate and plant patterns; and (3) species have different nutrient requirements, exploit nutrients with varying efficient crops and store or convert nutrients at different rates. In addition, changes in land use affect input and output of nutrients and carbon in soils and vegetation.

The disturbance of soils has had the ultimate effects of adding to, or subtracting from, the products of soil weathering that change the rate of soil development (Mesfin, 1998). This implies that different soil management systems influence the physical, chemical and biological properties of a given soil (Wakene and Heluf, 2003). Studying the changes in physical and chemical characteristics of different soil types under different management systems is therefore a prerequisite to safeguard them before they go out of production. For instance, Chow *et al*. (2004) found that, maize-based land use has a negative effect on soil quality in terms of bulk density, hydraulic conductivity and water holding capacity. Soil under different land use types show remarkable differences in several properties, especially in distribution of C, N, and P within the soil profiles (Gong *et al*., 2005). Geissen and Guzman (2005) found that there is significant difference in organic matter and both extractable and plant available phosphorus content under different land uses.

According to MoA (1995) the major indicators for soil characterization and evaluation of potential fertility of soils are: (1) effective soil depth, (2) organic matter, (3) cation exchange capacity (CEC), (4) soil pH (5) soil texture, and (6) available phosphorus (P). In addition, fertility attributes such as soil pH, organic carbon N, P, and K are also important factors in terms of plant growth, and crop production and microbial diversity and function (Doran and Parkin, 1994). These parameters are generally sensitive to soil management, and hence they are regarded as part of minimum data of soil chemical indicators (Doran and Parkin, 1994).

Analysis on changes of soil properties due to the land use change can also support decision and policy-making processes at regional and national levels (Gong *et al.*, 2005). These include soil physical, chemical and/or biological properties (Mulugeta *et al*; 2005, Gong et al., 2005). Their changes may be assessed by measuring and comparing present values against the values at the commencement of the monitoring period, historical data when available, and soil properties under reference ecosystem or by using values measured at different time intervals (Mulugeta *et al.*, 2005; Gong *et al.*, 2005).

2.2.1. Morphological and Physical Properties

Color is a function of pH, redox and organic matter. Hence it is often related with specific physical, chemical, and biological properties of soils of a given location. Under forests black color usually indicates the presence of organic matter while red color indicates the presence of free iron oxides common in well-oxidized soils (Buol *et al*., 2003). However, color could also indicate the material from which the soil is derived and the stage of weathering or soil development. Moreover, color variations among the different land use systems at the surface horizons were attributed to differences in SOM content (Wakene and Heluf, 2003).

Soil structure is one of the soil physical properties, which is very sensitive to soil management practices. Intensive cropping undoubtedly tends to deteriorate the structural properties of soils, ultimately become difficult to manage and decreases productivity (Saini and Grant, 1980). Changes in soil structure because of different management systems have pronounced effects on bulk density, porosity, aeration, infiltration, water storage capacity, water characteristics, erosion and run off water (Cameron et al., 1981).

The texture of a soil is not a causal factor (Sandor *et al*., 1986) and one of the inherent soil properties less affected by management, although it determines nutrient status, organic matter content, air circulation, and water holding capacity of a given soil (Hillel, 1980). Ladd *et al. (*1990) reported that soils relatively higher in clay contents tend to stabilize and retain more organic matter than those low in clay contents. The texture of a soil also indicates its potential fertility, infiltration, water-holding capacity, degree of leaching, etc. These properties are used to decide irrigation frequency, fertilizer application and other soil management practices.

The rate of increase in stickiness or mouldability of soil as the moisture content increases depends on the silt and clay contents, the degree to which the clay particles are bound together into stable granules and the organic matter content of the soil (Russell, 1973). The author also suggested that when organic carbon falls below 1.5%, structural deterioration is likely to cause serious difficulties in soil management.

The presence of iron oxides and various heavy minerals increases the average value of particle density whereas the presence of organic matter lowers it. However, in most mineral soils, the mean particle density is about 2.60-2.70 gm per cubic centimeter (Brady and Weil, 2002). Different management practice and various soil properties easily affect bulk density. Bulk densities of soil horizons are inversely related to soil organic matter, which is highly influenced by land use or management practices (Gregorich *et al*. 1994).

Total porosity of soils usually lies between 30 to 70% and may be used as a very general indication of the degree of compaction in a soil in the same way as bulk density is used. For example, sands with a total pore space less than about 40% are liable to restrict root growth due to excessive strength whilst in clay soils limiting total porosity's are higher and less than 50% can be taken as the corresponding value (Landon, 1991). Compaction, hardpans and crusting are three major causes of physical degradation (Steiner, 1996). Soil compaction is an increase in bulk density caused by external loading, leading to deterioration in root penetration, hydraulic conductivity, and aeration. There are many ways of reducing soil compaction. Hardpans are common in alluvial plains in semi-arid areas with a pronounced rainy season. Crusting is due to the destruction of aggregates in the top soils by rain, and is closely linked to soil erosion. Crusting reduces infiltration and promotes water run-off.

Biological degradation is related to the depletion of vegetation cover and organic matter content in the soils, but also denotes a reduction in beneficial soil organisms and soil fauna. Biological degradation is the direct result of inappropriate soil management. Soil organisms and soil organic matter content can influence and improve the physical structure of the soils, especially with regard to transportation within the soils, mixing mineral and organic materials, and changes in soil micropore volume (Doran and Parkin 1994).

2.2.2. Chemical Properties

The pH of a soil indicates the degree of availability of plant nutrients and lime requirement of a soil. A number of soil fertility characters can be interpreted from the soil pH (Landon, 1984; 1991). Soil pH also reflects percent base saturation (PBS) of the CEC. This term refers to the relative number (percentage) of the CEC sites on the soil colloids that are occupied by bases such as calcium, magnesium, and potassium. Soil pH (KCl) indicates the potential acidity and presence of weatherable minerals when the difference (ΔpH) of soil pH (H_2O) and pH (KCl) is greater than unity (Buol *et al*., 2003)

Electrical conductivity of saturation soil extract (ECe) provides the measure of soil salinity that contains a concentration of neutral soluble salts sufficient to seriously interfere with the growth of most plants (Brady and Weil, 2002). According to Landon (1991) the critical level of ECe for most crops was 4 dSm^{-1} at 25^0C. Soils with ECe 4 dSm^{-1} or greater than, the soil is said to be saline soils are commonly found in arid and semi arid regions such as rift valley where rainfall is insufficient to leach soluble salts below the root zone (MoA, 1995). Good organic management practices do not increase soil salinity (OFRF, 2002) However, on irrigated farms, inadequate drainage systems and inappropriate land leveling and irrigation practices could result in high level of soil salinity.

Research findings revealed that cultivation of the land results in reduction of organic carbon and total nitrogen, and increases C: N of soils (Saikhe *et al*., 1998a). The wider C:N ratios in the surface soils than the corresponding subsoils suggested that nitrogen was limiting in agricultural productivity (Tamirat *et al*., 1996). On the other hand, Chan *et al*. (1992) reported that significant loss in total nitrogen, exchangeable Ca and Mg as well as reduction in biological activities and aggregate stability accompanied reduction in organic carbon. They also demonstrated that loss of 1% organic carbon resulted in a loss of 2.97 cmol (+)/ kg soil of negative charges. Such great damage was encountered mostly due to intensive soil cultivation.

Soil organic matter is very important fraction of the soil because of its high cations exchange capacity and retaining nutrients against leaching losses. According to Gong *et al*. (2005), different land use types have different affects on SOM and SOM in turn influences both chemical and physical properties of soil. SOM under different land use types decline with the increase in soil depth. Vegetation restoration, such as shrub, tree and grass plantation and cropland abandonment increases the SOM Content. The increase rate varies among the different land-vegetation systems. Crop production may significant decrease SOM, and it appears that, the trend can be reversed with cropland abandonment and subsequent vegetation regeneration. This is because better soil conditions are favorable for vegetation growth; which in turn produces more vegetation litter to enrich soil C. This makes a beneficial cycle between soil and vegetation (Mitchell, 2000).

Different land use types have different effects on SOM (Gong et al., 2005). SOM influences stability of soil structure, microbial activity and soil fertility (IFOAM, 2002) and is closely related to total nitrogen (TN). According to the results of fertilizer trials carried out in Ethiopia (NFIU, 1989), the critical organic matter values for the common cereals grown are: barley and wheat 2.5%; maize 3.0%; sorghum and teff 2.0%. SOM contents <1, 1.0-2.0, 2.1-4.2, 4.3-6.0 and >6 are rated as very low, low, medium, high and Very high, respectively (ILACO, 1981).

According to Gong *et al*. (2005), soil TN accumulates at the topsoil layer of 20 cm, and soil TN under different land use types decline with increase in soil depth. Different land use (vegetation) species have different N requirements, exploiting N with varying efficiency and storing or converting N at different rates (Gong *et al*., 2005). The distribution of soil N is closely related to root distribution (Berger *et al*., 2002). Many studies have found that nitrogen- fixing species can significantly increase soil TN while others found no correlation between the nitrogen fixing species and soil TN, accumulation in surface soil (Gong *et al*., 2005; Islam, 2000). Soil TN is related to SOM accumulation and indicated that the potentiality of soils for release of available nitrogen through mineralization.

The carbon: nitrogen (C: N) ratio of the OM supplied to the soil is a controlling factor in the formation of stable humus. A ratio of about 20:1 is considered ideal (Bellevue, 1992). If greater amounts of carbon present, decomposition is reduced as microorganisms become nitrogen starved and compete with the plants for available nitrogen. Nitrate nitrogen practically disappears from the soil because microbes need nitrogen to build their tissues. If there is too much soil nitrogen, the decomposers produce soluble nutrients in the form of effective humus, but little stable humus. These conditions can give advantage, to weeds rather than the crop (Bellevue, 1992). A good C: N ratio will result in the formation of both effective humus and stable humus. In general, the C: N ratio decreased with cultivation for a given period of time (Lal, 1994)

Soil TP under different land use types decline with soil depth (Gong *et al*., 2005). Differences in soil storage may result from changes in biological and agrochemical processes at different depths after human disturbance (Gong *et al*., 2005). But available P values are good indicators of the P status of soils.

According to Tekalign and Haque (1987a, 1991), volcanic ash soils (Andosols) sorbed the maximum P, while Fluvisols and Regosols sorbed the least. They also observed that sorption of P was significantly correlated with exchangeable and extractable forms of Fe and Al as well as pH and organic matter.

Cation exchange capacity measures the quantity of potentially available cation nutrients that are in stable and accessible form (Bellevue 1992). A cation exchange capacity of 8-10 me/100 gm soil is minimum for satisfactory crop production, provided that the other factors are favorable (FAO, 1979). According to Landon (1984), a general interpretation of CEC values for top soils rating is as follows: less than 5 (Very low), 5-15 (Low), 15-25 (Medium), 25-40 (High), and greater than 40 (very high).

According to Gao and Chang (1996), cation exchange capacity is highly correlated with organic carbon content of the soil, which is in turn affected by different soil management practices such as intensive cultivation, fertilization, and changes in land use. Cation exchange capacity increases with increasing soil organic matter, clay content and soil pH (Saikhe *et al*., 1998b).

Percent base saturation (PBS) is also directly related to soil pH and represents the relative availability of many positively charged nutrients (Cations) such as calcium, magnesium, and potassium (Bandle and Meisinger, 2002). Bierman and Rosen (2005) as indicated that cation exchange is the major nutrient reservoirs of K^+, Ca^{2+} and is also important in holding N in the ammonium (NH_4^+) form. Major causes of soil acidity are leaching and plant up take of basic cations (Ca and Mg). The primary issues and from fertility standpoint, the actual amount of exchangeable Ca or Mg in soil, rather than the ratio between them, is the most critical factor. According to Bandel and Messenger (2002) in cases where contamination from seawater is suspected, an exchangeable sodium may accumulate When Na is present at very high levels (above 15% saturation of EC) soil aggregates may be dispersed (soil puddling), causing a loss of soil structure, drainage, and aeration (Landon, 1991; Norman *et al*., 1995).

The variation in the distribution of potassium depends on the mineral present, particle size distribution, degree of weathering and soil management practices (Venkatesh and Satyanarayana, 1994). In general, the potassium content of a given soil depends on the climatic condition and degree of soil development, the intensity of cultivation and the parent materials from which the soil is formed. For instance, soils formed from sedimentary materials are generally low in K content, while soils formed from crystalline rocks contain relatively high K (Buol et al., 2003). The effect of land use on soil exchangeable K is different (Gong *et al*., 2005). Thus, vegetation restoration increases the accumulation of soil K because the nutrient-rich branches, twings and coarse litter fraction are all-important nutrient sources. The loss of K from litter was relatively rapid at the initial decomposition stage (Gong *et al*., 2005).

In highly weathered soils of the tropics, the quantities of exchangeable bases of the soils become a limiting factor in soil productivity as a result of acidification of the upper layers of the soil. Cultivation has been found to aggravate the situation to the extent that it causes a significant reduction of the exchangeable Ca^{2+} and Mg^{2+} compared to the adjoining uncultivated weathered Indian soils (Saikhe *et al*., 1998b). Because cultivation enhances leaching of Ca^{2+} and Mg^{2+} especially in acidic tropical soils (He *et al*., 1999; Baker *et al*., 1997).

Though different crops have different optimum ranges of nutrient requirements, the response to calcium fertilizer was expected from most crops when the exchangeable calcium is less than 0.2 cmol (+)/kg of soil, while 0.5 cmol (+)/kg of soil was the deficiency threshold level in the tropics for Mg (Landon, 1991).

The first attempt of diagnosing the micronutrients status in Ethiopian soils showed that Fe and Mn were adequate, Zn varied between low to high, and Cu was deficient throughout the investigation sites (Sillanpää, 1990; Haque, 1987). The concentrations of Fe, Mn and Zn are negatively correlated with soil pH (He *et al*., 1999),

The solubility and availability of micronutrients is largely influenced by clay content, pH, organic matter, CEC, phosphorus level in the soil and tillage practices (Fisseha, 1992). Copper in the soil is adsorbed on clays and oxides that complexed with organic matter, thus inducing its retention and immediate unavailability for plant (Haque *et al*., 1992). The authors have demonstrated that organic enriched surface horizons often contain higher concentration of Cu than the lower horizons.

3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location

The study was conducted in Gamo Gofa Zone of Southern Nations, Nationalities and Peoples` Regional State, Southern Ethiopia, some 250 km from the Regional Capital, Awassa and at about 500 km south of Addis Ababa. The study area is found at 6^0 5' N and 37^0 35' E and altitude of 1200 masl in between Lake Abaya Chamo Basin (ACB) (Fig. 2). It is situated at the west of Lake Abaya around the south end, and at the base of the escarpment east of the Arba Minch town, and within Arba Minch Zuria Wereda in Gamo Gofa Zone. Four PAs that cover about 3243.6 ha were considered within the catchment for the study. The catchment is found in the semi-arid agro-ecology of the country (semiarid climate) with native vegetation of comprised steppe-like in nature with some bunch grass and short shrub and trees (Murphy, 1968).

3.1.2. Hydrology and Geology

A small river called Hare, which is used for irrigation in the catchment, flows in NW-SE direction, passing the study area and ends in the Lake Abaya. There are many intermittent streams joining the Hare River. Lake Abaya in the south, and Basso and Kulfo rivers in the east and west, respectively, also bound the study area, (Fig 2). Ground water is found extensively within lacustrine deposit surrounding the lake. The lake is moderately saline and alkaline, permanently brown in color due to fine materials in suspension (Wayand *et al.*, 1999).

The geology and geomorphology of the Rift Valley occurred from Miocene to Pleistocene deposits (King and Brachall, 1975). In general, the pattern of topography of the catchment is composed of flat plain in the east-around Lake Abaya and the Rift Valley escarpment hills in the west and north. The parent materials of catchment are alluvium along river and lacustrine along lake which are derived from the rocks (Geological map of Ethiopia, 1975).

3.1.3. Climate

The long-term weather information at Arba Minch Meteorological station revealed that the rainfall pattern of the study area is a bimodal type with a total rainfall of 830.7 mm per annum. The major peak in April and another small peak in October (Fig. 1) extends from April to October with maximum rain in the months of June, July and August. The mean minimum, mean maximum and average temperatures are 14.1, 27.9 and 20.6 ^{0} C, respectively. The cachment falls in the semi-arid moisture regime where evapotranspitation exceeds precipitation.

In general, the length of Growing Period (LGP) of Arba Mich area is 61 days (Lemma Gonfa, 1996). This implies that evapotranspiration is by far greater than rainfall and the need to supplement by irrigation water for the growing of different crop.

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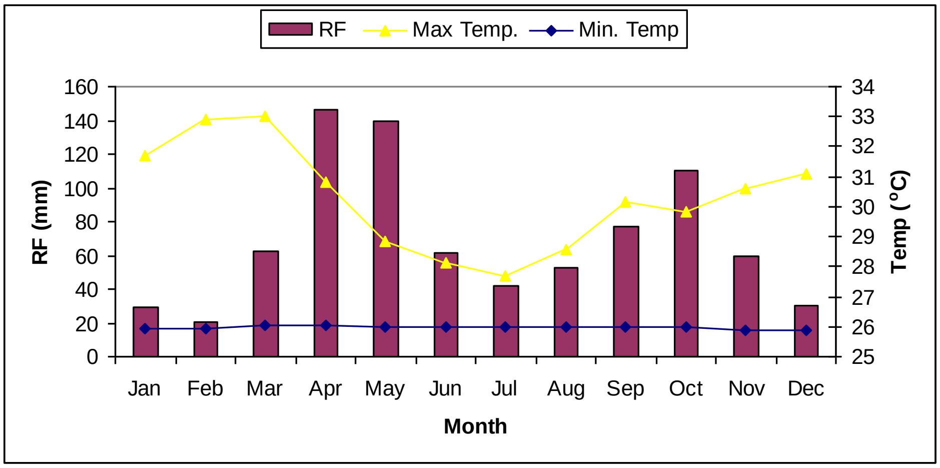

Figure 1: Rainfall and Temperatures of ACB (1987-2006)

3.2. Primary Data Collection

Semi-structured questionnaires were used to gather information about land use, history of cultivation, cropping patterns, soil management etc,. In addition, observation, discussion and interview were carried out at each PA level. At each PA of the catchment, discussions were made with on over all performance, history of the respective land use systems and institutional aspects. Participants were community elder groups, PA Administration member, Development/extension agents, some selected household heads and water development committee. The general discussions were made with 10-12 people from each PA. With respect to the farm level, five adjacently located farm owners were interviewed in order to know the farm history. Field survey was carried out to collect data on the current land use systems and the physiognomic vegetation classification system in accordance with FAO (1985, 1990, and 1995), and secondary data were collected from respective PA offices

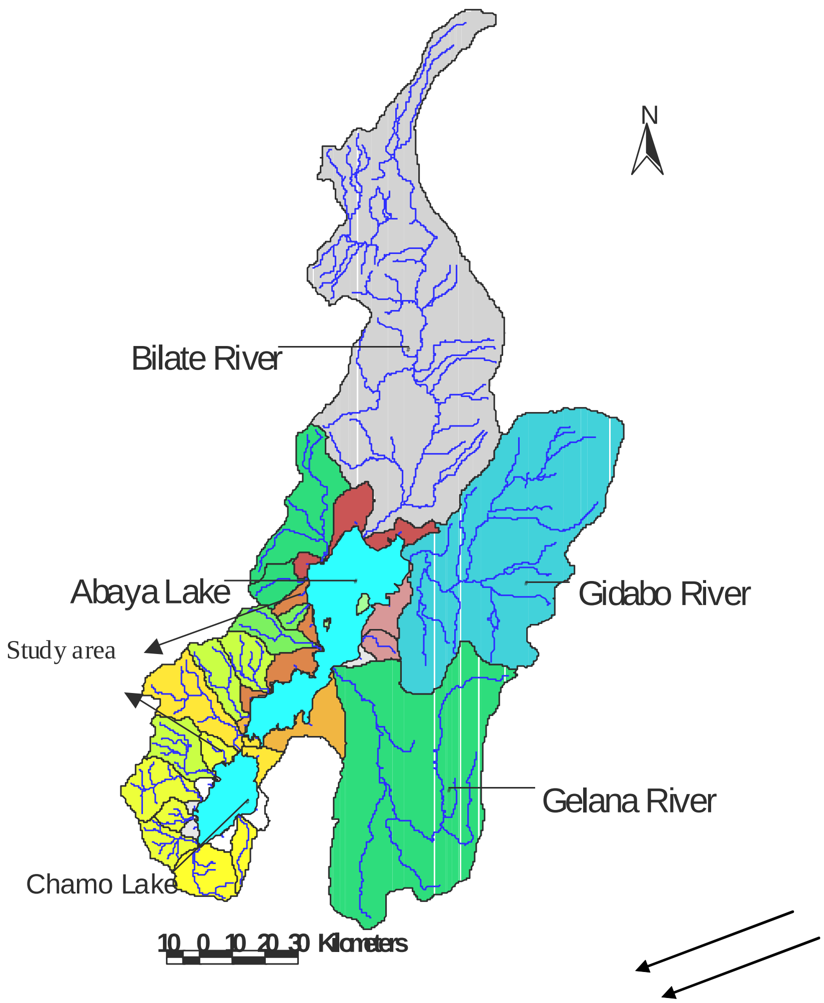

Figure2: Location Map of the Abaya Chamo Basin, ACB

3.3. Description of Farming System

Field observation and selection of representative soil profile sampling sites were based on the predetermined set of criteria, which were related to soil management and farming systems of different land use types. The farming practices are dominantly of monocultures cash crops (banana monoculture), mixed farming of banana with mango (poly-culture), and subsistence farming of maize, other cereals and cotton. Four land use types were selected based on the information obtained from assessment conducted and field observations made during the survey. Accordingly, subsistence-farming system (maize field); representative virgin land; monoculture farming system (banana monoculture field), and mixed farming system (banana-mango mixed field) were considered and used as pedons excavation sites.

3.3.1. Subsistence Farming System (P1)

Based on the information from the owners of the land, the subsistence farming fields were continuously cultivated for about three decades. Currently, the fields are used for medium maturing maize grown by smallholder farmers under low input. In this system rotation between maize and cottons is a common practice.

3.3.2. Representative Virgin Land (P2)

The field identified as representative virgin land has no recorded of cropping history. The remnants of forests in some patches and pockets, which were estimated to cover about

8.5%, are found in the catchment along the Lakeshore. The dominant tree species is Acacia alibida.

3.3.3. Monoculture Farming System (P3)

The system represents smallholders' farm field under banana monoculture cultivation owed by market-oriented farmers. The fields were used for cultivation of banana crops for more than ten years. Generally, this type of monoculture banana farming system in the area is managed with low inputs, and practised by preparing low mound or ridge for planting and maintaining the soil fertility, ratoon development, and to avoid weeds and pests from the banana plantation.

3.3.4. Mixed Farming System (P4)

Banana and mango were identified as the dominant fruit crops under traditional production system in the area. The fields of banana and mango were further intercropped with short season crops such as maize, pepper and tomato in the spaces between the two main crops for the first 3-5 years. Then after, the dominant crop will be mango, which will develop to pure stand in 12 to 15 years.

3.4 Soil Characterizations and Sampling.

A 2m x 2m x 2m soil profile pit was excavated on each of the farming system (subsistence farming, virgin land, monoculture farming and mixed farming). The soil profiles were described in situ following guidelines for soil description (FAO, 1990). Soil samples were collected from every identified horizon. In addition, 120 soil samples were randomly collected from surface layer (0-30 cm) and 12 composite samples were prepared. The soil samples were air dried and passed through 2-mm sieve for determination of physical and chemical characteristics.

3.5. Soil Analysis

Soil color (dry and moist) was determined using the Munsell color chart (Munsell Color, 2000). Bulk density (Bd) was estimated from undisturbed soil sample collected from each horizon except for C-horizon using core sampler. Particle density (Pd) was determined by the pycnometer method as described by Blake (1965) Total porosity was estimated from the bulk and particle densities. Particle size distribution was determined by hydrometer method following Day (1965) procedure.

The pH of the soil was measured potentiometrically using a digital pH meter in the supernatant suspension of 1:2.5 soil to liquid ratio where the liquid was water and 1 M KCl solution and ΔpH was determined by subtracting the values of pH (KCl) from that of pH (H_2O). Electric conductivity was measured from saturated extract. Exchangeable bases were extracted with 1M-ammonium acetate at pH 7. Exchangeable Ca and Mg were measured from the extraction with atomic absorption spectrophotometer whereas exchangeable K and Na were determined from the same extraction with flame photometry. Percent base saturation (PBS) was determined by dividing total exchange bases by the CEC of the soil and multiplied by 100%. Cation exchange capacity (CEC) of the soil was determined from ammonium-saturated samples that were subsequently replaced by Na from a percolated sodium chloride solution. The excess salt was removed by washing with alcohol and the ammonium that was displaced by sodium was measured using kjeldahl (Chapman, 1965) and reported as CEC.

Organic carbon was determined following the wet digestion method as described by Walkley and Black (1934), whereas Kjeldahl procedure was followed for total nitrogen determination as described by Jackson (1958). Available phosphorus was determined by Olsen method (Olsen et al., 1954).

Available Fe, Mn, Zn and Cu were extracted from the soil samples with DTPA as described by Lindsay and Norvell (1978). All micronutrients extracted with DTPA method were measured by atomic absorption spectrophotometer.

3.6. Statistical Analysis

Simple Nested Design procedure was carried out for the selected soil physicochemical properties with the help of SPSS Version 12 (SPSS, 2001) statistical program to compare the effects of the different land use types and soil group. Separation of the means of the soil properties was performed using Bofforrni significance test.

4. RESULTS AND DISCUSSION

4.1. Land Use Systems and Farmers Perceptions in the ACB

The distribution of the land use in the study area has been changed greatly over time because of high population pressure and subsequent deforestation. The data obtained from the study area have shown that the total population is about 19674 with the density of about 596 people/km^2 (Appendix Table 7). Small part of the border area near Lake Abaya was covered with natural forest, whereas the top of mountains that was previously covered by grass and bushes was deforested. In the escarpment between lowland catchment and highland areas, the scattered trees were also leaving their original place to the new generation of human race.

Apart from the deforested hilltops, the study area was remarkably well covered by recently introduced fruit trees. There was a break through in production and transforming the livelihoods of the inhabitants from survival level to elevated way of life at lowlands in the irrigated zone. Improved farming methods such as mulching, intercropping, and shifting cultivation were also well practised. The land was used to be under government control whereby the production was divided amongst the members in 1970s. Later on, it was equally divided for inhabitants of the PAs resulting in more or less uniform land holdings (Table 1).

About 2588 ha (80%) of the total area was used for agricultural purpose, of which 262 ha and 1962 ha were used for non-irrigated and irrigated agriculture, respectively (Table 1). Further, these agricultural (cultivated) lands are subdivided as annual cropland (1227.6 ha;

47%) and perennial cropland (1361 ha; 53%). Forest and grasslands cover 270 ha and 168 ha, respectively. The rest of the area (217 ha) is occupied by the housings and other infrastructures (Table 1).

Table 1: Land use categories in the peasant associations of ACB, 2006

PAs	**Total Area (ha)**	**Cultivate land (ha)**		**Irrigable Area in (ha)**	**Irrigated land (ha)**	**Housing and infrastructures (ha)**	**Forest (ha)**	**Grassland (ha)**	**Av. Land holding by HH (ha)**
		Annual cropped area (ha)	Perennial crop area (ha)						
Kola Shara	800.00	251	391	617	617	100	20	38	0.970
Chano Dorga	744.60	281.60	120	242	242	43	200	100	1.50
Chano Chalba	799.00	199	450	649	649	90	40	20	1.50
Chano Mile	900.00	496	400	716	454	164	10	10	1.25
Total	3243.60	1227.6	1361	2224	1962	489	270	168	1.42
Percentage		47.4	52.6		60.49	12.2	8.32	5.2	

Source: Kola Shara, Chano Dorga, Chano Chalba, and Chano Mile PAs offices and Agriculture center.

According to the information obtained from farmers, there existed high spatial variability in crop growth pattern due to water sources and land quality differences. The cropping pattern of the area was substantially changed through time, particularly, the fruit crops' production was increased and fruits became the main plants growing in the area.

In areas located near the watercourse, lands were used for banana production, whereas those found at mid extreme with water shortage were under maize or cotton. The soils near the water course were locally termed as ‘’ fatty soils” that do not require much water to give adequate yield, since soils on river levees are porous and better drained compared to those of basin areas. During floods, fine sand or silt is deposited on top of the levees, and clay in the basins, whereas gravel and coarse sand are normally found on the channel floor (lag deposits) (FAO, 2001). However, texture is a relatively permanent feature of the soil that does not change appreciably over a human lifetime (Bellevue, 1992).

The Chano Chalba area used to be flooded by Hare River before the water was concentrated in its present watercourse. This was evident from the name given to a village as “AKO Shafe” which means, “Wider flood.” The soils of the area were considered to be of best quality and giving high yields as compared to others. Similar productive soils were also found in the middle parts of Chano Mile, Chano Dorga and Kola Shara PAs. The soil of Chano Dorga PA was characterized by farmers as“hard” due to its requirement of large quantity of water during irrigation and poor tilth. The soil remains dry within a depth of 1m, even after heavy rain.

The farmers at distant to water course adopt crop diversification and were growing mixed fruits to minimize risk of single crop. Crop diversification is a successful approach to achieve food and nutrition security, income growth, poverty alleviation, employment generation, thought full use of land and water resources, sustainable agricultural development, and environmental improvement (FAO, 1995).

The yields of major crops declined with distance from the watercourse (Appendix Table 10). Farms that were located at the verge of the watercourse or on the main flood plains of river systems were used for production of profitable cash crops, such as monoculture banana, mango or maize, whereas majority of those located at distant from the watercourse were predominantly used for mixed fruit crops. Based on the information obtained from the farm owners (farmers), the yield status of banana was also higher near the watercourse areas (219 quintal/ha) as compared to that of the distant areas (65 quintal/ha).

The selection of crops to be grown along watercourse was dependent upon: (1) food habit of the locality, (2) land suitability & adaptability of crops, and (3) accession to market. Community categorize their farming system based on watercourse soil fertility status, viz.: monoculture cash crop farming (nearby watercourse); subsistence farming (mid way watercourse); and mixed farming (at extreme distant to watercourse). Accordingly, the survey result from the PAs has indicated that monoculture banana and mixed farming systems were the dominant LUTs in Chano Chalba and in Kola Shara and Chano Dorga PAs, respectively, whereas subsistence farming system was dominant in Chano Mile PA (Table 2). As reported by Jarvis and Hodgkin (2000), farmers shape the distribution and degree of diversity for the crops both directly through selection, and indirectly, through management of biotic and abiotic agroecosystem components.

Table 2: Characteristics of the study sites ACB, 2007

Site & location	Altitude (m.a.s.l.)	Physiography	Slope (%)	PM	Drainage class	Moisture Condition	Erosion	LUTs
P1: **Chano Mile**	1215	Alluvial plain	2%	Alluvium	Well drained & permeable	Moist throughout	None	Maize field (CeMa) (irrigated)
P2: **Chano Mile**	1179	Plain	1%	Alluvium	Well drained & Permeable	Moist throughout	None	Natural forest (NF)
P3: **Chano Chalba PA**	1205	Lower slope	1%	Alluvium	Well drained & permeable	Moist throughout	None	Monoculture Banana fields (FrBa) (irrigated)
P4: **Cano Dorga PA**	1223	Alluvium mid plain	1%	Alluvium	Well draineds permeable.	Moist throughout	None	Mixed Banana – mango (FrBaMa) (irrigated)

4. 2 Influence of Land Use Systems on Soil Properties

4.2.1 Morphological characteristics

For ease of presentation, soil depth, horizon, color, structure and consistency are treated as soil morphological properties in this text. The studied land use systems were found at the foot slope and toe slope positions within slope range between 0 and 2%. The soils were young and derived from alluvium deposits (Table 2). Mesfin (1998) has also indicated that flooding obstructs the pedogenic material. The soils of the different land use systems were relatively deep (Table 3), although the pedons under the maize and banana fields had stratified layers at 74 cm and 46 cm, respectively. The soils are therefore, suitable for cultivation and variety of crops. Wakene and Heluf (2003) also indicated that soil depth is one of the important soils quality indicators, and determines the responses of soil to intensive land use. Generally, low runoff and well permeability of the study area soils (Appendix Table 1-4), might be due to the depth of the soil under the different LUTs

The moist soil colors of the surface horizons of the pedons ranged from black (10YR 2/1) under banana field to very dark brown (7.5YR 2.5/2) under maize field (Table 3). Generally, surface layers had darker color as compared to the subsurface horizons. On the other hand, there were few color variations among the land use systems in the B- horizons.

The color variation of the subsurface horizons could be attributed to differences in soil organic matter contents. This implies that soil color is highly influenced by soil organic matter in the A- horizon. This is due to the effect of OM and its continuous transformation processes (Havlin *et al*., 1999; Foth, 1990, IFOAM, 2002).

Table 3: Selected soil morphological features under different land use systems in ACB, 2007

Depth (Cm)	**Horizon**	**Color**		**Structure**	**Consistency**		
		Moist	Dry		Dry	Moist	Wet
Pedon 1	Maize field						
0-20	Ap	7.5YR 2.5/2	7.5YR 4/4	WMSB	HA	SFm	SST, SSP
20-48	A1	7.5YR 2.5/3	7.5YR 3/3	MCSB	HA	SFm	SST, SSP
48-74	A2	7.5YR 3/2	7.5YR 3/2	WCAB	HA	Fr	SST, SSP
74-108	2C1	7.5YR 3/3	-	-	-	-	-
108-138	2C2		-	-	-	-	-
138-165+	3C		7.5YR 4/4	MA	HA	Lo	NS, NP
Pedon 2	Natural forest						
0-30	A1	10YR 2/2	10YR 3/3	WMGR	HA	Fr	NS, NP
30-60	A2	10YR 3/3	10YR 5/4	WMSB	HA	Fr	NS, NP
60-93	AB	10YR 3/3	10YR 5/4	WMSB	HA	Fr	NS, NP
93-160	Bw	10YR 3/2.5	10YR 6/3	WMSB	HA	Fr	MST, MP
$160-200^{+}$	2C	10YR 3/3	10YR 6/3	MA	HA	Fr	SST, SP
Pedon 3	Banana monoculture						
0-46	Ap	10YR 2/1	10YR 3/3	WMSB	HA	Fm	ST, PL
46-60	2C	10YR 3/3	10YR 4/3	MA	HA	Fr	SST, SP
60-95	3Ab1	10YR 3/1	10YR 5/4	MA	HA	Fr	SST, SP
95-187+	3Ab2	10YR 3/3	10YR 4/4-	MA	-	Fr	SST, SP
Pedon 4	Mixed banana and mango						
0-45	Ap	10YR 2/1	10YR 3/3	WFSB	HA	SFm	MS, PL
45-105	Bw	10YR 3/4	10YR 4/4	MMSB	HA	Fr	ST, PL
105-162	2C	10YR 3/3	10YR 5/3	MA	HA	Fr	SST, SP
$162-200^{+}$	2B	10YR 3/2.5	10YR 4/3	WMAB	HA	Fr	ST, SP

The Descriptions were made following Guidelines for Field Soil Description (FAO, 1990)

The structure of the soils was mainly weak sub angular blocky on the surface and massive on the sub surface horizons. The massive structure of subsurface horizons under the maize and banana land use systems compared to granular structure at the surface horizon of the virgin land were due to frequent depositions and stratification of layers, indicating the that weak development of subsurface horizons in these fields. An ideal soil structure is often described as granular, which provides good movement of air and water through a variety of pore sizes (Bellevue, 1992). Biological activity, organic matter, and cultivation and tillage practices affect soil structure (Bellevue, 1992).

The consistencies of most horizons were found to be slightly sticky to non- sticky/non-plastic, which might be due to the large proportion of silt in the soil. Generally, silt dominated the particle-size distribution in almost all pedons. The non-sticky/non-plastic consistence in the pedons under virgin land could be also due to the influence of high organic matter content. Although consistence is an inherent soil characteristic, the presence of high organic matter could modify it (Wakene and Heluf, 2003).

4.2.2. Physical Properties

The textural classes of soils determined by feel method in the field was found to be similar in most cases, with the determinations carried out in the laboratory (Table 4 and 5). The textural classes of the surface layers ranged from silty clay, silt loam, silt clay and silty clay loam for pedons of maize, virgin land, banana and mixed fruit croplands, respectively (Table 4). The clay content of pedons decreased with depth, whilst the sand content increased throughout the profiles.

Table 4: Physicochemical properties of the pedons under different land use systems, ACB. 2007.

Pedon	Depth (cm)	pH (H_2O)	pH (KCl)	EC (dS/m)	Bd (g/cm^3)	Pd (g/cm^3)	Porosity (%)	Sand (%)	Silt (%)	Clay (%)	Textural class
P-1	0-20	6.6	5.4	0.11	1.57	2.57	38.91	10	48	42	SiC
	20-48	7.2	5.4	0.08	1.33	2.40	44.58	18	46	36	SiCL
	48-74	7.4	5.3	0.06	1.26	2.52	50.78	50	30	20	L
	138-165	7.2	4.9	0.05	-	-	-	46	40	14	L
P-2	0-30	7.4	6.1	0.42	1.34	2.68	50.00	18	56	26	SiL
	30-60	7.1	6.2	0.94	1.42	2.60	45.38	20	60	20	SiL
	60-93	7.2	6.3	4.93	1.26	2.25	44.00	10	86	4	SiL
	93-160	7.3	6.4	5.30	1.19	2.29	48.03	14	82	4	Si
	160-200	7.5	5.2	3.65	-	-	-	10	70	20	Si
P-3	0-46	6.9	4.8	0.06	1.33	2.29	41.92	14	46	40	SiL
	46-60	7.0	4.8	0.06	1.65	3.05	45.96	36	38	26	L
	60-95	6.3	4.8	0.05	1.42	2.68	47.01	24	48	28	CL
	95-187	6.7	5.0	0.05	1.52	2.48	38.71	26	48	26	L
P-4	0-45	6.4	4.5	0.09	1.16	2.82	58.86	10	54	36	L
	45-105	6.3	4.8	0.05	1.39	2.54	45.28	16	54	30	SiCL
	105-162	6.9	5.9	0.05	1.39	2.48	45.28	20	60	20	SiCL
	162-200	7.5	5.8	0.08	1.52	2.56	41.01	16	56	28	SiL

The bulk densities of the surface layers were found to be lower than that of the layers in beneath, except for the maize field (Table 4). The highest bulk density (1.57 Mg $^{-3}$) recorded in the surface layer of maize field (Table 4) may be attributed to compaction, as was also observed from the lowest porosity value (Table 4). Similarly, the bulk density of the monoculture banana field in the B- horizon (1.65 Mg $^{-3}$) was greater than that of the other land use systems.

The highest subsurface bulk density in the banana field could be attributed to the strata of sand with massive structure as a result of alluvial deposition (Table 3 and Appendix Table 3). The bulk density was negatively correlated with organic matter (r= -0.15), primarily because of less organic matter and decreased aggregation. This is because OM makes soils loose, porous, or well aggregated and thereby lowers bulk densities. Besides, the density of organic matter is very low as compared to mineral particles and hence higher organic matter content results in lower density. The highest bulk density noted under the surface horizon of maize field and subsurface horizon of banana field could limit root growth, gas exchange and availability of less mobile essential plant nutrients, such as P and K (Dolan *et al*., 1992). However, the bulk densities recorded in the present study except for the subsoil layer of banana field were not greater than the critical values (1.63g/cm^3) indicated by Amusan *et al*. (2001). Further, lower bulk density implies greater pore space and improved aeration, creating a choice environment for biological activity (Werner, 1997).

The surface layer of the mixed fruit cropland had highest porosity (58.86%) compared to the other LUTs. This layer also possessed the highest particle density (Table 4), which shows that the highest porosity was not result of organic matter content. The probable reason might be good structural stability of the soil. On the other hand, the lowest total porosity was recorded in maize field (Table 4) that could be attributed to the highest bulk density. Field clearings, deforestation, overgrazing and continuously land use can lead to land degradation, with drastic adverse changes in soil properties such as decrease aggregation and aggregate size distribution and increase in susceptibility to erosion.

Further more, these effects contribute to an increase in bulk density, a reduction in available water-holding capacity and a decrease in macroporosity and infiltration capacity (Lal, 1996). According to the same, the effects are exacerbated by a reduction in the activity and species diversity of soil fauna, a decrease in the quantity and quality of soil organic matter content, and a possible reduction in the formation of organic mineral complexes (Lal, 1996).

4.2.3. Chemical Properties

4.2.3.1. Soil pH and EC

The pH (H_2O) values in all horizons of the pedons were higher than the values obtained using KCl solution (Table 4). Consequently, delta pH values remained positive, which is an indication of negatively charged clay surface. Gurmessa (2002) also indicated that pH (H_2O) is higher than pH (KCl) in soils dominated with layer of silicate minerals and oxides of iron and aluminum. The soil pH (KCl) values consistently increased in the virgin and mixed fruit croplands was obtained whereas slightly decreased with increasing soil depth. The pH values were neutral and near neutral indicating that there is no toxicity of aluminum, manganese and hydrogen; rather cations such as K, Ca, and Mg are abundant (Fall, 1998). Moreover, neutral and near neutral pH values do not impair the availability of nutrients especially in alluvial soils (FAO, 2001)

The pedon under natural forest exhibited relatively high EC values (3.65-5.30) in the subsoil. These high values were resulted from the shallow ground water (<2 m) with electrical conductivity of 14.3 dSm^{-1}. The salinity hazard in flooded soils may be greater than the ECe values of the soil because of the soil reduction and the solvent action of carbon dioxide that releases large amounts of ions into the soil solution, but due to dilution it may be less than the ECe values may be suggested (FAO, 1995). EC value of the soils was positively correlated (r= 0.65*, 0.53) with Ca, Mg), respectively (Appendix Table 8). Changes for conductivities are highly related in soil solutions with the Ca and Mg bicarbonate concentration in the alkaline soils (FAO, 1995).

4.2.3.2 Exchangeable bases

Concentrations of exchangeable cations were generally in the order of Ca>Mg>K>Na (Table 5). This might have resulted from the strong energy of adsorption of Ca, making it typically more abundant as an exchangeable cation than are Mg, K or Na (Foth, 1990). Ca is more strongly absorbed than Na because it is a divalent and has the smallest hydrated radius.

As a result of the small energy of adsorption of Na, it is more likely to exist in the soil solution and be removed from the soil by leaching (Foth, 1990). The maximum values exchangeable Na content of the soil was measured in pedons under the virgin land, where the values increased with increasing the depth in the profiles (Table 5). The exchangeable sodium percentage (ESP) also ranged from 0.83-18.65 indicating that sodicity problem exists in the subsoil layers. Although the pH of the soil was in slightly alkaline range (Herrera, 2005), the soil is saline-sodic having ESP and ECe values of greater than 15 and 4 dSm^{-1}, respectively (Havlin *et al*, 1999).

Table 5: Exchangeable bases, cation exchange capacity (CEC) and percent base saturation (PBS) under the different management systems in ACB, 2007.

Pedon	**Depth**	**Na**	**K**	**Ca**	**Mg**	**Sum**	**CEC**	**PBS**
	cm			cmol. (+)/Kg				%
P-1	0-20	0.19	1.61	39.32	14.31	55.43	50.40	110
	20-48	0.17	0.43	42.96	16.78	60.34	36.00	168
	48-74	0.13	0.38	26.45	10.61	37.57	36.00	104
	138-165	0.20	0.48	29.24	12.66	42.58	51.20	83
P-2	0-30	0.46	4.09	39.82	14.64	59.01	55.20	107
	30-60	0.92	0.62	33.03	13.08	47.65	52.60	91
	60-93	2.06	0.33	40.02	16.94	59.36	62.80	95
	93-160	6.14	0.19	34.83	20.07	61.23	48.20	127
	160-200	8.58	0.17	31.59	18.34	58.67	45.80	128
P-3	0-46	0.33	0.66	29.39	11.02	41.40	37.60	110
	46-60	0.22	0.39	32.78	12.75	46.13	44.40	104
	60-95	0.22	0.28	33.73	12.50	46.74	44.60	105
	95-187	0.14	0.38	31.74	11.76	44.02	52.40	84
P-4	0-45	0.24	1.18	42.81	12.50	56.73	55.40	102
	45-105	0.23	0.27	46.66	14.56	61.71	50.00	110
	105-162	0.18	0.31	41.12	11.10	52.70	53.80	168
	162-200	0.30	0.53	43.31	14.23	58.37	48.60	104

The high values of exchangeable Na and thereby ESP of the soil under virgin land could be due to the shallow ground water from the lake. The lake is moderately saline and alkaline, permanently brown in color due to fine materials in suspension (Wayand *et al.*, 1999). In alluvial soils, high Na saturation is not uncommon and high levels of electrolytes in the soil moisture can be problem as well (FAO, 2001).

The dominant exchangeable cations were Ca and Mg in all the studied pedons. The dissolution of carbonates during extraction using NH_4AOc has partly contributed to the increased Ca values. The highest exchangeable K value was recorded in the surface horizon of the virgin land, whereas the lowest was obtained in the surface horizons of the cultivated banana fields. Similarly, the exchangeable values of K in the sub-surface horizons were higher in the virgin land as compared to that of the cultivated lands (Table 5). Many research results indicated that weathering, intensive cultivation, leaching and generally harvesting all parts of the crop for different purposes affect the distribution of K in the soil systems and enhance its depletion (Baker *et al*., 1997; Saikh *et al*., 1998 b).

4.2.3.3 CEC and PBS

The CEC of the soils in surface layer ranged from 37.6 (P3) to 55.4 (P4) and was generally high according to Landon (1991), who rated CEC values as very low (<5), low (5-15); medium (15-25), high (25-40), and very high (>40). The CEC of surface and subsurface soils varied among the different land use types (Table 5). The variation could be attributed to the differences in OC and clay contents of the land use types. CEC represents the primary soil reservoir of available K, Ca, Mg and several micronutrients. It also helps to prevent nutrients from leaching. The larger the CEC the more nutrients the soil can supply, and it is directly related to the inherent fertility (exchangeable nutrient contents) of the soils (Bandel and Meisinger, 2002).

The percent base saturation of the soil in the pedons ranged from 84 (in the lowest depth of P3) to168 (at 20-48cm and 105-162cm depths of P2 and P4, respectively). The very high

PBS of the pedons indicates the presence of $CaCO_3$, which would be dissolved during CEC determination using 1M NH_4AOc ammonium acetate of pH7, and contributes to the values exchangeable Ca. Therefore, it would not be possible to make generalization on PBS of the soils based on these values.

4.2.3.4 Organic carbon and total nitrogen

The organic carbon (OC) and total nitrogen (TN) values in the pedons varied from 0.34 to 2.74% and 0.02 to 0.27%, respectively (Table 6), and both decreased with depth. The OC contents of surface layers of P1 and P2 could be considered as high according to Herrera (2005), who categorized soil OC values greater than 1.74 in high range. According to Landon (1991), however, the OC contents of the surface layers of the pedons could be rated as very low to medium. The low levels of SOM in the soil is partly because of high temperature of the area that increases decomposion, and partly because of the biological activities is also affected by flooding and water logging which are common phenomena in the ACB. Maintaining a sufficient level of soil organic matter is very important in tropical countries. Similarity, the TN content of the surface layer of P2 is high according to Havlin *et al.* (1999), who indicated TN as low (<0.15), medium (0.15-0.25) and high (>0.25), whereas all the other pedons contained medium TN.

Table 6: Organic carbon (OC), total N (TN) and available phosphorus (AP) under different land use systems; ACB, 2007.

Pedon	Depth (cm)	TN (%)	OC (%)	C/N	AP (mg/kg)
P-1	0-20	0.13	1.80	14	28.38
	20-48	0.09	1.05	12	8.26
	48-74	0.04	0.52	14	9.12
	138-165	0.02	0.34	19	7.34
P-2	0-30	0.27	2.74	10	51.34
	30-60	0.06	0.87	14	3.60
	60-93	0.03	0.59	18	2.08
	93-160	0.03	0.53	18	3.84
	160-200	0.03	0.36	12	2.82
P-3	0-46	0.11	1.07	9	18.12
	46-60	0.07	0.55	8	10.80
	60-95	0.04	0.69	16	9.46
	95-187	0.046	0.61	13	11.12
P-4	0-45	0.12	1.41	12	14.92
	45-105	0.04	0.59	16	3.86
	105-162	0.03	0.41	13	3.86
	162-200	0.04	0.62	16	2.68

OC and TN content decreased with depth in all the pedons. Similarly, depletions in OC and TN were also reported by Solomon *et al*. (2002) from southern Ethiopia soil that was subjected to traditional oxen plowing for 25 year. The TN was very highly and positively correlated (r=0.92***) with OC, indicating the strong influence of organic matter on TN content. The organic carbon (OC) and the total nitrogen (TN) were highly affected by the different land use systems particularly in the surface horizons. The decline in OC and TN in the A horizon of the maize field compared to that of virgin land were by 61 and 59%, respectively, whereas OC and TN were reduced in banana field by 48.5 and 55.5%; and in mixed fruit cropland by 34 and 52%, respectively, as compared to virgin land. This implies that intensive cultivation of annual crops has significantly depleted OC and TN as compared to virgin land. Amongst the cultivated lands, the highest SOM value was obtained from the banana field (3.42%) and the lowest from the maize field (2.68%), showing that the OM content of the maize field in (basin area) was lower than the critical value (NFIU, 1989). The decomposition rate of tropical organic matter is about five times faster in the tropics than in temperate regions. The most effective way to maintain soil fertility, soil structure and biological activity is to provide enough soil organic matter, or soil organic carbon pools, in the soil (Chen and Hseu, 1997).

4.2.3.5. Available phosphorus

The concentration of available phosphorus (AP) in surface layers of the pedons under different land use systems ranged from 14.92 to 51.34 mg kg $^{-1}$soil (Table 6), which was high according to Havlin *et al*. (1999), who rated P-Olsen values as very low (<3), low (4-7), medium (8-11), and high (>12). However, the AP content decreased with depth in all pedons because P is a less mobile plant nutrient in the soil profile (Table 6). The highest concentration of AP was recorded in the virgin land, whereas the lowest was found under the mixed fruit cropland. The highest concentration of AP under the virgin land is attributed to accumulation of organic matter due to little soil disturbance as compared to the cultivated lands. The very high and positive correlation (r=0.93**) obtained between

OC and AP also indicates organic matter highly contributes to AP of soils (Fig 3).

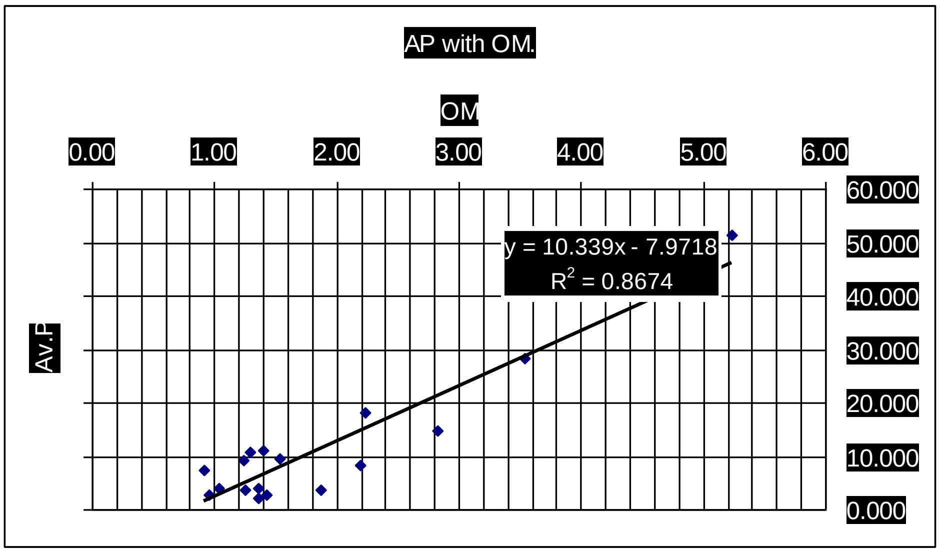

Figure 3: The relationship between AP and OM of the soils under different land uses ACB, 2007

The high organic matter content and its mineralization ensure release of phosphate ions, though most of the phosphate ion released in this way will be in topsoil (OFRF, 2002). The differences in soil AP storages may be resulted from changes in biological and geochemical processes at different depths after human disturbances (Gong *et al.*, 2005). Most alluvial soils have neutral to near-neutral pH values, which do not impair the availability of nutrients (FAO, 2001). The high concentration of AP in the surface soils might also be due to flooding condition prevalent at the site. In most soils, there is an increase in AP after flooding, largely due to a conversion of Fe^{3+} phosphate to Fe^{2} phosphate and hydrolysis of Al/Fe phosphate. Other probable reasons may include increased miniralization that increases the solubility of Ca phosphate in calcareous soils, and greater diffusion of P (Havlin et al., 1999).

4.2.3.6 Micronutrients (Fe, Mn, Zn, Cu)

The distribution of available micronutrients (Mn, Zn, and Cu) in pedons 2 and 4 decreased almost consistently with depth, whereas in pedons 1 and 3 available Fe, Mn and Cu did not follow similar trends (Table 7). The differences in available micronutrients observed in layers of the pedons could be attributed to the material from which the layers were formed. As was revealed by description of the soil profiles (Appendix Table 1-4), the horizon within the profiles were derived from different materials deposited in the area.

The available Fe content generally increased with depth in the pedons under different land uses (Table 7). The highest content (18.96 mg kg^{-1}) of available Fe was found in pedon under virgin land, and the lowest content (3.380 mg kg^{-1}) in surface horizon of pedon under maize field (Table 7). The values of available Fe obtained from surface layers of the pedons were within high range except for the soils of maize field, which was in marginal range according to Havlin *et al*. (1999), who categorized available Fe values as low (0-2.5), marginal (2.6- 4.5) and high (>4.5).

Table 7: Available micronutrients under the different land use systems; ACB, 2007.

Pedon	Depth (cm)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Cu (mg/kg)
P-1	0-20	3.38	12.97	1.00	111.53
	20-48	10.45	9.17	0.50	1.78
	48-74	9.36	8.86	0.46	1.37
	138-165	12.71	7.84	0.59	1.20
P-2	0-30	11.15	11.48	1.31	1.33
	30-60	11.82	4.17	0.27	1.09
	60-93	18.96	2.44	0.27	0.99
	93-160	7.39	2.58	0.24	1.21
	160-200	5.12	2.52	0.24	1.13
P-3	0-46	6.37	15.25	0.48	1.59
	46-60	7.21	8.93	0.23	1.66
	60-95	15.50	14.10	0.12	0.26
	95-187	12.62	7.60	0.32	1.28
P-4	0-45	15.09	13.61	0.70	1.30
	45-105	8.46	10.27	0.23	1.19
	105-162	11.99	4.83	0.19	0.86
	162-200	7.25	2.92	0.15	0.81

The available Mn content of the surface layer of the pedons ranged from 11.48 to 15.25 mg kg^{-1} and consistently decreased with depth, except for P_3 (Table 7). As the concentrations of Mn in the surface soil layers were greater than 11.48 mg kg^{-1} against the critical level of 5mg kg^{-1}, Mn toxicity would be expected in the study area. In spite of variations between available Fe and Mn concentrations, Fe and Mn were at toxicity levels for most plants at the surface horizons (Lindsay and Norvell, 1969).

The high concentration of Mn in these soils might be attributed to the flooding and water logging conditions prevalent at the site. Marscher (2002) indicated that water logging and flooding increases the quantity of Mn in the soils. Mn availability can be increased by poor aeration in compact soils and by local accumulations of CO_2 around roots and other soil micro sites. The resulting low- redox conditions will render Mn more available without appreciably affecting the redox potential or pH of the bulk soil (Havlin et al., 1999).

The values of available Zn in surface layers of the pedons ranged from 0.48 to 1.31mg kg^{-1}, which is very low according to Havlin et al. (1999), who rated available Zn values as low (0-0.5), marginal (0.6-1.0) and high (>1.0). The low Zn content in the soils might be due to the parent materials. Mengel and Kirkby (1987) indicated that soils derived from basic rocks are rich in Zn, whereas those derived from siliceous material are Zn different. The soils of the study area are derived from alluvium that might have consisted of more siliceous material. The relatively high Zn content in surface horizon of P_2 might be due to the OC content as Zn was positively and significantly (r=0.70*) correlated with OC (Appendix Table 8). Zn content decreased consistently with increasing depth in all pedons. The depletion of available Zn in the maize and mixed fruit croplands were by 60 and 28%, respectively, as compared to the highest records in virgin land. The depletion of available Zn from the cultivated lands is primarily related to depletion of OM. Although, high availability of P induces Zn deficiency, available Zn content was positively and significantly correlated (r= 0.71*) with AP content, indicating that both AP and Zn are from the same source (from OM).

The concentration of Cu in the surface layers of pedons under different land uses was found to be almost similar ranging from 1.30 to 1.59 mg kg^{-1} soil (Table 7). This indicates the level of available Cu in the study area is within low range for crop production (Havlin *et al*., 1999). Similar to that of Zn, this low level of copper in the soils might also be attributed to the parent material from which the soils were derived.

The trend of available manganese (Mn) concentration under the different LUTs was similar to that of Fe distribution but differ in maize field (Table 7). Moreover, the available Fe and Mn decreased consistently within soil depths of each land use systems, indicating that these two elements have similar chemical behaviors in tropical soils as described by Krauskof (1972). The high available Fe, Mn, Zn and Cu in the surface horizons may be due to complex formation with organic compounds that protects their leaching. As a result their concentrations decreased with depth in line with previous reports by Kolay (1993) and Havlin et al. (1999).

4.2.4. Classification of the soils

The soils were classified according to WRB (FAO, 2001), on the basis of their morphological, chemical and physical properties. Characterization and classification of the pedons is discussed below.

The surface horizons of P2, P3 and P4 had moist color of 10 YR with value and chroma ≤2 (Table 3). These pedons possessed 45-74 cm thick surface horizon having OC >1% and, PBS >50 and available (Tables 5 and 6). On the other hand, P1 possessed surface horizon having "very dark brown" color (7.5 YR 2.5/4, moist), 20 cm thickness, 1.80% OC, and PBS > 50. Thus, P2, P4 and P4 had mollic, whereas P1 had ochric epipedons.

Pedons under the maize and the banana fields were made up of material that is deposited at irregular intervals. The stratified layers of P_1 and P_3 were 41 and 63% of the volume of the soils within 125 cm of the surface, respectively. These pedons had >0.5% OC that decreased irregularly with depth within 125, AC-profile forms, and lithological discontinuities (Appendix Table 1and 3). Therefore, the pedons under maize and banana fields are classified as Eutric Fluvisols according to WRB (FAO, 2001). The reasons for the absence of clear genetic horizons in pedons under maize and banana fields could be due to due to younger age of the deposition and regular addition of alluvial materials from the surrounding mountains. On flood plain areas continuous saturation may inhibit horizons formation where material deposition faster than a soil profile can develop (Norman *et al*., 1995).

Pedons under virgin land had granular and sub angular blocky structure in their surface and the subsurface horizons, respectively (Table 3), whereas under the mixed fruit cropland had a sub angular blocky structure in their surface horizon and massive at the subsurface horizons (Table 3). This indicated that the pedons have moderately developed structure with little rock fragments. The moist colors of the subsurface horizons of the pedons under virgin and mixed fruit croplands were 10YR with chromas $\leq$ 4, which were stronger than that of the underlying horizons.

The whole horizons of the pedons under virgin and mixed fruit croplands were marked by dark brown to black color (Appendix Table 2 and 4). The B-horizons were characterized by considerable quantities of silt and uniform particle size distribution (Table 4), which indicated that the presence of weatherable minerals. The absence of clay skins (Appendix Table 2 and 4) indicates insufficient illuviation of clay. The soils also have high base saturation (93-128%). These show that the pedons have cambic (Bw) horizons and are identified as Eutric Cambisols according to WRB (FAO, 2001).

Following the Soil Taxonomy (Soil Survey Staff, 1999) classification system, the soils under maize and banana fields classified as Entisols, where as those under virgin and mixed fruit croplands as Inceptsols at the highest category of the system.

Transformation from the Fluvisols into Cambisols was expected when soil conditions preserve permanent or seasonal saturation with water and when soil formation sets in; a cambic subsurface horizon will quickly form from the stratified layers of the original deposits (FAO, 2001). However, the intensive human use of natural vegetation for the past 3 decades has probably resulted in faster depositions that may not give enough time for the transformation process and development of cambic subsurface horizons. Hence, addition process is higher than transformation. Mineralogical analysis of calcium carbonate equivalent was not determined in this study but the percentage base saturation (PBS) values ranged from 83 to 168% for all horizons of the soil profiles (Table 5), suggested that a high $CaCO_3$ concentration. Most alluvial sediments contain some calcium carbonate, and the exchange complex saturated with bases (FAO, 2001).

4.3. Influence of Changes in Land Use Types on Properties of the Surface Soils

The study provided information on major changes in crop cultivation during the last 30 years, at ACB. The original forests were converted to cereal and cotton cultivation during 1970s-1990s whereas the smallholders' perennial fruit crops cultivation progressively increased starting from 1991 and subsistituted the previous annual cropping system with settlement expansion and cultivation. However, subsistence farming system (maize cultivation) has been practiced in the area for home consumption purpose. Based on the information obtained from the survey, except selected farm owners and development agents, farmers were not using chemical fertilizers. In 2002, however, very few farmers have used fertilizers on their subsistence farming through the debit provided the government. But, the communities lost interest due to its cost and relatively good yield without fertilization, particularly from cash crops like banana. Thus, recently there is no chemical fertilizer distribution in the area. Organic fertilizer is not also widely practiced in the area, although it is cost effective and simple.

4.3.1. Physical properties

The percent silt content of virgin land was found to be the highest (57.33%) and significantly ($P \leq 0.05$) differed from that of maize (47.33%), which indicates that the cultivated land had relatively lowest value (Table 8). Further more, the clay content of maize field was highest (41.33%a) and significantly ($P \leq 0.05$) varied from virgin land

(27.67%), banana field (32.33%), and mixed fruit cropland (31.00%) (Table 8). This could be due to the deposition of fine-grained materials by rivers on the flood plain areas, where coarse textured particles remained in watercourse (levees) and more finely textured soil particles were transported to basin areas. In line with the present finding, FAO (2001) confirmed that the classical arrangement of soil particles in the flood plains is in the order of coarsely textured particles on the levees and more finely textured soils in basin areas further away from the river.

The surface soil percent clay content was negatively and very significantly correlated (r= -0.76**, -0.73**) with TN and OC, respectively, and significantly correlated (r= -0.66*) with Ca, Mg, PBS, and AP (Appendix Table 9). This indicates that nutrient diffusion through clay soils are much more likely to be attracted to adsorption sites on the clay than in a relatively coarse textured soils (Havlin *et al*., 1999). Casenave and Valentin (1989) demonstrated that, if soil surface is no longer in equilibrium with vegetation and soil fauna, surface crusting is a succession process corresponding to specific degradation stages. OM associated with the coarser fraction is more labile and the first to be affected by changes in land use and soil management (Christensen, 1996; Solomon *et al*., 2002).

Table 8: Physicochemical properties of surface soil (0-30cm) as influenced by LUT; ACB, 2007.

	Soil and Land use Relationship				
	Land use type means pair wise comparison				
	X CrMa	XNF	XFrBa	XFrBaMa	Std. error
pH: H2O (1:1.25)	6.77	6.93	7.10	7.00	0.21
pH: KCl (1:1.25)	5.40	5.83	5.87	5.53	0.25
EC (dS/m)	0.11	0.51	0.16	0.13	0.06
Sand (%)	11.33	15.0	15.00	20.33	3.89
Silt (%)	47.33	57.33	52.67	48.67	2.99
Clay (%)	41.33	27.67	32.33	31.00	2.16
Na (cmol (+)/kg)	0.19	0.36	0.19	0.12	0.05
K “	1.12	3.34	3.04	1.55	0.52
Ca “	39.92	38.49	29.74	34.30	2.88
Mg “	14.17	14.86	10.80	9.76	1.27
Sum (cations)	55.40	57.05	43.77	45.72	3.44
CEC (cmol (+)/kg)	55.87	45.67	46.33	49.27	4.28
PBS (%)	99.33	125.33	95.00	95.67	12.32
TN (%)	0.12	0.45	0.12	0.14	0.07
OC (%)	1.32	4.77	1.79	1.71	0.75
C/N (%)	11.33	10.33	16.00	12.67	1.63
AP (mg/kg) (Ols)	20.21	49.27	57.04	26.70	12.42
Fe) (mg/kg)	9.69	12.34	15.46	13.61	1.67
Mn) (mg/kg)	10.75	9.21	12.27	13.18	1.80
Zn (mg/kg)	0.59	1.13	1.20	0.8	0.47
Cu (mg/kg)	1.10	0.69	1.13	1.10	0.10

CeMa= Cereal, maize field; FrBa= Fruit, Banana; FrBaMa= Fruit, Banana and Mangoes mix; FN= Natural forest

4.3.2. Chemical properties

The EC values varied among the four land use types (Appendix Table 9), but still remained within the satisfactory levels for cultivated land use types (Table 8). Thus, EC in all surface soils of the cultivated land uses was below the critical level, as the result no salinity problem expected. The probable reason for low level of EC in cultivated lands is due to the soil management practices that were without any use of inorganic chemicals, which do not increase soil salinity (Clark *et al*., 1998; Werner, 1997).

The soil OC decreased from 4.77 to 1.32, 1.79 and 1.71 in maize field, banana monoculture and mixed banana- mango farms, respectively. This shows that continuous cultivation of soils like that of maize fields enhances depletion of OC. The changes in TN during 30 years were found to be 69, 73 and 74% for mixed fruit crop, monoculture banana and maize fields, respectively (Table 8). The decline in TN could be attributed the loss of OC due to cultivation.

Many studies have suggested that under continuous cultivation, SOM declined approximately by 50% in 40 to 70 years, depending on the environment and the quantity of residue returned to the soil. Crop productions significantly decrease SOM (Gong *et al*., 2005; Havlin *et al*., 1999; Islam, 2000). Changes in management can affect soil structure, SOC, and other nutrients (Yeshanew *et al*., 2004). Comparable losses of SOC and nutrients due to cultivation of forest soils have been reported in many studies in that differences in soil nutrients and C pools between once-farmed and never farmed land derived from agrarian practices and the differences could be attributed to the effect of continuous cultivation that aggravates OC oxidation (Lal, 1996; Solomon *et al*., 2002; Yeshanew *et al*., 2004; David *et al*., 2006).

The total nitrogen (TN) content of virgin land was the highest (0.45%), which was significantly different ($P \leq 0.05$) from all other land use system, whereas the lowest mean value of TN (0.12%) was recorded in maize field (Table 8). TN was positively and very highly correlated (r=0.99***) with OC (Fig. 4). The low levels of OC and TN in cultivated soils may have resulted from a combination of low C inputs because of less biomass return on harvested land and greater C losses due to aggregate disruptions, increased aeration by tillage, crop residue burning, microbial disturbance and livestock grazing (Islam, 2000). In contrast, greater OC and TN contents of the forest soils are probably due to higher litter production and N fixation by the leguminous Acacia species.

The temporal changes in TN was similar to those of SOC content for surface soils with a rate of depletion about 2.46 to 2.4% per year for maize field and at the rate of 2.4 to 2.1% per year for monoculture banana, and for mixed fruit crop land at the rate of 2.26 to 2.13% per year when compared to the virgin land. The TN and OC differed significantly between land use/land cover, and decreased with cultivation time (Lal, 1996). The changes in soil that decrease its productivity for crop plant may follow from three processes: cropping, erosion and leaching. These may adversely affect the physical condition or (Mitchell et al., 2000) the chemical composition of the soil or both (Amusan et al., 2001). In contrary, nearly four times increment in SOM and TN were obtained in the forest land over 40 years period. Murphy (1968) reported that the OM and TN contents of the natural forest site were 2.32 and 0.11%, respectively, which have increased to 9.04 and 0.45% at present.

In general the C: N ratio of soils increased in the cultivated lands compared to virgin land. The order of C/N followed virgin land (10.3) < maize field (11.3), mixed fruit cropland (12.7) < monoculture banana field (16.0) (Table 8). A good C: N ratio will result in the formation of both effective humus and stable humus and a ratio of about 10:1 is considered ideal (Bellevue, 1992). However, the C: N ratio decreased with cultivation for a given period of time (Lal, 1996). Generally, the SOC and TN associated with the annual crop management appeared to be more sensitive to changes in land use and management compared with that in perennial crop management.

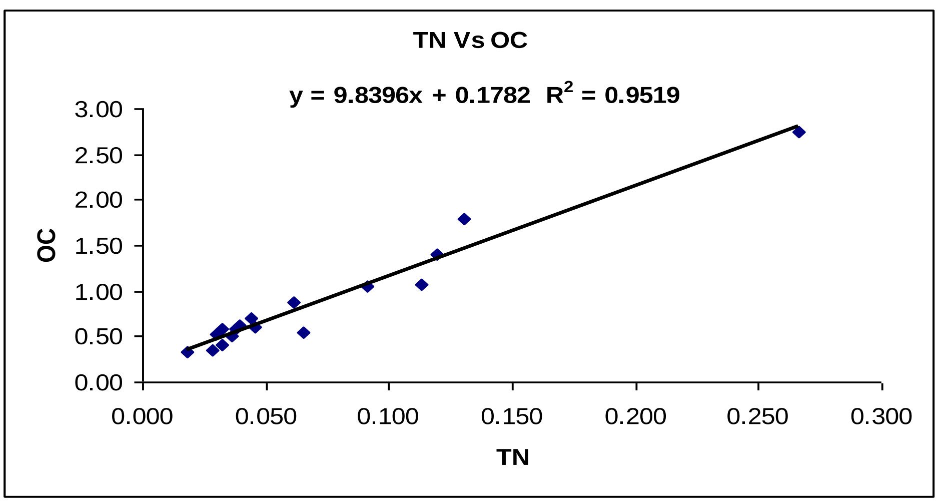

Figure 4: Relationships between TN and OC in surface soils of ACB

The available P was very high in surface soils of different land use types, which is in the order of banana field > virgin land > mixed fruit cropland > maize field (Table 8). The highest available P level in the area is likely because of irrigation/flooding in the alluvial flood plain environment. In most soils there is an increase in AP after flooding, due to increased mineralization of organic P in acid soils and increased solubility of Ca phosphate in calcareous soils, and greater diffusion (Havlin *et al.*, 1999).

The lowest level of K in cropland, for example in maize field and mixed fruit cropland, as compared to virgin land indicates the conversion of forest land into cropland can increase losses which could be attributed to run-off and crop residue clearing. Gong *et al.* (2005) also indicated that harvest could take high K values from the soil and hence results in lowering K levels in agriculture fields. The exchangeable K content of banana field was significantly different ($P \leq 0.05$) from that of maize field.

The high values of exchangeable Na under virgin land could be due to the shallow ground water from the lake. The lake is moderately saline and alkaline, permanently brown in color due to fine materials in suspension (Wayand *et al.*, 1999). As a result of shallow ground water from the lake, the amounts of exchangeable Na and ECe might have increased under virgin land. In alluvial soils, high Na saturation is not uncommon and high levels of electrolytes in the soil moisture can be problem as well (FAO, 2001).

Significantly lower values of exchangeable Ca and Mg were found in banana mixed fruit cropland, respectively (Table 8), indicating continuous harvest for the past three decades contributed for the depletion of Ca and Mg in the all cultivated lands. Although the CEC values of the soils under different land uses were high and did not significantly vary, relatively highest value was recorded under maize fields (Table 8). This might be attributed to the relatively highest clay content of the maize field, as clay increment would result in increased CEC. There was also a positive, but insignificant correlation between CEC and clay (Appendix Table 9).

The available micronutrients especially Fe and Cu were influenced due to different land use systems as compared to virgin land. The available Mn and Zn in the surface soils were not significantly varied may be due to complex formation with organic compounds that protects their leaching. This is in line with previous reports by Kolay (1993) and Havlin *et al*. (1999).

The soil properties considered in this study were influenced both by differences in land use/management and soil type (Appendix Table 6). Significant effects of the difference in soil type were obserebed on OC, TN, C/N EC, and available Cu. On the other hand, land use/management influenced all the soil properties considered, except pH, % sand, CEC, PBS, available Mn and Zn contents. This indicates that management factors largely determine changes in soil properties. Particularly, inappropriate land use aggravates the rate of degradation of these properties. Maddonni *et al*. (1999); Singh *et al.* (1995); Saikhe *et al*. (1998) reported that land use affects basic processes such as erosion, soil structure and aggregate stability, nutrient cycling, leaching, carbon sequestration, and other similar physical and biochemical processes, although processes in the soil depend on many factors such as land use systems, soil types, topography, and climatic conditions.

However, the absence of significant influences on the soil properties such as soil pH, sand content, CEC, PBS, Mn and Zn shows the existence of some properties, which were not responsive to management. IIASA (2006) also showed that, CEC and particle size were not responsive to land use/management effects. In general, soil functions depend on both stable and dynamic soil properties. The difference between management–dependent and inherent soil properties vary at temporal scales ranging from seconds to centuries and at spatial scales from millimeters to hundreds of kilometers. Over a sufficient time period, practices that affect dynamic soil properties and stable soil properties will change. Because land attributes are based on (1) climatic factors, (2) internal soil properties (temperature-regime, moisture regime, effective depth, pH, EC), and (3) external soil properties (soil slope, occurrence of flooding, erosion and soil accessibility) (Lal, 1996).

5. SUMMARY AND CONCULISION

The study was conducted to systematical examine, describe, characterize and assess the Fruit Based Land Use Systems and their effect on physicochemical properties of the soils in Gamo Gofa, Southern Ethiopia. The study comprised of four PAs and area covered is about 3243.60 ha, in Abaya Chamo Basin (ACB).

A semi-structured survey was carried out in the study area, keeping in view the heterogeneity of the LUTs. The farmers' categorization of the LUTs were based on watercourse soil fertility status, viz.: monoculture cash crop farming (nearby watercourse); subsistence farming (mid way watercourse); and mixed farming (at extreme distant to watercourse). Accordingly, the survey result from the PAs has indicated that monoculture banana and mixed farming systems were the dominant LUTs in Chano Chalba, in Kola Shara and Chano Dorga PAs, respectively, whereas subsistence farming system was dominant in Chano Mile PA (Table 2).

The soils of the study site were classified based of their morphological, chemical and physical properties obtained from field descriptions and laboratory analyses. The pedons under maize and banana fields dominated by recent sedimentation and stratified layers started at 74 and 46 cm, respectively. The deposits vary in short distance and depth of the soil throughout the profile. On the other hand, the morphological features of pedons under virgin and mixed fruit croplands showed change in color, structure and consistency, with insufficient illuvation of clay in B horizons. According to WRB (FAO, 2001), the soils of pedons under maize and banana fields were classified as Eutric Fluvisols, whereas those under virgin and mixed fruit croplands were classified as Eutric Cambisols.

The influences of land use/management systems, on soil properties indicated that the soil physical properties such as structure, bulk density and total porosity showed notable variations among land use systems, particularity in A- horizon. The highest bulk density (1.57 Mg $^{-3)}$ was recorded at maize field, whereas the lowest was (1.16 Mg m$^{-3)}$ in mixed fruit cropland of the surface horizon. The soil pH (H_2O) was 6.4 in mixed cropland as compared to 7.4 in virgin land. The depletion of OC and TN from the A-horizon of maize field compared to virgin land was 61 and 59%, respectively. Similarly, the depletion of 48.5 and 55.5% in banana field and 34 and 52% in mixed fruit cropland were recorded for OC and TN, respectively for the past three decades. Likewise, the depletion of CEC from the banana field and the maize field was 32 and 13%, respectively, as compared to the CEC of A- horizon in the virgin land. The available micronutrients especially Fe and Cu were also influenced by different land use systems (Table 8).

Total nitrogen and available phosphorous contents correlated positively and highly significantly with organic carbon and electrical conductivity. Clay, organic carbon, total nitrogen and available phosphorous contents decreased with increasing depth. Generally chemical properties such as percent base saturation, exchangeable K, Ca and Mg, available P, Mn and Fe contents were maximum under virgin land as compared to cultivated land use systems.

Considering the land use as a control variable, the statistical analysis of the surface soils revealed that most of the soil physicochemical properties were significantly influenced by different land use/management practices (Table 6). The soil properties considered in this study were influenced both by differences in land use/management and soil type (Appendix Table 6). Significance effects of the difference in soil type were obserebed on OC, TN, C/N EC, and available Cu (Appendix Table 6). On the other hand land use/management influenced all the soil properties considered, except pH, %sand, CEC, PBS, available Mn and Zn contents. This indicates that management factors largely determine changes in soil properties. Particularly, inappropriate land use aggravates the rate of degradation of these properties. In contrary, nearly four times increment in SOM and TN were obtained in the forest land over 40 years period. The OM and TN contents of the natural forest site increased from 2.32 and 0.11%, in 1968 to 9.04 and 0.45%, respectively, at present. There was no significant influence of change in land use on some properties such as soil pH, % sand, CEC, PBS, Mn, and Zn, contents indicating that, at least some of the stable soil properties are not responsive to management.

Generally, the SOC and TN associated with the annual crop management appeared to be more sensitive to changes in land use and management compared with that of perennial crop management. TN was found to be the most influenced property and hence depleted due to cultivation in the present study. Generally, the study revealed that most of the soil properties are influenced by land use systems, and cultivation has negative effects on physicochemical properties of the soils. Therefore, it could be recommended to include management practices that increase OC and TN in the system, when the land is continuously cultivated. Further, studies on selection of appropriate leguminous specious that bring N to the system, nutrient flows and soil- plant analysis are recommended to draw sound conclusion.

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APPENDEX TABLES

Appendix Table 1: Profile description of the Subsistence Farming System (Maize field) **(P1)** at ACB

Information on the Site

Field No:	1
Profile No:	P1
Date of examination:	1 January 2007
Location:	Chano Mille
District:	Arba Minch
Zone:	Gamo Gofa
Region:	SNNPR
Altitude:	1215 masl
Grid Reference:	
Coordinates:	37^0 35'42" E and 9^0 05'16" N
Author of Description	Tuma Ayele
Soil classification:	FAO-Eutric Fluvisol
	USDA: Fluvent
Surrounding landform:	Plain
Physiographic position:	Alluvial Mid Plain
Slope gradient:	2 % towards East
Moisture condition:	Moist through out
Drainage class:	Well drained
Ground water depth:	> 300 cm
Parent materials:	Alluvium
Erosion status: at site	None
Surrounding:	Moderate Sheet
Rock out crops	
and/or stoniness:	None
Land use/cover:	Under Cultivation of Maize & Cotton (Irrigated).

Horizon Description (P1)

Horizon	Depth (cm)	Description
Ap	0-20	Very dark brown (7.5YR 2.5/2) (moist), brown (7.5YR 4/2) (dry); clay loam; weak medium sub angular blocky structure; hard, slightly firm, slightly sticky and slightly plastic; moderate fine interstitial pores; many medium roots; clear and smooth boundary.
A1	20-48	Very dark brown (7.5YR 2.5/3) (moist), dark brown (7.5YR 3/3) (dry); clay loam; moderate coarse sub angular blocky structure; hard, slightly firm, slightly sticky and slightly plastic; common fine interstitial pores; common medium and fine roots; clear and smooth boundary.
A2	48-74	Dark brown (7.5YR 3/2) (moist), brown (7.5YR 4/3) (dry); fine sandy loam; weak course angular blocky structure; hard, friable, slightly sticky and slightly plastic; many medium interstitial pores and channels; few medium roots; abrupt and smooth boundary.
2C1	74-108	Extremely stony
2C2	108-138	Extremely gravelly
3C	138- 165	Dark brown (7.5YR 3/3) (moist), brown (7.5YR 4/4) (dry), silty; massive structure; hard, friable, non-sticky and non-plastic; common medium interstitial pores; very few fine and medium roots; abrupt and smooth boundary.
4C	165- 300	Successive deposition and Laminated layer.

Appendix Table 2: Profile description of the Representative Virgin Land (Natural Forest field (P2**)** at ACB
Information on the Site

Field No:	2
Profile No:	P2
Date of examination:	1 January 2007
Location:	
Chano Mille	
District:	Arba Minch
Zone:	Gamo Gofa
Region:	SNNPR
Altitude:	1179 masl
Grid Reference:	
Coordinates:	37^0 35’42” E and 9^0 05’16” N
Author of Description	Tuma Ayele
Soil classification:	FAO-Cambisols
	USDA: Inceptsol
Surrounding landform:	Plain
Physiographic position:	Plain
Slope gradient:	1 % towards East
Moisture condition:	Moist through out
Drainage class:	Well drained
Ground water depth:	> 200 cm
Parent materials:	Alluvium
Erosion status: at site	None
Surrounding:	Slightly Sheet
Rock out crops	
and/or stoniness:	None
Land use/cover:	Natural Forest.

Horizon Description (P2)

Horizon	Depth (cm)	Description
A1	0-30	Very dark brown (10YR 2/2) (moist), dark brown (10YR 3/3) (dry); loam; weak medium granular structure; hard, friable, non-sticky and non-plastic; many course interstitial pores; many fine to course roots; clear and smooth boundary.
A2	30-60	Dark brown (10YR 3/3) (moist), yellowish brown (10YR 5/4) (dry); silty clay loam; weak medium sub angular blocky structure; hard, friable, non-sticky and non-plastic; few fine interstitial pores; many fine to course roots; clear and smooth boundary.
Bw1	60-93	Dark brown (10YR 3/3) (moist), pale brown (10YR 6/3) (dry); silty clay; weak medium sub angular blocky structure; hard, friable, non-sticky and non-plastic; many fine and medium pores; common medium roots; clear and smooth boundary.
Bw2	93-160	Dark brown (10YR 3/2.5) (moist), pale brown (10YR 6/3) (dry), silty clay; weak medium sub angular blocky structure; hard, friable, moderately sticky and slightly plastic; many few and medium interstitial pores; moderate carbonate concentration; few medium roots; clear and smooth boundary.
2C	160-200^{+}	Dark brown (10YR 3/3) (moist), pale brown (10YR 6/3) (dry), silty clay; massive structure; hard, friable, slightly sticky and slightly plastic; many fine and few medium interstitial pores; strong carbonate concentration; abrupt and smooth boundary.

Appendix Table 3: Profile description of the Monoculture Farming System (Banana Monoculture field (P3) at ACB

Information on the Site

Field No:	3
Profile No:	P3
Date of examination:	1 January 2007
Location:	Chano Chalba
District:	Arba Minch
Zone:	Gamo Gofa
Region:	SNNPR
Altitude:	1205 masl
Grid Reference:	
Coordinates:	37^0 35'42" E and 9^0 05'16" N
Author of Description	Tuma Ayele
Soil classification:	FAO-Fluvisol
	USDA: Fluvent
Surrounding landform:	Flat
Physiographic position:	Lower slope
Slope gradient:	1 % towards East
Moisture condition:	Moist through out
Drainage class:	Well drained
Ground water depth:	> 300 cm
Parent materials:	Alluvium
Erosion status: at site	None
Surrounding:	None
Rock out crops	
and/or stoniness:	None
Land use/cover:	Under Cultivation of Banana Monoculture Irrigated.

Horizon Description (P3)

Horizon	Depth (cm)	Description
Ap	0-46	Black (10YR 2/1) (moist), dark brown (10YR 3/3) (dry); clay loam; weak medium sub angular blocky structure; hard, firm, sticky and plastic; many fine and medium channels; many medium and course roots; abrupt and smooth boundary.
2C	46-60	Dark brown (10YR 3/3) (moist), brown (10YR 4/3) (dry); gravelly clay; massive structure; hard, friable, slightly sticky and plastic; many fine and medium channels; many medium and course roots; abrupt and smooth boundary.
3Ab1	60-95	Very dark gray (10YR 3/1) (moist), yellowish brown (10YR 5/4) (dry); silty loam; massive structure; hard, friable, slightly sticky and plastic; many fine and medium channels; few and medium roots; clear and smooth boundary.
3Ab2	95-187	Dark brown (10YR 3/3) (moist), dark yellowish brown (10YR 4/4) (dry), silty loam; massive structure; hard, friable, slightly sticky and plastic; many fine and medium channels; clear and smooth boundary.
3C	187-270^{+}	Fine sandy layer

Appendix Table 4**:** Profile description of the Mixed Farming System (Banana-Mango Mixed field (P4) at ACB
Information on the Site

Field No:	4
Profile No:	P4
Date of examination:	1 January 2007
Location:	Chano Dorga
District:	Arba Minch
Zone:	Gamo Gofa
Region:	SNNPR
Altitude:	1223 masl
Grid Reference:	
Coordinates:	37^0 35’42” E and 9^0 05’16” N
Author of Description	Tuma Ayele
Soil classification:	FAO-Cambisol
	USDA: Inceptisol
Surrounding landform:	Plain
Physiographic position:	Alluvial Mid Plain
Slope gradient:	1 % towards East
Moisture condition:	Moist through out
Drainage class:	Well drained
Ground water depth:	> 300 cm
Parent materials:	Alluvium
Erosion status: at site	None
Surrounding:	Slightly Sheet
Rock out crops	
and/or stoniness:	None
Land use/cover:	Under Cultivation of Banana-Mango Mixed Irrigated.

Horizon Description (P4)

Horizon	Depth (cm)	Description
Ap	0-45	Black (10YR 2/1) (moist), dark brown (10YR 3/3) (dry); silty clay; weak fine sub angular blocky structure; hard, slightly firm, moderately sticky and plastic; many fine and medium interstitial pores; common fine and medium roots; clear and smooth boundary.
Bw	45-105	Dark yellowish brown (10YR 3/4) (moist), dark yellowish brown (10YR 4/4) (dry); silty clay; moderate medium sub angular blocky structure; hard, friable, sticky and plastic; many fine and course medium interstitial pores; few fine and common roots; clear and smooth boundary.
2C	105-162	Dark brown (10YR 3/3) (moist), brown (10YR 5/3) (dry); silty clay; massive structure; hard, friable, slightly sticky and slightly plastic; many fine and medium pores; clear and smooth boundary.

Appendix Table 5 : Descriptive Stastics value of Pedons

Identifier	Minimum	Mean	Maximum	Values	Missing
pH(H_2O) (1:2.5)	6.30	6.99	7.50	17	0
pH(KCl) (1:2.5)	4.50	5.39	6.40	17	0
EC (dSm^{-1})	0.05	0.94	5.30	17	0
Bulk density (g/cm^3)	1.16	1.38	1.65	17	2
Particle density (g/cm^3)	2.25	2.55	3.05	17	2
Porosity (%)	38.71	45.71	58.86	17	2
Sand (%)	10.00	21.06	50.00	17	0
Silt (%)	30.00	54.24	86.00	17	0
Clay (%)	4.00	24.71	42.00	17	0
Na (cmol (+)/kg)	0.13	1.22	8.58	17	0
K (cmol (+)/kg)	0.16	0.72	4.09	17	0
Ca (cmol (+)/kg)	26.45	36.40	46.66	17	0
Mg (cmol (+)/kg)	10.61	13.99	20.07	17	0
Sum	37.57	52.33	61.71	17	0
CEC (cmol (+)/kg)	36.00	48.53	62.80	17	0
PBS (%)	83.17	111.70	167.60	17	0
TN (%)	0.018	0.07	0.27	17	0
OC (%)	0.34	0.87	2.74	17	0
C/N	8.49	1.86	5.23	17	0
AP (mg/kg)	2.08	11.27	51.34	17	0
Fe (mg/kg)	3.38	10.28	18.96	17	0
Mn (mg/kg)	2.44	8.208	15.25	17	0
Zn (mg/kg)	0.12	0.43	1.310	17	0
Cu (mg/kg)	0.260	1.211	1.780	17	0

Appendix Table 6: Tests of Between Subjects Effects and their univariate Tests of mean values of soil samples from a depth of 0-30cm at ACB

S No	*Dependent variable*	*Sum of (Independent) variable Effects*	*SS*	*Df*	*MS*	*F*	*Signi*	*Adjusted R square*	*Remarks on subsets Test effects*
1	pH H_2O	Soil	0.003	1	0.03	0.052	0.825ns	0.023	No eaffected
		Land (Soil)	0.173	2	0.087	1.351	0.312ns		
		Land	0.177	3	0.059	0.918	0.475ns		
2	pH KCl	Soil	0.008	1	0.008	0.081	0.783ns	0.159	
		Land (soil)	0.462	2	0.231	2.495	0.144ns		>>
		Land	0.469	3	0.156	1.611	0.246ns		
3	EC	Soil	0.097	1	0.97	15.920	0.004	0.189	Both effected
		Land (soil)	0.226	2	0.113	18.490	0.001		
		Land	0.323	3	0.108	17.633	0.001		
4	Sand	Soil	60.750	1	60.750	2.680	0.140ns	0.182	No effected
		Land (soil)	63.833	2	31.417	1.386	0.304ns		
		Land							
5	Silt	Soil	27.000	1	27.000	2.025	0.193ns	0.493	Land use was affected on soil
		Land (soil)	155.333	2	77.667	5.825	0.027		
		Land	182.333	3	60.778	4.558	0.038		
6	Clay	Soil	168.750	1	168.750	24.107	0.001	0.655	Land use affected
		Land (soil)	138.167	2	69.083	9.869	0.007		
		Land	306.917	3	102.306	14.615	0.001		
7	Na	Soil	0.009	1	0.009	2.040	0.191ns	0.655	Land use affected
		Land (soil)	0.091	2	0.046	10.908	0.005		
		Land	0.100	3	0.033	7.952	0.009		
8	K	Soil	0.392	1	0.392	0.982	0.351ns	0.685	Land use affected
		Land (soil)	10.373	2	5.186	12.975	0.003		
		Land	10.765	3	3.588	8.977	0.006		
9	Ca	Soil	7.332	1	7.332	0.587	0.465		Land use affected
		Land (soil)	181.825	2	90.912	7.283	0.016		
		Land	189.157	3	63.052	**5.051**	0.030		

10	Mg	Soil	0.094	1	0.094	0.039	0.849s	0.647	Land use affected
		Land (soil)	56.101	2	28.051	11.562	0.004		
		Land	56.195	3	18.732	7.721	0.01		
11	Sum	Soil	9.738	1	9.738	0.548	0.480ns	0.643	Land use affected
		Land (soil)	395.319	2	197.660	11.125	0.005		
		Land	405.057	3	135.019	7.599	0.010		
12	CEC	Soil	39.603	1	39.603	1.443	0.264ns	0.272	None of the subjects were affected
		Land (soil)	155.767	2	77.883	2.838	0.117ns		
		Land	195.370	3	65.123	2.373	0.146ns		
13	PBS	Soil	533.333	1	533.333	2.342	0.164ns	0.324	>>
		Land (soil)	1348.333	2	674.167	2.960	0.109ns		
		Land	1881.667	3	627.222	2.754	0.112ns		
14	TN	Soil	0.092	1	0.093	12.666	0.007	0.684	Both subjects were affected
		Land (soil)	0.144	2	0.072	9.845	0.007		
		Land	0.237	3	0.079	10.785	0.003		
15	OC	Soil	8.578	1	8.518	9.965	0.013	0.684	
		Land (soil)	14.367	2	7.184	8.405	0.010		>>
		Land	22.885	3	7.628	8.925	0.006		
16	C/N Ratio	Soil	14.083	1	14.083	3.521	0.097	0.494	Both subjects were affected
		Land (soil)	40.833	2	20.417	5.104	0.037		
		Land	54.917	3	18.306	4.576	0.038		
17	AP	Soil	1.229	1	1.229	0.005	0.944ns	0.453	Land use was affected
		Land (soil)	2798.638	2	1399.319	6.043	0.025		
		Land	2799.867	3	933.289	4.031	0.050		
18	Fe	Soil	0.480	1	0.480	0.115	0.744ns	0.467	Land use was affected
		Land (soil)	52.449	2	26.224	6.266	0.023		
		Land	52.929	3	17.643	4.216	0.046		
19	Mn	Soil	0.301	1	0.301	0.056	0.819	0.158	None of the subjects were affected
		Land (soil)	27.037	2	13.518	2.503	0.143		
		Land	27.338	3	9.113	1.687	0.246		
20	Zn	Soil	0.031	1	0.031	0.091	0.766	0.685	None of the subjects were affected
		Land (soil)	0.677	2	0.339	1.037	0.398		
		Land	0.708	3	0.236	0.723	0.566		
21	Cu	Soil	0.170	1	0.170	11.566	0.009	0.685	Both subjects were affected
		Land (soil)	0.226	2	0.113	7.657	0.014		
		Land	0.396	3	0.132	8.960	0.006		

Appendix Table 7: The Demographic feature of the study area at ACB

		Number of Households			**Population**				**Density**
		Male	Female	Total	Male	Female	Total		Popn/Km^2
1	Kola Shara	800	164	964	2358	2474	4832	800	604
2	Chano Dorga	413	20	433	1403	1363	2766	800	346
3	Chano Chalba	751	175	927	2339	2713	5052	799	632
4	Chano Mile	821	102	923	3950	3074	7024	900	780
	Total	4759	591	5351	17494	12450	19674	2499	596

Source: The Kola Shara, Chano Dorga, Chalba, and Chano Mile PAs offices and Health Extension Offices

Appendix Table 8: Simple correlation between soil, land use and soil properties

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Treat	EC	Bd	Sand	Silt	Clay	Na	K	Ca	Mg	TN	OC	AP	Fe	Zn	Cu
1	EC	1.00	0.19	-0.66	0.34	0.77	0.03	0.91**	0.65	0.53	0.84**	0.95***	0.84**	0.75*	0.80*	0.40
2	Bd			-0.17	0.26	0.07	-0.03	0.32	0.23	0.14	0.13	-0.14	0.33	-0.25	0.04	0.06
3	Sand				-0.85**	-0.94***	-0.41	-0.55	-0.67	-0.44	-0.84**	-0.83**	-0.66	0.37	-0.30	-0.13
4	Silt					0.62	0.30	0.32	0.58	0.40	0.47	0.53	0.40	0.06	0.1	-0.19
5	Clay						0.42	0.61	0.61	0.39	0.96***	0.89**	0.74*	-0.60	0.38	0.32
6	Na							0.11	-0.12	-0.17	0.42	0.20	0.29	--0.25	-0.05	-0.005
7	K								0.38	0.25	0.73*	0.87**	0.94***	-0.75*	0.88**	0.29
8	Ca									0.94***	0.57	0.64	0.28	-0.19	0.31	0.23
9	Mg										0.39	0.46	0.07	-0.09	0.32	0.29
10	TN											0.92***	0.81*	-0.78*	0.55	0.49
11	OC												0.88**	-0.68	0.70*	0.30
12	AP													-0.78*	0.75*	0.25
13	Fe														-0.66	0.71*
14	Zn															0.46
15	Cu															

*, **, *** Significant at 0.05, 0.01 and 0.001 or than probability levels, respectively.

Appendix Table 9: Simple correlation surface soil (0-30cm) between less land use and soil properties

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Df
	Treat	Fe	Mn	Zn	Cu	Ec	Silt	Clay	Na	K	Ca	Mg	CEc	PBS	TN	OC	AP	
1	Fe	1	0.54	-0.29	-0.31	0.06	0.15	-0.26	0.02	0.11	-0.24	-0.05	-0.48	0.19	-0.03	0.04	0.17	9
2	Mn		1	-0.65*	0.12	-0.5	-0.50	0.41	-0.66*	-0.66*	0.29	-0.23	0.02	-0.03	-0.49	-0.46	-0.52	9
3	Zn			1	0.07	0.55	0.42	-0.23	0.56	0.65*	-0.36	0.16	-0.38	0.19	0.54	0.56	0.82***	9
4	Cu				1	-0.74**	-0.68*	0.73**	-0.54	-0.36	-0.38	-0.63*	0.52	-0.74**	-0.74**	-0.74**	-0.18	9
5	Ec					1	0.74**	-0.78**	0.84***	0.69*	0.05	0.55	-0.58	0.66*	0.98***	0.98***	0.61*	9
6	Silt						1	-0.64*	0.61*	0.75**	-0.02	0.59	-0.52	0.57	0.69*	0.72**	0.64*	9
7	Clay							1	-0.75**	-0.66*	-0.03	-0.32	0.54	-0.53	-0.76**	-0.75**	-0.45	9
8	Na								1	0.70*	-0.10	0.58	-0.60*	0.58	0.75**	0.74**	0.55	9
9	K									1	-0.40	0.23	-0.47	0.29	0.61*	0.64*	0.87***	9
10	Ca										1	0.47	-0.06	0.56	0.12	0.08	-0.57	9
11	Mp											1	-0.52	0.81***	0.47	0.46	0.08	9
12	CEC												1	-0.82***	-0.52	-0.56	-0.54	9
13	PBS													1	0.63*	0.63*	0.20	9
14	TN														1	0.99***	0.56	9
15	OC															1	0.61*	9
16	AP																1	9

*, **, *** Significant at 0.05, 0.01 and 0.001 or than probability levels, respectively.

Appendix Table 10: 2005/06 Crop Yield Report from the study area Pas at ACB

		Kola Shara			Chano Dorga			Chano Chalba			Chano Mile		
		Area Cropped	Yield Qtl/Ha	Total yield quintal	Area Cropped	Yield Qtl/Ha	Total Yield quintal	Area Cropped	Yield Qtl/Ha	Total Yield quintal	Area Cropped	Yield Qtl/Ha	Total Yield quintal
1	Banana	382	50	19100	104	38	3952	427	40	17080	205	25	5000
2	Maize	130	31	4030	196	24	4704	130	29	3770	200	20	1200
3	Cotton	27	13	351	50	17	850	24	16	384	209	18	3762
4	Mango	7.25	69	500.25	10	97	970	20	105	1470	15	54	270
5	Sweet Potato	60	40	240	15	64	960	15	76	1140	50	39	78
6	Teff	25	13	325	8	14	112	10	33	330	5	20	100
7	Others	10.75			12.6			23			32		
	Sum	642			402			649			716		

(Source: The Kebele Agriculture development Center Accomplishments Report).

BIOGRAPHICAL SKETCH

The author was born on 27 October 1972, in Alpha-Kutcha, Gamo Gofa province, Southern Ethiopia. He attended elementary school education from 1980 to 1985 at the Chosho Elementary School. He then transferred to the Selamber Junior Secondary School from 1986- 1987. He joined Chencha High School in 1988 and attended for one year, after which he was transferred to Sawla High School till completion of high school education 1991.

He joined Awassa College of Agriculture in December 1997 for the tertiary level education and graduated with B.Sc. degree in Plant Sciences in July 2000. Soon after his graduation, he was employed by MoA in 2000 and after five years of service, he joined the School of Graduate Studies at Hawassa University in September 2005 to pursue his M.Sc studies in Soil Science.

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